

POPULAR MECHANICS



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WRENCHES **P.66****

**HOW TO INCREASE
YOUR HOME'S
WATER PRESSURE **P.22****



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How We'll Die on Mars

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Ryan McSparran of Orvis-Endorsed Budge's Wilderness Lodge on a wet-wade exploration into seldom-seen trout water. Colorado High Country.

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pg **28****How We'll Die on Mars**

→ At long last, a cover story about how living on Mars is more reality than dream. Thank you, SpaceX.

Even in 2016, when I first visited the remote Brownsville, Texas, beach where SpaceX planned to build a spaceport, the company's ambition of developing a rocket and lander to colonize Mars seemed far-fetched. Now its massive Starship lander and booster is on track to nail its first orbital launch from Starbase this year—and become the most powerful rocket ever flown.

Starship is the most likely vehicle to land people on Mars. Even if a crewed NASA mission comes first—which could involve Starship, as is the case with the Artemis moonshot—SpaceX has laid out the clearest plans yet for a Martian mission. As its massive lander goes, so does humanity's quest to become an interplanetary species in our lifetime.

Last year, I returned to Starbase, where the gap between imagination and engineering has closed fast. If the idea of a Mars colony still seems crazy, all I can say is it's easier to envision from here.—*Joe Pappalardo, writer*

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NATURE IS NURTURE

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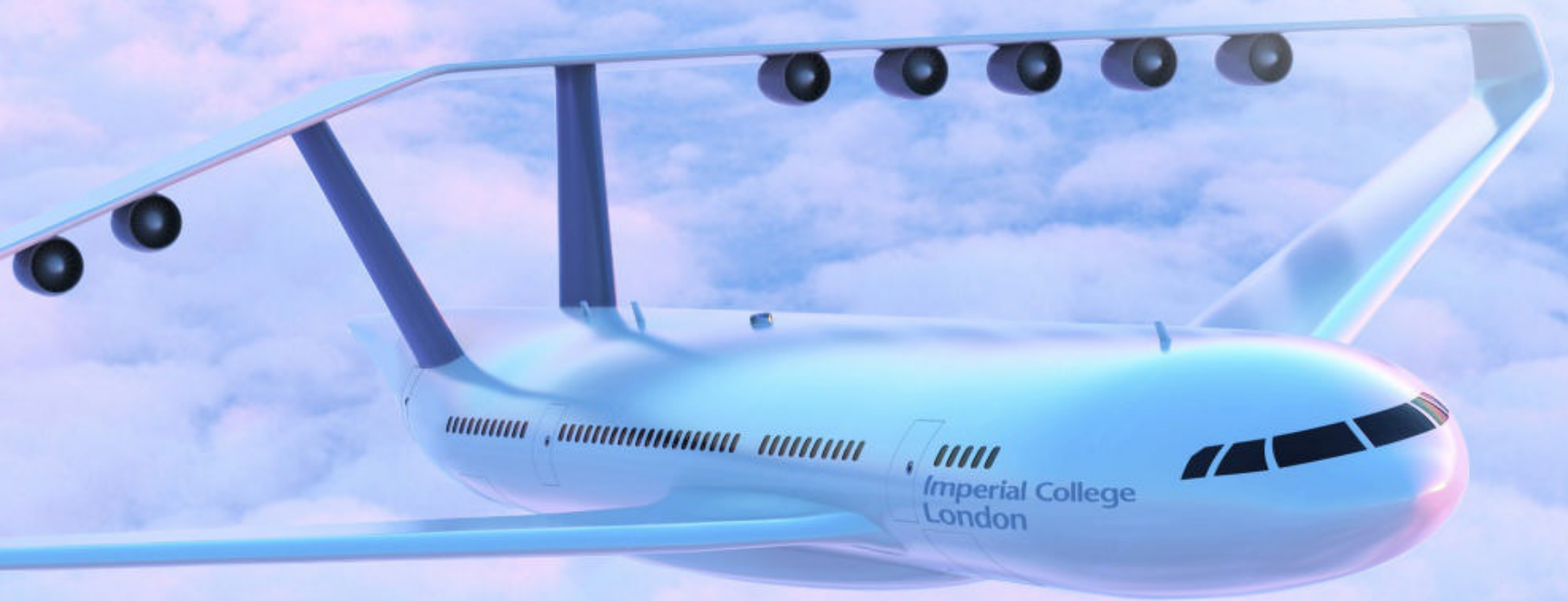
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LET'S  TEXAS

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pg 38

Can Structural Batteries Save Electric Aircraft? →

Everyone agrees the aviation industry needs to reduce its carbon footprint ASAP, yet no one can agree on the best replacement for conventional (and carbon-intensive) aviation gas. Will it be batteries, hydrogen, or biofuels?

These new technologies will unlock a variety of new form factors for both small- and large-scale passenger aircraft. As Gregory Davis, the CEO of Eviation told me, their all-electric airplane, Alice, looks different from conventional commuter planes because “the entire aircraft was designed around the batteries.” Alice’s fuselage is lined with battery packs, and the aircraft’s structure was optimized around the power source.

The same is true for other alternative power sources such as hydrogen and biofuel. Emile Greenhalgh, a materials scientist at Imperial College London, showed me a mock-up he had commissioned of a hybrid-electric box-wing passenger aircraft that looked like something ripped out of a sci-fi novel. Rather than two wings jutting out of a fuselage as we’re accustomed to on most planes today, the wings on Greenhalgh’s concept aircraft form a ring around the fuselage and are lined with 10 jet engines.

These futuristic planes don’t just look cool. The engineering decisions behind them are meant to make them far more efficient than aircraft today, an absolute must regardless of whether they’re powered by batteries, hydrogen, or biofuel.—*Daniel Oberhaus, writer*



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Includes Free ATEM Software Control Panel

ATEM Mini is a full broadcast television switcher, so it has hidden power that's unlocked using the free ATEM Software Control app. This means if you want to go further, you can start using features such as chroma keying for green screens, media players for graphics and the multiview for monitoring all cameras on a single monitor. There's even a professional audio mixer!

ATEM Mini Pro
\$295



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Big Important Product

→ I was just 17 years old when I brought \$950 to a Target parking lot in Brentwood, New York, one of Long Island's sketchiest neighborhoods and a hotbed for gang activity. An hour earlier, I had tried the PlayStation VR headset at a Best Buy, demoing the *Star Wars Battlefront X-Wing* experience. This was my gateway into high-fidelity VR; I'll never forget my first time hopping behind the cockpit and feeling my stomach dip as I barrel-rolled across space. I knew immediately that I had to buy a system. Unfortunately, they were sold out, so I headed to the platform of deals gone wrong: Craigslist.

Armed with a fat stack of cash, I was greeted by a chunky scalper in his mid-40s. As he carefully counted my money, I marveled at the box art. To him, he had just pocketed an extra \$500 over the \$399 retail price. But for me, I held the next frontier of gaming. After running home to wire it up, I jumped between online worlds, interacting with players from all over the globe in military combat simulators and street racing around Japan.

A month later, I got a marketing job at a local virtual reality studio and spent the rest of my teen years showcasing games across the country. Since then I've tried every major consumer VR headset—up to the new PlayStation VR 2 in this issue.
—Hunter Fenollol, *Home Tech Editor*



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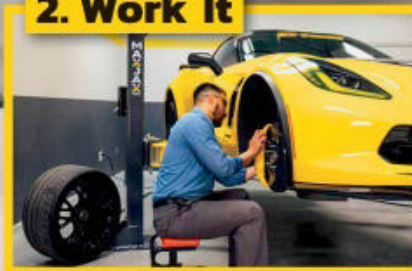
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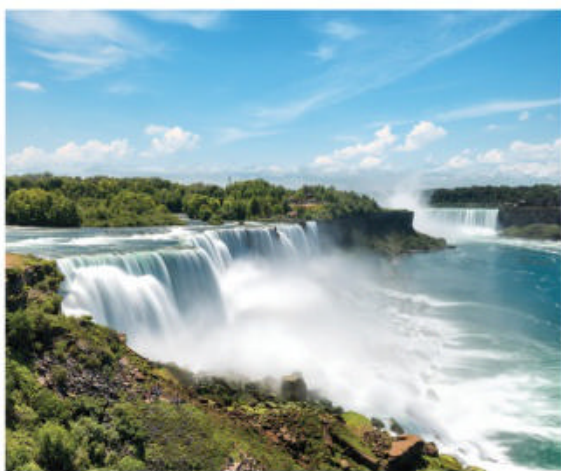
The Truth Is Out There. So Is Lue Elizondo. → I'm a natural skeptic. Before I started reporting on **Lue Elizondo**, I was pretty dubious of the idea of UFOs and UAPs. But after talking at great length to not only Elizondo but also a number of military servicemen and women who saw unexplainable things while on the job, I'm far more inclined to believe there's something to these sightings. It's the depth and specificity of the stories that highly credible people told me. Not just people who saw something funny in the night sky, but military pilots who witnessed objects up close, in the course of their duties, and their observations were backed up by sophisticated radar and other technology.—*David Howard, writer*



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pg **24**

Can't Stop Thinking About →

ChatGPT wasn't really what I would call uncharted territory for someone like myself. However, after spending some time with it, I realized the AI chatbot can actually be quite useful—when used in the right way, for the right job.

For instance, instead of asking it how to plan an entire dinner party, I merely requested a “new” Negroni spin-off to check the box on cocktails. And it gave me surprisingly solid results.

- 1 oz gin
- 1 oz Campari
- 1 oz dry vermouth
- ½ oz pineapple juice
- ½ oz lime juice
- ½ oz honey syrup
(equal parts water and honey)
- Dash of orange bitters

The only real misstep was that it wanted me to shake the Negroni before serving, when it's normally just built in the glass and stirred. That being said, I'm surprised to report that it was objectively a pretty solid cocktail.—*Matt Crisara, Service Editor*

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JACKIE APPEL

Associate News Editor

Professional question-asker.

I'M AN EXPERT IN...

Being curious, as cheesy as that may sound. I know a little about a lot, and thanks to my job, I get to talk to experts all the time to learn more.



EAR GEAR

I just got a set of **Bose QuietComfort 45 headphones**—they're incredible for noise cancellation on flights. And I never go anywhere without my second-generation Apple AirPods. I prefer the regular version over the Pro. Even though they're a bit out of date, they're more comfortable, IMO.

A Hack So Simple, It's Brilliant

If you have a top-load washer, get laundry detergent with a dispenser tap and store it above the machine. That way, you can just pull it forward and dispense it right into your laundry. Silly tip? Sure. But it makes me happy every time I get to use it.

Best. Album. Ever.

Queen's ***A Night at the Opera***. It's maybe the least deep cut of their archive, but it's such a perfect representation of the band that it feels wrong to choose anything else. And I firmly believe no one, to this day, can touch Freddy Mercury vocally.



MY CURRENT PASSION PROJECT

Right now, I'm learning how to sew. I want to learn how to make and mend my own clothes so I can contribute less to the fast-fashion industry.



What's on My Desk Right Now

My cat, Puck. And a replica "Box of Doom" dice tray, because I've been learning to play Dungeons & Dragons lately.

The Most Mind-Blowing Fact I Know

The thing that messes with my head the most is that there's no such thing as "before" the Big Bang, because the Big Bang kickstarted time!

I Wish the World Knew More About...

The process of science. If science as a discipline were viewed more widely as the process that it is rather than just a set of rules, I think people would be more understanding when it takes a few tries to get things right.

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A photograph of a Space Shuttle launching at night. The shuttle is positioned vertically in the center, with a massive plume of fire and white smoke trailing from its base. Two tall service towers are visible on either side of the shuttle. The launch is reflected in a body of water in the foreground. The top of the image has a blue gradient background.

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ZOË HANNAH

Deputy Editor, Commerce

A nerd for words with a passion for travel, outdoors, and anything pickled.

My Professional Superpower

As a commerce editor, I'm an expert in shopping and evaluating products. I can see right through marketing speak and analyze a product from the standpoint of the average consumer, while keeping an eye out for features you might not notice.

3 PRODUCTS I CAN'T LIVE WITHOUT

1 / My Snow Peak titanium spork. I used it everyday during my year of van life in New Zealand. It's lightweight, it's easy to clean, and it works for

piercing food and scooping it up. What more could you ask for?

2 / I always have my Timbuk2 bag on me at the *PopMech* office.

It's great for commuting on the subway or on my bike.

3 / I almost always keep my reMarkable 2 tablet on me for easy note taking.



What I'm Reading Right Now

The Priory of the Orange Tree. I'm a former-judgmental-non-fantasy reader, but I made a personal goal to read all of my partner's favorite books from childhood (e.g., *The Lightning Thief*, *Eragon*). Such began my obsession with finding the most literary fantasy I could, and the queer love story in *Priory* has stuck with me since I picked it up. If you aren't afraid of a 700-pager, give it a go.



I'm Obsessed With...

Cults! I can't stop learning about cults and cultish clubs, gyms, and groups. I think if everyone understood the language that makes us buy into concepts and ideas, maybe we'd have better media literacy overall.

Listen Up, Musk!

I don't think colonizing space is a good idea. Who's to say there aren't indigenous aliens? Let's work on our home planet before we start polluting the next atmosphere with failed space colonies and billionaire expeditions, please.

BEST APP EVER

Libby. I'm extremely passionate about libraries—they're one of the only spaces where we can exist in public and receive services without purchasing something. I don't always have time to go to the library, nor do I always prefer to read a physical book, so Libby keeps me reading without spending loads on new books. You can check out e-books and audiobooks right from the app and send them to your devices with a single button. It's well-designed, is easy to use, and supports libraries.



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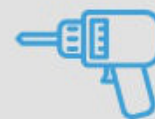
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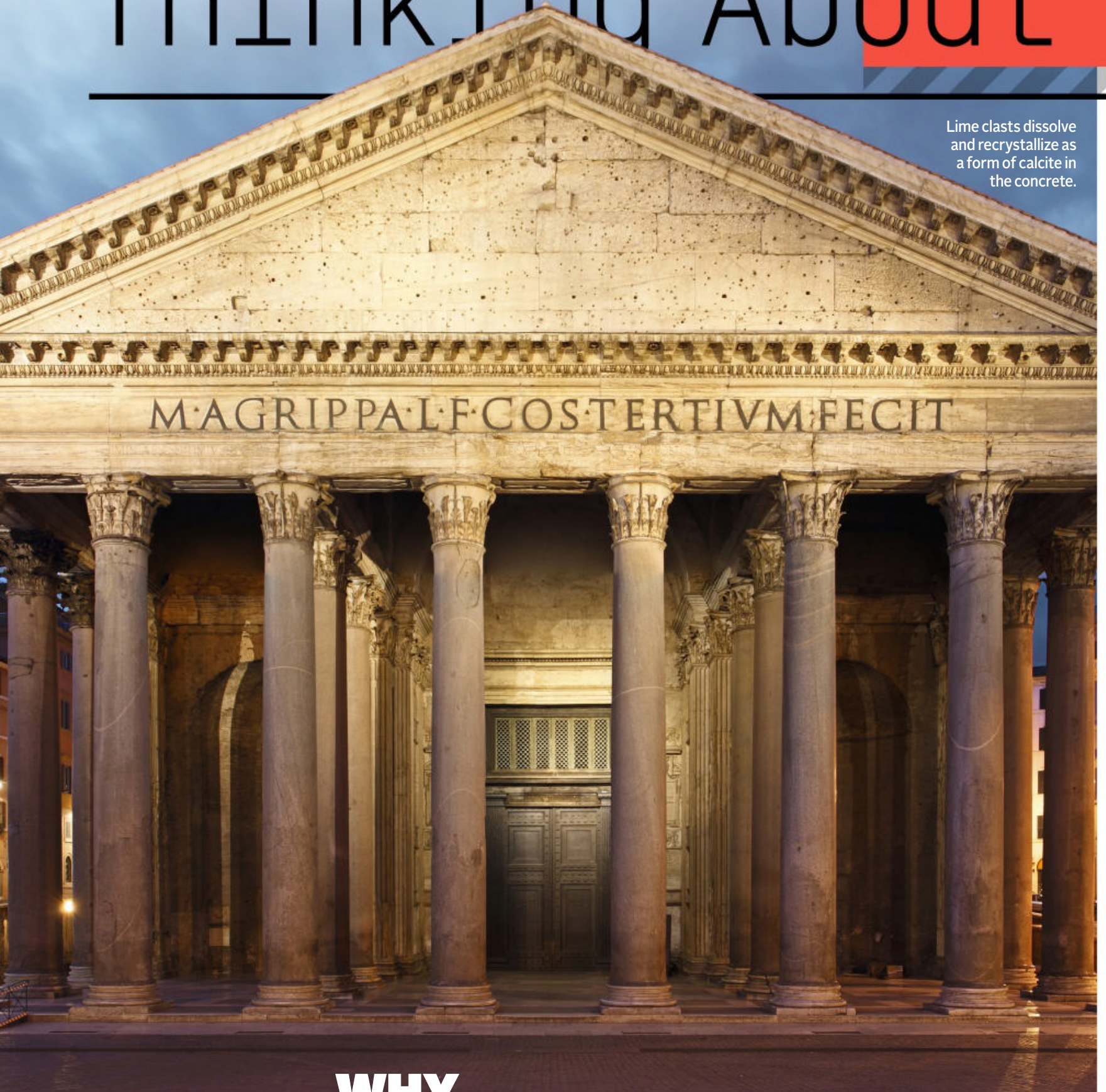
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Can't Stop Thinking About

3

Lime clasts dissolve and recrystallize as a form of calcite in the concrete.



WHY ANCIENT ROMAN CONCRETE IS SO DAMN STRONG



A TEAM OF RESEARCHERS FROM M.I.T., HARVARD, ITALY, AND

Switzerland discovered that ancient Roman concrete gets its strength from self-healing properties, which help fill in cracks as they form. The true star of the show is “hot mixing,” a process of creating concrete that forms reactive calcium. In other words, these small lime-clast chunks can react with water, post-mixing, to recrystallize as calcium carbonate, and fill cracks while reacting with the ash for further strength. The reactions take place spontaneously, self-healing the cracks before they spread.—*Tim Newcomb*

How Sonar Actually Works

IN THE EARLY DAYS OF WORLD WAR II, ALLIED navies faced a stark challenge: how to detect Germany's growing fleet of U-boats and prevent them from repeating the havoc wrought in World War I. While German subs exacted a horrifying toll in the years between 1939 and 1945, a new technology—sonar—helped the Allies locate and sink Axis submarines. Today, sonar has evolved into a sophisticated military tool used in everything from submarines to helicopters, stalking both surface and subsurface targets with one goal: dominance of the world's oceans.

Active Sonar // This type of sonar involves a warship broadcasting directed sound waves underwater: If the sound waves strike an underwater object such as a sub, they're reflected back to the ship, which registers it as an object worth investigating. The ship can determine the distance of the object by counting how long it takes for sound waves to return. Repeated returns can even allow sub hunters to determine if an object is moving, what direction it's moving in, and how fast it's going.

"There is no easy way to hide from active sonar," says Eric Moreno, a U.S. Navy veteran who served on the USS *Hampton*. "Submarines have tiles that are attached to the outside of the hull to help dampen the return. Like aircraft, the only real way to hide is to go low."

An active sonar system typically involves both a transmitter for broadcasting powerful sound pulses and a receiver for catching the pulse returns. This setup is normally placed in the bow of a ship, just under the waterline. On a submarine, the active sonar transmitter and receiver are located in the nose. The actual sonar sound, unlike the dull ping heard in submarine movies, is more of a high-frequency screech. Active sonar is the more effective sonar method, because it can detect an object perfectly still and quiet in the water. A major problem with active sonar is that the sound waves are detectable, just as radar and light waves are detectable.

Passive Sonar // This form, on the other hand, is a means for detecting ships that does not involve revealing the user's location. For that reason, submariners favor this sonar method. Passive sonar simply involves listening, via sensitive hydrophones, for telltale signs

of nearby ships. These signs include the sounds of ship engines and other mechanical noises, as well as propellers churning through the water.

This allows subs to detect enemy ships without revealing their own position. Surface ships can also use passive sonar, using a long cable to tow a passive sonar in their wakes to minimize detection. Helicopters can hover and lower hydrophones into the water, listening for sounds below. Passive sonar is particularly useful to sub hunters, as they can track submarines without revealing their hand.

"Passive sonar is all about being quiet," Moreno explains. "If your boat sends out its own noise, an enemy submarine can triangulate that position. U.S. submarines are trained for what is called 'Ultra Quiet'—time to break out the paper plates and plastic forks because cleaning dishes is loud. You are also required to stay in your rack [bed] unless you are on watch."

Even small, otherwise insignificant noises are avoided during Ultra Quiet. "If you ever see a toilet lid tie-strapped to the piping behind it, you know why. Toilet seats falling and banging are a top offender of noise. Also, proper lubrication doesn't just save joints...it stops squeaking to keep you silent and safe."—*Kyle Mizokami*



A "Y" gun fires depth charges from a sub chaser during World War II.



If We'll Ever Reach Warp Speed

THE SECRET TO FASTER-THAN-LIGHT physics could be to double down on the number of dimensions, according to research published last December in the journal *Classical and Quantum Gravity*. Specifically, the solution may lie in three dimensions of time, with just one representing space.

The key concept at play is the “superluminal observer,” a hypothetical thing that is looking at the universe while traveling faster than light. It’s you in your *Star Trek* warp-speed shuttle.

Superluminal observers marry together two very different sides of physics: general relativity and quantum mechanics. General relativity is the work proposed by Albert Einstein; it governs how spacetime functions as bodies move around the universe at subluminal, or slower-than-light, speeds. Quantum mechanics explains how subatomic particles behave, or don’t behave, in very strange ways on the smallest of scales.

Led by theoretical physicist Andrzej Dragan of the University of Warsaw and the National University of Singapore, the team has theorized that many parts of quantum physics can be explained if you take general relativity and apply its princi-

You can circumnavigate the globe 7.5 times per second at light speed.

ples to the superluminal observer. In other words, how messy does spacetime get if we take our shuttle up to warp speed? Is everything suddenly in multiple places at once?

Dragan’s new work indicates that it’s at least a possibility. Perhaps more interestingly, the way general relativity becomes quantum phenomena at speeds greater than light doesn’t seem to introduce any causal paradoxes. In earlier work, published in the *New Journal of Physics* in March 2020, Dragan and his coauthor studied “just” one space dimension and one time dimension, known as 1+1. In the new paper, the researchers upped the ante to include one space dimension and three time dimensions, or 1+3.

Why do we need three time dimensions? // To understand, we have to bring in some math. “Despite our common perception, time and space are strikingly similar according to relativity, and mathematically the only difference between them is the minus sign somewhere in the equations,” Dragan explains. That’s ▶

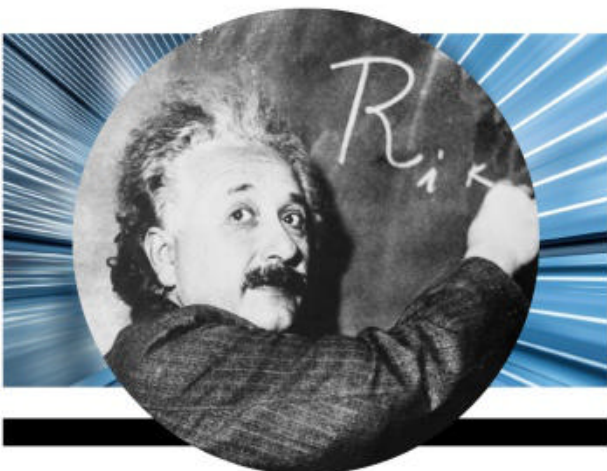
► a small difference in complicated math, but think of the algebra example of the difference of two squares: $x^2 - 16$, for example, is the result of $(x - 4)(x + 4)$. With one flipped sign, the middle term in the polynomial falls away.

But when the observer is going faster than the speed of light, the difference in signs also changes. That's because time and space must flip in the math. "The time of the superluminal observer becomes space of the subluminal one, and their space becomes time," Dragan says. In other words, the regular, non-light-speed observer's space and time turn into the time and space, relatively, of the faster-than-light observer. "So their corresponding signs have to interchange."

In a 1+1 scenario, that means the two dimensions are the same, making it redundant. If $50 = 50$, does it matter which 50 is which? (In logic, we call this a tautology.) That means that if we want to truly study space and time as different things, we have to add a second "set" of two dimensions: Space and time 1, together, represent space, while time 2 and time 3, together, represent time. It's not quite the difference of two squares, but we have two balanced sets of dimensions.

But the superluminal observer is just a thought exercise...right? Dragan isn't so sure. "The last remaining question is whether superluminal objects are only a mathematical possibility, or they actually exist in reality," he concludes. "We believe the latter to be that case, and [the] purpose of our further research."

This means our warp-speed shuttle, once the most far-out thing science fiction writers could even imagine, could embody an elegant theory that brings together two very different kinds of physics. Indeed, objects in the superluminal mirror may be closer than they appear.—*Caroline Delbert*



These Tips to Increase Your Home's Water Pressure

W

HEN SHOWERHEADS IN YOUR HOME ARE WEAK, water dribbles out of faucets, and the washing machine takes forever to fill, the problem could be low water pressure. This is a relatively common plumbing problem that can be caused by any number of things, ranging from clogged pipes in a municipal water system to worn-out components in a private water well. Here are a few simple tests you can run to get to the bottom of the problem.

Water-Pressure Test // To quickly and accurately calculate the water pressure in your home, purchase a pressure gauge, which will run you about \$10. Tighten the gauge's female-threaded fitting onto an outdoor garden-hose faucet. Check to make sure that all the valves closest to the water meter are fully opened (in the case of a well system, this would be valves closest to the home's pressure tank). Next, open the hose faucet all the way, and read the water pressure on the gauge's needle dial. Any reading that's less than about 40 pounds of pressure per square inch (PSI) is considered low water pressure. For most homes, 50 PSI is ideal.

Check the Flow Rate // Water flow is measured as a rate. If

the demand for water exceeds the amount that the system can supply, then it may seem as if your home has low water pressure, when that might not be the case.

To check your home's water flow rate, start by turning off all faucets and appliances that use water. Then, connect a garden hose to an outdoor faucet and line up three empty five-gallon buckets. Turn the water on full blast and start filling the buckets. Stop after 60 seconds, and measure how much water you've captured. If you fill two-and-a-half buckets, then your home's water flow rate is about 12½ gpm (gallons per minute).

The average household uses 100 to 120 gallons of water per person per day, so an ideal flow rate would be 6 to 12 gpm.

Call the Local Water Department // If your home is connected to city water, call your municipal water department and ask them to check the water pressure coming from the street into your house. They'll run a pressure test—often at no charge to you—to confirm that adequate pressure is being delivered. If they find no problem with the main water pipe, then the issue is in your home's water-supply system.

If you draw water from a well and are experiencing low water pressure, call a well contractor to inspect the well pump and the expansion tank, which pressurizes the water once it's pumped from the well into the house.

Adjust the Pressure-Reducing Valve // A quick and easy way to increase water pressure (for homes supplied by a municipal water system) is to adjust the

pressure-reducing valve, which can be found on the main water-supply pipe; look for a conical-shaped valve next to the water meter, close to where the main water pipe enters the house.

Protruding from the top of the valve is a threaded bolt. To raise pressure, loosen the bolt's locking nut, then turn the bolt clockwise. Use the pressure gauge to determine when you reach a water pressure around 50 PSI. Then, tighten the locknut to secure the valve.

With homes supplied by a well, you may be able to adjust the cut-in and cut-out pressure for the pressure tank and well pump, increasing the pressure of the water supply in the process. By adjusting for higher system pressure overall, the well's pump will cycle more frequently, and so you will experience an increase in electricity use, but you will have higher water pressure inside the house.

Install a Pressure Booster // When all other methods have failed, hire a licensed plumbing contractor or well contractor to install a water-pressure booster pump. These compact but powerful electric pumps are cut into the water-supply line, where they turbo-charge the incoming pressure and raise it to the proper level.

Note that booster pumps come in a wide variety of sizes and styles, and range in price from about \$100 to over \$700.—*Joseph Truini*



THE 389 WAYS TRAIN DERAILMENTS CAN OCCUR

The Rail Equipment Accident database categorizes derailments using 389 “cause codes” to help experts study trends. “Derailments occur for a number of possible reasons,” explains David Clarke, a retired transportation researcher who previously headed the Center for Transportation Research at the University of Tennessee. “One possible reason is something goes wrong with the track. Another is [that] something goes wrong with the equipment that rolls on the track. And the third is [that] the train, through some human factors error in operation of the train, develops internal forces that push it off the track.”—*C.D.*

If AI Can Take Our Jobs

CHATGPT HAS RECENTLY BLOWN UP THE internet with its ability to replicate human speech. Powered by OpenAI—an artificial intelligence research laboratory in San Francisco, California—the chatbot has given way to headlines claiming that it can write college-level essays, successfully debug code, and even pass the bar exam. But should you really be worried about your job security disappearing overnight?

To find out more, we talked to Sameer Singh, an associate professor of computer science at the University of California Irvine; Singh works on machine-learning algorithms, as well as other models that analyze text to mimic the idiosyncrasies of human writing, much like ChatGPT.

What Is ChatGPT? // Generative Pre-Training Transformer (or ChatGPT) is a plugin for OpenAI that taps into a neural network to make sense of writing, and then uses that knowledge to become really good with words. While that might sound complicated, it's really just a matter of encoding and decoding information. Neural networks are algorithms trained to replicate the way that neurons in the human brain communicate with each other. Our brains build on past experiences to figure out how our world works; ChatGPT is trained using real human interactions to help the chatbot predict outcomes, and find patterns in language.

How Does It Work? // The first process involves analyzing as much publicly available text as possible—essentially everything it can possibly find online. “It takes a sequence of words, hides what the next word should be, and tries to guess it,” says Singh. “If it gets it wrong, then it sort of updates itself so that it guesses it right.” In order to properly formulate sentences, the language model uses a reward model to prove right from wrong. Once the model puts a coherent sentence together, it still needs help discerning fact from misinformation. This is where the second step of the process comes in.

Since it's a bad idea to value some of the internet's takes at face value, there's some more fine-tuning that needs to be done in order to point the language model in the right direction. “AI will probably find a lot of documents that claim Barack Obama was born in Kenya, rather than in Hawaii,” Singh explains. If you were to ask it to write an article about Barack Obama, its response wouldn't be directly pulled from an article online. “When you ask it a question, it's not actually looking up the answer... It's just trying to guess what looks like the correct answer,” Singh says. However, this is problematic because ChatGPT will simply decline questions it can't answer—which kills the novelty.

Will It Put Us Out of Work? // “I think some people may be thinking that, but they just need to play around with it for 10 minutes,” Singh says, seeming unfazed. “It's not happening.” He summed up ChatGPT as a “very sophisticated guessing engine,” and we think that says it all.
—Matt Crisara



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Whether We Should Bring Back the Woolly Mammoth



AT FIRST BLUSH, IT SOUNDS LIKE A LINE from *Jurassic Park*, the fictional dream of resurrecting creatures long dead: “We have the DNA, the technology, and the leading experts in the field. Next, we will have the woolly mammoth. Alive again.”

But this is a very real statement from Dallas-based biotech company Colossal, which is serious about its genetic engineering mission to recreate a version of the six-ton animal that roamed the Siberian tundra 10,000 years ago. The company’s de-extinction project aims to fill an ecological niche by allowing woolly mammoth 2.0 to pound the Arctic tundra once again—as soon as 2027. “Most importantly, it will inhabit the same ecosystem previously abandoned by the mammoth’s extinction,” according to Colossal’s website.

Ecological researchers aren’t convinced. // The vision of herds of insulated elephants roaming

the northern plains is a pipe dream for several reasons. Conservationists need to keep in mind these three rules of thumb to ensure the highest chance of returning a disappearing or extinct species, according to ecologist and conservation biologist Douglas McCauley, who studies the ecology of rapidly changing ecosystems at the University of California, Santa Barbara.

→ Choose to bring back a species that was truly unique, meaning its ecological role cannot be filled by another species.

→ Bring back a species that was recently lost to ensure it knows how to survive in the modern ecosystem.

→ Recover the actual behavior of the species in its ecosystem. That may mean ensuring its return to previous natural population levels.—*Manasee Wagh*



THE MATH THAT MADE COLOR TV POSSIBLE

The invention of color TV is a great example of the Fourier transform, which is a key algorithm that turns the graph of a signal varying in time into a graph that describes it in terms of its frequencies.

In the 1950s, television was just black-and-white. Engineers at RCA developed color TV and used Fourier transforms to simplify the data transmission so that the industry could introduce color without tripling the

demands on the channels by adding data for red, green, and blue light. Viewers with black-and-white TVs could continue to see the same images as before, while viewers with color TVs could now see the images in color.

Packaging signals that represent sounds or images in terms of their frequencies allow us to analyze and adjust sound and image files, says Richard Stern, a professor of electrical and computer

engineering at Carnegie Mellon University. When the signals are represented in terms of frequency, you can suppress or strengthen those frequencies.

You can also use the transform to store data efficiently. For example, you can code MP3 files, which makes it possible to store thousands of songs on a smartphone—something that would be impossible with WAV files.—*Kat Friedrich*



BACK-BREAKING WORK REQUIRES SOME HELP

Everyone feels the hurt as you age, but CBD can help you deal with it

Life really does fly by. Before I knew it, my 60s had arrived, and with them came some new gifts from dear ol' Mother Nature—frequent knee pain, stress, low energy and sleeplessness. Now, I'm a realist about these things, I knew I wasn't going to be young and springy forever. But still, with "golden years" nearly on my doorstep, I couldn't help but feel a little cheated. That is until I found my own secret weapon. Another gift from Mother Nature.

It began a few months back when I was complaining about my aches and pains to my marathon-running granddaughter, Jen. She casually mentioned how she uses CBD rub to help with her joint pain. She said that CBD gave her more focus and clarity throughout the day and that her lingering muscle and joint discomfort no longer bothered her. She even felt comfortable signing up for back-to-back marathons two weekends in a row this year. That made even this self-proclaimed skeptic take notice.

But I still had some concerns. According to one study in the Journal of the American Medical Association, 70% of CBD products didn't contain the amount of CBD stated on their labels. And, as a consumer, that's terrifying!

If I was going to try CBD, I needed to trust the source through and through. My two-fold research process naturally led me to Zebra CBD.

First, I started calling my family and friends. Call me old fashioned but I wanted to know if there were people whom I trusted (more than anonymous testimonials) who've had success using CBD besides my granddaughter.

Secondly, I wanted cold hard facts. Diving deep into the world of CBD research and clinical studies, I came across Emily Gray M.D., a physician at the University of California at San Diego (UCSD) Medical School and medical advisor to Zebra CBD who is researching the effects of CBD. Dr. Gray wrote "early results with CBD have been promising and we have a lot of research underway now. I've had several patients using CBD with

good success. It's important that you know your source of CBD and how to use it properly."

After hearing it from the doctor's mouth, I returned to my research, asking more people and was amazed by the number of close friends and family who were already on the CBD train. Apparently, I was the only one without a clue! And funny enough, a couple of friends who commented were using the same brand as my granddaughter—Zebra CBD. There was no consensus as to why they were using CBD, but the top reasons given were for muscle & joint discomfort, mood support, sleep support, stress and headaches, as well as supporting overall health & wellness.

Eventually, even the most skeptical of the bunch can be won over. With a trusted CBD source in mind, I decided to give it a go.

When I viewed Zebra CBD's selection online, I was impressed by its array of products, including CBD oils called tinctures, topicals, chewable tablets, mints and gummies. After reading on their website that all their products are made with organically-grown hemp, I ordered... and it arrived within 2 days!

The first product I tried was the Rub. Now this stuff was strong. Immediately after rubbing it on my knee, the soothing effects kicked in. It had that familiar menthol cooling effect, which I personally find very relieving. And the best part is, after two weeks of using it, my knee pain no longer affected my daily mobility.

The Zebra Sleep Gummies, on the other hand, had a different but equally positive effect on my body. To take it, the instructions suggest chewing thoroughly. This was simple enough, and the taste was, well, lemony. After about 15 minutes, a sense of calm came over my body. It's hard to describe exactly; it's definitely not a "high" feeling. It's more like an overall sense of relaxation—and then I fast asleep. Needless to say, I slept great and woke up refreshed. I haven't slept like that in a long time.

While it hasn't been a catch-all fix to every one of my health issues, it has eased the level and frequency of my aches. And it sure doesn't seem like a coincidence how rejuvenated I feel.

All-in-all, CBD is one of those things that you have to try for yourself. Although I was skeptical at first, I can safely say that I'm now a Zebra CBD fan and that I highly recommend their products.


Also, I managed to speak with a Zebra CBD spokesperson willing to provide an exclusive. If you order this month, you'll receive \$10 off your first order by using promo code "PM10" at checkout. Plus, the company offers a 100% No-Hassle, Money-Back Guarantee. You can try it yourself and order Zebra CBD at ZebraCBD.com/PM or at 1-888-762-2699.

HOW WE'LL

DIE ON



MARS



Establishing a permanent human presence on the Red Planet will be risky, but researchers are finding solutions that will keep future residents alive long enough to die peacefully. Here's how it could happen.

G

athered in a common room, the mourners say goodbye to the body of their pioneering geologist, dead from a brain aneurysm. The Mars base memorial service remembers a fellow colonist, but also celebrates a milestone for humanity: On June 23, 2034, she

became the first person to die of natural causes on Mars.

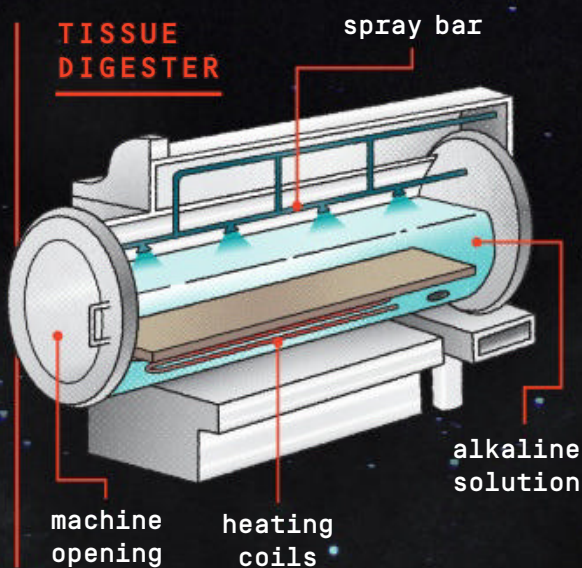
After the service, while the mourners head to the public grove that serves as a graveless cemetery, a pair of technicians undress the body and move it to a room ringed with stainless-steel pods. These are **tissue digesters**. The techs transfer the body into an empty pod and seal the lid. Soon it fills with water spiked with potassium hydroxide, a caustic base. Then the pod is heated to 300° Fahrenheit and pressurized to 70 psi.

After about 12 hours of pressure-cooking alkaline hydrolysis, the pod drains with an automated whoosh, leaving only the bones. The broth is piped to the colony's anaerobic digester, where microorganisms break down biodegradable waste to produce methane gas that will fuel spacecraft and other vehicles. The remaining liquid becomes fertilizer along with the bones, which are heat-dried and crushed into a nitrogen- and mineral-rich powder. Nitrogen is a key component of chlorophyll, making this a valuable addition to the fertilizer used to grow Martian crops. Any remaining solids are transferred to compost bins to eventually form building materials like walls, deck planks, and particle boards. Every molecule is reused. There are no landfills on Mars.

Dying on Mars means living on Mars, and that our species has mastered the dangers the Red Planet poses. The hazards—the journey through space, treacherous landing, and brutal realities of life on an alien planet—are formidable. And the longer people stay on Mars, the greater the challenges grow.

Undaunted, engineers today are developing solutions that could lead to Martian funerals tomorrow. And the first humans could land as soon as 2029, if SpaceX can keep its ambitious timeline to settle Mars. “This is a very hard, dangerous, and difficult thing, not for the faint of heart. There’s a good chance you’ll die,” SpaceX founder Elon Musk told a conference in September 2020. “It’s going to be tough going, but it will be pretty glorious if it works out.”

Getting things to “work out” on Mars will mean designing a generation of new equipment, spacecraft, landers, and infrastructure to deliver and support permanent residents on an alien world. From the moment the spacecraft leaves Earth, each step of colonization will be defined by the engineering that is meant to let settlers live a full life on Mars.



ALYSE MARKEL (TISSUE DIGESTER)



PART ONE:

PERILOUS VOYAGE

FROM INSIDE THE ship's recreation room, the Mars-bound geologist can see a landscape of motionless stars through a high-impact quartz glass porthole. It's just wide enough for a single person to get a glimpse, and she can't help but wonder if this narrow view of deep space was worth the cost and risk. The quartz can withstand heating and cooling without cracking, but each window represents an interruption in the structural integrity of the hull.

Each porthole is a symbol of stubborn, human defiance and biocentrism. Why take the species this far without granting them the ability to see, with their own eyes, where they're going? It's also a sign of humans' psychological frailty. Staring at something, anything, beyond the confines of the spaceship bulkheads is a welcome relief for the mind as well as the eyes. NASA's Human Research Program rates "isolation and confinement" as one of the key threats to human health during long-duration spaceflight. Getting to Mars requires a journey of around 35 million miles, representing at least six months on a likely cramped, regimented vessel.

The days of gnawing zero-G nausea can meld together, separated only by interior lights approximating Earth's solar cycle. The passengers are kept busy with a daily routine of exercise, chores, and medical checks, all of which is meant to keep themselves, and their companions, physically and mentally fit.

The human body is designed around gravity. It is, essentially, a pressurized container of fluid, and gravity pulls those fluids down to our feet. But in space, that fluid freely flows into the upper body, raising arterial pressure in the skull enough to make the head swell, damage vision, and reduce cognitive ability.

Earthbound doctors combat pressure imbalances with lower-body negative pressure (LBNP) chambers that draw body fluid toward the legs. Cosmonauts strapped themselves into similar machines in the late 1970s to prepare for high-G landings, fearing blackouts when the body's fluids recalibrated under intense gravity, but they were uncomfortable and took too much time to set up.

An updated version of LBNP could soon return to space. In December 2019, Alan Hargens, PhD, a space physiologist at the University of California, San Diego, published a paper in the journal *Aerospace Medicine and Human Performance* describing his design of a mobile LBNP suit. "It works like a vacuum cleaner that sucks an object off the floor," Hargens says. "But in this case, you suck in some person's body up to their waist, and they're sealed in the chamber with sort of a kayak skirt."

RAISE THE SHIELDS!

The journey to Mars would expose travelers (and their electronic equipment) to six to nine months of cosmic radiation if they're unprotected. The average annual dose from cosmic radiation on Earth totals 0.33 millisieverts (mSv), and a medical CT machine delivers anywhere from 2 to 10 mSv of radiation per scan. The *Curiosity* rover turned on its radiation detector during the trip to Mars and measured an average of 1.8 mSv per day. Using this data, the Southwest Research Institute calculated that a trip to Mars would expose travelers to a whopping 330 mSv. One thousand mSv increases fatal cancer risk by 5 percent; NASA's limit for astronauts today is 3 percent. Any spaceship heading to the Red Planet must have robust radiation shields, and researchers are coming up with novel approaches.

1 / LIGHTWEIGHT ARMOR ▶ The main obstacle to shielding spacecraft from radiation is weight, but advances in materials science have made a physical shield more appealing. For example, a 2020 study found the seldom-used silicon polymer perhydropolysilaxane is a good absorber of x-rays, gamma radiation, and neutrons. Another 2020 NASA study found that mixing oxidized metal powder (rust) into a polymer and then incorporating it into commonly used coatings helps repel charged particles while adding minimal weight.

2 / CHARGED SPIDERWEB ▶ An elegant solution to radiation could come by unfurling a large lightweight gossamer structure that is charged to a high negative voltage to repel all inbound, positively charged ions. This electrostatic shield guards against proton storms caused by explosions from the sun called coronal mass ejections, and could be deployed only during those events while the ship relies on another system for day-to-day protection.

3 / INVISIBLE BUBBLE ▶ If a magnetic field protects Earth from space radiation, why not bring one for the trip to Mars? NASA has sponsored years of research into this technology. The most promising, a design called Magnetospheric Dipolar Torus (MDT), features an enormous superconducting ring magnet that produces a magnetic field to repel most forms of cosmic radiation. A compensation coil with an opposite-moving current deflects the field from the ship itself. Ongoing research for NASA is heading toward a small-scale MDT prototype for testing.



PART TWO:

SURVIVING THE LANDING

LANDING PADS ON DEMAND

To the delight of 1950s pulp science fiction fans, retrorockets have become the preferred method of landing spacecraft. But on Mars, those plumes will tear deep gouges in the terrain below, exactly where the lander aims to set down, says Matt Kuhns, former chief engineer at Masten Space Systems. In partnership with NASA's Innovative Advanced Concepts office, Masten (now part of Astrobotic) developed a possible solution called an Instant Landing Pad that adds a flat surface to a crater on demand.

HOW IT WORKS

1 → A few hundred meters above the surface of Mars, the lander hovers.

2 → Aluminum pellets are fed into the engine exhaust nozzle, where they partially melt, and are blasted onto the surface.

3 → The pellets form a layer on the surface of the landing location, which almost

immediately hardens into a shell less than an inch thick. "Once you get the first layer down, the rest of it should be able to build up pretty easily," Kuhns says.

4 → After deploying the spray for 15 seconds as many as five times, the lander sets down on the clean, stable surface under the power of its main engines.



THE LAST MOMENTS of the journey to Mars are the most dangerous. Strapped to her seat, the geologist tries not to picture what's happening outside: entering Mars's thin atmosphere at 16,000 mph. Each passenger was warned that the craft would "decelerate aerodynamically," but the phrase doesn't capture being pressed into their seats by more than five times Earth's gravity.

Six miles high, the atmosphere becomes thick enough to produce lift. The spaceship rotates its tail fins to tilt the nose up until it looks like a missile soaring backward across the Martian landscape.

The engines flare to life a mile and a half above the

surface, shedding enough speed to land safely. With another wiggle of its fins, the ship stands fully upright, engines aimed straight down and still roaring. It slowly settles down on the planet under a cushion of exhaust, the edges of the tail fins now doubling as legs.

Landing on Mars is notoriously difficult. The atmosphere is 100 times less dense than Earth's, the ground often obscured by dust, and the terrain littered with boulders, craters, and slopes. And "[Mars] has enough of an atmosphere to be really annoying and not enough of one to be quite as useful as we would like," says Matt Kuhns, who formerly worked as chief engineer at Masten Space Systems but has since joined SpaceX.

Over the years, space agencies have used a combination of protective armor, speed-shedding parachutes, last-minute sky cranes, and bouncing touchdown cocoons to deliver rovers and landers to the planet's surface. The direct, propulsive landing profiled above—most notably used by SpaceX's Starship, which is currently being built and tested in South Texas—could provide a relatively safe alternative.

Setting down with precision will be vital to building a permanent presence on Mars, since a steady cadence of delivery rockets will need to land near and not on the colony's infrastructure. Fortunately, humans have already scored impressive interplanetary bull's-eyes. On February 18, 2021, NASA's Mars rover *Perseverance* took pictures of the ground while parachuting through the atmosphere and matched what it saw to an onboard map made by the Mars Reconnaissance Orbiter. This system enabled the rover to touch down within an 82,000-square-foot-wide area—a bit bigger than a football field—making it the most precise Mars landing ever.

The spacecraft must also ensure the landing spot is free of hazards. In October 2020, Blue Origin launched a capsule carrying NASA's next-generation alien landing device, the Safe and Precise Landing-Integrated Capabilities Evolution (SPLICE). Four miles above the West Texas scrub, SPLICE shot and compared 3D images against a map, then automatically adjusted the lander to stay on target and confirm the terrain was free of obstacles.



PART THREE:

MARS IS TRYING TO KILL US

THE MARS GEOLOGIST *tries to keep her hand from trembling as she stows the final sample of volcanic rock from the slope of Olympus Mons. Collecting samples of the solar system's largest volcano by hand should fulfill any geologist's dream. Instead, she's racing a deadly, invisible solar flare.*

It's a short trip back to the rover, a ruggedized golf cart. But there's no time to drive back to the safety of the colony, and so her expedition partner has already started to unpack a pill-shaped emergency shelter for two. The fabric walls have wide pouches that hold carbon-fiber plates that block radiation, while a battery

pack and oxygen tanks replenish their suits.

A solar flare makes an already-bad background radiation on the Martian surface—about 38 times that on Earth—even more dangerous.

For this reason, the first Martians will likely live in underground bunkers. “We’ll need to take precautions, such as putting a meter or two of dirt on top of settlements,” says Bruce Jakosky, PhD, professor of Geological Sciences at the University of Colorado and principal investigator of the Mars Atmosphere and Volatile Evolution (MAVEN) orbiter, which studies the planet’s climate. “Water can also provide protection, so one could build habitats that are covered with water tanks.” Of the two, using dirt makes more sense. Even

though hydrogen molecules are effective blockers of radiation, in water they spread out. For this reason, it takes about 14 feet of water to reduce gamma radiation penetration to safe levels, as opposed to just a few inches of Martian soil in a bag or baked into bricks.

Detecting incoming solar storms is as critical to saving lives as a tornado warning system on Earth. A large ejection could bring a radiation dose that can kill within minutes, and the accumulation of radiation from many small storms can cause long-term health problems, including cancer. Local Martian space weather forecasts require their own satellites and ground stations working together, one measuring the particles striking the planet and the other detecting how many reach the surface and how fast they're traveling. The higher the velocity, the more the damage. During a bad storm, Martians could retreat to underground chambers protected by thick layers of dirt or water, Jakosky says. Those caught on the surface must shelter in place.

The atmosphere is an unbreathable 95 percent carbon dioxide. Temperatures skew colder, between 70° and -200° Fahrenheit, compared to Earth's 116° to -114° Fahrenheit. Luckily, colonists will enjoy hot showers since steam is ubiquitous at a nuclear-powered base. Unlike on Earth, there's no debate over energy policy here: NASA, SpaceX, and the China National Space Administration recognize that only nuclear power is reliable and efficient enough for a budding Martian colony.

The difference in temperatures across the planet—hot at the equator and cold at the poles—causes enormous low-pressure systems and polar fronts, resulting in seasonal windstorms. Mars's thin atmosphere deprives the wind of actual force, even at hurricane speeds. But the fine surface particles that swirl in those gusts create dust storms that can envelop much of the planet. This dust is dangerous, and not just because it obscures views and clogs machinery. Rovers and satellites have detected concentrations of toxic perchlorates—a salt so reactive that it's used on Earth to make rocket propellant—on the Martian surface that would be swept up in the wind. "These are also a human health hazard because they block the uptake of iodine by your thyroid if ingested," says Tanya Harrison, PhD, a science team collaborator on several NASA Mars rovers and manager of science programs at Planet Federal in Washington, D.C. "And we don't know the global distribution and concentration of perchlorates [on Mars]."

By the time people reach Mars, the weather will be less mysterious. NASA's newest Mars rover, *Perseverance*, arrived in 2021 carrying a suite of weather sensors called Mars Environmental Dynamics Analyzer (MEDA) to record the changes in dust levels, wind speed, atmospheric pressure, relative humidity, air temperature, ground temperature, and radiation.

"We'll actually have *InSight*, *Perseverance*, and *Curiosity* operating at the same time on Mars," says Cornell University's Don Banfield, PhD, a principal research scientist for several MEDA sensors. "While

they are all quite distant from one another on Mars, comparing the results from all of them will be similar to how one can learn from looking at the weather in Miami, New York, and Tokyo." (NASA's *InSight* lander has since shut down due to dust accumulation.)

Despite the fleet of intrepid NASA probes, there's little equivalent information available to judge the risk of another alien quirk: Gravity on Mars is about 38 percent that on Earth. "We haven't spent much time on fractional gravity," says Alan Hargens, the UCSD space physiologist. "We've only done it on the Moon, which is one sixth of our gravity, and only for a few days. We really don't know how well we'll adapt."

Studies have found that microgravity can alter the shape of the brain, muscles, intestines, and individual heart cells. An even stranger effect may be lurking, as researchers in 2020 found patterns of changes in the genomes of nematode worms that had gone to space. These genetic changes included a decrease in the thickness of muscular thick filaments, which may help explain why astronauts lose muscle mass in space. The worms' cytoskeletal layouts also evolved to be shorter and fatter than worms that had not traveled to space.

HOME SWEET HOME

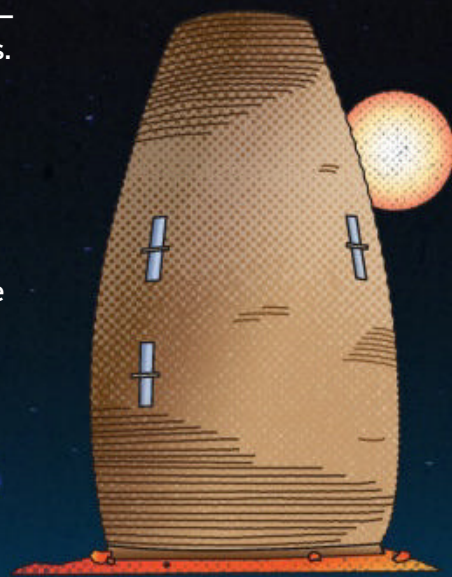
Within years of their arrival, the underground structures in which the Martians first lived have been replaced by free-standing habitats that look like they were built by giant wasps.

Robotic arms 3D-print the ruddy-brown Martian dwellings by applying wet construction material—a mixture of reinforced basalt fibers and polylactic acid sourced from the waste-fueled bioreactors—in quickly hardening layers.

Cylinders are an ideal shape for a pressure vessel because their curved surfaces can withstand higher pressures. They also afford the most interior space. Each of the buildings, shielded from the elements and interconnected by subsurface tunnels, are divided into floors with comfortably sized rooms.

Each structure is double-hulled with

thermoplastic material. The space between the inner and outer walls serves as a light well, bringing natural rays from the structure's tip to other floors through inner-wall windows. A clear, water-filled roof bathes an exercise room with soft sunlight. The goal is not to build a utilitarian submarine on the Mars surface, but a comfortable home.



PART FOUR:

LIVING TO DIE A COLONIST

WHEN THE CHOICE CAME, it was no choice at all. The geologist decided she would stay on Mars as a permanent resident. When large-scale mining production of oxygen and water from Martian ice began, she knew it was only a matter of time before the base would evolve into a colony.

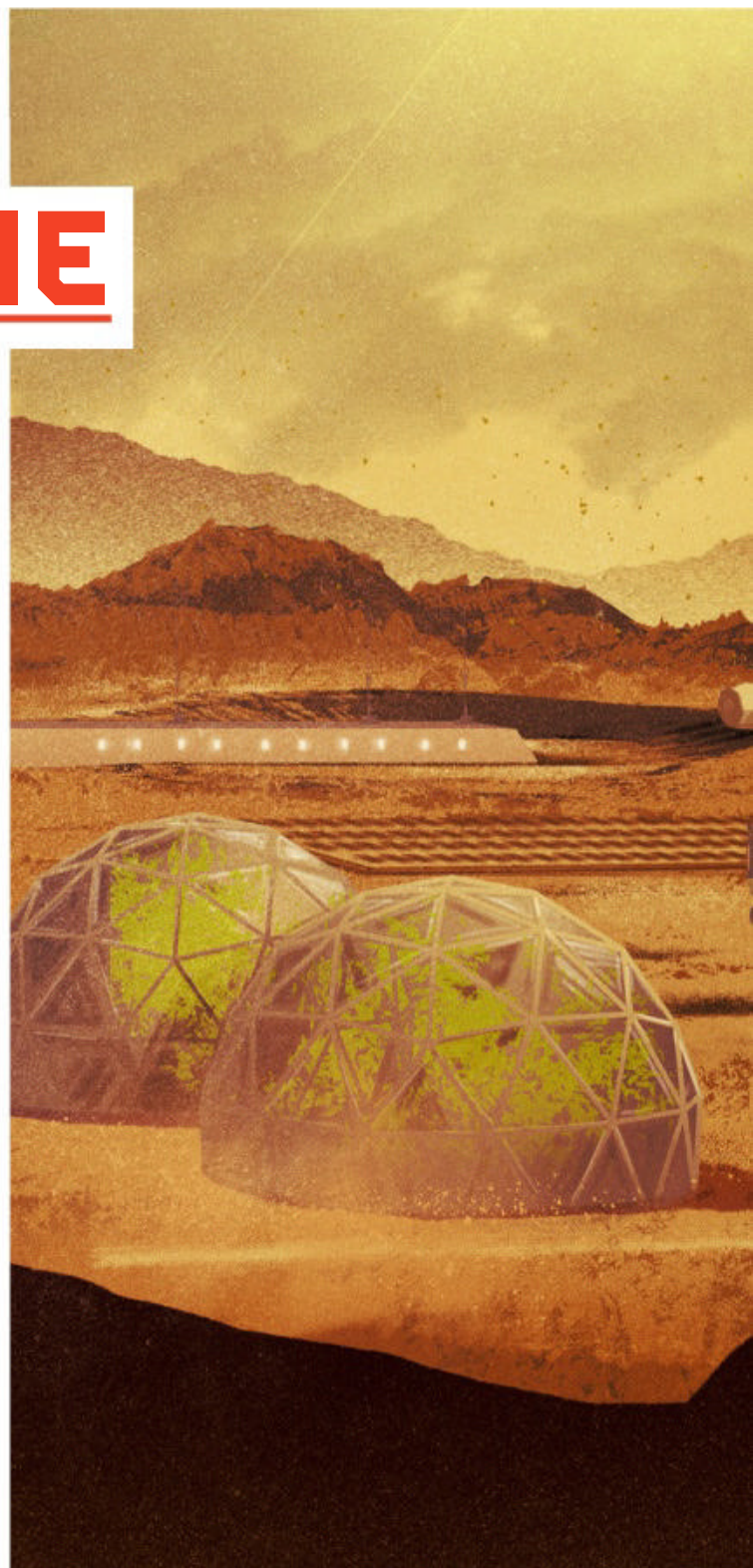
Now, decades after her arrival, there's a growing army of riding-mower-sized robots scouring the eastern crater rim of the Hellas glacier for chunks of ice they'll bring to solar-powered factories for purification. Some facilities turn the ice to water; other facilities split the ice into oxygen and hydrogen for life-support systems and rocket engines. The geologist has never seen the robots in person—the crater walls are steep and the automated machines are hazardous—but she knows they're out there, keeping the self-sustaining base alive.

The vanguard of an automated Martian workforce is already taking shape today. NASA has held an annual Robotic Mining Competition at Kennedy Space Center for a decade, leading to a plethora of possible schemes. In the past, development focused on single, ultracapable autonomous mining robots. The current leading concept is a fleet of small robots, each designed to travel on treaded wheels and fetch small portions of ice. The benefit of a swarm is that some can break down, and the life-giving mining will continue.

Masten Space Systems at one point proposed a higher-volume approach, which would capture the icy ejecta from rocket blasts in a small dome. “We could harvest hundreds of tons of water ice in a very short amount of time,” says Matt Kuhns, who once worked for Masten but now works for SpaceX. “The small dome basically builds up the pressure so you can get the deep excavation, and then also captures any volatiles.”

With air and water accounted for, the next step is to grow food in hydroponic setups similar to those on Earth. The water would need to be sanitized before use, and the soil requires “remediation for known impurities, like salts and perchlorates,” says Stephen Hoffman, PhD, a systems engineer with the Aerospace Corporation who's working at Johnson Space Center with NASA's Mars Architecture Team. Martian farmers would also need to add nutrients to the soil.

Research performed by the Center for the Utilization of Biological Engineering in Space (CUBE), a



NASA collaboration with multiple universities to create the underlying tech to create a self-sustaining, zero-waste human settlement on Mars, reveals the true scope of the challenge. CUBE researchers are studying microbes that can produce nutrients from toxic land, using nanotechnology to enhance the production of complex molecules within living cells, and designing greenhouses optimized for cramped, restricted spaces.

Technicians could clone animal cells to make lab-grown meat to supplement a mostly vegan diet. An Israeli food technology startup, Aleph Farms, cultivated meat in space for the first time during a 2020 experiment on the International Space Station (ISS). Eating meat during holidays could become a Martian tradition.

And if for any reason rockets slow or stop deliveries, the colonists will need to make their own medicine, clothing, tools, vitamins, and rocket fuel. Additive




manufacturing, which uses common materials to build a nearly infinite number of products with a single machine, could help. It's common for high-end factories and hobbyist garages alike to have 3D printers; there are two NASA-funded 3D printers on the ISS that have been churning out parts since 2014 and 2016. A space doctor could manufacture specific medicines on demand from an inventory of base ingredients.

The scale of this *in situ* production will be staggering if the colony is truly to be considered self-sufficient. Elon Musk has said that reaching full sustainability requires sending around 1 million people to live on the planet. That's more than a colony or even a city; at that point, Mars will become its own political entity.

At this phase of its development, the concept of technological risk changes. The machinery that has kept humanity alive has been perfected but could

introduce societal threats. "A small number of specific humans will control the fundamental elements of life: air, water, light, hydroponic systems," wrote Dr. Bleddyn Bowen, a professor of international relations at the University of Leicester, on the Spacewatch Global blog in October 2020. "The citizens of space habitats...will need to subordinate their individual freedoms to the pure needs of the technology's ability to sustain life."

When the geologist decided to finish her life on Mars, she accepted these personal sacrifices, just as she resigned herself to the tissue digester. Her remains would never find a permanent resting place here, but her role as a scientist-pioneer will never be forgotten. Maybe those left comfortable on Earth wouldn't fully understand, but for her, Mars became more than a mission. It was a new life, and not just for herself. 

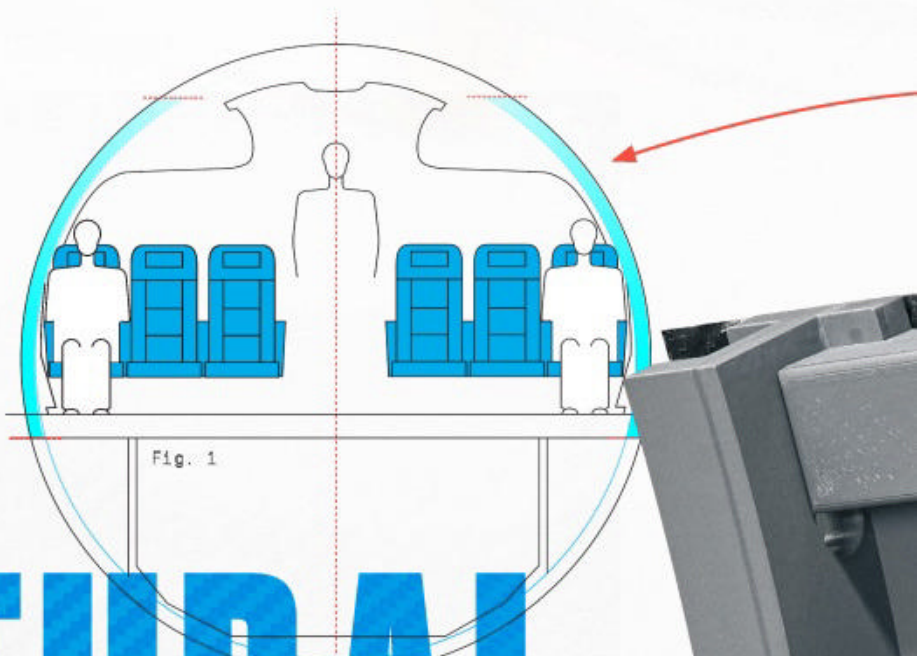


Fig. 1

CAN STRUCTURAL BATTERIES SAVE ELECTRIC AIRCRAFT?



The two largest aircraft manufacturers in the world have snubbed battery-operated aircraft. Researchers in Europe think they might have (part of) a solution: **Make the plane out of the battery.**



← Made from carbon-fiber composite, this structural battery could someday act as a support beam in a passenger plane.

▣ *by* **Daniel Oberhaus** ▣ *photography by* **Sam Chick**



AT THIS MOMENT, THERE ARE AROUND 8,000 COMMERCIAL JETS CRISSCROSSING THE GLOBE AND SPEWING GREENHOUSE GASES INTO OUR ATMOSPHERE.



These jets are critical for moving people and goods around the world, but they are also wildly out of step with global efforts to fight climate change by reducing emissions. Airlines and aircraft manufacturers are aware of their large and growing carbon problem. Aviation is responsible for about 2.1 percent of global CO₂ emissions, which is roughly comparable to the CO₂ emitted by all gasoline motor vehicles in the U.S. annually. But nobody can agree how to fix it.

The technologies contending to decarbonize the airlines are hydrogen, biofuels, and batteries. Boeing and Airbus, the two largest aircraft manufacturers in the world, have very different opinions on which of these heralds the future of large passenger jets. But they appear to agree on one thing: The cost, complexity, and lackluster performance of battery-electric propulsion makes this technology a dead end for large-scale aircraft. After Airbus mothballed its most advanced hybrid-electric prototype, the 100-passenger E-fan X, in 2020, the company has switched its focus to hydrogen fuel cells. Boeing has largely placed its bets on biofuels and hydrogen for large passenger jets, though the company is making strategic investments in smaller-scale electric aircraft such as the “air taxi” being developed by Wisk Aero.

But for a small and growing number of researchers and engineers, the dream of completely electrifying passenger jets is far from dead. There is another energy-storage technology that could reduce airplane carbon emissions by hundreds of tons every year without having to change anything about the jet engine. A tentative step toward this future lies on a workbench in the lab of Emile Greenhalgh, PhD, a materials scientist at Imperial College London. It’s a seemingly unremarkable chunk of carbon-fiber-composite component shaped as a perfect replica of the C-beams that

provide structural support for the fuselage of an Airbus A380. It is also a supercapacitor, a remarkable feat of engineering that Greenhalgh hopes will help chart an alternative course for the future of aviation.

WHY ELECTRIC AIRCRAFT HAVE STALLED /

The challenge in building an electric aircraft comes down to energy density of fuel. A higher energy density means you need less fuel to do the same amount of work. The jet fuel typically used in commercial aircraft is slightly more energy dense than the gas you’d put in your car, and when a Boeing 787 Dreamliner takes off on an 8,000-mile trip, up to about 30 percent of its total weight is jet fuel. The energy density of jet fuel is good enough for most aviation needs, but it could be better. Not only does burning it release greenhouse gases into the atmosphere, it’s also only about one-third as energy dense as hydrogen.

Still, it’s a lot better than a standard lithium-ion battery, which is about 50 times less energy dense than aviation fuel by weight. To compensate for this performance hit, an electric plane that replaces fuel with a large battery would have to fly shorter distances, carry fewer passengers, or both. Consider that intercontinental trip by the 248-passenger Dreamliner. Replacing its jet fuel with the highest-performing batteries currently available would require a battery pack weighing nearly 7 million pounds (about twice the weight of a fully fueled SpaceX Falcon Heavy rocket). To think about this on a small scale, a Tesla Model 3’s battery pack weighs just over 1,000 pounds compared to the roughly 100 pounds of gasoline carried in a full mid-to-large-size gas tank.

The lithium-ion battery’s modest energy density means that electric aircraft have thus far been limited to small planes capable of carrying a few passengers on short trips. Pipistrel’s Alpha Elektro, the first electric general aviation plane to be certified as airworthy by the Federal Aviation Administration, can carry two people for up to 90 minutes. Late last year, Eviation conducted its first test flight of Alice, the world’s first all-electric commuter plane, which can carry up to nine passengers on trips up to 250 nautical miles.

“The chemistry of a battery defines how much energy it can produce, and there are mathematical limits to it,” says Gregory Davis, the CEO of Eviation. “You’re not going to see electric aircraft flying passengers across the Atlantic or Pacific Oceans, but half the world’s air travel is 500 nautical miles or less. Battery technology will allow for those shorter-range flights.” There are plenty of other passenger electric planes under development—some estimates say that 200 electric aircraft are in various stages of development—

but most are not expected to enter production for several years, and few will carry more than a dozen people.

THE STRUCTURAL BATTERY SOLUTION /

While lithium-ion batteries—or alternative fuels like hydrogen or biofuel—are unlikely to dethrone jet fuel in the next decade, they may still have an important role to play in decarbonizing aviation in the near future. The trick is to transform the battery from mostly dead weight into something that performs a useful function even when its energy is depleted. This is a concept known as a structural battery, and it's significantly different from the batteries you find in your phone, computer, or car. Structural batteries don't exist independently of the object that they're powering. Instead, the object itself is built out of batteries. Whereas it's easy to take the back off your phone and identify the battery, when it comes to structural batteries you can't tell where the battery starts and the object it powers begins.

Structural batteries could, in principle, be used to create cabin walls, floor panels, and even wings. Like conventional lithium-ion batteries, structural batteries in aviation wouldn't be nearly energy dense enough to deliver the large amounts of power required by an aircraft propulsion system. But for other uses, such as cabin electronics and avionics, structural batteries could reduce the load placed on the main battery pack and engines without adding extra weight. While floor panels made out of batteries may not sound sexy, integrating structural batteries into passenger jets could potentially save thousands of tons of emissions annually by making aircraft engines more energy-efficient.

For the past decade and a half, electrochemists and aerospace engineers have been racing to make structural batteries a reality. Creating a material that can both store energy and bear mechanical load is a wickedly challenging problem. Conventional lithium-ion batteries contain a liquid electrolyte, which helps ions flow freely from one electrode to the other as the battery charges or discharges. Liquid electrolytes aren't great for holding up mechanical loads, but their alternative—solid electrolytes—tend to block the free flow of ions from one battery terminal to another. To solve the problem of structural batteries, researchers need the best of worlds: the electrochemical performance of liquid electrolytes and the mechanical strength of solid electrolytes.

“The fact is that you have to combine two properties that are intrinsically not matching,” says Natasha Shirshova, PhD, an associate professor of engineering at Durham University in England and an expert on structural electrolytes for

multifunctional energy-storage devices. “It should have good mechanical properties and high strength, but then the ions cannot really move. Solving this isn't trivial.”

In the past, researchers have tried to find a middle ground between solid and liquid electrolytes by creating a gel electrolyte that had properties of both. The problem with this approach, as Shirshova puts it, is that “you're not going to build an aircraft out of Jell-O.”

Shirshova's solution was to create an electrolyte that was a mixture of solid and liquid. The solid would bear the loads and the liquid would help ions move between the electrodes. In her system, the solid is a porous material whose network of cavities is filled with the liquid electrolyte. Think of it like a sponge full of water.

DESIGNING THE FUTURE OF ELECTRIC AVIATION /

This leads us to the beam in Emile Greenhalgh's lab at Imperial College London. The prototype C-beam is three feet long, a few inches wide, and made from a black carbon-fiber composite, a lightweight material that is twice as strong as steel. From its perch on the lab bench, the beam could easily be mistaken for some run-of-the-mill hardware you would find at Home Depot.

The beam contains eight supercapacitors linked together. Like conventional batteries, supercapacitors work by shuttling an ionic liquid between positive and negative electrodes separated by an electrolyte. A primary difference between a supercapacitor and the lithium-ion batteries found in consumer electronics is that supercapacitors are designed to discharge their energy rapidly

↓ This beam-shaped structural battery, developed by Greenhalgh's lab, could someday be built into the frame of aircraft.



instead of providing a steady drip. Greenhalgh and his colleagues decided to use supercapacitors because they are relatively simple to work with compared to batteries.

By Greenhalgh's estimation it is likely the largest structural energy-storage device that has ever been built at this level of performance. Ideally, it would one day replace a large bank of supercapacitors hidden in the fuselage wall near the door of most passenger jets. These supercaps are a critical safety mechanism designed to force the plane's door open in the event of a hard landing. But for the vast majority of flights that land safely, the bank of supercaps is a dead weight. If the beam could do double duty, providing electrical energy and support at the same time, it would save on the weight that the plane's propulsion systems must lift.

Greenhalgh's supercapacitor beam was one of the results of a project called SORCERER, a four-year collaboration between academics and industry, funded by the European Commission, that was intended to create structural-battery prototypes. While Greenhalgh was working on his structural supercapacitor beam, one of his frequent research collaborators, a professor in lightweight composite materials at Chalmers University in Sweden, Leif Asp, was busy working on another important problem for structural batteries: boosting their energy density. Structural supercapacitors are useful for delivering small amounts of energy quickly, but they aren't sufficient for more energy-intensive applications. Asp's goal is to create a panel that can be integrated into the floor of an aircraft cabin that can deliver power to energy-hungry devices like avionics.

The panel that Asp and his colleagues in Sweden have recently created consists of six structural batteries connected in a series. Each cell is just two inches long by

one inch wide and about twice the thickness of a human hair. But when connected in a panel, these cells are capable of producing 17 volts, which is approaching the typical 28 volts required to power in-flight electronics like overhead lights, entertainment systems, and airplane avionics.

Asp's panel achieved an energy density of about 25 watt-hours per kilogram, only about 10 to 20 percent of the energy density in commercially available conventional lithium-ion batteries. Still, this is by far the most energy dense structural battery ever made. By the end of this year, Asp and his team hope to produce a structural-battery panel capable of achieving 75 watt-hours per kilogram. This puts it in shooting distance of lower-end conventional batteries such as lithium-iron phosphate cells, which have energy densities around 100 watt-hours per kilogram and are already used for short-range electric vehicles.

Asp and his team focused on floor panels because they don't face the extreme conditions that wings and other components outside the cabin experience during flight. This reduces the performance levels that the structural batteries have to achieve before they can be put to practical use, which will help advance the state of the art as researchers "learn by doing." The experience gained from working on more mundane applications for structural batteries could lead to their use in more critical applications, such as powering the avionics on the flight deck.

In the meantime, however, swapping out floor panels for structural batteries would substantially reduce the amount of wiring that is required to supply electricity to cabin electronics. A large passenger jet has hundreds of miles of wiring in the fuselage, which adds thousands of pounds of weight to the aircraft. A recent study by Greenhalgh and some colleagues found that replacing the floorboards in an Airbus A320 with structural batteries could reduce its weight by more than 570 pounds, which would lower the amount of carbon dioxide emitted per aircraft by more than 280 tons every year.

OUT OF THE LAB AND INTO THE SKY /

Researchers will need to show decision-makers in the largest aircraft manufacturers that structural batteries can meet the stringent safety standards of the airline industry. It helps that the components being considered—fuselage beams and floor panels—aren't subject to the same immense mechanical stresses of a wing and other critical flight surfaces. If a structural battery in the floor of the cabin fails, it isn't likely to result in catastrophe. This may make aircraft manufacturers and regulators more amenable to giving the technology serious consideration.

▼ The Next Class of Electric Aircraft



Eviation's Alice

/ The northern Mexico-based regional airline Aeris announced a deal this year to purchase 30 of Eviation's nine-passenger airplanes, which run on two electric-propulsion engines.



Pipistrel's Velis

Electro / The first electric aircraft to be Type-certified by the European Union Aviation Safety Agency (EASA), the Velis Electro can ferry two passengers using two electric-propulsion engines.



NASA's X-57

Maxwell / NASA's four-passenger electric plane—a modified Tecnam P2006T—is powered by seven propellers on each wing. It could hit the tarmac for a 20-minute test flight later this year.



And then there's production at scale. All of the structural-energy-storage demonstrators made to date—including Greenhalgh's beam and Asp's panel—have been made by hand in the laboratory, a painstaking process that is both technically challenging and impossible to scale. The next step is to show that they can be reliably made with automated processes without sacrificing performance.

Helmut Kühnelt, PhD, a senior research engineer at the Austrian Institute of Technology is working on it. As the project coordinator for SOLIFLY, a hybrid-electric-aviation research project sponsored by the European Commission under the CleanSky2 program, he and his colleagues are integrating structural batteries into carbon-fiber composites to produce an aviation-grade structural battery component using manufacturing techniques that are familiar to the aerospace industry. If their work is successful, it may prove to be the critical bridge that helps structural aircraft batteries make the leap out of the lab and into the real world.


Since January 2021, Kühnelt and his colleagues have been working on structural batteries that will be demonstrated with a floor panel that will be 30 inches long and 16 inches wide. They hope to make the full-size floor panel this year and subject it to a variety of tests designed to push the limits of its mechanical properties. This typically involves applying pressure to the structural-battery panel until it breaks, which is key to understanding its load-bearing capacity.

Researchers are exploring other creative solutions to electrical energy storage. For instance, the unique form factor of Eviation's commuter

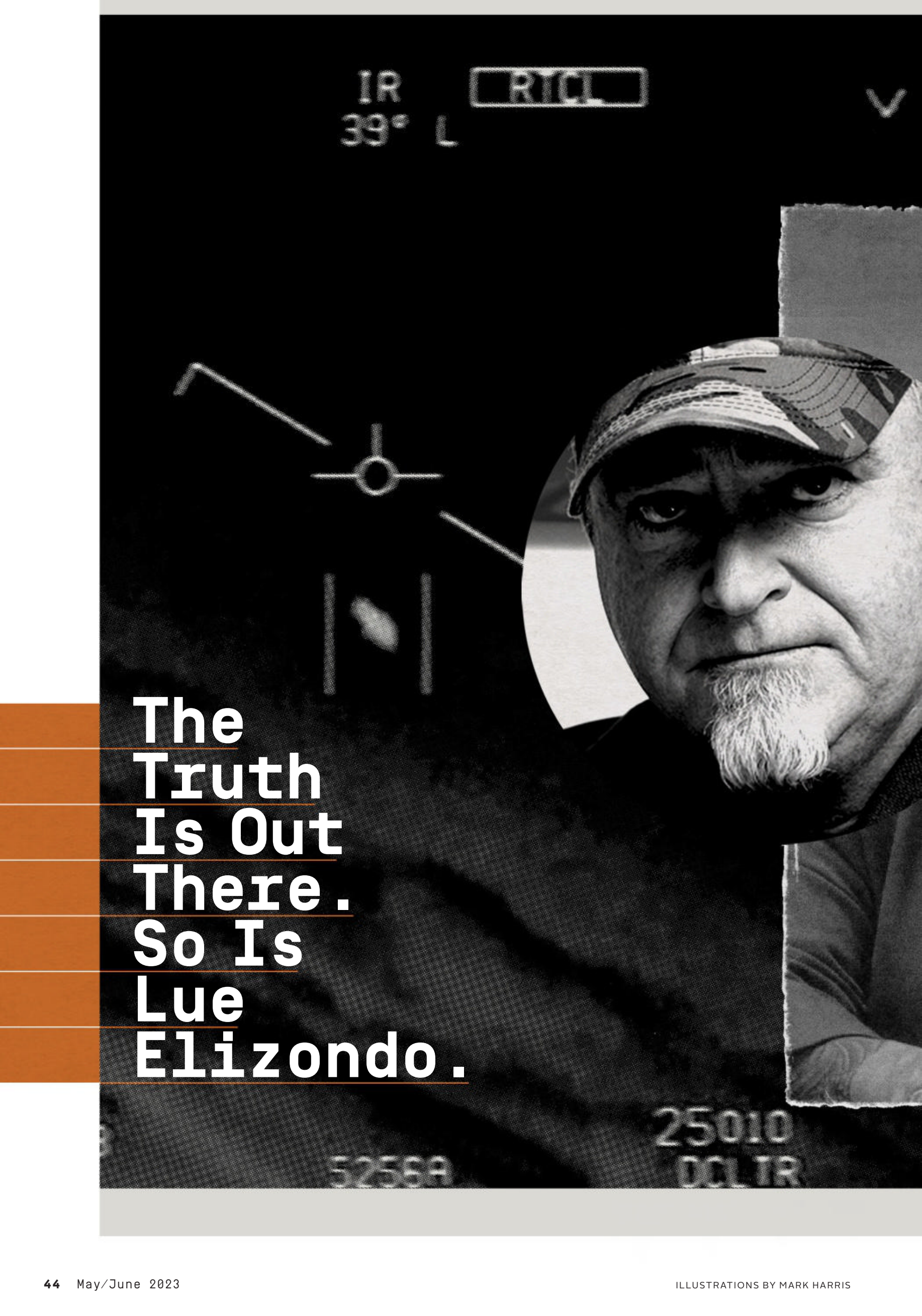
plane (see "The Next Class of Electric Aircraft"), Alice, is the result of the company designing the plane around the battery, rather than taking the approach of companies like Wright that attempt to retrofit existing plane designs with large battery packs. Gregory Davis, Eviation's CEO, says that the company has explored a middle ground to structural batteries where they use conventional battery packs to line Alice's floors and fuselage walls. While these battery packs aren't perfect structural batteries in the sense that the structure itself is capable of holding electrochemical energy, the batteries that are embedded in the structure do provide extra stiffness in a similar way to the approach Tesla is taking to embedding batteries in the chassis of its vehicles.

"In our applications it's not likely that a battery cell would become a structural element, but the surrounding structure can be used to hold all the cells together," says Davis. "You can find advantages in the way you both mount your batteries and use their structure to reduce the overall weight of the aircraft and make it as efficient as possible."

Ellen Ebner, director of Sustainability and Future Mobility at Boeing, says the company is "exploring structurally integrated battery technologies," but noted that structural batteries will "require significant technology maturation and evaluation prior to consideration for inclusion on passenger aircraft." Meanwhile, structural batteries are spurring interest from other industries, including the space sector, which sees it as a promising technology for satellite energy systems.

As more industries adopt this technology, it will give researchers an opportunity to continue to study structural energy storage in depth and gain the confidence and insight in this technology that they need for structural batteries to finally take flight. 

✦ Sang Nguyen, a researcher in Emile Greenhalgh's Imperial College London lab, tinkers with a structural battery.



**The
Truth
Is Out
There.
So Is
Lue
Elizondo.**

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Left: A still from UAP footage captured by a Navy pilot.
Center: Lue Elizondo.
Right: A flying saucer prototype schematic commissioned by the Air Force in the 1950s.

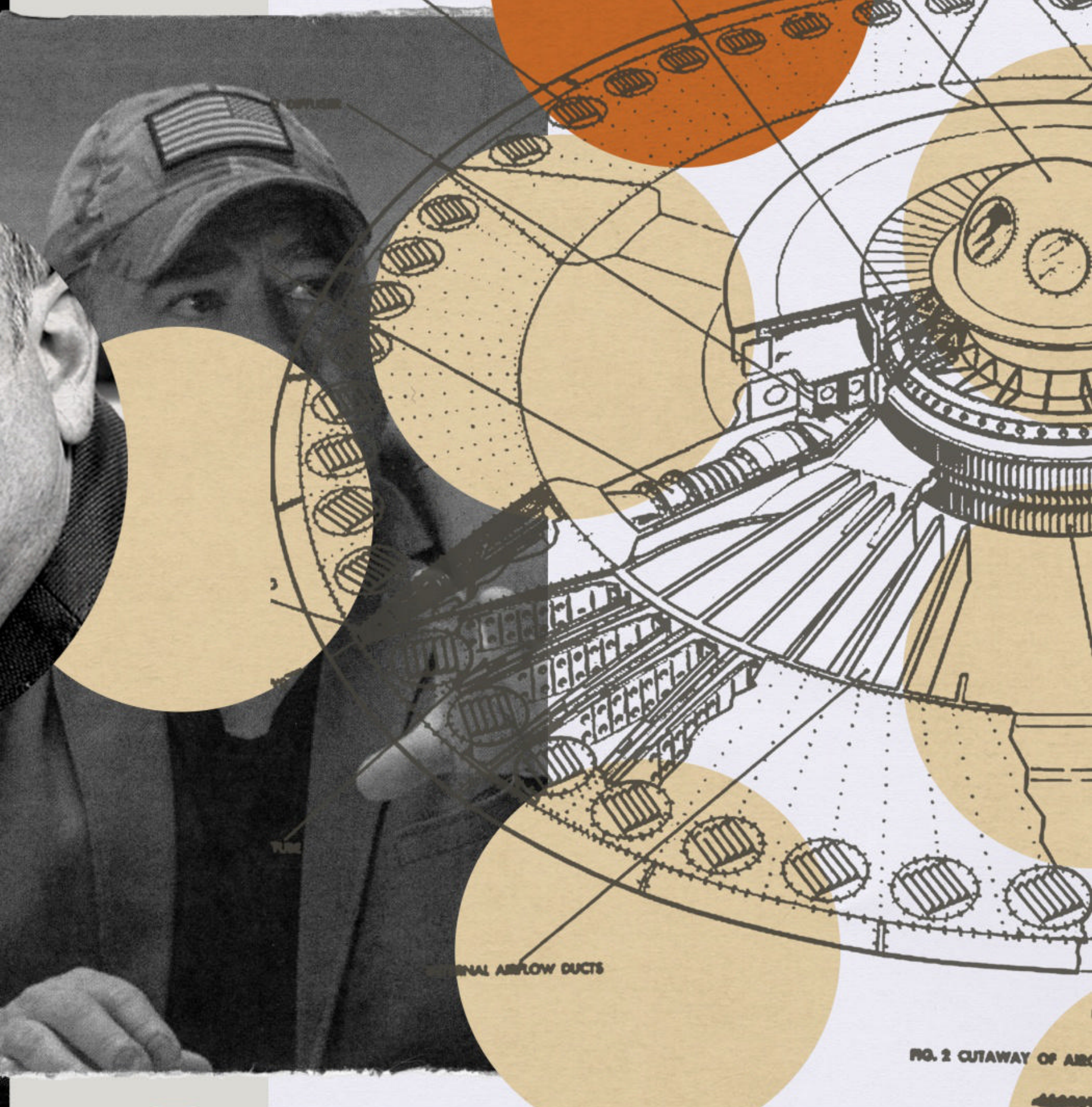
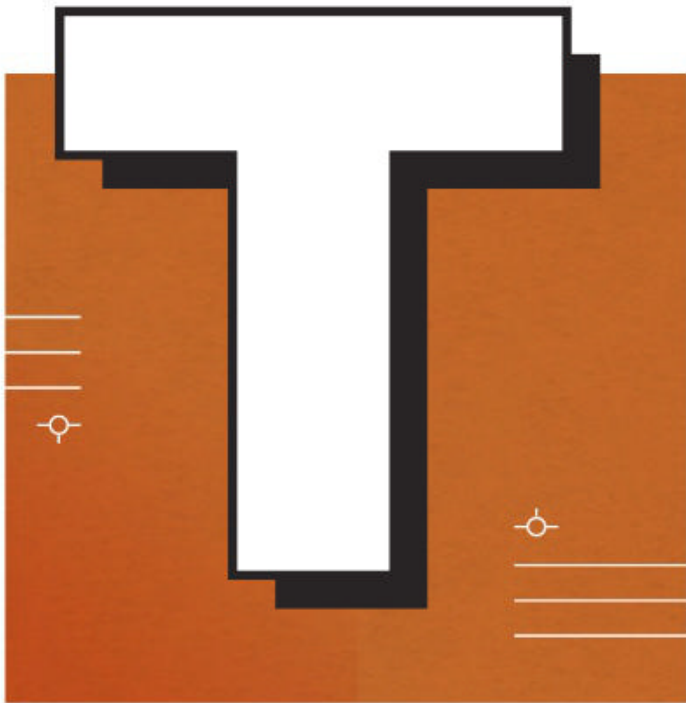


FIG. 2 CUTAWAY OF AIRCRAFT

Unidentified craft are entering restricted U.S. airspace. Elizondo wants to ensure they don't cause the next Pearl Harbor.

By David Howard



THE RV WAS PARKED INSIDE A MOUSE-INFESTED hangar at the edge of a horse pasture. It was a 38-footer—a plausible amount of space for Luis “Lue” Elizondo, his wife, Jen, and their two German shepherds, Hercules and Paris. But this was no KOA, with handy sewer and water lines.

The drinking water from the spigot made them both sick before they realized it was best left to the livestock. Every week or so, Elizondo humped out the 20-gallon black-water tank to dump into the sewage tank they’d put in the ground. There was no air conditioning, and flies were incessant. It was, in other words, not the kind of arrangement you’d expect for the star of a newly launched History Channel show.

Still, Elizondo figured it wasn’t so bad, trudging across the pasture, sidestepping horse patties. This was 2018, more than a decade after he’d served as a counterintelligence officer in Afghanistan under far more precarious conditions. Here in rural Southern California, the hazards were entirely of the mind. Elizondo had to embrace his decision to forgo his corner office at the Pentagon, with its steady and reliable paycheck; he had to avoid giving mental energy to vindictive employees within the Department of Defense who were furious about his departure and his new life in the public eye. In a nation both ravenous for and divided by conspiracy theories and pseudoscience, he had to block out threats and character attacks emanating from the nether regions of the internet. And he had to reassure Jen when she was perturbed with him, which was often, because more than two decades into their marriage she felt obligated to point out the ways in which their circumstances had taken challenging turns. Such as, most people don’t live 15 feet from their own waste.

Elizondo understood that this was on him. This was his self-appointed mission as a Pentagon whistleblower: to compel the U.S. government to own up to the public about what it knew—to share what he’d seen in his Pentagon days—about UFOs, which have been rebranded UAPs, or unidentified aerial phenomena.

He viewed this as a necessary sacrifice.

The irony was that to the outside world, it looked as if Elizondo had launched a glamorous new life, as if he had jettisoned an anonymous job deep in the folds of the military-industrial complex to launch his star turn in the infinite sunshine of California. He and his billy-goat soul patch were costarring on the TV series *Unidentified: Inside America’s UFO Investigation*. His name was on the front page of the *New York Times*. He was a talking head on cable news. He had triggered a bidding war for a UAP book that will highlight “profound implications for humanity,” according to his publisher, HarperCollins imprint William Morrow. He could be heard on a dozen different podcasts at once.

It seemed as if he had arrived—except that Elizondo had long operated in the shadows, and that was how he preferred it. He was doing all of this because it was the only way, as he saw it, to make people grasp that the government was hiding important truths about what was happening overhead. He was, in his mind, working to prevent another September 11 or Pearl Harbor-type calamity. He was doing it with the notion—far-fetched though it seemed in the moment—that someday Congress might revolutionize the government’s approach to UAPs, and a president might sign it into law.

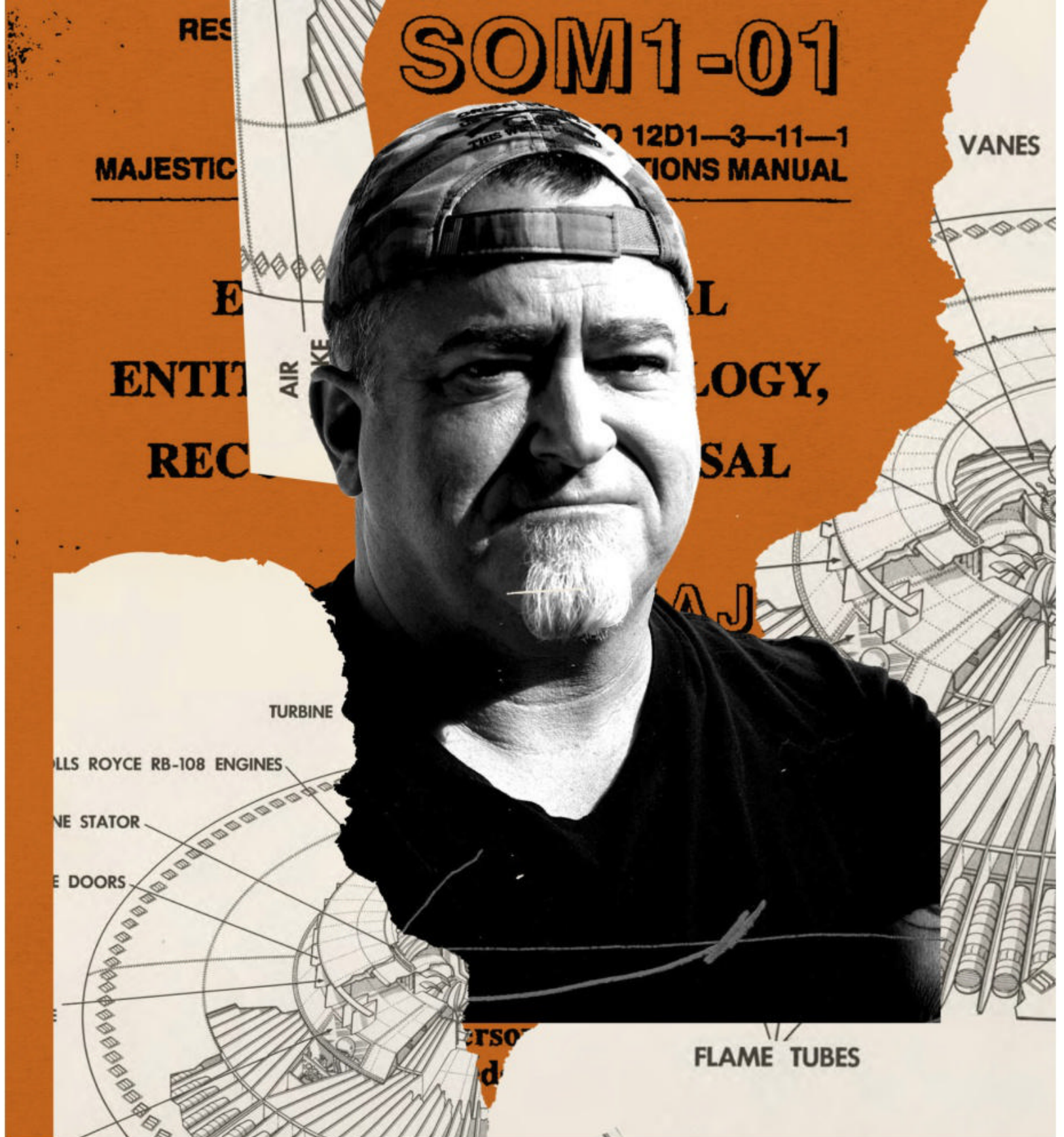
If there was ever a stray doubt, it stemmed from a buddy—a longtime colleague with whom he’d served in Afghanistan and on the UAP issue, and whom Elizondo respected explicitly—who had tried to talk him out of this. “My advice to Lue was, ‘Don’t do this,’ knowing how difficult it would be,” says the retired career intelligence official who requested anonymity to avoid poking the nest of murder hornets that is the UAP community. He estimated Elizondo would have a 5 percent shot at pulling it off—“and later I revised that down to a 1 percent chance of success, because I knew what he was up against.”

Elizondo himself now had a pretty good idea.



UFOS HAVE HOVERED at the fringes of America’s collective imagination for nearly eight decades. In the summer of 1947, a private pilot named Kenneth Arnold reported a formation of nine shiny objects flying past Mt. Rainier at two or three times the speed of sound. When this was widely published, it created a full-blown cultural phenomenon. The term “flying saucer” geysered from newspaper headlines into the public lexicon, and in the following six months, at least 850 similar observances were reported, according to one tally. About 50 percent of the nation believed in UFOs in the second half of the 20th century.

From the first reports, a scattering of scientists and military personnel sought to apply data and deeper



↑ Elizondo in a portrait taken for his History Channel show, *Unidentified: Inside America's UFO Investigation*.

research to the question, but the U.S. government waffled on how to respond. Members of a classified 1948 study, Project Sign, were divided on whether various reports indicated “interplanetary” phenomena or erroneous sightings—the celestial version of eye floaters. Thousands of sightings continued to pour in, and in 1952, Maj. Gen. John Samford, the Air Force director of intelligence, called a news conference to try to calm a rattled nation. Between 1,000 and 2,000 reports had been analyzed, he said, and in most cases, the military had determined they had nothing to do with aliens or spaceships. “However,” he allowed, a number of them “have been made by credible observers of relatively incredible things. It is this group of observations that we now are attempting to resolve.”

From 1947 to 1969, the Air Force secretly filed such reports to Project Blue Book, a program set up to investigate and debunk UFOs. But Blue Book, and similar government and military programs in subsequent decades, made no headway on the question, at least publicly. And the lack of answers, or even acknowledgment, fueled widespread fascination and frustration.

As one of the leading mainstream journalists investigating the phenomenon over the past 20-plus years, Leslie Kean shares this enduring vexation. She began reporting on the issue in 2000, and in 2010 published the bestseller *UFOs: Generals, Pilots, and Government Officials Go On the Record*, widely considered a seminal book on the subject. For years, she advocated for the creation of a federal agency to openly address the topic. “We

need government involvement here, because the civilian organizations are not equipped to deal with these phenomena,” she tells me. “And the government was just ignoring them—or making up stories about them.”

A key inflection point in the struggle for greater government transparency came in December 2017, when Kean and two other reporters published a piece in the *New York Times* about the existence of a secret Pentagon unit—the Advanced Aerospace Threat Identification Program (AATIP)—that had been working on the UAP issue under Lue Elizondo’s leadership. The sensational story came embedded with two videos recorded by military personnel, apparently showing aircraft flying without any visible means of propulsion and making maneuvers that seemed to defy physics. (A third video was later released.) Navy pilots expanded on these visuals with eyewitness accounts.

When the *Times* story on AATIP was published, Sean Cahill was riveted. In November 2004, he was a naval officer stationed aboard the USS *Princeton* off the coast of San Diego. He was standing watch on the bridge one night when the chief petty officer called to ask him to change navigation, letting slip that there was an anomaly they were looking into. Cahill made a joke about UFOs, but then, he says, “I just took the information, put my guys to work, steered the ship on certain courses, and ordered my lookouts to report anything they see.”

A couple of days later, Cahill, back on the bridge, received another call from the same officer. “He told me what he wanted me to do and where he wanted us to look, and he was really adamant about it. He was like, ‘Sean, I really need you to take this seriously.’”

He went outside and scanned the horizon with binoculars. Several thousand feet up “were five to seven lights—very bright white lights. No color, no blinking... And they were all moving in a circular pattern towards the center of this pattern,” he says. “Suddenly, one by one, when they reached the center of the circle, they disappeared.” It was as if they all passed through a funnel.

Cahill turned to a lookout nearby and said, “Did you fucking see that?” The lookout nodded.

The next day, in one of the most notorious incidents

in UAP history, two crews in Navy FA-18F Super Hornets from the nearby USS *Nimitz* carrier investigated an object that had been detected on the *Princeton*’s radar and dropped 80,000 feet in an instant.

One of the people flying that day was Alex Dietrich, a strike fighter pilot from the VFA-41 “Black Aces” stationed on the *Nimitz*. Dietrich, who retired in 2021 as a lieutenant commander, earned a Bronze Star and an Air Medal in combat and had 1,250 hours of flight time. In November 2004, she was flying one of the two jets that were rerouted by air traffic controllers from their scheduled flight plan. “We argued with them, because we were supposed to go to a different working area that we had pre-briefed, but they said, ‘No, this is a real-world contact we need you to check out,’” she recalls. En route, a colleague speculated that a drug runner was headed up the coast in a Cessna. “That’s when somebody in the flight looked down and saw this disturbance in the water.” They observed a long, white oblong craft moving randomly at the water’s surface. The crews saw no exhaust coming from any visible source of propulsion. When Dietrich’s flight partner descended to take a closer look, the object rose toward his plane then abruptly disappeared. Later that day in a separate encounter, another flight crew recorded video on the so-called “Tic Tac” incident.

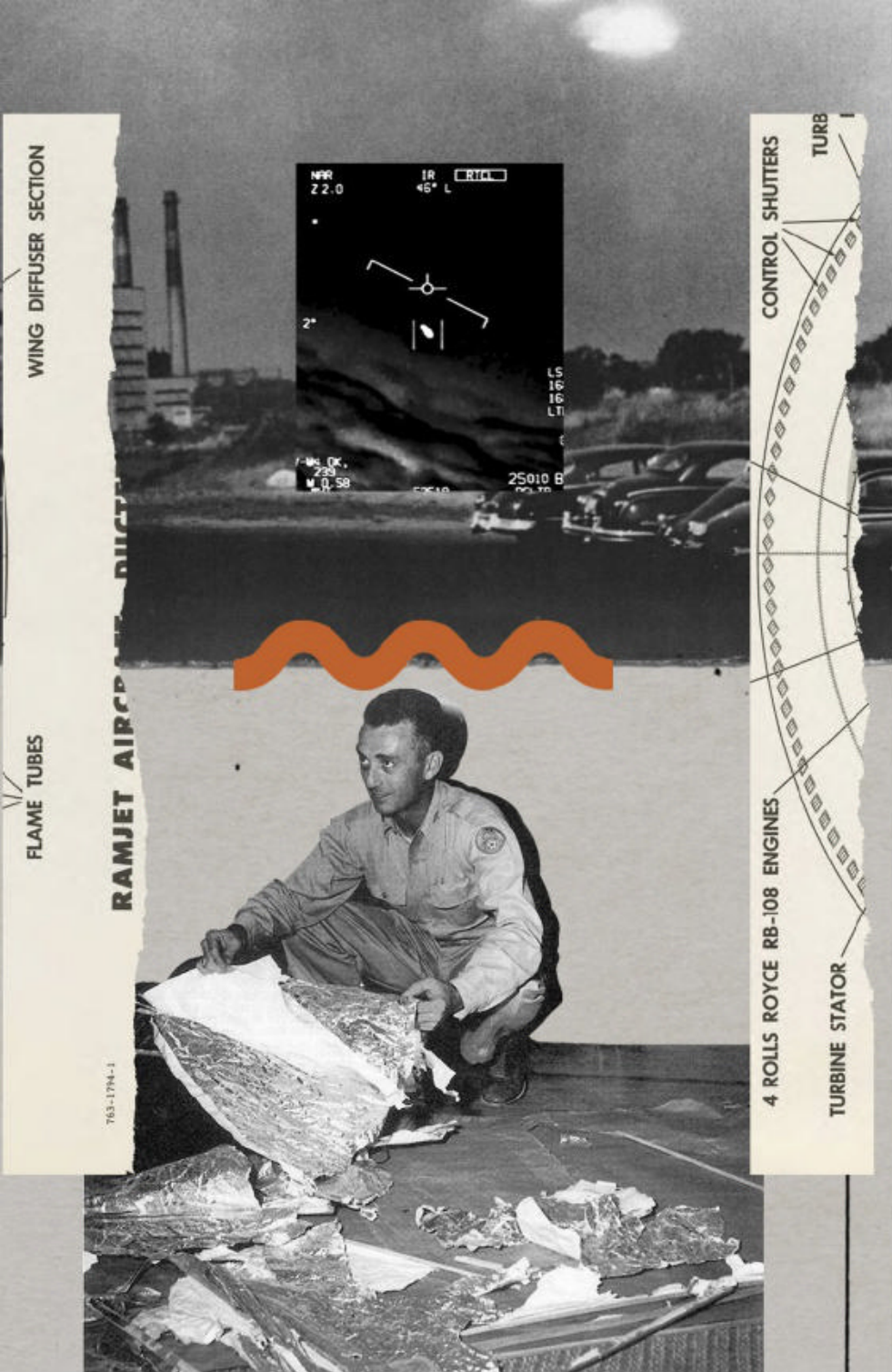
She wasn’t ordered to keep the event confidential, but she chose not to say anything publicly while on active duty. Four years passed after the incident before the Office of Naval Intelligence interviewed her about it. It wasn’t until 2021—when she had retired and the timing felt right—that she shared the story.



ON A RAW, drizzly night in Crystal City, Virginia, the exterior of the Kebob Palace is lit up like a neon fever dream, and the windows peer in on exuberant displays of Turkish art and vast quantities of tender meat on a stick. A thinly bearded man huddles cross-legged under a sliver of awning, spare-changing passersby. He looks vaguely alarmed when a man with an Abrams-tank physique suddenly looms over him.



FROM A NATIONAL SECURITY PERSPECTIVE, THIS WAS AN EXISTENTIAL THREAT.



↑ Top: A UAP, seen in 2015 footage taken by a Navy F/A-18 pilot. Bottom: An Army intelligence officer poses with debris from the Roswell site in 1947.

“Hey, brother,” Lue Elizondo says. “How about a meal?”

The man nods numbly, and Elizondo heads inside. It’s now February 2022, and more than four years have passed since he was a regular during his Pentagon days, but he knows the Kebob Palace will do a man right. He’s also aware that chicken biryani is not likely his new friend’s fix of choice. “But sometimes,” Elizondo says, “you have to give people what they need instead of what they want.”

He walks the extra plate back outside, then settles into a booth behind a hillock of rice, salad, bread, and seasoned chicken, seeming oblivious to the larger metaphor at hand. This question—of what people want versus what they need—has become a central mobilizing force of his life. Many Americans are happy to go about their lives, ignoring the possibility of UFOs. Elizondo says this is no longer a viable strategy.

While working for seven years on AATIP, he saw hard evidence that entities unknown to the Penta-

gon are using technology the United States cannot match or reproduce to have their way with the nation’s restricted airspace and sensitive nuclear sites. From a national security perspective, this was an existential threat. Yet the government has refused for decades to officially acknowledge it.

And so here he is. On TV, he’s a casting agent’s dream: an articulate, thoughtful, no-nonsense public speaker who happens to rock creative facial hair, a buzz cut, and a natty assortment of baseball caps and T-shirts. Pulling up photos on his phone from his time in Afghanistan, he jokes about his “sausage fingers,” leaving unmentioned his ferociously gnawed-off fingernails. One of the tattoos on his heavily inked oak-trunk arms reads *Acceptum painetio*—Latin for “accepted with regret.” It refers to his service during the war in Afghanistan. “There’s things that I’ve done in my life,” he says, by way of explanation, “that I wish I didn’t have to do.”

Elizondo approaches the emotionally charged UAP topic with a stubbornly phlegmatic disposition, addressing it in a way that’s forceful yet deliberate, calm, and measured. All of these traits seem to make him ideally suited to reach across America’s sociopolitical and geographical chasms. He’s flown to the nation’s capital from his home in Wyoming, where many of his neighbors are similarly desirous of personal space, or are a little paranoid, or both. He’s been up for 30 straight hours due to overlapping travel and work schedules, but over the next few days he’ll attend a series of meetings with individuals from the Department of Defense and Capitol Hill. Elizondo visits roughly once a month, disseminating data points, forging new alliances, and generally serving as a thread that weaves together the UAP narrative. His job, as he describes it, is to move between vastly disparate quadrants of government, informing the left hand that the right exists. “I’m just simply here,” he says, “to offer assistance in helping them understand the intricate nature of this topic.”

And the stakes, he says, are unmistakably high. “We know they”—unknown extraterrestrial beings—“are conducting some sort of ISR—intelligence, surveillance, and reconnaissance—on our military weapons systems and our nuclear technology, globally. That’s not up for debate, because we have declassified reporting to prove it.”

What remained to be seen was whether the government could be convinced to do something about it.



ELIZONDO WAS BORN into a family of Cuban activists. His father, Luis Sr., was 16 years old when he boarded the USS *Houston* to take part in the Bay of Pigs invasion. When the operation went sideways, he hid on a farm and swapped out his uniform for the

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farmer's clothes, but Castro's troops identified him by his boots. He was held for two years as a political prisoner in Cuba, more than a year of which he spent in the notorious Isle of Pines prison.

When he was released, he joined the rest of his family in exile in Miami. There he started a series of businesses, including a high-end restaurant in Sarasota. By the time Luis Jr. arrived, in 1972, the family lived comfortably but remained faithful to the cause. For the Elizondos, one of the era's geopolitical saddle burrs took on stark real-life dimensions—strangers showing up at their home, his father hosting late-night meetings with the house surrounded by armed guards. There were death threats, and Elizondo remembers security sometimes picking him up at school in dark sedans. “I didn't know it was politics; I just thought it was reality,” he says. “It was kind of weird growing up—most kids were playing G.I. Joe; we were kind of living it.”

His parents had a troubled marriage—intense passion interspersed with china-shattering blowouts. “It was a very difficult relationship,” Elizondo says. Their divorce, when Lue was 10, carried catastrophic financial consequences. He lived with his mother, who was suddenly destitute; the bank foreclosed on their home and she had to hock her possessions to keep them housed. Lue recalls selling some of his clothes at a local flea market. He left a private school to attend far larger public schools, where he faced bullying.

“That's when my life changed irrevocably,” he says. “I made a lot of dumb, dumb decisions as a kid...trying to get attention from anybody that would listen.”

His salvation was the ROTC. “I went in voluntarily, probably because I was pissed and probably because I was looking for a sense of purpose,” he says. “They were my parents and my mentors and my teachers when nobody else would be.”

He took out loans to attend the University of Miami, where he majored in microbiology and immunology as a pre-med, inspired by his grandfather, a well-known dentist in Havana. By then, he was a regular weightlifter and martial arts practitioner, and he worked as a bouncer, partly to take out his aggression on drunken miscreants.

After graduating in 1995, he returned home to Jen one day—they were living together at the time—and said, “I have something to tell you.” He had joined the Army.

“I realized I didn't want to look at test tubes for the rest of my life,” he says. “What I really wanted to do was serve—to get back to that feeling of being part of something bigger than yourself.”

After basic training, he eventually found his way into counterintelligence, with which he immediately connected. The work involves protecting the military from the opposition's intelligence-gathering apparatus, and it might involve harvesting information and conducting activities to prevent spying, sabotage, or other disruptive actions. “It's kind of like medicine,” he says. “You're trying to figure out cause and effect on what makes a country do something, using the scientific method and deductive reasoning.”

Elizondo was deployed to Afghanistan not long after the war started in 2001. His assignment was to coordinate counterintelligence teams across the southern part of the country. His former colleague, the now-retired intelligence officer, says that in Kandahar, Elizondo was also de facto senior intelligence officer and “right-hand guy” for General James Mattis. During Mattis's morning intelligence briefings, Elizondo often sat to his right. “Anytime there was anything questionable, Mattis would look at Lue for either confirmation or not,” the intelligence official says. (Mattis declined through a spokesman to comment, citing a “longstanding practice not to discuss questions related to intelligence matters or intelligence officers.”)

Elizondo “had a very direct and very broad knowledge of literally everything that was happening in the country, especially in southern Afghanistan,” the former intelligence official says. “Mattis trusted him implicitly, and Mattis is a brilliant guy. He's not one who would put a stock in anyone who was fly-by-night.”

When the intelligence official returned to the U.S., he began working in an advisory capacity on AATIP. Run by the Department of Defense's Defense Intelligence Agency, the program was created in 2007 at the behest of then Senate majority leader Harry Reid, who harbored

a deep fascination with UFOs. In a 2009 letter requesting designation as a special access program, or SAP, which confers a high level of secrecy, he wrote that AATIP's mission was to "assess far-term foreign advanced aerospace threats to the United States."

The intelligence officer recommended Elizondo for a role, and a Pentagon official asked him for his opinion on UFOs. Elizondo said he'd never given them a thought. "I never had the luxury to do that," he says. "I was too busy chasing bad guys."

That was apparently what they were hoping to hear. He says he was "voluntold" to join AATIP in 2008, and by 2010, he was in charge. "He was basically a perfect fit," the intelligence official says. "He had the CI background, but he also understood tech, especially how you protect and operate in support of what is colloquially referred to as black programs—classified technology programs."

Elizondo had seen plenty in Afghanistan and elsewhere. But what he learned in the first months in AATIP shocked him.



THE AFTERNOON AFTER the Kebob Palace meeting,

I walk into the Lebanese Taverna in Pentagon City to find Elizondo and two men sitting in a semicircle at the back of a near-empty dining room. Flanking Elizondo are his lawyer, Daniel Sheehan, and a Pentagon employee who asks to remain anonymous. Sheehan is a legendary attorney with a storied history of clashing with the government; a Watergate burglar and the Black Panthers were among his clients. He is a burly man with an unruly tumble of curly gray hair who has spoken in public about alien encounters. Elizondo says he thinks of Sheehan as his flak jacket.

The three men agree that it's a fraught time. The Pentagon employee looks grim-faced when the topic turns to internal tension over the UAP issue. Everyone orders lunch except for Elizondo, who only wants Turkish coffee, then grazes on the bread basket.

Today he's adopted an inner-Beltway look: blue dress shirt and suspenders, a navy suit jacket hanging on a nearby hook. His trademark baseball cap is gone, revealing a Brillo of dark hair. The conversation wends to the Pentagon's default binary response to any threat: either extend a hand or point a weapon. The table's consensus is that more options need to be available for potential intergalactic visitors.

↓ Left: A bogus UFO from a doctored photo. Center: A 1995 protest in Washington, D.C. Background: Area 51 and a UAP still from a Navy pilot's footage.



The Truth Is Out There. So Is Lue Elizondo.

With time to kill before the afternoon's Capitol Hill meetings, he drives us around Pentagon City to the unremarkable buildings where he worked. There's a walkway outside one of them, during his AATIP days, where he'd join a friend for a breather and they would shake their heads in disbelief at what they'd just seen, he says.

We next stop by the Pentagon's 9/11 memorial, which happens to be temporarily closed. Standing at the fence, Elizondo recounts the hijacked airplane's trajectory and collision with the building's west side. He gazes at the scene for a long time, and an air of wistfulness passes over him. But when we head to the Capitol and he takes a call from a high-ranking member of the military about UAPs, he brightens.

Elizondo's military indoctrination remains an inextricable element of his persona; his conversations are sprinkled with *IO-4s* and *rogers*. In rare windows of free time, he hunts deer—though he's quick to point out that he uses the whole animal for sustenance. ("I'm not a trophy hunter," he says. "I don't like the act of killing.") He restores old vehicles, especially military jeeps; one dates to the Korean War. "I have a bit of a workshop," he says, "for when I just want to get away and play some rock and roll music and smoke a cigar while turning wrenches."

Over near Capitol Hill, he ditches the car on a side street, 10 minutes away—a reminder of how much his life has changed since his corner-office days. His group heads into the Longworth Building for a session with Representative Tim Burchett, a Republican from Tennessee and lifelong devotee of the UAP issue. As a Christian, Burchett says, "I've always been curious about the unknown."

Burchett also has long harbored a "genuine distrust of government"—going back to his boyhood, listening to his father's stories about his World War II service in the Pacific and one mission in particular: "They told him it was going to be a mop-up kind of thing, and it was the bloodiest battle in the entire war," he says.

This history sharpens his suspicions around UAPs. He believes the government has covered up important information about the phenomenon from Roswell through the present—and the only way to gain transparency is if regular Americans demand it. So when he flipped on the History Channel one evening and caught *Unidentified*, he was riveted.

Over the course of several meetings, Burchett has come to think of Elizondo as a friend and "kindred spirit"; Burchett, in turn, has become an agitator within Congress. "Dad-gum it, [people] need to talk to their own representatives and just say, 'We need total disclosure—what we know about what this is. And stop with all the nonsense and release the videos—everything they've got.'"



ALMOST IMMEDIATELY AFTER he joined AATIP in 2008, Elizondo says, he learned that UFOs were not the imaginary conjurings of the tinfoil-hat crowd. "I realized within

a couple of meetings that there was something to this," he says, "that this was real, and there were things coming into our controlled airspace affecting our military pilots, and we had no understanding of what it was."

He and his team took a scientific, data-driven approach to the investigation, much like a counterintelligence officer would tackle it. "He didn't jump to conclusions," the intelligence official says. "He let the facts and evidence speak for themselves. And we came out of that with some very unexplained things and some inescapable conclusions—not the least of which is, we're vulnerable."

This focus on science extends to Elizondo's own UAP sighting. He doesn't share details "because it is important that my personal observations do not get in the way of valid data collection and analysis—keep the data clean. We need to remove any type of confirmation bias. And that even includes myself."

In 2016, Elizondo met Chris Mellon, who had been invited to an AATIP meeting by a mutual CIA acquaintance. Mellon had 20 years of experience in the intelligence field; he'd served as deputy assistant defense secretary for intelligence and advised members of Congress from both parties. The meeting's topic was reports of regular intrusions in restricted airspace by unidentified aircraft. "These had been going on for two years at that point," Mellon says, "and I was absolutely flabbergasted—horrified—to discover that nobody was doing anything about it, except for Lue."

As Elizondo and Mellon began sharing connections and intelligence, they became increasingly alarmed. Over the past 76 years, the military has documented UAPs encounters with alarming frequency around U.S. nuclear assets. In one notorious instance in 1967, a UFO seemed to shut down nuclear-armed missiles at the Malmstrom Air Force Base in Montana.

AATIP was also documenting encounters at sensitive military installations, and with carrier strike groups training for deployment, in some cases as they crossed the Atlantic. "We've had military exercises canceled because there were unidentified aircraft on the training range, and they were afraid of midair collisions," Mellon says. "These are aircraft that don't have transponders, and haven't filed flight plans, and nobody knows what they are." The numbers of these encounters spiked in 2014 and 2015, to the point that former Navy pilot Ryan Graves said in a 2021 interview with *60 Minutes* that sightings were a daily occurrence.

Just as shocking? No one at the Department of Defense (DoD) seemed interested. UAPs are a complex topic, and for all its elite war-making capabilities, the Pentagon is not an engine for processing nuance. The various branches and services are diffuse and siloed. Intelligence, no matter how useful, is generally hoarded.

In 2010 and 2011, Alex Dietrich served on the ground in Afghanistan as an engineer. She was struck by the degree to which the government operates on an information hamster wheel. "I kept being reminded that [the American military] hadn't been there for 10 years—we had been there for one year 10 times... With each personnel upcycle there's learning

the projects, there's figuring out the security situation, and there's actually trying to get something done. And then it's time to go home. Any program in the Pentagon has a similar turnover of leadership, and similar cycling."

So it was with UAPs—only at the Pentagon, it wasn't just bureaucratic churn; some people there didn't want the information. Because of the little-green-men stigma, some bureaucratic substrata insulated their bosses from any involvement—including General Mattis, who by then had become Secretary of Defense, Mellon says. And several stymied AATIP efforts because the possibility of extraterrestrial life runs counter to their religious beliefs.

For others, by countenancing UAPs, the intelligence official says, "they have to admit that there actually is a legitimate, validated national security threat that they can't do anything about." Pentagon officials "always want to control the narrative, and if they can't, their instinct is to kill it."

Complicating things further, Elizondo felt compelled to exclude his boss, Garry Reid, from briefings, because he had a reputation for playing favorites and treating people poorly, including a case involving one of Elizondo's reports. (In 2022, the DoD inspector general concluded an investigation determining that Reid, a now retired career military officer and career civil servant, had "created a widespread perception of an inappropriate relationship and favoritism" with a female subordinate.) Elizondo says his stance was: "I'm not going to tell you what I'm doing because I can't trust you'... And that pissed a lot of people off." (Reid did not respond when I reached out for comment.)

As political winds shifted, AATIP funding officially dried up in 2012, forcing Elizondo to bootstrap the program. "At that point," he says, "we had to get very clever." Because the program was never officially disbanded, he siphoned funds from other programs he was running.

"It was kind of his sheer force of will and personality that even kept it alive," the intelligence official says. The problem was, the nation's military leadership and elected officials didn't grasp the urgency of the matter—and neither Elizondo nor anyone else in AATIP could do anything about that. At least, not while they were cloistered inside the Pentagon.



RUNNING OUT OF options to keep AATIP afloat as autumn 2017 arrived, Elizondo grew increasingly frustrated. He and his team knew that once they disbanded, the UAP issue would likely blink out. Gathered in their SCIF—Secure Compartmentalized Information Facility, a room where classified activities take place—Elizondo and his colleagues spitballed strategies. Elizondo could have leveraged his old relationship with Mattis and just walked into the Secretary's office—but "he wasn't going to do an end run and do it the wrong way," the intelligence official says.

Mellon knew two direct reports to Mattis, and he too tried

to work the chain of command. His impression was that aides surrounding the Secretary were worried that someone might use the issue to try to discredit him. "It finally became clear that nobody was going to do anything serious about this," Mellon says.

Elizondo couldn't accept the idea of doing nothing. "I don't think that we should keep this conversation quiet," he says. "It hasn't worked for [76] years. Let's have a conversation."

As he saw it, his only remaining play was to "take it to the streets."

On October 4, 2017, Elizondo sent his resignation letter to Mattis. He cited "bureaucratic challenges and inflexible mindsets" that prevented Pentagon leadership from evaluating "unusual aerial systems interfering with military weapon platforms and displaying beyond next-generation capabilities."

He and Mellon had plotted his next steps by analyzing where they and others had failed before and how they might avoid similar mistakes. They pieced together a five-point approach: legislative outreach; executive branch-level engagement; international engagement; media appearances; and public engagement (which included *Unidentified* and social media). Mellon focused on matchmaking pilots and other military personnel who had UAP experiences with members of Congress. Elizondo met with members of the Trump and Biden administrations to open a channel to send UAP information directly to the White House without the bureaucracy of the DoD or intelligence community.

The day after leaving his job, Elizondo talked with Leslie Kean. She recalls being stunned when she read Elizondo's resignation letter. "It was historic that he was actually saying what he was saying to the Secretary of Defense," she says. "It was a really big moment."

Still, all of this shaped up as an extraordinarily difficult bank shot. Elizondo would try to accomplish what others had failed to do for nearly 80 years: convince the intractable and infinitely heterogenous United States government to finally, fully spill on the topic of UFOs.

His old ally in intelligence wished him well. "If anybody in the world can actually make this work, it's you," he told Elizondo. "But you've got to be prepared for what's gonna come."



JOSEPH OVERTON HAD an engineering degree, so when he took a job at the Mackinac Center for Public Policy, he decided to apply his science background to answer a central question of American life: How do politicians decide which issues to support? To answer it, he built a model, and learned that elected officials zero in on policies that are accepted by society as valid—policies that fall within what's now known as the Overton Window. Most officials avoid issues that lie outside that window, for fear that a fringe issue will be the career equivalent of stepping on the third rail.

What fits in the Overton Window fluctuates—not driven

The Truth Is Out There. So Is Lue Elizondo.

so much by prominent leaders or public figures, but by the complex and ever-shifting sands of community values and norms. Generally, policies come to be important based on societal consensus. For decades, the problem for those who cared about the UFO issue was that it fell outside the Overton Window. It was too out-there for people to take seriously.

That was now Lue Elizondo's challenge—and with his letter of resignation, it was also his burden. He soon realized no one was going to make it easy on him, either: The day after he submitted that letter, he received a call from his old boss, Garry Reid, who, as Elizondo later recounted in a formal complaint, “was clearly upset with me.”

Reid told Elizondo that if he continued on with what he was doing, he would “tell people you are crazy, and it might impact your security clearance,” according to Elizondo. In the month that followed, Elizondo received a number of calls from former colleagues warning him that Reid—furious for being excluded from AATIP briefings, among other reasons—was “coming after me” and insinuating that he was a fabricator.

In February 2018, Elizondo was told that his DoD computer had been confiscated in an attempt to determine whether he'd taken any unauthorized material when he left. That same month, he learned that the Air Force Office of Special Investigations had opened a probe into the release of the videos in the *Times* story, Elizondo says. The implication was that he had violated his security oath, but investigators found in 2019 that the videos were never classified. And in 2021, seemingly for good measure, he was again investigated and cleared.

Allies told Elizondo that Reid had even tried to revoke his access badge at the Pentagon, and security clearance. Though Elizondo was no longer working there, he was still meeting with DoD folks on the UAP issue. “I think they were literally watching his appearances, his social media, his press, his show, looking for any nugget they could use to go after him,” the intelligence official says. (Elizondo still retains his high-level security clearance.)

After the *Times* published its blockbuster, the story became global news. Many media outlets simply amplified the same report, but some were skeptical, questioning the existence of AATIP and Elizondo's role in it—germinating seeds of doubt planted by ongoing hostility from some within the Pentagon. In 2019, for example, *The Intercept* quoted a Pentagon spokesman who said that Elizondo “had no responsibilities with regard to the AATIP program.” In 2020, a second spokesperson echoed these claims.

Some issues resolved quickly; Senator Harry Reid wrote an open letter affirming “as a matter of record Lue Elizondo's involvement and leadership role in this program.” (The Senator died in 2021.) Elizondo tried to move on with his life. He relocated to California to be the head of security for To the Stars Academy of Arts & Science, the entertainment and research company created by Tom DeLonge, the former Blink-182 frontman and paranormal enthusiast. His presence there led to the starring role on *Unidentified*.

But by 2021, Elizondo was no longer playing defense. He retained attorney Daniel Sheehan and that year filed a 64-page complaint with the DoD Office of the Inspector General (OIG) alleging “malicious activities, coordinated disinformation, professional misconduct, whistleblower reprisal and explicit threats perpetrated by certain senior-level Pentagon officials.” A day later, the OIG announced an investigation “to determine the extent to which the DoD has taken actions” on UAPs. (Pentagon spokesperson Susan Gough referred questions about Elizondo's allegations to the inspector general's office. And Megan Reed of the OIG's office said that as a matter of practice, the Inspector General “doesn't provide status updates on Administrative Investigations.”)

Elizondo says that when challenged by people in the Pentagon, his mindset was: “I will go to the hilt. On speed dial right now, I can be in front of 40 million people in 10 minutes if I want to, and tell the people what I know. I don't, because I'm trying to let the system work... I don't want to break it; I want to fix it”—that is, cajole the government into holding itself accountable.

Meanwhile, he increasingly finds himself alternately embraced or vilified by various UFO subcultures—the conspiracists, the debunkers, the religious adherents, the profiteers, among others. Mick West runs an online forum called *Metabunk*, which is dedicated to unwinding conspiracies; over time, it has become focused on offering alternative explanations for purported UAP sightings. The soft-spoken Brit says that Elizondo is “a difficult person to read,” but he “thinks that aliens are real” and is trying to raise alarms about them. “That's my charitable assessment of what he's doing,” West says.

The uncharitable version? “He's making stuff up for some nefarious reasons—like either he's running a covert operation for the government, to cover up some kind of black operation, or it's something else... but I always tend to go with the more charitable interpretation.”

Other critics feel aggrieved that Elizondo has elevated the issue—at the expense of government resources—without tangible, public proof that aircraft are capable of doing what various witnesses have described. Elizondo understands that frustration, to a point.

“Unfortunately this involves classified information,” he says, “but there absolutely is precedent for how these things move and it's not just stories or eyewitnesses. There's historical radar data, and some of those things are moving at 13,000 miles an hour in the 1950s. We have more than 70 years of data.”

On the three groundbreaking UAP videos, West argues that the “glowing aura” in one clip is “an artifact of the infrared camera.” In the other two, the pilots were working with recently upgraded radar and other systems. “So the most likely explanation, without knowing anything else,” he says, “is that they were not picking up mylar balloons before, with their old radar.”

West concedes that it's a national security issue if military pilots encounter things that they can't make sense of and are

forced to abort missions. And Sean Cahill, the officer on the *Princeton*, says that West and his fellow skeptics might not realize that analytics crews on those ships immediately considered the same possibilities. After the 2004 sightings, he says, “They discussed everything the debunkers and everybody else thinks they haven’t figured out. These were highly educated tacticians. They talked about everything from temperature inversions to seagulls to these software glitches.” Nothing provided a plausible explanation. And none of the critics have access to classified Pentagon information that undoubtedly adds layers of detail and data.

By contrast, other factions of the UAP community are angry that Elizondo hasn’t released more data and videos—regardless of whether doing so violates his security clearance. For some devout ufologists, this perceived reticence has turned him into the skunk at the garden party. One Reddit thread titled “As time goes on, the more skeptical I get about Luis Elizondo” drew 697 comments such as “If Luis Elizondo stayed in his lane, I think he would feel way more trustworthy. But his appetite for speculating things that are unknowable is too big.” In another, a commenter described thinking that Elizondo was “the light leading us out of the darkness, now I’m convinced he’s a CIA plant.” Others assert that he is simply trying to cash in. Elizondo says the opposite is true: Leaving his job has created enormous financial stress for his family.

Elizondo concedes that the attacks have hurt. “It has been so tough on my family,” he says. (The Elizondos have two daughters; one is nearly finished with a bachelor’s degree and the other is in graduate school.) “It’s terrible. It’s been so bad, this whole journey... My wife is always asking me, ‘Why are you doing this? These people who don’t give a shit, who don’t appreciate your sacrifice?’ And I try to tell her all the time, ‘Look, I’m doing it for our kids. I’m doing it because it’s the right thing to do.’”

Especially after the attacks on Paul Pelosi and Salman Rushdie, he’s wary. “I’m way more worried about [UAP-related death threats] than I ever was about Al Qaeda or ISIS,” he says. Since 2021, he has stockpiled a small personal armory at home, and acquired two more German shepherds.



DESPITE THESE CHALLENGES, something remarkable has happened: The UAP issue has gradually moved inside the Overton Window. In May 2022, a House Intelligence subcommittee held its first public hearing on UFOs since the 1960s. Rep. Tim Burchett is not a committee member, because he won’t keep the government’s secrets on the topic, he says. He attended nonetheless, but left frustrated after being denied the chance to ask a question.

But what may not have been apparent in the moment was the extent to which the hearing amplified the conversation, lending the issue its own gravitational reality. Since then, senators who have taken up the UAP mantle include a presidential candidate from each party: Democrat Kirsten Gillibrand and Republican Marco Rubio. (Both declined to comment, through spokespeople.) Prominent past and present public figures in government have acknowledged the issue, including NASA administrator Bill Nelson; director of national intelligence Avril Haines and her predecessor, John Ratcliffe; former CIA director James Woolsey; even former Presidents Obama and Clinton.

“Reporters are finally coming out saying, ‘Hey, that guy just said that—we need to report it, whether we think it’s kooky or not,’” Elizondo says.

The military’s long-term UAP freeze-out is also showing signs of thawing. In April 2019, the Navy revised its official guidelines for pilots and other personnel, encouraging them to report UAPs without fear of internal blowback.

Beginning in 2020, AATIP was reconstituted several times, under different names, and Elizondo served as an advisor and aide-de-camp with each, helping advance their work. In July 2022, the Pentagon announced its latest iteration: the All-Domain Anomaly Resolution Office. Significantly, AARO’s mission is to synchronize efforts across the DoD and with other departments, which in theory will end the siloing of information. And in October, NASA announced the creation of an independent study team focused on UAPs, comprised of scholars, scientists, a former astronaut, and a Federal Aviation Administration official, among others.



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The Truth Is Out There. So Is Lue Elizondo.

Elizondo's efforts with the executive branch helped lead the Biden administration to create an interagency team to study the broader policy implications for the detection and analysis of UAPs—an initiative announced on February 13, days after the U.S. shot down several aerial objects over its airspace.

Amidst much of this, Elizondo pulled back from public view, extracting himself from social-media squabbles. He departed *To the Stars* in 2019 and wrapped *Unidentified* after two seasons, then left California for the wilds of Wyoming. Elizondo and his book editor are finalizing his manuscript, which he says will be “a very eye-opening read.” He is considering a future run for Congress. He believes the nation is ready for full disclosure on the UAP situation.

Elizondo's crowning achievement to date came on December 23, 2022. That day President Biden signed the National Defense Authorization Act, which includes numerous far-reaching UAP provisions. One requires the government to own up to whether it's been concealing physical evidence of alien spacecraft. “That was stunning,” Mellon says. “There was bipartisan support, and the reason is because they received credible sourcing and credible testimony indicating that that may, in fact, be the case.”

The law also requires the Pentagon to create a secure mechanism for government and defense employees to report UAP sightings. AARO will now provide regular reports, analyses, and briefings on UAP activity to Congress, and the Office of the Director of National Intelligence must provide an unclassified version. It must also develop an in-depth “science plan” to explain UAPs that “exceed the known state of the art in science and technology,” and deploy field investigations of incidents. Intelligence services from each military branch must send a liaison officer to AARO, and the agency head will report directly to top DoD and intelligence brass to avoid bureaucratic obfuscation.

There's more: For the first time, the U.S. will use the intelligence community's multibillion-dollar technical apparatuses, which include spy satellites, weather balloons, and the most powerful radars in the world, to track UAP activity in real time. “There's nothing that compares to the assets the U.S. intelligence community has. That power is now being harnessed to help answer [UAP] questions,” says Mellon.

And whistleblower protection—informed by Elizondo's experiences—will help ensure that no one fears retribution for calling out any failures to implement these new policies.

Meanwhile, the former intelligence official says that an army of more than 1,500 volunteers within the intelligence community now meets on classified networks where they analyze UAP videos and data. This group includes “literally everyone—CIA to the [National Geospatial-Intelligence Agency] and everyone in between.”

The legislation figures to end the Pentagon's gnomish, decades-long silence. Leslie Kean, the longtime UAP jour-

nalist, sees a “radical change,” all of it stemming from Elizondo's decision to go public. “Everything that's happened since then really stemmed from his resignation,” she says. “It's like a snowballing effect... It gave permission, in a sense, for Congress to do this without having to worry about the stigma anymore.”



THROUGH ALL OF this, sightings and reports continue to flow in. “They're happening all the time,” Elizondo says. This January, the Office of the Director of National Intelligence reported that 366 new UAP incidents had been reported to U.S. intelligence agencies since March 2021.

The numbers are such that Sean Cahill, for one, is frightened that humans are “about to get steamrolled by something.” But, he says, “I have really high hopes because we're having the discussion in the public eye.”

Maybe the amplified UAP conversation will prove to be pivotal for humanity, or maybe Mick West will be right, and all of the phenomena will finally be explained away. Maybe the military and NASA will uncover what Leslie Kean calls the ultimate goal: providing “some level of proof...that establishes the reality of this being a nonhuman, non-man-made technology or phenomenon.” Either way, Elizondo and his allies made it safe for the public to have a conversation about it, and for the government to have a conversation with itself. The window is now open.

Elizondo is not yet ready for a victory lap. His life is still frayed and diffuse. For income, he's now employed by a Washington-based software company that does work with the federal government. There is still information to be disseminated, research to be done, science to be conducted. And of course, there is still the question of what is up there, in the skies, causing so much tumult down below. “I'd love to say ‘mission complete,’” he says, “but we're not there yet. There's still more work to be done.”

And yet. The day Biden signed the historic defense bill, Elizondo walked out onto his front porch and allowed himself a quiet 10 minutes. His mind drifted back across the past five years: the meetings, the phone calls, the character attacks, the tweets, the travel, the arguments with both allies and detractors, the TV shoots and re-shoots, the requests to take his picture at random restaurants, the hefting of black-water tanks, the efforts to soothe his wife's frustration with the unforeseen radical detour that their lives had taken—all that went into the single-handed and collective pushing of the boulder up the hill, over and over, every day, until finally, finally, it stopped rolling back down.

As he stood there, all of those years of work, and all that might still happen, felt at least for a short time as far off as the Wyoming horizon. He inhaled the mountain air and gazed into the immense sky. The calendar had just flipped past the winter solstice, and the days were crisp and abrupt. In a blink, the sky would be full of stars.

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We did it—here's how you can, too.



by BRADLEY FORD



PIZZA OVENS HAVE surged in popularity in recent years. We learned why when we started testing them—a good pizza oven can cook a fantastic artisan pizza in less than two minutes. Plus you can make your pie any way you like, which is especially convenient if your family can't agree on toppings. In 10 minutes, you can crank out three 12- to 14-inch pies, and everybody is happy.

During one round of testing, we mused: How difficult would it be to make your own portable pizza oven? There's no shortage of plans for brick pizza ovens, but not many for smaller, portable ovens you can use anywhere. So we launched this DIY pizza oven project. The body is made from brushed stainless steel, found at our local salvage yard, and the pizza stone came from

Amazon. Making the burner was the challenging part, and it took a couple attempts to get it working well enough to bring the pizza stone up to temperature.

We've listed materials and tools for it below. It helps to have a couple specialized tools, like a metal-bending brake and a band saw, but they aren't necessary. I've used a vise and metal bar stock to clamp and bend sheet metal for years—having the brake for this job was a luxury. And while a band saw or sheet-metal shear makes cutting easier, there are plenty of other options for cutting sheet metal. Cutoff wheels on angle grinders and circular saw blades designed for metal are just two possibilities. One word of caution: Some cutting tools might heat up and discolor the stainless steel's finish.

→ FIND MORE DETAILED PROJECT PHOTOS AND DOWNLOAD THE PLANS AT [POPULARMECHANICS.COM/DIY-PIZZA-OVEN](https://www.popularmechanics.com/diy-pizza-oven).

TOOLS AND MATERIALS

- 14" x 16" pizza stone
- 3/8" FIP gas ball valve
- 3/8" brass close nipple
- 3/8" x 6" brass pipe nipple
- 3/8" x 4" brass pipe nipple
- 3/8" brass pipe cap
- 3/8" flare x 3/8" FPT coupling
- Yellow PTFE gas line sealant tape
- Propane jet nozzles, set of 4
- 4' 0–20 PSI adjustable propane regulator
- Stainless-steel pop rivets, 1/8" x 3/8" (x 150)
- Universal grill igniter
- Extra-long igniter electrode
- 1" ceramic blanket insulation
- 2' x 4' 22-gauge, brushed stainless-steel sheet metal (x 2)
- 2' x 3' 20-gauge, brushed stainless-steel sheet metal
- 36" metal-bending brake
- Band saw with metal-cutting blade or circular saw with metal-cutting blade
- Metal-cutting shears
- Pop rivet gun
- Belt grinder
- Metal files
- Sheet-metal finishing hammer
- Bench vise
- Pipe wrench
- Assorted wrenches
- C-clamps
- Step drill bits
- Drill bit index, including 1/8", 5/64", and 1/16" bits
- Drill
- Soldering iron
- Utility knife



GET STARTED

BUILD THE PIZZA OVEN FLOOR AND INTERIOR WALLS

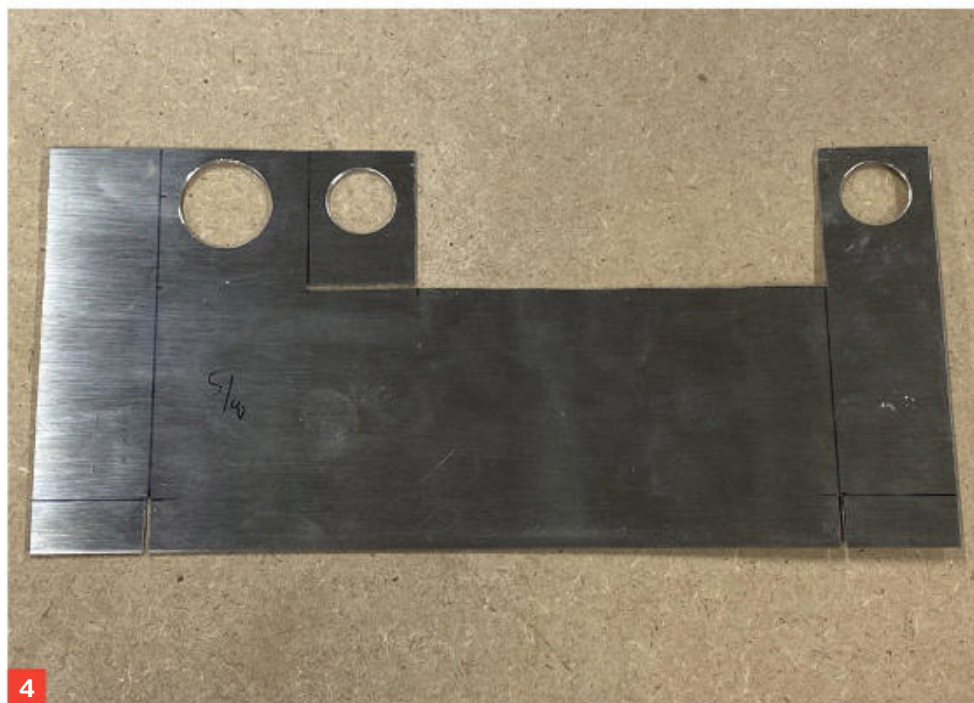
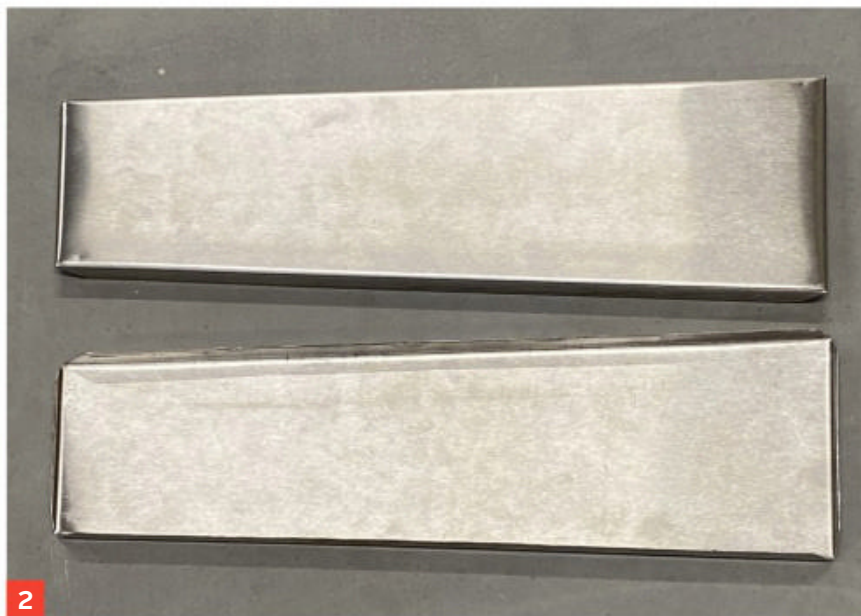
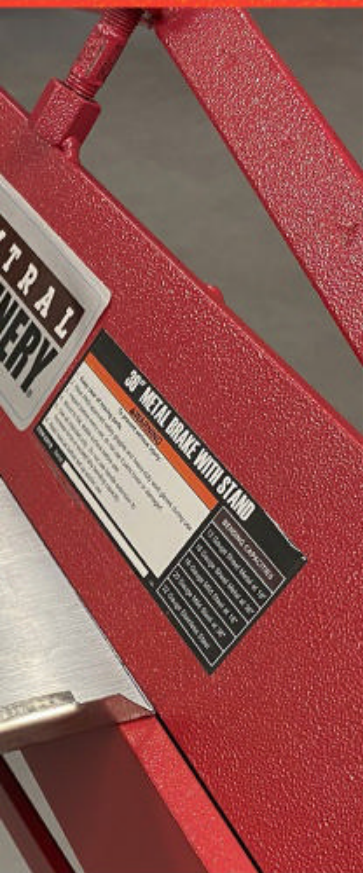
Using the dimensions found in the plans online, lay out the oven base, or floor, on 20-gauge sheet metal. A fine-tip Sharpie works well for this—it will clean off easily with denatured alcohol when you're finished. Cut out the base and clean up the edges with a file to remove any burrs.

Using a metal brake, bend the front and back edges of the base along the fold lines on the template. Start with the fold closest to the edge first, with the short flap sticking out the front of the brake. Then slip the sheet metal toward you, to the second fold line, and bend that up to create a hook.

Next, fold the side edges [1]. It will be difficult to bend the sides to a full 90 degrees using the brake, so you'll need to finish bending the sides by hand.

Stand the base on its side edge, on a workbench, and carefully tap it down with a sheet-metal finishing hammer. Keep your blows flat to keep the edge straight. Repeat on the other side.

Lay the pizza stone on the base with the shorter, 14-inch side flush with the front edge. Measure 1 inch in from the edge on the other three sides. Once the stone is centered, trace around it



on the three sides.

Lay out the interior side panels on your 22-gauge sheet metal. Note the fold line. The flaps along the edges of the right and left panels will be bent in the opposite directions.

Use the brake to fold the long edges first; the short-end flaps will be easier to bend with the finishing hammer. The left and right sides should look like this [2] when done.

Next, lay out, cut, and bend the two rear interior panels that go on the right and left.

Now, place the pizza stone on the

base and clamp the rear panels to the side panels, as shown in image [3].

BUILD THE BURNER BRACKET

Lay out the burner bracket on a piece of 20-gauge sheet metal. Mark the centers for the holes you need to drill, as indicated on the plans. Cut out the bracket and clean up any sharp edges.

Your bracket should look like image [4] once it is cut and drilled. We used a step drill bit because it cuts clean, large-diameter holes in sheet metal quickly.

Fold the end flaps on the bracket using the brake. The one flap on

the inside is easier to bend on a vise between two pieces of bar stock.

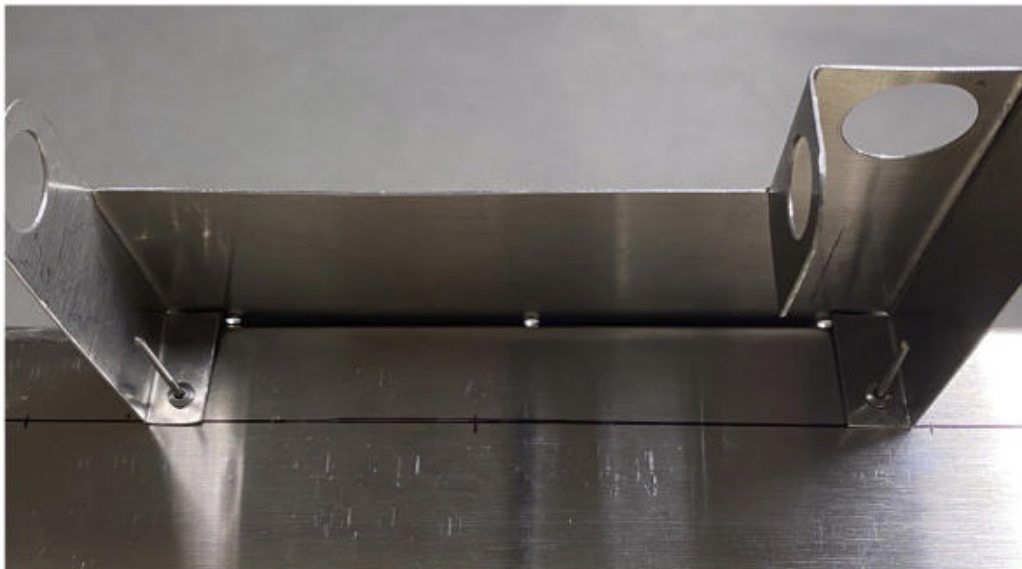
We also used the vice and bar stock to bend the tabs in on the bottom.

When you're finished, the bracket should look like it does in photo [5].

Test-fit the burner bracket on the oven. It should sit about ¼ inch from the left rear panel. Mark its right and left edges with a Sharpie.

Using a ⅛-inch drill bit, pre-drill three holes ¼ inch from the bottom edge of the bracket.

Then drill two ⅛-inch holes in the bottom tabs. Line up the bracket on



6



8



7

the base with the marks you made earlier. Using the holes on the tabs, mark the base and drill the two holes. Then slip two $\frac{1}{8}$ -inch pop rivets in the holes temporarily to keep the bracket from moving [6].

Now, using the three holes at the bottom edge of the bracket as a guide, drill through the oven base, then remove the pop rivets and bracket.

ASSEMBLE THE BURNER

Before you can put everything together, you'll need to prepare the propane jets, or nozzles. First, drill out the tiny orifice in the nozzles using a $\frac{5}{64}$ -inch drill

bit. Next, drill and tap the 6-inch brass pipe nipple so that you can install the nozzles. Drill four $\frac{17}{64}$ -inch holes, $1\frac{1}{8}$ inches apart, then thread the holes with a $\frac{5}{16}$ -24 tap.

Gather the burner bracket, four propane nozzles, 6-inch pipe nipple, brass pipe cap, 90-degree elbow, and 4-inch pipe nipple [7]. (Note: The photo shows a $2\frac{1}{2}$ -inch pipe nipple, but we changed it to a 4-inch after testing.)

Thread the 6-inch nipple through the bracket, left to right, and into the 90-degree elbow. Use an open-end wrench on the fitting and a pipe wrench on the nipple and be sure to get them

tight. The holes in the nipple should end up oriented 180 degrees from the elbow.

Install the pipe cap on the end of the 6-inch nipple. Make sure it is sufficiently tight.

Install the propane nozzles in the 6-inch nipple. Tighten them until they just bottom out on the threads.

Wrap PTFE tape on the 4-inch nipple and tighten it into the elbow, through the hole in the back of the bracket. Tighten the gas ball valve on the end of the 4-inch nipple. Wrap the close nipple with PTFE tape and use it to connect the ball valve and the flare coupling.

When assembled, the nozzles should angle up slightly and the elbow should angle down slightly.

Now drill an $\frac{11}{16}$ -inch hole below either of the center propane nozzles. Make sure the hole lines up directly below the nozzle.

We used an igniter with an extra-long electrode to be sure it would reach the propane nozzle. (We used two, but you only need one.) Install it in either position shown above.

Hold the electrode with a pair of pliers and bend it up by hand in front of the nozzle, about $\frac{1}{4}$ inch away [8].

Clamp the white igniter wire to the burner, cut and strip the ends of the

black wires from the igniter and electrode, twist together, and test. If you don't see a bright blue spark, adjust the position of the electrode relative to the nozzle until you get a reliable spark.

Once the igniter is working, use a sheet metal screw to secure the white wire to the burner bracket. Then solder the black wires from the igniter and electrode and wrap them with electrical tape.

ASSEMBLE THE OVEN FLOOR AND INTERIOR WALLS

Drill and rivet the right and left interior side and rear panels together. Be sure they're oriented perpendicular to the oven base.

Turn the panels over and pre-drill through the bottom flanges about every 2 to 2½ inches

Place the oven interior panels back on the base with the pizza stone in place and mark the holes at each end (i.e., the first and last holes).

Remove the panels, drill the two holes, then use two rivets to pin the panel in place while you mark the rest of the holes.

Once all the holes are drilled, put rivets through every hole, then use a pop rivet gun to fasten them one after another. Repeat the process for the other side.

Lay out the top interior panel on a piece of 22-gauge sheet metal. Cut out the top, clean up the edges, and use the brake to bend front and rear tabs up along the fold lines from the template. Test-fit as pictured [9].

The tab on the front will be bent slightly less than 90 degrees; the one at the rear will be bent slightly more.

Clamp the top to the side and rear interior panels. Mark along the side and rear for drilling every 2 to 2½ inches. Then drill each hole, dropping a rivet in them as you go. Doing this will keep the pieces pinned together and lined up. Once all the holes are drilled, use the pop rivet gun to set all the rivets.

Lay out the two pieces that will cover the sides of the burner opening at the back. Cut them out and bend along the fold lines using the brake.

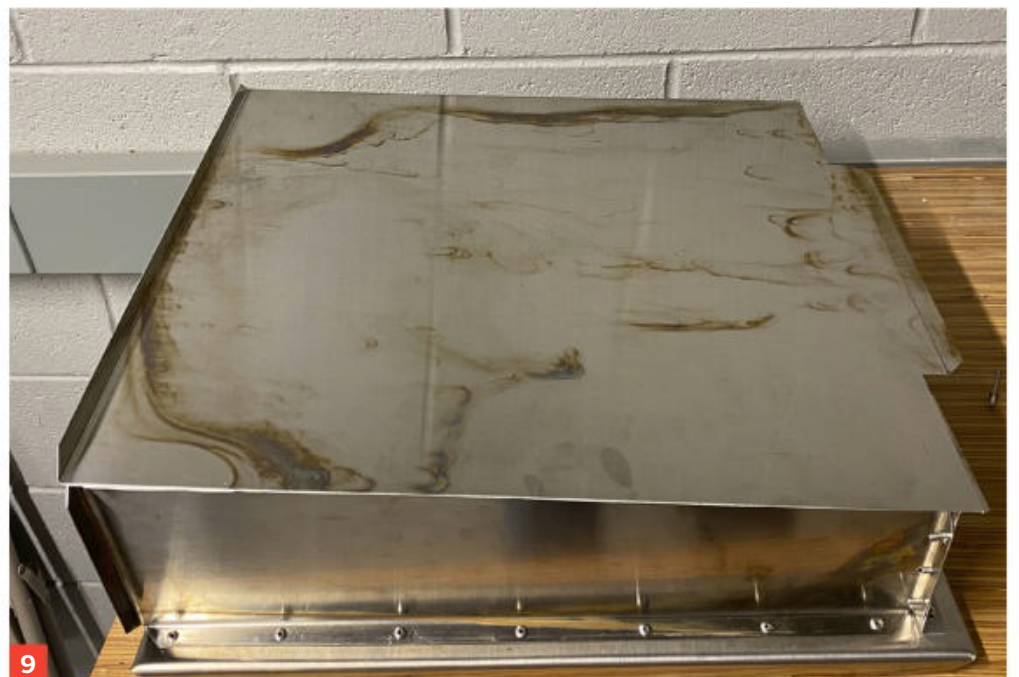
Drill two holes in each of the tabs on the interior rear panels, then clamp the side covers in place and mark the holes from the tabs. Remove, drill where marked, and rivet the covers in place. The oven interior should look like the picture below [10].

ADD INSULATION AND INSTALL EXTERIOR OVEN PANELS

Before you put the outer panels on

the pizza oven, you'll need to add the ceramic insulation. Laid flat on a piece of plywood, it's fairly easy to cut with a utility knife. Use gloves when handling the insulation, because it can be itchy if you get any dust or fibers on your skin. Rather than trying to measure precisely, you can press the side of the pizza oven against the insulation. It will leave a clear imprint you can use to guide your cuts. Trim a little on the generous side so that the pieces of insulation fit snugly.

As you press the pieces of insulation into position—the tabs on the top,



Make It

bottom, and ends should help hold it in place [11].

Two small squares will easily tuck behind the tabs of the burner opening to cover each side on the back panel.

Use 22-gauge sheet metal for the exterior side panels. Lay out, cut, clean up the edges, and bend the tabs along the fold lines on the templates for these exterior panels. Remember that the tabs on the right and left sides will be bent in opposite directions.

When marking where to drill holes along the bottom edge of the side panels, two holes on each end will need to be marked precisely because they will be used to attach legs to the pizza oven later. One needs to be $\frac{3}{4}$ inch from each end, the other 2 inches from each end. The rest can be 2 to 3 inches apart.

Clamp one side to the base, lining up both ends, then drill through both the panel and the base. Pop rivet the side on, leaving the first two and last two holes open to attach the legs. Repeat for the other side.

Using 22-gauge sheet metal, lay out,

cut, clean up the edges, and bend the tab along the fold line on the template for the exterior rear panel.

Mark the side panel for drilling along the right and left side, as well as the burner opening. The bottom holes on each outside corner should be $\frac{3}{4}$ inch from the ends and left empty. As with the side panels, these are for the legs.

The top and front panel will be made from one continuous piece of 22-gauge sheet metal. Lay out, cut, clean up the edges, and then use the brake to bend along the fold line on the template for the exterior top/front panel. You'll need to bend it a little past 90 degrees. Test the panel's fit to make sure you have the angle close, and adjust as necessary [12].

To pre-drill holes in the top/front panel, mark locations along the edges. Hole spacing should be about 2 to 2½ inches. Note that the bottom holes for each outside corner on the front panel should be $\frac{3}{4}$ inch from the ends and left empty when you rivet the panel in place. As with the rear panel, these will be used later to attach legs.

INSTALL THE LEGS

Using 22-gauge sheet metal, lay out, cut, and clean up the edges. Using the brake, bend the tabs along the fold lines on the template for the oven legs. Remember that the tabs on the right and left sides will be bent in opposite directions. The long side of the legs correspond to the long side of the oven; there are two, each the same.

To bend the corners on a leg, trap it between two pieces of bar stock in a vise, fold it over by hand, then gently tap with the sheet-metal finishing hammer.

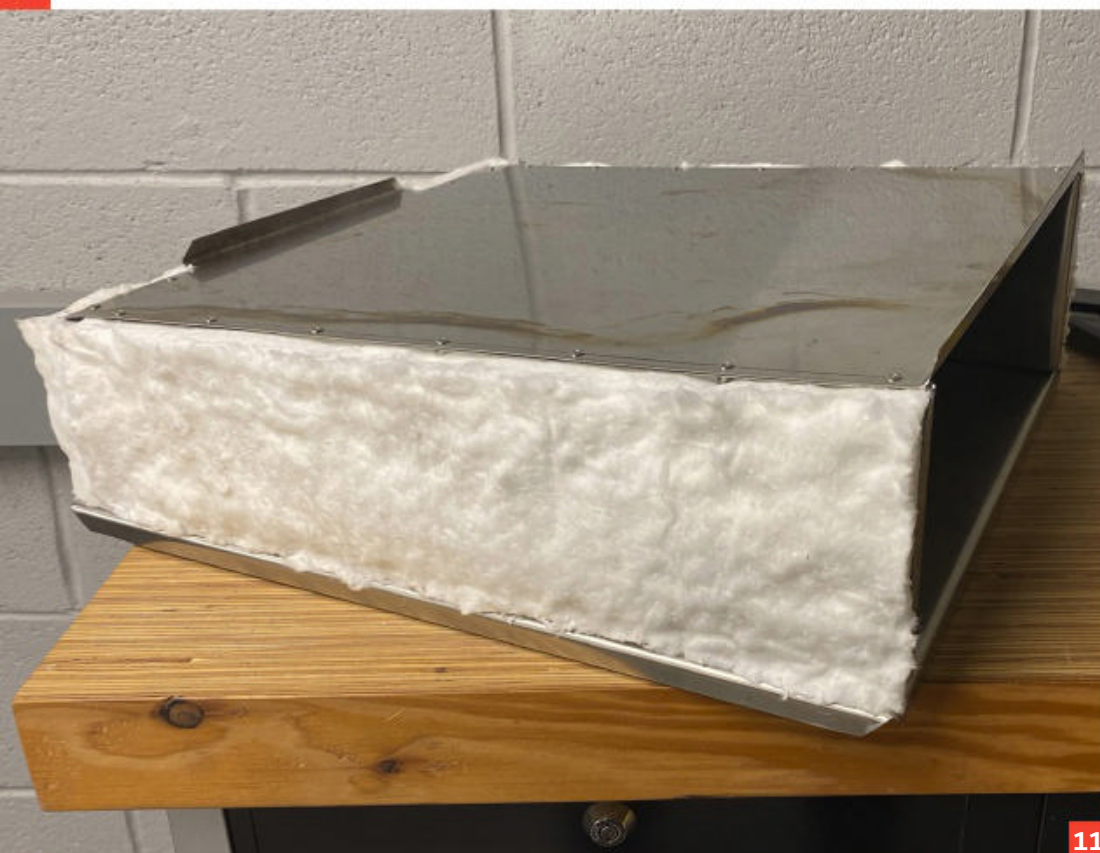
Clamp the legs into place in each corner. Be sure the bottom of each leg is the same distance from the oven body. Drill the legs through the empty holes in the oven body, then pop rivet them in place.

When all four legs are done, they should look like the ones in image [13].

INSTALL THE BURNER

Line up the burner bracket hole that you drilled earlier and pop rivet it in place [14]. Note that the two rivets through the oven floor will be installed through the bottom.

Using a step drill bit, drill an $\frac{11}{16}$ -inch hole through the leg to the left of the burner when looking at the rear of the oven. This will fit a standard grill igniter. Install the igniter and connect the two leads from the burner assembly.



11



12

ADD THE BURNER HOOD

After we finished building the pizza oven and tested it, we discovered the burner was susceptible to wind, occasionally pushing the flames out the back. So, we added this angled hood that shields the burner and creates a better draft to keep flames headed in the right direction.

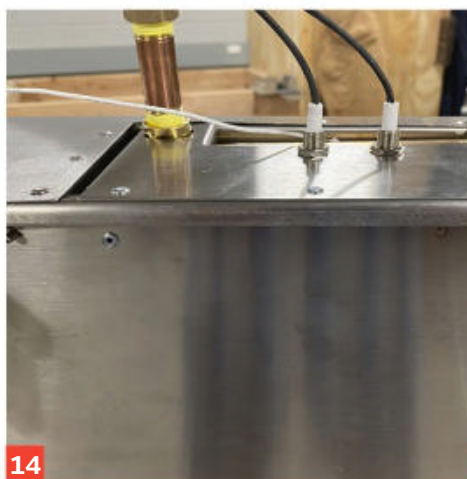
Using 22-gauge sheet metal, lay out, cut, and clean up the edges of the hood. Using the brake, bend the right and left triangles back along the vertical folds. Then flip it over, slipping the side tabs into the brake, and bend them out. Last, bend the top tab.

Mark the hole and slot for the propane supply pipe according to the measurements on the template. Hold it up alongside the pipe to be sure it looks like it will line up before drilling and cutting. If it looks good, drill the $\frac{3}{4}$ -inch hole, cut the slot for the pipe, and clean up the edges. Pre-drill the tabs, then drill through the rear panel and rivet the hood in place [15].

USING YOUR PIZZA OVEN

To fire up your pizza oven for the first time, connect the adjustable regulator to the propane tank and to the flare fitting on the burner. Turn the adjustable regulator off, open the valve on the propane tank, and open the gas valve on the oven. Then, slowly turn on the regulator until you hear gas coming out, and hit the igniter. After you hear the burner ignite, look in and carefully adjust the regulator until the flames reach across the roof of the oven and just lick at the top of the pizza oven door [16]. Before using your oven, you'll need to season it. Fire it up and let it burn for at least 25 minutes before you attempt to cook your first pizza. In use, it will generally take about 15 minutes to warm up, depending on temperature. If there is any breeze, make sure to orient the back of the oven toward the wind.

Now, go make some pizza! 





The Best Compact Impact Wrenches to Get the Job Done

TRADITIONALLY TETHERED TO A COMPRESSOR WITH A PNEUMATIC hose, impact wrenches were largely specialized tools used by those in professional trades. With the advent of cordless versions, they became not only more portable but also more versatile—they could be used on almost anything, anywhere. And, while originally a big, brute-force tool, they became a time-saver for common everyday tasks that require the removal of all manner of mundane nuts and bolts. Today, there is a variety of models available suited to all kinds of jobs, but the most useful, helpful, and adaptable are the compact models that excelled in our testing.

HOW WE TESTED

→ To test these impact wrenches, we performed specific assembly and disassembly tasks with each one. We first used them to remove and replace new, $\frac{1}{16}$ -inch, grade-8 bolts tightened to 200 foot-pounds. Next, we removed and reinstalled lug nuts on an eight-year-old vehicle that were tightened to 150 foot-pounds. Then we used the impact wrenches to drive lag bolts into pressure-treated lumber, without pilot holes—first using $\frac{5}{16}$ x 4½-inch lag bolts, then with $\frac{1}{2}$ x 8-inch lag bolts. We also used the impact wrenches for various jobs that came up around the *PopMech* shop. During testing, we cycled through every model's four drive modes and evaluated each impact wrench on performance, price, comfort, value, and versatility.



Size Matters

The most common-size impact wrenches are $\frac{1}{2}$ -inch-drive models—those with a square anvil measuring $\frac{1}{2}$ x $\frac{1}{2}$ inch that accepts $\frac{1}{2}$ -inch sockets. There are also smaller $\frac{3}{8}$ -inch and larger $\frac{3}{4}$ -inch-drive models, the latter of which is more commonly used for heavy-vehicle maintenance, agricultural equipment, or other industrial purposes.

Among $\frac{1}{2}$ -inch impact wrenches, there are also tool body sizes—generally called full, compact, and subcompact. If the tool isn't labeled specifically compact or subcompact, you can assume it is a full-size model. Full-size impacts will have larger,

longer tool heads and beefier internals, and thus are capable of higher torque. They're great for removing stubborn rusted nuts and bolts. However, these bigger tools may not fit in the spaces where you need them most.

Compact and subcompact impact wrenches have shorter, less-bulky tool heads that can be used in tight spaces more easily. Because they are smaller, they don't have the same torque of the larger models, but they have more than enough for most assembly/disassembly tasks an average person might encounter. Their size and capability for common tasks makes compact impact wrenches incredibly practical.

HOG RING? OR DETENT PIN?

Impact wrenches will have one of two features that prevent sockets from falling off. They will have either a hog ring or a detent pin. The hog ring gets its name from a metal ring locked through a pig's nose (used to keep it from rooting around). On the impact wrench, the hog ring is positioned around the tip of the anvil and exerts pressure on the socket when it is pressed on. This makes it easy to switch sockets by hand. Most impact wrenches, like the DeWalt and Ridgid models in this test, will come with hog rings. A detent pin, on the other hand, is a retaining pin in the anvil that must be depressed to release the socket.



DETENT PIN

HOG RING

BEST OF THE TEST



BEST ALL-AROUND

DEWALT ATOMIC 20V MAX ½ IN. IMPACT WRENCH KIT



Price: \$429 / **Power:** 20V / **Drive size:** ½-in. / **Motor:** Brushless / **RPM:** 2,500 / **IPM:** 3,550 / **Fastening/breakaway torque:** 300/450 ft-lb / **Drive modes:** 4 / **Battery:** 5 Ah (x2)

Using DeWalt's Atomic 20V Max in a drive mode optimized for timber screws, we were able to drive lags bolts just a little faster than with the other models—having the highest torque specs also helped driving speed. Like the Milwaukee, the Atomic 20V Max has a mode for bolt removal and fastening that prevents both runoff and overtightening—plus two speed settings. When repeatedly tightening similar fasteners, like lug nuts, we were able to get a feel for getting them all within 5 to 10 foot-pounds of spec. While the DeWalt was the most powerful, it was also the loudest model we tested.

BEST FOR MECHANICS

MILWAUKEE M18 FUEL ½ IN. COMPACT IMPACT WRENCH KIT



Price: \$379 / **Power:** 18V / **Drive size:** ½-in. / **Motor:** Brushless / **RPM:** 2,400 / **IPM:** 3,500 / **Fastening/breakaway torque:** 250/250 ft-lb / **Drive modes:** 4 / **Battery:** 5 Ah (x2)

The M18 Compact Impact Wrench handled every task in our test. With three drive modes that regulate speed, we found a setting suitable for most jobs. A fourth mode, bolt removal—perhaps our favorite—breaks bolts free and then slows down to prevent runoff or overtightening. With repeated use, and checking with a torque wrench, we found it was relatively easy to get a feel for tightening bolts and nuts to spec. Three LEDs around the anvil supplied us with ample light in dark conditions. The M18 Fuel is available with a detent pin anvil, as tested, or a hog ring.

EASIEST TO USE

RIDGID 18V SUBCOMPACT ½-IN. IMPACT WRENCH KIT



Price: \$189 / **Power:** 18V / **Drive size:** ½-in. / **Motor:** Brushless / **RPM:** 2,800 / **IPM:** 3,800 / **Fastening/breakaway torque:** 225/225 ft-lb / **Drive modes:** 4 / **Battery:** 2 Ah

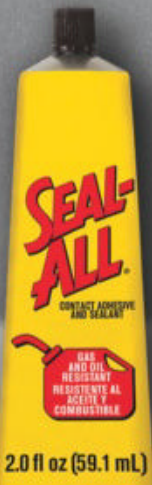
The only subcompact model we tested, the Ridgid 18V, is smaller and lighter than the others. While we found it easy to handle overhead or in tight spaces, it couldn't break free a ¼-inch, grade-8 bolt tightened to 200 foot-pounds, although it did at 175. Similarly, it struggled for us with a ½ x 8-inch lag bolt, but a smaller ⅝ x 4½-inch was not a problem. Despite this, the Ridgid was capable on tasks like removing lug nuts tightened to 150 foot-pounds. We were pleased with its bolt-tightening mode, which prevents overtightening by shutting down at about 20 foot-pounds.

Read about all the impact wrenches we tested at popularmechanics.com.



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PRODUCT

Rhino Ruler

MADE: 2022 | ACQUIRED: 2022 | FUNCTION: For measuring up to 6 feet

I MAKE MOST of my measurements with a 25-foot tape measure. I'd be lost without it. It's as familiar in my right hand as a hammer. But other times its shape and size seem clumsy. Enter the folding ruler, and in this case, the Rhino Ruler. Made in Switzerland and sold by U.S. Tape, the ruler (or rule, if you prefer) is built out of a rugged fiberglass-reinforced polyamide plastic.

The Rhino is identical in width, length, and hinge spacing to the famous Lufkin folding ruler (which I also own), but there are key differences. The Rhino's numbers are deeply embossed, its edges are square and sharp, and its reinforced-plastic construction makes it more wear-resistant and abuse-tolerant than the wood Lufkin.

The biggest difference between this and a traditional folding wooden ruler is that the Rhino's stainless-steel hinges never need oil and have a detent at 90 degrees. This allows you to fold the ruler open to 90 degrees and use it as a square with accuracy suitable for rough carpentry. The hinges feel a bit stiff when the ruler is new, but you'll get years of use out of this ruler before the hinges become sloppy. Like any of my other high-quality hand tools, I expect the Rhino to keep charging on, one measurement after another, for years to come.—*Roy Berendsohn*

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PlayStation VR 2 Is the Second Chance for Blockbuster VR

SONY'S PLAYSTATION VIRTUAL REALITY (PSVR) 2 headset represents the next generation of high-fidelity VR. These goggles pack some of the most advanced technology of any headset, like eye tracking and a crisp 4K HDR resolution OLED display for just \$549. This makes PSVR 2 the most affordable way to play the latest, most graphically demanding VR games. The rest of the VR industry is stagnant, focusing efforts on wireless standalone headsets held back by weak mobile chipsets. On the other hand, Sony's powerful hardware and talented game studios are poised to revive blockbuster VR experiences that are sorely needed in the space.

While virtual-reality headsets like the original PSVR have been around since 2016, VR finally broke into the mainstream with the 2020 release of the affordable all-in-one Meta Quest 2. This standalone system removed all the

barriers of room-scale VR by building the computer needed to run the games directly into the goggles, adding cameras to track your body as it moves around a space, and cutting the cord by having a built-in battery. Its ease of use, portability, and \$299 price tag made it a must-have gadget—and popular holiday gift. Even after a price increase up to \$399 late last year, the Quest 2 remains the VR headset of choice for many people.

“The Quest 2, before its price hike, was at the perfect sweet spot for sales and, as a result, was able to sell north of 10 million units, with some claiming it shipped upwards of 15 million units” says Anshel Sag, Senior Analyst of Mobility & VR at Moor Insights & Strategy. One way to keep prices down was by using a mobile Snapdragon XR2 chip to power the Quest 2’s processing and graphics. This eliminated the need for a separate expensive console or PC but lacked the power to render large-scale environments and sharp details. While this low-spec, low-cost approach made VR more approachable, it came at the cost of visual fidelity, which you can see in the screenshots in the sidebar to the right.

Three years after the Quest 2’s launch, its mobile hardware is showing its age. Not only is the interface starting to lag, but its limited graphical power is holding back VR game development. Since most players generally use this system, developers have tailored the scopes of their projects toward this weaker hardware. As a result, computer-powered titles featuring full-scale worlds ripe with interactive objects like *Half Life: Alyx* and *Lone Echo* have long been forgotten.

Sony’s PSVR 2 has fewer restrictions since it’s tethered to the massive 10.3 Teraflops of computing power of a PS5 console. This provides unmatched visuals in VR games complete with high-dynamic-range colors and light and richly textured environments, plus advanced physics that wipe the floor with previous triple-A VR titles. And when it comes to performance, some developers have claimed the PlayStation 5 is nearly 10 percent better than computers equipped with Nvidia 3090 graphics cards—some of the best money can buy. Since a console is more tightly optimized and requires less overhead than a gaming rig, Sony has the upper hand when it comes to value. In fact, the combined \$1,049 cost of the PSVR 2 and PlayStation 5 console needed to run it still comes out to



Quest 2 vs. PSVR 2



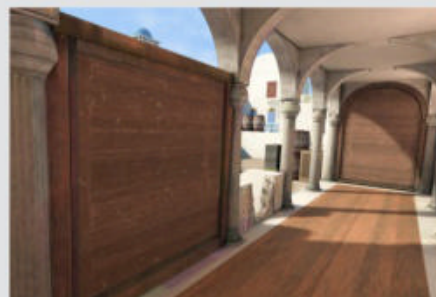
Mobile chips helped establish the consumer VR industry, but aren’t capable of rendering high-fidelity 4K experiences. The Quest 2’s games are more limited in world scale and look a bit jagged. Titles ported from the Quest 2 to PSVR 2 look a bit better, thanks to the PS5’s lighting and texture enhancements, but you can still see how certain mechanics were built around the constraints of mobile hardware.

This is best illustrated by the models and environments of the VR shooter *Pavlov*. On PSVR 2, you get realistic lighting, material textures, and set dressing like furniture and signs in spaces that make the world feel more lively. Look over at

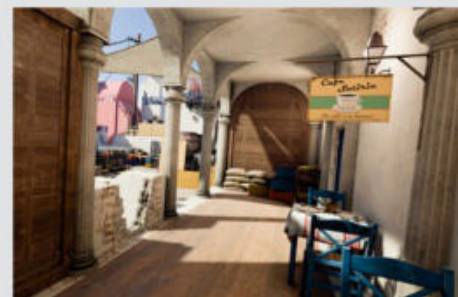
the Quest 2 and you’ll notice that surfaces appear soft, effects like muzzle flashes or blood spurts don’t have as much pop, and maps lack water and reflections. This is due to Quest’s various limitations—storage space and processing power—whereas the PSVR 2 can create photo-realistic environments.

Think of the PSVR 2 as a home video game system and the Quest 2 as a portable one. Both have a place and purpose, but the mobile hardware experience is far inferior to what you get when tethered to a powerful computer. While *Pavlov*’s core game mechanics make it equally fun to play on both systems, PSVR 2 is home to the definitive version with richer graphics and better features.

QUEST 2



PSVR 2





Sony's Sense controller tracks finger movements.

less than a comparable PC graphics card alone, not including the rest of the build or VR gear.

The PSVR 2 delivers immersive blockbuster VR games without so much as a stutter. More than just a processing bump, Sony uses eye-tracking cameras built around the lenses for a technique called foveated rendering. “In PSVR 2, we’re introducing dynamic foveated rendering using integrated eye tracking. The image quality of where the user is looking is improved, and it makes it very hard to see the image degradation in the peripheral area due to this smooth resolution change,” says Yasuo Takahashi, Product Manager at Sony Interactive Entertainment.

Simply put, this keeps a sharp 4K picture in the center of your gaze no matter where you look. Since your peripheral vision is naturally blurry, the PSVR 2 lowers the resolution in these spots. You won’t notice any impact on visual quality as you play, but this innovation frees up even more power for developers to push graphical boundaries to new limits. One of these developers is Firesprite Games, the team behind the system’s flagship title, *Horizon Call of the Mountain*.

Firesprite’s Game Director Alex Barnes explains, “This means we can make things like our lush rainforests come alive by packing them with more plants, animals, insects, and a dense pollen-filled air, whilst bringing incredibly high-quality machines to life in the same space.” Ultimately this allows for better-looking games with realistic levels of detail in virtual rooms,

jungles, and cities. “Foveated rendering lets us get the best possible visuals out of the PSVR2 headset’s 2000 x 2040 per-eye display resolution, and it wouldn’t be possible without eye tracking.”

Throw on the headset, and the lifelike 4K HDR fidelity is immediately apparent in character models and environmental details. You can see mountain ranges farther into the distance, view the seabed under a body of clear water, and even notice the sharp bristles of a character’s 5 o’clock shadow. Everything looks new and feels the part, too, when paired with eye tracking for new gameplay mechanics. One example is using your gaze to select an object from your inventory. Beyond visuals, the headset and PSVR 2 Sense controllers make it possible to interact with the digital worlds in new ways.

Haptic feedback built into the PSVR 2 headset itself lets you experience the pulsating drops of rain or the rumble as debris from an explosion hits your face. Pick up the Sense controllers and you can feel resistance while grasping digital objects in your hand through built-in actuators. “Adaptive triggers are the pinnacle of VR, especially when it comes to shooters. We have tuned the trigger pressure so that each weapon has its own resistance and recoil,” says Dave Villareal, the CEO of Vankrupt Games and creator of VR shooter *Pavlov*. Once you’ve experienced these lifelike graphics and sensations, it’s hard to go back to using other VR systems.

While the PSVR 2 is armed with the most immersive technology and graphics, its success will ultimately boil down to the quality of its content library. Gamers are willing to pay a premium for an exceptional adventure. “I could see Sony driving a higher attach rate with the PSVR 2 simply as a function of having fewer headsets with more mature content and better marketing,” says Sag. “Sony has some incredibly powerful IP with great brand recognition, like *Gran Turismo*, and I could imagine myself and others wanting to play that game again in a high-quality VR experience that makes it even more immersive, especially in a headset that’s capable of driving a smooth experience with high frame rates along with high resolution.” PlayStation’s talented developers, plus exclusive game series like *Gran Turismo* and *Horizon*, stand to usher in a new wave of high-fidelity VR, which has been cast aside for far too long. 



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I picked up a free sample-size tube of this grease at a trade show about 20 years ago. After packing it away in my toolbox, I forgot about it. But when a bolt with a slightly damaged tip refused to thread into its hole, I remembered it. I spread a tiny glob of grease onto the bolt tip and, to my amazement, the bolt slipped in as if it were freshly threaded. Several more incidents like that depleted the trade show sample, so I bought a full-size tube and have kept one in my toolbox to this day.

Some investigation into Super Lube revealed that it's silicone grease with micro powdered particles of PTFE (polytetrafluoroethylene; the most well-known version of this is Teflon). The grease is clean to apply and has no odor. I either dip a bolt in the top of the tube or spread the lubricant on with my fingertip. A tiny glob goes a long way—one tube provides several years of use. I can't verify everything the manufacturer says about it—that it lubricates parts up to 500 degrees or that it maintains its effectiveness in saltwater environments—but I wouldn't be surprised. What I can say is that it's as necessary in my toolbox as anything else in there.—*Roy Berendsohn*



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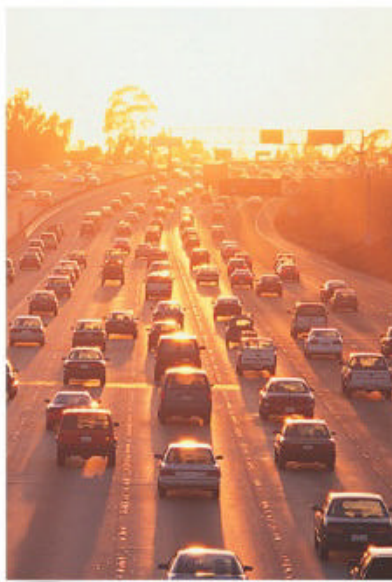
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ERADICATING “ZOMBIE CELLS” COULD BE THE KEY TO ANTI-AGING

As we grow older, our bodies fill up with a type of dysfunctional cell that permanently stops dividing, called a “senescent cell.” These so-called “zombie cells” linger in our tissues, emit inflammatory signals, and increase the risk of age-related diseases. And just like zombies, senescent cells can also infect their healthy counterparts through chemicals they emit. Ridding the body of them may even be the key to staving off old age.



DID YOU KNOW?

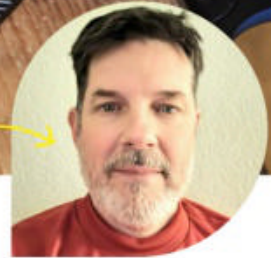
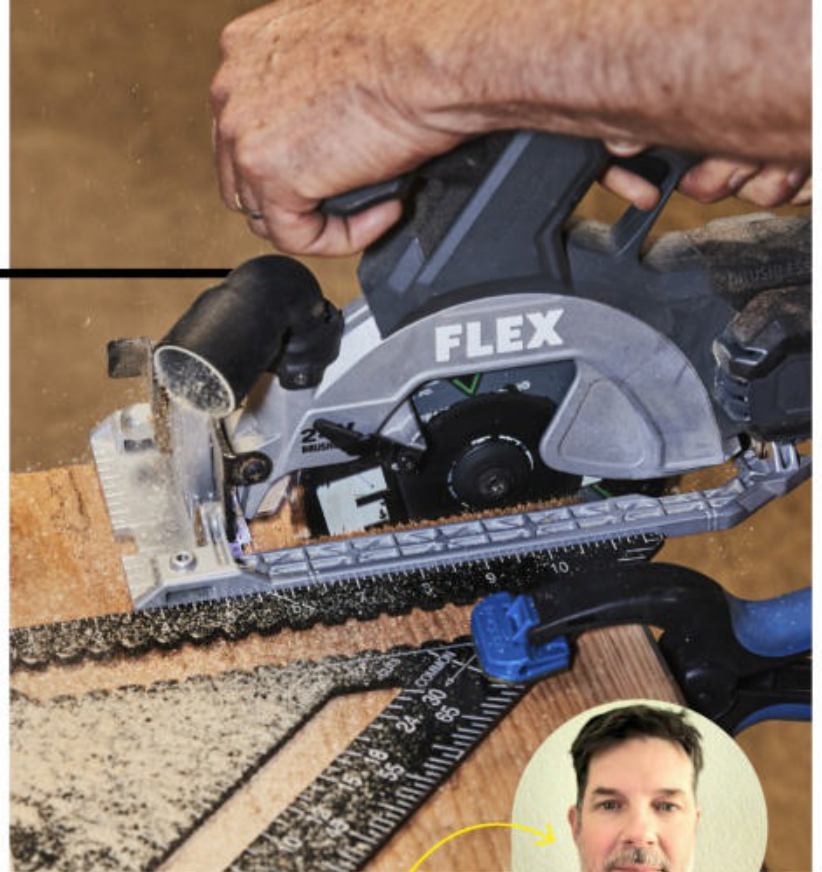
126,122 FEET

That’s the length of the Lake Pontchartrain Causeway in Louisiana, the longest bridge in the U.S. According to Guinness World Records, at nearly 24 miles, it’s the longest continuous bridge in the world that passes over water.



HOW TO UNLOCK A DOOR – WITHOUT THE KEY

Though finagling a lock with a screwdriver or credit card could work if you’re locked out at home, as a last resort, the door might need a good SWAT-style kick. If you go this route, first confirm the door swings open away from you. Kick with your dominant foot, and aim for a spot just above the doorknob (the weakest point). Make contact with a flat foot, and hit *hard*. If it doesn’t swing open or splinter, then it’s probably not going to give way. Find more (less-destructive) strategies at: popularmechanics.com/unlocked-door.



YOU TEST IT

PopMech Pro member **Tim Priebe**, of Colorado Springs, CO, got his hands on a Flex 24-volt 6½-inch brushless cordless circular saw (\$249) and used the tool to build an oversize house for his garage cat. “The saw has more power than I expected for a battery-operated tool,” said Priebe. “The blade stops quickly after the trigger is released, and I didn’t have a concern when placing it on the ground after a cut. It’s also engineered so that the wood shavings are thrown off to the side, so you don’t have to blow away the shavings while performing a cut.”

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THE GREATEST TREASURE HUNT IN AMERICAN HISTORY ENDED—AND THEN THINGS GOT REALLY WEIRD.

Forrest Fenn hid valuable treasure in a secret location in the Rocky Mountains, kicking off a journey filled with danger, conspiracy, and, of course, gold. With only a cryptic poem and a map of the Rockies, thousands took on the treasure hunt—until it came to an abrupt end.

Itching to find out more about this quest that captured the country’s imagination? Check out the latest digital issues of *Pop Mech* at: popularmechanics.com/digital-issues.



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