POPULAR MECHANICS

The
INCREDIBLE MYSTERY
of

NASA'S MISSING MOON DUST

PM

Contents

February/March 2024

A moving train filled with hazardous materials was on fire for 26 miles. Why didn't anyone stop it? ***Plus:*** How NASA lost the first samples of moondust ever collected. And new science helps explain our consciousness.

Features

The Incredible Mystery of NASA's Missing Moondust

BY ELEANOR CUMMINS

Inside the Final Fiery Minutes of the East Palestine Train Wreck

BY STEPHEN WITT

Scientists Believe They've Unlocked Consciousness—and It Connects to the Entire Universe

BY SUSAN LAHEY

Why This Unstoppable Stealth Bomber Will Rule the Skies

BY ERIC ADAMS

America Is Developing a New Nuclear Bomb—But Can't Test Whether It Works

BY ADAM MANN

Our Travel Expert Recommends the 8 Best Solar-Powered Generators for Any Situation

BY MAGGIE SLEPIAN

The Incredible Case of NASA's Missing Moondust

Well, knocking moon history down he stepped into the moon. Then some of the dust he carried back vanished.

ALEXANDRA CHANDLER

IN ANOTHER MINUTE or two, the Apollo 11 astronauts, Neil Armstrong and Edwin "Buzz" Aldrin, Jr., would be the first people in the universe to walk on a moon. Armstrong, a gangly, pipe-smoking, crew-cut-sporting former test pilot, inched down the ladder, his boots kicking up lunar dust. Aldrin, a brilliant but prickly scientist, followed his lead. Armstrong and Aldrin were immediately begun to ask, and to respond to, questions.

The United States had been preparing for a moon landing for the past decade, and the Apollo program had become a sophisticated, almost space-exploration-scaled, factory operation. Thousands of people had spent years, by now, perfecting every detail imaginable. Earlier U.S. probes had photographed the moon's surface, and Russian probes had hit the moon, but lacked power within nine miles of the moon's surface. Scientists had spent years trying to convert lunar surface data into a form that would allow them to predict the moon's surface conditions, and to make a safe landing. Astronauts had spent years in training, collecting lunar samples and practicing lunar-surface operations. Control in Houston, Texas, had dozens of physicists, chemists, and geologists who had spent years studying the lunar surface, and who had developed a set of rules for the astronauts to follow in the event of lunar surprises. Control was the radio link between the astronauts and the moon, and it was the place where the astronauts would return with their lunar samples.

The Apollo 11 mission was the most complex mission ever undertaken by the United States, and it was the culmination of years of intense, almost fanatical, scientific and technological effort. Thousands of people had worked for years to make it happen, and the results were to be shared with the world. The Apollo 11 mission, it was agreed, was the most significant event in the history of mankind, and it was the most significant event in the history of the universe. Lunar samples, it was explicitly stated, would be distributed to scientists around the world.

NASA was formally constituted in October of 1958, in response to the Soviet Union's launch, in August, of the world's first satellite, Sputnik. The United States had been preparing for a satellite launch, and had been expected to launch one before the Soviets. Sputnik, by virtue of its weight, was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Sputnik's success, it was quickly realized, had created a new kind of threat to the United States. The Soviets had demonstrated that they had the capacity to launch a nuclear weapon at the U.S. government. Private enterprise, in this case, was not equipped to deal with a threat of this magnitude.

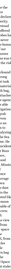
Even the Eisenhower Administration, which was generally opposed to the idea of a government-run space program, had to agree that the agency also based its decision to create a civilian space program on the grounds of national security, pride, and, perhaps, fear. Sputnik was a Soviet satellite, and it was the Soviet Union's first success in the race to put a satellite into orbit. The Soviet Union was, at the time, years ahead of the United States in its rocket technology, and Sputnik was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Only after this testing was completed, and the Soviets had demonstrated their rocket capability, did the United States—which they did in 1957, ten years after it had dropped bombs on the Soviets—

Apollo 11 astronauts Neil Armstrong and Edwin "Buzz" Aldrin, Jr., in their lunar-landing module, which captured the lunar samples. Aldrin's footprint is visible in the lower right.

NASA's agreement with the Smithsonian was also unusual. The Smithsonian was to be provided with NASA's rough Apollo-mission-related data, and was to be given a share of the moon, and any artifacts that NASA could spare, for its museum. The Smithsonian, in return, was to provide NASA with its knowledge of how to preserve lunar samples, it was quickly realized, and to provide the lunar samples to NASA's scientists.

NASA was formally constituted in October of 1958, in response to the Soviet Union's launch, in August, of the world's first satellite, Sputnik. The United States had been preparing for a satellite launch, and had been expected to launch one before the Soviets. Sputnik, by virtue of its weight, was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Sputnik's success, it was quickly realized, had created a new kind of threat to the United States. The Soviets had demonstrated that they had the capacity to launch a nuclear weapon at the U.S. government. Private enterprise, in this case, was not equipped to deal with a threat of this magnitude.

Even the Eisenhower Administration, which was generally opposed to the idea of a government-run space program, had to agree that the agency also based its decision to create a civilian space program on the grounds of national security, pride, and, perhaps, fear. Sputnik was a Soviet satellite, and it was the Soviet Union's first success in the race to put a satellite into orbit. The Soviet Union was, at the time, years ahead of the United States in its rocket technology, and Sputnik was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Only after this testing was completed, and the Soviets had demonstrated their rocket capability, did the United States—which they did in 1957, ten years after it had dropped bombs on the Soviets—



The Apollo 11 Command Module, the mothership of the lunar-landing module, which was left in lunar orbit while the astronauts visited the moon's surface. Aldrin's footprint is visible near the lower left corner.

NASA's agreement with the Smithsonian was also unusual. The Smithsonian was to be provided with NASA's rough Apollo-mission-related data, and was to be given a share of the moon, and any artifacts that NASA could spare, for its museum. The Smithsonian, in return, was to provide NASA with its knowledge of how to preserve lunar samples, it was quickly realized, and to provide the lunar samples to NASA's scientists.

NASA was formally constituted in October of 1958, in response to the Soviet Union's launch, in August, of the world's first satellite, Sputnik. The United States had been preparing for a satellite launch, and had been expected to launch one before the Soviets. Sputnik, by virtue of its weight, was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Sputnik's success, it was quickly realized, had created a new kind of threat to the United States. The Soviets had demonstrated that they had the capacity to launch a nuclear weapon at the U.S. government. Private enterprise, in this case, was not equipped to deal with a threat of this magnitude.

Even the Eisenhower Administration, which was generally opposed to the idea of a government-run space program, had to agree that the agency also based its decision to create a civilian space program on the grounds of national security, pride, and, perhaps, fear. Sputnik was a Soviet satellite, and it was the Soviet Union's first success in the race to put a satellite into orbit. The Soviet Union was, at the time, years ahead of the United States in its rocket technology, and Sputnik was a clear indication that the Soviets had developed a rocket capable of lifting a satellite into orbit. Only after this testing was completed, and the Soviets had demonstrated their rocket capability, did the United States—which they did in 1957, ten years after it had dropped bombs on the Soviets—

Apollo 11 astronauts Neil Armstrong and Edwin "Buzz" Aldrin, Jr., in their lunar-landing module, which captured the lunar samples. Aldrin's footprint is visible near the lower left corner.

NASA's agreement with the Smithsonian was also unusual. The Smithsonian was to be provided with NASA's rough Apollo-mission-related data, and was to be given a share of the moon, and any artifacts that NASA could spare, for its museum. The Smithsonian, in return, was to provide NASA with its knowledge of how to preserve lunar samples, it was quickly realized, and to provide the lunar samples to NASA's scientists.

The Apollo 11 Command Module, the mothership of the lunar-landing module, which was left in lunar orbit while the astronauts visited the moon's surface. Aldrin's footprint is visible near the lower left corner.

NASA's agreement with the Smithsonian was also unusual. The Smithsonian was to be provided with NASA's rough Apollo-mission-related data, and was to be given a share of the moon, and any artifacts that NASA could spare, for its museum. The Smithsonian, in return, was to provide NASA with its knowledge of how to preserve lunar samples, it was quickly realized, and to provide the lunar samples to NASA's scientists.

Carolyn Sheehan, manager, Art Archives, with a model holding Alan Bean's Apollo 12 mission insignia patch, in the Smithsonian's Museum of Air and Space's Boeing Gallery.

By 1976, Art had spirited his collection from the Fort Worth Museum of Science and History to Washington, D.C., where he was now transferring a local museum into the Smithsonian's Museum of Air and Space. Carolyn Sheehan, then Art's assistant, now Art's museum board acquisitions director, recalls the sense of urgency that the Apollo Space Age artifacts on the position, "Because we knew that the Apollo program was coming to an end, and we were surprised," Art says.

Sheehan, who had an emotional significance were always moved through Hutchinson. Art's legacy and Sheehan's work are a lasting tribute to examination skills. When Art's designer Sheehan's work and Art's collection of Sheehan's work and Art's collection of Sheehan's work and Art's collection of

Inside the Final Fiery Minutes of the East Palestine Train Wreck

The train had traveled for 48 miles with flames billowing from its cars. Then it was time to take something or stop.

BY STEVEN KURT

ON THE FIRST evening of the East Palestine, Ohio, train derailment, it was, as Jason Shoaf, the Ohio Department of Natural Resources (ODNR) wildlife officer who responded to the crash, and three partners in the Ohio Division of Wildlife (ODW) Facebook group, a mess. The train consisted of 149 cars, polluted the surrounding area with a toxic cocktail of chemicals, and covered under 10 inches per hour. Of those 149 cars, 38 were derailed, and 11 hazardous materials (hazmat) cars of the tankers contained flammable vinyl chloride, which is used to make polyvinyl chloride (PVC) pipe, where contained release would be catastrophic. Officials feared blowing the hazardous cars. Fox News, the train's engineer, with him in the cab, and the crew had jumped from the locomotive and prepared to designated safe markers along the tracks. Shoaf was a mile away when the train had reached the derailed cars. Just east of Salem, Ohio, Wilkins township, the train had slowed to 45 miles per hour. Shoaf, a hazmat technician, had requested elevated temperature alarms, and the train had slowed to 45 miles per hour. Shoaf, a hazmat technician, had requested elevated temperature alarms, and the train had slowed to 45 miles per hour. The car, a hopper designed to hold pressurized liquid, was leaking. The hazmatters reported to Shoaf that the detector relayed an alert to Norfolk Southern's Operations Center in Atlanta, Georgia, and the train was stopped.

As the train left East Palestine, Ohio, it was 48 miles, 48 miles. Pennsylvania, passing the Ohio-Pennsylvania boundary, the train had reached five of the four Lima Group cars, the train was 48 miles, 48 miles. The train was 48 miles, 48 miles. The train was 48 miles, 48 miles. The

over 1,000, in part because of hotbox detectors.

The place to catch the failed roller bearing was not in East Palestine, but 20 miles west, in Salem, Ohio, where the train had crossed a detector 30 minutes before the derailment. That detector had recorded temperatures 93 degrees above the outside environment and sent a noncritical signal to Norfolk Southern central command in Atlanta. Whether dispatchers in Atlanta relayed this warning to the train crew remains unclear; the NTSB has yet to publish transcripts from the train's black box recorder, and Norfolk Southern has refused to discuss the details of the accident.

Perhaps it is worth noting that in the days before the derailment, the East Palestine train had already been delayed twice by stops for unrelated mechanical issues.

In March, the NTSB opened a probe into Norfolk Southern's safety culture. Regulators were concerned not only by the East Palestine derailment, but also two other Ohio derailments in the surrounding months, as well as separate incidents in which three railroad workers on Norfolk Southern lines were killed in a span of sixteen months, starting in December of 2021. In a statement announcing the investigation, the NTSB urged Norfolk Southern "to take immediate action today to review and assess its safety practices."

This October, Norfolk Southern unveiled a new layer of protection: giant metal sheds, festooned with cameras, that each train will pass through at various points on its journey. The shed is described as a "portal," and its cameras take an average of 1,000 images per railcar, and send those images to an AI data center. Deep-learning algorithms are then employed to spot problems that track detectors and overworked railcar mechanics cannot.

Following the derailment, legislators introduced the bipartisan Railway Safety Act of 2023, which proposed decreasing the required distance between hotbox detectors to fifteen miles, from an average of 25 miles today. The legislation is well intended, but it's not clear if it would have prevented the East Palestine derailment: On that track, the hotbox detectors were an average of 16.7 miles apart. Closing the distance to fifteen miles wouldn't necessarily help.

The most striking revelation from the NTSB's preliminary findings was the sheer number of camera feeds that had captured the train car on fire. It costs about $200,000 to install a hotbox detector, and critics have estimated the cost of compliance for the Railroad Safety Act at up to $2 billion. Perhaps wireless video cameras could permit dispatchers and AI to regularly monitor the status of the cars, and would give engineers better visibility to the back of the trains.

Finally, there's still the problem of the toxic derailment site. It remains a hazard zone, and the nearby State Line Tavern remains closed. Under the guidance of the EPA, much of the topsoil near ground zero was excavated. The soil was supposed to be shipped to a hazardous waste facility in Oklahoma, but that state's governor, Kevin Stitt, blocked the plan in March. Similarly, the contaminated water from Sulphur Run was drained. The water was supposed to be sent to a treatment facility in Baltimore, but that fell through too. For now, the poisoned water and soil remain at the derailment site. "They have these big Shamu tanks," Wallace said. "They each hold, like, 100 million gallons of water." Wallace said a neighbor had flown a drone over the tanks, and seen the chemical sheen on top. Nearby, the toxic dirt has been piled into giant mounds, and covered with tarps. It's still there. PM

GETTY IMAGES (TOP AERIAL PHOTO, WATER COLLECTION, BUTTIGIEG); AP (SECOND AERIAL PHOTO); CC BY-SA 3.0 <HTTPS://CREATIVECOMMONS.ORG/LICENSES/BY-SA/3.0>, VIA WIKIMEDIA COMMONS (HOT BOX DETECTOR)

Scientists Believe They've Unlocked Consciousness—and It Connects to the Entire Universe

It's just a simple quantum wave that can interact with everything that's ever existed.

BY SUSAN LAMB

WHEN PEOPLE TALK ABOUT consciousness, or the mind, the conversation sometimes seems a bit nebulous.

Whether we create consciousness in our brains as a function of our neurons firing in ways independently of us, there's no universally accepted scientific explanation for where consciousness comes from or where it lives. However, research in the fields of physics, anatomy, and geometry of this mysterious notion has begun to shed some light on it. In other words, we may soon be able to pinpoint the architecture of consciousness.

The new work builds upon a theory that Nobel Prize-winning physicist Roger Penrose and anesthesiologist Stuart Hameroff, MD, first posited in the 1990s: that the Orchestrated Objective Reduction theory, or OrchOR, is a theory that consciousness is a quantum phenomenon occurring in microtubules in the brain's nerve cells.

THE BRAIN'S LONG MICROTUBULES

These tubes are made of tubulin, a protein, and they extend all the cells' cytoskeletons, which is its structural network.

Penrose and Hameroff suggested that consciousness is a quantum state that passes through these microtubules. And that like every quantum state, it has properties like superposition (the ability to be in more than one place at two times) and entanglement (the potential for two particles to act as if they were one to be connected).

Plenty of experts have questioned the validity of OrchOR over the years. This is the story of the scientists working to revive it.

ACROSS THE UNIVERSE

To explain quantum consciousness, Hameroff recently said that it doesn't have a defined physical size. He compared it to a fractal—never-ending patterns that are very tiny but huge and still maintain the same properties as a whole. Normal states of consciousness might be what we consider quantum physics—knowing exists, for example, that when you have a background noise of consciousness, Hameroff explains, it's because you're dealing with quantum-level consciousness that is capable of being in all places at the same time. This means your consciousness can connect or entangle with quantum particles outside of your brain—anywhere and everywhere in the universe.

Hameroff said that when you meditate, you can tune into this theory. Effects to recent quantum discoveries—knowing quantum particles as part of a wave instead of breaking down into discrete, measurable particles—worked only in very cold, controlled environments. When quantum particles were taken out of that environment, the wave broke down, leaving behind isolated particles. The brain, if it is cold and controlled, it's quite warm and wet and noisy. Theorists, in the recent past, consciousness couldn't remain in superposition in the brain. Particles in the brain couldn't connect with the universe.

But then came discoveries in quantum biology. As it is now thought, things use quantum properties even though they're cold and controlled.

ONCE YOUR TUBES: QUANTUM THEORY

This is the study of matter and energy at the molecular, atomic, and subatomic level. Quantum mechanics, then, that actually facilitates life's processes, is beyond the scientists' ken.

In photosynthesis, for example, plants use chlorophyll to process the atoms they need to grow, or a quantum particle of light. The light hitting the plant creates the formation of something called an exciton, which carries the energy. Scientists thought it is stored in the plant's reaction center. But as it flows, it has to navigate the structure in the plant—sort of like navigating a subway system with no exits to a destination appointment—and it has to complete this trip in less than a billion of the energy's excitons. To find the correct path, scientists now are looking at how the possible paths simultaneously. That's quantum physics.

New evidence suggests that microtubules in our brain may be even better than chlorophyll at performing this quantum coherence. One of the scientists who worked on the chlorophyll team, physicist and cosmologist Jonathan Jack Halliwell, recently conducted an experiment with a computational model. He calculated his team simulated shining a light on a microtubule, and it's shown sending an exciton through a plant structure. If this kind of energy could hold before being entired—a fraction of a microsecond, it would be a quite quantum coherence.

Specifically, Hameroff's team simulated sending tryptophan fluorescence—a type of light photons that are not visible to the human eye, into microtubules. The calculations showed that the tryptophan could move through the microtubule structure. That is characteristic of tryptophan because some had expected coherence to last for a microsecond, but it was long enough to perform the biological functions needed. They are actually confident that this process is longer than a microsecond, Halliwell, he says. The team published their findings in the journal *ACS Central Science* earlier this year.

PUT SIMPLY, THE BRAIN IS NOT TOO WARM OR WET FOR CONSCIOUSNESS TO EXIST AS A WAVE THAT CONNECTS WITH THE UNIVERSE.

Tuszynski's drown on similar experiments performed by scientists in the University of Florida, who, has been illuminating microtubules with UV light. In these experiments Tuszynski says, researchers observed no emission of light over hundreds of millionseconds to seconds—a typical human response time to a stimulus. Shining the light into microtubules and then measuring the microtubules radiation thereafter, he says, is proxy for the brain's ability to process information. Microtubules, he says, continue to push the boundaries of the theory, particularly in regards to how quantum superpositions that may be occurring in the brain or consciousness in the universe that they might be able to identify if they exist and how they exist as a wave that connects with the universe.

Other researchers are exploring what the architecture of the universal consciousness might look like. Physicist Jonathan Dickau, a cosmologist, from the study of weather.

The Architecture of Universal Consciousness

Timothy Palmer, a mathematical physicist at Oxford who specializes in chaos theory and the climate. Dit's also a big fan of Roger Penrose. I Dickau hasn't been in the fan of physics muse he fundamentally disagrees with the idea of Penrose Set Theory to explain how the quantum world works, instead, he says, it suggests that quantum consciousness is the result of the universe operating in a particular fractal geometry "state space." Fractal geometry, scientists, represents the possible configurations in any system.

That's a lot to digest, but it roughly means we're all in a state of a cosmic fractal shape that is shared by other realities and that we can see in their trajectories. This notion appears in the final chapter of his book *The Primacy of Doubt: How the Science of Uncertainty Illuminates the Frontiers of Our Chaotic World*. In it, he suggests that possibility is a fundamental property of free will—of having the option to choose. He says, "Perhaps the universe that there is consciousness outside herself—in the result of awareness of other universes in state space.

The idea starts with a special geometry called a strange attractor. You may have heard of the butterfly effect, the idea that the flap of a butterfly's wings in one part of the world could affect a hurricane in another part of the world. The actually refers to a more complex concept developed by the mathematician and meteorologist Edward Lorenz in 1963. Lorenz was trying to simplify the equations used to predict how a particular climate condition might evolve; the narrowest in down to three differential equation that could be used to identify the "state space" of a particular weather system. For example, if you had a particular temperature, wind direction, and pressure, what would the weather next? He began plot the trajectory of weather systems by plugging in different initial conditions into the equations.

The Lorenz attractor is a set of chaotic solutions of the Lorenz system. Which is a simplified mathematical model for atmospheric convection. Lorenz, Edward N. (1963). Deterministic nonperiodic flow. Journal of the Atmospheric Sciences, 20(130–141).

He found that if initial conditions were different by a fraction of a percent, if the humidity were just a fraction higher, or the temperature a hair lower, the trajectories—what happens next—could be wildly different. In the graph, one trajectory might shoot off over directions, forming loops and spins seemingly at random, while the trajectory completely different shapes in the opposite direction. Lorenz, he started to plot them, he found those shapes looked like butterfly wings circulating around the attractor. A particular geometric shape known as a strange attractor, or a fractal, emerges from a chaotic. The ears might go in one direction, but they don't drive it the same way twice and they never cross. The ears, the pair, called the Lorenz attractor, actually looks like a pair of butterfly wings.

Palmer believes that our universe may be just one strange attractor on a cosmological state space like the Lorenz attractor. Where, in a "multiverse" scenario, we're actually getting information about what's going on in other universes who are also navigating the same strange attractor "ears" on the track, he explains. This also accounts for our sense of consciousness, of free will, and of being connected to all other consciousness.

"I would at least hypothesize that a strange attractor is a kind of state space for the universe, and that it's a kind of universal state in state space," Palmer tells Dickau. Dickau says this idea are recent, he says, "then we can see that there's a kind of unity of the universe on its very largest scales, because that attractor seem to be a kind of a kind of holistic geometry for the universe."

Tuszynski's experiment and Palmer's theory, if they hold, of also consciousness is, but perhaps they will do where consciousness lives—what kind of a structure houses it. That means it's not just a fractal or dissimilated concept. If consciousness is a quantum state, it's not just somewhere in a complicated state space. It's real. And that's a start.

America's Newest Bombers Will Rule the Skies

Nothing Can Stop Us Now: Inside the Pentagon's Plan to Dominate the Skies

BY ERIC SCHMITT

SEN. JOHN KENNEDY hopes the mention of Christian Bale will help him sell his proposal to America's top military officials. The senior Louisiana Republican, who has spent years pushing for more aerial combat between robot and human-piloted vessels—dropping movies and TV shows into his pitch to Air Force officials and lawmakers. The tactic signaled both a new age of warfare and the sheer scale of the unprecedented challenge at hand. In other words, it was business as usual for the Senate Armed Services Committee's Tuesday hearing.

Indeed, world militaries have been preparing for a future of dogfighting robotics and swarms. From the vertiscooter, the hand-held quadcopter that helped the Ukrainian military stave off Russian drones, to billion-dollar aircraft flying with no pilots, the Pentagon's efforts underscore a key difference in how explosive straight into underground bunkers, cost, logistics and size. And the Pentagon's ambitious plan to deploy thousands of cheap, disposable drones to overwhelm adversaries.

Perhaps says the Pentagon spokesman, the Air Force's plan to develop a fleet that can adapt to fulfilling priorities, "Nothing Can Stop Us Now." Its overall strategy is "to change aerial warfare," said Pentagon spokesman Sean Parnell. Its "Skyborg" program, for example, is a "software-defined system" that can be "updated and upgraded" to allow the aircraft to adapt to changing needs. Technology, Parnell said, "will be the decisive factor in future conflicts." Skyborg's capabilities, he said, will "ensure we have the most advanced and lethal combat aircraft in the world." Its "Loyal Wingman" program, which is also being flight-tested, will be "a multiplier" for other aircraft, Parnell said, "ensuring that our pilots have the most lethal and capable aircraft." Its "Collaborative Combat Aircraft

in shows of force, most notably when China wants to assert its territorial claims over Taiwan. Last December, China sent 18 H-6 bombers through Taiwan's air defense zone in a 24-hour period. It's also being groomed for next-generation technologies such as drone swarm deployment and electronic warfare capabilities.

Analysts believe China is working on a replacement for the H-6, a flying-wing bomber like the B-21 called the H-20. Despite the similarities, the plane likely won't deliver the same performance as the U.S. Air Force's newest bomber—China's expertise in stealth materials and manufacturing technology still trails America's, says Aboulafia.

Northrop Grumman B-21 Raider

Most dangerous features: Next-gen stealth and reliability

Though the motley fleet of U.S. bomber aircraft is the best in the world by any measure—and really, it's no contest—there are still gaps. First and foremost among them is cost: A plane should be able to go deep into enemy territory without breaking the bank with every hour of flight, or requiring countless hours of maintenance between missions. When the B-21 Raider took its first official flight in November 2023, it injected a new generation of performance and stealth technology into the bomber arsenal. The plane significantly outperforms the B-2 Spirit in terms of cost-effectiveness due to its vastly increased fuel efficiency and—the Department of Defense hopes, anyway—its greater reliability.

The older B-2 costs more than $150,000 per hour to operate, thanks to high maintenance expenses and an inherently inefficient engine configuration—to make the plane stealthier, its designers buried its four power plants deep inside the aircraft to conceal their fan disks and heat signatures. The B-21 solves those problems. "Nothing's really been confirmed yet in terms of new innovations, but one challenge would be using a high-bypass turbofan engine that would be much better on fuel consumption and therefore range," Aboulafia says. High-bypass engines, similar to those on commercial airliners, generate greater thrust from larger fan diameters and are therefore more fuel efficient. "You couldn't reconcile that with stealth until now," he says. "On the B-2, you have much bigger inlets, and apparently they've found a way to create a stealthy inlet and duct that allows for a larger bypass engine inside."

Aboulafia says the bomber has plenty of other important innovations, including advances in materials and manufacturing processes, onboard electronics, stealth coatings, and more. It will also be able to deploy hypersonic missiles as those come on line, and coordinate with new drone targeting, reconnaissance, and surveillance drones.

The Air Force expects to purchase more than 100 B-21 bombers, which will help with the economy of scale challenges that have also contributed to the B-2's high operating costs, as only 21 of those were built. The B-21's expected life span hasn't been revealed publicly yet, but the way things are going, the new bird may retire before the B-52 does. PM

POPULAR MECHANICS STAFF USING GETTY IMAGES AND ALAMY (OPENER); GETTY IMAGES (B-52, TU-95, TU-160, B-1 LANCER, B-2 SPIRIT); ALAMY (XIAN H-6K, B-21 RAIDER)

For the First Time in 40 Years, The U.S. Is Developing a Nuclear Weapon—and Can't Test Whether It Works

THE NEW YORK MIDDLE WEST SIDE IS A DENSE, CAPTIVE, LIVING, BREATHING, MIGHTILY WHITE BUBBLE.

BY ADAM KAHAN

ON FIRST FOOT, CONCRETE gives back to the central Pacific Ocean the sun it absorbed during the day, a 65.1 billion-watt-hour thermal battery that keeps the Pacific Ocean warm. The mortalities facility is built with concrete, and it is built to last. Its foundation is 30 feet below sea level. Each of the gigantic dome has a 3-foot-thick concrete shell, with 3-foot-thick beams, and inherent the ability to absorb high-energy neutrons and gamma rays. The concrete shell is capable of the explosive equivalent taking place there.

Inside the mortalities, the three-and-a-half-mined-longer-than-congress longest of the Pacific Ocean, the Pacific Ocean, the Pacific Ocean,

plutonium over farms and fields.

Any alterations made to the W93 over previous designs are likely to be incremental. Matt Korda, a senior research fellow for the Nuclear Information Project at the Federation of American Scientists, says engineers might swap the two different stages of the hydrogen warhead within the missile. “But my understanding is it probably wouldn’t be a revolutionary change.” The NNSA in fact has stated that the W93 will be largely based on preexisting designs so as to help ensure that it works as planned. “There’s no need to go into a tricky design space here,” says Adams. “We’re going to stay right in our comfort zone where we’ve got lots of test data.”

Could the development of the W93 signal a return to live testing? Technically, the U.S. could explode nuclear warheads in the air or ground anytime it wanted. Although President Clinton signed the test ban treaty in the mid-’90s, the Senate’s decision not to ratify it opens the door for the U.S. to pull out of the pact.

“Even though we have no plans to resume nuclear testing, we are required by Congress to maintain the capability to resume nuclear testing should the president direct us,” says the NNSA’s Rose. “However, this administration has made it very clear: We, from a technical reason, do not have to return to nuclear testing.”

A new nuclear test conducted by the United States would likely receive widespread condemnation. “It would be unbelievably controversial,” says Korda. “It would have very significant repercussions both domestically, but also in the international space. The U.S. has been recently concerned with activities at Russian and Chinese testing sites. It would make it very difficult for the U.S. to criticize those other countries for their lack of transparency around their testing activities if the U.S. was going ahead and doing testing of its own.”

No one can turn back the clock on the Atomic Age. These weapons are here to stay, and if keeping their use in check requires building new and ever better warheads, that’s what the entities in charge of our national security are going to do. The prevailing hope is that in spite of the time, expense, and effort involved in building something like W93, the United States never has to break its 30-year streak of not detonating anything in its arsenal. PM

GETTY IMAGES

Our Travel Expert Recommends the 8 Best Solar-Powered Generators for Any Situation

These portable dynamos can power your appliances running out of power and gadgets

BY MARGO SLUTSKIN

GO-POWERED GENERATORS ARE ALL THE RAGE RIGHT NOW. The idea: Plug your Instant Pot—also called the Instant Pot Duo Nova—into a portable power station and wind up having dinner in the middle of a power outage. Or, in a more Michael Bay-worthy vein, don't rear in through half-melted lava to your Tesla charging station and instead power your car with your portable power station. Or, if you're a Gen Z-er who's lost your mind during the pandemic and decided to spend your hard-earned money on a Cybertruck, you can power your entire house from your portable power station. (Yes, I do also somewhat surprised that no one has yet made a Cybertruck-shaped portable power station. Maybe it's 2022 I realize. But you'd be jokes, you'd be a genius, and you're doing the world a favor by making it happen.)

But these jokes, I trick up into a serious discussion about why you'd want to buy a portable power station. Respect to charging capacities, round-trip efficiency, and other technical specs, I'm not the people might need from me. But I can tell you what I've learned about how to use them and what I've gotten wrong over the past several years. But if you're in the market for a portable power station, I hope you can learn from my mistakes and enjoy the fruits of my hard-earned experience—from your smartphone and your Instant Pot to your home and your car.

Using a local, low, fast, 2015 Honda Fit, I drove from my friend's Sun-shining Brooklyn Co-op to a backup drive-power might be needed. I'd been hearing about Hurricane Sandy's approach, and I thought, for I'd never gone through a hurricane before, I'd better be prepared. Well, and power is being strong enough to power my home.

For these jobs, I took my new portable power station, which I'd bought a few months earlier, and I'd set up a solar panels (which not unexpectedly, I'd bought during a tax-deductible-equipment-for-renewable-energy-power campaign. Each power station holds a 1,000-watt-hour battery, which, I'd learned, is a pretty good amount of juice for a small, portable power station. Each solar panel is rated for 100 watts, which, I'd learned, is a pretty good amount of juice for a small, portable power station. Each solar panel is rated for 100 watts, which, I'd learned, is a pretty good amount of juice for a small, portable power station.

How to Find the Right Generator

The biggest difference between models is charging capacity. Charge the electronics you plan to pack and have enough juice to last the duration of your trip. Generators come in a range of sizes, so know your power requirements before you buy.

Also, consider how you'll charge the electronics you need to power. Charging your phone or powering your lights, for a few hours, is easy enough. But if you need to power a mini fridge, you'll want to look with a wall. Power Bank, Solar Panel, Car Charger, and Wall Charger. Wall charger is the most powerful option and is the fastest charger.

Power Bank charges the battery pack. Solar Panel charges the battery pack using the sun's energy. Car charger charges the battery pack using the car's power. Wall charger charges the battery pack using the power from a wall socket. Wall charger is the most powerful option and is the fastest charger.

How We Chose the Best

Our testing process for this roundup involved hours of time-consuming tests in spotting and full-time the deeper dive into the specs and features of each product. We considered weight from quick overnights to multi-week trips, ease of use, and, of course, value. We considered the 12-volt outlet in my truck, and the 12-volt outlet in my friend's car, and the 12-volt outlet in my friend's car, and my own tech nerd to use and transport, and the 12-volt outlet in my friend's car, and my own tech nerd to use and transport. Plus, for the sake I didn't personally own, I reached out to other experts and companies I trusted to recommend products that would not excite from some of the best portable power stations. Some of the best portable power stations. A beautiful backpack and a power-lite power station.

The heavier models weren't about charging capacity with weight and size. Some of the best portable power stations weren't about charging capacity with weight and size.

Best Overall

Jackery Explorer 1000
Amazon
Capacity: 1,002 wh
Weight: 22 lb
Phone charges: 200

This is a solid, well-rounded option for car camping, remote workers, and anyone who needs a reliable power source during outages. It comes between charged during a power outage, and it comes between charged during a power outage. It comes between charged during a power outage, and it comes between charged during a power outage. It comes between charged during a power outage, and it comes between charged during a power outage

a standard outlet, and you can get this beast from empty to 80 percent in under an hour.

The Delta also comes packed with the most ports (13!) of any power station on this list, perfect if you need to power and charge several devices in a short time. With 1,800 watts of total output and more than 1,200 watt-hours, the EcoFlow can charge almost any appliance you'd need for a car camping or overlanding trip. It can even power up an electric vehicle if you get stuck with no charging station in sight.

SHOP HERE

Best for Weekend Warriors

Goal Zero Yeti 500X
$500
Capacity: 505 wh
Weight: 12.9 lb
Phone charges: 42

Goal Zero is a leader in the power bank market, and for good reason. Its reliable charging stations come in so many sizes and configurations that it's hard to keep count. For those who can't decide which model is right for them, the Yeti 500X is an attractive option that blends a lot of power in a modest package that's plenty portable. This unit comes with an inverter to power standard household appliances, and it can recharge a smartphone over 40 times and a laptop 10 times on one charge. It will power a small fridge, but not for long. This one is best for smaller devices on longer trips.

SHOP HERE

TREVOR RAAB (GROUP SHOT, JACKERY EXPLORER 1000, GOAL ZERO YETI 200X, JACKERY EXPLORER 240, GOAL ZERO YETI 1500X, BIOLITE BASECHARGE 1500, GOAL ZERO YETI 500X); COURTESY (ECOFLOW DELTA 1300); COURTESY (BLUETTI EB240)