PRINCIPIUM

The Newsletter of the Institute for Interstellar Studies™

Issue 7 | November/December 2013

www.I4IS.org

Scientia ad sidera

Knowledge to the Stars

Greetings from I4IS

Having met the I4IS' Executive Director Kelvin Long during a talk he gave about interstellar travel on behalf of the British Interplanetary Society (BIS), I was delighted to discover that the journeys my imagination took through the Universe were not unique and were indeed shared by others. Not only that, but these people were developing these dreams and ideas and attempting to make them a reality.

After that fateful day I joined the BIS and later became a researcher for I4IS. I now have the privilege of being the Executive Secretary for the Institute. I am currently studying for a degree in Physics and Astronomy in the hopes of contributing further to this endeavour. I hope that I can do justice to the role and that it will be one of long tenure.

We are told when we grow up that we should put away the dreams of childhood but it is this type of youthful imagination that will drive us onwards. I had the wonderful experience last week, in my role as a STEM Ambassador, of talking to a group of Year 10 students about space and astronomy. They approached the subject with the insouciance that only youth can provide. They do not push boundaries as they do not yet know they exist but ask questions that spur the imagination and demand answers.

As a STEM Ambassador I have the privilege and responsibility of talking to young people about space and astronomy with the hope of inspiring a new generation to think beyond the present and look to the future and I see this as part of the work that defines I4IS.

We all have that childhood imagination within us somewhere. Have you ever dreamed of space? Of far-off worlds with thriving societies, of exotic planets with green or purple skies, of twin moons rising in the evening? Then you are already an interstellar voyager in spirit and with the endeavours of I4IS and the other organisations in the field, maybe one day in body too.

Even if this does not happen in my lifetime I will be honoured if I am able to provide even a single word or idea that advances the journey.

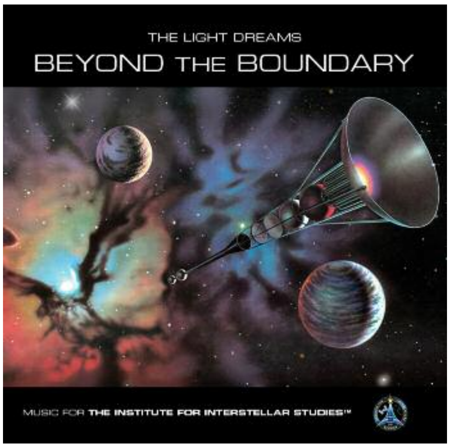
Sarah Margree
I4IS Executive Secretary

News from the Institute

Beyond the Boundary

Prepare for the new sound of space! I4IS' Interstellar Musician, the supremely talented Alex Storer, a.k.a The Light Dreams, has launched his new album, Beyond the Boundary. Sharing the name of the upcoming I4IS book, the Beyond the Boundary album is a musical adventure charting the departure from Earth of a starship on a voyage of interstellar discovery. Sporting gorgeous cover art from David A Hardy, the album will be available to purchase digitally from Alex's website, www.thelightdream.net/music.html.

Plus, don't forget about purchasing copies of Alex's previous albums, including the I4IS-associated Future Worlds. And why not make it a one–two and pick up a copy of the upcoming Beyond the Boundary book along with the album? See next issue for more details.



New Members

I4IS is delighted to announce a new member to our Board of Directors, as the new Director for Sustainability and Development. She is Dr Rachel Armstrong, who has previously worked with us as a consultant and has an impressive list of qualifications, experience and awards to her name. Dr Armstrong is an accomplished speaker, a trained medical doctor, a University Lecturer in architecture and an author. She is Co-Director of Advanced Virtual and Technological Architectural Research (AVATAR) in Architecture and Synthetic Biology at the School of Architecture and Construction, University of Greenwich, London. She is also a senior TED Fellow and a Visiting Research Assistant at the Centre for Fundamental Living Technology in the Department of Physics and Chemistry at the University of Southern Denmark.

Rachel is a sustainability innovator who investigates a new approach to building materials called 'living architecture', which suggests it is possible for our buildings to share some of the properties of living systems. She collaboratively works across disciplines to build and develop prototypes that embody her approach. She is also the Project Leader for Icarus Interstellar's Project Persephone. Rachel was a member of RESCUE working group, which is an interdisciplinary body of European experts collaborating to research the natural, social and human sciences in global change and making recommendations to the European Union for strategic investment into inter-disciplinary research into climate change.

Rachel Armstrong

Dr Armstrong was also part of the European Commission's TARPOL report, targeting environmental pollution with engineered microbial systems á la carte. In 2011 Rachel was named as one of the top ten UK innovators by Director Magazine, was featured in the 'Big Ideas, 10 Original Thinkers' article for BBC Focus Magazine and was selected as one of BMW/Wired's 'change accelerators'. She has also just released a TED book on living architecture, which is available on Kindle, Nook and iBook.

Chief among Dr Armstrong's responsibilities with I4IS is technology development for the Starship Cities strategy, which you can read more about on pages 10–11 of this issue.

We are also delighted to announce the appointment of Sarah Margree to the position of I4IS Executive Secretary, who will play an essential role in the running of I4IS. Read more from Sarah in this issue's introductory letter. We hope you will join us in welcoming both Rachel and Sarah to I4IS.

I4IS on AstroArts

Look out for an interstellar-themed month on Astronomy Without Borders' AstroArts website in January as I4IS takes it over for 31 days of blogs, art galleries and Google Hangouts. Featuring art from our cadre of interstellar artists, plus commentary on I4IS' relationship with art and how space- and astronomy-themed art can be utilised to promote visions for space exploration, it is an event not to be missed! So visit http://astronomerswithoutborders.org/blog/astroart-blog.html during January for some great I4IS material.

Inflight reading?

Buck Field, of the Starship Vlog (http://www.youtube.com/user/StarshipVlog), took this picture of Principium issue 6 on the seat-screen of a new Boeing 787 Dreamliner at 34,000 feet while on a flight to Peru.

Can anyone take a picture of themselves reading Principium in an even more remote location or at greater altitude?

Voyager 1 goes interstellar

The venerable space probe becomes humanity's first emissary to leave behind the Sun's heliosphere.

An artist's impression of Voyager moving through the denser plasma of interstellar space. Image: NASA/JPL–Caltech.

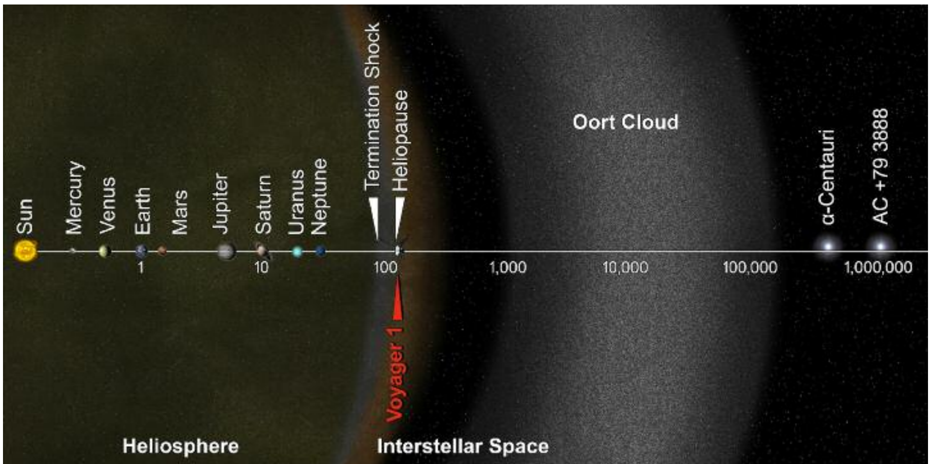
Ed Stone likened it to Neil Armstrong's historic first step on the Moon. Speaking during a NASA press conference in September, the Principle Investigator for the Voyager missions hailed the passing of Voyager 1 into interstellar space as a pivotal moment for humankind. "This is even more exciting because it marks the beginning of a new era of exploration, the exploration of the space between the stars."

Voyager 1, launched in 1977, passed into interstellar space on 25 August 2012, the day Neil Armstrong died, further cementing the link between the two epochal events. In this context, interstellar space means the space that lies beyond a magnetic bubble blown by the Sun called the heliosphere. Voyager 1 crossed the outer boundary of the heliosphere, known as the heliopause, at a distance of 121 astronomical units, or 18.1 billion kilometres, from the Sun. However, despite being in interstellar space Voyager 1 is, somewhat paradoxically, also still in the Solar System, amongst the cold icy bodies of the Kuiper Belt. Ahead of Voyager 1 lies the unexplored realm of the Oort Cloud – a domain of icy comets where the Sun's gravity still holds sway in the frozen depths. The difference is that the diffuse plasma through which Voyager 1 now cruises hails from other stars rather than the Sun, emitted into space by the ferocity of supernova explosions, the exhalations of red giants puffing off their outer layers, or from the constant breeze of stellar winds.

The date when Voyager 1 departed the Solar System coincided with the spacecraft detecting a 30 percent rise in high-energy cosmic rays. Stone and his team initially interpreted this as Voyager entering a 'cosmic highway' for particles both entering the heliosphere from beyond and solar wind particles escaping into interstellar space. Crucially they thought that Voyager 1 was still on the inside edge of the heliopause. The primary signal that would indicate Voyager 1 had departed the Sun's magnetic influence would be that the magnetic field direction would change once the Sun's magnetic field fell away behind the spacecraft.

For a reason that still remains unexplained, or is merely coincidence, the heliosphere's magnetic field seems to be almost perfectly aligned with the galactic magnetic field, meaning that Voyager never spotted the change. What tipped the Voyager scientists off was actually a wave of material unleashed months earlier by a coronal mass ejection (CME) from the Sun. When the solar plasma eventually caught up with and rippled past Voyager 1, the spacecraft's Plasma Wave Experiment detected oscillations in the plasma environment around it. These oscillations indicated that the density of the plasma environment was forty percent higher than it should be – as one nears the heliopause, the plasma density of the heliosphere should get thinner and should only start to become denser again once in interstellar space (the heliosphere is moving through the interstellar plasma, creating a bow shock where the plasma piles up). Based on the size of the oscillations, both in April 2013 when the CME debris moved past, and also in November 2012 when the signs of another CMB passing Voyager turned up in the archived data, the Plasma Wave Experiment's chief scientist, Don Gurnett, extrapolated back and found that Voyager 1 must have crossed beyond the boundary on 25 August.

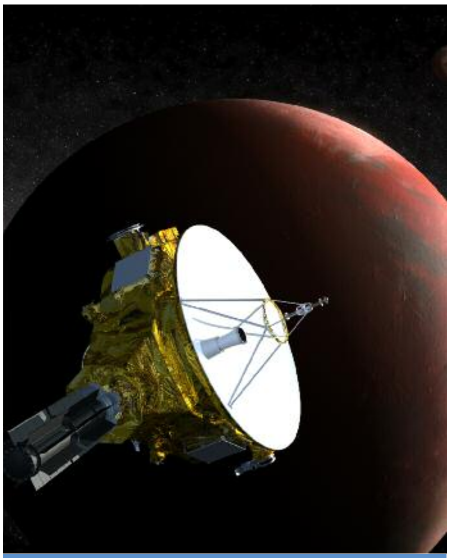
While we are certainly not an interstellar civilisation yet, the twin Voyager spacecraft (Voyager 2 is a few years behind Voyager 1 in its progress, having made detours to Uranus and Neptune in 1986 and 1989 respectively) are true pathfinders, currently on the leading edge of our expansion into space and crossing the heliopause is a major step to tick off. Our next major distance marker must be a mission to the Oort Cloud, gradually reaching out to 500 astronomical units, the point at which light is focused by the Sun's gravity acting as a gravitational lens.



To logarithmic scale, the location of Voyager 1 outside the heliosphere and the distance to the nearest star system alpha Centauri and the star AC +79 3888, which Voyager 1 will pass within 1.6 light years of in 40,000 years time. Image: NASA/JPL–Caltech.

A message for the stars

A new project aims to galvanise support for a message to ride to the stars onboard the New Horizons space probe.



An artist's impression of New Horizons passing Pluto. Image: JHUAPL/SwRI.

Would you like your name to fly to the stars? You and 9,999 other people could have your names, along with messages from humanity, beamed up to NASA's New Horizons space probe, destined to leave the Solar System and head out into deep space to ultimately fall into a long orbit around the galactic centre.

The opportunity is courtesy of the New Horizons message initiative launched by I4IS honorary artist Jon Lomberg, who was part of Carl Sagan's team in 1977 that created the gold-plated records that now adorn both Voyager spacecraft departing the heliosphere. When New Horizons launched in January 2006, destined for Pluto, the Kuiper Belt and eventually interstellar space, it carried no messages onboard. Now Lomberg and an advisory board of scientists and science journalists are campaigning for NASA to include a message, by using the Deep Space Network to transmit 100Mb of data to the spacecraft a year after its encounter with Pluto, when all data from the fly-by has been downloaded.

The New Horizons message, like the Voyager records and Pioneer plaques before it, fulfill two ambitions. First they are a time capsule, committed to deep space, potentially for our descendants to happen upon when they achieve regular interstellar travel. Second, they are humanity's way of making a statement to the Universe. Should our greatest fears come to pass and humanity is wiped from the face of Earth, the New Horizons space probe and those 10,000 names will still be out there, monuments to what once was, even if nobody should ever find them. The odds of intelligent extraterrestrial life happening upon New Horizons, Voyager 1 and 2 or Pioneer 10 and 11 is vanishingly small, even if providing a message for alien life to decode is their primary stated goal. It will take a long time for the probes to get anywhere; in 40,000 years time Voyager 1 will skirt the Oort Cloud of the star AC +79 3888. New Horizons, for whom a final trajectory has not yet been decided (dependent on its fly-by of Pluto and any Kuiper Belt objects that are chosen for it to subsequently visit) will have to wait a similar time, or longer, before it passes anywhere near another star.

"People love having their names cruise through space, but I always thought that it was a silly and naive notion that those names could mean anything to ETs. Our list of names will be different," Lomberg tells *Principium*. "First, it's leaving the Solar System and very few spacecraft have down that. Second, we will use some of our pictures to explain what a written name is. Think about it: everyone has a name. Even a slave with nothing has a name. But perhaps the idea of an individual name is new to ET. Showing a connection between a specific pattern of lines and a specific person could imply that 10,000 such patterns represent 10,000 persons. This is just one of many innovations in message content we hope to include."

Currently NASA has no funding for outreach activities thanks to austerity measures set down by the US Congress. If Lomberg can gather 10,000 signatures it is hoped they will be enough to persuade NASA to allow the project to go ahead (New Horizons' Principal Investigator, Alan Stern, has already given the initiative his blessing). So far signatories hail from 80 countries, from the remote islands of La Reunion in the Indian Ocean and St Helena in the South Atlantic, to war-torn Syria. "Can you imagine anyone in Syria taking the time to think about cosmic messages?" asks Lomberg. "Well, some do. And we just got our first signature from Antarctica!"

Once NASA *give the go-ahead*, Lomberg and his team of advisors will then embark on a fund-raising campaign using websites such as Kickstarter to gather the money required to assemble the message. They will use the Deep Space Network to transmit the message to New Horizons, which by that time will be greater than 33 astronomical units away from the Sun. The idea is to crowd-source the components of the message, using social networking as a primary source.

"We face tremendous challenges in the technical issues, the financing, the organisation and the management of the message building process," says Lomberg. This message can inspire people worldwide, as the Voyager record has done for the last four decades."

You can sign the petition and learn more about the project here: http://www.newhorizonsmessage.com.

Fusion breakthrough raises starship hopes

A vital breakthrough in the quest for sustainable nuclear fusion was achieved at the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratories in California in September, according to a report from the BBC. Fo the first time a fusion reaction was generated within the laboratory that produced more energy than it took to initiate the fusion in the first place. If nuclear fusion could be harnessed on a large scale it could pave the way not only for clean energy but also a suitable power source for an interstellar vessel.

NIF uses a technique known as Inertial Confinement Fusion, or ICF, to induce fusion in deuterium–tritium pellets using the most powerful lasers on the planet capable of delivering petawatts worth of energy (on the order of 10^{15} watts) in a pulse lasting a mere nanosecond. The laser pulses compress the pellet under pressures of 10,000 atmospheres to the point that the pellet implodes and the tritium and deuterium atoms fuse, releasing energy in the process.

Despite aiming to deliver sustainable reactions by September 2012, the fusion project at NIF had been stumbling along. As technical issues hampered the project the 2012 deadline came and went and funding began to be taken away from the project. Yet a year later scientists at NIF were able to produce the world's first ever sustainable fusion reaction.

NIF hasn't quite achieved its goal yet, which is to produce as much excess energy as the laser uses up, but this breakthrough offers hope that perhaps laser fusion can succeed and beat an alternative technique known as magnetic confinement that uses large, bulky tokamak chambers such as those at the upcoming ITER laboratory to be built near Marseille in France.

Should nuclear fusion become a widespread and affordable source of energy, the road to the stars will suddenly become that bit clearer.

A technician in the laser chamber at the National Ignition Facility. Image: LLNL.

Rogue planet wanders into view

A planet without a star – a gas giant planet six-and-a-half times the mass of Jupiter – has been discovered 80 light years away, possibly the tip of the iceberg of so-called 'free-floating' planets. Its discovery raises the possibility that there could be one or more free-floating planets closer to the Solar System than the nearest stars. If so, they would be an ideal target for our first interstellar mission.

The planet, designated PSO J318.5-22, was discovered by the Pan-STARRS 1 survey telescope in Hawaii. Follow-up observations with NASA's Infrared Telescope Facility and the eight-metre Gemini North Telescope revealed that, based on the amount of heat the planet is emitting, it can't be any older than 12 million years. For a planet, that's little more than a baby.

It is not clear whether the planet was ejected from a star system or formed on its own directly from a molecular gas cloud, like a star. Regardless, estimates suggest that there could be more free-floating planets wandering between the stars than there are stars in the Galaxy, as perturbations in planetary systems caused by migrating worlds can throw planets out of their orbits and into deep space.

"Interstellar space is likely to be occupied by many bodies that do not shine – from dust to planets," says Martyn Fogg, an I4IS consultant who graduated from Queen Mary, University of London with a dissertation on free-floating planets. "Some of these planets may have formed in a solitary manner, not orbiting a star at all. These are likely to be massive planets, heavier than Jupiter and lighter than brown dwarf stars. We see these by the heat of contraction they still emit. Others may be losers in a contest for an orbit in a new born planetary system. Planetary formation simulations show that new born planets can be ejected, via close encounters with other worlds, from the systems where they are born. Their fate too is to become interstellar wanderers in the cold and the dark."

The discovery of the rogue planet PSO J318.5-22. Image: N Metcalfe and Pan-STARRS 1 Science Consortium.

The discovery paper is available to read at http://arxiv.org/abs/1310.0457.

Project Icarus Concept Design Workshop

Rob Swinney reports from a special Project Icarus meeting that saw four starship concept designs competing against one another for the right to power the Icarus spacecraft.

Icarus team members gathered for the BIS design workshop.

Project Icarus volunteers, made up of members of the venerable British Interplanetary Society (BIS) and Icarus Interstellar (with I4IS members amongst them!) converged on the BIS' headquarters in Vauxhall, London, for a two-day workshop event in October. Organised as the culmination of a nine-month competition period intended to find the best Icarus concept design, four competing teams faced off in a bid to produce a winning propulsion system for the starship.

A bit of back story: Project Icarus is a study to update and redesign the renowned Daedalus project carried out by members of the BIS in the 1970s, which is to design a feasible and credible fusion-powered interstellar spacecraft that might be launched in the coming decades using 'current or near future technology'. The recent competition saw sub-teams made from Icarus members putting their prior research and expertise into actually designing a starship.

The rules were straightforward. The spacecraft had to be mainly fusion powered and on a 100-year mission carrying a 100 to 150 tonnes payload. The four teams that made it to the workshop with a complete design were the Munich Ghost Team headed up by Andreas Hein (who is also Director of Technical Projects at I4IS), the Icarus Firefly design by Robert Freeland II, the Ultra Dense Deuterium (UDD) concept design by Milos Stanic who has recently completed a PhD at the University of Alabama at Huntsville, and the Starship Resolution team led by Kelvin Long (I4IS' Executive Director).

Ghost Ship

Following presentations on each concept, it was put to a vote, with the unanimous decision that the Ghost Team (so named for quietly ghosting in late on the competition) had created the overall best design based on Inertial Confinement Fusion (ICF; fast ignition laser) using deuterium/deuterium (D/D) reactions – essentially high-powered lasers heating and compressing pellets of deuterium until they fused. So congratulations to Andreas Hein and his budding team of interstellar spacecraft designers! Commiserations but well done for the endeavours of the other participants whose efforts went beyond the Project Icarus call of duty.

The Icarus project team will now be working on the detailed design of the 'Ghost Ship' over the next 12 months while also taking forward the 'z-pinch' fusion of the Firefly design, which operates by the natural pinch of a conductor/plasma if a sufficiently high current is passed through it. Based on the D/D reaction, work is now being done to test whether the pinch is sufficient to cause continuous fusion. This single stage design with its 60-metre long glass structure containing glowing plasma gave rise to the moniker 'Firefly'.

The UDD concept, which featured a two-stage design and a form of 'ultra dense' deuterium that requires a much lower laser beam energy to bring to fusion, was thought to be too speculative because of a lack of corroborating research in the material itself and was instead classed as one to watch for the future.

Deuterium or helium-3?

Starship Resolution was another variation of ICF but this time by shock ignition. While all the other designs were based on the D/D reaction, Resolution relied on deuterium/helium-3 fusion reactions. Helium-3 does not occur on Earth and would have to be mined from the atmospheres of the gas giant planets. Despite great advantages of the deuterium/helium-3 reaction, mining it would require a Solar System-wide economy to make it possible. Given a last minute re-design to use deuterium / helium-3 for both the boost phase the deburn to slow down, it was felt there was a little more work required to finish the concept design.

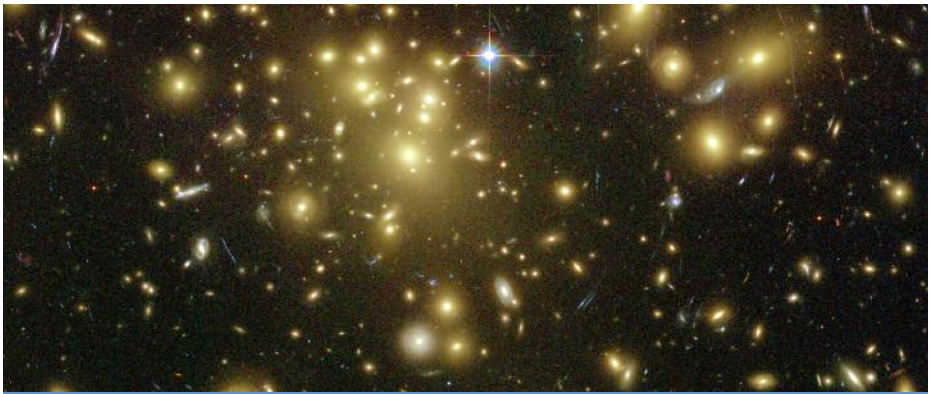
However, although deuterium is more readily available than helium-3, its performance as a fusion fuel dictates that the Ghost Team's ship be three times larger than Daedalus. Indeed, it is deliberately long and thin to move the ignition point as far from the main structures and propellant as possible to avoid the massive flux of high-energy neutrons created by the D/D reactions from damaging the rest of the ship. Nevertheless at the workshop Alan Bond, Daedalus' co-leader and now creator of Skylon and Reaction Engines Ltd, agreed that D/D would be the option to go for, given a suitable solution to the neutron flux.

The next stage will see work on preliminary designs, one for D/D ICF and the other for z-pinch, being completed by the end of 2014 and, once that is accomplished, the Icarus starship will really be shaping up.

Leader of the winning 'Ghost Team', I4IS' Andreas Hein.

Economics and Finance: The Front-lines of Galactic Evolution

August's Starship Congress in Dallas was an auspicious occasion, not least for it being the venue for the award for the first ever I4IS Alpha Centauri Award, given to the best presentation at the Congress and sponsored by Icarus Interstellar. The award was given by the judges to Dr Armen Papazian for his talk, 'Money Mechanics For Space'. Here Dr Papazian writes about his vision for a revolution in economics that will help propel us into space.



In a Universe that contains hundreds of billions of galaxies, does the notion of scarcity really make sense? (The galaxy cluster picture here is Abell 1689 in the constellation Virgo.) Image: NASA/ESA/L Bradley (JHU)/R Bouwens (UCSC)/H Ford (JHU) and G Illingworth (UCSC).

Our financial and economic imagination are as key as our technological imagination when it comes to extending our reach into the cosmos. As such, I argue that the frontlines of galactic evolution today are in two sciences that are holding many others and our species hostage: economics and finance.

Scarcity, as a principle as well as a field of analytical ontology, has led our species into a bottleneck. Scarcity is a human projection, an interpretation of a vast cosmic field of light that denies the very essence of what we now know in cosmology, astrophysics and a host of other fields. Curiosity landed and found water on Mars, Voyager has reached interstellar space; how should these factual discoveries be integrated into the economic interpretation of our reality? Indeed, must they be integrated? We are in the middle of billions of stars and billions of galaxies and our economics denies this by choosing scarcity as a starting principle.

> ***"As a species in the cosmos, we must be able to invent money in a way that suits our evolutionary intentions and aspirations without the artificial burden of debt."***

Debt creation

Today, money is created via debt and credit and expands through the same. Money is generated through a basic transaction between the government and the central bank. The central bank invents the money in circulation by purchasing government-issued debt paper and, more recently, bank-issued mortgaged-backed paper. This purchase happens on a logic of an instrument, i.e., debt, which involves time obligations in terms of scheduled interest and principle payments.

Money, once created via central bank purchases of government or bank assets, expands via debt and credit again, but this time via private entities, businesses, households and individuals. Debt-based money chains the species to calendar time. The number of governments, government agencies, municipalities, businesses, households, individuals and corporations chained to calendar time payments is simply astounding.

As a species in the cosmos, we must be able to invent money in a way that suits our evolutionary intentions and aspirations. Humanity must invent money in a way that allows it to invest as much as it needs in order to explore the evolutionary dimension it wants to pursue. We must be able to invest in our evolution without artificially created burdens such as public debt. Especially when governments and central banks invent money together and they are very much responsible for its mechanics and its implications. We must bring ourselves to invest in space timelessly.

Reinventing money

What is the appropriate economic ontology that fits a species that has just discovered water on Mars? Money can also be created through parallel alternative instruments, which lead to debt-free money mechanics. I have proposed previously and elsewhere that Public Capitalisation Notes (PCN), profit/asset sharing instruments without any debt component, can be used for money creation purposes. Thus introducing an equity like logic to money mechanics.

> ***"We are in the middle of billions of stars and billions of galaxies and our economics denies this by choosing scarcity as a starting principle."***

When issued by a government agency and/or sponsored by the Treasury, a PCN can be just as valid an instrument as a Mortgage Backed Security (MBS) for a central bank to use for their injection of new money. Nothing really prevents us from channeling newly invented money into NASA or the European Space Agency, as examples, rather than the big banks, except a debt-based logic of money creation.

Mortgage-backed securities, the instruments that the Federal Reserve is currently buying every month (85 billion dollars worth), create new money and inject this into the banking system. This quantitive easing is reflected into real spending when it leads to increased lending by the banks, otherwise it is just improving bank balance sheets and

Dr Armen Papazian presenting at the Starship Congress.

liquidity. While there are many issues with the debt-based system, one key reason for a stalled recovery is the fact that people and households, and companies and governments, must borrow and spend for there to be any money supply increase, while almost all are already under mountains of debt.

Public Capitalisation Notes, when used for new money creation, channel the money into the economy as income first, by directing investment into specific industries and projects, by creating value and assets from the beginning. My proposal is that 40 billion dollars of the next Federal Reserve injection into the banks must be redirected towards NASA, to rectify a policy error of cosmic magnitude. To see this, we must come to terms with the fact that we can afford to create as much money as necessary in order to invent humanity's future in space. We must embrace this enormous cosmos as our own true context, drop scarcity as a worldview and introduce new principles of value based on abundance and creativity.

Time, risk and space

Following this logic, I have proposed a new and still missing metric of financial valuation, which I have called Space Value of Money. Today, the finance discipline and industry use two key principles of value, 1) risk and return, and 2) time value of money. There is no reference to space. Furthermore, all financial models are geared towards analysing the profitability of cash flows, rather than their creative impact. Space Value of Money introduces a formal assessment of the impact of cash flows as an integral element of investment valuation. Here, space refers to time-space, as well as physical space on Earth and beyond.

By focusing on time- and risk-based return only, finance absolves its instruments from space responsibility. Space Value of Money is a 3D model of investment valuation that introduces, amongst others, the monetary, technological, social, environmental, human and non-human impact of cash flows in space, on Earth and beyond. As such, it introduces the creative force and its impact as a source of value and identifies its lack and negative impact when necessary.

Public Capitalisation Notes are designed to have an optimised level of Space Value of Money. This is because they are earmarked for industrial and economic projects that have a real impact on humans, their habitat and evolution. They can be directed at projects that a self-seeking mortal investor would never consider, due to his or her focus on time- and risk-based return. What if we wanted to invest in a project irrespective of time and irrespective of risk? Space exploration is an ideal example here because space defies the current laws of finance with distant cash flows and immense risks.

Investing in space

This is why space exploration has not attracted as much funding as we hope and think it should. Space cannot be truly explored when our money is debt-based and all those who have the funds are worried about risk. The few billionaires who are actually investing in space are either trying to sell seats for space tourists or are themselves dependent on government contracts. Building space infrastructure for our expansion into the Solar System is an evolutionary project that requires public debt-free financing and Public Capitalisation Notes can provide a possible channel for such an investment.

Space is the endless frontier that we seem unable to explore properly because we are chained to time and debts and banks, all thanks to a science whose raison d'être needs to be human prosperity and evolution. Investing in space and space technology has an immense impact on Earth, creates jobs, creates new knowledge and involves real value creation in a variety of industries. There is simply no excuse and scarcity is a distortion in our field of vision.

We are in the cosmos and our economics and finance need to catch up fast.

Dr Armen Papazian is Chairman and CEO of Keipr Ltd and is the first winner of the Alpha Centauri Prize, Progenitor Award.

The Alpha Centauri Prize

Aiming to set technical standards for those working in the interstellar community, the exciting Alpha Centauri Awards are a set of prizes launched by the Institute for Interstellar Studies, with the intention of incentivising progress and rewarding those whose work pushes interstellar research forward in some way. Launched at the Starship Congress, with a prize to the tune of $500 donated by Icarus Interstellar, the first Alpha Centauri Prize – the 'Progenitor Award' – was awarded to the presentation given at the Congress that it was felt by the three judges, namely I4IS' Dr Rachel Armstrong, Discovery News' Dr Ian O'Neill and Centauri Dreams' Paul Gilster, demonstrated the greatest potential for influencing the direction of research towards interstellar flight, in this case in an economic fashion.

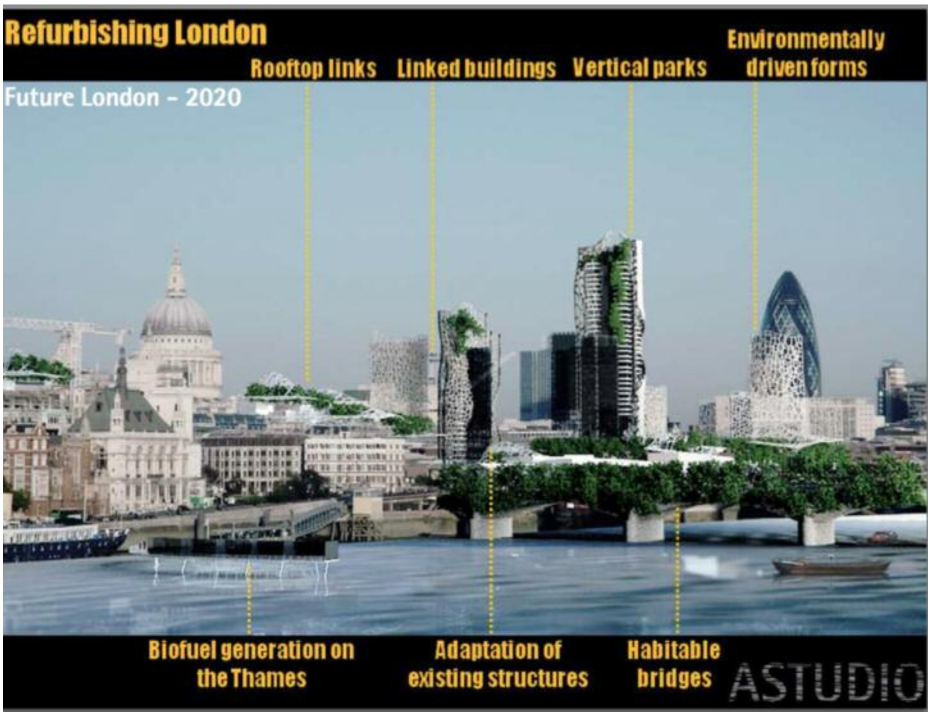

Dr Armen Papazian receives his Alpha Centauri Prize.

"Armen gave a passionate presentation and it was well deserved," says I4IS' Kelvin Long, who founded the Alpha Centauri Prize. "I am very happy to see economics being recognised as one of the important drivers for interstellar flight, the others being political and discovery-based."

You can watch Dr Papazian's award-winning talk on his YouTube channel: http://www.youtube.com/watch?v=DlIeLWvZhgA#t=466

Starships on Earth

Can integrating living systems into architecture and construction in twenty-first century cities pave the way forward for a sustainable technology for starships? Rachel Armstrong ponders the possibilities.



A bio-transformed future London, where biotech is able to turn inert buildings into energy producing centres. Such technology could one day work its way up into starship design.

Creating the conditions for habitability as we travel to the stars may be achieved in a very immediate and practical sense by weaving starship fabrics into our cities. Such interventions may help us understand more about 'ecopoiesis' in transforming inert environments into living systems and may not only help us increase the liveability of our surroundings but also establish the fundamental building blocks for constructing worlds.

Rather than needing a huge budget in understanding how to build ecologies in non-terrestrial environments, it is possible to explore existing opportunities in the sustainable design of contemporary cities. The production of architecture is, generally, a privately-funded enterprise and, with the relevant agreement of stakeholders and planning permissions, it may be possible to establish collaborations that build knowledge about the construction of 'sustainable' habitats. The principles underpinning these practices that promote ecological performance are as equally relevant to the growth of resource-constrained mega-cities as they are to the construction of living spaces within starships.

Importantly, such knowledge is not something that is theorised but that is actually lived and may be fine-tuned by generations of architects working in collaboration with the interstellar community. The goal would be to produce installations and buildings that develop the knowledge gleaned from living within closed environments, such as Biosphere 2, by conducting architectural 'experiments'.

Arcologies

Sustainable buildings have been an architectural concern since R Buckminster Fuller observed that we lived on 'Spaceship Earth' and architects have sought to identify forms of technology and social organisation that promote healthy living in our environments, such as the architect Paolo Soleri's notion of architectural ecologies, termed arcologies, where cities are formally entwined with their landscape, such as giant buildings with closed-loop systems, much like a spaceship. However, these living spaces are fundamentally constructed as 'machines' – being imagined as geometrically bounded objects that are organised in hierarchies. So, while we can suggest approaches that will produce more 'efficient' machines and conserve planetary resources, their designs do not promote life per se. Indeed, our widespread use of industrial processes and machine-based technology are collectively contributing to the 'reverse terraforming' of our planet, stripping it of its material resources and turning them into waste products with very low biotic value that inhibit living processes.

To begin this process, it is necessary to consider the kinds of processes that currently shape human development and consider how cultural practices as well as the kinds of technologies that we use impact on our environment. In constructing our living spaces, we may be able to use life-promoting technologies that have been developed over the last 30 years or so to design and engineer with the 'technology of nature'. Indeed, the biotechnology revolution has enabled us to work at such small scale and with such precision that we can think of living processes as being a kind of technology.

Algae reactors

The impacts and effectiveness of these 'living' technologies may be measured differently to machines. Rather than looking to parameters of efficiency and resource conservation, they may instead be assessed through their promotion of ecological relationships, by increasing fertility and orchestrating the flow and transformation of matter through dynamic, elemental systems. Drawings, models and prototypes of these proposals explore new possibilities that offer a very immediate set of actions that can be taken towards starship development and which may be tested by interweaving them with the fabric of our living spaces. Algae bioreactors, anaerobic digesters, bioluminescent light sources, heat absorbing and emitting substances (e.g. sodium thiosulphate) and even hygroscopic materials (e.g. calcium

An artist's concept of an 'Algae Studio'.

chloride) are examples of the kinds of systems that may begin to change the operating systems that underpin the way we live.

To develop such habitats to the stage where they are meaningful to starship design it will be vital to work with architects, scientists and construction engineers. Lessons learned from the construction, implementation and use of these systems might inform space-engineering requirements to decide whether the kinds of propulsion system for a particular starship is slow or fast, wet or dry. On Earth, these experiments will help advance further architectural developments in 'sustainability'. To monitor progress it is also essential to develop appropriate metrics that engage with ecological concepts so they are not simply collapsed back into a system of mechanical values. In other words we not only need to measure 'efficiency' but other livability factors e.g. biodiversity, fertility and recyclability.

Cybernetic installations

Currently I am working on a series of projects that may serve as examples of very practical projects that could help us take the first near-term steps towards our long-term goals in starship design and engineering. They are at their earliest stages of development and each of them demonstrates some of the principles outlined in this document. While the technologies themselves are not 'new', the way they are designed, engineered and applied within an urban context embodies a different kind of approach to the production of architecture.

Hylozoic ground series, which are installations by architect Philip Beesley, incorporate 'chemical organs' designed by the author. This cybernetic installation was first installed at the Venice 2010 Architecture Biennale. It proposes to offer an immersive environment as a model 'artificial ecology' that responds to the presence of visitors. Yet these interactions are not reflexive, but complex.
The primitive neural net is triggered by summated impulses and discharges in volleys of activity so that the environment is surprising and received as 'emotional'. Dynamic chemistries were entangled in the cybernetic system as a series of notional 'glands' that slowly changed colour in the presence of dissolved carbon dioxide, like artificial smell or taste organs.

This installation is a challenging tapestry of fabrics that speak of the 'nano-bio-info-cogno' convergence, where cutting edge technologies converge to provoke new human and economic impacts. This possibility was outlined in a report for the National Science Foundation in 2003 and has subsequently been adopted by the European Union through a series of jointly funded sand pits that encourage multi-disciplinary collaborations. The work embodies the idea of 'living' spaces and buildings that are not inert but are responding to many cues from their inhabitants becoming part of an intimate ecology of exchanges.

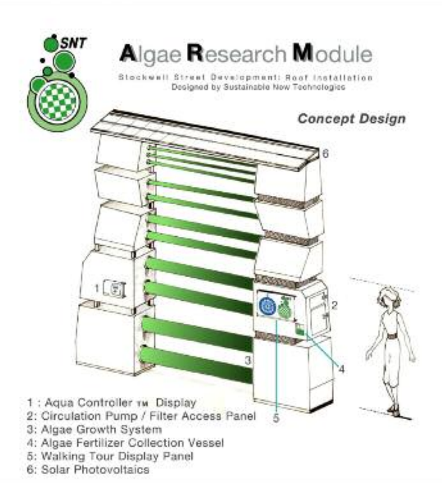
Such interactions and networks propose a paradigm shift in the way that architecture is practiced where the architecture is responsive to cues in its surroundings and is also able to produce a tiny amount of matter that records its environmental relationships. Although this award-winning work is pioneering, it has yet to be adopted into mainstream practice. The amount of carbon dioxide that can be scrubbed from the atmosphere is miniscule amounting to around a gramme of carbonate each month. Yet, the importance of this particular technology is not in its carbon-fixing efficiency but in its bold attempt to reverse the impacts of construction by going 'beyond' the current carbon zero ideals of ecological architectural programs and demonstrating that carbon positive impacts are possible. Currently, the Leonardo Building in Salt Lake City is the only building that has incorporated such a system into its atrium.

Algae in Greenwich

The Algaeponics Project at the School of Architecture Design and Construction at the University of Greenwich is the first permanent algae installation in the UK and was built by California-based engineers Sustainable Now Technologies. It will be situated at the new school of Architecture, Design and Construction at the University of Greenwich in 2014 and is a research station that will provide data on the performance of a local strain of algae.

Such modular, algae-based bioprocessing units are termed 'Greenstone devices' and are environmental technology to capture carbon, produce energy and matter, and

Philip Beesley's Hylozoic ground series installation, which incorporates 'chemical organs' that react to human presence.



A schematic of an Algae Research Module (ARM) such as that being installed at the University of Greenwich.

Rachel Armstrong speaking at the Starship London event, which was part of the 'SciFi London' science fiction festival.

promote 'green' business. The device is made up of one hundred 10-gallon 'alpha' bioreactor units containing water and algae. Effectively each unit is just an aquarium that houses tiny green organisms that absorb light and carbon dioxide as they are pumped through the aquarium by a small solar-driven motor to produce biomass.

The products of the system can be decanted off and processed in a variety of different ways, from 'cracking' the algae with an electrical current to release essential oils and a 'milking' process to burning the biomass.

Algae reactors like the Greenstone device can reduce the running costs of corporate buildings. For example, HSBC in London will house around 65 Greenstone devices that can produce about 19,000 tonnes of biomass using carbon dioxide each year. This potentially reduces total fuel consumption by up to 8.5 million litres of diesel per year. In a domestic setting a Greenstone device can fit in the back of a garage and produces around a gallon of biodiesel per week, making it possible to run a biodiesel-converted car on local trips around town at an average fuel efficiency of 30 miles to the gallon. The installation of a community-based fuel producing unit is being planned and tested for Lend Lease's Elephant and Castle development in London.

It is hoped that such facilities will enable us to further develop algae-based architectural fabrics in the built environment. The very first projects that aim to explore these kinds of systems are only just being built and are not yet mainstream. For example, Arup has built an algae façade with the International Building Association in Hamburg that uses sunlight and oxygen to produce biomass that is being used to produce energy in a social housing complex.

Yet, in the long term, the main benefit of using algae bioreactors is not their energy saving benefits but their cumulative effects where the 'waste' product left over when biofuels are extracted is beneficial to the environment by providing nutritious biomass for the production of fertile soils as they contain high levels of phosphorous and nitrogen. Potentially, the worldwide uptake of bioprocessing systems such as Greenstone devices in corporate and domestic settings could produce enough biomass to double our fertile soils within a hundred years.

The 'artificial ecology' in the atrium of the Leonardo Building in Salt Lake City.

On 12 October 2013 I4IS sponsored a 'Starship London' event at The Crystal in Stratford. This was an exploratory event that took the form of a series of expert presentations followed by a workshop. Members of the general public were asked to imagine with architects and the interstellar community how different London may seem if a section of the city was relocated within a starship, where the environment could not be assumed as a constant. Discussions ranged from how society may be organised around an ecological economy to the practicality of transporting sections of the city into orbit. While no solutions to starship design were formulated during the informed conversations, an enthusiasm for developing further conversations, partnerships and opportunities to explore critical issues for the future of humanity was established and how these may relate to interstellar exploration. Plans for further Starship Cities events are in development where issues related to life beyond the Solar System is positioned in a manner that is not just relevant to future generations but is something that can be, and should be, actively engaged today.

Dr Rachel Armstrong is I4IS Director of Sustainability and Development, a trained medical doctor and an architect lecturer at the School of Architecture and Construction at the University of Greenwich, London, where she is Co-Director of AVATAR (Advanced Virtual and Technological Architectural Research).

Retrospective: Art, Science and Lollipops: the story of the Enzmann Starship

One of the most distinctive starship concepts made is the Enzmann starship, ranging from 600-metre cruisers to vast worldships, all fuelled by a giant ball of frozen deuterium. This is the Enzmann starship's story.

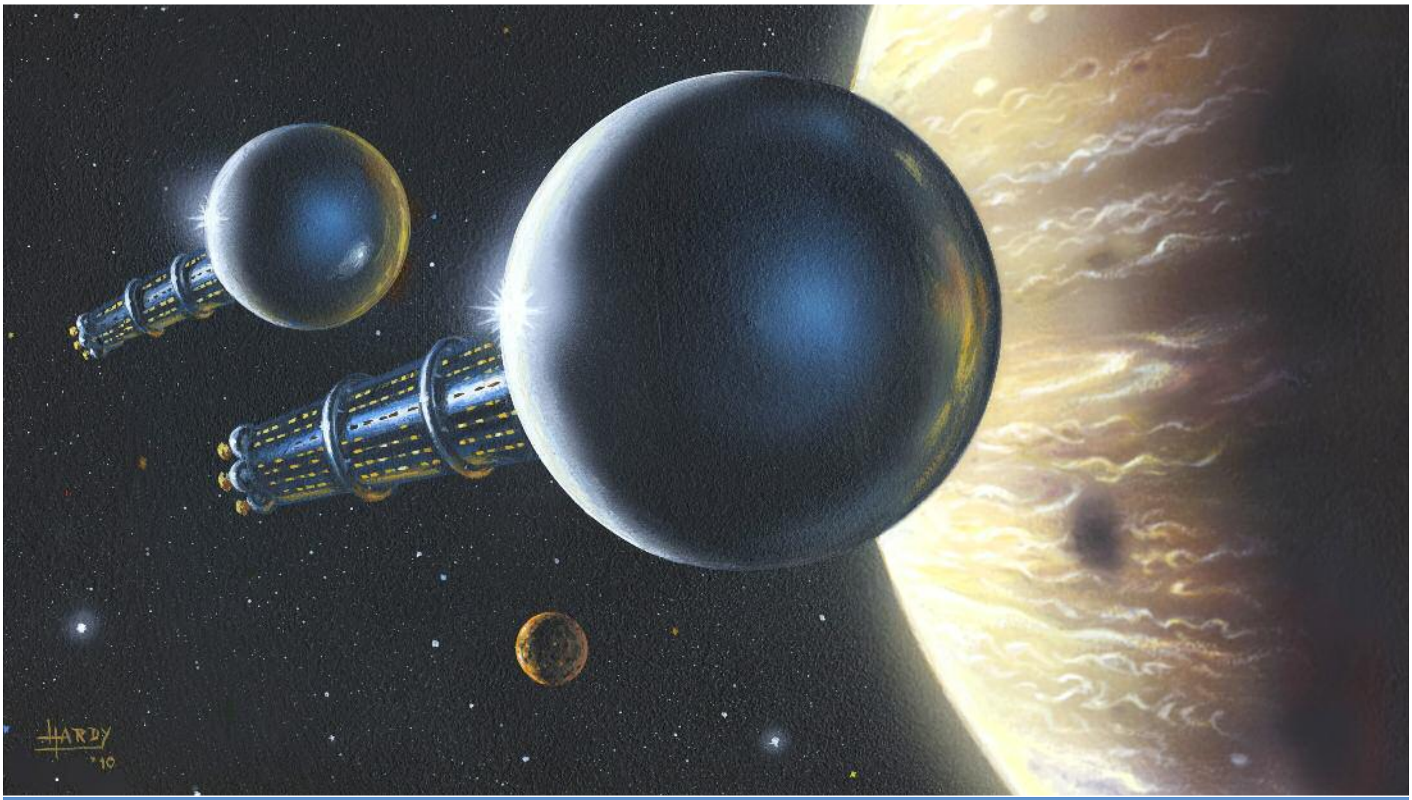
Technology has never laid claim to any kind of moral compass; that responsibility falls upon those who wield the technology. Their choices and the ethical decisions that accompany them make it possible for technology, at its greatest extremes, to be both horrifically destructive or powerfully liberating, capable of snuffing out life or taking humankind on voyages beyond our wildest imaginations.

So when Professor Robert Enzmann, a physicist at the Massachusetts Institute of Technology and the defence contractor Raytheon Corporation, heard of the fall of Hiroshima on 6 August 1945, a thought crossed his mind. Suppose nuclear power could be used to drive mighty engines on starships rather than murder thousands of people? Such engines would need fuel, of course, lots of it, but the power unleashed could push a starship up to a decent fraction of the speed of light.

Over the next two decades Enzmann further refined his ideas. His suggestion was for a cylindrical ship, housing the engines and crew habitats, attached to a three million ton (2.7 million metric tonnes) 'comet' of frozen deuterium. The deuterium would act as the fuel, either through deuterium-deuterium reactions, or deuterium-tritium. Encouraged by Project Orion, which was led by physicist Freeman Dyson and featured spacecraft literally dropping nuclear bombs from their aft section and riding on the shock waves, Enzmann reckoned that his starship could reach at least nine percent of the speed of light using nuclear pulse engines.

Yet initially Enzmann never got around to publishing his ideas. Its first appearance in print came in *Analog* magazine in 1973, in an article written by G Harry Stine. Although Stine himself had little contact with Enzmann, his article featured the work of two artists, Don Davis and Rick Sternbach, who had. Indeed, in the year prior to publication Davis and, in particular, Sternbach had visited Enzmann to help hone his ideas. Davis recalls that by the time he came onboard in November 1972, Enzmann and Sternbach (who also designed several starships for the *Star Trek* television series, including the USS Voyager) already had the basic design figured out. Rather than a naked lump of frozen deuterium, which as a solid could be quite fragile when exposed to the harshness of space, Sternbach had suggested encasing it within a tough plastic balloon acting as an insulation blanket, coated with a titanium alloy layer 1.3mm thick and added via vapour deposition. Hence the famous 'lollipop-look', with a vast sphere 521-metres in diameter filled with deuterium fuel, made famous in the artwork of Davis, Sternbach, David Hardy and others.

The number of engines also tripled, from Enzmann's original eight to a whopping twenty-four. The 'stick' of the



David Hardy's classic Enzmann starship artwork.

lollipop would be 600 metres long, The 'stick' of the lollipop would be 600 metres long, divided into three units housing the engines and habitats. Each section, 91 metres in width, would contain its own power plant, making sub-sections self-sufficient – a crucial element that will come back into play later in the Enzmann story. Meanwhile, a central corridor would run through the ship providing stability, while by rotating the cylinder twice every minute a centrifugal force could simulate the effect of gravity to a fifth the surface gravity on Earth. The crew would be protected somewhat from radiation by a frozen deuterium layer inside the hull. Meanwhile the revision of the Enzmann design with input from the artists also saw the deuterium fuel block increase in mass, with the craft lugging around up to 12 million tons (11 million metric tonnes) rather than the original three million.

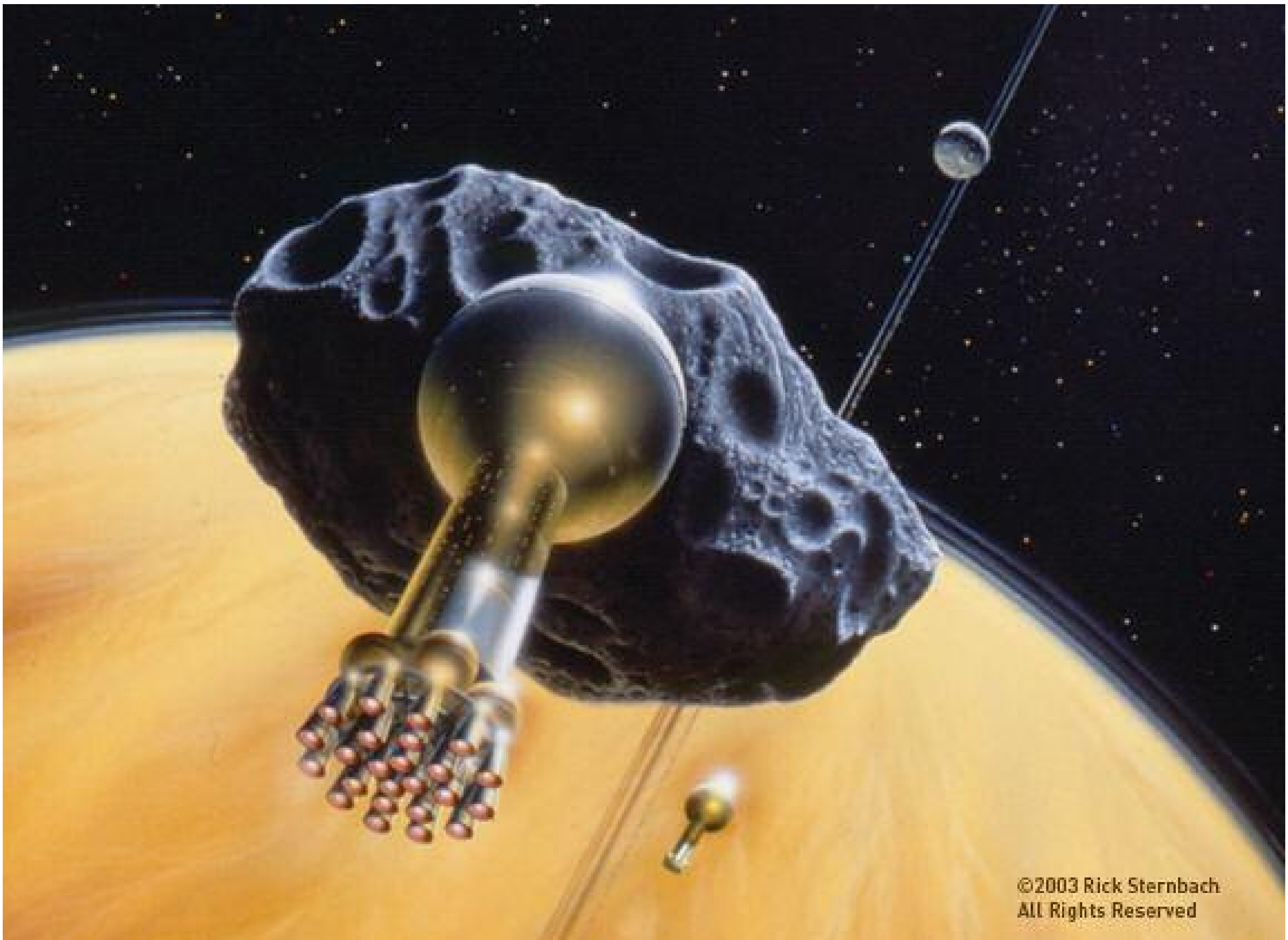
Boundlessly optimistic

Unfortunately Stine's article over-exaggerated how fast an Enzmann starship could travel. Claiming that an Enzmann starship could cruise through space at 30 percent of the speed of light, he set unattainable expectations for the concept. Recently Adam Crowl, Kelvin Long and Richard Obousy revisited the Enzmann project and, re-running the calculations, showed that at best, using a deuterium–tritium propellant, a velocity of 26,500 kilometres per second – 8.85 percent of the speed of light, very close to the nine percent that was within Enzmann's original range of velocities – could be achieved. Deuterium–deuterium reactions, on the other hand, producing tritium or helium-3 as by-products, are much less efficient, reaching only 4.64 and 4.17 percent of the speed of light. Nevertheless, even Robert Enzmann could be "boundlessly optimistic about what could be achieved," says Crowl, even to the point of having ideas for faster-than-light starships, as murky as the design specifics for them are.

Stine contributed to the over-excitement. In his *Analog* article he wrote of a fleet of Enzmann starships departing Earth, with the first to be built and launched by 1990 in a hundred billion dollar programme spread over two decades, ultimately accounting for ten percent of the total US GNP, based on

> ***"Enzmann reckoned that his starship could reach at least nine percent of the speed of light using nuclear pulse engines"***

1973 economic figures. It was hardly realistic – when Stine's article was published the Apollo programme had just been cancelled and we were settling into a nice lengthy spell stuck in low Earth orbit – but it made for great escapism. More articles and artwork followed, with Enzmann starships also appearing into the 1980s in *Science Digest*, *Astronomy* and the *National Geographic Picture Atlas*. Motivated by the resulting growing interest in his work, Enzmann began to experiment with his design, moving from a pulse drive to a starship driven by continuous fusion ('torch class') and then to the top-of-the-range 'Hyperon-Lance class' featuring a ramjet (see *Principium* issue three) using lasers that would ionise and direct atoms from the interstellar medium in front of the starship into a fuel collector where it would be compressed by magnetic fields for nuclear fusion.

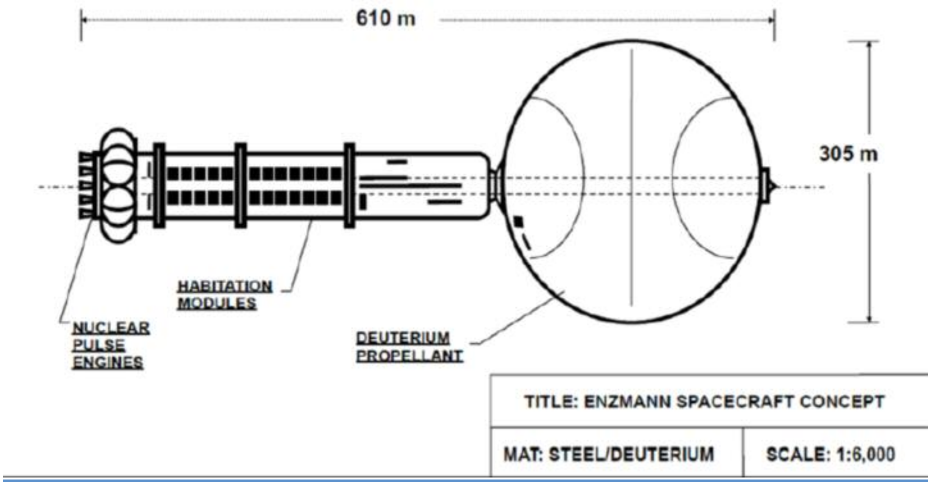


Rick Sternbach's 1983 painting of an Enzmann starship arriving at a gas giant in another planetary system, where it can find deuterium to refuel. Image: © 2013 Rick Sternbach – Used with permission.

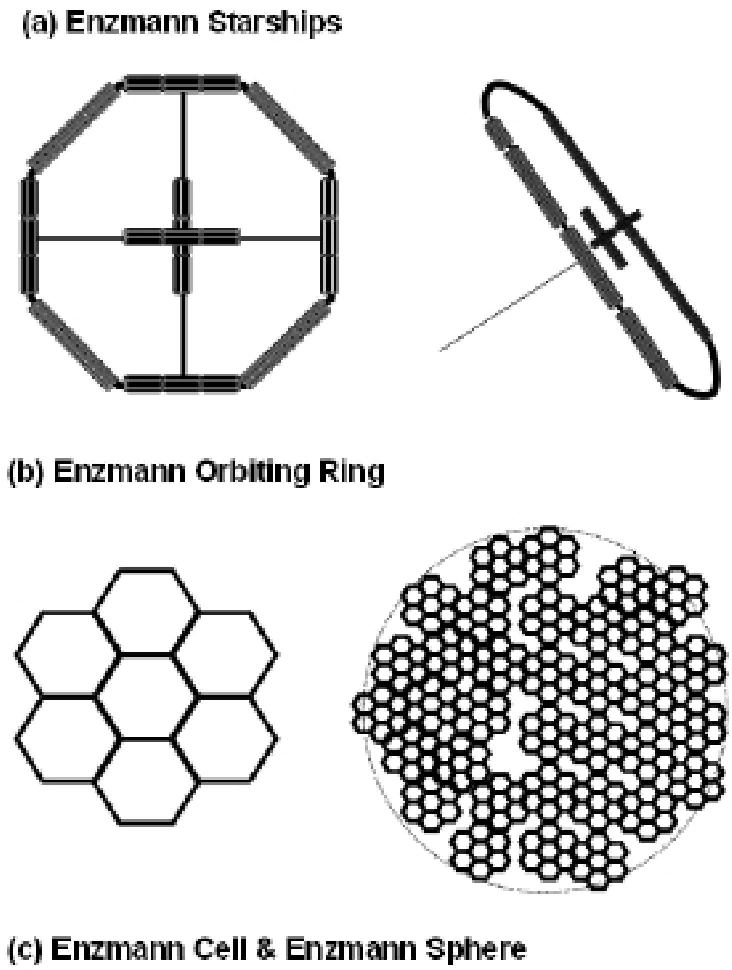
Enzmann cities

Regardless of the type of drive, the Enzmann starship's versatility provides added possibilities upon reaching a destination star. The problems faced with the thorough scientific exploration of a planetary system were highlighted at the recent Starship Century Symposium at the Royal Astronomical Society in London, where I4IS Advisory Council member Professor Ian Crawford raised the problem of how to explore multiple planets with just one main craft. One solution would be to load a mothership with a multitude of robotic rovers and orbiters that could be despatched to each world. The Enzmann starship, however, comes fully equipped for exploring more than one planet. The trio of sub-sections that make up its cylinder can detach, each sub-section linking up with eight of the fusion engines to form three individual spacecraft. By this time much of the deuterium lollipop would have been exhausted; whatever fuel the smaller craft need could be carried onboard of their much shorter journeys.

An Enzmann starship could even be further adapted for yet another use. Larger variations could act as worldships, suggest Crowl, Long and Obousy in their analysis for the *Journal of the British Interplanetary Society* (volume 65, number 6, pp185–199, June 2012). A ship 1.75 kilometres long, with O'Neill cylinders inside, could carry 20,000 people and become a permanent orbiting colony above the destination planet. Several worldships, sent one after another, could even link up to form cities in space, octagonal rings of Enzmanns with two further Enzmanns in the centre of the ring to provide stability. Many rings could then be joined together to form metropolises in orbit, essentially pre-fabricated structures ready to be assembled, although the stability of such structures remains undetermined. Furthermore, a Daedalus-style vessel would have the edge when it comes to maximum velocity. In both cases actually slowing down upon reaching their destination remains problematic. Yet the utility of the Enzmann design would seem to be without question, which could still be a deciding factor when judging what kind of craft should transport us to the stars.



A design concept for the basic Enzmann starship.

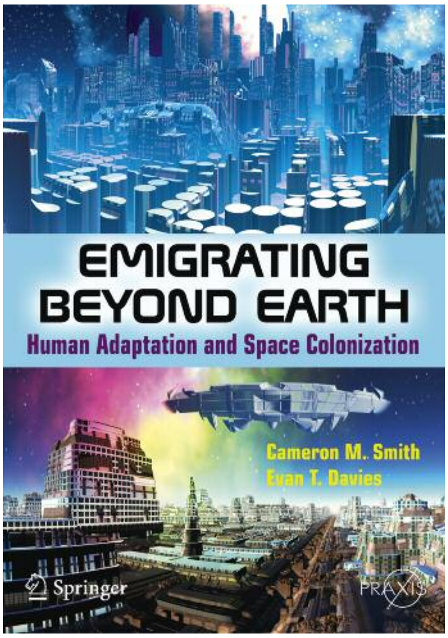


The Enzmann cylinders could be joined together at the destination to create large space habitats.

Reviews

Emigrating Beyond Earth

Cameron M Smith and Evan T Davies



A book so titled ought to provide answers to the following questions:

- why would we want to leave Earth ?
- how can we detect a suitable planet/exoplanet/moon ?
- how will we travel to that location ?
- what will we do when we get there ?

Sadly this book provides an answer only to the first question. The authors' backgrounds are anthropology and archeology which probably explains why their knowledge of astronomy and space is somewhat inadequate for a book of this kind. It also explains why very nearly half of this book is devoted to human evolution. We know where we have come from but what we need to know is where we are going!

The chapter 'A Choice of Catastrophes: Common Arguments for Space Colonisation' summarises quite well the reasons why we might want to leave Earth. The one blot on the landscape is the error strewn diagram of a comet. One additional question that might be raised in this chapter is what if 'the others' (p256) get here before we get there?' Not totally unreasonable to consider this point – if we are going to voyage through space why shouldn't other civilisations be doing the same ?

The related chapter 'False Choices: Common Objections to Human Space Colonisation' states that "..space is increasingly becoming privately accessible...". We have a very long way to go in this respect – getting to low Earth orbit is one thing, interplanetary /interstellar travel is quite another. Throughout this book one gets the impression that the authors have little time for national space agencies, believing that the answer lies with enthusiastic individuals such as Elon Musk, Burt Rutan and Richard Branson. Criticising a space scientist who spells out the technical challenges to be overcome is a bit rich for two people who, as mentioned above, are not blessed with an abundance of knowledge in this area, notably when they locate the Van Allen belts close to Mars!

Whereas we know enough about our Moon and Mars to ascertain what we would need to do to live there it is not so for exoplanets. In the chapter 'Distant Lands Unknown' the authors state that Mars is "suited to human colonisation." Even if Mars could be terraformed there are major problems, including that its atmosphere could still be lost by a combination of low Martian gravity and erosion by the solar wind, which is exacerbated by the lack of a magnetic field and which means that, unlike on Earth, any inhabitants would be at the mercy of the solar wind and coronal mass ejections. Furthermore, the spin axis of Mars is not stable and might increase to as much as 60 degrees, which would have a dramatic effect on the climate.

Exoplanets are a different matter – at best it will be ten years before we know enough about such a body to be able to make a rough guess as to whether it is suitable for human colonisation. The proposed Exoplanet Characterisation Observatory (EchO), if approved by the European Space Agency, will be a step in the right direction by studying exoplanet atmospheres.

As mentioned earlier the authors put their faith more in individuals than national space agencies to get us to other worlds, assuming that such people would do so for the benefit of all mankind – past experience shows this is not necessarily so. The relevance of the chapter 'Starpaths – Adaption to Oceania' is questionable and I admit to being confused by Figure 6.6 which appears to show the stars Aldebaran (in Taurus) and Alnilam (in Orion) passing close to Polaris. The Polynesians could live off the land or sea during their journeys, which would last for a relatively short time whereas travel to exoplanets may well take generations with no convenient stopping points on the way. The authors state there is no "bar to human colonisation of space technically" – a very questionable position. Journeying to the Moon or Mars is relatively simple compared with a journey to an exoplanet. Whatever our destination we still need to find a way of lifting men (and women) and material off the Earth – conventional rockets are far too costly so a space cable would seem more suitable. Even travelling at or near the speed of light, an interstellar journey may take generations so we must hope that NASA are successful in their efforts to create a warp drive.

The question of what we will we do when we reach our destination is discussed in the context of evolutionary and cultural changes but misses the practical aspects. For example, any technology we take with us, however simple, will not last for long so we have to find, extract and process the natural resources we require. It is truly mind boggling to think we would more or less have to start from scratch and recreate what we now have – stone age to the present day. If a planet is habitable it may well be inhabited. Would we be welcome and how would we behave? Past experience does not suggest a peaceful outcome.

Roger Dymock

Emigrating Beyond Earth: Human Adaptation and Space Colonisation

Authors: Cameron M Smith and Evan T Davies

Published by Springer (pb) 290pp

ISBN: 978-1-461-41164-2

Available from: http://www.amazon.co.uk/Emigrating-Beyond-Earth-Adaptation-Colonization/dp/1461411645/ref=sr_1_1?ie=UTF8&qid=1382982944&sr=8-1&keywords=emigrating+beyond+earth

Mission Statement

The mission of the Institute for Interstellar Studies is to foster and promote education, knowledge and technical capabilities which lead to designs, technologies or enterprise that will enable the construction and launch of interstellar spacecraft.

Vision Statement

We aspire towards an optimistic future for humans on Earth and in space. Our bold vision is to be an organisation that is central to catalysing the conditions in society over the next century to enable robotic and human exploration of the frontier beyond our Solar System and to other stars, as part of a long-term enduring strategy and towards a sustainable space-based economy.

Values Statement

To demonstrate inspiring leadership and ethical governance, to initiate visionary and bold programmes co-operating with partners inclusively, to be objective in our assessments yet keeping an open mind to alternative solutions, acting with honesty, integrity and scientific rigour.

Front cover: A starship nears a black hole's accretion disc. Art by Alex Storer.

Back Cover: A false-colour composite view showing submillimetre and near-infrared emission from dust within the star-forming nebula NGC 6334. The image was taken jointly with the ArTeMiS instrument on the Atacama Pathfinder Experiment and the VISTA telescope at the European Southern Observatory in Chile. Image: ArTeMiS team/Ph André, M Hennemann, V Revéret et al/ESO/J Emerson/Cambridge Astronomical Survey Unit.

www.I4IS.org

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

Join us on our Facebook page to join in the conversation!

principium@i4is.org

Editor: Keith Cooper
Layout: Adrian Mann

The Institute For Interstellar Studies is a pending institute in foundational start-up phase subject to incorporation in the United Kingdom