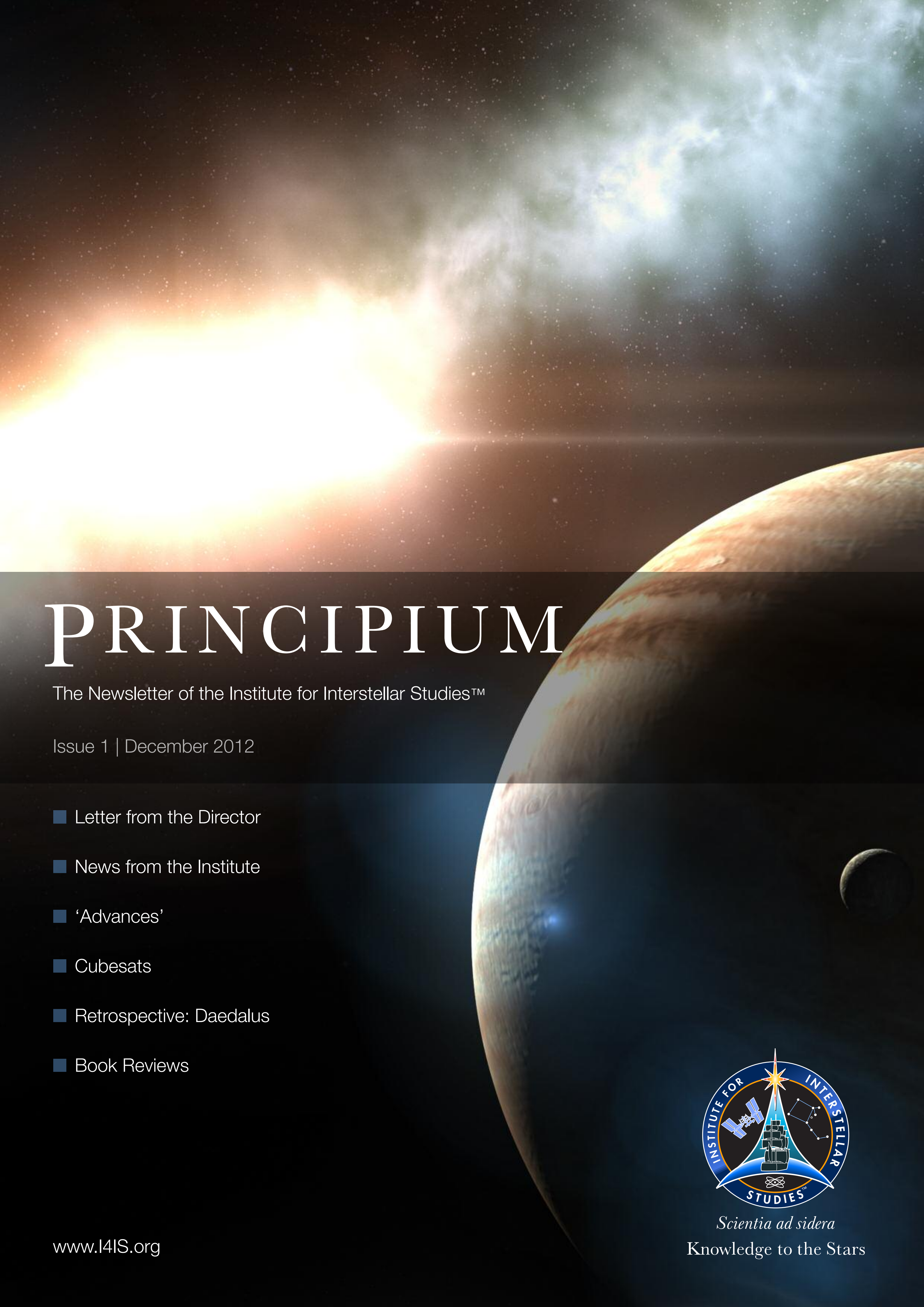


PRINCIPIUM

The Newsletter of the Institute for Interstellar Studies™

Issue 1 | December 2012

www.I4IS.org

INSTITUTE FOR INTERSTELLAR STUDIES™

Scientia ad sidera

Knowledge to the Stars

A letter from Kelvin F. Long

Dear friends,

We live in exciting times. In recent years many planets have been detected orbiting around other stars. This is helping us to realise that there are places to go, as predicted in the many works of science fiction over the last century. In addition, we are now witnessing the emergence of the commercial space sector and space tourism. This gives us hope and optimism that despite the challenges we face down here on Earth, better times lay ahead for our space-aspiring society. A key component of this is learning how to work together in a spirit of co-operation and friendship and this is precisely what interstellar societies tend to encourage. With optimism, hope and an inspirational vision, we can reach those distant stars.

The oldest interstellar society today is the London-based British Interplanetary Society (BIS), founded in 1933 and fast approaching its 80th anniversary. Although it examines the broad issues associated with robotic and human spaceflight, interstellar has always been a core component of its work, with studies like Project Daedalus in the 1970s and the famous 'red cover' issues of the Journal of the BIS that were published between 1974 and 1991. These considered subjects such as the design of World Ships, interstellar precursor missions and the prospect for intelligent life in the Universe. The BIS has been the torch-holder for the interstellar vision for many decades.

In the last few years many others have decided to address the interstellar problem, by the formation of organisations or societies. This includes Vision 21, PI Club, the Interstellar Propulsion Society, the Tau Zero Foundation, Icarus Interstellar and 100 Year Starship. The latest entry into this group is the Institute for Interstellar Studies™. Our main focus is the nurturing of people through our educational academy and the fostering of starship-related research and development.

I am proud to have been the originator of this organisation and I am deeply honoured that many others have shared in that vision and are actively assisting with its foundation. My colleagues and I will work to make the Institute a success in the coming years. This excellent newsletter represents our first publications outreach activity, other than the Institute blog page. In time we hope this newsletter will serve as an exciting information source for the community. I want to personally thank Keith Cooper for taking on this role of Editor and Adrian Mann for assisting with the editorial graphics and production. I hope you enjoy this first issue of Principium and keep an eye on the Institute's website as we gradually announce more activities in the coming months. Scientia ad sidera.

Kelvin F. Long

Executive Director
The Institute for Interstellar Studies™

News from the Institute

I4IS blasts off!

The Institute for Interstellar Studies™ (I4IS) was launched on 14 September 2012. Founded in the United Kingdom, it ultimately aims to have a global outreach. Executive Director Kelvin Long says, "I am very excited about this opportunity, for which the time has now come. Many have worked towards the fulfillment of an interstellar vision over the past decades, and it is hoped that the institute will pull the community together behind a common purpose and a bold enterprise."

Learn more in Kelvin's introduction to this issue on page 2.

Spaced-up

Dr Chris Welch, the deputy chair for I4IS' Senior Advisory Council, gave a presentation about the Institute to the SpaceUp 'unconference' (where participants decide the agenda) in Stuttgart in September. Introducing the Institute for the packed audience, he described I4IS as "a nexus for the activities related to the challenges of achieving robotic and human interstellar flight." He recounted the British Interplanetary Society's Daedalus project (see elsewhere this issue) and how I4IS plans to build on that work by seeking to conduct credible research into the science and technology of starships, ultimately progressing towards a capable and confident human species in interplanetary space, with benefits for life back home too. Welch also gave special mention to the prospect of the I4IS Academy (directed by Rob Swinney), which will see students takes MSc projects with the Institute through the International Space University near Strasbourg.

Dr Chris Welch introduces the Institute for Interstellar Studies at the SpaceUp 'unconference' in September.

The first four students to have signed up to the projects are investigating topics as varied as designing interstellar probes; learning how to decelerate an interstellar probe from a tenth of the speed of light as it approaches its destination star; and exploring agricultural techniques for a deep space microgravity environment, perhaps in a space station or a worldship, populated by a thousand people.

On the road to the stars

The I4IS held its inaugural planning and progress meeting in the fitting setting of the British Library in London on 29 September 2012. Discussing everything from the Institute's priorities during the coming years to Institute-led projects and revenue generation, the conversations during the workshop were abuzz with great ideas and a tremendous amount of hope for the future.

I4IS members present included Kelvin Long, Rob Swinney, Jeremy Clark, Jonathan Brooks, Richard Osborne, Stephen Ashworth and Keith Cooper. Look out for some of the things the Institute has planned coming over the next twelve months – the road to the stars starts here!

I4IS members, with Executive Director Kelvin Long on the left, discuss interstellar matters at the British Library.

Creating an interplanetary civilisation

I4IS team-member Stephen Ashworth has detailed his path for society to become an interstellar civilisation. Inspired by a posting on the Centauri Dreams website, he describes on his blog a "creative community of public and private institutions acting in concert... and a set of new technologies which both multiply wealth and introduce new problems." From thereon he describes a 14-point scenario, starting with government exploration of low-Earth orbit and the foundation of outposts there (already achieved) followed by the onset of space tourism and private space enterprises that we are seeing today, leading to solar power satellites to energise the burgeoning interplanetary civilisation that could embark on new Moon missions and a lunar colony by 2050, Mars and Venus by 2080 and bonafide colonies on or in orbit around numerous planets by the beginning of the 22nd century. By the beginning of the 23rd century the interplanetary economy could have grown by ten billion compared to today's economy, writes Ashworth, with asteroid mining in particular contributing to it and most of our descendants living in space.

Do you agree with Stephen Ashworth's roadmap? write to us and tell us your visions of the future.

To keep up to date with the latest I4IS news, check out the Starship Log on the Institute's **Interstellar Index**
☞ http://www.interstellarindex.com/ blog/

or follow the Institute on **Facebook**
☞ http://www.facebook.com/InterstellarInstitute

and **LinkedIn**
☞ http://www.linkedin.com/groups?home&gid=4640147&trk=anet_ug_hm

Ahead Warp Factor One!

Could we warp space to our will, reducing interstellar travel times to just weeks rather than years? It seems fantastical, but a new experiment may just be the turning point needed to transform fantasy into reality.

A laboratory experiment to test whether space can be artificially 'warped', potentially leading to a 'warp drive' for starships, has been designed by Dr Harold 'Sonny' White and his team at the advanced Eagleworks Labs at NASA's Johnson Space Center in Houston.

When limited to conventional physics, interstellar travel is really going to be a game for the patient explorers amongst us. Chemical rockets and gravitational slingshots would propel probes on interstellar journeys that take tens to hundreds of thousands of years. Even the mighty blast of a fusion-powered engine like Daedalus' (see Page 9 for more) would still lead to journeys lasting decades or centuries. Those are realistic expectations, but science fiction has given us the dream of travelling from star to star in a few weeks. Such dreams can be hard to shake.

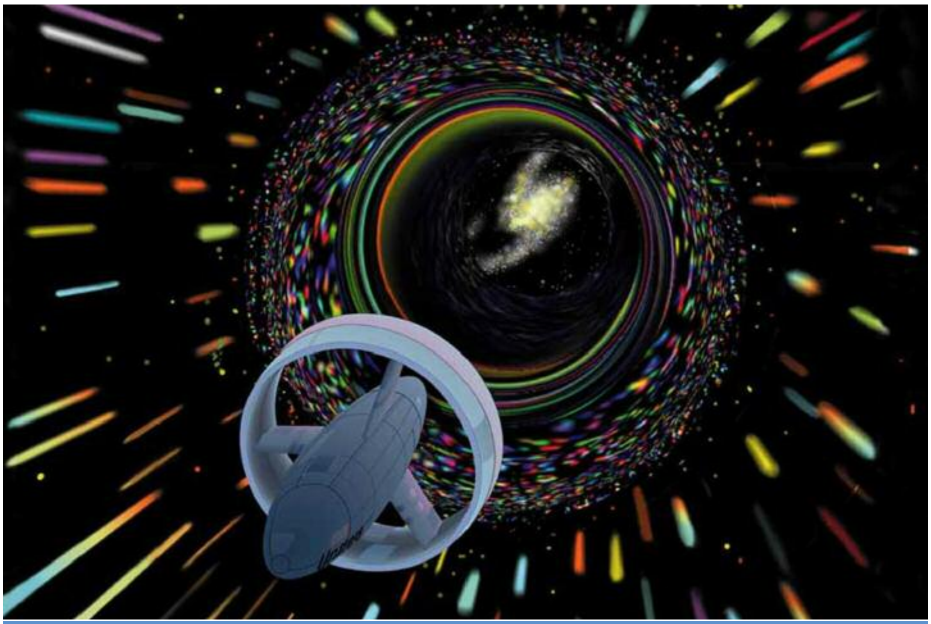
Albert Einstein showed that nothing can travel faster-than-light through space – but relativity doesn't rule out space itself moving at incredibly fast speeds. We're witnessing it today – dark energy is causing the expansion of the Universe to accelerate faster than the speed of light. In the very first fractions of a second after the big bang, the Universe experienced another burst of runaway growth thanks to inflation. In 1994, influenced by the science behind inflation, physicist Miguel Alcubierre, who was at Cardiff University at the time and today is at the National Autonomous University of Mexico, derived solutions to Einstein's General Theory of Relativity that suggested it was possible to warp space for very rapid and perhaps near instantaneous travel across the Universe. There was only one drawback: you would have to convert every atom in the visible Universe into pure energy to obtain the required power.

Less energy to warp space

It seemed like the dream of faster-than-light travel had died. Inflation, dark energy, the entire rest-mass energy of the visible Universe – these are forces of nature wildly bigger than anything we can control but since 1994 there has been a determined downsizing effort going on. By revisiting Alcubierre's calculations, successive physicists have been able to twiddle with the initial conditions of the equations and reduce the amount of energy required, first down to the mass-energy of a galaxy, then a star and a gas giant planet. Now White has reduced the energy requirements to an amount that, at first glance, seems eminently obtainable: about 500 kilograms, the mass of the small family car that you drove to work this morning.

What would that energy do? Imagine you have a starship moving away from Earth under conventional propulsion at some sub-light speed – call it impulse power. Then the starship uses the energy to activate its warp engine to create a 'bubble' of warped space around it. Inside the bubble, everything is normal, with space-time flat. The bubble, however, causes space in front of the craft to contract, in essence pulling the target destination towards it. Behind the vessel the bubble allows space-time to relax and expand again, giving the starship a boost of many orders of magnitude in the direction the craft had been moving under impulse power. It's like a rug being pulled underneath you or, as physicist Eric Davis at the Institute of Advanced Studies at Austin, Texas describes it, surfing on a wave of space-time where the wave is doing the work, not the surfer. So a warp bubble could turn a velocity of a tenth the speed of light into ten times the speed of light, making a journey to alpha Centauri 4.3 light years away last a mere 0.43 years, or just over five months.

The reduction in the required energy from the days of Alcubierre is a result of toying with the thickness of the warp bubble. The thicker this bubble is, the lower the energy density required, although this reduces the volume inside the bubble and the optimum trade-off between volume and bubble thickness has yet to be determined. However, before we get too excited, there are some quite formidable obstacles to overcome, not least the energy requirements. Although the mass-energy of a car doesn't sound too bad, in real terms it amounts to 10^{19}



Could a warp drive enable faster-than-light travel? Image: NASA.

joules, which is almost equivalent to the annual energy expenditure of the United States. However, a civilisation that uses all available energy falling onto its planet from the Sun, boosted perhaps with widespread use of fusion reactors, would find such an amount of energy to be much more realistic.

More problematic is the type of energy, and this is why we describe warp drive as unconventional physics – the warp bubble only works if negative mass and energy, produced by some exotic form of matter, is used. We have experienced negative energy both cosmologically, in the shape of inflation and dark energy, and closer to home in the Casimir Effect (the slight repulsive force created as a result of vacuum energy – produced by virtual particles popping in and out of existence thanks to the uncertainty principle of quantum mechanics – between two metal plates marginally separated). But accessing large quantities of negative energy, storing it and then utilising it are all currently problems without answers.

> ***It's like a rug being pulled underneath you, or a surfer on a wave of space-time where the wave is doing the work, not the surfer.***

Lab experiments

Nevertheless, White has come up with a way to test his theories in the lab. He's designed an experiment called the White Juday Warp Field Interferometer that will use a helium-neon laser to detect an artificially-created warping of space across a diameter merely one centimetre across. The interferometer will be able to detect a perturbation in space-time as small as one ten-millionth of a centimetre by monitoring the timing of the laser reflecting off mirrors and passing through the warped space. If the warp bubble created in the experiment were around a spacecraft, it would boost its velocity by 1.0000001 times.

The beauty of a warp drive, if it could work, is that there would be no relativistic effects – no time dilation or length contraction. Inside the bubble the starship would experience the same frame of reference as we do here on Earth (or at least one close to it if the starship were already moving at a small fraction of the speed of light before engaging the warp bubble). Astronauts would not venture off to the stars and return only to find that centuries or perhaps millennia have passed on Earth as the soldiers in Joe Haldeman's novel *The Forever War* experienced. Instead they could return home to find their loved ones have barely aged at all.

It's still early days and nothing has yet been proven in the laboratory; some physicists are sceptical that Alcubierre's solutions would even work in real life. Yet if the solutions do work and if the huge problem of the large quantities of exotic negative energy can be solved, perhaps our private fantasies of a *Star Trek* future can be achieved after all.

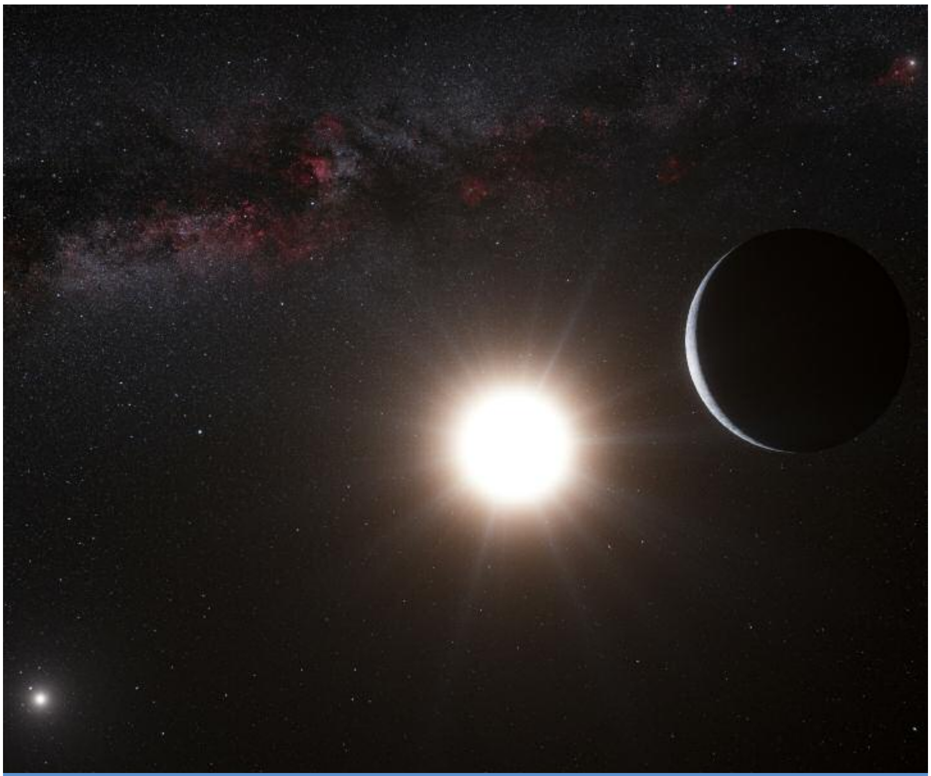
News from alpha Centauri

News of the nearest exoplanet to home has raised the stakes among hunters of alien worlds.

Have starship, will travel – but to where? The destination for our intended interstellar craft is going to be a crucial piece of the jigsaw – too far away and we won't be able to get there, too inhospitable and there will be little to attract us. A potentially habitable planet orbiting one of the Sun-like stars in the alpha Centauri system, the closest to our Sun at a 'mere' 4.3 light years distant, would by the culmination of two decades of exoplanet-hunting and now a new discovery takes us part of the way there; a planet, slightly more massive than Earth, orbiting the star alpha Centauri B.

"There's not been a more exciting result for an individual star, even with the long line of spectacular results from the last two decades," says Professor Debra Fischer of Yale University. "The indication that our nearest neighbour has rocky planets is incredible!"

Fischer leads a team that has been hunting for planets around alpha Centauri for several years, but her group



An artist's impression of the alpha Centauri system. Alpha Centauri B and its attendant planet are in the foreground, with alpha Centauri A to the lower left and our Sun a bright star in the upper right, 4.3 light years away. Image: ESO/L Calçada/N Risinger (skysurvey.org).

were beaten to the discovery by European astronomers mostly based at Geneva Observatory using the HARPS (High Accuracy Radial velocity Planet Searcher) instrument fitted on the 3.6-metre telescope at the European Southern Observatory in Chile, which has pushed our exoplanet detection abilities to the limit. HARPS is a spectrometer that is able to detect slight ‘wobbles’ in the star caused by the gravitational perturbations of accompanying planets. In the case of alpha Centauri Bb, as the new planet is known, the wobble it induces in its parent star amounts to a movement of no more than 51 centimetres.

Lava oceans

Alpha Centauri Bb orbits its star at a distance of just 5.98 million kilometres – close enough to fall into gravitational step with its sun and become tidally locked so that it always shows the same face to its star. Consequently there is no hope for oceans of water; the dayside will bear the brunt of the star’s heat, its surface melting in temperatures up to 1,220 degrees Celsius. Rather, oceans of lava will be the order of the day. Such worlds, where the molten surface evaporates to form a thin silicate atmosphere, or exosphere, have been found by the Kepler space mission to be common, points out Professor Greg Laughlin of the University of California, Santa Cruz.

“There is nothing unusual about this planet,” he says. “Around fifty percent of the stars in the solar neighbourhood have close planets smaller than Jupiter so, no offense to the Geneva team, but this planet is completely run of the mill!”

So why does it excite those of us who share an interstellar vision? It’s not the planet itself, but what its presence potentially promises. “It turns out that most of the low mass planets are in systems of two, three or more planets, all the way out to the habitable zones,” says Stephane Udry of Geneva Observatory. “So there is a very large probability that there are more planets around alpha Centauri B.”

Reasons to go

If indeed more planets exist, possibly in the habitable zone, alpha Centauri becomes a hugely attractive destination. “If a potentially habitable planet is found we might see a groundswell of excitement to look towards new propulsion technologies that can get a probe there within a human lifetime,” says Laughlin. “It’s twice as easy to get there than other stars.”

In our neighbourhood of the Galaxy stars are, on average, distributed four light years from one another, but most of those stars are cool red dwarfs or dim, dreary brown dwarfs. It is quite unusual for two Sun-like stars to be so close – and in the alpha Centauri system we have the bonus of two Sun-like stars.

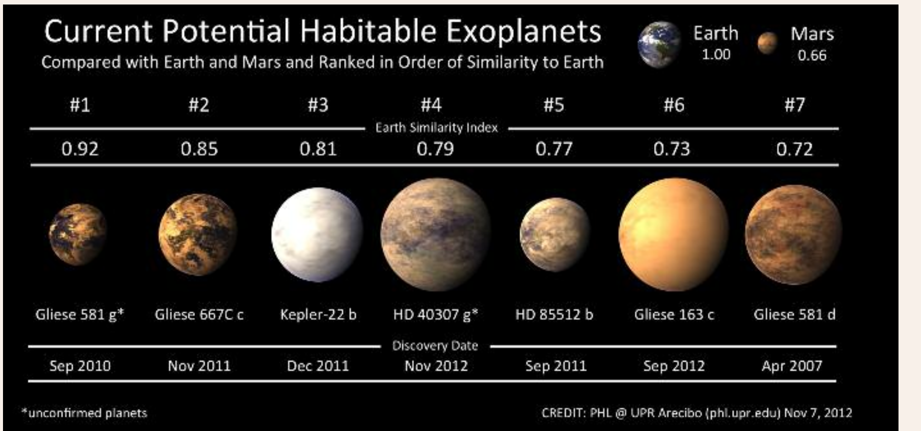
“The odds that we would have such an extraordinary star so close to us is one in a thousand,” says Laughlin. “A million years ago alpha Centauri was far away and not visible; in another million years it will have passed by. Right now is its closest approach.”

Naturally any potentially habitable worlds will also be of interest to SETI, the Search for Extraterrestrial Intelligence. “At just four light years away a technological civilisation, if it existed, would be watching recent news from Earth,” says Fischer. So as we watched President Obama being re-elected, denizens of Alpha Centauri would be witnessing the run-up to his triumph in 2008, and watching Spain beat all before them in the UEFA European Football Championships.

Second Earth?

A possible planet, seven times more massive than Earth, has been found sitting smack-bang in the habitable zone of a star 42 light years away. The system, HD 40307, is home to six planets, all rocky ‘super-earths’, but it is planet g that has captured the imagination the most. Discovered through re-analysis of data from the world’s greatest radial velocity planet detector – the HARPS instrument at the European Southern Observatory in Chile – by a team led by Mikko Tuomi of the University of Hertfordshire, 40307g orbits its orange K-class star (which is cooler than the Sun) every 198 days at an average distance of 90 million kilometres, or about 0.6 astronomical units (where one astronomical unit is the mean distance from the Sun to Earth, 149.6. million kilometres). Although unconfirmed at present until other astronomers are able to detect it independently, if it does exist it may be the closest thing to Earth found so far.

The star’s habitable zone exists between 0.43 and 0.85 astronomical units and planet 40307g will receive 62 percent of the solar heating that Earth receives from the Sun. In order to be potentially habitable, it will need an atmosphere thicker than Earth’s to trap the heat, but such a massive planet (the surface gravity would be almost twice that of Earth) should have no problem retaining a thicker atmosphere to ensure temperatures appropriate for liquid water. The main problem may be that the planet is too massive – recent work by MIT’s Vlada Stamenkovic indicates that such super-earths could possess interiors that have not separated into a core and mantle, therefore ruling out protective magnetic fields created by a dynamo effect within the planet, and the churning of continents through plate tectonics that is vital for recycling carbon and regulating planetary temperature.



All the potentially habitable exoplanets discovered thus far, compared to Earth and Mars. Image: PHL@UPR Arecibo.

The billion-year plan

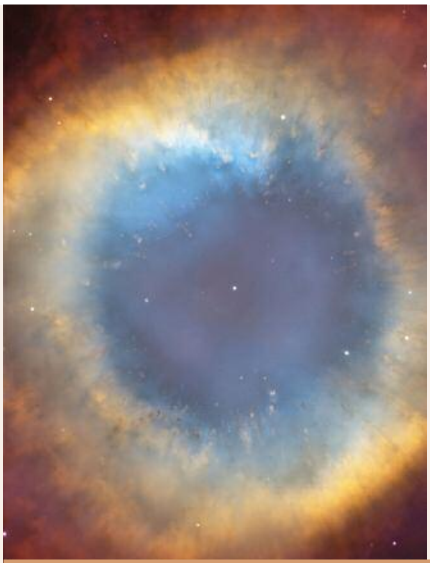
Maybe the century-long outlook of I4IS and other interstellar groups is too short? Writing on the website KurzweilAI.net, Lt Col Peter Garretson, Chief of Future Science and Technology Exploration for the United States Air Force, believes we should start planning now for the far future and the billions and trillions of years to come.

"It isn't enough just to plan for two or 20, or even the fabled Chinese 100 year periods," he writes. "We need to be thinking and planning on the order of billions of years. Our civilisation needs inter-generational plans and goals that span as far out as we can forecast significant events."

The first of those events include the uninhabitability of Earth within a billion years as the Sun warms. Garretson proposes that we build giant O'Neill colonies (named after the NASA astrophysicist Gerard O'Neill who popularised the idea in the 1970s in his book, The High Frontier) from material in the Asteroid Belt that could potentially become home to 100 trillion humans. However, it's a more pressing race against time than it at first glance appears – with just a few hundred years of natural resources remaining on Earth, and other looming crises such as the environment or war, we need to develop a space programme based around the long-term survival of humanity now, before it is too late.

Even the Sun won't last forever, with Garretson recognising the need for interstellar colonisation – the further we spread ourselves, the greater the probability that some will survive. He even speculates towards the end of the Universe, when the stars go out, atoms decay and the black holes themselves begin to evaporate, leaving one possible door open to us – the creation of new, baby universes into which we could escape.

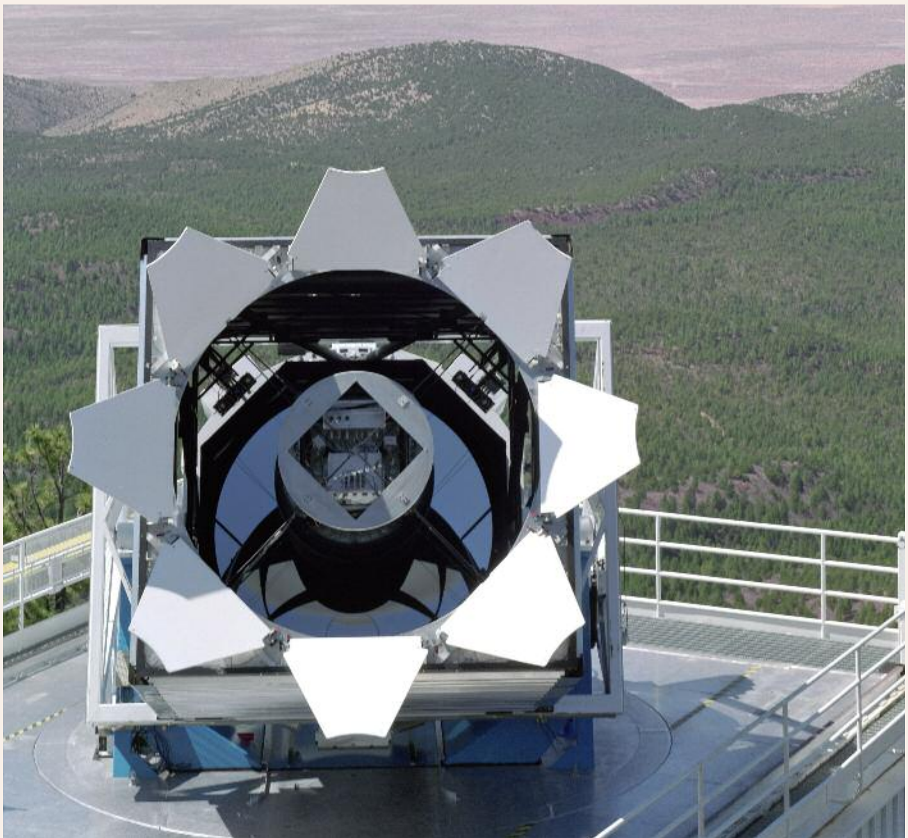
You can read the full article at ☞http://www.kurzweilai.net/what-our-civilization-needs-is-a-billion-year-plan



When the Sun goes out and expands into a red giant before billowing away into a planetary nebula some five billion years into the future, such as the Helix Nebula pictured here, humanity will have to move on to other stars to survive. Image: NASA/ESA/C R Dell (Vanderbilt University)/ M Meixner/P McCullough.

Spectroscopic SETI

During our interstellar travels it is feasible that we'll bump into other intelligent species out there, but perhaps we will have discovered their existence beforehand. One way to do this could be to detect signals from them, perhaps in the form of powerful laser pulses. Currently, unlike searches for radio signals from extraterrestrial civilisations in the form of all-sky surveys, optical searches for lasers have to take the slow road, going from star to star. Now Ermanno Borra of Université Laval, Québec, might have a solution. He points out that a pulsating laser source modulating its frequency over periodic time periods as small as 10^{-10} to 10^{-15} seconds would be detectable as frequency shifts in astronomical spectra, of the kind routinely taken by all-sky spectroscopic surveys of stars such as the Sloan Digital Sky Survey in New Mexico. These surveys produce huge amounts of data, much of it barely analysed, which scientists could sift through searching for anomalous frequency patterns that might be indicative of an alien calling card. Borra's report is published in the *Astronomical Journal* and a pre-print can be found here:
☞http://arxiv.org/abs/1210.5986v1



The 2.5-metre telescope of the Sloan Digital Sky Survey (SDSS) at Apache Point in New Mexico could theoretically discover laser signals from intelligent extraterrestrials during its all-sky spectroscopic surveys designed primarily to measure the redshift and hence distance of galaxies and stars. Image: Fermilab Visual Media Service.

IT'S HIP TO BE CUBED

THE GREAT CUBESAT REVOLUTION

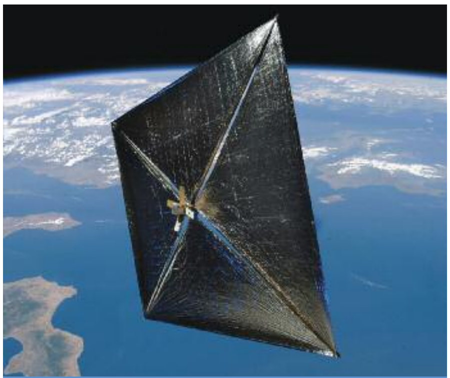
Tiny cube-shaped satellites weighing just a kilogram are making space exploration affordable and they may ultimately provide the first precursor missions for what will eventually be a voyage to another star system.

Big dreams start small. The first space mission that the Institute for Interstellar Studies™ will launch won't be a fusion-powered starship to Fomalhaut; it won't be a graceful solar sail to Sirius; it won't even be an automated probe to alpha Centauri. In fact, the Institute's first mission won't even reach beyond Earth orbit or be larger than a few bags of sugar.

Project CATSTAR is the Institute's programme to launch a cubesat, which are small satellites built from off-the-shelf electronic components, no larger than 10 centimetres cubed and sometimes stacked in twos or threes, piggybacking on rocket launches delivering other satellites into space to keep launch costs down. The idea is to use the cubesats – built by Institute scientists, engineers and team-members – to test new technologies necessary to begin building the foundations of an interstellar craft and, by doing so, increasing what is termed their Technological Readiness Level (TRL).

Get ready

The TRL is a measure of how advanced a specific technology is. An ion drive, for instance, has the highest TRL rating of nine, implying it has been fully tested on successful missions, such as the European Space Agency's SMART-1 mission to the Moon or, more recently, NASA's extraordinarily successful Dawn mission to the asteroids Vesta and, in 2015, Ceres. Solar sails have a TRL of eight, indicating they have been flight tested but not put to work on any real missions yet. At the other end of the scale a fusion-based propulsion system only rates a two and a warp drive, where not even the theory is nailed down, has a TRL of one. The only way we can increase their TRL is by testing, experimenting and optimising them for use in future missions and, perhaps one day, an interstellar voyage.



NASA's NanoSail-D2 cubesat was a testbed for solar sail technology that one day may aid the voyage of an interstellar craft. Image: NASA.

That's where cubesats come in. We might not be able to test an antimatter drive in a cubesat, but we can test solar sails for example – NASA's NanoSail-D2 mission in 2010 utilised a cubesat-like satellite from which unfurled a ten-metre square sail made from kapton film just two microns thick. There are also other, less dramatic, applications, from testing radiation shielding, communications systems and software, or even used as a telescope for detecting transiting exoplanets as in the case of MIT's ExoplanetSat launching some time in the next 12 months.

Mission training

Cubesats had a modest beginning. Initially developed by Jordi Puig-Suari at the California Institute of Technology and Bob Twiggs at Stanford University in the late 1990s, they were intended as training platforms to give students the opportunity to practice building, testing and operating low-cost spacecraft. A single cubesat can set you back as little as £50,000 and even the most expensive rarely top a quarter of a million pounds. Basically launching a cubesat is like sending a bag of sugar into space – similar size, same mass – except that the cubesats can be combined into configurations of two or three 'units', or 2U or 3U in the shorthand notation of the growing cubesat community.

The first cubesat to reach orbit launched on a Russian Soyuz rocket in June 2003 and since then another 74 have followed it into space. Far from the training exercises they were envisaged as, scientists are now using them as low-budget options for their research.
The first British cubesat, a 3U configuration called UKube-1, will carry five experiments including one to demonstrate the feasibility of using cosmic ray hits to generate random numbers that can be used to secure communication links. It will blast off on a Soyuz rocket in March 2013.

Project CATSTAR seeks to take cubesat technology and apply it to developing the science for interstellar travel, but there is no need to rush. Cubesats fall into the natural scheme of science and engineering, coming after theory, table-top experimentation and fully-fledged ground demonstrations.
If a cubesat mission is successful the next step is to utilise the technology in a precursor missions to the other planets in the Solar System or perhaps to the outer boundary of the Sun's influence in the distant Oort Cloud of icy cometary bodies. From there it is but a giant leap for a real mission to the stars.
From small seeds do great things grow and, if the first interstellar missions do carry technology that was initially tested in diminutive cubesats, it will be symbolic of our growth from small scale space missions to conquering interstellar distances.

Three small CubeSats are deployed from the International Space Station on 4 October, 2012. Image: NASA

Retrospective: Project Daedalus

The greatest starship design isn't the Enterprise or a Star Destroyer, but Daedalus – a real attempt at creating a blueprint for a vessel that could travel to one of the nearest stars and beyond at 12 percent the speed of light.

We at the Institute for Interstellar Studies™ fiercely believe that starship building will be a major part of the future of humankind, but what many may not realise is that to reach the future much of our inspiration is going to come from the past. For in the 1970s, members of the British Interplanetary Society accomplished something that had never before been achieved, something revolutionary: the design of a starship.

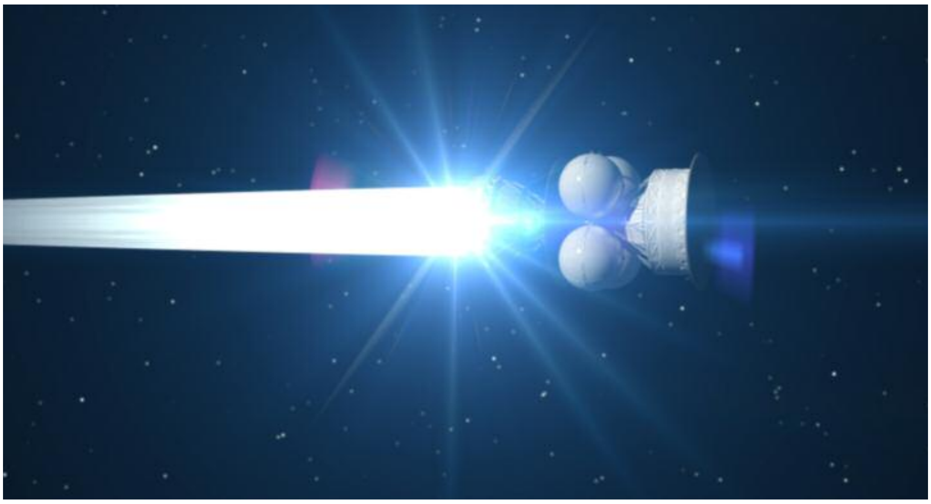
Interstellar dreams

It was 1973 and the promised land of regular spaceflight throughout the Solar System and the untold riches that it could bring were still in sight. Apollo had ended a year previous, with the United States embroiled in a war it could ill afford, but the talk was of more ambitious missions: permanent space stations, colonies on the Moon and flights to Mars. Such talk led to dreams of how far we humans could go.

> ***"An unmanned probe that would accelerate to 12 percent of the speed of light, whizzing past Barnard's Star."***

Dreams, however, are not particularly scientific. Led by Alan Bond, a group of skilled enthusiasts sought to remedy this. Science fiction, from the popcorn Golden Age classics of E E 'Doc' Smith to the more refined 'hard' SF of Arthur C Clarke or Isaac Asimov, regularly portrayed interstellar travel as a natural progression of human ingenuity, but was it really possible to go galavanting around the Galaxy like Captain Kirk? Moreover, the answer would solve some riddles about our own future and the apparent absence of extraterrestrial life in the Galaxy; if interstellar travel was inordinately hard, we could not reasonably have expected aliens to have reached our planet, neatly answering the puzzle of why we see no evidence of intelligent extraterrestrial life close to Earth. On the other hand, if interstellar flight was achievable, it could raise more concerns about where everybody is.

And so Project Daedalus was born: a five-year study to produce a solid, scientific design for an interstellar craft, bringing the dreams of SF into the realm of hard calculations using 1970s technology or near-future tech, extrapolated from where science and engineering was at in 1973. Beyond this the only other requirement for any mission launched based on the Daedalus blueprints was for it to be completed within the working lifetime of a mission scientist. To these ends, Daedalus was designed to keep things simple, with an unmanned probe that would accelerate to 12 percent of the speed of light, whizzing past its target destination (Barnard's Star) and returning data to Earth.



Fusion power to the stars

Nuclear fusion was the power system of choice for the spacecraft in the 1970s and even today, when interstellar spacecraft designs are discussed, fusion propulsion is often top of the list. Daedalus was to carry ten tanks of tiny pellets composed of deuterium and helium-3, around 54,000 tons in total, equating to a total of 30 billion pellets. When bombarded with electron beams these pellets would undergo nuclear fusion, producing energy, helium-4 and protons that would be directed by magnetic nozzles out through the engine to provide thrust. By igniting 250 pellets per second Daedalus would produce 10^{13} watts – around one megajoule per pulse – to power the starship out of the Solar System.

The tank layout is a vital part of Daedalus' design. Like the Saturn V or the space shuttle's external tank and solid rocket boosters, Daedalus would be a multi-stage system. Six tanks, in total carrying 50,000 tons of pellets, would form the first stage, with two tanks dropping away after 250 days of powered flight, having reached a distance of 0.0039 light years from the Solar System. Another tank is left behind at 0.0178 light years, another at 0.0503 light years and then just over two years into the mission the entire first stage is discarded into interstellar space, having driven the starship up to seven percent of the speed of light. Without the redundant mass of the first stage and its empty tanks, the 4,000 tons of propellant in the second stage doesn't have to work as hard, burning for 320 additional days, ending three years after leaving the Solar System at a distance of 0.21 light years. Daedalus would then continue the rest of the way coasting at 12.2 percent of the speed of light (36,500 kilometres per second) for around 46 years. There is no

> *If we can realise the technological steps in nuclear fusion and electronics, predicted by reasonable extrapolation of today's technology, then interstellar missions of a limited type will be possible.*

reason why the starship could not have even more stages, producing higher velocities, but even then we are still looking at many decades travel time with Daedalus before we reach the nearest stars. As the Daedalus report described in a special edition of the Journal of the British Interplanetary Society in 1978, "A complete mission would involve about 20 years design, manufacture and vehicle checkout, 50 years flight time and six to nine years of transmitting information back to the Solar System. Therefore, it appears that even the most simple interstellar missions will require a commitment of support for 75–80 years... Even if the exhaust velocity of the rocket could be doubled, thus permitting deceleration at the target, flight times would still be measured in decades and so manned interstellar flight does not look very promising."

Problems with power

Even unmanned interstellar flight using the Daedalus system currently faces two big problems. The first is nuclear fusion itself. Regardless of the type of fusion – whether it be electron beams, inertial confinement fusion (ICF) with high-powered petawatt (10^{15} watts) lasers or a magnetic confinement reactor with tokamaks containing a plasma of deuterium and tritium that is heated to a million degrees until the atoms fuse – no fusion reactor has yet produced more energy than is put into the system. For example, the best the Joint European Torus magnetic confinement reactor in Oxfordshire, UK has achieved is a 16 megawatt output for two seconds following an input of 25 megawatts. However, technological advances in tokamaks and ICF should remedy this problem within the decade and it is expected that by 2050 a substantial proportion of the energy on the National Grid will come from commercial fusion reactors.

So that's one problem solved; the other is going to take a bit more work. You'll notice that in Earth-based reactors deuterium and tritium are used as the reactants, whereas in Daedalus deuterium and helium-3 is preferred. That's because helium-3 is a more efficient fusion fuel. However, it is rarely found on Earth. If we want access to helium-3 we must either produce it ourselves in reactors on Earth (through deuterium/deuterium or lithium-6/neutron reactions, but this is costly and time-consuming), collect it from the solar wind (where we would need an enormous and impractical collecting area) or on the Moon where the solar wind deposits it (but the concentrations are low), or head out to Jupiter and mine it from its atmosphere (requires a space-based society and an interplanetary infrastructure). Perhaps surprisingly, Jupiter was the preferred choice of the Daedalus team, who imagined that the starship could be built nearby the Jovian fuel depot, the manifestation of a wealthy, Solar System wide society mining and transporting helium-3 for use in fusion reactors on Earth and in various colonies.

The study concluded that, "If we can realise the technological steps in nuclear fusion and electronics, predicted by reasonable extrapolation of today's technology, then interstellar missions of a limited type will be possible." This modest judgement perhaps belies their ambition and optimism in embarking on the project – the degree to which we can become an interstellar civilisation remains to be seen, but Project Daedalus certainly bolstered hopes rather than constrained them.

Barnard's Star, which is a red dwarf star 5.9 light years away and which has the highest proper motion of any star on the sky, seemed a good choice of destination in the 1970s as circumstantial evidence pointed to the existence of planets in orbit around the star. Alas, that evidence turned out to be false, but with planets now being discovered in the alpha Centauri system our nearest star system is looking a much more promising target.

Wherever its destination, after the fly-by Daedalus was fated to never return home. It would carry on deep into interstellar space, continuing to do science in the interstellar medium as long as power and communication with Earth held out. Had it flown to Barnard's Star, its trajectory would eventually have taken it about 13,500 light years above the Galactic Centre in about 180,000 years time and ultimately out of the Galaxy – from being our first interstellar explorer to becoming lost in intergalactic space, Daedalus' voyage would become the greatest adventure of all time.

Project Icarus

In Greek mythology Daedalus had a son, Icarus. Both built wings of wax, but Icarus flew too close to the Sun and the wax melted, sending him plummeting to the sea below. Project Daedalus has also bequeathed Project Icarus, a twenty-first century design-study for an interstellar vehicle.

Once again initiated by members of the British Interplanetary Society, originally headed up by I4IS Executive Director Kelvin Long, Icarus began as a five-year study – now in its penultimate year – but has since taken on a life of its own as the foundation for a non-profit organisation called Icarus Interstellar, dedicated to interstellar flight and initiating many projects into deep space propulsion. To find out more, visit www.icarusinterstellar.org.

Jargon Buster

Helium-3/helium-4

These are differing isotopes of atomic helium. Helium-3 has one neutron and two protons; helium-4 has two neutrons and two protons.

Nuclear fusion

The process by which two atomic nuclei are fused together to form a larger nucleus, releasing energy in the process

Fermi Paradox

This conundrum asks, if intelligent extraterrestrial life exists and if interstellar travel is possible, why has Earth not been already colonised by aliens at some point in its 4.5 billion years history? Where is everybody? Project Daedalus aimed to inform the Fermi Paradox discussion by showing whether interstellar flight was possible or not.

Light year

The distance light travels in one year, which is 9.46 trillion kilometres. Barnard's Star is 5.9 light years away, or 55.8 trillion kilometres.

The Daedalus Starship

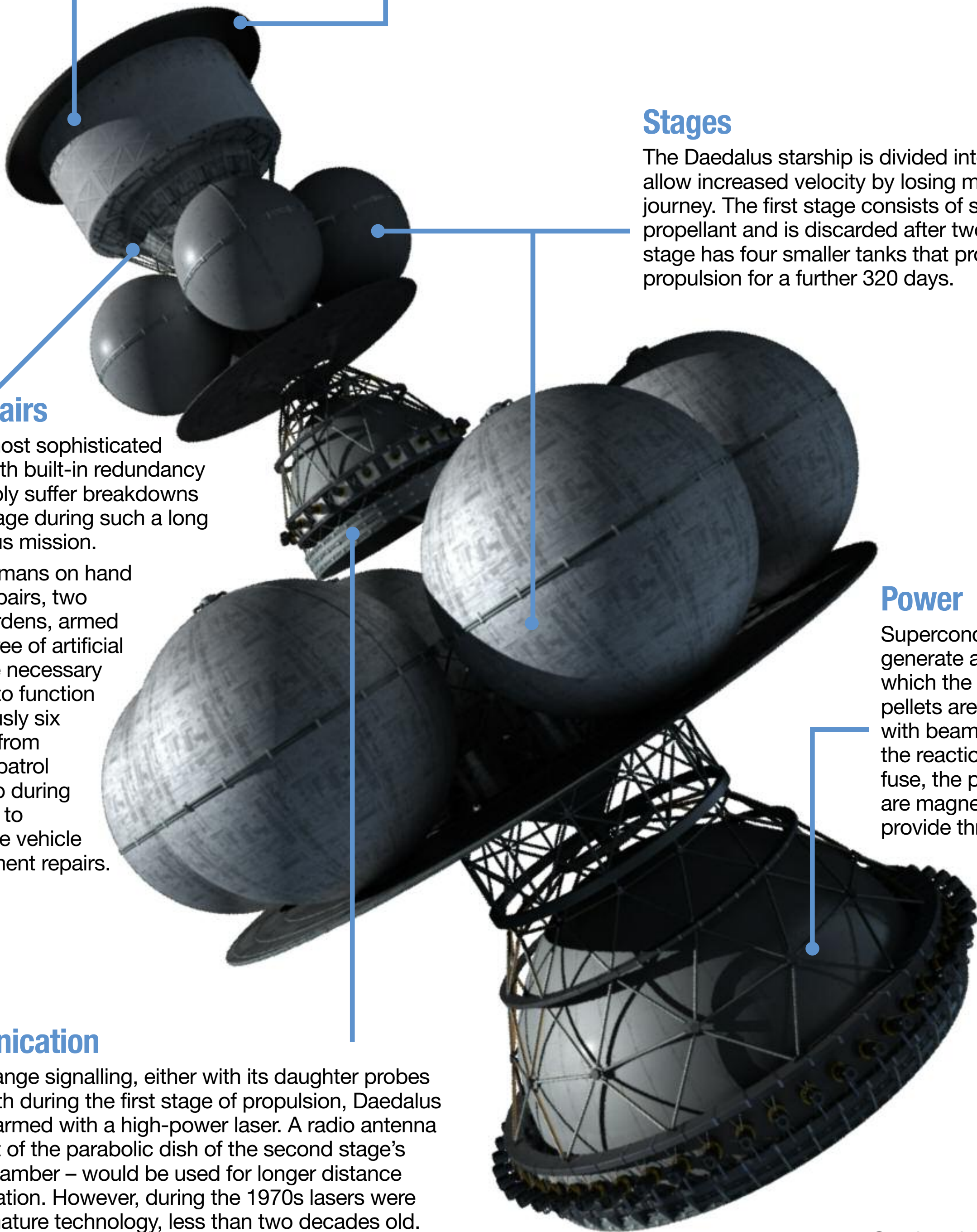
Probes

Daedalus wasn't designed to slow down, so its visit to Barnard's Star would be fleeting, passing through at 12 percent the speed of light. In order to better study the star system, Daedalus would deploy 18 scientific probes to investigate the star and any attendant planets closer

Deflector shield

Powering through space at 12 percent of the speed of light requires a clear path – hitting even the tiniest piece of space dust at that velocity would pack the punch of an atomic bomb.

In order to protect the ship a deflector shield must be employed in front of the vessel in the form of a cloud of micron-sized dust particles that would intercept anything from dust to small asteroids up to 500 kilograms and vapourize it on contact



Stages

The Daedalus starship is divided into two stages to allow increased velocity by losing mass during the journey. The first stage consists of six tanks of propellant and is discarded after two years; the second stage has four smaller tanks that provide added propulsion for a further 320 days.

Self-repairs

Even the most sophisticated systems with built-in redundancy will inevitably suffer breakdowns at some stage during such a long and arduous mission.

Without humans on hand to make repairs, two robotic wardens, armed with a degree of artificial intelligence necessary to be able to function autonomously six light years from home, will patrol the starship during the voyage to maintain the vehicle and implement repairs.

Power

Superconducting coils generate a magnetic field into which the deuterium/ helium-3 pellets are injected to collide with beams of electrons inside the reaction chamber and fuse, the products of which are magnetically driven out to provide thrust

Communication

For short range signalling, either with its daughter probes or with Earth during the first stage of propulsion, Daedalus was to be armed with a high-power laser. A radio antenna – made out of the parabolic dish of the second stage's reaction chamber – would be used for longer distance communication. However, during the 1970s lasers were still an immature technology, less than two decades old. Today lasers are considered a far superior mode of long distance communication.

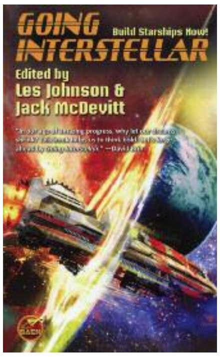
Dimensions

One hundred and ninety metres long, Daedalus would not be an especially giant starship – the fictional starship Enterprise was 300-metres long – but it is still far larger than any spacecraft or space station built to date. Its sheer size requires that Daedalus would have to be assembled in space.

Book Reviews

Going Interstellar

Edited by Les Johnson and Jack McDevitt



This isn't the first starship anthology to put the science into the fiction, and it won't be the last, but it is certainly one of the best. Proclaiming 'Build Starships Now!', every page fizzes with bold ideas and clever use of imagination.

Which you would expect from the pedigree on show. Les Johnson is Deputy Manager for NASA's Advanced Concepts Office at the Marshall Space Flight Center; Jack McDevitt is a celebrated SF author with Nebula and Philip K Dick awards under his belt. Together they've accumulated some of the best starship fiction around, headlined by the great SF veteran Ben Bova and including Charles Gannon, Louise Marley, Michael Bishop, Sarah Hoyt and Mike Resnick. Interspersed between are essays on real starflight concepts from I4IS' Advisory Council Chair Dr Gregory Matloff, Icarus Interstellar's Richard Obousy and Johnson himself. Indeed, amidst all these stellar names it's Johnson who gets the book off the starting block with a contender for the best short story within its pages, 'Choices', where the use of virtual reality as a tool to stimulate the mind during hibernation threatens to derail an interstellar colony mission. The main character's solution is ingenious, to say the least.

Also worthy of mention is McDevitt's 'Lucy', a charming tale of artificial intelligence and curiosity versus stagnation. Bova equips himself well in 'A Country for Old Men' in which an old scientist feeling redundant onboard a starship crewed by young people and an AI finds a new reason for existence in navigating the hydrogen fields of the interstellar medium. Meanwhile, Gannon's 'Lesser Beings' exists in a Universe where humans have already colonised the stars and oligarchic houses engage in conflict and introduces a new motivation for interstellar travel: expulsion. Sarah Hoyt's 'The Big Ship and the Wise Old Owl' is a slightly contrived look at ensuring the crews of generation ships don't lose sight of their goal while Michael Bishop's 'Twenty Lights to the Land of Snow' is the only real letdown, a meandering and unfocused novella about the reincarnation of the Dalai Lama onboard a Tibetan colony ship that lacks a strong climax.

The accompanying essays are comparatively brief and are aimed mostly at the newcomer to starship and propulsion physics, but they are concise and surprisingly comprehensive overviews of solar sails, antimatter and fusion starships. Overall, *Going Interstellar's* innovative and engaging prose and essays are packed with enough thought provoking ideas to make it a real winner.

Going Interstellar

Authors: Michael Bishop, Ben Bova, Charles E Gannon, Sarah A Hoyt, Les Johnson, Louise Marley, Gregory Matloff, Jack McDevitt, Richard Obousy, Mike Resnick

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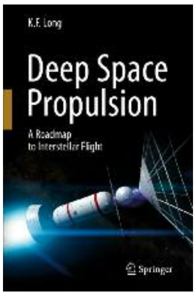
Deep Space Propulsion

Kelvin F. Long



The first few chapters move rapid-fire through many different propulsion systems (21 variations in all) and reasons why we should dream of interstellar travel. In subsequent chapters Kelvin Long, I4IS' Executive Director, expands on these systems, rigorously describing the workings of electric and nuclear-based propulsion, fusion drives, solar sails and the possibilities of antimatter and Bussard ramjets, charting their development all the way back to basic flight principles. These rigorous workings include many mathematical proofs, but the non-mathematical enthusiast shouldn't be put off - it's good to try and follow the maths, although for the general reader it isn't essential and can be skipped over.

Long goes beyond propulsion technologies to look at general mission design and architecture, which is where the book really earns its stars to become the very roadmap that Long asks for within its pages. His (self-confessed) optimistic timeline on page 321 has technology demonstrator missions blasting off in the next few decades, sending a pathfinder probe to 1,000 astronomical units (the outer edge of the 'focal point zone' where the Sun can be used as a gravitational lens); the first interstellar probe launches in 2100 to arrive at a nearby star (possibly the alpha Centauri system) by 2160 and the launch of the first human interstellar colonising mission by 2250. To put this into context, popular science fiction such as the original *Star Trek* and *Babylon 5* are set around the 2250s and Long notes that without a breakthrough discovery that could revolutionise space travel, such as warp drive or wormholes, meeting the expectations of those SF tales is going to be difficult.

Long hits his stride best when discussing the overall structure of mounting an interstellar mission; on the other hand, some early chapters about exploring the Solar System and beyond seem rather incongruous amidst the discussion of propulsion and mission technologies and, as a result, the text here feels uneasy, listing facts about the planets that needn't be in a book about propulsion. That aside, *Deep Space Propulsion* is an otherwise excellent guide to starship design and the chapters, replete with practice exercises at the end of each chapter (and not all of them are mathematical, giving readers of all abilities a chance at having a go) almost seem to have been arranged to suitably fit a lecture course on the topic. If you have the time, this 'homework' is well worth the effort and is a really nifty idea on behalf of Long.

For anyone with a serious interest in the subject, Kelvin Long's essential book may be the best around.

Deep Space Propulsion

Author: Kelvin F. Long

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The young star cluster NGC 3603 in Carina. Image: NASA/ESA//R O'Connell (University of Virginia)/F Paresce (National Institute for Astrophysics, Bologna) / E Young (Universities Space Research Association/Ames Research Center) / WFC3 Science Oversight Committee / Hubble Heritage Team (STScI/AURA).

We'd love to hear from you, our readers, about your thoughts on Principium, the Institute or interstellar flight in general.

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www.I4IS.org