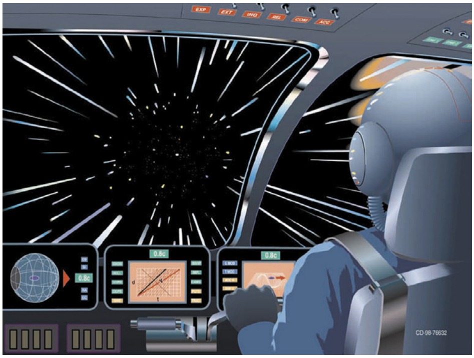
The stars our destination?

By Colin Johnston, Science Communicator

Looking back, it seems that the Golden Age of Astronautics may have occurred in the era 1960-80. Satellites were orbiting the Earth and men soon followed. The Moon was reached shortly afterwards. Most space enthusiasts expected bases on the Moon and flights to Mars to be achieved in the next twenty years (sadly, decades later on these goals are still twenty years away). Looking further into the future from those days, it seemed obvious that the twenty-first century would see the exploration and later, the settlement of the Solar System. Perhaps by the mid twenty-second century, Pluto would be the site of the Solar System's suburbs, and the inevitable 'final frontier' would be the stars. The date when travelling to the stars (interstellar travel) becomes feasible has stretched into the future, but it is still a living dream.

How could people travel to the stars? Space is very big indeed. Imagine the Sun is the size of the full stop at the end of this sentence. If shrunk down to this scale, Earth would be a microscopic speck 5 cm from the Sun, Mars would be a tinier still speck 7.5 cm from the Sun and Jupiter a dust mote about 28 cm from the Sun's dot. Eccentric Pluto would be on average 2 metres from the Sun. The relatively small unmanned probes of today take months to years to span these interplanetary distances. For example, New Horizons was launched on a very fast trajectory and added speed with a gravitational assist from Jupiter, but will still take nine years to reach Pluto (keep in mind that in our scaled down Universe it takes nine years for a one-way journey of 2 m). By applying extremely advanced but plausible engine designs it does not seem impossible that people may one day make similar interplanetary journeys (see the feature on the Orion nuclear spacecraft in the December 2006 Astronotes for what could be possible). The stars however are another matter. Alpha Centauri, the nearest star system to our Solar System, is 4.3 light years from the Sun. On the Sun = Full Stop scale, Alpha Centauri would be nearly 14km from



High speed flight This fanciful view from the cockpit of a hypothetical spacecraft travelling at eight-tenths of the speed of light shows the visual distortions that would be experienced at such high speeds. There is no foreseeable technology that will allow us to achieve such speeds in reality.

Image Credit: Art by Les Bossinas (Cortez III Service Corp.) via NASA

the Sun! If a 2m journey takes nine years, how long will a 14 000m journey take? The answer is 63 000 years to reach the closest star to our Sun. This is many times longer than recorded history and a significant portion of the time that the human species has existed.

Enormously powerful rocket engines that could reduce journey times between the stars are theoretically possible. These are not rockets burning a chemical fuel and an oxidiser as our present day launch vehicles do: for interstellar (and let us be honest, serious interplanetary) flight nuclear propulsion will be essential. Compared to theorised nuclear rockets, chemical rockets are hopelessly inefficient. Nuclear fission engines (such as NASA's 1960s NERVA concept) are better but still scarcely good enough. A reasonable interstellar rocket will have to harness the same energy source as the stars; fusing atoms into heavier elements. Rather like moon bases and Mars missions, generating power by nuclear fusion is still a couple of decades away, but it will one day be possible and later may be applied to spacecraft. What will this technological advance make possible?

In the 1970s, towards the end of the Golden Age, engineers drew up plans for a two-stage nuclear fusion powered interstellar probe they called Daedalus. Their report is still essential reading for anyone interested in interstellar flight and is available on CD-Rom from the British Interplanetary Society which sponsored the research. The researchers assumed that a certain amount of futuristic technology was attainable – but no science fictional magical technologies existed- and an enormous infrastructure in the Solar System (such as mining the planets for resources) pre-existed.

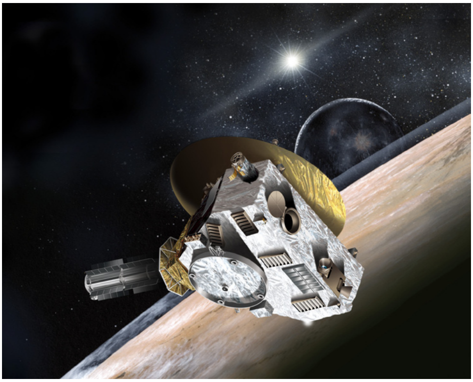


Image Credit: NASA

New Horizons The fastest ever probe is shown flying past Pluto and Charon on 14 July 2015.

The Daedalus vehicle would be enormous; some 190m tall and with a mass of about 52 000 tonnes at engine ignition. In contrast the mighty Saturn 5, still the largest operational launch vehicle every constructed stood 110 m tall and weighed a mere 3 000 tonnes. Like modern launch vehicles, used the 'staging' approached. When the fuel in the vehicle's first stage was exhausted it would be released, allowing the much lighter second stage to dart ahead unhindered. A Daedalus craft would be assembled in space and its fuel tanks filled with deuterium (heavy hydrogen) and helium 3 fuel extracted from the atmosphere of Jupiter. This sounds fantastic but imagine how unbelievable today's routine off-shore oil and gas drilling would sound to our Elizabethan ancestors. The deuterium and helium would be brought together in the vessel's engine to be 'ignited' to fusion by a powerful beam of electrons. Directed by a magnetic nozzle, the resulting plasma would thrust Daedalus forward, accelerating past the Sun's escape velocity, eventually reaching seven per cent of the speed of light. At this point the craft's first stage fuel tanks would be empty so the first stage would be jettisoned, allowing the comparatively small second stage to accelerate to 0.12c (c, it should be explained, is the accepted symbol for the speed of light – hence 0.12c means 12 % of the speed of light).

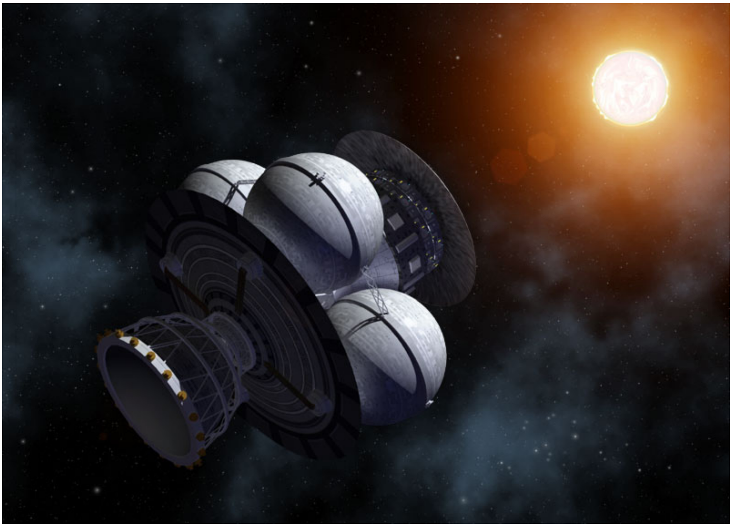
The craft could cover the six light years to Barnard's Star – chosen as a destination as it was believed to have a planetary system at the time of the study - in fifty years and would have burned 50 000 tonnes of fuel in the process. Fifty years cruising through emptiness is of course useless were the starship to have carried a crew but is acceptable for a robotic vehicle. Daedalus would be controlled by a sophisticated computerised artificial intelligence with an intellect approaching (or quite possibly exceeding) human level

"The Daedalus vehicle would be enormous, dwarfing a Saturn V"

However the final 500 tonne Daedalus probe would whizz past Barnard's Star at 36 000 km per second without stopping. The probe would scan the star and its planets with an impressive suite of instruments, including a pair of telescopes each twice the aperture of the Hubble Space Telescope. Eighteen autonomous sub-probes would be launched from the main vessel to add to the encounter's scientific bounty beamed back to Earth. The British Interplanetary Society study suggested that travelling to the stars in a long but reasonable time is not impossible. It is important to bear in mind though that it will require at minimum many decades of technical advances before we could attempt to build such a craft; we simply could not even venture to undertake this today.

Why was Daedalus not intended to stop at its destination? To come to a halt it would need to fire its engines to decelerate, expending even

Image Credit: artwork by Adrian Mann



Approaching Barnard After a multi-decade voyage the upper stage of the Daedalus starship nears its destination. Artwork from http://www.bisbos.com/rocketscience/index.html and reproduced with the kind permission of the artist. This website features some wonderful artwork of spacecraft and aviation concepts

more fuel in the process. That fuel would have been launched with the rest of the probe and more fuel would need to have to be used initially to do this. How much more? The mathematics of rocketry has been established for more than a century so it is easily calculated that at minimum

> "A Daedalus craft would be assembled in space. Its fuel would be extracted from the atmosphere of Jupiter"

740 000 tonnes of propellant in total would be needed at the initial launch. A bigger or faster vessel would need still more fuel. Building a starship capable of accelerating to interstellar velocities then decelerating to a standstill means building an enormous (potentially planetoid-sized) vehicle.

To summarise the last couple of paragraphs, using very advanced technology it may be possible to send a craft slightly bigger than the completed ISS to a nearby star and bring it to rest. The journey would take decades and need the best part of a million tonnes of propellant. Sending a human crew in such a vehicle seems a non-starter, a much vaster still vessel would be necessary to carry people to other stars. Futurists have imagined huge 'space arks' or 'generation ships', essentially space going cities, which cruise majestically between the stars over decades or even centuries. Eventually it is the great-grandchildren of the original crew who arrive at the destination star. Engineering a completely self-contained environment that can maintain human life for centuries may be more difficult than building the engine. Finding people prepared to spend the rest of their lives (and their children's too) in a spaceship may be harder still.

> "...the future may belong to the Cylons "

Perhaps we could explore the stars by sending an advanced artificial intelligence instead. We already explore the planets this way. In the end, it may be that machines and not humans that conquer the stars. The future may belong to the Cylons of 'Battlestar Galactica' rather than the noble crews of 'Star Trek'.

Further reading:

Project Daedalus - The Final Report on the BIS Starship Study, A. Bond et al. JBIS Interstellar Studies, Supplement 1978 (available on CD-Rom from British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, http://www.bis-spaceflight.com/index.htm)