A life for the stars?

By Colin Johnston, Science Communicator

Elsewhere I have discussed the possibility that humans (or our robots) may one day travel to the stars. Using even the most advanced plausible rocket designs, such as the British Interplanetary Society's Daedalus concept, we seem resigned to one-way journey times of decades or centuries to reach even the nearest stars. Such vessels would be enormous, thanks to their colossal propellant requirements.

Some of you may be thinking that this is hopelessly unimaginative. "What about travelling faster than light through warpdrive, wormholes or hyperspace?" you may be asking. Sadly we have no idea how these things could be made real. In fact they are almost certainly impossible. A century ago Albert Einstein proved that light travels at the fastest speed possible, some 300 000 km/s, and nothing can exceed this cosmic speed limit. Faster than light (FTL) travel is an essential element for much of science fiction but it is at heart a fantasy concept. I would really, really like to be proven wrong about this.

"Space is not quite a vacuum "

Robert W. Bussard, who passed away in October 2007, was a US nuclear physicist who is best known for a speculative space propulsion concept he proposed in 1960, back in the heady pioneering days of astronautics. The Bussard Interstellar Ramjet offered the intriguing possibility that one day it could be possible for astronauts to get on board a spaceship to travel anywhere in the galaxy or even beyond in their (and note, only their) lifetimes. A Bussard ramjet (in aviation a ramjet is a rarely used form of jet engine, not to be confused with Bussard's concept) avoids the problem of excessive mass by not carrying its fuel with it. Instead it would gather fuel as it flew between the stars.

Space is not quite a vacuum. An incredibly tenuous interstellar medium pervades the space

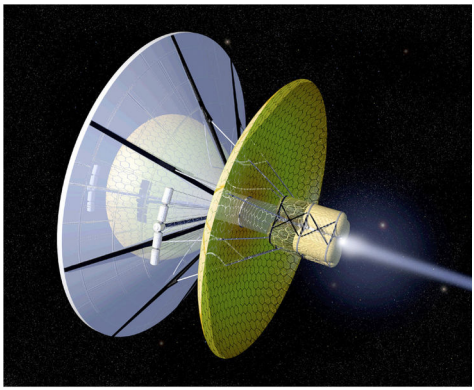
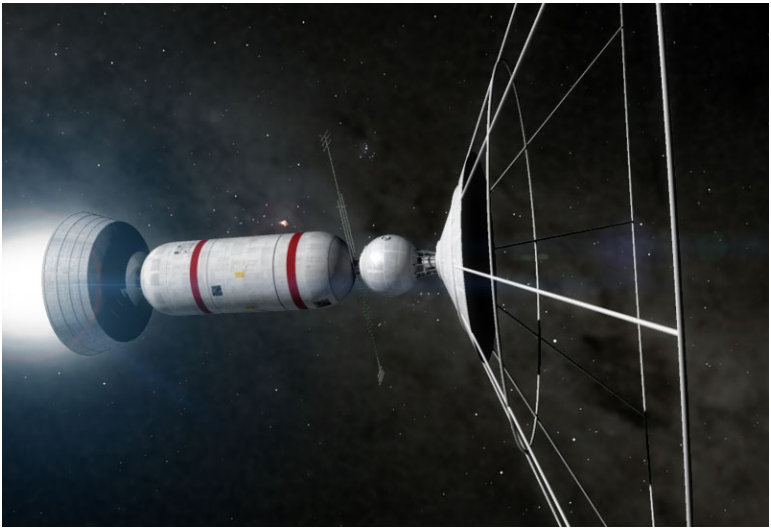


Image Credit: NASA

Bussard Ramjet Starship 1 An artist's impression of the concept. It is hard to depict the craft's scale: almost certainly it would be kilometres across. It will be millennia before we could hope to construct such a vehicle.

between the stars. Imagine a cube of interstellar space 1000 km across, it initially appears entirely empty but if you carefully examine its contents you will find about a gramme of material. About 99% of this thin stuff is gas of which about 90% is hydrogen and nearly 10% helium with traces of other elements. Bussard Ramjets would scoop up this material as they flew (hence their alternative name of ramscoop), use the hydrogen as nuclear fusion fuel and accelerate continuously through their flight. If the acceleration could be maintained at roughly 9.8 m/s^2 (1g or the gravitational acceleration near the Earth's surface), the crew would be able to comfortably walk on their vessel's decks as though it were sitting on the Earth's surface.

As it accelerated, a strange thing would happen to time on board the ramjet starship. This is no place to explain Einsteinian Relativity, it is sufficient to say that century old mathematics show that time runs more slowly on a fast moving starship than it does on the worlds it left behind. The closer it approaches the speed of light, the slower time will run on board. For example, at 0.95c (ninety-five percent of the speed of light), shipboard time is running about a third of



Bussard Ramjet Starship 2 Another artist's impression by the very talented Adrian Mann. If you are interested in more thought-provoking artwork of futuristic space craft see his website http://www.bisbos.com/rocketscience/.

1g for half the trip then decelerating a 1g for the other half, would do it in about 7.5 years as observed by people on Earth- but about four years to its crew! Perhaps human beings could travel to the stars in person after all!

This effect proves more and more useful for longer distances. A ramjet could travel the fifty light years to the sun-like star 51 Pegasi (home of at least one planet) in about 52 years

the rate it does on Earth. To the ramjet's crew nothing unusual is happening but a stationary observer would see them moving in slow motion, (apologies to any relativistic physicists reading, I am simplifying an awful lot here). At the end of their 15 minute tea break, an hour and four minutes have passed on Earth. This effect gets more extreme as the ramjet accelerates. At 0.999c, an hour on board the starship passes in a day of Earth time.

"Einstein's time dilation sounds crazy but will really happen"

This, Einstein's celebrated time dilation, sounds crazy, but there is excellent experimental evidence that this will really happen. No spacecraft yet built has travelled fast enough to experience this effect, but accelerating short-lived subatomic particles to near-light speeds physicists have lengthened their time of existence. Imagine if we could really build a Bussard Ramjet. The robotic Daedalus probe discussed in the last issue would cross the six light years to Barnard's Star in about fifty years, a ramjet, accelerating at measured on Earth, but less than eight years to the crew. On their arrival back on Earth, less than two decades will have passed for the intrepid explorers, but they will return more than a century after they departed. The Earth they come back to may be as alien to them as any exoplanet. Even more fantastic trips would be possible; a really determined young crew could set off on a round trip to the Galactic Core, 26 000 light years away. They would experience a 40 year journey, but the by now middle-aged crew would return to Earth 52 000 years after they left. Even intergalactic missions would be possible. A Bussard ramjet offers return trips anywhere in the Universe and one-way trips to the future. The concept has been a wonderful gift for science fiction authors.

Could we build such a craft one day? Even on a superficial examination there are difficulties with the idea. The Bussard ramjet must be boosted to a certain minimum speed before the scoop action functions. This speed may be as high as 6% of light speed (0.06c), necessitating a Daedulus-style rocket as an auxiliary propulsion system.

The ramjet would need an enormous collection area to capture its fuel. Bussard calculated that a 1000 tonne ramjet vessel would need a scoop

more than 100 km across. Doubtless this collector would not be a material object but cleverly shaped magnetic and electric fields generated by the vessel. This could be useful: as the ramjet approaches its destination, the polarity of the fields could be reversed, creating a drag force, slowing the ramjet to an eventual halt.

Possibly the toughest of all the technical issues with the concept is that trying to use hydrogen (as opposed to a hydrogen isotope like deuterium) in a fusion reactor requires us to use a reaction, the proton-proton cycle, which as far as we know can only happen in the awesome extremes of heat and pressure found in the cores of stars. This fact alone makes the original Bussard concept only a tiny bit less impossible than FTL travel.

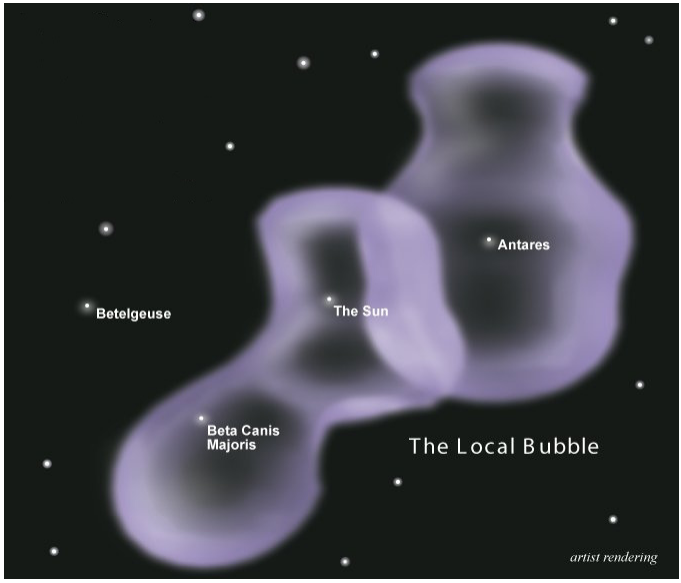


Image Credit: NASA

Empty Space Beta Canis Majoris is the B class variable Gomeisa, visible near Procyon. Antares is located in the neighbouring Loop I Bubble.

Finally there is an astronomical problem to overcome. Earth is not favourably positioned in the Galaxy as a home base for Bussard Ramjets. For at least the previous three million years, the Sun has been passing through a huge void in space called 'The Local Bubble'. Shaped roughly like a peanut, it is about 300 light years across and the Sun is currently located near the centre. The Local Bubble may have been created when a star went supernova (the neutron star Geminga may be a remnant of this cataclysm). The blast wave from the explosion swept through space, blowing away interstellar matter. The interstellar medium within the Local Bubble is about ten times lower than in the rest of the galaxy. This makes the interstellar matter in our Sun's vicinity a poor fuel source for a Bussard ramjet, limiting its performance. The craft would accelerate slowly, taking decades to reach relativistic velocities – until it escaped the Local Bubble!

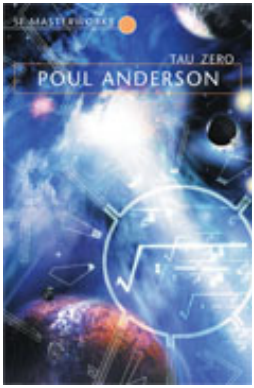


Image Credit: Illustration by Dominic Harman via Amazon.co.uk

SF Classic Bussard ramjet starships have appeared in memorable novels by Larry Niven, Bob Shaw and Vernor Vinge. Greatest of all is Poul Anderson's 'Tau Zero', the story of the strange fate of the crew of the Leonora Christine, a ramjet which runs out of control. The characters are carried helplessly into the very distant future.

The technical difficulties mean that humans will probably never build an interstellar ramjet exactly as Dr Bussard originally described it. Yet the idea of gathering fuel as you travel, rather than carrying it with you is so elegant that it is hard to imagine that it will not be applied in some fashion one day. Then, perhaps, the stars will be in our grasp.