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Commentary: Let’s send the DOE to Alpha Centauri

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Commentary

Let's send the DOE to Alpha Centauri

The announcement of an Earth-mass planet orbiting the closest Sunlike star[1] has renewed discussion of the costs and benefits of an interstellar probe. The planet, Alpha Centauri Bb, is in an extremely hot orbit, but its existence increases the probability that a planet with a liquid-water ocean orbits Alpha Centauri. Data from NASA's *Kepler* telescope now show that there are about as many habitable-zone, Earth-sized planets as stars,[2,3] and in April NASA decided to fund a follow-up spacecraft, the *Transiting Exoplanet Survey Satellite*. Before this decade is out, we will probably discover an ocean-bearing planet orbiting a nearby star. When we do, should we send a mission?

Scientific rewards from such a mission would extend to all fields. Earth's climatic complexity, biosphere, and geodynamics are unique in the solar system. If we could double our sample of planets that have surface oceans, geophysicists would have a chance to understand whether Earth's environmental stability is an inorganic phenomenon, a result of global biological feedback (the Gaia hypothesis), or a statistical fluke that allowed us to survive to witness it. Astronomers and space physicists would gain from study during a probe's travels, both interstellar cruise and the exploration of a second circumstellar environment—especially the environment of Alpha Centauri, a multiple-star system. Topics would include the planet's chemistry, orbital environment, and climate. Finally, a mission would address questions that can never be convincingly answered by near-Earth telescopes: Could the planet be made habitable? Is it already inhabited?

Any robotic flyby of Alpha Centauri in the foreseeable future would be led by the US. Compared to the technologies of NASA's *Voyager 1*, currently 0.7 light-days from Earth, improved guidance, navigation, control, and autonomous operations would be required. For example, longer-baseline parallax measurements are needed to reduce errors in calculating Alpha Centauri's position. Optical links are better suited to interstellar communications than is Voyager's radio transmitter.[4] Even if the probe carried a *Hubble*-class telescope, such as the two recently made available to NASA by the National Reconnaissance Office (see PHYSICS TODAY, July 2012, page 26), it would not be able to send back high-resolution images of the target star early enough for humans to update the encounter plans, so some autonomy is essential.

Artist's impression of the Earth-mass planet (crescent) and two stars (center and lower left) in the Alpha Centauri triple-star system. A spacecraft propelled by a fusion or antimatter rocket could travel the 4.4 light-years from Earth to capture detailed images and spectra of the planets in this system. From this vantage point, our own sun (upper right) is the bright star piercing the Milky Way in the constellation Cassiopeia. (Image courtesy of ESO/L. Calçada/Nick Risinger, skysurvey.org).

Engineering and materials science challenges are involved in building a spacecraft that would be reliable for the long term and rugged enough to withstand collisions with interstellar dust at speeds much greater than 10^3 km/s, and the limited number of received photons will force a tradeoff between spectral resolution and spatial detail for the flyby. But all those challenges are within NASA's reach, and they could indeed provide a new stimulus and focus for the agency.

However, NASA alone cannot reach Alpha Centauri. The rocket equation states $M_f/M_{sc} = \exp(V/V_e)$, where M_f is fuel mass, M_{sc} is spacecraft dry mass including payload, V is cruise speed ($10^{-2}\,c$ to $10^{-1}\,c$, where c is the speed of light), and V_e is engine exhaust velocity. Ion engines reach V_e of approximately $10^{-4}\,c$; chemical rockets are even less efficient. Much higher V_e is needed to reach the stars in a reasonable time, and that requires antimatter or fusion propulsion.[5]

Turning a high-energy physics experiment into a propulsion system has been done before: Within six years of its inception in 1949, the Naval Reactors organization, then led by Hyman Rickover, developed the first fission reactors for the US Navy's nuclear fleet. However, the problem is not one that NASA is designed to solve.

Developing technology for an interstellar rocket makes scientific sense when there is a compelling scientific reason, when the physical principles of the technology are well understood, when going still faster would require unanticipated new physics, and when the technology will not be developed for another purpose. All four conditions are true for fusion and antimatter propulsion. With fusion or antimatter propulsion, V is approximately $0.03\,c$ or, very optimistically, $0.1\,c$ or higher.

Could an interstellar mission hold the public's interest for the duration—two or three times as long as the *Voyager* missions? Then again, since the costs of construction would exceed the costs of operation, sustained public interest might not matter.

The US Department of Energy and its international partners have committed approximately $100 billion to fusion power research over the years. In doing so, they have gambled that fusion power will not face the same public opposition that has stymied fission power. The tenor of the recent debates leading to nuclear switch-off in Germany and Japan suggests that fission versus fusion is a fine distinction that will not be made. A fusion propulsion system would be assembled from radioactively inert components in high orbit—that is, in no one's backyard. Fusion propulsion requires only that ejecta momentum is aimed in one direction, and it does not require net power output.

Inertial confinement fusion—and pulsed fusion more generally—is a step toward interstellar flight. Although the main purpose of the National Ignition Facility (NIF) is to sustain an arsenal of nuclear weapons, Lawrence Livermore National Laboratory has promoted peaceful uses for NIF's successor. Even from a narrow national-security perspective, that approach is reasonable: A revolutionary mission with peaceful purposes is valuable for attracting talented people, demonstrating continued US leadership, and maintaining a technological edge. The national laboratories most associated with weapons design—Los Alamos, Lawrence Livermore, and Sandia—take pride in solving complex physics and engineering problems. But the National Ignition Campaign has not succeeded as scheduled (see PHYSICS TODAY, June 2013, page 20), and the post-Fukushima opposition to nuclear power is hardening. Interstellar propulsion offers a substitute complex problem, so exoplanet discoveries provide an alternative focus for fusion research.

If the extremely high efficiencies needed for interstellar travel cannot be achieved with a fusion rocket, NASA and DOE would still have produced an extremely capable vehicle for travel to Mars, asteroids, and the moons of Saturn and Jupiter; it could be used for science, terraforming, or settlement.

Clearly, an interstellar probe would represent something beyond the continuation of long-running programs at NASA and DOE. In the current fiscal climate it is tempting to dismiss it as unacceptably ambitious. But powerful images reset assumptions: Pictures of Earth—*Blue Marble* and *Earthrise*, for example—taken by Apollo astronauts helped to launch the global environmental movement. Similarly, an image of an ocean planet around another star[6] would unsettle our assumption that Earth is the only planet in our own long-term future. Such a widening of horizons has happened before: The detection of the New World broke European scholasticism and contributed to the Copernican revolution.

Four hundred years later, we scientists still wonder if Earth and life on it resulted from chance or necessity.[7] Until SETI succeeds or we can build optical telescopes the size of Los Angeles, an interstellar probe is the only experiment that can end that speculation. Galileo Galilei wrote that living beings beyond Earth "would be extremely diverse, and far beyond all our imaginings." Let's put his hypothesis to the test.

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