A Starship is Born

By Robert W. Bussard

When the legendary inventor Daedalus prepared to flee Crete, where he was held captive by King Minos, he made wings from the feathers of birds for himself and his son Icarus. Held together by wax, the wings worked well until Icarus flew too near the sun, our local star. The wax melted, the wings dropped off, and Icarus plunged to his death. Daedalus stayed away from the sun and made it safely all the way to Sicily.

Clearly, Daedalus had an ingenious technology, but not one that was developed enough for starflight.

Is anybody else's? Are any of the technologies on which we are working likely to succeed in getting us to the stars, or are they fruitless exercises of the imagination? I believe that at least one of them will get the job done. Solid research and development work has been under way for some time on technologies showing the most promise. It is true that much of the work is being done for reasons that have very little to do with starflight, but perfectly logical extensions of the present work can lead to capabilities necessary for the grand adventure.

No Fuel Stop

If you are going to drive from San Francisco to New York, you top off your gas tank, but you also have the assurance that there are plenty of gas stations along the way where you can refuel. For starflight, at least for the foreseeable future, there are no places to stop. Either you take your fuel with you, or you make it as you go along.

The Orion starship, powered by fission, has generally been talked of only for interplanetary travel. Although fission research can probably lead to a design for a hypothetical starflight vehicle, the amount of expensive fuel it would have to carry makes it an unlikely candidate for flights involving the enormous distances we are talking about.

Other proposals, however, are more promising. The British Interplanetary Society's Daedalus starship will be powered by the fusion of deuterium pellets ignited by a laser. The result will be a series of pulsed micro-explosions, which provide a series of impulses in a magnetically insulated "thrust chamber" to propel the ship. Since 1970, nearly a billion dollars have been spent on laser fusion research at Los Alamos, at the Livermore National Laboratory and in the Soviet Union.

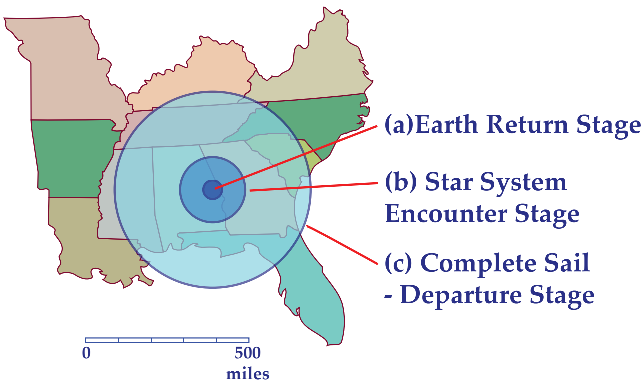
The Enzmann deuterium rocket awaits magnetically confined fusion power units that will provide constant drive. These so-called magnetic bottles have been under study for 30 years and $10 billion have been invested. Once pure fusion passes energy break-even-energy output equal to energy input-and can be confined in a magnetic bottle, fusion rockets are sure to follow. Work at Princeton's tokamak test reactor suggests that break-even may be only a few years away. Starflight will need a hundred to a 'million times more fusion power than any of the present research is designed to produce, but the successful debut of tokamak late last year is a giant step in the right direction.

Annihilation Energy

Another solution to the problem is "annihilation energy." When a particle of antimatter collides with a particle of normal matter, energy is released, and that energy can be used to power a rocket. Antimatter research has been under way since 1975 at the CERN particle accelerator near Geneva, Switzerland, and at

Fermilab in Illinois. By accelerating protons to close to the speed of light, then smashing them into a target, antiprotons can be produced.

Before antimatter can be considered a practical for for starflight, two things have to happen. Today, a million protons have to be smashed to produce one antiproton; this process has to become 10,000 times more efficient before annihilation energy is practical. The second challenge is antimatter storage. At present an antiproton has been stored for 10 hours, but what is needed is condensed blocks of antimatter that can be stored for years aboard ship as it flies to the stars.



The size of the light sail becomes clear when it is sketched on a map. Section c is its brake. Maneuvering is done by a and b.

Next, let us look at technologies that are proposed for making at least some of the fuel while the trip is in progress. The first of these, the ram-augmented interstellar rocket (RAIR), will follow the successful development of deuterium fusion. Interstellar hydrogen will be scooped up during the flight, and its kinetic energy used to augment the on-board fuel supply. The RAIR will perform like a rocket until it has achieved sufficient velocity for its hydrogen intake to reach proper levels.

The Bussard interstellar ramjet will gather all its fuel in flight, but again there are developments that must be awaited. The work on the magnetic bottle must be completed. Once this has been achieved for deuterium fusion rockets, the ramjet engine requires the extension of this technology to hydrogen, for it is hydrogen, not deuterium, that is found between the stars. The hydrogen will be collected by vast magnetic fields generated by a coil wrapped around the craft. The fields will need to be hundreds or thousands of miles in diameter. The extension to hydrogen fusion offers no fundamental obstacles. The investment will be another $10 or $20 billion, and we are already on the road to successful deuterium fusion.

Advances in two technologies that are essential for the Forward light sail are on their way. Lightweight sails have been studied for a decade, and sample materials and structures have been developed. The majority of these studies have been funded by NASA. Over a billion dollars have already been spent on laser research, and solar-drive lasers that will be necessary for the light sail have been built and demonstrated. It is quite true that the work has been on a small scale. The power required for starflight is thousands to millions of times greater than anything at hand can provide, but again, it is only a question of time and money.

We have obviously made progress since Icarus. The beginnings of the technology necessary for starship engines are well behind us, Work now in progress, even though most of it is being done for other reasons, will carry the technology further. Barring a global catastrophe or a nuclear war, we should see mankind moving out into the galaxy within a hundred years just about 400 million years after our earliest ancestors evolved out of the Precambrian seas.

Interstellar Reading

The Illustrated Encyclopedia of Space Technology, Chapter 21. Chief author, Kenneth Gatland. New York: Harmony Books, 1981, 290 pp, $24.95.

Most publications on starship design an, tucked away in technical journals; "A Program for Interstellar Exploration," by Robert L. Forward, published in the Journal of the British Interplanetary Society, October 1976, is a good place to begin and includes diagrams. www.bis-spaceflight.com/JBIS.htm

Solar Sailing

Laser-powered sails may be a long way off, but a solar sail is just around the corner, and the gift of a rocket booster from Hughes Aircraft's space and communications group has brought it even closer. The World Space Foundation's test sail is scheduled for launch in 1985 or 1986, and the booster could provide the power to send it into orbit.

The sail will either be launched by the French rocket Ariane or from the U.S. space shuttle. If it's the shuttle, the sail will be accompanied by the Hughes booster, which will lift it into orbit after it leaves the shuttle. The shuttle circles the Earth at 125 to 250 miles, yet the sail must trace an elliptical orbit ranging between 750 and 200,000 miles above the Earth. If all goes well, it will then soar beyond Earth's gravity and into an independent path around the sun.

After the folded sail drops from the shuttle, the booster will fire it to a higher altitude. Once there, the motor will drop off, and the kite-like sail will orient itself to the sun and unfurl to catch its rays. About half the size of a football field and weighing under 450 pounds, the sail will glide effortlessly through space, propelled by the impact of millions of photons striking its thin metallized plastic sails. Acceleration will be slow, but the sail may eventually reach speeds of 20,000 miles an hour. Since it requires no propellant, it is ideal for transporting payloads in space and exploring the solar system.

If the sail blasts off with the Ariane, which reaches an altitude of 22,000 miles, the booster will be used later to propel another sail three-quarters of the way to an asteroid. Sailing to an asteroid is the World Space Foundation's next mission, and according to its president, Robert Staehle, will be possible by 1990.[1]

- Elizabeth Hettich

About Robert W. Bussard

Physicist Robert Bussard, designer of the interstellar ramjet, hasn't read much science fiction over the past 20 years. "I'd rather be doing it," he says. "When I was seven, I decided I wanted to spend my life getting man off the planet."

President and founder of INESCO, which conducts research and development on fusion power, he began his career designing rocket propulsion systems for Hughes Aircraft. Since then, he has worked for the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory, where he developed the world's first nuclear reactor for rocket propulsion. "The idea for the ramjet came out of a blue sky while I was eating," he recalls.

Bussard: "The quest for the technologies to reach to the stars is already in progress."

[1] Although no solar sail has yet been successfully deployed as a primary propulsion system as of 2007, research and development continues with attempts in June 2005 and February 2006.

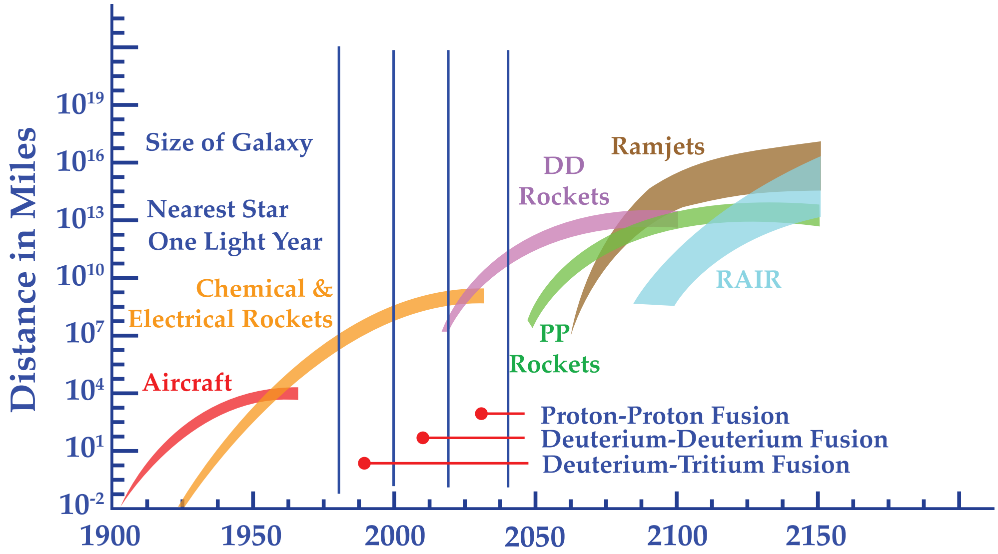


Figure 1 — Starcraft Timetable: Fusion (DD and PP) rockets await development of new nuclear technologies; the self-fueling ramjets and RAIRS will ultimately travel the farthest.

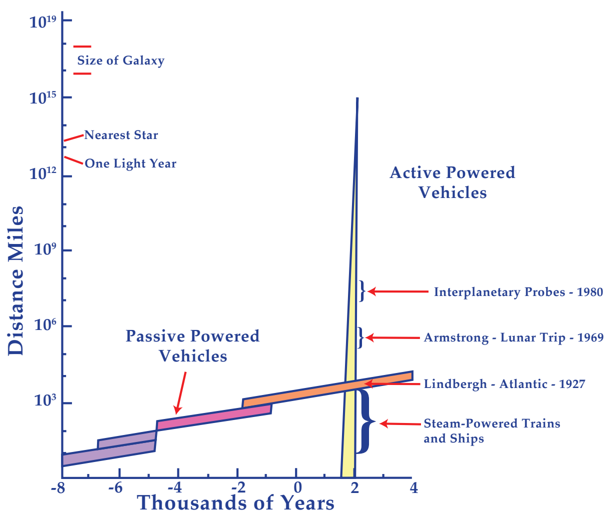


Figure 2 — For thousands of years, man's range was limited by the power of wind and water, yet actively fueled vehicles have brought him halfway to the stars in less than a century.

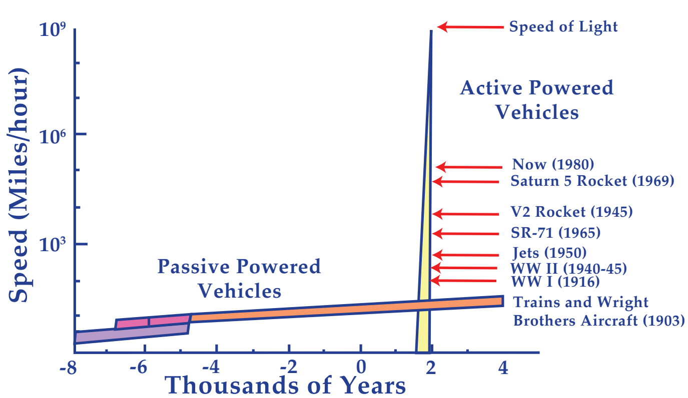


Figure 3 — If today's speeds were to continue increasing a the rate they have to date, we would reach the speed of light by the year 2000; more likely, the pace will begin to slow.