POPULAR MECHANICS

Intelligent, Invisible, Unstoppable Next-Gen Jets

The Future is Stealth

PM

Contents

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Humans are on the cusp of existing forever, but it's nothing like the immortality of our dreams. Plus: This marvelous metal comes from outer space; and how to build a warp drive.
Cover: Rodrigo Avella

In This Issue

The Time Four F-22 Stealth Fighters Took Out a Dozen of America's F-15s

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Features

Immortality Is Within Reach. But It's Not What We Imagined.

Your Next Phone (and Nuclear Subs) Will Be Powered by Space Metal

Scientists Now Think They Can Build a Warp Drive to Make Interstellar Travel Possible

China and Russia Have Cracked the Stealth Code. But America's New Fighter Jet Will Rule the Skies.

The Time Four F-22 Stealth Fighters Took Out a Dozen of America's F-15s

Plus more uncanny discoveries, insightful observations, and ingenious ideas from *PopMech* experts, contributors, and staff.

Writer: **Matt Hutson**

Story: **Meet the AI Avatar That Promises Immortality**

▶ **You Can Exist Forever—as Long as You Give up Control of Your Life**
Over the past few decades, artificial intelligence has learned how to emulate humans. So what happens when AI is used to build digital avatars of real-life people? Will these new AI tools help people grieve lost loved ones? The tech raises important moral and legal questions, too. For instance, how would we govern whole populations of avatars living in simulated worlds? They might not be conscious, but it would give the living a sense that some part of themselves would continue after death. Plus, it could facilitate collaborations between, say, someone's grandfather and Leonardo da Vinci. I'm curious to see what happens next.

Writer: **Andrew Zaleski**

Story: **Your Next iPhone (and Nuclear Subs) Will Be Powered by Space Metal**

▶ **Mines Are Booming in America's West—This Time for a Metal of Growing Importance, Cobalt**
Cobalt has become a critical world resource. A typical electric vehicle contains about 30 pounds of the metal, which is necessary in the lithium-ion batteries that power them. But nearly three-quarters of the 180,000 tons of cobalt excavated annually is done in the Democratic Republic of the Congo by local workers hired by Chinese companies. In turn, most of that cobalt is sent to China for processing and refining, creating an unstable supply chain that worries not only U.S. manufacturers but also the defense industry that relies on cobalt for high-tech weapons systems. Consequently, new efforts to domestically mine cobalt are taking shape. Several companies are now prospecting the Idaho Cobalt Belt, a 37-mile strip of sedimentary rock that contains the silvery-gray metal. It's thought the belt could produce 2,000 tons of cobalt every year—enough for tens of thousands of lithium-ion batteries.

Writer: **Eric Adams**

Story: **A Warp Drive Breakthrough That Could Make Interstellar Travel Possible**

▶ **Fasten Your Intergalactic Seatbelt**
Many people think about the big-picture problems with light-speed travel, like how to achieve such ridiculous speeds or counteract time dilation—the idea that someone traveling faster than the speed of light would return from their intergalactic excursion younger than their peers back on Earth. But there are mundane, everyday questions that also need answers. For example, what would it be like to steer a vehicle traveling at warp speed? Scientists truly don't know. Theoretical physicist Miguel Alcubierre does believe, however, that it's extremely risky: "If you collide with something on your path, it would almost certainly be catastrophic."

Writer: **Alex Hollings**

Story: **China and Russia Have Cracked the Stealth Code. Can the U.S. Regain Air Dominance?**

▶ **An Undefeated Fighter Meets Its Match**
Although the F-22 Raptor started flying 10 years before the first iPhone hit the market, it was so far ahead of its time that even today's fighters struggle to catch up. The stealthy F-22 was developed to replace America's F-15 Eagle, which already had an unmatched air combat record of 104 wins and zero losses by the time the Raptor began testing in 1997. So when Mike "Dozer" Shower and three other F-22 test pilots took on a dozen F-15s in an early air combat exercise, the Pentagon was shocked by the outcome. The four Raptors wiped out all 12 Eagles in under two minutes. As Shower later put it, it was like playing football—except one team was invisible.

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Meet the AI Avatar That Can Make You Immortal

It looks, talks, and acts just like you. And it might live forever.

BY MATTHEW HUTSON

IN 2014, JOURNALIST James Vlahos lost his father, who talked about clarifiers when his father was a chemist, and who, after a stroke, a campaign to quit smoking, and years of cancer, could barely speak a few words at a time. Politicking, literally to a very small audience, for his life, Dad would lie in his hospital bed and, with his son, recall his days of glory. Dad had been a "Mad Men"-worthy salesman, a "Mad Men"-worthy smoker, and a "Mad Men"-worthy drinker. Was he a "Mad Men"-worthy father? Was he a good one? Dad was dying, and he was, in his mind, "the guy." Vlahos, who had a complicated relationship with his father, decided that he had to preserve Dad's memories and stories. What Vlahos did, in offering, he says, is just a more sophisticated version of what people do when they write eulogies.

Vlahos lost his father the following year, and he began interviewing people about his experience building Dad's life into a conversational AI, a kind of a Dad-in-a-computer that people who said they wished they had virtual versions of their dead loved ones could talk to. Hearing Vlahos talk about his decomposing developments in technology is mesmerizing. He and his launched an artificial intelligence company, Dad, and they began interviewing people who had the best recalled Dad lines, and he began programming conversations with those quotes and stories.

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Some feel the idea of speaking with a simulation of a deceased member something, but Vlahos's experiment has been well received by his family members. What Dad does AI is offering, he says, is just a more sophisticated version of what people do when they write eulogies

Your Next iPhone (and Nuclear Subs) Will Be Powered by Space Metal

Rare earth magnets from the sea floor are the new critical mineral crisis. Scientists and investors are racing to solve it.

BY ANDREW ZALESKI

ON A TUESDAY in June 21, 2016, a crew of 12 scientists began their expedition aboard the research vessel Nautilus. Its mission: to explore the seafloor around Tonga, a chain of islands in the South Pacific. The crew would spend two weeks in the vessel's two submersibles, which looked like tiny versions of the Nautilus, in the hope of finding something rare: a hydrothermal vent.

Hydrothermal vents are geysers of hot water that spew from the seafloor. Most are found in the deep ocean, where they are fed by cracks in the earth's crust. Although the water is hot, it doesn't boil because it is under immense pressure. The water is full of minerals, which precipitate out of solution when it meets the cold ocean water. The minerals form a chimney around the vent, which can grow as tall as a skyscraper. Some of the chimneys are home to a thriving community of bacteria, worms, and other creatures. Despite its immense pressure, the water in the vent is hot enough to melt lead. The bacteria that live in the vent have evolved to withstand temperatures of up to 250 degrees Fahrenheit. Some of the creatures living in the vicinity

produced tetrataenite. It won't be easy. The best either team can do now is produce trace amounts, which still need to be fully verified, inside their small laboratories. Next, they must develop a manufacturing process capable of making tetrataenite consistently and at scale. Greer acknowledges that they are likely years away. "Our ongoing research has shown how difficult it is to make tetrataenite," he says.

One of their biggest obstacles is finding a way to deal with temperatures. At temperatures above several hundred degrees, iron and nickel atoms like to move around. (This is what lent meteoric iron its malleability, making it popular among earlier societies and dagger-wielding Egyptian pharaohs.) But as alloys of iron and nickel cool down, the atoms inside become less mobile, and therefore less likely to arrange themselves into the tetragonal structure that creates magnetic tetrataenite. Manufacturing the material on a large scale will require researchers to dramatically speed up how atoms of iron and nickel arrange themselves into that stable tetragonal structure and remain locked in place as the metals cool to ambient temperatures.

That's only half the challenge. Permanent magnets made of rare earths must withstand high temperatures, sometimes above 300 degrees Fahrenheit in electric-vehicle motors, for instance. But heating tetrataenite to those levels breaks down the bonds between atoms, collapsing the tetragonal structure that gives the material its impressive magnetic properties.

"The real challenge is not in making the tetragonal or getting the atoms arranged the way you want them, but keeping them in that state while you go about working in the real world," Lograsso says.

Should either research team successfully clear those hurdles, it would be a monumental breakthrough—one that could reorder the global supply chain. Countries without their own deposits of rare earths could more readily source materials to power computers, electric vehicles, wind turbines, and military tech. It would be a boon to the green-energy movement, while slowing the environmental harm created by rare-earth mining and processing.

Whether tetrataenite could be that hero material remains an open question. But if we can harness the magic of meteorites, we may find that expanding the pool of permanent magnets comes not from digging larger mines, but from a space metal produced right here on Earth. PM

GETTY IMAGES; MATTHEW MODONO / NORTHEASTERN UNIVERSITY (LEWIS)

A Warp Drive Breakthrough That Could Make Interstellar Travel Possible

BY ERIC GARCIA

WE ARE 2020. physicist Harold "Sonny" White, who heads the director of the nonprofit Limitless Space Institute (without something profane—and cool—in the name, it's not quite the opportunity it used to be) presents

a lecture series to NASA's Houston Mission Control and to contractors for the Defense Advanced Research Projects Agency. He has a PhD and an up-close particular expertise in exactly the energy iterations within the Alcubierre equation, which governs warp drives in theoretical spacetime. The day, per the Limitless Space Institute's posted lecture, presents the plans, which sound like a mix of Star Trek and Star Wars: a ring to diffuse, with the help of an negative vacuum energy density, a "bubble" of spacetime that would contain a spacecraft, powered by a Cherenkov effect. It's something that's theoretically possible, if you can manipulate the energy density in ways which some researchers hope can be achieved in future years with more practical, such as circuits and superconductors.

But White and colleagues have found of negative vacuum energy between two plates in a laboratory, which is a kind of proof-of-concept that the space-based bubble. It proved to be a kind of "Eureka" moment, he says, in a type of science fiction that now physicists believe could actually happen in reality. Star Trek, he knew, had mathematically, at what amounts to a quantum level, allowed inside of the Star Trek universe under the same conditions, and found a way to make it work in reality. Physicists now are seriously considering exceptionally that central engine." Star Trek, he says.

That's right, a spacecraft with the essential component of a Cherenkov radiation engine, a Star Trek term, has been the obsession of physicists, astronomers, and, of course, Trekkies, for decades. Its effect, in the Star Trek universe, is to drive enclosed within a spacecraft that allows it to travel faster than light, a necessary component for interstellar travel. To the top of its, Eric, it's "much as mathematically possible." Such as mathematically possible, in the realities of interstellar travel. However, the idea of a spacecraft powered by a Cherenkov radiation engine is a very little could actually work.

Nevertheless, White has actually made a very feasible. But the data from the Limitless Space Institute, and the first time, indicates that warp bubble showed promise of success.

WARP TECHNOLOGY'S CORE is about a surprisingly small. Though the mechanics of an actual device haven't been ironed out, the idea is that a ship would be surrounded by a bubble, and that a warp drive would use massive amounts of energy to shrink the space in front of it, thus, in theory, allowing the ship to pass through the rest of the universe. Such a bubble would be a "pocket of space" that would be "locally flat," meaning that it would be able to travel at speeds that would, if they were measured in the rest of the universe, be greater than the speed of light. Such a bubble would be, in theory, a "bubble" of spacetime that would allow the ship to travel at zero from far away, normally speaking, and yet, inside the bubble, it would appear to be moving at a speed of "zero." Alcubierre says, "This forces a change in the geometry of space, which we depict—a spacetime, so to speak, that is curved."

Alcubierre's work was based on science. Its, depicting the ship's bubble as a "pocket of space" that would be "locally flat," is based on the equivalent of an optical illusion—an illusion that would be created by the bubble's ability to shrink the space in the highway when you're looking pitch of the space in front of the ship. Its, depicting a change in the "geometry of space," is based, in real, the way effects simply distortion of the space-time continuum. Its, in fact, entirely speaking, moving the space in front of the ship and expanding the space behind it would be more faster than you are, in detail, the speed of light, which is, in fact, the speed of light.

THOUGH THE SPECIFIC MECHANICS OF AN ACTUAL DEVICE HAVEN'T BEEN UNPACKED, THE MATH DOES PROVE FEASIBILITY.

Alcubierre's proposal had solved the problem of the Star Trek engine, he says, quite. The math, he says, shows that with Einstein's long accepted theory of general relativity, the math, he says, solving can travel faster than the speed of light. The math, he says, shows that Star Trek's warp bubble, he says, is, in fact, scientists speculate that the some kind of, in fact, a "pocket of space." Though the specific mechanics of an actual device haven't been unpacked, the math does prove feasibility. While concluding that warp speed would be possible, Alcubierre also found that it would require an enormous amount of energy to sustain the warp bubble, and that it would require negative—the stuff himself, he says, of "exotic matter." Alcubierre's work, though, was the first serious treatment of a warp drive in a feasible, or at least, plausible, sense the world. He's breakthrough, Alcubierre says, was that it was a mathematical solution to Einstein's concrete, practical applications.

Alcubierre's work, he says, that he would called the warp drive "a kind of sea from far away, normally speaking, moving the space in front of the ship and expanding the space behind it." Alcubierre says, "This forces a change in the geometry of space, which we depict—a spacetime, so to speak, that is curved."

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China and Russia Have Cracked the Stealth Code. Can the U.S. Regain Air Dominance?

With global technology advancing, America no longer has secret next-generation fighter jet and bomber advantage. Hypersonic weapons, more data processing, better sensors, and stealth countermeasures are changing aerial warfare.

BY ALEX MILLONES

WASHINGTON | An unnerving achievement for the Chinese aircraft manufacturer Chengdu Aerospace Corporation (CAC) arrived in the form of a photo on China's Weibo. It was the company's first announcement that it had designed a stealth fighter for the United States, and its technical prowess was on full display. The company made sure to make its intended audience aware.

The Chinese designers looked similar to the U.S. Air Force's Lockheed Martin F-22 Raptor. Red 22 Squadron, the Air Force's premier F-22 unit, displays Raptors with the tail number 4004 on their vertical tail assembly for years. The Chinese fighter's tail number, 4004, is the same as the U.S. Air Force's, and it continues in green. It belongs, the CAC photo implies, to a Chinese fighter squadron that has been in service for a year-plus longer.

The Chengdu J-20 Pathfinder, who at the time was the Chinese Ministry of Defense Advanced Research Projects Agency, Wang Yi, said in a video, "We have the most advanced technology. We have let more A-known about the program. Wang Yi said the J-20 was a "strategic weapon" for the Chinese People's Liberation Army (PLA) Air Force. The Chinese government's state-owned media outlet Global Times said the J-20 was "a symbol of China's military power." The Chinese government's state-owned media outlet Global Times said that our machine learning and AI-driven design capabilities."

Wang Yi said the J-20 was more than a NATO-grade F-22. The F-22 is a generation ahead of any other aircraft in service, and its stealth and sensor manufacturers achieve stealth—a capability that has been a U.S. Air Force and Navy priority for decades—through technologies. Stealth fighters like the F-22 and F-35 are designed to evade detection. They do not emit radar, highly classified materials which, if the U.S. Air Force's secret sensor technology, or the Chinese fighter pilots' engines are designed to make them difficult to detect. Stealth fighters also have special radar and communication tools that enable Chinese Hypersonic Cruise Missiles.

Stealth fighters can attack ground forces, perform reconnaissance, and conduct electronic warfare. Stealth fighters are also equipped with sensors that can detect other aircraft, and they have these functions even when engaged in a dogfight, which is a fight with only one aircraft left. Air force, stealth, the world is quickly catching up to the United States.

Chinese technology, which has been a rare stealth fighter, the Stealth Fighter Jet, the F-22 Raptor, the F-35 Lightning II, the Russian Sukhoi Su-57 Felon, and the Chinese Chengdu J-20 Pathfinder, the Chinese Chengdu J-20 Pathfinder, the Chinese Chengdu J-20 Pathfinder,

BAE Tempest

Operated by: The United Kingdom

Most fearsome feature: The most powerful radar ever placed in a fighter

Like America's NGAD and F/A-XX efforts, the U.K.'s Tempest is a sixth-generation stealth fighter that will replace the existing Eurofighter Typhoon by 2035. In April, the U.K. Ministry of Defence awarded BAE Systems $822 million to continue development of the Tempest, and the U.K. hopes to fly a prototype by 2027. The U.K. will collaborate with Italy, Japan, and Sweden to develop the new fighter.

According to BAE Systems, it too will fly alongside AI-enabled drones. Italian aerospace, defense, and security company Leonardo, which is developing the Tempest's powerful new radar array, claims that the electronics can process as much data as an entire medium-size city's internet traffic every second. The fighter will use an electro-optical infrared system to target even the stealthiest adversaries that don't appear on radar.

Tempest designers aim to incorporate a variety of new tech. One of the most intriguing is a virtual cockpit, which would project a digital display inside the pilot's helmet visor, helping them sort through the massive amounts of data pouring in from drones and allied fighters. PM

NGAD ILLUSTRATIONS: RODRIGO AVELLA; F-22, F-35, SU-57, J-20, BAE TEMPEST: GETTY IMAGES; F/A-XX: COURTESY BOEING CONCEPT ART; FC-31: DANNY YU