

POPULAR MECHANICS

HOW
YOUR WORLD
WORKS

SPECIAL
ISSUE

On the Job
With the
NYPD's Massive
Counterterrorism
Force

PAGE 82

Sweating Out
the FBI's
Secret Bomb
School

PAGE 96

Inside the
Mind of the
World's Top
Explosives
Detective

PAGE 104

THE PROTECTORS

MEET THE PEOPLE
WHO KEEP
AMERICA SAFE
IN THE AGE OF THE
MASS GATHERING

Officer
Andrew Bershad,
Times Square,
New Year's Eve,
2016

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- 4 From the Editor
- 6 PM Everywhere
- 8 **The First Story:** The oil rig that's unlocking the secrets of the Gulf of Mexico
- 14 New lawn care essentials
- 16 **Stupid or Amazing?** Cutting the cord
- 18 **Things Come Apart:** BioLite CampStove
- 20 Want to step up your Facebook Live videos? Use this **new camera**.
- 22 **Great Unknowns**
- 24 **Maker City:** Charleston, South Carolina
- 26 Baldness
- 28 **Tool Test:** Tillers and computer monitors
- 32 A fly rod that will amaze you
- 34 **Ask Roy**
- 36 **Road Tested** with Ezra Dyer: BMW, Nissan, and Volkswagen
- 41 **McLaren's** newest, fastest supercar
- 42 **The New Vintage:** A 40-year-old truck with only two owners
- 44 **Parts & Service:** Useful new inventions for people who love driving
- 46 **The Barn Job**
What's the best way to test the newest paints, brushes, rollers, and sprayers? A very old barn.
BY ROY BERENDSOHN
- 71 **IPAs** are everywhere. But why? We drank 99 bottles to find out. For you. Definitely only for you.
- 76 **The Life:** Santa Barbara surfers
- 110 **Project:** A side table that can charge your phone
- 112 **Shop Notes**
- 114 **Popular Mechanics for Kids**
Air hockey table!
- 120 **The Tools They Use**
Chris Morris, master distiller, Woodford Reserve.

SPECIAL ISSUE:

THE PROTECTORS



82 / THE PARTY PLANNERS

Two million people squeeze into Times Square every New Year's Eve. Here's how the NYPD keeps them safe.

BY MARK WARREN

94 / MY DOGS

K-9 units keep civilians and military personnel safe on bases at home and abroad. Meet the four-legged partners with whom I served.

BY ROBERT VRABEL

96 / "WE SAVE THE WORLD AGAIN!"

The FBI's plan to combat explosives-based terrorism is simple: Start at the beginning and work your way to the end. Go step by step. Never stop.

BY REEVES WIEDEMAN

104 / THE BOMB DETECTIVE

After a terrorist's bomb goes off, the race to put it back together begins. And it's usually led by Kirk Yeager.

BY PETER FLAX

On the cover: NYPD Emergency Service Officer Andrew Bershad photographed for Popular Mechanics by Edward Keating, December 31, 2016.

FROM THE EDITOR

Safety and Freedom and Magazines

The issue you're holding represents a fortunate confluence of events.

It started last fall, when I was having lunch with Mark Warren, a gifted reporter and writer, and Rob Vrabel, an Army veteran and a talented writer himself. We were talking about crowd control for some reason, specifically New Year's Eve in Times Square. How does that work? How do the police protect all those people? Mark said he'd call John Miller, a former journalist—he was the last western reporter to interview Osama bin Laden, in 1998—and the current deputy commissioner of intelligence and counterterrorism for the New York Police Department.

Meanwhile, I recalled that Rob had handled explosives-detection K-9s in the Army. I asked if he would consider writing about that. He said he'd dig up some photos of the dogs he handled and see what emotions they stirred.

Meanwhile, executive editor Peter Martin and articles editor Jacqueline Detwiler both had stories cooking with the FBI. We all live in and around New York City and were shaken by the bomb that exploded on 23rd Street last September. They got on the phone with the

FBI the next morning to find out what's being done to protect us from future attacks, in New York or any other American town.

These dots started to come together into a compelling picture. Quite suddenly, we Americans find ourselves living in an age when people are taking to the streets in large numbers on a regular basis, and the nation's police must figure out how to keep those gatherings safe. At the same time, we're trying to live and enjoy our lives in a free and open society—as those injured on 23rd Street were doing that night, and as the nightclub revelers in Orlando were on June 12, 2016, when they were shot to death—and that suddenly needs protecting, too.

This special issue is devoted to the people (and dogs) charged with shielding all Americans from the shock of attack. Deputy Commissioner Miller called Mark back, and granted him unprecedented access to the NYPD's counterterrorism force for the entire New Year's Eve festivities on December 30 and 31. The riveting story that resulted begins on page 82. Rob Vrabel wrote a beautiful essay about the



bomb-sniffing dogs he handled over the years. Jacqueline worked with Reeves Wiedeman, who got exclusive access to the FBI's bomb training facility in Alabama, and Peter Martin and writer Peter Flax took a fascinating look inside the mind of a legendary specialist in explosive forensics.

It's a blockbuster issue. You're already safer just by holding it in your hands. I hope you enjoy reading it.

RYAN D'AGOSTINO
Editor in Chief
@rhdagostino

POPULAR MECHANICS

SINCE 1902

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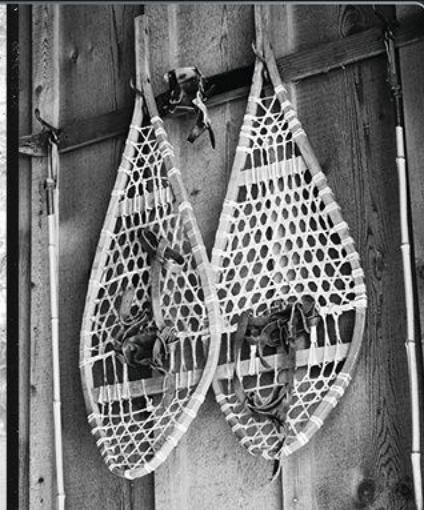


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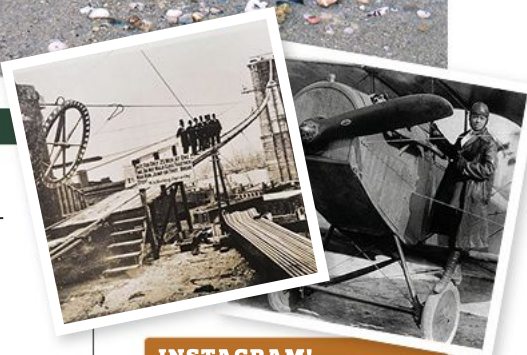
EVERYWHERE

WHAT WE'RE UP
TO BEYOND THESE
PAGES



ON THE WEB!

The strangest cash cow we've ever heard of: horse-shoe-crab blood. It's used widely in the biomedical industry, where it can be worth up to \$15,000 per quart. We follow a group of researchers tracking and studying the blood-drained crabs to see if they can survive the procedure—as some have claimed. Check out the fascinating—and weird—story at popularmechanics.com/horseshoecrab.



INSTAGRAM!

In honor of Throwback Thursday (#tbt), we're posting weekly snapshots of some of the greatest engineering feats of all time. Check out this week's photo and history lesson on Instagram, [@popularmechanics](https://www.instagram.com/popularmechanics).

VIDEO!

The new Mevo camera (reviewed on page 20) lets you shoot studio-worthy video with pans and cuts, all without the need for a production crew—or even a second hand. To test the camera's capabilities, we used it to make videos on a better way to check your cell reception, how Roy makes lunch in the workshop, and more. Check them out at popularmechanics.com/mevo.





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What's That, Deep in the Gulf of Mexico?

Scientists don't know as much as they should about the farthest fathoms of a valuable body of water—but that's about to change.

BY KEVIN DUPZYK

THE SURFACE

Two hundred thirty miles southwest of New Orleans, a vessel called the *Turritella* floats on the surface of the Gulf of Mexico. It's an FPSO, which stands for floating production, storage, and off-loading facility—basically a cross between an oil platform and a tanker. This particular FPSO belongs to Shell Oil Company, and it is connected by very long pipes to the deepest oil and gas well in the world, in an area called Stones Field. There's just one huge problem: In a strong storm, an FPSO like the *Turritella* can cut loose from the well and run.

One and a half nautical miles away, a yellow sensor buoy called a metocean station monitors meteorological and oceanic conditions. This helps Shell protect the *Turritella* from unexpected storms, which could dislodge the pipes from the oil well, which would be a disaster. Every well in the gulf has a metocean station, but the *Turritella*'s is special: It is tied to the bottom of the gulf by a plasma rope, a shark-resistant tether that cuts through a rare watery territory that scientists know very little about.

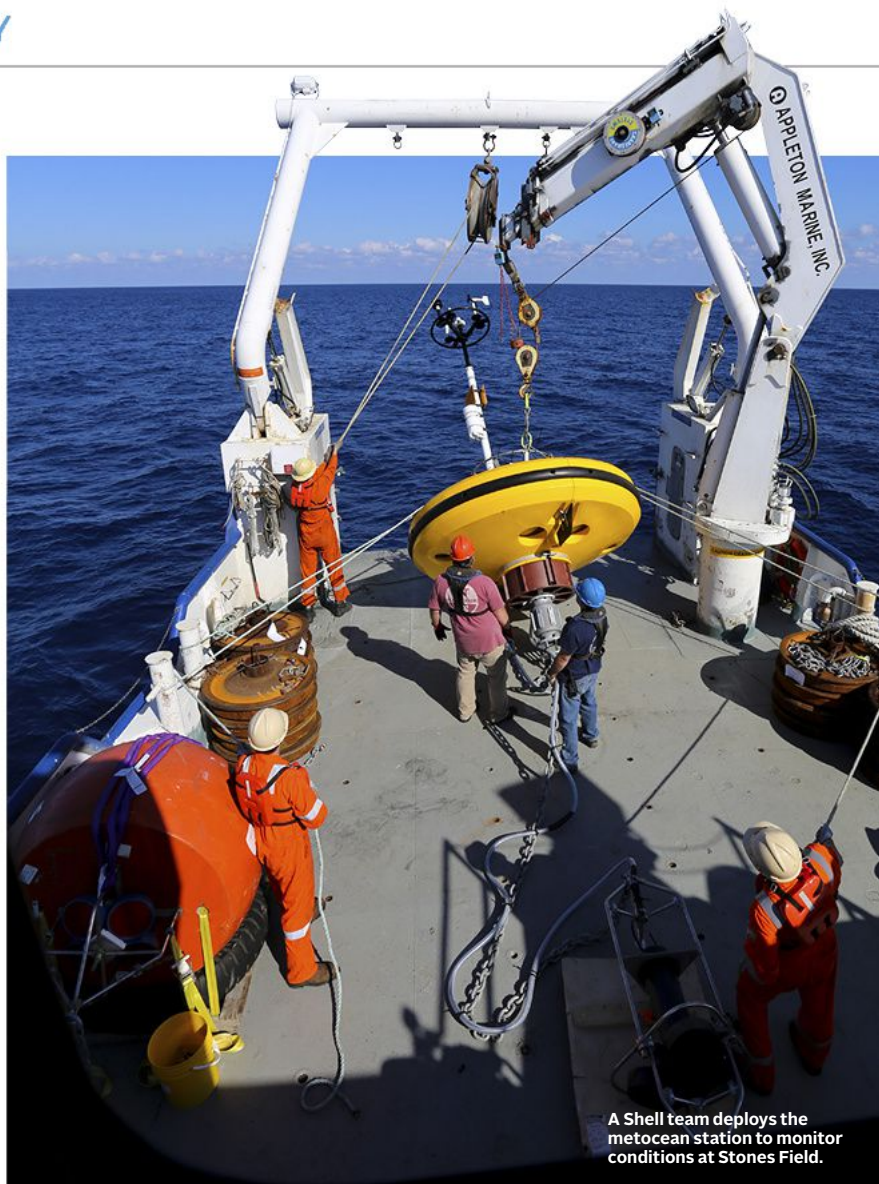
Water deep beneath the surface has its own weather—cold and warm masses of water interacting and forming currents, just as air does in the atmosphere. Storms can brew underwater, affecting the health of the gulf's

\$900 million fishery, and the operation of its wells, which in 2015 produced 553 million barrels of crude oil and 1.3 trillion cubic feet of natural gas (16 percent and 4 percent of total U.S. production, respectively). Oil companies monitor for bad weather, but there is a lot more to study, and many oceanographers would love to expand their research deeper. But the equipment required to do so is expensive. That's why two oceanographers with whom Shell scientists had previously collaborated—Stephan Howden, from the University of Southern Mississippi, and Steve DiMarco, from Texas A&M—were thrilled when Shell contacted them in August 2016 and invited them to attach sensors to the *Turritella*'s

metocean station's 2,900-meter tether. This month, Howden and DiMarco plan to journey with Shell to deploy new instruments, which will hang from the line like charms on a bracelet, filling in, meter by meter, the picture of the deep.

THE SHALLOWS

“With the surface, I can pretty much assure you currents are going clockwise, looking down at the basin,” says DiMarco. Water in the gulf comes in from the Yucatan, shadows the American Gulf Coast, and leaves. “But once I get away from deeper than 200 meters or 300 meters from the surface, I can't tell you which way they're going. That's crazy,” DiMarco pauses. “And I'm the one that would know.” ➡



A Shell team deploys the metocean station to monitor conditions at Stones Field.

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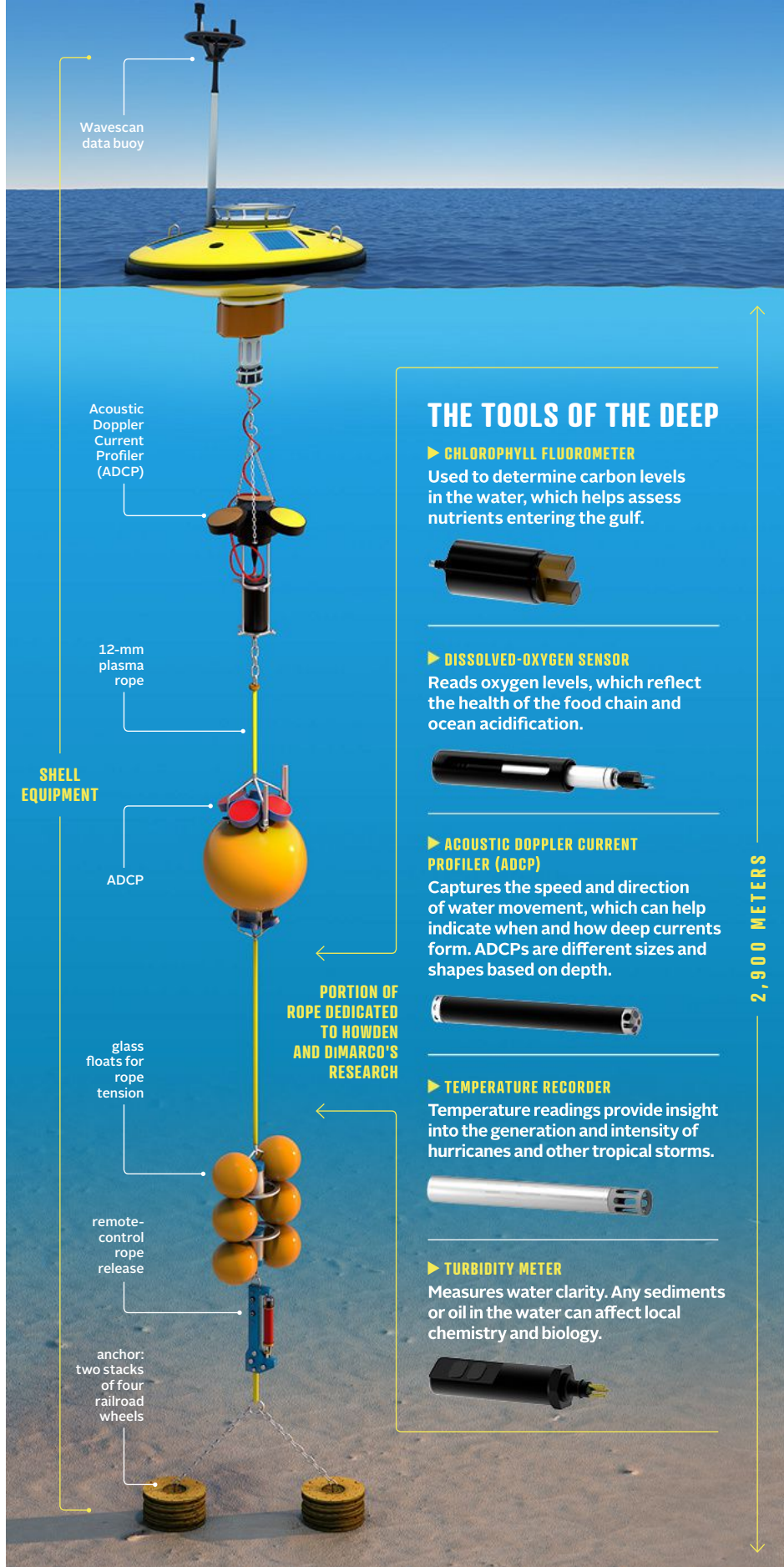


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**PORTION OF
ROPE DEDICATED
TO HOWDEN
AND DIMARCO'S
RESEARCH**

THE TOOLS OF THE DEEP

► CHLOROPHYLL FLUOROMETER

Used to determine carbon levels in the water, which helps assess nutrients entering the gulf.



► DISSOLVED-OXYGEN SENSOR

Reads oxygen levels, which reflect the health of the food chain and ocean acidification.



► ACOUSTIC DOPPLER CURRENT PROFILER (ADCP)

Captures the speed and direction of water movement, which can help indicate when and how deep currents form. ADCPs are different sizes and shapes based on depth.



► TEMPERATURE RECORDER

Temperature readings provide insight into the generation and intensity of hurricanes and other tropical storms.



► TURBIDITY METER

Measures water clarity. Any sediments or oil in the water can affect local chemistry and biology.



2,900 METERS

Nineteen years ago, with improving technologies allowing oil and gas companies to shift focus from relatively shallow wells on the continental shelf to deepwater projects, DiMarco was on a team that won a government contract to gather all the data that had been collected on the deep gulf. There wasn't much. But the authors noted that the oil and gas companies were gathering a lot of useful information to protect their people and equipment and suggested they share it. That suggestion eventually became law and led to the Stones Field collaboration.

Today DiMarco studies hypoxia, a lack of oxygen in water that every summer produces a dead zone for sea life on the continental shelf of Louisiana. It's caused largely by water that has become hypoxic due to an abundance of nutrients pouring in from the Mississippi River. Ocean currents can pull that water into the deeper gulf, where it's less of an issue, but DiMarco can't be sure the problem disappears entirely. At Stones Field, he plans to install fluorometers to measure biological activity and dissolved-oxygen meters to watch for hypoxia throughout the water column, to ensure that the dead zone doesn't expand.

► THE DEEP

A depth of 1,000 meters marks the edge of Shell's legally required observations. But they have an interest in what's going on farther down. "They're having to put pipes down from that rig all the way to the ocean floor," DiMarco says, "and if a current comes by and strums that pipe like a guitar string, it could vibrate, and that vibration could cause fatigue, and the fatigue could cause it to fail."

DiMarco and Howden will add current sensors throughout the water column. But at 1,000 meters, pressure is 100 times

ILLUSTRATION BY SINELAB

that at the surface. Instruments that can function in those conditions are expensive. Hiring a boat just to place instruments might cost \$12,000 per day at the cheapest, says Howden. DiMarco says a good boat is probably more like \$25,000 a day, and adds that just paying out 2,900 meters of rope is a full day's work. By spotting the universities both the line and the boat, Shell isn't just making the work convenient—it's making it possible.

➔ **THE ULTRADEEP**
Fifty meters from the seafloor, Howden wants a turbidity sensor to measure the amount of sediment in the water. Deep eddies disturb material on the floor, introducing nutrients that feed organisms at the bottom of the food chain, which has ripple effects for the animals up top. With a system the size of the ocean, ripple effects and long-term patterns are of great significance. For scientists like DiMarco and Howden, beholden for funding to organizations like the National Science Foundation and the National Oceanic and Atmospheric Administration that fund work for, at most, a few years at a time, it's practically impossible to study some aspects of the gulf, which may unfold over a decade or more.

But in April and every six months thereafter, until *Turritella* goes home for good—decades from now—Shell will send a boat out to the metocean station for routine maintenance. It will carry emissaries of USM and A&M. The crew will trigger a remote-control release that floats ten meters off the seafloor and then pull up the rope. Data will be collected and new instruments will be added as part of the longest, deepest study of the Gulf of Mexico ever known, and knowledge will grow in an unprecedented way. Then the rope will be reattached to its anchor—two stacks of four railroad wheels. They're fixed to the ocean floor, 5,200 meters above a monumental cache of oil and 2,900 meters below the surface of the gulf, sentinel to two resources of incalculable value.

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A bump in the road drains your speed by converting your momentum from forward to upward. Specialized Bicycles minimized this effect in its new **Roubaix**

(starting at \$2,600) with a novel technology it calls the Future Shock. Most road-bike forks absorb forces by bending backward, but joint research with McLaren Applied Technologies found that a vertical front shock was the most efficient way to soak up rough roads. A mountain-bike-style telescoping fork adds too much weight and dulls the handling as the fork bobs. So to create the Future Shock, Specialized boiled down the technology to three concentric springs above the head tube of its Roubaix frame. This gives the handlebars 20 millimeters of vertical travel and isolates the rider from road vibrations so that only the bike moves vertically. Even better: Though Specialized sought a faster bike—and it is—the Future Shock also gives the Roubaix beach-cruiser comfort.

Measure Anything With This Pen

There are limits to what a tape measure can do, such as give you the dimensions of a curved surface. Or add. But the new **InstruMMents 01** (\$149), despite its clunky

name, can do nearly everything a traditional tape measure can and those other things, too. It uses a small rolling wheel built into the top of a pen. (It also converts to a pencil or stylus.) Line up your measurement with the 01's laser guide, then roll the wheel to get your number. A free app syncs the pen to your phone, so all you have to do is press the pen's top to stop, record, and store a measurement. Upgrade to the app's Pro version, available this spring, and those dimensions can be transformed into 3D renderings. There are some hiccups—the roller wheel won't always engage on slippery surfaces and keeping a straight line can be challenging over long lengths—but for measuring uncommon things like the rounded edge of a table or the cumulative rise and run of a flight of stairs (for a carpet runner, say), there's no better tool.

The InstruMMents 01's measuring wheel converts dimensions for any scaled drawing. Useful if you're an architect—or just really into accurate plan drawings.

Cut Square Holes in Seconds

The **Quadsaw** (\$249 for preorder) has a very specific purpose—cutting rectangular and square holes in drywall for old-work electrical boxes—but it's absolutely the

fastest way to get the job done. A rotary saw is still your best bet if you're hanging fresh drywall. However, for remodeling and renovation projects, the Quadsaw saves time and headaches, working through walls like a cookie cutter through dough. This drill attachment powers four oscillating blades that cut through plaster with minimal mess in seconds. The Quadsaw also includes vertical and horizontal levels to line up cuts and a pack of six blades that can be popped into the two standard box shapes. And though the initial Quadsaw was designed for U.K./EU construction standards, the company behind it, Genius IP, says the U.S. version for single- and double-gang boxes is coming later this year. Blades for wood, ceramic, and masonry cuts are also in development.





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The New Yardwork Essentials

If you want a nice yard this summer, now is the time to plan for it, and these are the tools you'll need (along with some sunscreen).

BY ROY BERENDSOHN

Washable Leather Gloves

Mechanix Wear FastFit leather gloves (\$25) have the breathability of synthetics and the toughness of leather. And you can throw them in the wash when you're done.

A Machete

Swing it with one hand, and clear debris with the other. The Fiskars Clearing Machete (\$30 for 24-inch model) has a slippery coating on its blade to keep sticky sap from slowing you down and holes in the blade to reduce weight and move the center of gravity closer to the handle for more power and control.

Weed Killer That Can't Miss

Roundup's new Precision Gel (\$15) uses glyphosate to destroy a weed's ability to process nutrients. Anything you touch—and only what you touch—is toast.

Your New Favorite Grass Seed

Thanks to the addition of shade-friendly Titan Rx seeds, the Seed Super Store's new grass blend (Product SS1002; \$64 for a ten-pound bag) handles intense sun as well as it does intense shade, and provides increased resistance to a variety of lawn pests.

A Hose That Stands Up to Everything

The Goodyear Max-Lite hose (\$35) can handle scorching sun and hot water up to 165 degrees Fahrenheit, and still stays flexible even at 40 below. Get it in a bright color and you'll avoid one of the few things the Max-Lite can't withstand: being run over by a lawn mower.

Wetter Water

Landscape pros have a secret weapon: surfactants that reduce water tension to help water penetrate soil. Distribute Scotts' new EveryDrop (\$10 for a 3.6-pound jug) on your grass or in your garden, and you'll cut your water use by as much as 25 percent.



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STUPID OR AMAZING?

Cutting the Cord

Streaming-video apps keep adding original shows and live TV options. But quitting old-school cable means you still miss out.

BY GARY DELL'ABATE



I like to be in the loop. On Monday morning, I don't want to be the guy at the office who doesn't know what's going on in *Game of Thrones*. Now that video apps like Hulu have added cable-like features, including live broadcasts, I've had to think about ditching my cable box for the world of Netflix and HBO Now.

Young people who grew up with the iPhone and iPad, they've already cut the cord. For them, Netflix marathons have already replaced channel surfing, so the question of whether to quit

cable is partly a generational thing. Me, I have the highest package you can get on Cablevision (now called Altice USA/Optimum, another merger that further complicates the whole thing). I pay more than \$100 a month for the TV alone, which sounds expensive. But if I ended that and just paid for internet (around \$70) and streaming subscriptions, costs add up. You start with Apple TV (\$150) or a smart TV (\$250 and up). Then, you load up on apps. Netflix (\$10 a month) is a must, Hulu (\$8 a month) is a must, HBO Now (\$15) is a must. Sling TV (\$20 a month) or DirecTV Now (\$35 a month) will get you live ESPN and CNN.

But even then, you're still going to miss episodes. Say there's a new, awesome show on FX. Even if you get FX through DirecTV Now, you're not going to see the latest episode unless you plan around the broadcast or are willing to wait. Back before Hulu's deal, if you wanted a CBS show without cable, you had to pay \$5.99 a month for CBS All

Access. That one was weird for me. CBS had a show that I liked, so I paid the \$6. But then I stopped when I realized: I'm not paying \$6 a month just so I can watch a show I only sort of like. Channels like ABC and ESPN have apps, too, but you have to sign in with a cable subscription to use them. No doubt about it, those apps are meant to supplement your cable package, not replace it.

I have a friend who's done it. He's been without cable for two years, and he's one of the biggest TV watchers I know. You talk to him, and he's telling you 20 shows you need to see. But he can do this because he doesn't mind watching an episode a couple days or even a couple weeks after it comes out. And, just as important, he cares nothing about sports. He's a binger. He does a bit of work

to find new shows, waits, and when something great arrives on Hulu or Netflix, he watches the whole series. If that's your mindset and you don't care about when you watch something, you can quit cable.

But not me. I'd miss out. Besides seeing episodes late, I'd lose the chance to get surprised. Cable means changing channels and finding a movie you haven't seen in a while, but you would

never seek out. It's watching a show you never heard about and going, wow, this is really good, I wonder if anyone has ever heard of it. I still depend on streaming apps, too. I download Amazon Prime Video movies before flights and watch Netflix exclusives like *Stranger Things*. But you don't have to do both cable and streaming. You can do either and still have all the entertainment you need. You just need to think about what you really want. And despite all these promises from new TV apps, the decision still isn't easy.

You're not going to see the latest episode unless you plan around the broadcast or are willing to wait.



STUPID

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A PHOTOGRAPH BY TODD MCLELLAN

DISASSEMBLY REPORT

BIOLITE
CAMPSTOVE**MODEL:** BIOLITE
CAMPSTOVE 2**PRODUCED:**
DONGGUAN, CHINA**TIME TO
DISASSEMBLE:**
1 HOUR,
51 MINUTES,
17 SECONDS**NUMBER OF PARTS:**
79

NOTES: The idea behind BioLite's CampStove is simple: Build a fire, use the fire to generate electricity, then use a portion of the electricity to power a fan that helps the fire burn cleaner and hotter for longer, so it can keep making power. The guys who built the first prototype were mostly interested in using it for camping, so it's about the size of a large can of pork and beans and weighs just a couple of pounds. But a fortuitous misadventure at a combustion conference led them to realize their simple idea could be useful in developing countries, so they also make and sell a larger version for cooking family meals and powering homes.

**BUILDING THE FIRE**

To start the CampStove, you've got to start a fire in the **combustion sleeve (1)**, a large container with four rows of perforations in the side. Sticks and other light fuel from around your campsite go into the chamber, and as they begin to burn, the heat they generate rises, passing over the **aluminum probe (3)**, warming it up. Heat intensity is indicated by the **fire strength indicator (16)** on the **power pack (15)**.

GENERATING ELECTRICITY

The probe is connected to the **thermoelectric generator (6)**, a thin layer of 250 cubes made of a thermoelectric material—a material that generates a voltage when its two sides are different temperatures. The probe heats

up one side of the generator, and a **heat sink (4)** ensures the other side stays cool. Each cube generates only a few millivolts, but they're wired in series, so that in total they generate enough electricity to be usable.

GROWING THE FIRE

When the fire is just getting started, it doesn't produce much electricity. But the CampStove's main **printed circuit board (11)** sees how much is being generated, and when it crosses the necessary threshold, it tells the unit's **fan (5)** to turn on. This is the highest-priority use of electricity, because it provides oxygen to keep the fire going and ensures that it burns cleanly.

Air from the fan is collected by the **scoop (9)** and directed into the air manifold between the combustion sleeve and the **second wall**

(8). As the manifold fills with air, it becomes pressurized, so that air jets through the perforations and into the combustion chamber. The bottom row of **primary jets (7)** are used not to fuel the fire but rather to induce a process called gasification, which converts the fuel in the wood into a gaseous form that burns more efficiently than burning the wood directly. Then the **top jets (13)** inject oxygen that is combusted with the gaseous fuel, producing a clean, smokeless fire. The **hybrid jets (14)** in between contribute to both processes.

The fan starts out at the lowest of four possible speeds, so it doesn't blow the fire out. But as more wood is added and the fire grows, the **fan control (12)** allows you to ramp up the speed and grow the flames.

STORING ELECTRICITY

With a roaring fire, the CampStove generates more than enough electricity to power the fan. The PCB routes the excess electricity to the onboard 9.6-watt-hour **battery (2)**. When the battery is storing a charge, you can connect a device via the **USB port (10)** to power the device or recharge it. The **battery indicator bar (17)** provides a visual guide to the battery charge status: The number of illuminated LEDs indicates how full the battery is; green flashes mean the battery is charging; and when the indicator turns orange, it means the CampStove battery has gotten too low, electricity is being routed only to the fan, and the device you've plugged in is no longer getting power. Which could be a sign it's time to get off Instagram and start making s'mores. —Kevin Dupzyk





The Camera That Makes Movies for You

Whether you're broadcasting on Facebook Live or helping the kids with a school project, all you need is Mevo.

BY DANIEL DUBNO



When I was working for the TV news years ago, every story went a little like this:

You're under deadline. You need to get two guests in with a correspondent for interviews. So you quickly book a studio (or rent a nice hotel room) and—as the correspondent waits impatiently—have two camera crews cart in and set up nearly half a ton of lights, cameras, and audio gear. Sometimes the hot lights char the ceiling tiles and the heavy tripods scratch the floors. You'll hear about (and maybe pay for) that later. In the meantime, you have to hustle the video back to the editing room and assemble your story to be broadcast to the world. All before 6:30 p.m.

Of course now that I'm done with that life, there's Mevo (\$399). The two-inch-tall camera is narrower than a soda can. It fits in your pocket. And

it replaces all of the camera equipment and most of the headaches I went through years ago. It almost replaces me. Mevo packs a 150-degree wide-angle lens and a UHD 4K sensor, plus a rechargeable battery, its own Wi-Fi hot spot, and a stereo audio system all into its compact body. Download the free app, and with your iPhone or iPad, you control as many as nine virtual camera angles, each at a crisp 720p resolution. Instead of switching physical cameras, you tap a part of your screen to change angles. Or you can let the system's facial-recognition switch them for you. The whole process feels a lot like being in a studio, but with even smoother pans. The editing part is easier, too. The smart software tracks each figure in the frame, and can automatically show the “camera” for that person. The top of the camera has a circling LED that lets you know when the Mevo is powered on, paired, and broadcasting. It also lets your interview subjects know whose face is currently on camera. If a red light is pointing toward you, you are currently in the frame. It works the same whether there is one person in front of the camera or four. Attach Mevo to a tripod, and you have an instant mobile studio. The device's only real weakness is its sound-recording capability. It has built-in stereo microphones, but they're only passable in quality. You'll want to supplement them with an external mic, which runs you less than 100 bucks.

To be clear, Mevo doesn't replace a production studio. It'll never replicate great lighting and fancy effects between cameras. But most of us don't need that. We just need a simple setup and a simple editing process that will let us make a home video or broadcast on Facebook Live. My brother and I used the Mevo to record and share his newest invention—a brilliant adjustable robotic tentacle lamp that automatically repositions each lighted arm. I had to learn how to tap and switch between “cameras” while remaining the intrepid interviewer. It was a challenge, but I did it. Alone. No cameramen, no sound guys, and no bright lights to make me sweat through my sport coat. And all of it was broadcast live to a world I hope is watching.

HOW IT WORKS



TAP TO SET YOUR FRAMES

Touch anywhere on the screen to pick the view from the camera. Mevo will automatically size the shot to what it thinks is appropriate, or you can set it yourself.



AUTOMATICALLY DETECT AND FOLLOW FACES

Mevo's face detection offers multiple shots to choose from, including individual faces, small groups of people, or wide.



PINCH TO ZOOM FOR A WIDER SHOT

Changing the camera angle is done the same way you'd zoom in or out on a picture. After you resize the shot, Mevo smoothly pans in or out to the new framing.



DO NOTHING AT ALL

With the automatic setting, Mevo will edit for you on the fly, changing camera angle and frame size as the software sees fit. It's easy to get used to.

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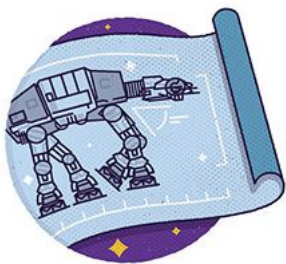


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GREAT UNKNOWN'S

**BIG QUESTIONS.
ANSWERS YOU
CAN'T FIND ON
THE INTERNET.**



In *The Empire Strikes Back*, what were the original AT-ATs constructed from?

The AT-ATs (All Terrain Armored Transports, or Imperial Walkers, as they were also known) were fashioned from the crushed hopes and pathetic tears of the Rebel Alliance, dispirited by the Empire's resilience following the destruction of the Death Star and distraught over the discovery of their doomed base on the ice planet Hoth. And hand-machined aluminum, mostly.

Nowadays (as in the excellent *Rogue One*), such cinematic creations are completely computer-generated. But a long time ago in a galaxy much resembling our own, the special-effects Jedi at Industrial Light & Magic used models and stop-motion animation to bring the Empire's stork-legged strike force to life. First, skilled craftsmen custom-fabricated complex, movable aluminum armatures, which were then skinned with molded materials, typically foam, to assume their final appearance. The most-used models were about 18 inches tall, but the team worked with a range of sizes from a half-dollar-size miniature to a single foot that was three feet in diameter. Since the moving models had to be photographed 24 times in 24 different positions to produce a single second of action, the ability to shift them in tiny, highly precise increments between individual frames was critical.

ILM's Paul Huston, chief model maker for *The Empire Strikes Back*, says it might have taken animators—who would pop up in the miniature “set” through a trapdoor—two hours of work to produce a second's worth of film. “It's more than just mov-



ing something from frame to frame,” he says. “It's actually understanding the acceleration and deceleration at different points in motion, and how the leg supports the body, and the weight of the body—it drives me crazy just to talk about it.” Huston, still with ILM, harbors some nostalgia for the bygone days, though he acknowledges the advantages of contemporary digital wizardry. “I love the old stuff. I love certain things about that work process and about how things looked,” he says. But, “We would never have the films we have today if we were still doing it this way. It's just too difficult and expensive and there are so many things that you can't do.”

Top: A stop-motion animator adjusts an AT-AT model through a pop-up hatch in the miniature Hoth landscape during the filming of 1980's *The Empire Strikes Back*. Above: Computer-generated AT-ATs battle X-wing starfighters in 2016's *Rogue One*.

Do you have unusual questions about how things work and why stuff happens? This is the place to ask them. Don't be afraid. Nobody will laugh at you here. Email greatunknowns@popularmechanics.com.

ILLUSTRATION BY GREG CHRISTMAN



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MAKER CITY CHARLESTON



The wealthiest colonial city south of Philadelphia, Charleston, South Carolina, is a cosmopolitan mix of European and Caribbean style, with more than 1,400 historically significant buildings. Two artists explain the role preservation plays in their city's new wave of modern craftsmanship.

BY FRANCINE MAROUKIAN



THE MAKER
MICHAEL DUBOIS
HIS COMPANY
DUBOIS
METAL WORKS

Before transplanting to Charleston, I was a structural ironworker on high-rise buildings in Atlanta. Then I found a job with a local blacksmith and eventually opened my own metalworks. Wrought iron is woven into the iconography of Charleston. Unlike cast iron, poured into a mold and endlessly duplicated, wrought iron is a malleable, almost fibrous metal that's hand-forged, allowing the blacksmith to be original in his design. Softening the metal with heat and then shaping it under a hammer into a forever thing lets us embed some of our own character into the work we do. It is personal for us, and it is personal for the client: We make the kind of things that go into your will, what you leave to your descendants.

HE RECOMMENDS



THE BURGER AT THIS PLACE

"I don't know quite why the burgers and fries at Moe's Crosstown Tavern are so awesome. But they've got it."



A STROLL

"A long architectural walk through the historic residential section. Even with all the natural catastrophes, this town is resilient. It holds its history."



THE MAKER
CAPERS
LANDRUM
CAUTHEN

HIS COMPANY
LANDRUM
TABLES



After disassembling my grandmother's dilapidated barn, I had a lot of good wood and built a table. My business grew from there. I was looking to do something meaningful, and saving the character—the true beauty—of indigenous Lowcountry wood is my contribution to our local preservation efforts. I don't throw out anything. A two-foot piece can become a shelf. A four-by-four stud turns into a leg. Letting the imperfections of age become a design feature has become our signature: We are the link between fine and primitive furniture.

HE RECOMMENDS



THIS COFFEEHOUSE

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SOME HISTORY

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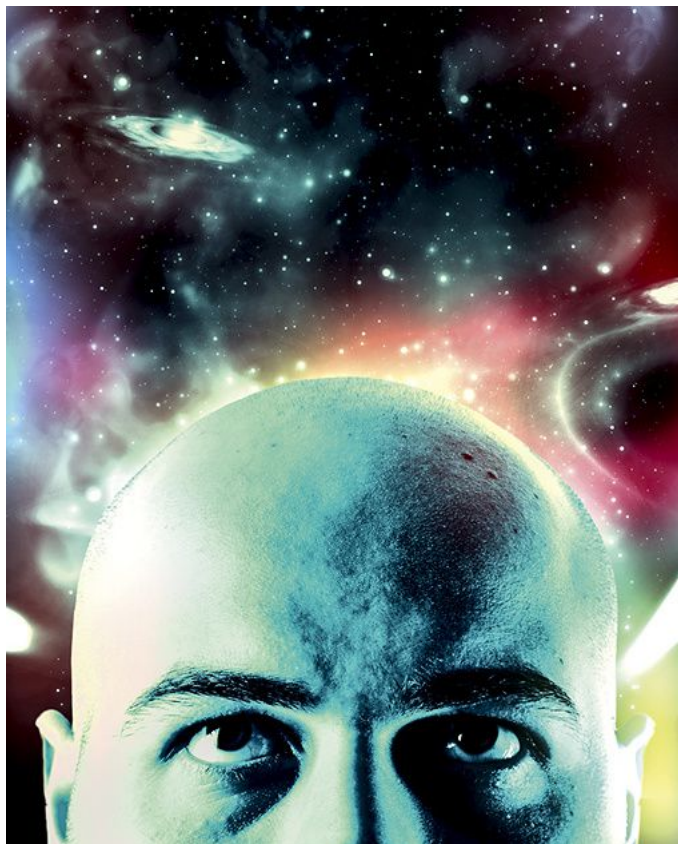
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Baldness: The Final Frontier

There's still no cure for baldness, but your body might contain clues.

BY LARA SOROKANICH



My dad's dad went bald in his 30s. My father's response was lifelong use of vitamins, hair tonics, and a medicine cabinet full of other treatments. He's made it to 60 with a full head of hair, but not without preaching the same daily prevention regimen to my three brothers, aged 20 to 31. You'd think in the 50-some years since my grandfather lost his hair, we'd have figured out better solutions to male pattern baldness. Not yet—though experts think we're getting closer.

Traditional balding treatments, like my father's, prevent hair loss. Until recently, there was little that could be done if hair had already started disappearing. But increasing interest in hair loss has led to new research that holds promise even for those already balding, says Wilma Bergfeld, a dermatologist and researcher at the Cleveland Clinic in Ohio.

On a normal, healthy scalp, hair has three life phases: two to five years of growing, a few weeks of resting, then about three months of shedding. Then the cycle repeats. When men start balding, the growing phase gets shorter and shorter, until eventually the hairs don't grow long enough to poke out of the scalp.

Bergfeld says male pattern balding is caused primarily by genetics, though being in poor health can also contribute. Since it is polygenic (caused by several genes), taking a gene-based approach to a cure would be complicated.

Older balding treatments often focused on prolonging the growth phase to prevent balding altogether. Rogaine, for example, blocks a hormone that's known to stunt hair growth over a lifetime. You keep your hair as long as you use it daily.

But some promising new treatments may help those already balding by revitalizing damaged follicles and even restarting the growth phase. They're still being researched, but below are some of the most interesting options.

—This story is dedicated to my brothers, Bob, Steve, and Dave. —L.S.

THREE NEW WAYS TO GET HAIR

All based in actual science.

With thanks to Omer Ibrahim of SkinCare Physicians in Boston.

- **Platelet-rich plasma**
 - **STATUS:** Available in some doctor's offices
 - **HOW IT WORKS:** Doctors draw blood and remove the blood cells from it, leaving behind a fluid called plasma. The plasma is then injected into the scalp, where doctors believe that cytokines—proteins in the blood that induce blood vessel growth and help to repair wounds—cause the patient's hair follicles to revert to the growing phase.
- **Micro-needling**
 - **STATUS:** Available in some doctor's offices
 - **HOW IT WORKS:** Doctors prick balding areas of the scalp with very tiny needles. ("Almost painless," says Ibrahim.) The tiny injuries cause the skin to go into repair mode, which in turn releases cytokines that make hair go into a growing phase. Micro-needling has been used on its own, but has also been shown to be effective in conjunction with Rogaine.
- **Stem-cell therapy**
 - **STATUS:** Still being researched
 - **HOW IT WORKS:** Stem cells from your own body can be used to regrow specific types of tissue, like new skin for burn victims. It's thought the same can happen with hair follicles if stem cells are applied or injected into the scalp. Scientists have even considered using them to 3D-print new follicles outside the body, but, like all stem-cell research, this is in its infancy.

PHOTO ILLUSTRATION BY CHUCK ANDERSON



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TILLERS

We challenged three of the newest tillers to churn their way through dirt, rocks, and soil in an enormous vegetable patch. Better them than us.

BY ROY BERENDSOHN

A / Husqvarna DRT900



★★★★★

TILL WIDTH, DEPTH: 17 inches, 6½ inches

LIKES: Shifts smoothly and with a short throw from forward to reverse, or in and out of tilling. Drives as smoothly as the Cub. Other details, like positioning the throttle by the operator and designing side guards that float over rocks and tilled soil, contribute to its ease of use.

DISLIKES: None.

\$800

USA
MADE

ENGINE
208 cc



PHOTOGRAPHS BY ZACH DESART



B / Troy-Bilt Bronco Axis

★★★★☆

TILL WIDTH, DEPTH:
16 inches, 6½ inches

LIKES: The Bronco's tines rotate on the vertical axis instead of the horizontal, which—in the right conditions—lets you push through the soil in only one pass.

DISLIKES: There is no way to drive the Bronco without tilling action. If you need to get it into your truck, be ready for a shoving match with a 280-pound opponent. Same problem arises if a rock gets stuck in the tines. There's no easy way of driving the tiller out to remove the rock.

\$900

C / Cub Cadet RT 65

★★★★★

TILL WIDTH, DEPTH:

18 inches, 7½ inches

LIKES: Somehow drives just as easily with the tines engaged as without (during transportation). The operator control lever is so sensitive that fingertip pressure is all it takes to keep it moving in forward or reverse.

DISLIKES: Throttle controls are inconveniently located on the engine, not by the operator.

\$800

★ USA
MADE



TILLER TIPS

Let the tiller pull you. Don't try to push it. ➔ Never till with a bent tine. Remove it and bang it into rough shape with a big ball-peen hammer before reinstalling. ➔ Hose the undercarriage and tines clean after every job. ➔ No flip-flops.

COMPUTER MONITORS

With a bigger monitor, you don't need to sit so close to your screen—a huge upgrade for your eyes and posture.

BY ALEXANDER GEORGE

A / Dell UltraSharp U2417HA

SIZE
24 in.

★★★★★

LIKES: Color-accurate right out of the box. The crisp resolution, four USB ports, and ultrathin bezel make this an exceptional value.

DISLIKES: Compatibility issues with Macs lead to slightly pixelated fonts.

\$350

B / Acer H277HU

SIZE
27 in.

★★★★★

LIKES: The stand and thin bezel are modern art. Black levels are visibly darker than others in this price range, and the image remains sharp regardless of viewing angle.

DISLIKES: Doesn't include a DisplayPort-to-Thunderbolt cable, so older Macs need an adapter. The Acer's stand cannot be height adjusted. You can control only the tilt, which means you'll need books to get the level right.

\$500

C / LG 38UC99 UltraWide

SIZE
38 in.

★★★★★

LIKES: Unlike curved TVs, which are somewhat silly, curved monitors work brilliantly, since you sit close enough to feel enveloped by the image. You'll feel like you're working in a DARPA compound. The stand has a nice small footprint, especially for such a big monitor.

DISLIKES: No adapter cable included. Unless you actually do work for DARPA, four figures for a monitor is probably overkill.

\$1,500

D / ViewSonic VX2475SMHL-4K

SIZE
23.6 in.

★★★★★

LIKES: Single-port connection to laptop is fast. Although 4K is still unnecessary for most consumers, it makes for a very sharp picture, especially with 4K Netflix or Amazon Prime Video.

DISLIKES: No adapter cable included. Nineties-era design and clunky interface. And the lack of USB ports means you won't be able to plug in an external drive or keyboard when you run out of ports on your computer.

\$430

Note: The color gradient on the background of this page shall hereby be known as Tequila Sunrise.



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 **TOYOTA**
Let's Go Places

Technologically Amazing Fly Rod of the Month

This thing actually enhances your talent as an angler—whether you know what you're fishing for or not.

BY JON GLUCK



If you want to know what makes the Scott Meridian fly rod special, I can spell out all the science-y reasons. A good fly rod is light and strong and allows you to cast with just the right balance of power and finesse. In developing the Meridian's state-of-the-art composite materials, Scott used a new process that creates bonds between each graphite fiber that are 20 percent stronger than those found in traditional rods. They pioneered a damping system that keeps vibrations from sapping energy from your cast without adding excess materials that up weight and compromise feel. The rod's anodized aluminum surface is so hard, durable, and corrosion-resistant you might well hand the thing down to your grandkids' grandkids. At the International Fly Tackle Dealer Show, the industry's top trade event, the Meridian won both the best saltwater fly rod and best-of-show awards. Karl Andersen, buyer for the high-end Manhattan fly shop The Urban Angler, calls it "the biggest rod breakthrough in a decade."

But what good is technology if it doesn't allow you to do something amazing? To experience the awesome? To come away with a good braggy story? Last spring, I traveled to El Pescador Lodge on Ambergris Caye, in Belize, in an attempt to land my first permit. Among the most prized saltwater game species, *Trachinotus falcatus* are notoriously finicky eaters and bruising pound-for-pound fighters. To land one, you've got to make a cast of maybe 60 feet or more (any closer

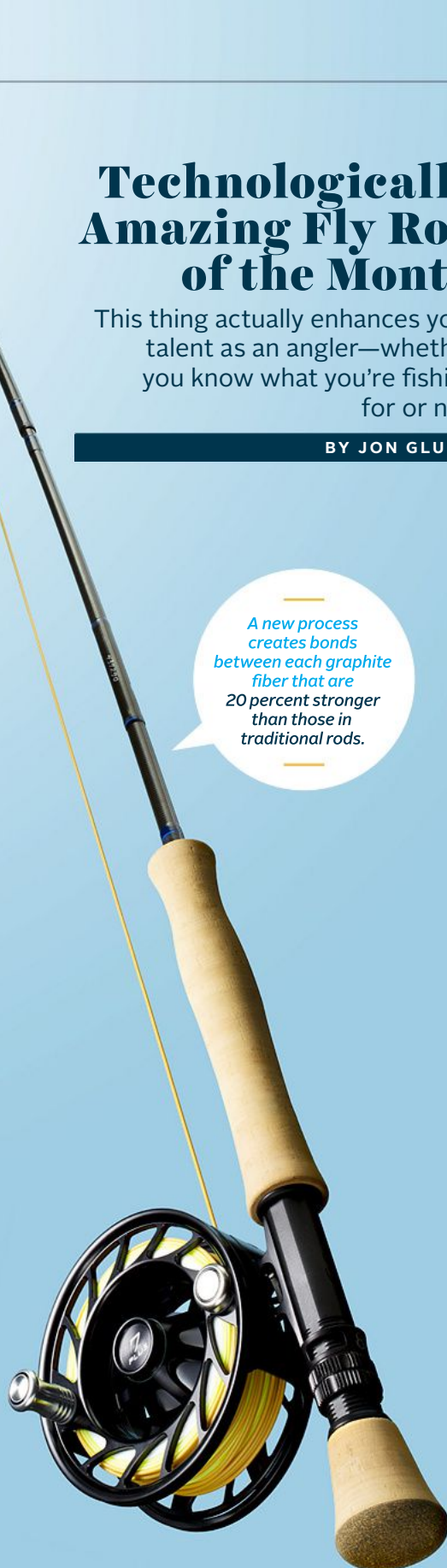
and he'll see you and take off), drop your fly within a foot of the fish's nose (any farther and he won't notice it), and then, if you're lucky enough to get a strike, wrestle your prey to the boat as he tries to beeline it for the horizon. A permit of five or six pounds might run 100 yards before you can even begin to reel him in, then, just when you've brought him to within a few feet of the boat, run 100 yards more. Half-hour tussles are not uncommon.

Armed with a 9-weight Meridian outfitted with a Hatch 7 Plus Finatic large-arbor reel (a fine piece of machinery in its own right), I found myself in the middle of a good-size school of permit within the first hour of my first day. She cast like a dream—an impossible mix of howitzer and surgical instrument. A guy can spend days trying to hook a permit without any luck, but after just 25 casts or so, I managed to put a shot on the money, and—chomp, hook set, fish on. The ensuing fight lasted 20 minutes or so, but really, the poor little fella never had a chance. If he was the irresistible force, the Meridian was the immovable object.

Oh right, one more thing: Between the time I began casting to the school in question and the time I hooked up, I thought I was fishing to an altogether different species called a bonefish. Although that is not an entirely unheard-of error, it is a mortifying one nevertheless. You know how they say it's not the hammer, it's the guy swinging it? That's usually true.

A new process creates bonds between each graphite fiber that are 20 percent stronger than those in traditional rods.

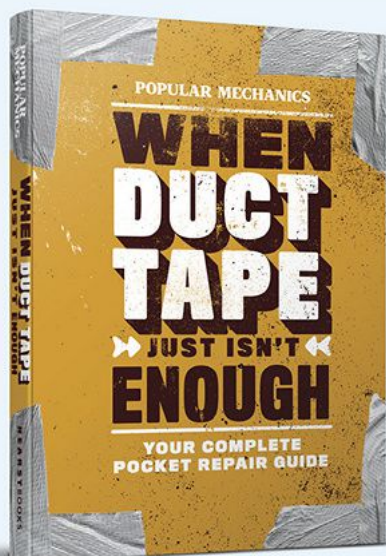
Scott Meridian Fly Rod
\$865; scottflyrod.com
Hatch 7 Plus Finatic Reel
\$600; hatchoutdoors.com



PHOTOGRAPH BY LEVI BROWN



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This knife boasts a full tang blade, meaning the blade doesn't stop at the handle, it runs the full length of the knife. According to *Gear Patrol*, a full tang blade is key, saying "A full tang lends structural strength to the knife, allowing for better leverage ...think one long steel beam versus two."

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POPULAR MECHANICS' SENIOR HOME EDITOR SOLVES YOUR MOST PRESSING PROBLEMS. BY ROY BERENDSOHN



I want to build a three-foot-high retaining wall behind my house out of pressure-treated wood. Thoughts?

SHAWN B., SIOUX CITY, IOWA



Go ahead, but do your homework. First, call 811 before you dig. The free service locates all underground utilities on or in front of a property. (It's unlikely that you'll hit these in the backyard, but you never know.) Readers are probably tired of hearing me say this, but in most cases, you'll need a

building permit. The town's zoning and building department will want to know how close the wall is to property lines. If there's a chance the wall could encroach on a neighbor's property, they'll ask for a surveyor to mark the lot lines. Assuming your wall is nowhere near a property line, you'll just fill out some

paperwork, submit a sketch, then post the permit in your front window and get to work.

For the actual construction, use pressure-treated lumber rated for ground contact. (Some of it is rated for aboveground use.) Your fasteners should be hot-dipped galvanized, stainless steel, or rated by the manufacturer for construction with pressure-treated wood. And, finally, if the retaining wall is holding back earth that receives a lot of runoff, or you live in a wet region, use perforated pipe, gravel, and drainage fabric behind the wall to keep it dry. That's it. Your wall should last for years.



Every year or two, the stain on my deck peels off. I stain it again, and it peels again. What am I doing wrong?

EMILY F., ROCHESTER, NEW YORK



The key word here is *peel*. Most stains absorb into the wood surface, so they don't form a film that could peel off. They just weather away. I suspect the deck was either painted or that it received multiple coats of stain. Both are bad ideas, because they don't allow the wood to breathe.

What you need to do is use a professional-grade wood stripper, such as Flood Pro Series. Apply it straight out of the bottle, let it stand for half an hour, scrub with a deck brush, and then pressure-wash the deck. It may take several applications to remove the old coating. Complete the job with a coat of high-quality semitransparent stain. Flood also makes an ideal product for these applications, a semitransparent alkyd/oil stain formulated to soak in and bond, not just adhere to the top layer.



When I took a Master Gardener class, the instructors used a sharpening stone on a handle. I can't find one anywhere. Do you know what it might be?

WARD P., GROVE CITY, OHIO



Most likely you mean a **Norton Utility File**, a tool that has a well-earned reputation for quickly sharpening or deburring a variety of cutting surfaces, so long as they don't have to be

honed to a razor-sharp edge. It's perfect for sharpening shovels and hoes and lawn-mower blades. Although it's called a file, the tool is more like you described it: a sharpening stone on a stick.

The wedge-shaped 100-grit oilstone is made from silicon carbide, a medium-hard sharpening abrasive that is harder than the steel it's meant to sharpen, yet wears away at a rate that constantly exposes a new—and sharp and clean—abrasive surface. For only \$20, you'll get several years out of the Norton file. To use it, squirt a little machine oil on the blade that you're sharpening and then rub the stone over the surface in a circular motion. All four working surfaces are the same. They're just there to make sure you don't wear one surface out. Simply rotate the tool as you work. When you're done, rinse the sharpened surface with a little clean oil and put it back on the shelf.

Email your home and yard questions to askroy@popularmechanics.com and watch for Roy's answer in an upcoming column.

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1

2017 BMW M2

The most entertaining M is also the smallest.

➔ The M2 is spiritual heir to the old straight-six M3 coupes, compact cars that hid wild performance beneath restrained bodywork. I used to own one such M3, a 1998 model, and the M2 feels immediately familiar—a hearty rasp from the exhaust, a slightly aloof manual transmission, a cabin cozy enough that when the officer asks for your registration, you don't have to reach too far for the glove box. That's important, because the M2 is obliterate-your-license quick, almost brutal in the

lower gears. The acceleration from the turbocharged 365-hp 3.0-liter straight-six is nothing like the old naturally aspirated screamers, which delivered a linear climb toward a frenetic crescendo. The M2's 370 lb-ft of torque is binary: Boom, here it is, hope you've got clear road and two hands on the wheel.

There's not a lot of frippery here, no rear-wheel steering or all-wheel drive or maze of electronic performance menus. The steering is quick off-center, possibly to imply that nervous energy equates to feedback, but that's the only real dynamic complaint. Unlike Porsche (911) and Chevrolet (Corvette), BMW can't seem to stick with a single name over the years. But this car is the modern 2000tii, the true spawn of the M3 gene pool. And whatever they call it, I'm glad they still know how to make it.



FIVE-WORD REVIEWS



JEEP CHEROKEE TRAILHAWK

Fiat for formidable forest forays.



TOYOTA SIENNA

Energized engine earns extraordinary esteem.



LEXUS CT 200h

Pedigreed Prius proves plenty pleasant.



2

2017 Nissan Armada

In crossover times, a big SUV.

➔ The last Nissan Armada was an SUV version of the Titan pickup truck. This time, it's an Americanized version of the Patrol, Nissan's rugged SUV sold in other parts of the world. In Dubai, they use Patrols as cop cars. So that's way cooler than a Titan with seats in the bed.

The 5.6-liter V-8 makes 390 horsepower, which out-muscles the domestic competition, and the interior is thoroughly free of any semblance of pickup. Except in the ride. While its more expensive sibling, the Infiniti QX80, uses a clever hydraulic antiroll system to keep the body magically serene over bumps, the Armada has conventional springs and antiroll bars that toss your head from side to side. For the roughly \$19,000 price difference, maybe you can handle some mild jostling.

Three-row, V-8-powered SUVs are probably a dying breed, but they still serve a purpose for people who want body-on-frame construction and low-range four-wheel drive. If you don't need that stuff, get a Pathfinder. But if you do, this is a pretty fine way to patrol the dunes.



Base price: **\$26,670**

Safety feature: **Family Guardian**, which alerts you if the car goes too fast or leaves preset boundaries.



3

2017 Volkswagen Golf Alltrack

A jacked-up Golf hunts for Outbacks.

➔ Okay, so the Golf Alltrack is a Golf SportWagen with a 0.6-inch lift kit and black fender flares. If those modifications sound profoundly pointless, they are—in the practical sense. But in the public imagination, fender flares and a slightly taller stance transform a humble wagon into an active-lifestyle adventure machine, the kind of car you'd drive to one of those endurance events in which you pay money to wade through electrified

mud and climb walls made out of wasps. Sleep with one eye open, Subaru Outback, because the Alltrack wants a piece of your pesticide-free, sustainably grown organic turf.

While most Outbacks pair a naturally aspirated four-cylinder to a CVT transmission, the Alltrack uses a 170-hp turbocharged four mated to either a six-speed dual-clutch gearbox or a six-speed manual. Either way, you're getting some pretty choice hardware for a car that costs less than \$30,000. And even though the Alltrack's off-road pretensions are silly, I nonetheless pointed it up a steep off-camber hill that I use to challenge trucks, and it scampered right up—in the snow, no less. So maybe that tiny lift isn't totally pointless after all.

Volkswagen, as you may have heard, has deep problems with its own loyal customers. A car like this, cheeky and affordable, might help win a few of them back. And maybe some of Subaru's, too.

Base price: **\$45,995**

Collectible Nissan: **The Patrol**. Nissan imported just 2,616 between '62 and '69.

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THE BRITISH BRUISER

MCLAREN'S NEWEST,
FASTEST SUPERCAR ARRIVES.

BY ALEXANDER GEORGE

In Track Mode, the dashboard folds down to become a tiny sliver showing only the essentials: rpm, gear, and speed.

Any time British supercar maker McLaren releases a new model, it's news—the latest example of its engineers chasing the company's unique understanding of perfection. Cometh the 720S. It out-accelerates all but a few road-legal vehicles ever made. Its hydraulic suspension cushions your tailbone against potholes, but stays stiff through corners. It has swing-up doors. It has Apple CarPlay. To adjust Drift Control on the center-mounted tablet, you move the sliders as a little animated car shows how much you'll kick out the tail in real life. For the few who must weigh these features against a Ferrari or Lamborghini, understand this: You don't see McLarens in paparazzi photos. This is for drivers who want history and comparative modesty. But even if you never know the 720S beyond this paragraph, remembering that engineers across the sea are building vehicles like this should make you feel a little better about the world.

PRICE
\$285,000 (estimated)
HORSEPOWER
720
ZERO-TO-60
2.8 seconds
TOP SPEED
212 mph
QUARTER-MILE
10.3 seconds
ENGINE
4.0-liter twin-turbo V-8
WEIGHT
2,828 pounds





1978 Ford F-150 SuperCab

OWNER:

Ryan Bettis

LOCATION:

Wheat Ridge, Colorado

FOUND

ON:

Craigslist

PURCHASE

PRICE:

\$2,800

YEARS

OWNED:

Two

IT WAS WINTER, and in winter, four-wheel drives are just too desirable. I gave up looking for a Bronco and found this ad for an F-150. It was listed as “Ford Truck” and had a single terrible photo. I think that’s why no one had gone to look at it.

I dealt with the owner’s son. Story was, his dad bought it new in ’78, and it was his everyday vehicle up until the ’80s. They used it for camping and towing their fishing boat, and were planning to restore it until the dad had a stroke. The son had the motor rebuilt, did some body work, but the truck kind of sat there. They had just

decided to let it go.

It was exactly what I wanted: a supercab with a 400-cubic-inch V-8 and a four-speed manual. I fixed some issues with the fuel system, and since then it’s always started, never left me stranded or stuck. I added an aluminum Edelbrock intake manifold, switched it from two to four barrels with a Holley carb, installed a bigger muffler. I had it painted back to the original brown—my dad hates it, but I love it. The interior is still mostly original and needs to be redone. But honestly, I like the old feel. It’s 40 years old and I’m the second owner.

PHOTOGRAPH BY THEO STROOMER



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A / Carbon Revolution Wheels

One part that unequivocally benefits from being made of carbon fiber. If terms like *unsprung weight* make you sleepy, look at the Shelby GT350R and the new Ford GT (which come with these wheels) as evidence.

Starting at around \$4,000 each

B / Dickies Multi-Pocket Performance Shop Pant

Like regular work pants, they're strategically reinforced—knees, belt loops, crotch. Unlike regular work pants, the fabric stretches and wicks sweat. Worth wearing for the dedicated phone pocket alone.

\$26

NEW WAYS TO LOVE YOUR VEHICLE

We see a lot of useless inventions marketed to people who love cars and driving. Here are some that are actually useful.



C / WeBoost Drive 4G-X

Ever have Google Maps cut out mid-road trip? Terrifying stuff. This antenna amplifies weak cell signals so every phone in the car always has bars, even on remote roads.

\$479

★ USA
MADE

D / Line-X

A trick off-road guys use: Spray the exterior panels with bed liner, the protective coating for pickup beds. Line-X makes a version specifically for exteriors using a patented combination of long-chain molecules. Result: Your lifted truck gets a dent-resistant exterior from only 0.015 inch of paint.

Starting at around \$500

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THE BARN JOB

Using the newest paint technology and high-efficiency equipment, we prepared this barn for its next 150 years.

BY ROY BERENDSOHN

PHOTOGRAPHS BY HENRY HUNG



Most people see a rustic, weathered old barn, its red coat faded by sun and wind, its paint chipped in a perfect mosaic of time and history, and they think, How beautiful.

I look at the same barn and think, Needs paint.

One evening last summer, I saw such a barn. I was walking in a field with some friends and their dog on land I know well. We stood in the green grass taking in the view as swallows dipped and weaved through the dusk. The barn stood at the far end of the field soaking in the last of the light, assuming the sense

of purpose old structures often do—a purpose larger than that for which they were built. Its silhouette seemed to outline the passage of time itself, a symbol of endurance and ingenuity and utility.

And yet, man, did it need a coat of paint.

Barns, the simplest of wooden structures, need paint. Each time you seal a barn with a solid coat of good paint, you buy it ten years of life, I say. And yet, as easy as it would seem to paint a barn—four flat, red sides, some white trim if it's fancy—with the wrong equipment it can be a chore.

I've worked at this magazine for

nearly three decades and I can't remember a story about painting a barn. And it's probably been twenty years since we did a major painting story at all. It was time.

We talked to the owner, said we wanted to paint his barn. He didn't resist. I and a small team immediately inspected the structure and laid out a plan. The thing needed window sashes, repair carpentry, and some general sprucing up. We'd do the paint job and enough repair carpentry to achieve a nice look. Everything else was the owner's problem.

Landing on the right color for a barn is trickier than you'd think.





THE BETTER BRUSH

Homeowners hate painting because most homeowner-quality tools are flimsy. Pro-duty brushes last longer, speed the job, and make you look like a better painter than you are. If you do nothing else, invest in better brushes.

A / Purdy Clearcut Elite Pip

This classically proportioned Purdy may be the perfect brush to cut-in for house painting. It uses synthetic DuPont filaments instead of irregularly shaped natural-fiber bristles and attaches them to the handle with a rustproof stainless-steel ferrule. The ultra-rigid filaments have a round cross section and taper to a spear point. They hold a lot of paint and stand up to repeated cleanings. Most importantly, the brush cuts a clean, crisp line even on a surface as rough as barn board.

\$28



B / Wooster Gold Edge

Wooster's Gold Edge brushes have polyester filaments that are treated chemically to give them an extremely fine taper, which provides a smooth finish—you could almost paint a car with this thing. Yet the back of the filaments is rather stiff, increasing the brush's paint-holding ability. The short-handled model shown has an overall length of about four inches.

\$9 to \$23, varies by size



NAILS POKED OUT IN EVERY DIRECTION, JUST WAITING TO BITE YOUR HAND OR SNAG A ROLLER.

settled on Benjamin Moore's Country Redwood in a high-quality Regal Select Exterior, a high-quality all-acrylic coating that provides a much thicker film than a typical coating. (See "Paint for the 21st Century," page 50.)

With the paint lined up, I set out to find the best new tools on the market—there

had to have been some improvements in the past twenty years. You don't want to mess with homeowner-grade equipment, especially on big jobs. Good tools pay for themselves on the first job and help you complete the work in half the time.

We selected Purdy Power Lock extension poles in two sizes, equipped with eighteen-inch-wide frames and a Purdy Marathon roller cover with a $\frac{3}{8}$ -inch nap. (See "Big Tools for Big Painting," page 52.) Most of us are familiar with applying paint with a nine-inch roller. You can't believe how fast painting goes when you use products like this. The paint goes on more than twice as fast.

Some parts of the barn were not accessible with hand tools. While the north, east, and west are shiplapped vertical cedar siding, the south side is weather-beaten board-and-batten. Worse, the rafter tails are exposed on the north and south faces, and many

continued on page 50

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PAINT FOR THE 21ST CENTURY

Making paint used to be simple: Grind and mix pigments, then blend them into a sticky resin. Next, thin with a solvent.

But most old paints contained lead pigment, and their solvents were pollutants. Their performance depended on the skill of the painter—usually a guy with huge forearms from spreading heavy lead-based coatings with a four-inch brush. These days we expect paints to last longer, apply easily, and not create air pollution. Oh, and they have to look great and clean up with water.

The best paint at doing all that is the one we used on the barn, **Benjamin Moore Regal Select Exterior Paint**. Its resin is 100 percent acrylic, a form of liquid plastic that can be emulsified in water. Since resin is the glue that sticks the pigment molecules to each other and to the surface, you might say it's the heart of the paint. All-acrylic paints have become popular in recent years, in part because of their chameleon-like ability to be formulated for indoors or outdoors, on nearly any surface. More expensive versions (Regal Select is \$55 per gallon) also offer incredible longevity. We likely won't have to paint the barn for another ten years.

Regal Select is a "high build" type. It dries to a film that's about twice as thick as the average coating. For us it provided single-coat coverage and smoothed the barn's weathered exterior. And because the resin is emulsified in water, cleanup is just soap and water.

To formulate such a paint, according to Carl Minchew, vice president of color

innovation and design at Benjamin Moore, the molecules need to move smoothly past one another in the fluid state, yet lock together rapidly as the water in the paint evaporates. (This has to do with rheology, the branch of physics that studies the flow of matter.) Think of pancake batter: It spreads nicely over a horizontal surface but runs down a vertical one.

Moore is one of the few companies that formulates the entire coating—the resin, the color, the works. As Minchew says, "By formulating our own resins, we can design them to meet specific criteria that we know our customers demand for a particular coating." Like a barn long past its sesquicentennial.

TWO NEW PAINTS WORTH THE MONEY

Rust-Oleum Universal

A spray paint formulated to paint any surface material, indoors or outdoors. \$7.



Zinsser Odor Killing Primer

Even the best paint won't fulfill its promise if a stink comes through. This primer is formulated with a styrene copolymer resin that seals in stink, once and for all. \$35.



of the bays are studded like a cactus with nails poking out in every direction, just waiting to bite your hand or snag a roller.

The answer was simple: We would spray as much of the barn as possible.

We were ready to paint—but the barn was dirty, one of its main doors was off its hinges, and the bottom edges of all the doors looked like they had been chewed by rats.

So I did what any sensible editor would do, I called Richard Romanski, contributing editor and Guy Who's Good at Everything, and asked if he could lend a hand. "That's more work than two guys can handle," Richard said. "Call Andy."

Andy Northshield is worth mentioning for a couple of reasons: He's a

full-time firefighter whose dad was an industrial-arts teacher, so he's incredibly handy. He's also a combat-hardened Marine. I called him up and described the job. He said only: "I'll be there."

• • •

It goes like this: You wash from the bottom up to remove dirt and mildew. Then rinse from the top down. At the same time, you scrape and pressure-wash to remove loose paint. If needed, you might have to do a second light rinse to remove dust from any scraping and sanding. Next, prime bare areas. If, even after washing, the paint is severely weathered and coated with a dusty layer of paint pigment (called chalk by paint

pros), you apply a coating of oil-based alkyd primer because it bonds tenaciously, even through chalk. Finally, when the preparations are complete, you apply a latex topcoat.

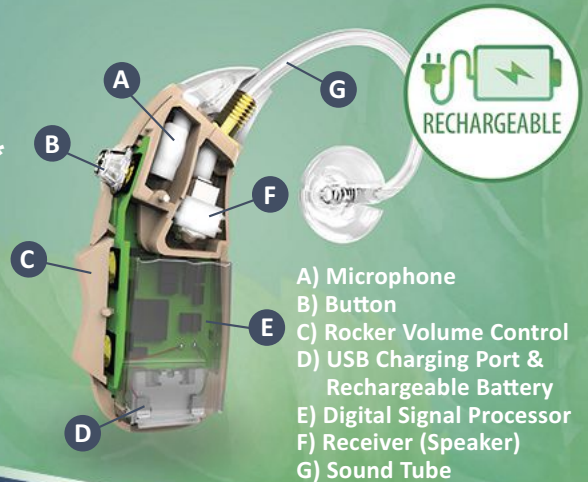
Andy went to work pressure-washing one side of the barn. Richard and I went about spot-fixing the rotted doors. Barn doors are heavy, and it takes two guys to lift them off their hinge pins. In no time, we were soaked with sweat, so I walked over to Andy to take a break. I was astonished when I saw how far he had progressed. The paint was so weak that the pressure washer hadn't just blasted off the loose chips, it had removed most of the paint from the entire barn. Andy was soaked with spray-back and his

continued on page 54

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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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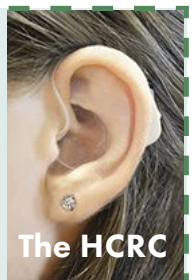
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A / Graco TrueCoat 360DS paint sprayer

At first we thought it might have been overkill to equip ourselves with two sprayers, but in the end we were glad we could shoot two colors independently. The TrueCoat doesn't pump paint out of a bucket. It carries the paint with it in a disposable flex liner bag attached to a frame on the bottom of the gun. We found it was the perfect solution. One guy stayed busy painting siding while I went up and down the ladder shooting rafter tails and the underside of the roof deck with the TrueCoat. I even painted a hornet's nest! With a little practice, you can spray with surprising accuracy and almost no overspray.

\$160

B / Graco ProX17 paint sprayer

This is a pro-duty sprayer on a stand that's designed for remodelers who paint a lot. It sucks unthinned paint out of the bucket and feeds it down a 50-foot hose to the spray gun, and is rated to shoot 0.34 gallons per minute—as fast (or probably faster) than any nonprofessional painter can work.

\$570

C / Purdy Power Lock extension poles and 18-inch rollers

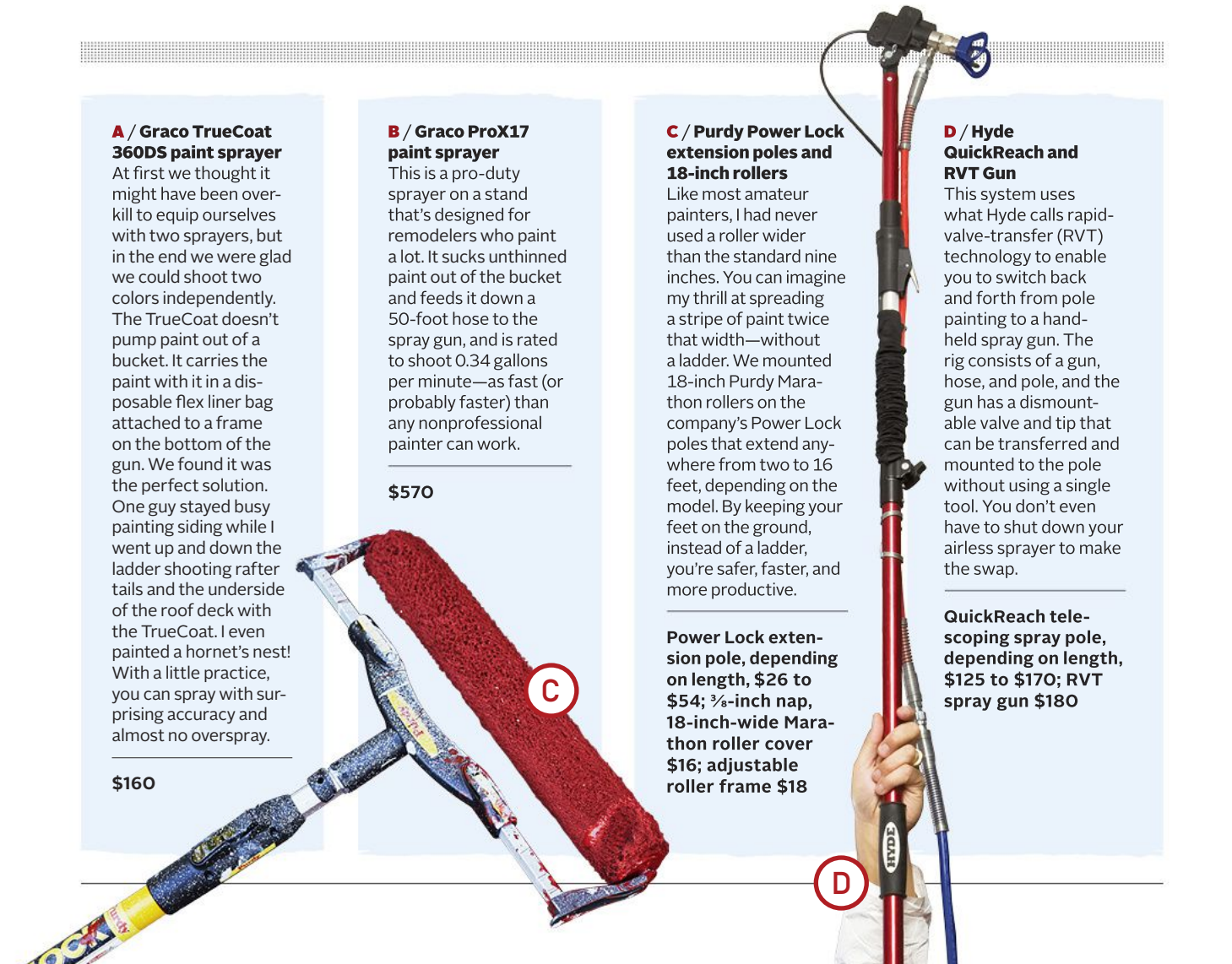
Like most amateur painters, I had never used a roller wider than the standard nine inches. You can imagine my thrill at spreading a stripe of paint twice that width—without a ladder. We mounted 18-inch Purdy Marathon rollers on the company's Power Lock poles that extend anywhere from two to 16 feet, depending on the model. By keeping your feet on the ground, instead of a ladder, you're safer, faster, and more productive.

Power Lock extension pole, depending on length, \$26 to \$54; $\frac{3}{8}$ -inch nap, 18-inch-wide Marathon roller cover \$16; adjustable roller frame \$18

D / Hyde QuickReach and RVT Gun

This system uses what Hyde calls rapid-valve-transfer (RVT) technology to enable you to switch back and forth from pole painting to a hand-held spray gun. The rig consists of a gun, hose, and pole, and the gun has a dismountable valve and tip that can be transferred and mounted to the pole without using a single tool. You don't even have to shut down your airless sprayer to make the swap.

QuickReach telescoping spray pole, depending on length, \$125 to \$170; RVT spray gun \$180



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safety goggles were caked with red. "I guess we'll be priming a lot more of the barn than I thought," I said. Andy shrugged. Richard had ambled over with a cup of coffee and a cider doughnut.

"Yep," he said.

(We did find, in the pachysandra, the hand-forged hinge pin that was missing from a broken door. These crude things look like a giant square-cut nail with a pin forged into its top. You hammer it into a barn timber and then the other part of the hinge—attached to the door—slides on top of it.)

The rest of the barn went pretty much in that fashion. We blasted it clean—so much that at times I was worried Andy was going to blast the whole thing to the ground. But of course, this old barn was a lot stronger than a pressure-washer. In more than a century and a half, it had housed all manner of tools and farm implements, bales of hay, livestock (we think), children's toboggans and bicy-

cles and army helmets, two Triumphs and an MG in various stages of repair, lawn tractors, table saws, extended families of mice and chipmunks, and a large collection of clay planting pots belonging to the current owner's wife. It was a living barn, a wondrous barn, and we were simply helping it continue to serve, the way other small groups of friends probably did in the 1970s and fifties and thirties and aughts and for decades before that.

With the washing and scraping on the siding complete, we turned our attention to the rafter tails and trim. We were relieved to find that once the weak top layer of paint was removed from these surfaces, the underlying paint was sound. So we didn't have to prime them, we simply sprayed the topcoat. Then we painted the red siding below, by both brush and spray, getting as close to the rafter tails as we dared. And we did dare. With practice, we managed to get the paint within a fraction of an inch. Some parts of the

barn were so high off the ground (more than twenty feet) that you couldn't tell if there was a narrow gap where one coat of paint stopped and the other began. Still, we carefully went over the structure and touched up by hand and cut in to a clean, crisp line everywhere. We did a similarly meticulous job painting the flat black metal hinges and door hasps. Barns deserve respect.

One fine autumn morning, the barn job was complete. Since we never spent a full day on the project but rather worked on it as time permitted between other tasks, it's hard to say how long it all took. Several days, would be my inexact estimate.

But it was satisfying. The barn looked proud, and we had given ourselves a first-rate education in how to paint big structures. Orange maple leaves drifted down and made a fine sight in contrast with the red and white backdrop.

I stepped back, took it in and thought, That's beautiful.

PM

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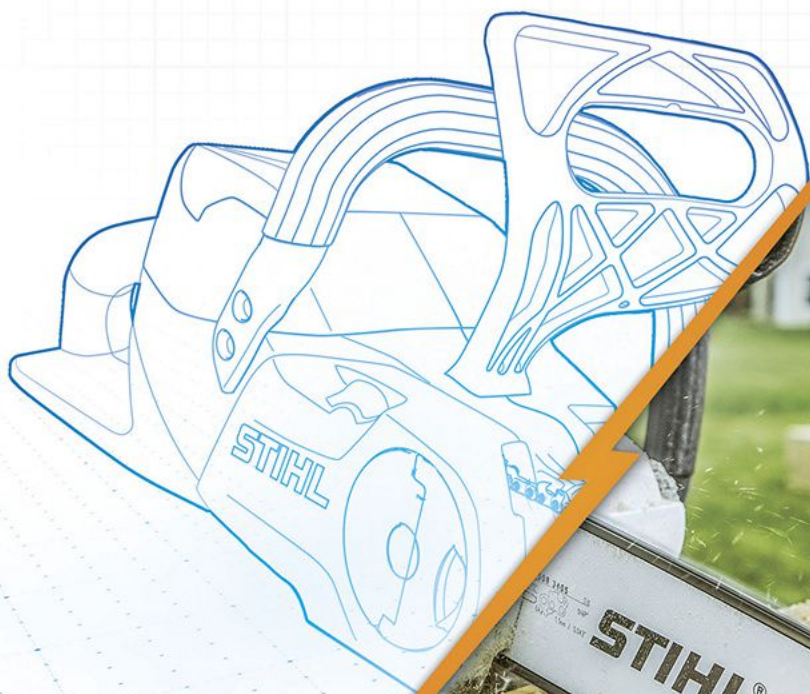
STIHL
LIGHTNING
BATTERY SYSTEM™



STIHL LIGHTNING BATTERY SYSTEM™

The STIHL Lightning Battery System™ is designed to get more out of every charge. Our AI, AK and AP series include over 20 pieces of equipment and give you multiple battery solutions. Whether you're an experienced professional or a demanding homeowner, you'll get just what you need – the power of STIHL in a battery.

FROM
THE LAB



TO
THE LAWN

MULTIPLE SOLUTIONS

AI SERIES

Integrated batteries make this series perfect for smaller yards and condominiums.

| INTEGRATED BATTERY |



HEDGE TRIMMER



BLOWER



TRIMMER

AK SERIES

With multiple battery options, this series is ideal for maintaining suburban yards.

| BATTERIES | AK 10 | AK 20 |



HEDGE TRIMMER



BLOWER



CHAIN SAW



TRIMMER

AP SERIES

More power and longer run times make this series great for a wide range of properties.

| BATTERIES | AP 100 | AP 300 | AR BACKPACKS |



HEDGE TRIMMERS



BLOWERS



CHAIN SAWS



TRIMMERS



EXTENDED
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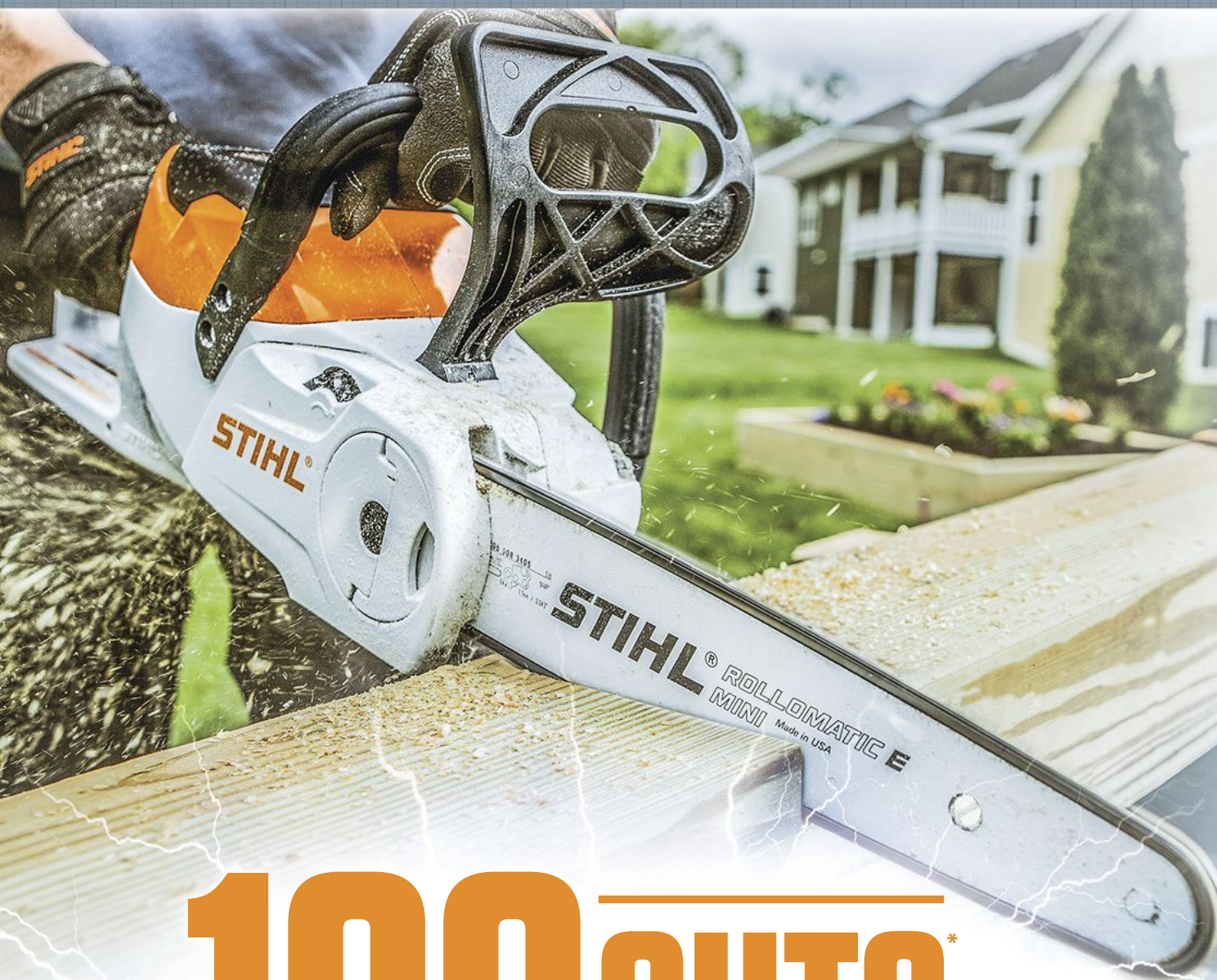
LAWN MOWERS



CUT-OFF MACHINE

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100 CUTS*

• ON A SINGLE CHARGE •

ON A SINGLE CHARGE

CHAIN SAWS

STIHL Lightning Battery System™ chain saws bring the best of both worlds to your property. First, they deliver strong, consistent performance thanks to STIHL Lithium-Ion technology. STIHL Battery-Powered Chain Saws are also quiet and start instantly with the squeeze of a trigger. It's big performance in a small, lightweight package.



MSA 120 C-BQ



MSA 160 C-BQ



MSA 200 C-BQ



STIHL LIGHTNING BATTERY SYSTEM™



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• ON A SINGLE CHARGE •

TRIMMERS

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AI
SERIES ▶ **FSA 45**



AK
SERIES ▶ **FSA 56**



AP
SERIES ▶ **FSA 65**



AP
SERIES ▶ **FSA 85**



AP
SERIES ▶ **FSA 90 R**



STIHL LIGHTNING BATTERY SYSTEM™



**CLEAR A
SIDEWALK** **7** **FOOTBALL
FIELDS LONG***

• **ON A SINGLE CHARGE** •

• **ON A SINGLE CHARGE** •

BLOWERS

When you need to clear debris quickly, the benefits of battery power are easy to see. STIHL Lightning Battery System™ blowers are lightweight, powerful and start instantly with the squeeze of a trigger. STIHL Battery-Powered Blowers can also be used in either your right or left hand.



STIHL LIGHTNING BATTERY SYSTEM™



TRIM THE
LENGTH OF **3** FOOTBALL
FIELDS*

• ON A SINGLE CHARGE •

ON A SINGLE CHARGE

HEDGE TRIMMERS

Whether you use them daily, or just a few times a season, STIHL Lightning Battery System™ hedge trimmers are ready to get the job done. Just pull the trigger and you're ready to tackle overgrown hedges and shrubs. STIHL Battery-Powered Hedge Trimmers are lightweight, start instantly and deliver quiet, powerful performance.



▶ **HSA 45**



▶ **HSA 56**



▶ **HSA 66**



HLA 65 HEDGE TRIMMER



EXTENDED



HLA 85 HEDGE TRIMMER



TELESCOPING



HTA 65 POLE PRUNER



HTA 85 POLE PRUNER



TELESCOPING



RMA 370 LAWN MOWER



16.25" DECK

RMA 410 C LAWN MOWER



17.75" DECK

RMA 510 LAWN MOWER



21" DECK

SPECIALTY SOLUTIONS

STIHL offers one of the largest selections of battery-powered outdoor equipment available. With a single battery, you can power a wide range of specialty equipment, including pole pruners, extended reach hedge trimmers, lawn mowers and our cut-off machine.



PROFESSIONAL SOLUTIONS

TSA 230 CUT-OFF MACHINE



STIHL LIGHTNING BATTERY SYSTEM™

INTEGRATED



AK 10 | AK 20



AP 100 | AP 300



AR 900 | AR 3000



STIHL BATTERIES AND CHARGERS

STIHL batteries are based on STIHL Lithium-Ion technology, hitting the sweet spot of performance and weight. They're also custom engineered by STIHL to include a host of advanced features.

They're designed to last – even after 500 charges, the battery retains over 80% capacity. Our batteries include specialized voltage monitors and temperature sensors to help ensure optimal operation and a long service life.

QUICK CHARGE GUIDE

	CHARGERS				
	AI	AL 100	AL 101	AL 300	AL 500
BATTERIES	AI 210-300				
AK10		80	80	30	30
AK 20		150	150	45	45
AP 100		90	90	50	35
AP 300		250	250	75	35
AR 900				250	130
AR 3000				300	160

MINUTES TO FULL CHARGE

AL 101



CHARGER



AL 100 | AL 300 | AL 500



CHARGER



WHAT CAN **YOU** DO ON A SINGLE CHARGE?

CHAIN SAWS	
<div>AK</div> 	<div>MSA 120 C-BO</div>  <p>Make around 100 cuts through a 4" log.</p>
	RESULTS USING AK 20
<div>AP</div> 	<div>MSA 160 C-BO</div>  <p>Make around 200 cuts through a 4" log.</p>
	RESULTS USING AP 300* <small>* AP 300 is an upgrade on some models</small>
TRIMMERS	
<div>A</div> 	<div>FSA 45</div>  <p>Trim 1,312 linear feet. Based on trimming 10.5" swath of grass</p>
	RESULTS USING AK 10
<div>AK</div> 	<div>FSA 56</div>  <p>Trim 1,640 linear feet. Based on trimming 10.5" swath of grass</p>
	RESULTS USING AP 300* <small>* AP 300 is an upgrade on some models</small>
<div>AP</div> 	<div>FSA 65</div>  <p>Trim 2,559 linear feet. Based on trimming 10.5" swath of grass</p>
	<small>* AP 300 is an upgrade on some models</small>
BLOWERS	
<div>A</div> 	<div>BGA 45</div>  <p>Blow 2,153 square feet.</p>
	RESULTS USING AK 20
<div>AK</div> 	<div>BGA 56</div>  <p>Blow 6,458 square feet.</p>
	RESULTS USING AP 300* <small>* AP 300 is an upgrade on some models</small>
<div>AP</div> 	<div>BGA 85</div>  <p>Blow 10,333 square feet.</p>
	<small>* AP 300 is an upgrade on some models</small>
HEDGE TRIMMERS	
<div>A</div> 	<div>HSA 45</div>  <p>Trim 262 feet. Based on trimming 18" wide hedge top</p>
	RESULTS USING AK 10
<div>AK</div> 	<div>HSA 56</div>  <p>Trim 918 feet. Based on trimming 18" wide hedge top</p>
	RESULTS USING AP 300* <small>* AP 300 is an upgrade on some models</small>
<div>AP</div> 	<div>HSA 66</div>  <p>Trim 1,673 feet. Based on trimming 18" wide hedge top</p>
	<small>* AP 300 is an upgrade on some models</small>

*Run time may vary based on battery type, charge level and capacity, model, operating style and conditions.

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STIHL

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99 BOTTLES OF IPA

Why is everybody suddenly drinking this beer that's been around since the 18th century? A Popular Mechanics investigation.

BY JACQUELINE DETWILER AND MATT ALLYN

ON THE WALL

In the bar of your life, IPA is that college friend who always shows up at the perfect hour, with a cool story about the time you taught a monkey to operate a keg during your semester abroad in Indonesia. It's piquant and funky, and sometimes smells a little bit like weed. But what *is* an IPA, really? The acronym stands for India pale ale, a type of beer with high alcohol and a ton of hops designed by the English to withstand the long journey to colonies in South Asia (hence the "India"). But we wanted to know more, so we found out the hard way: by drinking a ton of them.

West Coast IPA

The style of American IPA that arguably promulgated the craft-beer revolution around 1996. Usually quite bitter, with a dry finish, it traditionally contains the three C's: Cascade, Centennial, and Columbus hops, which are grown in the U.S. and often used in combination.

THE REGIONAL RIVALRY



New England IPA

A reaction to West Coast IPAs that's slightly more malty, less bitter, and unfiltered. Most beer people point to Heady Topper, made since 2003 by The Alchemist brewery in Waterbury, Vermont, as the first New England IPA to gain widespread admiration among beer cognoscenti.



GLOSSARY OF TERMS

Double/Imperial	A term for a beer that is stronger and hoppier than a regular IPA. Does not necessarily contain double the hops, just more. Usually around 100 IBU. (See IBU, below.)
Dry-hop	To add hops late in the brewing process rather than during the boil; adds aroma and flavor but almost no bitterness.
Hop	The seed cone of the <i>Humulus lupulus</i> vine, and one of the four main ingredients in beer. Fruity, weedy, or citrusy. Also bitter.
International Bitterness Unit (IBU)	A number used by brewers as a proxy for bitterness. It's complicated, but here: Budweiser is about 10 IBU. A normal IPA is closer to 50.
Session	A lower-alcohol beer—typically around 5 percent—that a person can consume throughout an entire drinking "session" without getting tanked.
Wet-hop	To add fresh, undried hops within hours of picking them. Wet-hopped IPAs are pungent, and, for obvious reasons, limited to hop-growing regions during the annual harvest.

LET'S GET STARTED...

Dogfish Head originally used a vibrating electric football game to slowly and continuously dose its IPAs for 60, 90, and 120 minutes.

Odell named its rich Myrcenary imperial IPA after myrcene, an oil found in hops that's believed to bring big floral and fruit flavors.



Barley typically acts as a silent hops delivery system, contributing only minor flavor in IPAs. But rye, as it's used in Bear Republic's Hop Rod, complements most hops with its spicy, earthy flavor.

It's not unusual for brewers to amplify IPAs with hop oil extracts, but Sierra Nevada's Hop Hunter uses a unique oil made from steam-distilling fresh hops in the fields, moments after they've been picked.

Most breweries blend hop varieties in hopes of a more complex beer. But a handful of hops, like the grassy, tropical Mosaic used in Lost Nation's Mosaic IPA, are bold enough to stand alone.

Dry like champagne and bursting with hop flavor, Russian River's Blind Pig set the first standard for West Coast IPAs more than 20 years ago.

The Alchemist's Heady Topper can implores you to drink straight from the can, but pouring the milky-looking brew in a glass lets you enjoy the thick, layered hop aroma.



FIELD TEST

THE INDIA PALE ALE
PHENOMENON:

A TASTING SESSION

BEERCOUNTER

1 **Jacqueline Detwiler:** Cheers, everybody! Thanks for coming by to help. You've all heard the song, and there's a lot of beer here. So, you know: Take one down.

Alexander George: Song?

Jacqui: The "99 bottles of beer on the"—are you serious?

6 **Kevin Dupzyk:** You know, "99 bottles of beer on the wall, 99 bottles of—"

Jacqui: Stop.

Matt Allyn: Anyway, for the record, it's two o'clock in the afternoon, and a few of us are in a glass conference room about to plow through 99 bottles of IPA. Our colleagues can see us in here. While they work.

12 **James Lynch:** Not that I'm complaining, but why are we doing this again?

Jacqui: We're doing this to find out why IPAs are having a moment right now. Why, when you walk into pretty much any bar in the country, there are four or five IPAs on draft. Why people wait in line for hours just for a taste of the best and strongest. How the disparate notes of flowers and pine and citrus combine to approach a single, atavistic flavor but still retain their individual identities. How within the humble IPA is a bounty as boundless as the sea—

Kevin: Did you have a speechwriter or something?

Jacqui: I'm just excited.

30 **Matt:** Jacqui's right. For example, I really like this **Melvin 2x4 DIPA**, out of Jackson, Wyoming. It's piney and juicy and peppery. It's like if you crossed a beer with a really good lassi. That's something you can only do with hops, of which there are hundreds. If you think about the potential combinations of hop varieties and brewing styles, the putative complexity of any single IPA is virtually infinite.

Jacqui: See. Matt gets it.

Kevin: What's a lassi?

Matt: An Indian smoothie typically made with mango and yogurt.

James: This next one is **Pipeworks' Glaucus**. That's a weird name.

42 **Kevin:** I think my grandmother had a bout of glaucus last summer.

Matt [ignoring]: Glaucus is a Belgian IPA, so it's spicy like a Belgian-style beer, with that wintery, mulled kind of depth. And there are wild-yeast IPAs, like this **New Belgium Brett IPA**, that have a funky leathery sort of flavor to them. There are red IPAs, like **Ninkasi's Dawn of the Red**, here. And there are white IPAs and black IPAs. Any kind of beer you could possibly want can also be an IPA. Which is kind of the point here.

James: I liked that **Breaking Bud** from Knee Deep.

Kevin: I refuse to endorse pun beers.

James: **Drake's Denogginizer**. Good beer name, or great beer name?

Kevin: You know what I like is this **Pipeworks Ninja vs. Unicorn**. I mean, aside from the truly horrific can design. It's got all the punch of a double IPA, but none of the sweetness you normally get with the extra alcohol. Maybe because it's unfiltered? What a great beer.

50 **Alex:** [Moans.]

Jacqui: What?

Alex: I just realized I haven't eaten lunch.

A Danish photographer appears with a tray of cheese and meats.

Alex: It's an angel!

Alex stands and painstakingly creates five tiny sandwiches out of cheese and prosciutto. Everyone else eats hunks of cheese and shreds of prosciutto like normal people.

Kevin: I have to use the bathroom.

James: I also have to use the bathroom.

Alex: Are we on the last shelf yet?

James: I feel like I'm being punished.

Kevin: I would trade the rest of these IPAs for a single porter.

75 **Matt:** Next up is the **Dogfish Head 120**.

James: You guys put this at the end? What is wrong with you? This is like a million percent alcohol.

Jacqui and Matt: Sorry.

Alex: Why is it called 120?

Jacqui: I think the Doghead people—Dog. Fish. They boil the wort for 120 minutes and they put hopes in the whole time to pile in more flavor.

Kevin: Hopes?

Jacqui: Hops.

Kevin: Be weird if they put hopes in it. Be amazing, actually.

Matt [laughing aloud, suddenly]: I'm hoarding all the **Pliny the Elder**. It's West Coast perfection. If they made a Pliny cologne, I'd buy a case.

James: Hey, hey, hey. Hey. Speaking of cheese, do you ever think about how expensive cheese is? Like that, pound for pound, cheese is way more expensive than gasoline?

Kevin: Uh.

James: And that, like, if you made a cheese station that pumped Cheese Whiz instead of gas it would be so awesome.

85 **Kevin:** How does this relate to beer?

James: No, I'm just saying that when we end up in whatever multifront trade war we're going to end up in, we'll all be stuck eating American cheese. No good Swiss. No good Camembert. No good Parmesan. Can you imagine eating a Reuben with American cheese?

Jacqui: There's goat cheese.

Alex: At least we'll be okay on beer. It's China who's gonna lose out on beer. In a trade war.

James: Totally. You ever tried Tsingtao? No thank you.

Everyone [raising various cans, bottles, and vessels]:

TO BEER. [Pause.]

99 **James:** Do you guys think I'd make a good bounty hunter?

Kevin: I have to use the bathroom.



To see the cast of characters, turn to the masthead on page 4.

BEACH PEOPLE



The story of a surfboard shop, ample waves, a half-Chihuahua, and three guys who seem to have things pretty well figured out.



Photographs by
ERIN FEINBLATT





Great waves are a scarce resource. In a crowded community like Santa Barbara, California, the surf lineup can turn into a melee in which friends fight like brothers to catch the same wave.

Locals admit it's an aggressive scene, but when they're out of the water, they have a sanctuary in the Trim shop to decompress and talk about the barrels they *did* land.

The Trim shop exudes a pastel hippie vibe, complete with an old yellow couch that looks like a curbside rescue. Between rows of boards, a window looks into the workshop where owner Ryan Lovelace shapes boards by hand with his power planer. The central picnic table is scattered with photography books and board sketches. And throughout the day friends of the shop drop by on

their way to nowhere in particular for the chance to talk waves, when they can't be in the water.

Lovelace opened the surf shop in the summer of 2015 with his girlfriend, Katie McLean, to give Santa Barbara an indie alternative to the town's relatively button-down shops filled with CNC-machined boards from corporate surf brands. Out in the lineup, Lovelace says he'd see scores of weird, experimental boards, but back in town no shop embraced the strange and eccentric.

Lovelace's boards display a vintage aesthetic on the surface, but the shaper doesn't want you to mistake them for old, reheated retro designs. Lovelace takes inspiration from the past, but not boards that made it big. Rather, he's a surf archaeologist, digging up, refining, and perfecting old boards lost to the blinding

progress of the 1970s where, he says, every new board spawned five more shapes and good ideas were dropped on a whim.

Lovelace's flagship, the v.Bowls, takes cues from an early board shaped by surf prodigy Wayne Lynch in the late 1960s. Most surfboards keep their center of mass forward, for greater speed, but at the cost of maneuverability. In Lynch's design, he saw an opportunity to make an uncompromising board. He narrowed the front for a "backwards board," pushing the bulk toward the tail. He also gave it sharper edges to release water. The resulting shape offered more responsive handling and just as much speed—the holy grail of attributes among board shapers. As one happy customer describes riding the v.Bowls, "It's squirrely, like I'm on the edge of falling off, but that's the fun."

A > Surf Santa Barbara

Sitting a couple hours up the coast from the heart of Southern California surf culture, Santa Barbara, as Lovelace describes it, is a SoCal satellite with more than enough high-quality waves and people to make up for its relatively small size.

B > The Crew

Musician Chris Everett (right) plays guitar in the shop-favorite band Pleasure. Joe Yee (left) apprentices under Lovelace, shaping boards for the house brand Trim Craft.

From left, on Yee: Pendleton sweater (\$159). On Everett: Rhythm hat (\$40), Purnell shirt (\$76).



A



B



C

A > Sandspit

Santa Barbara's Sandspit break is notoriously flat, but when a swell comes in, like today, you can ride the right-breaking barrels nearly a quarter-mile.

Hurley wetsuit (\$280).

B > The Assistant Manager

Herbie, 13, is Lovelace's loyal half-Chihuahua, half-dachshund sidekick.

C > In the Workshop

Lovelace shapes up to three surfboards a day. Each begins as a polyurethane-foam blank, which he shapes to his design with a power planer. A glassing shop in Ventura finishes his boards, adding the artwork, laminating resin, and fiberglass.

Trim shop hat (\$25), Rhythm fleece (\$100), Faherty pants (\$148).

D > The Funk Zone

The Trim shop sits in Santa Barbara's Funk Zone, a former warehouse district now filled with art galleries, restaurants, and breweries.

From left, on Yee: Rhythm beanie (\$20), Levi's jeans (\$70), Converse sneakers (\$50). On Lovelace: Pendleton Surf Popover (\$139), Rhythm track pant (\$80), Vans sneakers (\$50). On Everett: Freemans Sporting Club hat (\$48), Retrosuperfuture sunglasses (\$249).



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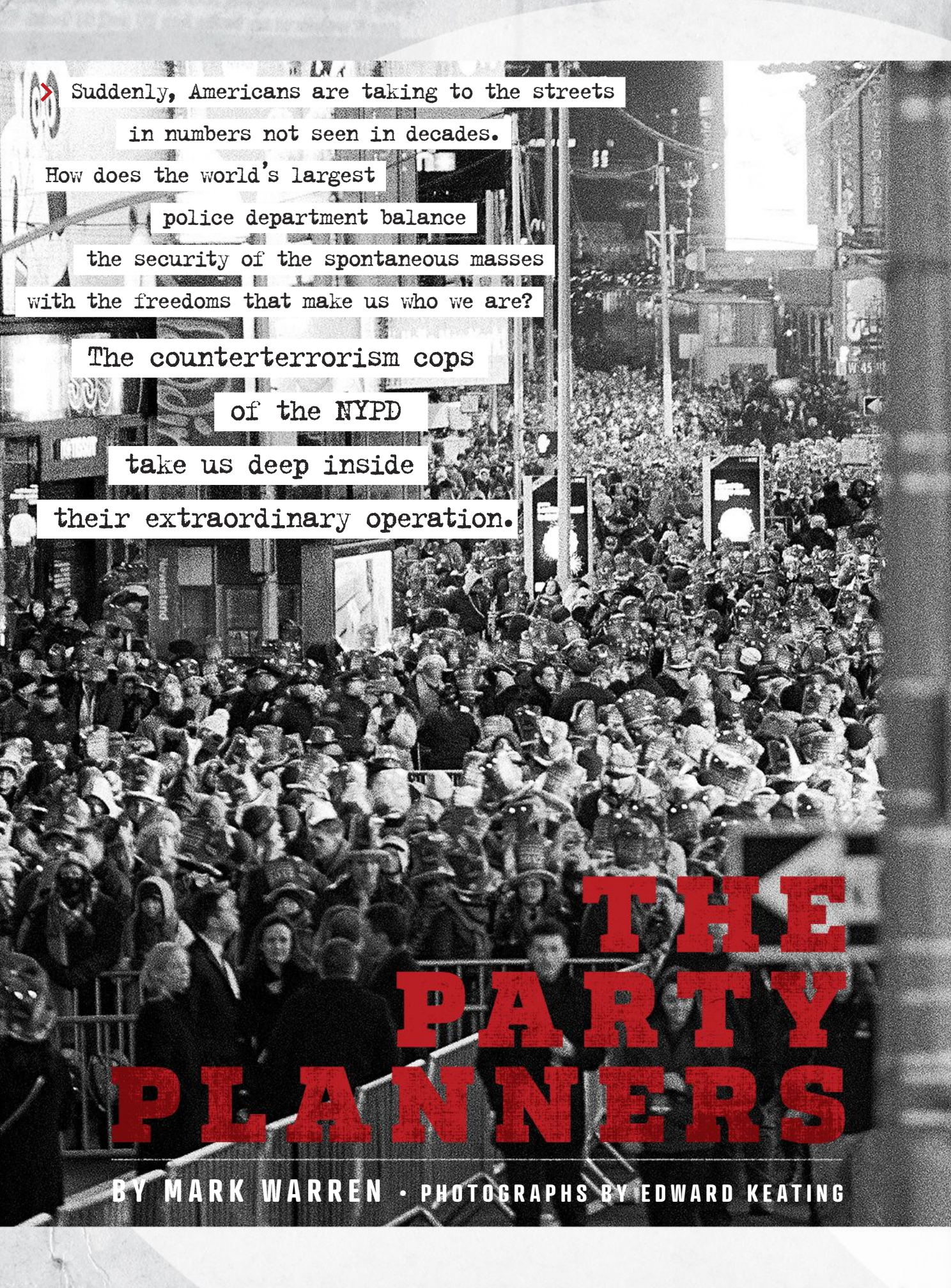
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in numbers not seen in decades.

How does the world's largest

police department balance

the security of the spontaneous masses

with the freedoms that make us who we are?

The counterterrorism cops

of the NYPD

take us deep inside

their extraordinary operation.

THE PARTY PLANNERS

BY MARK WARREN • PHOTOGRAPHS BY EDWARD KEATING

There are 1,000 cops in the department's Counterterrorism Bureau, but for some big events, other police personnel wear the division's insignia, too, which sends a powerful signal to the public.



T

HE TONGUES OF native New Yorkers land heavy on consonants, and on vowels, too. On words and sentences. On poetry and prose, on *dese*, *dem*, and *dose*. For all the worry that television has homogenized all the fun accents out of existence, the sons of certain neighborhoods in Queens and Brooklyn—they still speak the hell out of all the words. Make a real meal out of them. No posh Manhattan private school diction for these guys, not on your life. And these guys here—these guys are cops, and when they're on the job, people aren't people, they are the more formal *in-duh-vi-jew-wuhls*, and by the time this man here, Jim Waters, chief of counterterrorism, New York

Police Department, gets up the slopes and down the valleys of that word, it's picked up another syllable or two. For reference, Waters sounds a little like the old actor Broderick Crawford, who played a lot of cops. And Waters may be chief of counterterrorism now, but he started out life walking a beat in the 110 Precinct, Elmhurst, Queens, which isn't as quaint as it sounds.

It's just after 2:00 in the afternoon on New Year's Eve, cold dappled sunlight splashes up and down Seventh Avenue, the universe's own spotlight giving God a better look at what in hell is happening down in New York. Everybody, it seems, is curious about this particular spot on the dirty globe today. Chief Waters is standing right in the middle of the street, facing north toward Central Park, keeping a close eye out as the hearties and the crazies and the curious stream from Forty-Sixth Street, take a left toward Times Square, and enter into the "chute" for screening by cops under his command. They're all here for The Show—*Midnight in Times Square, baby!* hollers a young Asian woman who doesn't look dressed warmly enough at all, as she dances past to join her friends. Chief Waters smiles and nods. His aide-de-camp, Captain Danny Magee, shakes his head, a bemused expression on his face. Magee's always looking to bust somebody's balls.

"Some of 'em mighta already had a few," he says. "Once they're screened and in the pens, it's hard to leave and there's nowhere to pee." He pauses, thinks about two million people—that's how many guests they're expecting tonight—with no place to pee. "They're gonna need a jar!" he says, his face erupting in a crinkly smile. If Waters is Broderick Crawford, Magee is more Jimmy Cagney. Very Brooklyn, total wiseass. Mother, wonderful woman, still lives in the house he grew up in. "Maybe a friend can hold up a sheet, so they can take turns using the jar! 'Cause they're gonna need a jar." You cannot spell *jar* the way Magee says *jar*. His voice is snappy and he is shouting a little because this intersection—Forty-Sixth and Seventh—is madness, the center of an enormous mobilization of a security apparatus that has no peer anywhere in the world in terms of civil police departments. In the name of fun and freedom of assembly, seven thousand cops are at this moment being deployed to harden a grid in the center of Manhattan between Thirty-Eighth Street and Central Park, and between Eighth



Avenue and Sixth Avenue. As mass gatherings of the public go, this is the big enchilada, the Super Bowl. A couple years ago, incidentally, the city hosted an actual Super Bowl at MetLife Stadium across the way in Jersey—Chief Waters threw that party, too. “That’s all we are—party planners,” says Magee. “Party planners with big guns and a bomb squad.” Waters smirks. “That’s why we keep Danny around,” he says. “For his sense of *yuma*.”

It’s not just Magee. Everybody’s in pretty good humor today. The pizza guy on the block is sending a platoon into the jovial crowd with fresh hot pies. “Thirty bucks!—that’s a helluva markup,” says Magee. “He’s making his nut for the year today.” But he sure is keeping them fed in the pens. Waters says there are forty-eight of the block-long enclosures, from here all the way up toward the park. They were erected by hundreds of cops using thousands of metal barriers starting at midnight last night. Any brave souls who want to watch the ball drop are entering the grid from the east and west, and at entry points on either Sixth or Eighth avenues, they subject themselves to a hand-held magnetometer that detects any ferrous metals, and maybe a pat down, a radiological detection test, random explosive-trace detection in which something that looks like litmus paper is wiped on their hand or run down the length of the zipper on their jacket, and everybody gets sniffed by a dog. They then will walk toward Seventh Avenue or Broadway, past at least one twenty-ton sand truck, two on the wider streets—each topped off with another fifteen tons of sand—blocking the street, past the row of six-foot-long, two-ton concrete blocks blocking the sidewalk. Counterterrorism cops have to pay attention and learn from what’s in vogue among people who want to kill as many people as possible, and this year’s innovation in mayhem has without doubt been driving a big truck into as big a crowd as possible. So today, Waters is hard-



ening the perimeter of the grid with trucks so heavy that “ain’t nothing gonna move ’em,” but that have the added convenience of being portable, so at the end of the night you just drive them away. Down the block the once-screened stream of humanity goes toward the pens. They walk, silly hats on and bottled water in hand, and when they reach Seventh Avenue, they run into Chief Waters and his boys and are screened all over again. Two million people, screened twice. Magnetometer, radiological, dog. All the while, “red cell” teams of cops in plainclothes are dispersed among the crowd, trying to breach the system, probing its vulnerabilities, and “that bag can’t come in here, ma’am. *Ma’am*, no bag,” Magee says. “What’s that? You can either walk out the way you just came in, or you can donate it to our growing bag collection here.” Magee pulls back a tarp to reveal bins and bins of bags of all shapes and sizes and degrees of fanciness that have already been surrendered. A young woman, thinking better of the whole idea, is clawing deep into the bin to retrieve a bright-green leather bag to be on her way.

Captain is an old-man rank, a retirement

To harden a perimeter, and protect against truck attacks such as those last year in Nice and Berlin, the NYPD uses the city’s 20-ton sand trucks. Add a load of sand, and the truck doubles in weight.

rank, and Magee isn’t yet forty. Probably ought to pay attention to that name, he’s going to be somebody. Waters is on the verge of fifty-seven, and with compulsory retirement coming when he hits sixty-three, he is both state-of-the-art in counterterrorism and nearing the end of his career in counterterrorism. He’s been pulling New Year’s Eve duty since infancy—

“I remember, I was a young sergeant, ’86 I think it was. Forty-Seventh and Seventh, and they told us to bring our hats and bats—riot helmets and nightsticks. That was about the height of technology at the time. I had ten cops and by 7:00 or 8:00 p.m., the crowd was already somewhat, uh, intoxicated...” Not to mention completely unregulated, and somewhat aggressive. Bottles were flying, and so Waters told his men to put their chin straps on. One of his cops wouldn’t do it, and a couple minutes later, he took a bottle to the head, knocking his helmet sideways. “I said, Are you gonna put your chin strap on now?” The threats were different then—FALN (militant Puerto Rican nationalists) and the like—but nobody really knew yet what counterterrorism was, or why it might be necessary.

A black Lab at the end of a cop’s leash brushes your leg as he methodically pushes his way through the crowd, padding spryly back and forth across the avenue. That’s

The threats were different then—FALN and

the like—but nobody knew yet what

counterterrorism was or why it was necessary.

HOW CROWD CONTROL WORKS

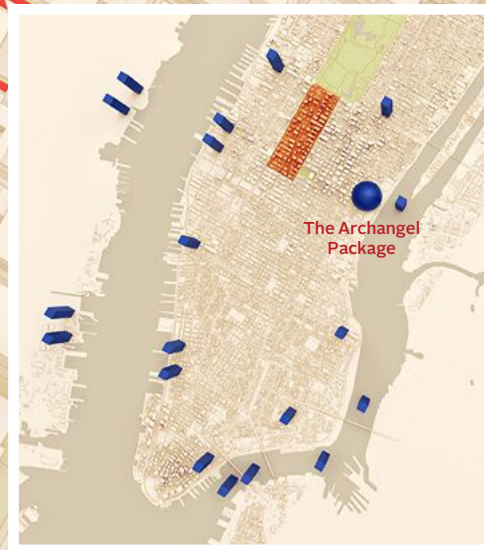
"You have concentric circles of security," says Deputy Commissioner John Miller. "A graded system. You're gonna catch most things at the first ring, and if not there you'll catch it at the second ring, or a dog may catch it at the third ring. Before you go into those pens, there is a pretty good chance that going through all those baffles and filters, somewhere along the line, if there's something that needs to be caught, it'll get caught."

First Screening Points

Second Screening Points

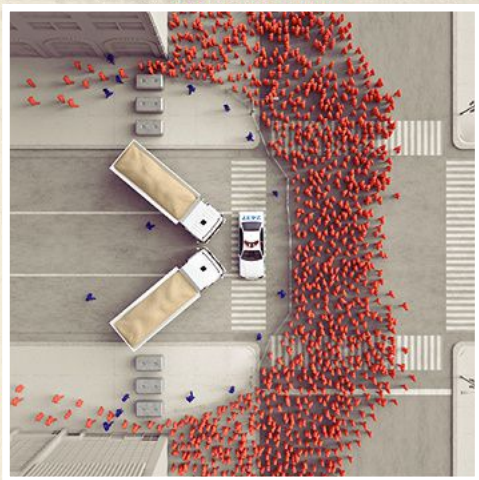
OTHER ASSETS

> **At mass gatherings** in a large city—say, New Year's Eve—when you have assets dedicated to securing a specific spot, you need to have resources free and able to move on a moment's notice (such as the Archangel Package, a.k.a. the Holy Shit Package, see page 90) either to the gathering or to another area of the city.



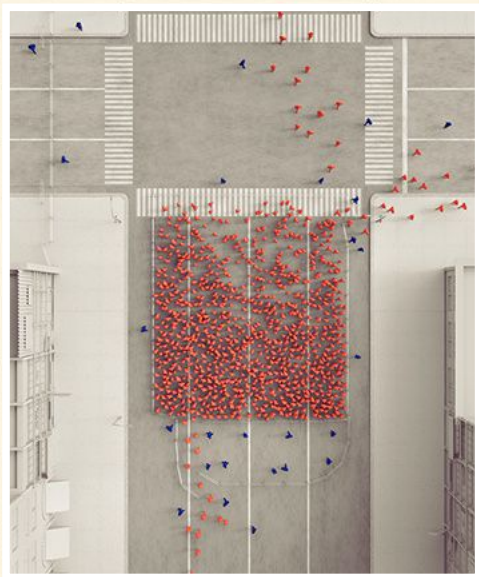
The Archangel Package

NORTH



SCREENING

➤ **For a controlled event** (as opposed to a more spontaneous exercise of free speech) of two million people, screening is essential, as is blocking access to where the largest concentrations of the crowd will be assembled. In addition to the street being blocked by fully loaded sand trucks, the sidewalks are blocked by two-ton concrete blocks.



PENS

➤ **Back in the old days**, New Year's Eve in Times Square was an unsecured, alcohol-drenched free-for-all, which, in a post 9/11 world, is simply unheard of. Now, following screening, the secured revelers are congregated in "pens," less free to move, but less likely to get hurt.

Kevin, one of the department's vapor-wake dogs. German shepherds are very good at sniffing a bomb in a backpack stuffed under a mailbox, but these Labs, specially trained at Auburn University, are expert at moving targets. As each of us moves through the world, we constantly displace air, disturbing a universe of molecules, and it is the plume of air left in the wake as each reveler cuts through the space in front of him that Kevin is sniffing, in patient search for precursor bomb material or radiological matter of any kind. We give off molecules, and so do bombs. Once, during a half-marathon in the park, one of the Labs alerted on a runner wearing only shorts and a tank top, and was insistent that there was something suspicious on the man. "Excuse me, sir, are you undergoing radiation treatment of some kind?" The dogs sometimes alert on cancer patients. The man dug into the pocket of his shorts, and brought out a tiny pill. Nitroglycerin. Somebody had told him that taking one halfway through the race turbocharges you for the second half. The vapor-wake dog had discovered his secret.

To secure the grid for tonight, forty of the NYPD's dogs are on the job, including eight of the vapor-wake Labs. Magee says that the department favors the Labs, both for their extraordinary skills but also because people sometimes have negative associations with shepherds. Labs aren't as intimidating. Regardless of breed, all the counterterrorism dogs are named after a fallen cop. Kevin is named after Kevin Gillespie, a street-crimes cop who was killed on the job in 1996. And here comes Vin, named after Vinnie Danz, an emergency-services cop killed on 9/11.

Waters plans to spend all afternoon in constant communication with his officers deployed around and throughout the grid, making certain that this massive undertaking that has been in planning for the past 364 days is proceeding smoothly. He'll be traveling back and forth to the Joint Operations Cen-

ter at 1 Police Plaza downtown, the nerve center of all police operations but especially, today, counterterrorism and intelligence, which will be collecting information from NYPD assets stationed in thirteen foreign countries, including most of the current hot spots. He will be looking at those thirteen countries as they go to midnight, like dominoes heading to New York. If midnight passes without incident in London, Tel Aviv, and Istanbul, Waters will breathe a little easier. He knows and has staked out every parking garage in the grid, to make sure no bad guys go in to plant something, or out, unscreened, to do harm. Two days ago, he had every manhole cover in the vast swath of midtown Manhattan marked, a job so big that it alone would strain the ability of most other cities to do it. The checklist of all that Waters and the seven thousand cops deployed here today have to do reels in his head. You can see it. He is buttoned-up but cordial, talking easily one second and lost behind his eyes the next. But look around today and you are likely to find Chief Waters, given a spare moment, down on the ground—or in this case, kneeling on the street—playing with a large variety of dogs, all of whom are official New York City police officers, wearing shields and signs that read "Do not pet."

Just then, an interloper with brown hair and glasses—with a look of determined nonchalance—gets through these layered and concentric circles of security wearing a backpack, walks right on through, and after screening his share of approximately five hundred thousand people so far today with nothing so much as a false positive on a bologna sandwich, Vin goes nuts. He strains at his leash so hard he almost pulls his partner off his feet. Vin points at the object of his concern with his snout, almost touching the backpack on the man's back, and then he sits on his haunches, supremely alert. The man is now frozen in his tracks. "You know it's a definite hit when the dog sits down," Vin's partner

says. “These dogs do not make mistakes.” Vin has alerted on a decoy, a test of the system. The guy with glasses was let through on purpose, and in his backpack he carried a half-pound of smokeless powder that Vin could smell from here to tomorrow.

Magee taps his watch, and now Waters is up again and moving, heading to Forty-Second Street, past pen after pen, full of the most joyful revelers with the greatest bladder control you ever saw. Everywhere he walks, officers stop and salute. They’re not used to seeing a three-star on the job on a day like this—maybe for the ball drop, but not *working*. He is congenitally modest and is always trying to deflect attention from himself to “more deserving people, the men and women of the NYPD.” He has eyes that droop slightly, hair high and tight, and lumbers along like a workman. As he passes a young woman up against a barrier with some friends, she sees him and says, a little sleepily, “Thanks for protecting us...” she slowly leans forward to read the name on his jacket... “Waters.” Her arms are crossed tight and she has the sleeves of her sweater pulled down to cover her hands. She looks up at him and smiles a rheumy smile.

“You look cold,” Waters says.

“Oh, I am not cold, believe you me,” she says right back.

“Well, have a great time tonight,” he says, and he’s off.

A few steps away, his smile gone, he’s all business. “I am not worried about a nuclear device going off here tonight,” he says. “We know well the capabilities out there, and I’m confident that’s out of the question. What I am worried about is the lone wolf that we don’t know, that we *can’t* know. The ISIL model now is to say, *Act where you are, with what you have*. That’s where the Nice and Berlin Christmas market truck attacks came from. So I’m worried about

that guy.” He walks on, picking up his pace toward Forty-Second Street. “But we don’t worry. We act. That’s what everything you see here today is all about.”

Waters has been chief of counterterrorism since 2008, running a select division of one thousand cops. Before that, he was head of the Joint Terrorism Task Force for five and a half years. It’s been all terrorism all the time since shortly after September 11, 2001. Before 9/11, there was no counterterrorism at the NYPD. So it’s kind of his baby. That’s the kind of duty that is impossible to leave at the office. And so he’s got a hyper-vigilance that just won’t quit, he doesn’t sleep much, and when he does sleep he is frequently awakened in the middle of the night with news of the world that ripples all the way to New York, all the way to his bed on Long Island. And then he’s up for good. “Chief hasn’t had a decent vacation in like, ever,” Magee says, laughing. “His poor wife, you know?”

“Oooh, my wonderful wife,” Waters says. “Sometimes we just can’t catch a break.”

One Saturday night last September,

Waters had driven into the city to pick up a couple of suits that he’d had tailored, and “I said to Joanne, C’mon, we’ll go to dinner. There was a place in Brooklyn that she liked.” No sooner had they gotten on the Williamsburg Bridge than a job came over the radio. Didn’t sound like much at first, but Waters knew he had to listen to it. Traffic was light going to Brooklyn but terrible coming back to Manhattan, and by the time Waters and his wife got to the other side of the bridge, “Uh, ya know, the first units were on the scene, and they were calling for ambulances.” A bomb had gone off on a random block in Chelsea. The United Nations General Assembly was in town, 120 heads of state, and they picked Twenty-Third Street instead.

Waters made a U-turn, told Joanne, “Hold on. If you have to close your eyes, close your eyes,” and he floored it, weaving in traffic back across the bridge, lights flashing. He was on the scene in ten minutes, pulling up just behind the bomb squad. He parked his truck, and walked up, trying to absorb the extent of the damage, trying to get an assessment of the number of injured, looking for secondary devices, which was at the top of his checklist that evening as he approached. “Seeing a first sergeant, I said, ‘What are we doing?’ I wanted to see what he says. ‘We’re doing a search for secondary devices.’ That was music to my ears.”

That’s the constant drilling to these guys: Second devices target first responders. Assume there’s a second device, and find it.



The NYPD has 3,000 cameras of its own all over the city, and access to 7,000 more through private partners. From a command center, they can activate and turn the cameras to the desired view.

Showtime: On a day like New Year's Eve, Chief Jim Waters of the Counterterrorism Bureau (left) is in constant motion, along with Captain Danny Magee (third from left), making sure that all of the assets and the 7,000 cops detailed to the grid around Times Square are where they are supposed to be.

And then of course there's the technology. The NYPD has three thousand cameras of its own all over the city, and access to seven thousand more through partnerships with private businesses.

From a command center downtown, they can even activate and turn the cameras to the desired view, or consult footage from thirty minutes or three hours or three days ago to get a clear picture of the who and the what. Because of a program called the Domain Awareness System, and software developed between the NYPD and Microsoft, all of these video resources, as well as data on all ongoing and active calls and a database of what is known about previous police interactions with any given address in the city, are instantly available to all thirty-six thousand NYPD cops—on every desktop and on thirty-six thousand department-issue Nokia Windows devices that each cop carries in his pocket. DAS has revolutionized policing. Now, when there is a domestic violence call, no cop has to go blind into the situation—he or she knows instantly of previous calls at that apartment, whether there are outstand-

ing warrants, whether there might be weapons present, or whether there is no history at all. That technology can save lives on both sides of the door.

And then, *hallelujah*, within two hours of the first call, cops found that second device on Twenty-Seventh Street. The news reports had gone out about the explosion on Twenty-Third Street, and Waters cautioned the investigators to make sure it wasn't some kind of copycat device. "We play everything for real, and as soon as I got there, the fellas said, 'No, it's real.' I can't say enough about the courage and focus of the bomb squad guys."

It was a pressure-cooker bomb, in the mold of the Tsarnaev brothers' work in Boston. It was carefully removed to the outdoor range, at Rodman's Neck, in the Bronx, to be taken apart and rendered safe. They pulled up the Total Containment Vessel, which is a vehicle that is so armored that if you sealed the device inside and it detonated, you wouldn't hear it. But the trick, of course, is getting the device inside the vehicle. At the scene, the bomb squad

removed the phone—which was designed to be used as either timer or detonator—from the pressure cooker. Then with a robot, cops remotely brought it to the TCV. There's a basket inside, which hangs on a couple of sturdy straps, and a cop with a joystick placed the device into the basket so that it was suspended and would be able to move with the motion of the vehicle without bouncing around too much. And here's the tricky part, because once it's in the basket, then a bomb-squad technician has to put the suit on and go close that door. So for that thirty seconds, he's in very close proximity to that device. Call it a bomb. And one of these has already exploded, injuring dozens of people. He locks the door. Good. Now if it explodes, it explodes, there'll be no danger to anyone. Drive it up to the Bronx, and go through all those steps in reverse. Then take the device to the pit area, which is surrounded by three walls of blast-proof concrete block that go up about fifteen feet and is open on the fourth side. Hard ground, steel workbench, industrial vise on the end. Here, they practice with an identical pressure cooker. *How are we gonna do this?* Dry run after dry run after dry



run, to get comfortable. Time for the real pressure cooker. They first try to open the lid, which doesn't work, so, using "a couple of bomb-squad techniques," they pop the lid off. Now what? It could explode, which wouldn't be good for the preservation of evidence and the invaluable forensic analysis. *But because of the care the professionals took, it didn't explode, and the FBI evidence collection guys had, ya know, a perfect crime scene, if you will.* They had the pot, they had the lid, they had all its contents, perfectly preserved. All of the evidence they could want. Not only for the trial, but to study, learn from, and defend against the next attack.

It's a pretty elaborate deal, a messy, sprawling civil society of eight million of the loudest, most opinionated people, all with freedom to move and assemble and protest and express themselves and push and test the limits of what is acceptable as their *birthright*, because "that's what makes 'em Americans and that's what makes 'em New Yorkers," the chief says. And it's his job to let 'em express and assemble and scream to their heart's content, and be safe doing it. And now there's a president of the United States who has a building or two in his town, and a lot of the guy's neighbors seem to want to regularly demonstrate their appreciation by showing up at his door by the hundreds of thousands and giving him the old Bronx cheer. Why, the United States has suddenly entered into a new era of such mass gatherings, both planned and spontaneous, often both at the same time. Like when you're expecting sixty thousand for the Women's March up Fifth Avenue and four hundred thousand show up. "Ha!" the chief says. "It never does get boring!"

Now Waters is standing at ground zero for tonight—Forty-Second and Seventh—and the light is changing as the afternoon accelerates and the checklist is scrolling behind his eyes. Two days ago, in the police commissioner's executive command center, Commissioner James O'Neill's executive staff had run through the plan for New Year's Eve. The command center is a conference room that looks just the way it would look in the movies—all blacks and grays, leather and marble, the walls covered with screens and data and images from all over town and all over the world. *Whaddya got?* Commissioner O'Neill said, taking a seat at the head of the table. And one by one, the executives ran through a list of plans and assets and allocations that would compare

Opposite page, clockwise from top left: For New Year's Eve, the two million expected revelers get screened twice—magnetometer, explosive-trace test, radiological test, sniffed by a dog—takes about 15 seconds; Chief Waters; officers man the Joint Operations Center at 1 Police Plaza as the clock ticks down to midnight.



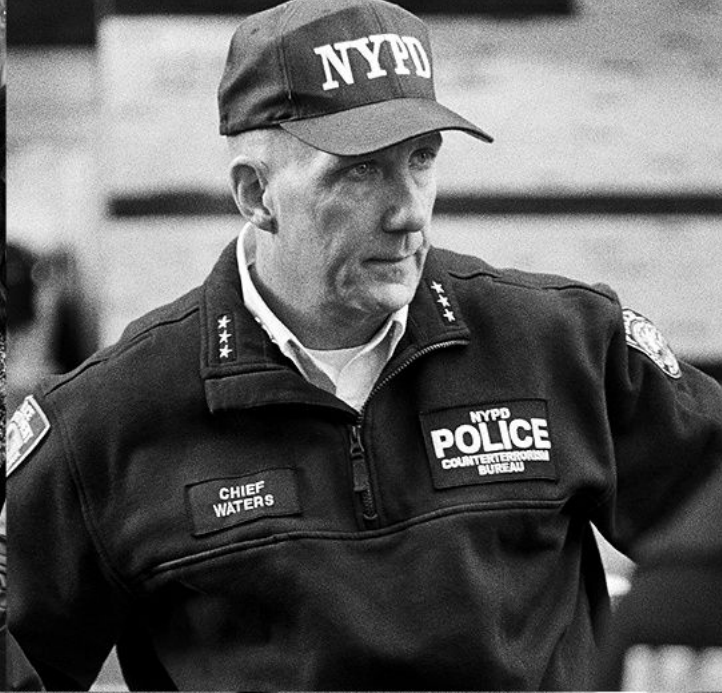
decently to the landing at Normandy:

Five Joint Terrorism Task Force response teams; the bomb squad is broken down to four response teams within Times Square alone, with additional response teams to cover the rest of the city should something happen; somebody remember to thank the sanitation commissioner for the sand trucks; gotta seal the manholes, check and double-check that, yes you; five ballistic vehicles spaced out strategically; large tactical harbor unit for interdicting and boarding a boat or boats, accompanied by SWAT team, prepositioned and ready to go; ten prepositioned light trucks in case there is a blackout—enough to illuminate all of midtown Manhattan so people can see to move around safely, no panic; ten observation teams positioned on high ground—made up of two cops, one to observe, one to communicate, with a "sniper component," with corresponding response teams on the ground; armored vehicles on Forty-Sixth and Forty-Second, with tactical-weapons component, to neutralize anything serious at Times Square; "Archangel" team, a.k.a. "the Holy Shit" Package (this consists of an REP—emergency services truck, WMD team, canine team, light truck, Total Containment Vessel, a BearCat armored truck in case you have to roll into a raging gun battle to rescue people, that's the thing you're gonna use, WMD response trucks, two vapor-wake dogs, seven EDCs [explosive detection canines] and six patrol dogs); air-sea rescue at HUSH [Harbor Unit

Station House] on the Brooklyn side, with helicopter and divers standing by, because if the assault starts with them shooting at one of those party boats in the harbor, that's not the time to think about how are we gonna get resources out to them; a Hazmat/chem/bio team stage on the East Side with quick access into and out of Forty-Second Street; gotta implement flight restrictions below 110th Street, nothing under four thousand feet; seven harbor launches in harbor ready to respond, and four harbor launches doing Staten Island ferry escorts; Hostile Surveillance Teams [plainclothes cops at eight critical subway stations in midtown, wearing the funny hats but looking for hostile surveillance]; new emergency-vehicle routes designed; new radio frequencies for everything...

Captain Magee interrupts the reverie. "We have to get downtown," he says. "To the JOC." That's the Joint Operations Center at 1 Police Plaza, the war room of coordinated interagency activity on any night, but especially tonight. "Yeah, yeah," Waters says. "I'll be right there."

There is a profound tension to this work, and a sobering recognition that in an open society you can only ever be so secure. A police state might be perfectly secure, but no one with will or imagination would want to live there. The roiling civic conversation of our time has been about the opposing demands of security and freedom. And that is the seam that Chief Waters works, very sensitively. All of this—the vast array of





12:02 a.m. Waters being congratulated on a job well done by the mayor of New York, Bill de Blasio, and First Lady Chirlane McCray.

police assets deployed to both project power to the bad guys watching—they're always watching—but also as lightly as possible so as not to unduly burden the people they are serving—is being done with the ultimate goal of... absolutely nothing happening. A good party, and that's it. So that at twenty seconds to midnight, as the countdown proceeds and the crowd noise suddenly doubles, a guy says, "Go confetti," and on that word, 120 people high on top of seven buildings encircling Times Square will begin to drop three thousand pounds of two-inch-by-two-inch pieces of colored tissue paper, one handful at a time, and the paper will float up on the frigid air of the vortex of the high-rises, swirl around in thick clouds before snowing back down to earth, landing on the shoulders of the tactical units with their long guns, and landing on the head of a little girl, who will squeal, "I can't see, it's so much!" and landing silently on the ground of the grid, the only unscreened and unscrutinized objects allowed anywhere near here all day.

And Mayor Bill de Blasio and his beaming wife will make a beeline for Waters and bend down slightly to shout, "You did it! Great job!" and clap him on the back, and the secretary general of the U.N. will nod and smile, and the governor, and the secretary of Homeland Security, and various celebrities. All deeply appreciative for all that goes into having absolutely nothing happen. Grateful for the herculean task that goes into making a quiet night.

Waters heads to his car. There's a ton to be done before then.

Seven hours to midnight.

"I FIND TYPICALLY that the more money I make, the smaller my office is."

That's John Miller talking. He is the deputy commissioner of the NYPD for Intelligence & Counterterrorism and former broadcast journalist who could well be the only cop in the world whose ride-along partner was once Barbara Walters. "In TV, my office was usually just a glorified cubicle." He has a pretty big office right down the hall from Waters's, in the unbeautiful suite of offices that make up the eleventh floor of 1 Police Plaza, the city-state that houses the administration of the largest municipal police force in the world. "My own army," former mayor Michael Bloomberg once called it.

Miller is also probably the only cop who has a picture on his office wall of himself with Osama bin Laden—from 1998, at bin Laden's hideaway in Afghanistan, the last time an American journalist interviewed the terrorist. In 2011, after an American SEAL team killed bin Laden, Miller was in the top-secret CIA briefing with Director Leon Panetta, and at the end of the briefing Panetta said, any questions? "I'm like, uh, did he say anything? Like when they confronted him on the stairs, was there any dialogue? And he laughed and said, There wasn't a lot of conversation. I thought, Excellent, so I actually still do have the last interview with Osama bin Laden." There are many other pictures in the office—Miller with the pope, with President Obama. He keeps his Emmys elsewhere. All of which

testifies to the utter bizarreness of Miller's career—which spans from calling in news reports to local New York TV stations from his bike in the early seventies, to being the authority on John Gotti and the mob in the eighties, to a first foray in law enforcement in the mid-nineties, to hopscotching back and forth ever since—from NBC and ABC, cohost of 20/20, to Sheikh Omar Abdel-Rahman, to 9/11, when he sat by Peter Jennings's side for sixteen hours calmly explaining global jihad to a stricken country, to going to work for the FBI and the Office of the Director of National Intelligence, to now overseeing the strategy and mobilization of police resources to protect any self-respecting terrorist's bucket-list target city—you can get whip-lash just reading Miller's résumé.

When Popular Mechanics contacted the NYPD to ask about how police design security for mass gatherings in the age of terrorism, it was Miller who said, "Talk to Chief Waters." But the same skills that made Miller a good reporter—taking in information, synthesizing it, telling you what it means—have made him sort of a philosopher king on the subject, too.

"You've got New Year's Eve, where you have concentric circles of security," he says, "on the idea that you can't let a million people in and have total security. So you've got to have a graded system. You're gonna catch most things at the first ring, and if not there you'll catch it at the second ring, or a dog may catch it at the third ring. Before you go into those pens, there is a pretty good chance that going through all those baffles and filters, somewhere along the line, if there's something that needs to be caught, it'll get caught. But that's about the event. When you design a mobilization for New Year's Eve, with extraordinary assets pointed at a single spot, you also can't take your eye off the rest of the vast metropolis outside of your grid. You can't have all your assets tied up in one place. There's the whole rest of the city out there."

What police learn from so many of the recent events around the world is that the attacks come where the security isn't. "Take Orlando," says Miller. "Where is the counterterrorism package in Orlando? It's focused on Disney. That's where the concentric circles of security are. But the single largest loss of life in a terrorist incident on American soil since 9/11 occurred in Orlando, but not at Disney. It was miles away, at two o'clock in

the morning, in a nightclub, on Latin night. So you can do all the targeting and analysis about where you should put your resources, but there is a randomness to these things, and we have to prepare for randomness, too.”

So if you apply that thinking and these “security overlays” to New Year’s Eve and Times Square, what does randomness look like? In the great feedback loop of the universe, as the clock ticks down to midnight, and the pens fill up and the air gets colder and millions of people mill about in the charged atmosphere, NYPD executives, with their checklists being checked and rechecked, get their answer.

Five thousand miles away, at 1:14 a.m. local time, at a nightclub in Istanbul called the Reina, randomness happens. A gunman opens fire with a Kalashnikov at people dancing, drinking, and laughing in the new year, slaughtering thirty-nine of them before disappearing into the night. Within minutes, as help is still on its way, the mobile device on Jim Waters’s belt starts ping-
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ing. He was about to get a bite to eat, for christakes, but no time for that now. In a situation such as this, a man in Waters’s position has to grab the analyst in his office and find out

Waters’s lone wolf, who has been thinking about making his mark but maybe has doubted his abilities or has hesitated for some reason, and he sees the news from Turkey and finds in it his inspiration to impulsively act, where would he go? When would he go there? How would he maximize the statement he’s trying to make?

“There are neighborhoods that compare to the neighborhood in Istanbul,” Waters says. “Concentrations of nightclubs and restaurants, active street life. The Village all the way up the West Side, Chelsea, the Meatpacking District. We haven’t touched a single asset for New Year’s Eve, haven’t pulled and won’t pull anything out of Times Square. Everything will remain here as it is. But we are directing available tactical units with long guns already on for the 4-to-12 shift to circulate in the area—up to a dozen cars—they’ll leave their guns in the trunk for now, don’t want to alarm people. Just establish contact with proprietors, let them know they’re there. Be seen. Establish deterrence. Put people at ease so they can have a good time. Ten, fifteen minutes at each place—now you see us, now you don’t. Move on to the next one, then come back. Over the course of

Waters and his coterie are in motion and remain in motion, making their way back and forth through the clotted blocks at the heart of Times Square, checking with lieutenants, detectives, inspectors, there’s Commissioner O’Neill over there talking with the press, and Mariah Carey again—“she walks through like she’s the Dalai Lama or something,” Magee cracks, “eats up resources, but that’s okay, it’s part of why everybody’s here”—and the music is loud and man, Ryan Seacrest wears a lot of makeup, and the empty zone right in front of the ball begins to fill with cops, and three hours collapses in an instant.

Midnight is upon us. Further uptown, near Central Park, the magnetometers and the dogs are still working as the stragglers get screened, and the semi-official position of the New York Police Department might be described as lighthearted vigilance. Jubilant wariness.

Joanne would normally be here for the ball to drop, but she’s running the midnight 5K up in the park tonight. Chief Waters checks on the security for the run, then makes a last call. “How are things in Chelsea? Quiet? Good.” He hangs up, slips his phone into his pocket, and is quiet for the first time in hours, amid the roar at the crossroads of the world.

One minute to go.

In his head, he’s getting to the bottom of that checklist. “Now is when I always call my *muthah*,” Captain Magee says, turning away to talk on the phone. Waters smiles. “I know his mother,” he says. “Wonderful woman.” He is still smiling when his eyes suddenly get cloudy. “I lost my mother this year...” he says quietly. He turns away for just an instant.

Thirty seconds.

He turns back, all business again. Checks his watch. Looks up at the ball. “You know, the most important thing for us to remember,” he says, “is that we are a free society, and we do our job well when people are as free to move and as safe as possible doing it.”

Twenty.

“You can’t protect everything all the time, or you actually protect nothing.”

There is a sign Waters keeps in his office. Reads it coming and going, every day. “Did you do everything today to prevent an attack tomorrow?” it says.

Here we go.

10...

9...

8...

M

Approved By
Five thousand miles away, at 1:14 a.m. local time, at
a nightclub in Istanbul, randomness happens. Within
minutes, Chief Jim Waters’s mobile device pings.

as much good information about the circumstances and target in Istanbul as he can, quickly, and then consider soft targets in his own city that might be similarly vulnerable, all while hosting a party for two million guests. Tonight is busier than last year, could be a record. By 8:00 p.m., the pens are filled all the way up to Fifty-Fifth Street, thirteen blocks north of Times Square. “You can’t even see the ball drop from Fifty-Fifth!” says Captain Magee. “But you can hear the roar of the crowd I guess, feel the vibrations, say you were there.”

With the news from Istanbul, the executives at NYPD in charge of counterterrorism can feel another, unwelcome vibration. There are nightclubs too many to count all over New York City, in all five boroughs. But if there is a disaffected guy out there, Chief

an hour they’ll be in four or five locations.”

One more tactical ball in the air for Waters and his cops to juggle. One more jolt of adrenaline to propel everybody toward tomorrow. As the crowd and the colors swirl around him, as Mariah Carey struts the stage right over there not singing, the chief of counterterrorism is on the phone constantly with all of his executive staff, getting one-minute briefs from all sectors and levels of responsibility for the grid. He smiles. “The way I work is, I know if they say, ‘Everything’s great, chief, no problem,’ I know I’m not getting the truth. Either they aren’t doing their job, or they’ve already corrected a problem and feel like they don’t want to bother the boss. That’s policing—situational awareness and constant adjustment to conditions on the ground.”

M Y D O G S

On bases at home and overseas, K-9 units help to keep civilians and military personnel safe. An ex-Army cop recounts five loyal partners with whom he served. **BY ROBERT VRABEL**



The author, holding Nero's leash, Bosnia, 1998.

NERO

► **Dutch shepherd.** Sweet dog. He was seven years and twelve handlers into the job, a lifetime in the K-9 patrol business. Me, I was two fresh weeks out of the schoolhouse, the Military Working Dog Handler Course. I chose him from the lot at Fort Bragg Kennels—three unassigned patrol dogs, the other two younger and probably faster and stronger. But I picked Nero. I just liked him. His eyes sparkled.

Patrol dogs are trained to search for people attempting to elude the military police, whom they will then attack. Nero's record showed he'd had two justified bites in his career. That was good. Not all dogs can step up. Some become so accustomed to the practice

stuff—the burlap sleeve, the bite suit—that when it comes time to bite flesh, they become confused. But Nero was sharp. Within two months, we passed the Army certification test as a team and were patrolling the streets of Fort Bragg the next night: 163,000 acres, 41,000 active-duty soldiers, and tens of thousands of civilian employees, contractors, and family members. Me and Nero. Lots of long nights, most of them quiet. You get a feel for a dog walking him like that, with a shared purpose.

A year after that, we were picked to accompany a NATO SFOR (stabilization force) mission on a six-month tour out of Tuzla Air Base, in Bosnia. It was 1997, and Bosnia and the former Yugoslavia were no place you wanted to be, ravaged by genocide and incompre-

sible violence. I jumped at it: My first combat deployment. I was excited and terrified.

Nero and I walked for miles every night through cold Balkan winds and snow blowing sideways. We'd stop for tea and dog treats at command outposts—American, British, Swedish, Dutch—and guys would scratch Nero behind the ears, which he loved. Then it was back into the cold, black night.

Most of the time we provided simple perimeter security at the base. But sometimes we worked alongside special operations forces, silently making our way through one bombed-out village after another, clearing each building one room at a time, watching for snipers through the green glow of night-vision goggles.

The decline began in ways visible only to a dog's handler. The continuous operations in the raw Balkan winter were wearing Nero down. His alertness wasn't as keen and his pace flattened—slightly at first, but I saw it. At the start of one of our last nights of work, I entered the kennel as usual. He lifted his head, as excited as ever, but instead of bounding over to me he lay in one spot. I called him, and he tried to push his body up off the floor, but placing any weight on his hind legs made him whimper. I carried him to the veterinarian's quarters, where it was decided we'd have to fly to Ramstein Air Base in Germany the next day for an examination.

Nero lay on the cargo netting of the C-130 with his head on my lap for the entire flight. At Ramstein, waiting for

tests, I slid my fingers through his brown fur—I knew it was the last time.

I flew back to Bosnia. Two days later, I got word.

I felt proud to have served as Nero's handler, the way you feel proud to have known a human being.

BORIS

► **In his records** Boris's breed was listed as "unknown." He looked and acted like a short-haired Lab on steroids. He was powerfully built with a brawny white chest, and nicknamed Junkyard Dog. Boris was the best narcotics dog at Fort Bragg, and later proved during the FORSCOM MWD (Military Working Dog) competition that he was the best in the United States Army, placing first overall in narcotics detection. Whenever a first sergeant or company commander suspected drugs in his unit, they called Boris. If there were so much as a marijuana seed buried in the passenger seat of a car or the back of a desk drawer, Boris would somehow jam his enormous head as close to the source as he could, then sit and await his reward.

Crazy, brilliant Boris. In 1998, when the Customs Service requested eight drug dogs from all military branches to be sent to El Paso, Texas, Boris and I were chosen. He searched hundreds of vehicles each day at the three major border crossings. Boris found drugs sealed inside half of a welded gas tank. He found them buried deep behind the panels of a car. He found them wrapped inside layers of ground beef and mustard. Boris was amazing.

Boris could sniff out other things, too. One summer evening on patrol, at a traffic light on Bragg Boulevard I heard laughter through my open window. A boy in the next car was holding an ice cream cone out the window, and Boris had craned his head out there and was licking the thing with Boris-like zeal.

JOEP

► **A hundred pounds** of muscle, the largest Belgian Malinois I've ever seen. Though we became dual-certified in patrol work and explosives detection,



Molly at an Iraq training facility in 2013 (left); Victory, the cutest bomb-sniffing dog you ever saw.



Joep enjoyed bite work the most. He wasn't mean-spirited, but he wasn't affable like Nero and Boris. Joep didn't cuddle. He was a capable bomb dog, but the attack command was what he lived for. While most dogs targeted the forearms because the bite sleeve is what's presented to them during training, with Joep the trainers had to wear an entire bite suit when "catching" (acting as the perpetrator while training). Joep preferred to target either the center of the shoulder blades or the soft tissue of the triceps. And when he hit you, you would soon be hitting the ground.

One time I asked another handler to grab Joep from his run while I tended to some paperwork. The handler returned a few minutes later and told me he had started to put Joep's collar on, but something in the dog's eyes told the guy to stop. Joep had dark, yellow, intense eyes—and the power to scare the hell out of you.

MOLLY

► **Years after my time** in the military, I got hired by a recruiter for a contractor doing security for U.S. Embassy and State Department personnel in Baghdad. After the security and weapons-qualification vetting, I found myself on a flight to Iraq.

Molly was a small German shepherd. We worked alongside the Iraqi police and U.S. Army at checkpoints throughout the city. I was armed with a customized M4 carbine and Glock 17 pistol, but still the work felt dangerous. At least once each day, I

heard windows rattle—an IED detonating somewhere not far.

My nerves were already worn, and this didn't help. I had a wife and two kids now, and after six months I left combat behind for good. On our last day of work together, Molly and I went to a training site just off the embassy grounds. I ran a bomb exercise through a building, loaded her into the back of the Suburban, and walked her back to my room. She slept on the floor next to my bed all night.

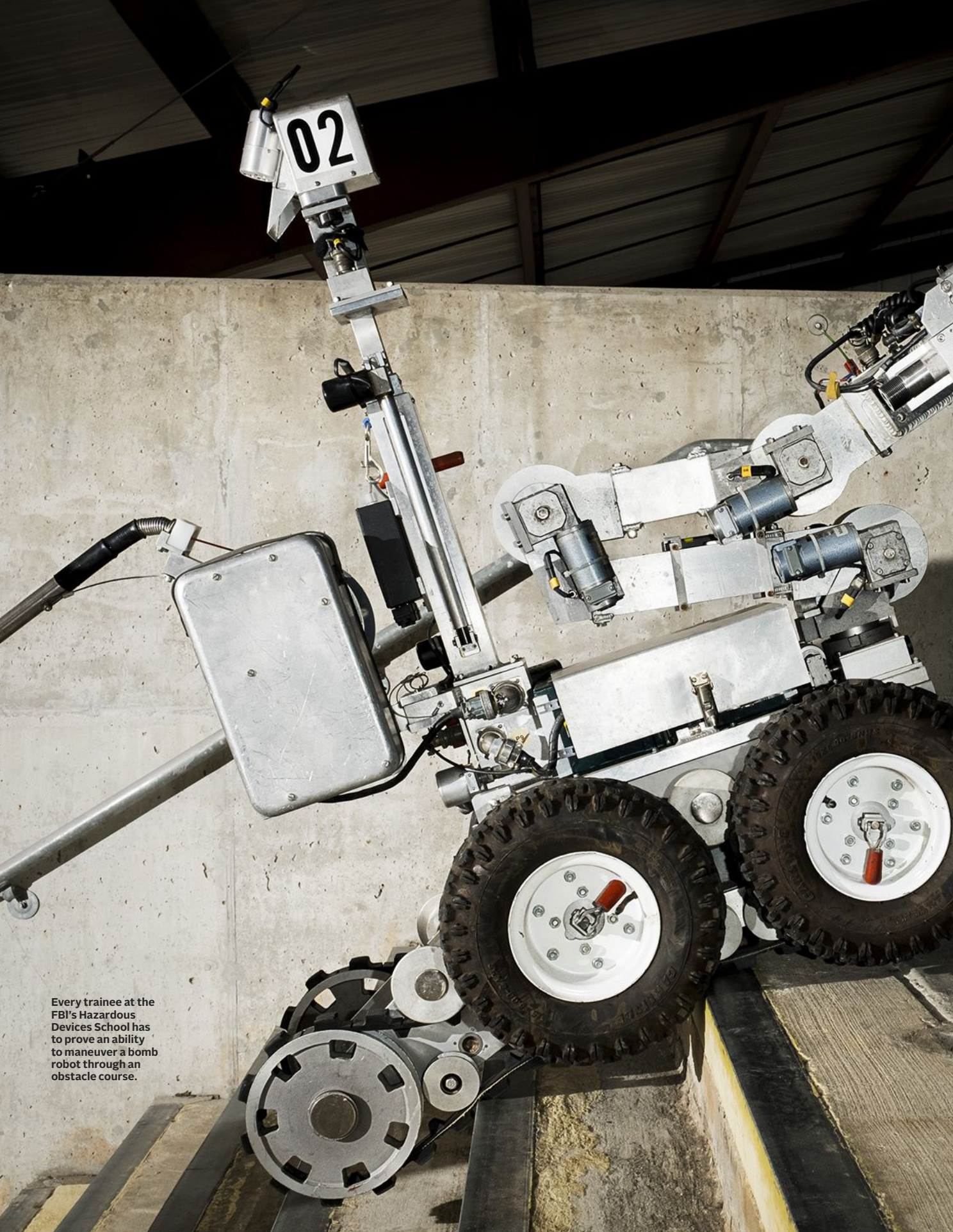
VICTORY

► **Victory** was the last dog I worked, and will ever work. She was a tiny black Lab—she looked like she belonged in a dog-lover's calendar. Instead of the blistering heat of Baghdad, Victory and I searched for explosives in Manhattan for a private domestic security contractor. This was in 2013, and New York City could feel like a battlefield in its own right. We searched the hulking cruise ships docked at the West Side piers, we searched the caverns of Madison Square Garden, we rode the Staten Island Ferry.

Victory lived at home with me. We'd leave for work at 4 a.m. She'd spring up when she saw me trudge out of the bedroom, I'd let her outside to pee, and we'd drive the hour into Manhattan.

But at night, at home—at home she was our pet. My daughter walked her, my son ran her around the backyard. At home we forgot the job, the smells of Semtex, C4, and black powder.

At home, I was a dad, and Victory could just be a dog. ■



Every trainee at the FBI's Hazardous Devices School has to prove an ability to maneuver a bomb robot through an obstacle course.



“

WE
SAVE
THE
WORLD
AGAIN!

BY REEVES WIEDEMAN

PHOTOGRAPHS BY JONNO RATTMAN

The FBI maintains a sprawling campus in the Alabama woods devoted almost entirely to the discovery and disposal of explosive materials and devices. They see dozens of explosions a day. Why? So you never see a single one.

HAZARDOUS DEVICES SCHOOL

In a chilly winter afternoon, five men stand in a circle outside a strip mall, their lips pursed and brows tight with concentration. The group includes a police officer from Monroe, Louisiana; another from Manatee County, Florida, wearing a hunter's orange stocking cap; and an eager young member of the Arlington, Virginia, fire department in his dark-green fireman's jumpsuit. The men are talking deliberately, with long pauses, as they think through how to deal with the nasty problem at hand: A hundred yards away, in the strip mall, they have just discovered a motel room filled with explosive material.

Inside the room at the Rocket City Hotel, the bed frame has been thrown up against the wall. A piece of brown parchment paper covered with chemical equations is taped up next to it. A single light is on, in the bathroom, illuminating a beaker on a hot plate. There are improvised detonators and pipe bombs all over the room.

"You said the bathtub was filled with some kind of powder?" an FBI special agent asks Justin Scott, the Arlington firefighter, who is wearing a baseball cap with his jumpsuit. Scott has just returned from a reconnaissance mission into the room, where he found syringes, a box of baking soda, and a basin full of citric acid.

"The powder is drying on a big sheet in the bathroom," Scott says.

"What color is it?"

"Whitish-gray."

The Rocket City Hotel is not a real hotel. The strip mall was built by the FBI in 2004 and sits on the campus of its Hazardous Devices School (HDS), part of the Redstone Arsenal, a thirty-eight-thousand-acre U.S. Army facility in Huntsville that's also home to the Pentagon's Missile Defense Agency, NASA's Marshall Space Flight Center, and the Army's Aviation and Missile Command. As you walk around the campus, what sound like large explosions ring out every few hours from distant corners.

The men standing in a circle are trainees, learning how to approach, identify, defuse, and generally keep humans safe from explosive materials. The strip mall also contains an auto repair shop and a diner and is one of twelve villages built by HDS to simulate real-world situations. There's an airport baggage carousel, a church, and a movie theater. (The marquee advertises *The Hurt Locker*, the 2008 film about a bomb-disposal team in Iraq that won six Academy Awards including best picture.) At another location, a group of students is figuring out how to remove a suicide vest attached to a mannequin's body.

At the motel, the trainees stand around a white utility truck that carries their equipment—bomb suits, X-ray machines, water cannons, and a robot they've already rolled off the back. They consider the new information from Scott's reconnaissance: Most



explosive powders are white or gray, except TNT, which is yellowish. Not much to go on.

As recently as 2014, improvised explosive devices caused 42,627 casualties worldwide. In one six-month period in 2013, there were 172 IEDs reported in the United States alone. Many of these devices are defused without incident, usually by people like the bomb techs in Huntsville—young law enforcement officers drawn to the profession by the promise of doing something more interesting than writing traffic tickets. Every one of these techs—about thirty-one hundred spread across 466 squads—trains here at Huntsville.

"Today is a homemade explosive lab, tomorrow morning's gonna be a suicide bomber, and tomorrow afternoon will be a car bomb," says Ed Marshman, a burly former FBI agent with a white goatee who is now an HDS instructor. "Thursday will be a WMD."

Bomb makers constantly adapt and change their methods over time as new technologies present new ways to cause destruction, and bomb technicians are expected to know everything—DC electricity, robot operation, how to build and countercharge a bomb themselves. Students at HDS start their work in the classroom. In the first room I visited there was a row of mannequins wearing bomb suits from the 1960s to today. At one end of the display a large floor chart showed the relative danger of standing over an explo-



1. This classroom display illustrates the dangers to techs at different distances from a bomb.

2. Robots in imitation bomb-making labs are used to train students.

3. Some training houses at HDS have reinforced concrete to withstand small explosions during practice runs.



with different projectiles: sometimes blank shotgun shells, but more often simply water. “Water does not compress, so if we push it fast enough, it does a lot of ripping and tearing,” Hamann says later, driving past one of HDS’s two demolition ranges. He points down the range at a row of cars, each of which has a hole in the side that looks as if a small asteroid has burst through it. “That was explosively driven water,” he says.

PAN disrupters are often attached to robots, and the school stores dozens of them in a dedicated maintenance shop. Bomb-defusing robots first appeared in the field in the 1990s, but they couldn’t do much. Today, they’re equipped with X-ray machines and can be operated by remote video link. Every bomb squad is required to have one, and all HDS students have to prove their ability to maneuver them through a concrete obstacle course featuring stairs, handicap ramps, and tight corners.

At the motel room, the members of the bomb squad debate their options. They’d prefer not to have a human breach the doorway, but they may not have a choice. They’ve noticed that the hot plate in the bathroom, with its carafe containing an unknown liquid, is plugged in to the wall. It’s an explosion waiting to happen. And there’s only one way to neutralize it.

sion, a half-pound block of TNT without fragmentation, at different distances: Four feet away, a bomb tech might suffer hearing loss; from three feet, there’s a high chance of severe lung damage; any closer, even in a bomb suit, and survival becomes much less likely.

The chart is displayed prominently, and its presentation on day one is deliberate. At some point, every bomb tech will have to get closer than he’d like to a live explosive. Of course, much of what the techs learn here is designed to prevent that very thing. The day before the motel exercise, Kent Hamann, HDS’s chief of basic training, led me into a room filled with dozens of portable X-rays the bomb techs use to glean information about improvised explosives from afar. They come in a variety of setups, but the most common look like large camping flashlights. Hamann pulled up an image from one of the X-ray machines on a computer screen. It looked like a medical X-ray—only instead of a broken ulna, there was a sickening nest of wires connecting a cellphone to an explosive charge.

When Hamann first became a bomb technician in 1984, the preferred tool for disarming a bomb from afar was a shotgun. Today, it is a PAN disrupter. He leads me past a room full of these devices, which look simple—like the barrel of a rifle attached to a stand. A PAN disrupter is a sort of high-tech shotgun—it can fire at varying speeds, depending on the type of bomb that needs disarming, and

TERRORIST EXPLOSIVE DEVICE ANALYTICAL CENTER



few minutes’ drive from the Hazardous Devices School sits an entirely different facility: the Terrorist Explosive Device Analytical Center (TEDAC). If the thirty-one hundred bomb techs scattered across the country are the fingers that defuse each individual bomb, TEDAC is the brain.

Here, every minute of your visit reminds you that you are dealing with the most powerful law enforcement agency in the land. When you arrive, having already gone through one checkpoint that looks like an interstate tollbooth manned by armed guards, your car will be thoroughly searched by a security officer who spends several minutes digging through your trunk before circumnavigating the vehicle, inspecting the undercarriage with a mirror. Once you’ve gone inside the building, you pass through a metal detector and then hand over your phone, which has to be checked into a locker.

TEDAC is in the process of moving its operations from its old home at the FBI Crime Lab in Quantico to this new \$132 million facility. Most of TEDAC, but not all, is now in Huntsville, where it has one operational building and two more on the way.

In spite of the construction, the halls inside always seem to have been recently swept. (In one suspiciously clean lab room, an employee tells me it isn't usually so neat, but they had been working on something they couldn't talk to me about.) The corridors are dotted with clocks showing the current time in Quantico, Baghdad, and Kabul. I saw four or five signs that read "Do not discuss classified info in hallways" on the walls on my limited tour.

The office of Corey Scott, like most of the rooms here, is littered with cardboard boxes of all shapes and sizes, each of them sealed with multiple layers of bright-yellow evidence tape. Any time an analyst at TEDAC examines a document or piece of evidence from any case, he puts it back in its box, adds a layer of yellow tape, and signs his initials to record the chain of custody. One room I visited contained a dozen boxes labeled "Car Search" and "Post-Blast" and "104 Elmora"—the address of a restaurant run by the family of Ahmad Khan Rahami, the man suspected of placing bombs in Elizabeth and Seaside Park, New Jersey; and New York City in September 2016.

Scott is an analyst in the Toolmarks department. When an exploded IED is recovered, or when one is captured early and defused, Toolmarks is typically its final stop at the FBI. (See right.) Biometrics—fingerprints and DNA—determines the who. Chemical Analysis tells the FBI the what. Toolmarks is the how.

"Toolmarks is the final resting place," Scott says. "It's basically, We don't know what else can be done with it, so send it to Toolmarks."

Wearing rectangular glasses and a blue gingham shirt and slacks, Scott sits down at a comparison microscope. He has brown hair and is of average height. He could pass for an accountant. "I feel like a dentist a lot of the time," he says. He lines up pieces from two different explosive devices next to each other, revealing that they have nearly identical markings. They may have been made by the same person, or at least with the same blade or hammer. "We can link devices that come from two different countries back to the same manufacturer," he says.

Bomb remnants can spend years at TEDAC, with the goal of giving law enforcement everything they need to find and prosecute individual bomb makers anywhere in the world. The first device that ever arrived at TEDAC, back in 2003, was an Iraqi bomb attached to a doorbell. At the height of the insurgency, the facility received as many as five hundred boxes a day filled with evidence, some from Indonesia, Pakistan, and Saudi Arabia. It has now examined more than 105,000 devices, most of which are stored in a warehouse in Redstone.



hat's the diaper," Justin Scott says, as the other officers attach a layer of Kevlar around his groin. He's getting ready to enter the motel room. Modern bomb suits weigh eighty pounds and come with an exoskeleton spine to protect against blasts that send bomb techs flying. It takes two of the other trainees to lift the chest protector up and over Scott's head.

It's gotten colder and a light rain falls, but Scott is sweating even before he begins walking the hundred yards to the motel. A technician can typically last twenty minutes in a bomb suit before exhaustion begins to impair his decision-making skills. Before that time is up, Scott will have to unplug the hot plate and dispose of the improvised detonators, a task with no high-tech solution.

"What should every bomb tech have in his possession?" Marshman, the HDS instructor, says before Scott begins his long walk.

"One of those things old ladies use to pick things up off the

HOW TEDAC WORKS

When a device arrives at the Terrorist Explosive Device Analytical Center, it moves through three different types of examination based on what law enforcement or intelligence agencies need to know most quickly. "They tell us what they want, and we start pushing evidence out immediately," Mark Whitworth, who runs TEDAC's forensics unit, says. Here's how it works.

► **Situation: A bomb has gone off. The suspect is in custody.**

► **Department: Biometric Analysis**

Explosions do not always destroy DNA—traces can be found in hairs or droplets of sweat—or fingerprints. TEDAC examiners scour for prints using shortwave ultraviolet light, fluorescent dye sprays, and a refrigerator-size tank that can vaporize superglue to allow it to settle on the prints, revealing and preserving them. Viable prints are cross-checked on the FBI's Next Generation Identification biometric system, which spits out the top twenty possible matches but is so precise that investigators typically never need to look beyond the first three.

► **Situation: A bomb lab has been found with no bombs in it.**

► **Department: Chemical Analysis**

Gas chromatographs and mass spectrometers can determine the chemicals used, which can provide clues to where, how, and by whom a device was made. The HDS students who were clearing the fake motel room, for example, found urea nitrate, a chemical rarely used by domestic bomb makers. Urea nitrate was used by the bomber of the World Trade Center in 1993, and the foiled millennium bomber, both of whom were foreign Al-Qaeda operatives. The presence of urea nitrate might indicate that the motel chemist had come from overseas.

► **Situation: Biometric and chemical analysis have revealed nothing.**

► **Department: Toolmarks**

Certain cuts or scrapes might come only from a particular blade made by a particular manufacturer in a particular country. A torn piece of tape can be matched to the remaining roll found in a suspect's home. The way in which a wire was cut can reveal the type of tool used. Over time, clues can reveal an unwitting signature: The Unabomber, for instance, always skinned the labels off of his batteries and wrapped them in monofilament tape.



1. A mock-up of the underwear bomb worn on an airplane in 2009.

2. Forensic examiner Corey Scott.

3. An FBI model of a book bomb used by the Unabomber, Ted Kaczynski.

4. Evidence hung in a fuming chamber allows vaporized superglue to settle on some fingerprints, revealing and preserving them.

5. The FBI makes precise re-creations of each bomb it studies.

6. Any time an analyst examines a piece of evidence, he replaces it, then adds a layer of tape and his initials to record the chain of custody.



At first glance, we'd agree with the Portia

ground?" says the officer from Louisiana.

"Bingo. If that improvised det goes off in your hands, what's gonna happen? You're Captain Stumpy," Marshman says, picking up a blue trash grabber. "If it goes off at the end of this, you've just got to clean your bomb suit."

Unfortunately, there are some occasions when something as simple as a trash grabber is the best technology a bomb tech can use. After a large explosion, civilians will immediately turn and run, often dropping whatever they've got in their hands: purses, water bottles, plastic bags, backpacks.

"Go back and look at the pictures," says Hamann, of the aftermath of the 2013 Boston Marathon bombing. "There are backpacks everywhere, and somebody's got to clear every one of them." There's no time to deploy a robot when another bomb could go off at any second. Bomb-sniffing dogs are worthless when an entire scene is covered in explosive debris.

Hamann's face morphs into a look of extreme distaste. "At a certain point," he says, "it's cut open and look."



he job of a TEDAC examiner is less immediately exhilarating than a bomb tech's—there's good reason *The Hurt Locker* won best picture while *The Kingdom* (2007), based on a TEDAC investigation, is largely unmemorable. TEDAC is a place for people who would rather engage in focused study in quiet lab rooms than walk

downrange, hearts pounding, in bomb suits. And yet no job related to homemade explosives is entirely safe. In another room, Colin Pollard, a chemist who works in the TEDAC Improvised Explosives Detection and Synthesis Center (TIEDS), stands next to a fume hood in a lab filled with beakers, mixing the elements necessary to make a compound called silver fulminate. "It's a very angry explosive. I'm trying to make it without it bursting in flames," he says, cheerily.

Pollard came to TIEDS from Los Alamos and Sandia, two of the government's most elite laboratories, where safety regulations were much stricter. TIEDS can set off an explosive with just a few hours' notice to clear the airspace above the test site. They don't want to accidentally pick off a small aircraft. As Pollard says, "We have the capability to make any explosive known to man here."

Once he's done mixing, Pollard scoops out a pinch of silver fulminate, a white powder, puts it on a plate, and sculpts it into a neat pile. He hands me a pair of earphones, then smacks it with a hammer while I wince. There is a loud pop. This is an impact test, he says, just one of the many kinds of exams the chemists at TIEDS conduct on dangerous materials, along with heat, friction, and electrostatic energy. On the demolition range, they use high-speed cameras to determine the size and velocity of any of the fragments that fly off in different directions during an explosion, and pressure gauges to determine the force of the explosion's shock waves. In the lab, one of Pollard's colleagues pulls up a video clip from a recent test of ammonium nitrate and nitromethane, an especially explosive mixture. The clip shows three distinct shock waves radiating across the screen in the first instants after the explosion,

Left: One of a bomb technician's most important tools is the trash grabber, which provides an extra few feet between a technician and an explosive device. **Right:** This training van contained an explosive device that was disarmed using a PAN disrupter, which fires explosively driven water.



before the dirt on the ground even begins to kick up.

Of course, most terrorists don't use laboratory-grade equipment to make their bombs. "We need to do it our way first, so we know what we're dealing with," says Kenneth Lee, who runs TIEDS. "But then we try to do it the same way they would." That means buying ingredients at a home center or hardware store and mixing them in plastic buckets and bathtubs. In one room, the TIEDS crew has a grinder that reads "Fresh Ground Coffee"—except the word *Coffee* has been crossed out and replaced with *Explosives*. Why grind explosive materials in a coffee grinder? It increases their surface area, making the explosion more deadly. TIEDS' experiments show exactly how much damage can be done by explosives cooked up in makeshift home labs by terrorists, so that engineers can design buildings to withstand potential blasts.

As I walk through TEDAC's various departments, I feel simultaneously encouraged and disheartened. The attention to detail is stunning: In one room, an examiner is packing up a device from Afghanistan, armed by a Casio F-91W digital watch, to send over to HDS for use in training. Another analyst is doing tests on a bomb suit to determine why it caused a technician to pass out. To witness this work being done is to feel a little bit safer in the world.

But then there are those yellow-taped boxes. So many of them,

in so many rooms. The number of devices flowing into TEDAC has declined since the height of the wars in Iraq and Afghanistan, but so many arrived then that some still remain unexamined. There are rooms and rooms of these boxes, some containing evidence from bombings we've heard about. Most contain items from the ones we haven't. No matter how skilled the analysts are, the sheer scale is terrifying.



There's a memorial on the grounds at the Hazardous Devices School. Every aspiring bomb tech visits the site on his or her first day. The memorial eulogizes the fifteen American public-safety bomb technicians who have been killed in the line of duty, stretching back to 1903, when the New York Police Department created the country's first dedicated bomb squad. The first five plaques are all members of the NYPD. The most recent, from 2008, commemorates an Oregon bomb tech killed by an IED at the site of an attempted bank extortion. The sixteenth plaque is left intentionally blank, to remind students that no matter how well they are trained, and how safely they act, they have chosen an extraordinarily dangerous profession.

The instructor's point in bringing the trainees here is this: Know the risks of what you've chosen to do. But also know that you are a hero. The stakes for ordinary civilians are monstrous if you fail. That day at the motel, Justin Scott carefully picks up each of the improvised detonators with his trash grabber and carries them outside, one at a time. He breathes heavily, laboring to finish his job before exhaustion overcomes him.

In the white truck, his colleague from Manatee County monitors the situation through the robot's three different cameras. When the detonators have been removed from the building, one of the other students meets Scott outside the motel with a shovel. They walk carefully over to a plot of grass, where they mime digging a hole and setting the detonators inside. If this were a real incident, the hole is where they would safely blow everything up, while everyday citizens driving by the motel would never know how close to danger they had come.

"We save the world again!" the instructor yells to the crew. ■

BOMB TOOLS

► PAN Disrupter

This device, basically a high-tech rifle, allows a bomb tech to choose different rounds to disable a pipe bomb versus a pressure-cooker bomb, or a device with a remote control versus one with a timer. To disarm more sophisticated IEDs, bomb techs sometimes fire multiple projectiles (such as blank shotgun shells or water) at different speeds within milliseconds of one another.

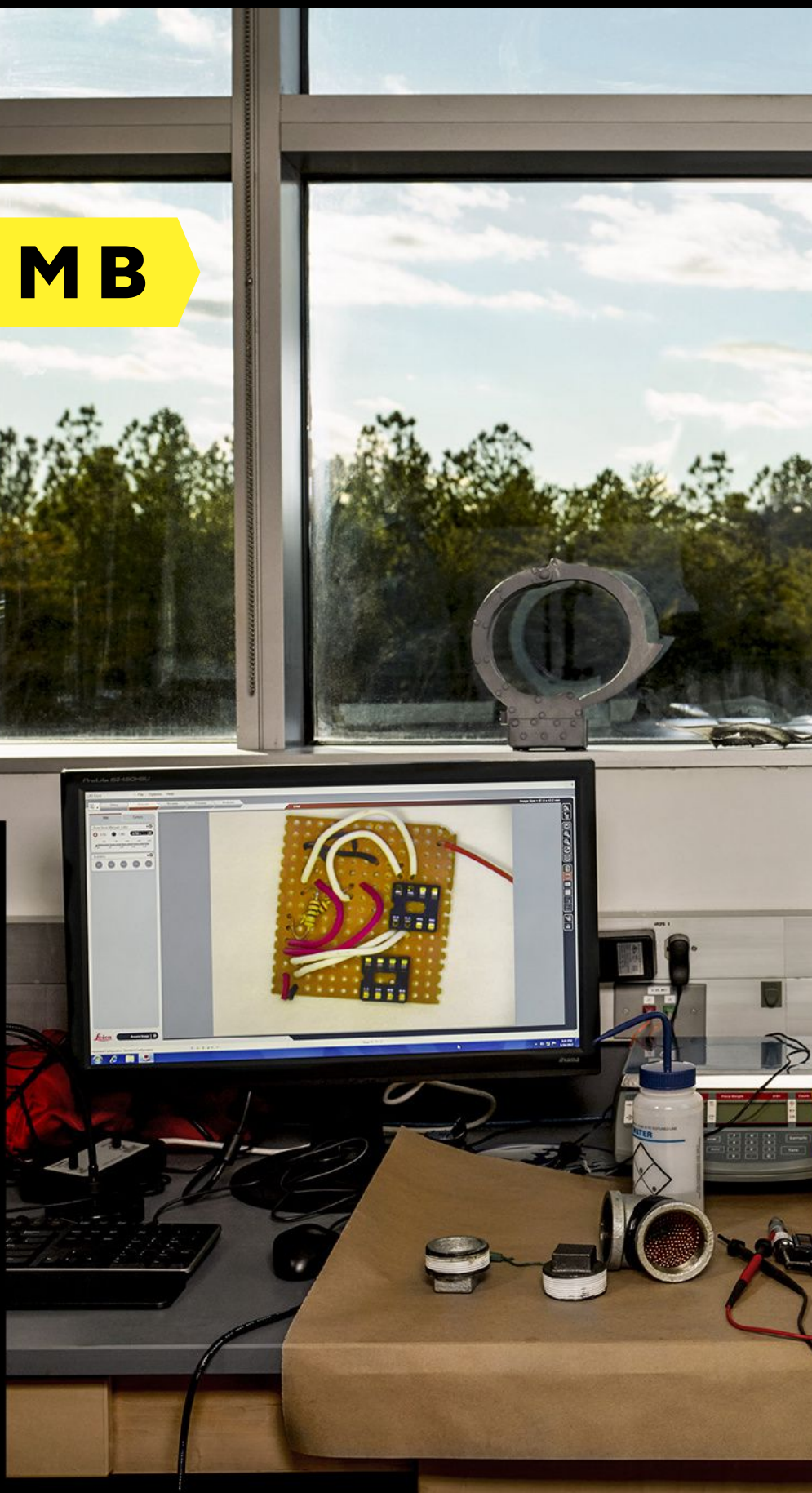
► Total Containment Vessels

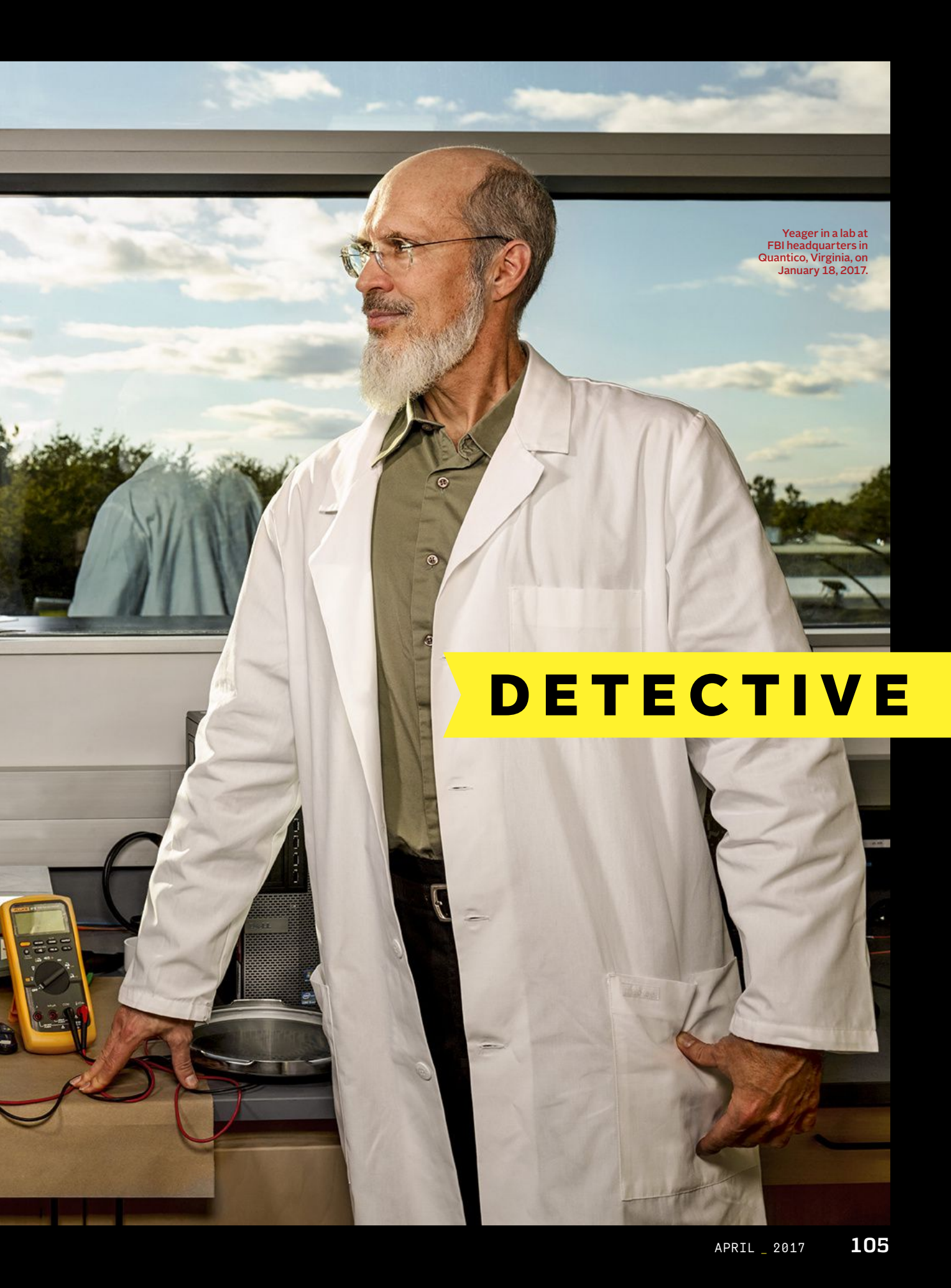
A trailer-mounted lead-and-steel sphere capable of containing a blast with the power of up to 25 pounds of TNT. Inside the vessel a bomb can be transported through city streets without the need for evacuation. If an explosion does occur, the fragmentation and shock wave will be contained while pressure escapes from a series of small vents. Some versions can be outfitted to contain the effects of biological or chemical weapons.

THE BOMB

After a
terrorist's bomb
goes off, the
race to put it
back together
begins. And it's
usually led by
KIRK YEAGER.

• BY PETER FLAX
•
PHOTOGRAPH BY
CHRIS BUCK



A full-page photograph of a man with a grey beard and glasses, wearing a white lab coat over a green button-down shirt. He is standing in a laboratory setting, looking off to the side. In the foreground, there is a workbench with a yellow multimeter, some red and black wires, and a small metal dish. The background shows a large window with a view of a blue sky and some greenery outside. The word "DETECTIVE" is printed in large, bold, black letters on a yellow banner across the middle of the image.

Yeager in a lab at
FBI headquarters in
Quantico, Virginia, on
January 18, 2017.

DETECTIVE

There's no cooler job title: Chief Explosives Scientist.

The person who holds it, the FBI's Kirk Yeager, spent decades in the field, examining tiny pieces of evidence, most of them partially destroyed, and working backward until he had a bomb, a bomb location, and, more often than not, clues that led to a suspect. "Imagine if you dump out a thousand-piece puzzle, throw out half the pieces, and light the other half on fire," Yeager says. He's good at burnt puzzles.

Yeager is matter-of-fact, telling stories about a bomb site in Beirut as if he were recounting a trip to the pharmacy. And he has a good sense of humor, even for a guy who doesn't wear a lab coat every day. Like when he talks about briefing former FBI director Robert Mueller, who hated any suit that didn't include a white oxford and a tie. Yeager wore a scarlet shirt and a white bolo. "I spent six years in New Mexico," Yeager says. "It's the tie I prefer." He looks mischievous as he says it, but that's probably just the effect of his eyebrows, which curl up like the tips of a hipster bartender's mustache.

Among the things he keeps at his desk are a device called a hell box—the plunger used by nearly every cartoon character about to blow something up with dynamite—and the model he made of a pipe bomb from the Boston Marathon bombing. He's proud of the replica, and patient as he describes the components (ball bearings, a fuse, gunpowder) and how it would work. Yeager's curiosity started as a kid, he says. "I've always been obsessive. There's a reason for things, and I like to know what that is." This work gives

him the chance to push the limits of what normal chemistry and physics do. "We have to understand explosions in microseconds," he says. We asked him to explain what that feels like:

"Every bombing is the same thing. You're walking into chaos. You don't know what's in front of you, you don't know where the path is going to lead you, and as you start pursuing different avenues and closing down idle speculation that's wrong, and finding forensic clues, you start developing a fuller and fuller picture.

"What really sticks in your head is not what you see. I'm used to seeing chaos and carnage. But couple that with the oppressive heat and the smell of burnt diesel fuel and decay of bodies and all sorts of unpleasantness like that, and it's overwhelming. All your senses are engaged, basically the minute you hit a scene. One time, there were cars and chaotic traffic and noise, beeping horns. Just a flux of activity all around me. But the streets were closed off around the scene, and as I went closer and closer, the noise receded into the background and it became qui-

eter and quieter. There's a reverence to every scene because these people have been shocked to their core. It takes on a very serious gravitas, and so getting into the scene is very quiet. We almost whisper to each other.

"If you've never been into a true chemistry lab, it's hard to describe what we set up in the field. There's all these instruments that are designed to do chemical analysis. They look like massive microwave ovens with tubing and tanks attached to them. There's gas chromatography, there's infrared spectroscopy, there's mass spec analysis—the things that we use to identify chemicals.

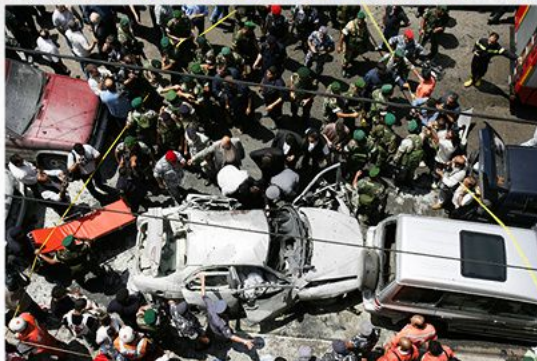
"You start doing swabs of things. After a bomb goes off, it sends residue everywhere for the main charge. Explosives aren't 100 percent consumed in any event, so if, for example, a bomb goes off in the street, you find nearby street signs and you swab them. At the most rudimentary level you take a pair of tweezers and a sterile cotton swab, and you sit there and rub it over the surface area and collect soot. And then you take that back to that suite of instruments and you extract that swab with water or maybe acetone to pull the explosive materials off and then you run it through your instruments to see what the bomb deposited. Part of what you're trying to figure out is the main charge. To determine that, you use the residue that's left behind.

"You're not so much using fancy equipment as you're using years and years of training and an understanding of explosives. Because a bomb can consist of anything. Once, we had this bar and we knew a bomb went off in it, but we didn't know if it was a suicide bomb or if someone threw a bomb in from the street, because we had conflicting witness reports. Another bomb guy and I were trying to figure out where the epicenter of the blast was. That's the first clue. This bar had a whole bunch of pillars. Imagine you're in the room with a bomb and there's a big support pillar. Where would you want that pillar to be in relationship to the bomb? You'd want to be behind it, because the

fragmentation is going to be blocked by that pillar. So if that pillar is in the middle of the room, and you have a whole bunch of frag strikes on the wall behind it, you can tell where the sheltered area is. We got a whole bunch of twine and a whole bunch of sticks, really long sticks, like six or eight feet long. If you have enough pillars, and you bring string from the sheltered area past those pillars, you can actually zero in on the epicenter of the device. We figured out that basically the device was three feet off the ground. We saw no crater in the concrete, so that meant it was sitting on top of a table or was worn like a backpack. Someone didn't throw it in.

"At another bombing scene on a fairly quiet street, a portion of the curbing was totally destroyed where the bomb hit it. It was obvious where the bomb was sitting. I'm looking around and I see trees, trees with scars on them. It looks like something is penetrated in. So I get out my knife and I dig around these scars and start pulling out fractions of wire. Now at this point, I know that this bomb is probably an electric fusing system just from that, because I got wire, I got a conductor in there. There's always a setup to a bomb: Someone could actually do a chemical initiation, someone could light a fuse like Wile E. Coyote, someone could call into a phone, there could be wiring. I'm pretty sure I got wiring so I start doing a whole scan of the area and start pulling things out of trees, sweeping through gutters, and we start finding bits of sections of a phone. Within a couple of hours we had enough portions of a phone to take it back to the lab and start doing searches and figure out the exact make and model of that phone. We got lucky. We had a part that had a very unique identifier number on it. It can take days if you don't have really good pieces.

"Looking back, there's a feeling of pride and satisfaction. That's one of the things that drives you to do this job, quite frankly. It's hard to go through a scene like that and not feel the pain of the people involved in it."



Yeager has worked many of the most notable terrorism bomb attacks in recent history. From top: Bali, October 12, 2002; Beirut, June 2, 2005; and Boston, April 15, 2013.



"What really sticks in your head is not what you see. It's the oppressive heat and the smell of burnt diesel and decay of bodies."



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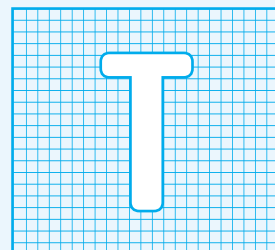
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PROJECT

A Side Table That Can Charge Your Phone

Because the best-looking charger is one that you can't see.

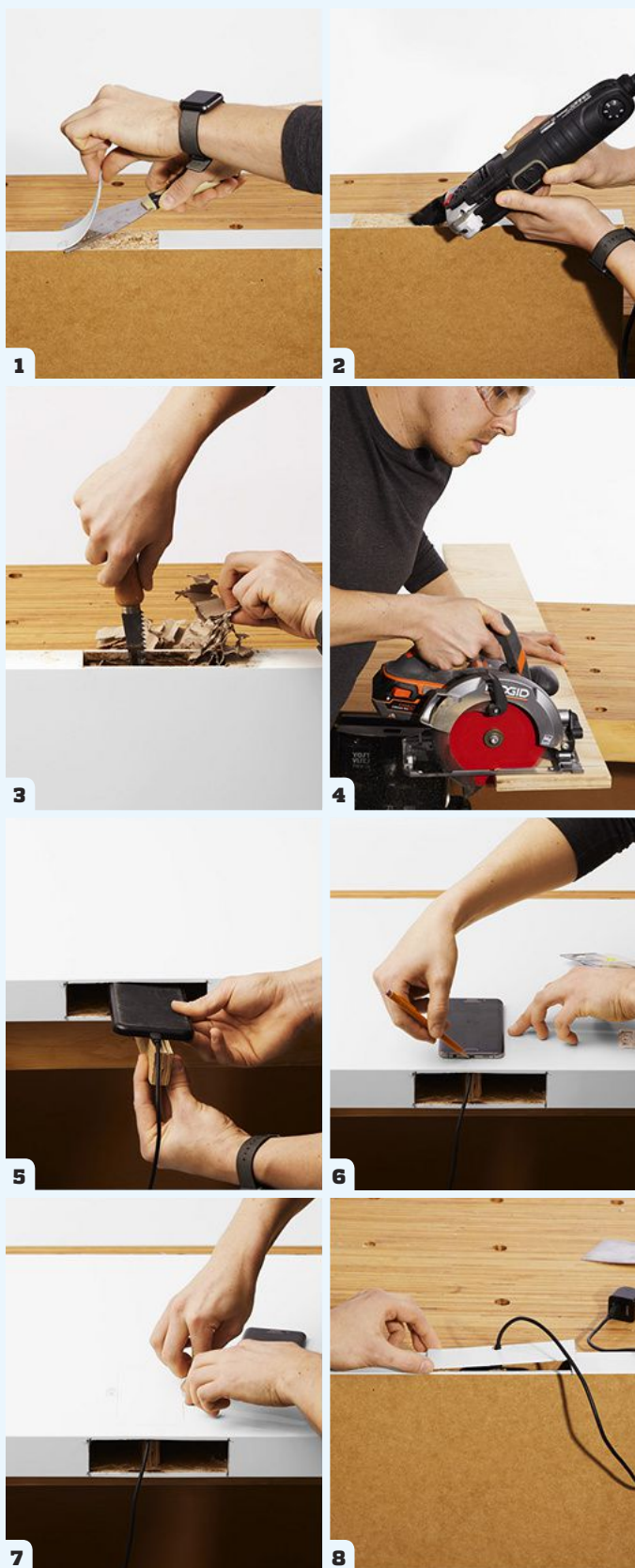
BY ALEXANDER GEORGE



THERE'S A DRAWER in my apartment that holds a rat's nest of micro USB and Lightning cables, the ugly life force for my devices. Every night I dig out the right cable and plug, then feel behind the nightstand until the prongs find the outlet. I drape the kinked, discolored wire across an otherwise attractive nightstand, and plug it in so my phone has enough juice for the morning commute. I thought there was nothing I could do to avoid this, until I discovered inductive charging.

It's simple to use. Just place your phone on a charging base, and your battery percentage climbs. No fishing for the right cable, no finding an outlet. The most ubiquitous version of this technology is called Qi (pronounced "chi," like the harmony feng shui decorators talk about), and it's built into phones like the Samsung Galaxy S5, S6, and S7 and the Google Nexus 6. If you have an iPhone or Google Pixel, you have to slip a \$40 aftermarket charger behind your phone's case. The idea goes back to Nikola Tesla: Generate a fluctuating magnetic field, usually with a coil wrapped around an

PHOTOGRAPHS BY PHILIP FRIEDMAN



iron core, and it sends energy short distances. Unlike microwave energy, it's not harmful to humans. You see it in devices such as electric toothbrushes, which can charge with minimal contact with the base.

In exchange for the convenience, you lose charging efficiency—in our tests, inductive charging is about half as fast as plugging in. But for a top-off, or an overnight charge, Qi charging is simpler and more elegant than slapping a fraying cable across the table. The only problem with it is that the charging bases aren't that attractive. Ikea makes its own version of a charging table, but we wanted something more seamless and subtle. Since Ikea tables are hollow and inexpensive, however, they do make for perfect prototype material. If you have something against Swedish housewares, you can do this with any piece of furniture. If the top isn't hollow, you'll just need a router (keep the amount of wood between the charger and the phone as thin as possible). And a lot more patience.

MATERIALS LIST

- Ikea Lack side table (\$10)
- Mophie Charge Force Wireless Charging Base (\$40)
- Scrap wood
- Peel-and-stick bumpers

INSTRUCTIONS

- 1 On one side of the tabletop, mark an opening for the charging base, around six inches long, and peel off the laminate with a utility knife. Set it aside for later.
- 2 Using an oscillating multitool or a jigsaw, cut the opening for the charger. Be sure to cut the opening slightly smaller than the piece of laminate you removed, so that there is a surface to glue it to. If you use a jigsaw, you'll first need to bore a starting hole. Be careful to keep the top and bottom laminate layers intact.
- 3 Remove the cardboard from the inside cavity.
- 4 Cut strips of scrap wood to a height that will hold the charger tightly against the underside of the laminate, but not enough to bulge it up.
- 5 Set the charging base on the scrap-wood strip and slide it into the cavity of the table.
- 6 With the charging base plugged into the wall, slowly move your phone over the table above the base until the phone beeps to indicate that it's charging. Be patient. The phone can be finicky. Lightly mark the outline of the phone with a pencil on the table.
- 7 Place peel-and-stick bumpers at the center of the side borders of the outline to indicate where to set your phone, then erase the outline.
- 8 Take the laminate strip you removed and cut a small notch in it to allow the cord to pass through. Glue it back to the table, and you have a nearly seamless finish.

SHOP NOTES

EASY WAYS
TO DO
HARD THINGS



Rules of Thumb for Pouring Concrete

When you're preparing for a concrete pour, the hardest part can be figuring out how many bags of mix to buy. Once you've calculated the surface area you need to cover (hint: section the pour into rectangles, whose areas are easy to calculate), use these tips to ease the math.

► If you're framing with two-by-fours, the slab is about four inches—one third of a foot—thick. So you can simply divide the surface area in square feet by 3 to get the volume in cubic feet. Similarly, if using two-by-sixes, divide by 2.

► One 60-pound bag of mix makes about one-half cubic foot of concrete. So once you've got the volume, multiply by 2 to determine how many bags to buy.

The World's Simplest Magnifying Lens

If you're ever in a pinch—you lost your reading glasses or found a really cool bug you must observe immediately—you can make a crude magnifying glass using only a smooth plastic bottle and some water. Here's how:

1. Draw a circle on the **curved shoulder** of the bottle.
2. Cut the circle out. It should have a curvature similar to a lens.
3. Fill the plastic with a few drops of water.
4. Hold it over the object you'd like to magnify. When you look through the water, it will be bigger.



Metal Collar Stiffens Bristles

A parts-cleaning brush, with its stiff bristles, is the best tool for applying solvent to small parts. But if you don't have one around, you can control the stiffness of the bristles on a normal paintbrush by wrapping them in a collar that effectively shortens their length. Aluminum flashing can be bent to fit tightly around the bristles and held in place with duct tape. Moving it up or down changes the working length of the bristles—the closer to the tip of the bristles you go, the stiffer they'll be.

THE HARD REBOOT

A reboot will fix most smart-phone problems—if it's a hard reboot, which completely powers down the unit and restarts the hardware (a soft reboot only restarts software). On most phones, you can trigger a hard reboot by holding down a specific combination of buttons. Do it once a month to keep your phone running smoothly.

iPhone 7/7 Plus: Sleep/wake and volume down
iPhone 6s and earlier: Sleep/wake and home
Samsung Galaxy: Sleep/wake, home, and volume up
Motorola G4 and most Androids: Sleep/wake and volume down

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DIFFICULTY

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Time: 90 minutes Ages: 9+

MATERIALS LIST

- Six $\frac{1}{2}$ x 36-inch poplar **square** dowels
- $1\frac{1}{2}$ x 40-inch poplar **round** dowel
- piece of felt, approximately 7 x 4 inches
- $\frac{1}{8}$ -inch x 2 x 4-foot piece of hardboard
- 2 x 4-foot dry-erase hobby board
- electric fan
(part No. 1238AXCF-115VAC120mm*)
- 2-inch air hockey pucks
(part No. 55120-UK2*)
- Six 1-inch screws
(any type)
- package #18 x $\frac{3}{4}$ -inch finishing nails
- piece of $\frac{3}{4}$ -inch scrap wood

*Available on Amazon.

DIRECTIONS

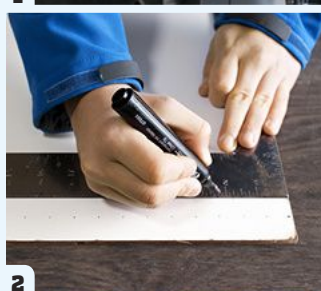
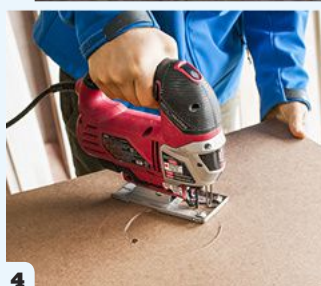
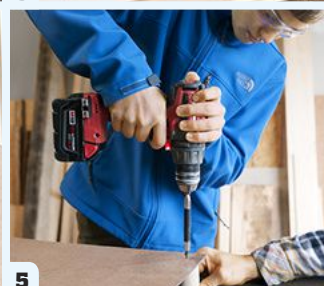
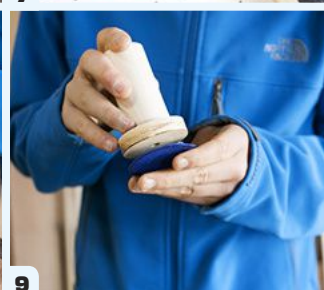
KID | PARENT | PARENT AND KID

- 1 Use a table saw or jigsaw to cut the dry-erase board and hardboard to 24 x $15\frac{1}{8}$ inches.
- 2 Create a $\frac{3}{4}$ -inch grid pattern on the top of the dry-erase board with a permanent marker.
- 3 Place the dry-erase board face up on a piece of scrap wood. Use a $\frac{5}{64}$ -inch bit to drill holes through the grid you just made.
- 4 Using a jigsaw with a fine-tooth blade, cut a $4\frac{1}{2}$ -inch-diameter hole on center in the hardboard.
- 5 Cut six 3-inch lengths from the round poplar



OUR BUILDER: Davis Shenkman is a 14-year-old from Pennsylvania.

PHOTOGRAPHS BY REBECCA MCALPIN; ILLUSTRATION BY GEORGE RETSECK



DIRECTIONS cont'd

dowel with a miter saw, and set two of the lengths aside. Attach the other four dowels 1 inch in from each corner of the bottom of the hardboard by drilling pilot holes, adding glue to the top of the dowel, and securing with 1-inch screws.

5-inch lengths from the remaining scraps. These will form the boundary of the dry-erase board. Glue the pieces to the board, using the short dowels to create a goal opening on each end. Tack the dowels down with the small finishing nails.

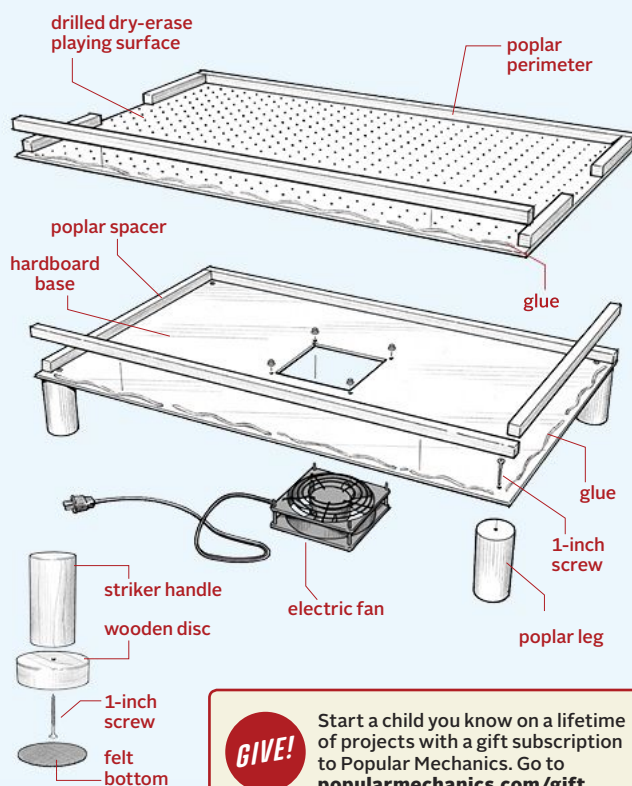
6 Cut two 24-inch lengths and two 14 $\frac{1}{16}$ -inch lengths from the square dowels. These will be the spacers between the hardwood and the dry-erase surface. Use wood glue and clamps to secure the dowels along the perimeter of the bottom of the dry-erase board, then glue the hardboard to the other side of the spacers.

7 Cut two more 24-inch lengths from the square dowels, and four

8 Using the provided screws, attach the fan and shroud to the bottom of the hardboard to direct airflow to the playing surface.

9 To create the striker, use a 2 $\frac{1}{2}$ -inch holesaw to cut two discs from a $\frac{3}{4}$ -inch-thick piece of scrap wood. Attach the remaining 3-inch sections of round dowel to the discs with glue. Drill pilot holes and fasten with 1-inch screws. Cut the felt (use the discs for size) and glue to the bottom of the striker.

THE PLANS



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