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PROXIMA CENTAURI

Could we reach this star before the end of the century?

Learn what it would take

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Interstellar travel remains the stuff of science fiction, but breakthroughs could be in reach, provided we're willing to compromise on some of our more fanciful visions of interstellar travel. ***Michael Peck*** *spoke to experts about the feasibility of getting a spacecraft to another star before the end of the century.*

The date is December 31, 2099,

the last day of the 21st century. The place is Proxima Centauri, a red dwarf star tucked into a corner of the Milky Way galaxy. A metal cylinder attached to a device that looks like an umbrella approaches the star at one-fifth the speed of light. As it zooms past, a tiny antenna transmits a stream of data. A little over four years later, the first close-up images of another star arrive back at Earth.

For millennia, this could only have been a dream. When the ancients looked at the stars, they beheld the face of heaven. When astronomers peered up, they marveled at the wonders of the cosmos. But always those brilliant points of light seemed unattainable, too distant for humans to visit. However, new technologies and scientific research suggest that travel to the stars may be in reach, if not as easy as "Star Trek" makes it seem. The first interstellar flight could, in theory, begin by midcentury, using technology that isn't far beyond what we have today.

"I think you could send a vehicle the size of a Coke can to the stars," says Kelvin Long, a British aerospace engineer and

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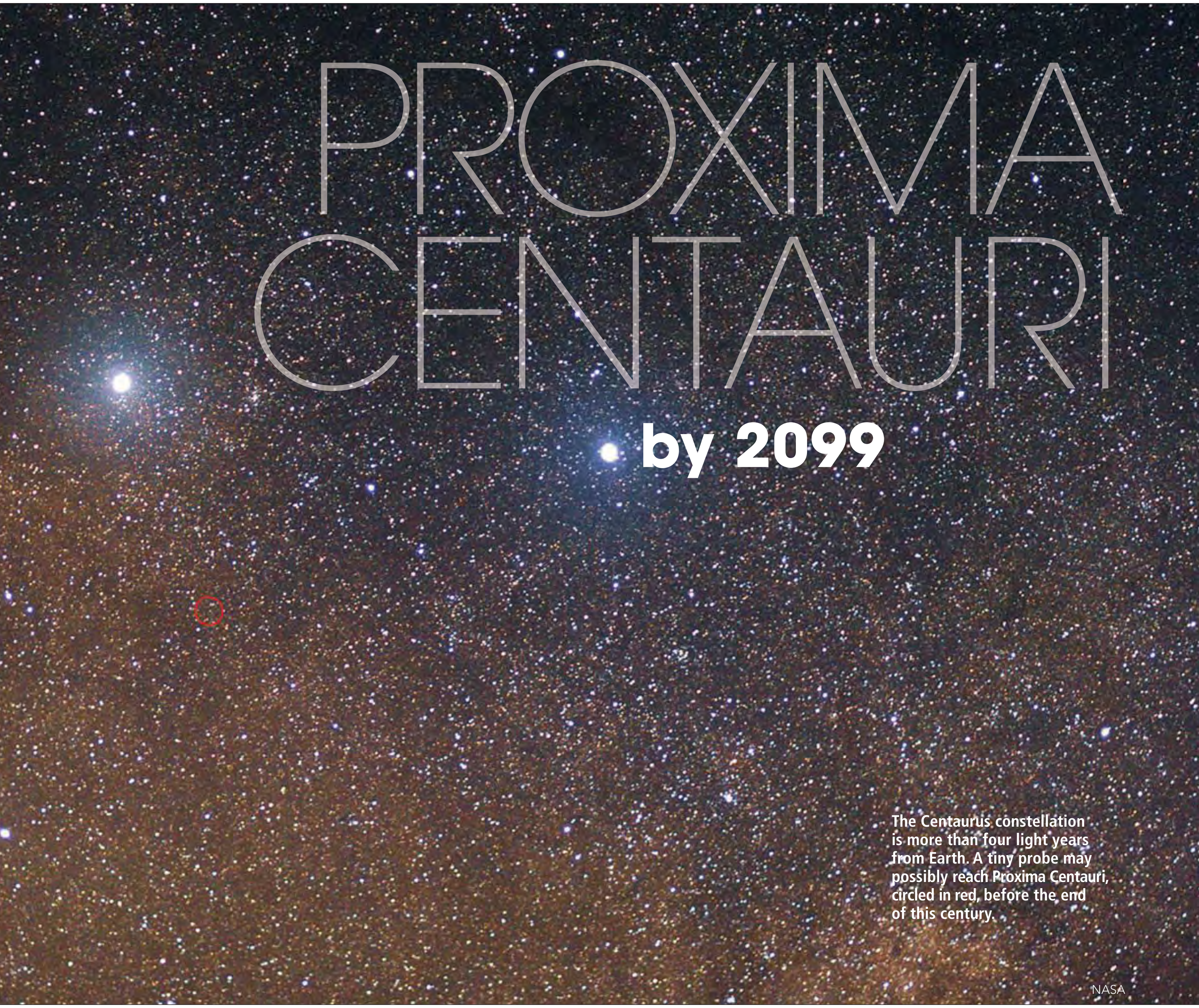
PROXIMA CENTAURI by 2099

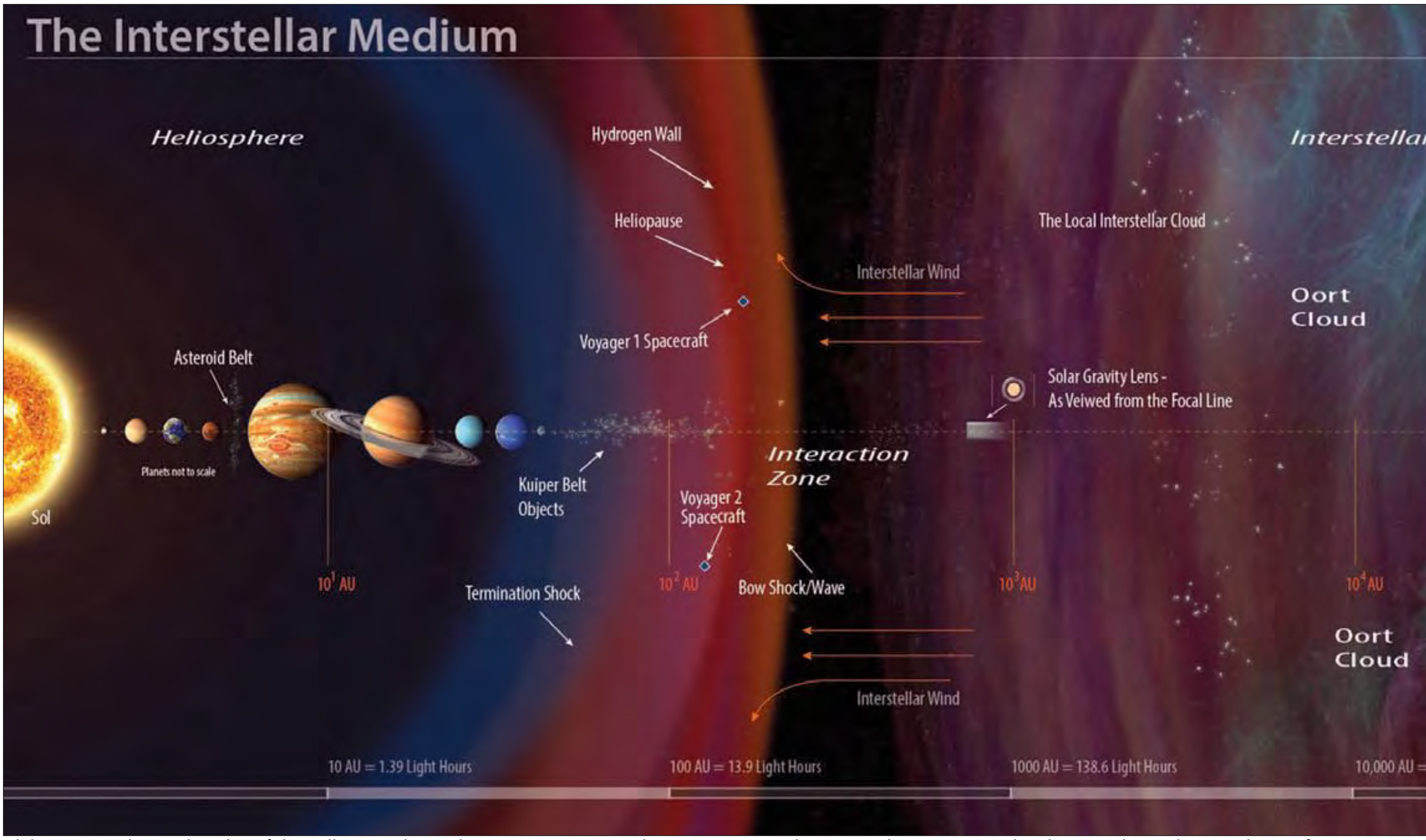


The Centaurus constellation is more than four light years from Earth. A tiny probe may possibly reach Proxima Centauri, circled in red, before the end of this century.

NASA

executive director of the Initiative for Interstellar Studies, a privately-funded offshoot of the British Interplanetary Society. Long imagines a probe propelled by laser beams reflecting off a light sail. Because the spacecraft is small, it would require a comparatively small amount of energy to accelerate it to 20 percent of light speed. If launched around 2050, it could reach Proxima Centauri by the late 2000s, equipped with a variety of instruments to observe Earth's nearest neighbor, as well as any nearby exoplanets.

A starfaring Coke can isn't exactly the starship Enterprise, but it is the sort of practical solution that will probably be needed to confront the daunting obstacles to interstellar journeys. As any science-fiction fan knows, there has never been a shortage of ideas for interstellar travel, from laser propulsion to fusion power to anti-matter driven starships. The real problem has been how to separate fact and feasibility from dreams and wishful thinking. Long is among a new breed of researchers who are attempting to inject here-and-now rigor into



Alpha Centauri lies at the edge of the Milky Way. This Keck Institute map, created in January 2015, shows NASA's Voyager 1 probe, the most distant human object, after it entered interstellar space in 2012, some 20 billion kilometers from Earth and the sun. Voyager 2 is now in the heliosheath, the outermost layer of the heliosphere.

a domain once dominated by futurists.

"A lot of people who work with interstellar think very big picture," Long says. "The problem with being too big picture is you lose your connection with the bottom line of what is really practical."

Scoping the problem

NASA's Voyager 1 probe is now leaving our solar system at 17 kilometers per second. The New Horizons Pluto probe is headed off into our solar system's Kuiper Belt at 14.4 kilometers per second. That sounds fast until you consider the distances. Proxima Centauri, the nearest star to our own, is 4.3 light years away. If a probe were dispatched toward it at Voyager or New Horizons speeds, it would arrive 70,000 years later, long after its makers had died and their descendants had ceased to care. The Apollo 10 spacecraft that passed behind the moon in 1969 was the fastest that humans have ever traveled, and that was 9.3 kilometers per second. At that rate, it would take about 139,000 years to reach Proxima Centauri.

An interstellar vessel would need to have a speed of at least 10,000 kilometers per second, or 3.3 percent of lightspeed, according to Long, a member of the team that in 2011 won DARPA's 100-Year Starship competition to design an interstellar craft.

Wafersat

One option would be to start small. Long's "Cokesat" probe seems positively enormous compared to an even tinier spacecraft envisioned under the Directed Energy Propulsion for Interstellar Exploration project, a research collaboration between NASA and several California universities. The aim is to apply directed energy to send a "wafersat" to the stars. Project leader Philip Lubin, a physicist at the University of California, Santa Barbara, envisions a 10-centimeter probe weighing one gram — about the same weight as a small paper clip — attached to a one-meter sail (the name "wafersat" was derived because one of the spacecraft being developed is literally a silicon wafer).

First, 50 million one-kilowatt laser amplifiers, each weighing perhaps one kilogram, would have to be launched into orbit, where they would be joined together like a

Chuck Carter/Keck Institute for Space Studies

Lego set to form a scalable laser array that might be, say, 10 kilometers long. Once wafersat is launched to a position near the array, photons would be projected onto the wafersat's sail, propelling the craft like wind on an oceanic sailing ship. This would boost the probe to a maximum speed of 20 percent of the speed of light, or 60,000 kilometers a second. Equipped with miniaturized sensors and communications equipment to beam data back to Earth, a wafersat could reach Alpha Centauri, a three-star system composed of Alpha Centauri A, Alpha Centauri B and Proxima Centauri, in about 20 years.

A one-gram probe doesn't sound impressive compared to other starship designs, but the directed energy approach has its advantages. A spacecraft doesn't have to lug its propulsion system, which allows a smaller vehicle. The system can launch any size of sail-driven ship, though the larger the craft, the less velocity. And for bite-sized probes at least, millions can be dispatched at relatively low cost in a shotgun exploration program. "You can launch a new wafer every five or 10 minutes," Lubin says.

Most of all, directed energy appears solidly grounded in current science and technology, such as lasers and orbital structures. "It is very different than invoking a wormhole, or anti-matter engines, or fusion drives," Lubin says.

Fusion

But others continue to pursue the exotic. One option would be to tap the same basic process that lights up Proxima Centauri and our own stars. In the 1970s, scientists and engineers working under the British Interplanetary Society's Project Daedalus conducted a serious attempt to design a spacecraft that could reach Barnard's Star 5.9 light years away. The designers ultimately settled on a fusion drive that would have trained electron beams onto cryogenic deuterium and helium-3 pellets to ignite them, which would fuse their atoms and expel a plasma exhaust that would move the ship at about 12 percent of light speed, according to Rob Swinney, a British researcher with Project Icarus, a privately-funded group that was launched in 2009 to rekindle the dream of Project Daedalus.

Long can foresee a fusion-powered vessel up to several thousand tons in mass and carrying a crew of several hundred. The Daedalus-like vessel would entail a decades-long journey that would tax the limits of human longevity. Thus Long also suggests a vessel capable of at least partly surmounting the challenges of interstellar distance and time: a small ship, using anti-matter engines to transport a crew of 12. Traveling at 30 to 50 percent of light speed, it could reach Alpha Centauri in a couple of years.

In 2013, Project Icarus unveiled five conceptual designs based on various flavors of fusion propulsion, with each ship hundreds of meters long and thousands of kilograms in mass. Four of the five designs would involve fuel pellets and fusion cooling systems, and the fifth would use a plasma stream compressed by a z pinch. Equipped with a 150-ton science payload, including mini-probes, and traveling at around 5 percent of the speed of light, they could reach Alpha Centauri within 100 years.

"In general, the fusion technology we have investigated suggests that it will be possible to make a 100-year journey to Alpha Centauri sometime in the near future, but still quite some decades away," Swinney says.

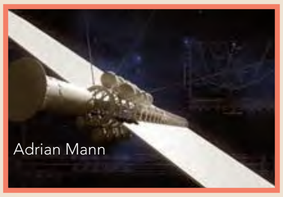
Five fusion concepts

When atoms of deuterium, a hydrogen isotope, or helium-3 are mashed together, the resulting release of energy could, in theory, propel a spacecraft fast enough for interstellar travel. Since 2009, researchers from the U.K., Germany, India, the U.S. and elsewhere have been studying competing concepts for how that might be done. The work is happening under Project Icarus, a volunteer theoretical engineering study to design a spacecraft that could reach another solar system within a human lifetime.

Michel Lamontagne

Firefly

Deuterium fuel would be injected as a continuous plasma stream into the z pinch region, which is created when a large current creates a strong magnetic field that pinches inward and squeezes the plasma until it fuses and is then exhausted rearward.
Lead designers: *Robert M. Freeland II, Michel Lamontagne, Icarus Interstellar nonprofit foundation*



Adrian Mann

Ghost Ship

Deuterium fuel pellets would be ignited by lasers through a fast ignition, inertial confinement process that would compress the pellet until fusion occurs. Pellets would be repeatedly ignited in rapid succession. The concept earned the original Best Entry award in the early Project Icarus Concept Design Competition.
Lead designers: *Lukas Schrenk, Nikolaos Perakis, Technical University of Munich*

Adrian Mann

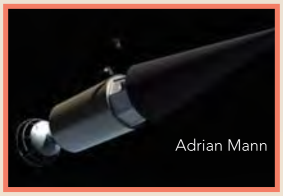
Resolution

Fuel pellets of deuterium and helium-3 would be ignited by lasers. Using helium-3 significantly reduces the release of high-energy neutrons that would otherwise rapidly damage the spacecraft, but helium-3 is a rare commodity.
Lead designers: *Kelvin F. Long, Richard Osborne, British Interplanetary Society*

Adrian Mann

UDD (ultra dense deuterium)

A simplified single laser pulse striking pellets of ultra dense deuterium fuel is sufficient for fusion to occur. To date, there has been no independent validation of the phenomenon of ultra dense deuterium, and UDD is no longer under active consideration under Project Icarus.
Lead designer: *Milos Stanic, Project Icarus*



Adrian Mann

Zeus

Zeus has supplanted UDD in the Project Icarus design program. The complicated ignition has two spherical plasma slugs of magnetically confined deuterium fuel fired together. Then hydrogen plasma is fired at the resulting plasmoid, compressing to fusion. This is known as plasma jet magneto inertial fusion. Researchers so far have been unable to fully model the Zeus's complex ignition physics without making estimates about propulsion, mass and other systems requirements.
Lead designers: *Damien Turchi, David Evinshteyn, Drexel University in Philadelphia*

Sources: Rob Swinney, Project Icarus; Aerospace America reporting

Fusion is not the only theoretical option for interstellar travel, but Swinney says it was the best candidate for the project's goal of using current or near-future technology.

"Chemical, ion and plasma cannot conceivably meet the requirements," he says. "Anti-matter drives are out of near-future reach, and any sort of warp drive or other faster-than-light travel is seemingly beyond reality if not theoretical physics."

Anti-matter

However, other scientists are indeed eyeing anti-matter propulsion. One of them is Eric Davis, a physicist at the Institute for Advanced Studies in Austin, Texas. Anti-matter engines — made famous by Star Trek — would mix particles of matter and anti-matter, such as protons and anti-protons, which are identical but have opposite electric charges.

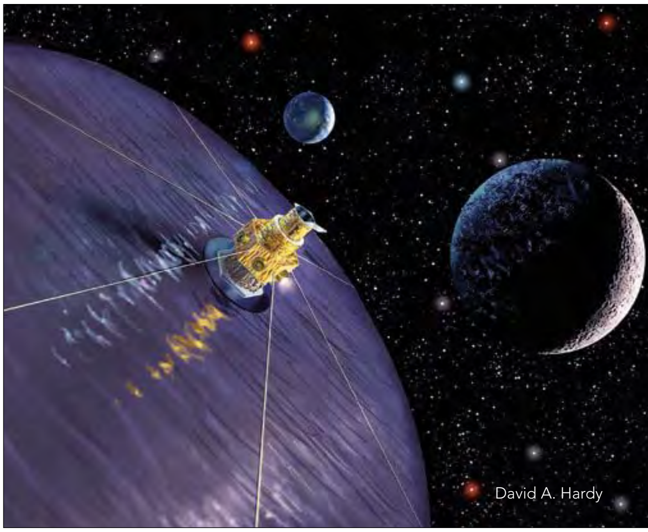
"When anti-matter meets matter, both annihilate in a flash of energy," explained a 2006 NASA article discussing the possibility of an anti-matter spacecraft sending astronauts to Mars. "This complete conversion to energy is what makes anti-matter so powerful. Even the nuclear reactions that power atomic bombs come in a distant second, with only about 3 percent of their mass converted to energy."

In fact, the NASA article stated that a few tens of milligrams of anti-matter — one milligram being about one-thousandth the weight of a piece of M&M candy — would be sufficient to send a ship to Mars. For interstellar purposes, Davis says that an anti-matter engine would be so efficient that a ship could travel at almost the speed of light, which means a trip to Alpha Centauri would take only about five years.

Long imagines a huge spacecraft traveling at 10 to 20 percent of light speed, propelled by fusion engines or anti-matter catalyzed fusion (anti-matter injected into fusion engines).

Davis says key elements are missing though: "The two things that need to be solved to implement anti-matter rocket propulsion is the production of copious amounts of anti-matter, and the storage of anti-matter," he says.

There is one other concept, and it's the most exotic of them all: wormholes, those hyperspace tunnels in which objects enter one end and emerge out the other end at a distant point in space. Davis, who is studying the physics behind this, says the wormhole could be created by negative vacuum energy, which he describes as "an engineered form of quantum vacuum energy produced by the quantum fields of the elementary particles and their interaction forces."



The 2015 winner of the Project Dragonfly contest for a small, laser-sail spacecraft, from Technical University of Munich, would be propelled by reflecting laser light off a sail made of graphene, a thin sheet of carbon, mixed with reflective material.

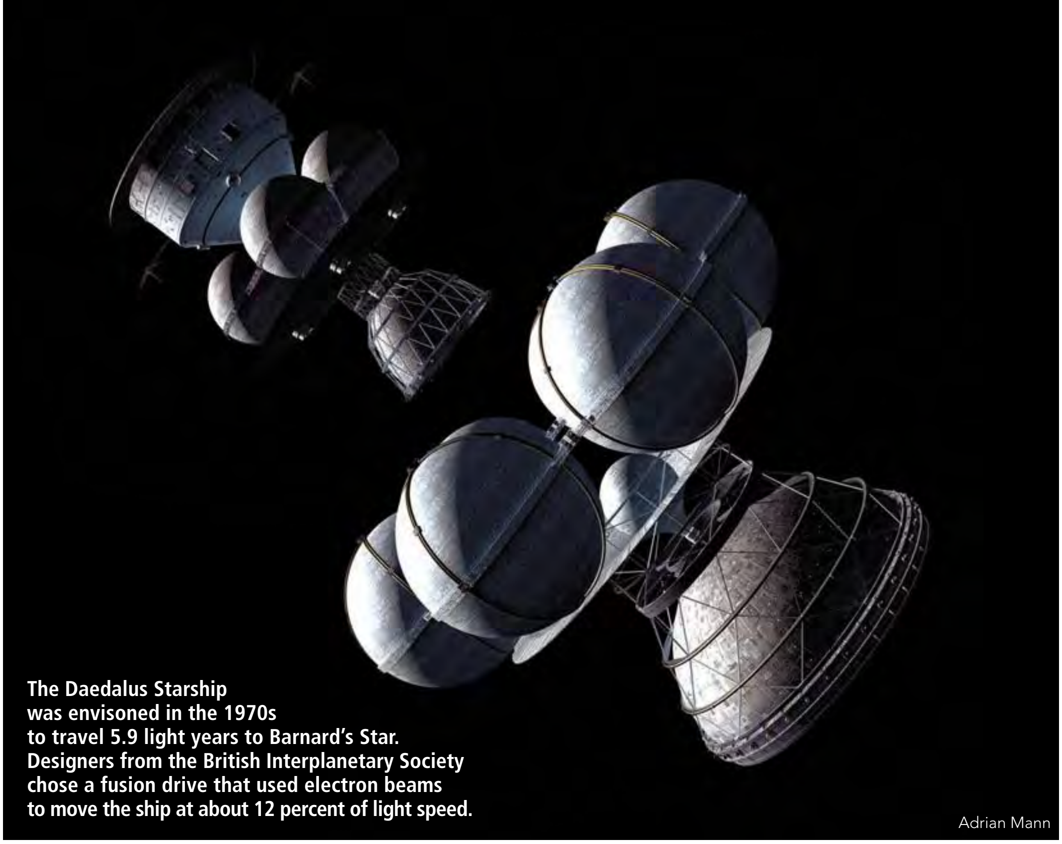
Davis believes a traversable wormhole would have a tunnel several Astronomical Units long, which a ship would have to spend time traveling through. While this means wormhole travel wouldn't exactly be instantaneous, it would be a clever way to bypass the Einsteinian prohibition against faster-than-light travel. "The travelers would move at much less than light speed through the wormhole, while all outside, static observers would view the travelers as having traversed multi-light year distances between the departure star and destination star at faster-than-light speed," Davis says.

What if the goal weren't so much to go fast as it is to carry lots of people? For that scenario, Long imagines a gargantuan "world ship," a gigaton-size vessel carrying millions of people, though only at 1-to-3 percent of light speed. Such a massive vessel would be moved by nuclear-pulse propulsion, in which carefully controlled nuclear bombs generate thrust (a concept explored under Project Orion, a late 1950s U.S. government and private initiative).

Private research

Ultimately, despite all the ideas, there simply does not seem to be one form of propulsion that stands out as light years ahead of all the others.

"We have never even sent anything to relativistic speeds," notes former NASA astronaut Mae Jemison, who flew as a mission specialist on the space shuttle in 1992. She now heads the 100-Year Starship Foundation, descended from the DARPA project of the same name (though DARPA



The Daedalus Starship was envisoned in the 1970s to travel 5.9 light years to Barnard's Star. Designers from the British Interplanetary Society chose a fusion drive that used electron beams to move the ship at about 12 percent of light speed.

no longer provides funding).

Jemison's organization is trying to lay the groundwork for achieving interstellar flight.

"Everybody says, 'let's put together a technology roadmap.' But we're not there yet, because that assumes you know where you are going and you know how to get there."

That is why Jemison's project, which is privately funded, isn't focused on designing specific interstellar craft with a specific launch date, but rather on developing the fundamental capabilities that allow humans — if they so choose — to launch a human interstellar expedition by 2112. These capabilities must span everything from propulsion, to keeping people fed for long voyages, to creating clothing that can endure for years without replacement.

Jemison predicts interstellar flight will be a gradual process that might include stepping stones like a moon base.

"It's not Alpha Centauri or bust," she quips. Long says that once humans can travel to the outer planets of our solar system, humans will be halfway to achieving the capacity for interstellar travel.

Justification

With so many options for interstellar travels, and so many of those options difficult or expensive, critics say that we need to begin with a fundamental question: Why?

Sten Odenwald, a retired NASA astronomer who wrote "Interstellar Travel: An Astronomer's Guide" in 2015, argues that just traveling to another star doesn't make much sense.

"There are three simple questions that drive exploration of any kind: Where are we going to go, what are we going to do when we get there, and how will it benefit people back home?" he says.

As Odenwald sees it, the Alpha Centauri system is unlikely to have terrestrial planets, nor anything else of scientific value that would justify spending hundreds of billions of dollars to explore. For the public to support a long-term project with no immediate benefits, there has to be more of a reward than merely showing the flag on another planet. There has to be something that will interest the taxpayers back home, such as a planet that appears to have signs of life.

"That will be the best motivation for the first interstellar probe," Odenwald predicts. "There will be a destination we know about, a reason for going there, and the prospect of finding something fascinating."

For Jemison, the undertaking would itself be worth the effort, regardless of what is discovered or not discovered.

"The most incredible thing about interstellar travel is the challenge that it presents to us," she says, "and how solving some of those issues will fundamentally change life here on Earth."