

Principium

The Newsletter of the Initiative for Interstellar Studies™

Issue 10 | August 2015

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Scientia ad sidera
Knowledge to the Stars

A letter from Kelvin F. Long



It has been a very exciting time for i4is and as we approach our three year anniversary in September, it is appropriate to reflect on all that has been achieved by our outstanding team.

We have formalised our core committees and each is now doing productive work focused towards our mission of interstellar flight. The educational academy committee led by Rob Swinney is working with multiple schools and universities, including the International Space University. They are also developing an innovative curriculum which we hope to launch next year.

The technical committee, led by Andreas Hein, is pushing forward multiple small projects, and our flagship Project Dragonfly, for which we have just completed a highly successful crowdsourcing campaign and the delivery of four excellent technical team reports looking at laser-sail based propulsion.

The Sustainability & Development committee, led by Professor Rachel Armstrong, is looking at more Starship Cities events and how we can best work with architects to emerge Starship technologies from the ground up.

The Enterprise (business) committee, led by myself is thinking carefully about how to best incubate new ventures and innovations and to assist the next generation of entrepreneurs to fulfil their dreams.

In addition to our committees, we have our defined our own legal constitutional articles, created

a high quality looking web site, attended or organised many events, including Dysprosium, The World Science Fiction convention, The Philosophy of the Starship symposium, the Physics of Wormholes symposium. Our team continues to produce other output, including outstanding art, music albums, books, smart phone app - there are so many activities that we are having to pause and consider how best to manage the organisational development for improved sustainability and growth.

I am really excited about all that has been achieved, and also the work we do with our partners, particularly the British Interplanetary Society and the International Space University. Then with successful achievements in spaceflight, such as the amazing New Horizons arrival at Pluto, and the continued discovery of exoplanets around other stars,...it really does feel like the time for the stars is approaching. I can't wait to begin the next three years work and I want to thank everyone in our team for their contributions, too many to name, although Gillian Norman, John Davies, Alex Storer, Terry Regan and Angelo Genovese deserve a special mention in dispatches.

As I close this introduction for the current issue of our in house magazine Principium, don't forget to look up the Icarus Interstellar Starship Congress Hackathon which takes place 4-5 September, Drexel University, Philadelphia (see News item below). It's sure to be a lot of fun for those involved.

Kelvin F. Long

Executive Director

The Initiative for Interstellar Studies

Editorial

In this edition you will find the second part of the account by Kelvin Long of our Wormhole symposium, "Wormholes Come to London". This includes the contributions of Silke Britzen, Tiffany Frierson, Remo Garattini and John Davies.

On a related theme, we have the feature "Wormhole-Stargates: Tunnelling through the Cosmic Neighbourhood" by Eric W. Davis.

We very much welcome an account by Zachary Fejes of the Icarus Interstellar Project Voyager, a software development for interplanetary and interstellar navigation.

Our first major international event, the 2014 WorldCon, the World Science Fiction Convention, took a lot of preparation and we hope you will be entertained by an

account of the thrills and spills on the way to the show.

"How do we survive on a distant world?" by Roger Dymock considers what we might face on a habitable planet of another star.

Our News this time begins with the upcoming Starship Congress and the New Horizons triumph at Pluto - there is a connection! We also mention another SF outreach, this year's UK Eastercon. And finally an item about the Dragonfly workshop of June 2015. We will be covering Project Dragonfly in more detail in later editions. We have to disappoint readers who were expecting a meditation on the interstellar implications of the Rosetta comet probe and its Philae lander and a report from the 2014 Tennessee Valley Interstellar Workshop (TVIW). We hope to bring

you the former next time and your editor will be doing his best to find a reporter from the next TVIW!

Our front cover feature is "i4is goes Stratospheric" with a brief account of the balloon experiment which, amongst other achievements, displayed the i4is logo at its greatest altitude so far! More about this in our i4is Goes Stratospheric! And for the rear cover we have Pluto and Charon as seen from New Horizons, courtesy of NASA, of course. These images join the work of other talents who have kindly provided their work to Principium - Stavros Hios, David Hardy, Alex Storer, Jon Lomberg and Adrian Mann. We will be featuring the best work from these and other visual authors in future editions of Principium.

We have now reverted to 3 column layout; give us your views.

John I Davies, Editor Principium

News

Starship Congress

2015

Dr Ralph McNutt, a distinguished interstellar advocate, will be a keynote speaker at Starship Congress 2015. Dr McNutt is Co-Investigator of the New Horizons mission to Pluto (see below and our back cover). He led the NASA NIAC (NASA Institute for Advanced Concepts) project "A Realistic Interstellar Explorer" in 1999. Starship Congress 2015, Interstellar Hackathon, September 4-5, Drexel University, Philadelphia, PA, USA. See the ad at the end of this issue of Principium including the supporting Kickstarter.

New Horizons - Pluto

July 2015 saw the NASA New Horizons spacecraft successfully execute a flyby of the dwarf planet Pluto to within a distance

of just over 12,500 km. We'll be analysing the implications of this major stepping stone to the stars in later issues of Principium. In this issue we congratulate the team on their design and execution of this mission and feature a composite of Pluto and its companion Charon on our back cover.

i4is at Dysprosium

As we promised, i4is continues its outreach to the science fiction community with attendance at the national UK annual Eastercon. This year it was Dysprosium at London's Heathrow Airport. John Davies explained how to derive Tsiolkovsky's rocket equation by cheating (slightly), we sold many copies of *Beyond the Boundary* (see our ad at the end of this issue) and we met the endlessly imaginative SF community again. More in the next issue of Principium.

Project Dragonfly

Workshop

Project Dragonfly is the first international contest to let students shape the future of interstellar travel. 100 backers pledged £6,387 (€9,000, \$10,000) via Kickstarter to help bring this project to life, including a most generous contribution from Dr Vinton G Cerf, one of co-creators of the Internet. The four finalist student teams came to London to present their concepts for a laser-push probe to a jury and interested peers on Friday, July 3rd. Written reports were assessed beforehand and, taking into account the presentations at the workshop, the final ranking was - 1. Technical University of Munich, 2. CranSEDS (Cranfield University UK and associates) 3. UC Santa Barbara 4. Cairo University. More in our next issue.



Participating teams & i4is staff at the i4is Project Dragonfly Laser-Sail workshop



Judging panel members at the i4is Project Dragonfly Laser-Sail workshop



Feature: Wormholes Come to London, "Interstellar Wormholes: Physics and Practical Realisation" Part 2

Kelvin F. Long

The first report from our November 2014 event, "Interstellar Wormholes: Physics and Practical Realisation" was in Principium 9. Look there for the first presentation "Space-Time Metrics from Black Holes to Worm Holes and the Einstein-Rosen Bridge".

Observations of Black Holes – Towards the Event Horizon

Our second speaker at the Wormhole event was Dr. Silke Britzen, of the Max-Planck Institute for Radio Astronomy, from Bonn, Germany. Her topic was electromagnetic radiation covering the whole spectrum from the radio up to Gamma-rays, and the spectral energy distributions of Active Galactic Nuclei (AGN) such as Seyfert 1, Blazar Mkn 501 and Quasar 3C273. The Global Very Long Baseline Interferometry (VLBI) forms a virtual telescope with an Earth-like diameter to give the highest angular resolution in terrestrial astronomy. To search for wormholes in AGN was one – among many other scientific reasons – to build the radio antenna in space: This may include active galaxies as current or former entrances to wormholes, see Astrophysics of Wormholes, N.S. Kardashev, I.D. Novikov, A.A. Shatskiy (2006).

The theory of black holes originates from Albert Einstein's General Theory of Relativity. Black holes are essentially specific solutions of the vacuum field equation of Einstein's gravity. Different types of black hole solutions have been proposed. They

include the static, neutral Schwarzschild black hole (1916), the static but electrically charged Reissner-Nordstrom black hole (1918), the rotating but neutral Kerr black hole (1963) and the rotating but charged Kerr-Newman black hole (1965).

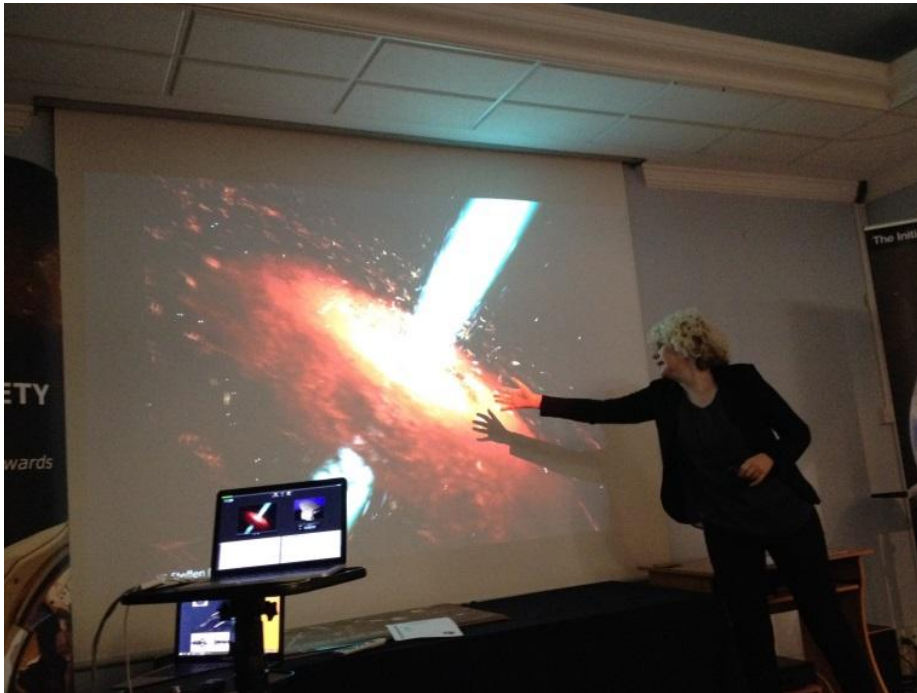
For these objects the black hole mass is hidden within either a ring or point singularity and in general they were defined by the 'no hair' theorem which simply states that objects can be fully defined by their mass, spin and charge.

Supermassive black holes are important to understanding how the first galaxies formed, and how they and black holes have evolved together. This is also crucial with regard to our understanding of cosmological evolution. Our own galaxy contains a supermassive black hole of approximately 4 million solar masses.

There is a proposal for a telescope that may be able to see at unprecedented resolution around black holes. This is the Event Horizon Telescope (EHT) which would have dramatic increases in resolution and sensitivity compared to the existing VLBA. Such a

telescope may even be able to detect a so-called black hole shadow, which is caused by the photon sphere around a gravitating object.

Finally Professor Britzen discussed an innovative paper titled "Distinguishing black holes and wormholes with orbiting hot spots" (Zilong Li and Cosimo Bamb, May 2014) which discussed the possibility that supermassive black hole candidates at the centre of galaxies might be wormholes created in the early universe, connecting either two different regions of our Universe or two different universes in a Multiverse model. The Very Large Telescope Interferometer (VLTI) instrument, GRAVITY, will have the capability to image blobs of plasma orbiting near the innermost stable circular orbit of the black hole in the centre of our own galaxy. The secondary image of a hot spot orbiting around a wormhole would be substantially different from that of a hot spot around a black hole, because the photon capture sphere of the wormhole would be smaller and its detection could thus test if the centre of our galaxy harbours a wormhole rather than a black hole.



Silke Britzen shows a very energetic astronomical object (left) and Remo Garattini expounds on Casimir and Einstein (right)

Traversable Wormholes and the Casimir Energy in Modified Gravity

Professor Remo Garattini is a senior i4is researcher and wormhole expert from Bergamo University, Italy.

Remo began by discussing the Einstein field equations and explaining the Einstein tensor and the stress-energy tensor. There is a possible solution to the field equations which neatly describes both black holes and wormholes, the standard Schwarzschild solution. The traversable wormhole metric was derived by Morris and Thorne in 1988 even if, it was Ludwig Flamm the first one who recognised that the Schwarzschild solution of the Einstein's field equations represents a wormhole. Note that the term 'wormhole' was introduced by John Wheeler in 1962. The detailed mathematics show how to produce equations for the radial pressure and negative energy density and pressure.

Is it possible for a gravitational field without external sources to sustain the traversability of a wormhole with the help of a gravitational Casimir effect? This references research done by Hendrik Casimir in 1948. This original work hypothesised that the zero point energy was responsible for the Casimir effect - later confirmed

experimentally by the Philips Laboratories. This effect is induced when the presence of electrical conductors distorts the zero point energy of the quantum electrodynamic vacuum. Two parallel conducting surfaces, in a vacuum environment, would attract one another by a very weak force that varies inversely as the fourth power of the distance between them.

This kind of energy is a purely quantum effect and no real particles are involved, only virtual ones. It is evident that, separately, each contribution coming from the summation over all possible resonance frequencies of the cavities would be divergent and devoid of physical meaning but the difference between them in the two situations (with and without the plates) was well defined.

In Quantum Field Theories, the Casimir effect gives contributions to the total nucleon energy in the quantum chromodynamic bag model of hadrons. This has applications to spontaneous compactification of extra spatial dimensions in Kaluza-Klein field theories, gauge theories, SUSY, SUGRA, and string theory. In condensed matter physics, the Casimir effect leads to attractive and

repulsive forces between the closely spaced material boundaries which depend on the configuration geometry, on temperature, and on the electrical and mechanical properties of the boundary surface.

This is responsible for some of the properties of thin films and has to be taken into account in the investigations of surface tension and latent heat.

In gravitation, astrophysics and cosmology, the Casimir effect arises in space-times with nontrivial topology. The vacuum polarization resulting from the Casimir effect can drive the inflation process. In the theory of structure formation of the Universe due to topological defects, the Casimir vacuum polarization near the cosmic strings may play an important role.

In atomic physics, the long-range Casimir interaction leads to corrections to the energy levels of Rydberg states.

A number of the Casimir-type effects arise in cavity Quantum Electrodynamics when the radiative processes and associated energy shifts are modified by the presence of the cavity walls. In mathematical physics, the Casimir effect has contributed to the development of zeta functions and heat kernel

expansion techniques for the regularization and renormalization of infinities.

Therefore, it appears that the Casimir effect has multidisciplinary applications. However for the traversability the wormhole it is fundamental because it represents a source of negative energy density mimicking exotic matter, which is the basic ingredient to obtain a traversable wormhole. To do calculations in practice, it is better to separate the metric of space-time from Einstein's gravity into a background and a perturbation term. The Einstein tensor can also be divided into a part which is unperturbed and related to the background geometry and a part related to quantum fluctuations.

Remo showed how to compute the expectation value of the perturbed Einstein tensor, using a variational procedure with Gaussian

wave functionals. The challenge then is to show how this is connected with Casimir energy. It is assumed that there will be a boundary located at the wormhole throat and the other at infinity. When computing the zero point energy (equivalent to the Zeta function) in these two configurations with the same asymptotic behaviour, you are essentially computing the Casimir energy of the gravitational field itself. Remo's conclusions were that, in theory, quantum fluctuations of gravity could sustain the wormhole, but there is a need for a regularization and renormalization procedure to eliminate the quantum divergences. Nevertheless, using a distortion of gravity termed 'Gravity's Rainbow', it is possible to avoid such a regularization/renormalization scheme. Gravity's Rainbow has been

introduced by Maguejio and Smolin in 2004. The price you have to pay is the introduction of two unknown functions depending on the ratio E/E_p , where E_p is the Planck energy and E is the energy of the graviton. Such functions, call them $g_1(E/E_p)$ and $g_2(E/E_p)$ enter the metric since the beginning and they activate at the Planck scale in such a way to give finite results, at least in the first approximation.

Remo concluded by saying that semi-classical Einstein field equations were a source for self-consistent solutions. The obtained 'traversability' would have to be regarded as 'in principle' rather than 'in practice' due to the wormhole radius likely. In this procedure, what is really fundamental is an amplifying mechanism which is very difficult to implement.

Using Micro-Wormholes in Interstellar Communications

Tiffany Frierson is an i4is researcher and a student researcher in Icarus Interstellar.

Tiffany skyped in live from the US to deliver her contribution to the Wormhole event. She started by discussing radio frequencies and optical systems, as typically used by NASA's Deep Space Network.

Radio frequency systems had been recommended as the main communication system for the British Interplanetary Society 1970s Project Daedalus study but lasers are also a candidate for long distance communication. Tiffany argued that RF systems are better understood and tested, but laser systems offered higher data rates, less power requirements, smaller equipment and less signal dispersion.

We need a solution that will reduce (or eliminate) current interstellar communications issues, and one possibility is a faster than light solution – which may be permissible using wormholes.

Using wormholes to facilitate interstellar communication would have the benefits of instantaneous or near-instantaneous communications between Earth and starship. In addition, the space short-cut would reduce the signal distortion issues. Tiffany cautioned that engineered wormholes would require negative energy densities and possibly lots of exotic matter.

However quantum field theory permits the generation of negative energy density from the quantum vacuum, and very small amounts of negative energy have already been demonstrated in the laboratory by the Casimir effect. A better technology for generating negative energy to build wormholes may be by the use of parabolic mirrors, where every incoming ray of light that is parallel to the mirror's axis would become focused at one point. Instead the incoming energy could

be vacuum fluctuations and these could, in theory, be focused.

In such a set-up, the energy density will be negative near the focus of the parabolic cylindrical mirror.

Tiffany finished by suggesting that we will realise a micro-wormhole before a human or starship sized one is produced. A micro-wormhole requires much less negative energy than a larger one.

As an example calculation, for a wormhole with one millionth of a



Tiffany skypes in across the Atlantic

metre diameter, requires a negative energy of around ten to the power of thirty seven Joules; which is still a

very large number. Engineering the actual wormhole will be difficult, but not impossible. Once we figure

out wormhole engineering, we can utilize it to vastly improve interstellar communication.

“Wormholes in Science Fiction”

The Wormhole event presentations ended with John Davies talking about fictional use of wormholes.

Beginning with a quote from J. G. Ballard ‘Fictions of Every Kind, 1971’, *“Everything is becoming science fiction. From the margins of an almost invisible literature has sprung the intact reality of the 20th century”*. Fiction has used different types of worm holes. Big ones for which you could fit a ship or a person through, little ones sufficient for photons and information transport, and related concepts such as use of extra dimensions.

John began with Alice’s Adventures in Wonderland (1865), maybe the rabbit hole is just a large wormhole where Alice falls without feeling it. Lewis Carroll went on to write ‘Through the Looking-Glass and what Alice Found There’ (1871) a way to an opposite chirality through a portal like television’s Stargate.

A major event in the science fiction of wormholes was the

publication of Carl Sagan’s novel ‘Contact’ (1985), which features an intergalactic network of paired wormholes – like the London Tube map! The novel ‘Timelike Infinity’ by Stephen Baxter, from his Xeelee sequence, also featured a “towable wormhole” Published more than ten years before similar ideas in Iain M. Banks ‘The Algebraist’ and several years before J. Michael Straczynski’s ‘Babylon 5’.

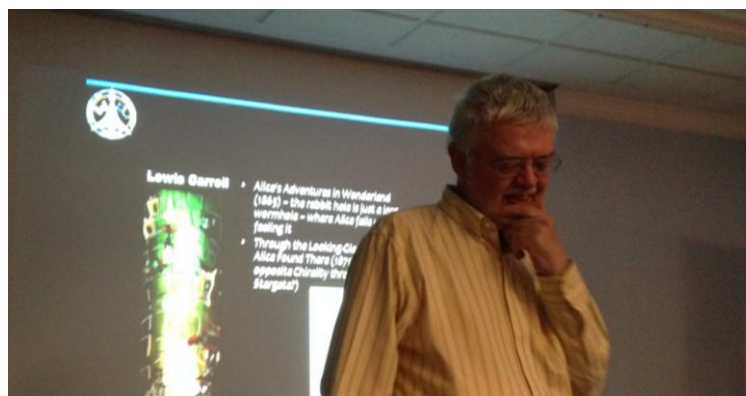
The TV series ‘Babylon 5’ built its own wormhole, in contrast to the Star Trek ‘Deep Space Nine’, where a convenient nearby wormhole brings new plot material every week to the show. It is worth noting that both shows aired for the first time in 1993, and one can only speculate if there was any connection between the screen writing. Wormholes were imagined very differently in 1994 with the first airing of ‘StarGate’, using ancient unearthed technology for interstellar transport.

Other notable novels which featured wormhole-like technology include ‘The Subtle Knife’ by Philip

Pullman (1997), ‘Diaspora’ by Greg Egan (1997), ‘The Light of Other Days’ by Arthur C Clarke and Stephen Baxter (2000) and ‘The Algebraist’ by Ian M Banks (2004).

The latest contribution to the subject of science fiction wormholes is, of course, the film ‘Interstellar’ (2014) directed by Christopher Nolan, which features wormholes devised by the physicist Kip Thorne, already mentioned extensively in the hard science part of the Wormhole event. Thorne mentions in his associated book that the CGI effects team at Double Negative, the visual effects/computer animation company, had produced new physics insights by applying Thorne’s equations.

John ended the presentation with a movie clip from ‘2001: A Space Odyssey’, which shows the astronaut Dave Bowman going on a trans-galactic voyage through some kind of wormhole. For a moment, perhaps, the audience felt like Alice in Wonderland.



John ponders wormholes in Lewis Carroll

Panel: The Practicality of Wormhole Engineering”

At the end of the day, the speakers assembled as panellists to discuss physics, cosmology, gravity and all things wormholes. This was chaired by Rob Swinney. Topics included the probability of natural or artificial wormholes, questions

about cosmology and the evolution of stars. The panel were asked about evidence for a Multiverse. It was the consensus of the panel that there was no evidence currently to support such an idea, but Kelvin referred to interesting

interpretations of quantum mechanics and cosmological models which permitted such a possibility.

The wormhole meeting was voted a great success, with discussions continuing in the usual way at the local pub!



Rob Swinney (Chair), Kelvin F Long, Remo Garattini, John I Davies, Silke Britzen at "Interstellar Wormholes: Physics and Practical Realisation" i4is Symposium at BIS, 24 November 2014

Feature: Wormhole-Stargates: Tunnelling Through The Cosmic Neighbourhood

Eric W. Davis

It was many years ago when science fiction media (TV, film and novels) began to adopt traversable wormholes, and more recently “stargates”, for faster-than-light (FTL) interstellar travel schemes that allowed their heroes and heroines to travel the cosmic neighbourhood. Little did anyone outside of relativity physics know but that in 1985 physicist Kip Thorne and his students at CalTech had in fact discovered the principle of traversable wormholes right out of Einstein’s General Theory of Relativity (M. S. Morris and K. S. Thorne, *Am. J. Phys.*, 56:395-412, 1988; M. S. Morris, K. S. Thorne and U. Yurtsever, *Phys. Rev. Lett.*, 61:1446-1449, 1988).

Thorne and collaborators did this as an academic exercise, and in the form of problems for a physics final

exam, at the request of Carl Sagan who had then completed the draft of his novel *Contact*.

Sagan wanted to follow the genre of what I call science “faction”, whereby the story’s plot would rely on real physics concepts to make it more realistic and technically plausible. This little exercise ended up becoming one of the greatest cottage industries in general relativity physics – the study of traversable wormholes and time machines.

Real stargates exist in principle; they are merely a form of what are called traversable wormholes, and they are one type of FTL propulsion. These are unlike the well-known, non-traversable Einstein-Rosen Bridges or Schwarzschild wormholes that are formed from collapsed stellar matter (black holes)

or spherically symmetric vacuum regions.

However, even Einstein-Rosen bridges can be made traversable by an infinitesimal tweaking of their spacetime metric.

Wormholes are hyperspace tunnels through spacetime connecting together either remote regions within our universe or two different universes; they even connect together different dimensions and different times.

Space travellers would enter one side of the tunnel and exit out the other, passing through the throat along the way. Unlike black holes, traversable wormholes do not have an event horizon or a singularity on the inside that obstructs the throat, nor is there any crushing gravitational field anywhere inside the tunnel/throat.

Space travellers going through a traversable wormhole do not violate Einstein's Special Theory of Relativity by always remaining inside their local light-cone along their time-like trajectory while moving below light speed through the wormhole between interstellar departure and destination points.

This is because the wormhole's unique spacetime geometry acts to tilt-over the space travellers' local light-cone, thus giving rise to their apparent FTL motion between stars as seen by remote outside static observers whose local light-cones are far away from, and unaffected by, the wormhole's spacetime geometry – the light-cone of space travellers moving along their time-like trajectory through the wormhole lies within the space-like hypersurface of the remote outside static observers' light-cones, thus the space travellers undergo FTL motion between stars as seen by outside observers.

Another interesting consequence of the spacetime geometry of traversable wormholes is that the space travellers' local proper time through the wormhole can be the same as the local proper time for remote outside static observers, thus eliminating any undesirable relativistic time dilation effects. Using traversable wormholes as time machines is beyond the scope of this discussion, because we are only interested in their potential for FTL interstellar travel.

Traversable wormholes are creatures of classical General Relativity Theory allowing for very comfortable travel through the cosmic neighbourhood. Wormholes can possess normal or backwards (in special cases) time flow, normal or nonexistent gravitational stresses on space travellers moving through the throat, and their entry/exit openings (or throats) can be spherically shaped, cubic shaped, polyhedral shaped, or generic shaped, etc. A by-product of traversable wormhole studies has been the development of wormholes possessing flat entry/exit openings (E. W. Davis, *AFRL-PR-ED-TR-2003-0034*:2-11, 2004).

These are essentially what a true "stargate" or flat doorway through spacetime would be. Energetics considerations and mathematical theorems show that traversable wormholes with the lowest energy requirement to construct are those that have a single throat (or tunnel).

To produce the spacetime geometry of a stable traversable wormhole, one requires an exotic form of matter whose rest-energy density and/or internal pressure must be "negative" or its internal pressure must be greater than or equal to its rest-energy density.

There are two other variations on this theme. In comparison, the matter that we are all familiar with in our daily lives has positive rest-energy density and positive or zero internal pressure. The exotic matter must be distributed locally in a finite volume of space in such a way that it threads the throat of the wormhole.

Negative rest-energy density and/or negative pressure produce the gravitational repulsion that is needed to open a topological "hole" or "tunnel" through spacetime.

The greatest misunderstanding about exotic matter being perpetrated by certain academic physicists and science news writers is that it is fictional or that it does not exist. That claim is false.

It is very well known that quantum field theory predicts exotic matter, and there is a very long list of the different types of exotic matter that are predicted to exist: there are a few types that occur naturally in our universe, a few that are man-made, and many others that are theoretically predicted but not yet experimentally discovered (E. W. Davis, *JBIS*, 66:68-84, 2013).

Cosmological dark energy, having positive rest-energy density and negative pressure, is one example of naturally occurring exotic matter and there are other types that remain to be discovered, all of which are responsible for the observed values of the cosmological parameters of the universe (M. Visser, *Science*, 276:88-90, 1997).

Examples of the man-made types of exotic matter include, but are not limited to, the negative vacuum energy and negative vacuum pressure associated with the Casimir effect and the squeezed vacuum states of laser beams – most of the types of man-made and theoretically predicted exotic matter are a special type of quantum vacuum energy which is preferred for traversable wormhole studies.

There are even classical (non-quantum) scalar fields that have exotic matter properties which could be used to produce traversable wormholes, if they are found to exist.

A few theoretical physicists harbour a strange prejudice against the idea of producing large amounts of negative vacuum energy to construct traversable wormholes. So nearly 40 years ago and thereafter, a few theoretical physicists derived theoretical constraints against the creation and use of large amounts of negative vacuum energy over long time intervals, which they call the Quantum Inequalities (QI) (L. H. Ford and T. A. Roman, *Sci. Am.*, 13:84-91, 2003).

The QI are an ad hoc version of Heisenberg's Uncertainty Principle in curved spacetime, and they state that the larger the amount of negative vacuum energy one produces, the shorter the time interval one has available to use it. However, the QI have been re-evaluated by many theoreticians over the past 15 years and the verdict is they are not generalisable to any 4-dimensional curved spacetime, while astronomical observations and lab experiments produce results that contradict their constraints (E. W. Davis, *JBIS*, 66:68-84, 2013). Recent theoretical attempts to replace the QI with something better have not succeeded.

Another proposed constraint against long-lived traversable wormholes is the effects of quantum back-reaction on the wormhole's spacetime geometry.

Quantum back-reaction is the distortion of quantum vacuum zero-point fluctuations – in the form of nonlocal Hawking radiation and local vacuum polarization – that is produced by spacetime curvature (a.k.a. the gravitational field) which is simultaneously accompanied by the back-reaction of the two distorted-vacuum fluctuation effects upon the spacetime curvature. A recent study has shown that the order of magnitude of quantum back-reaction effects on traversable wormholes is $\ll 10^{-30}$ compared to ≥ 1 for the case of black hole event horizons, so quantum back-reaction has a very negligible impact on traversable wormholes (E. W. Davis, *JBIS*, 66:68-84, 2013).

Einstein's General Theory of Relativity does not include assembly instructions for traversable wormholes. How does one deploy negative vacuum energy or other forms of exotic matter to assemble a traversable wormhole? Does one

need to pull a traversable wormhole from out of the putative quantum spacetime foam (i.e., Planck length-sized multiply-connected-fluctuations of spacetime geometry) and enlarge it to macroscopic scale, or will wormhole engineers need to produce extremely large spacetime curvatures to “punch a hole through space” (i.e., change the topology of spacetime), and then stabilize either approach using negative vacuum energy?

The spacetime-geometrical instructions for constructing a traversable wormhole are even more strange: 1) take two copies of flat spacetime, one each near the departure and destination stars; 2) remove identical hypervolumes (i.e., 3-dimensional surfaces of 4-dimensional spacetime) from each spacetime; 3) identify at the boundaries (i.e., “sew” the two leftover “holes” together to form a throat). How this can be translated into a practical engineering blueprint will require further theoretical studies accompanied by trial-and-error lab experiments. In any case, the bad news is that a series of past and recent cosmological observations have not found any evidence for quantum spacetime foam in the universe.

The good news is that the problem of changing the topology of spacetime has been solved.

Studies of a new quantum gravity approach in 2-dimensional space and 3-dimensional spacetime, which is not a theory of gravitons but of shape-shifting spaces, explicitly show that the topology of spacetime can change, thus supporting the creation of traversable wormholes (S. Carlip, *Sci. Am.*, 306:40-47, 2012).

Another complication is that General Relativity Theory does not provide any recipes for navigation, guidance and control through traversable wormholes to the desired interstellar destinations.

The technical description of a trip through a traversable wormhole is simply given by the proper time and distance of travel through its throat as measured by space travellers who always move on time-like curves, while the velocity of their starship through the throat is always less than the speed of light (M. S. Morris and K. S. Thorne, *Am. J. Phys.*, 56:395-412, 1988).

Whatever proper time and distance values one desires for their interstellar journey through a

traversable wormhole will depend largely on 1) the type of exotic matter that one chooses to assemble the wormhole and 2) the particular type of wormhole throat geometry, which serves as further input to wormhole stability analysis, determining the tidal gravitational forces exerted on the starship crew, etc. Additional theoretical studies along with trial-and-error lab experiments will need to be done in order to address the interstellar navigation issue.

Modern energetics analysis of traversable wormholes shows that arbitrarily small (i.e., near zero) amounts of exotic matter are the minimum that is required to create and stabilize a traversable wormhole (E. W. Davis, *JBIS*, 66:68-84, 2013). However, as the amount of exotic matter decreases to arbitrarily small values, the longer it will take a starship to traverse the wormhole and reach its interstellar destination as measured by the clocks of remote outside static observers, while the travel time and distance through the wormhole will become intolerably long for the starship passengers.

In the opposite extreme, the shortest travel time and distance through a wormhole can be had in what are called “short-throat” traversable wormholes which require a total energy of $-10^{44} r_{\text{throat}}$ (Joules), where r_{throat} (meters) is the size of the wormhole throat. This amount of negative energy is impossible to engineer, and physicists and engineers will likely have to find the optimal amount of negative energy that can be produced for an optimal traversable wormhole. At present, laboratory Casimir cavities and quantum optical squeezed vacuum states produce extremely minute amounts of negative vacuum energy.

An experimental program by this author and co-workers is underway at the Institute for Advanced Studies at Austin in Austin, Texas to explore the negative vacuum energy that is (theoretically) produced by using a cylindrical-parabolic mirror to focus quantum electromagnetic vacuum zero-point fluctuations onto the focal line of the mirror (L. H. Ford and N. F. Svaiter, *Phys. Rev. A*, 62:062105, 2000; *Phys. Rev. A*, 66:062106, 2002). This device will be evaluated to ascertain how much negative vacuum energy it produces, whether it is scalable and controllable, and

whether it is feasible to engineer and test in the lab.

It is possible that new technical implementations or new quantum field boundary conditions or interacting quantum fields will be discovered that can produce large amounts of negative vacuum energy in the lab. The engineering parameter space for the quantum optics devices that produce squeezed vacuum states will also be explored to discover whether new implementations can produce and isolate negative vacuum energy in scalably large amounts.

Other recently published proposals for creating traversable wormholes using classical electromagnetic fields and other non-exotic matter approaches are also undergoing evaluation. An integral component of this experimental program is the construction and testing of a quantum optical tomography-balanced homodyne detector that will be used to spatially and spectrally image the negative vacuum energy that is produced by quantum optical squeezed vacuum states, Casimir cavities, and the cylindrical-parabolic mirror device (E. W. Davis, *JBIS*, 66:68-84, 2013).

A future version of this detector will visually image the location of the negative vacuum energy that future wormhole engineers produce so that they will be able to manipulate and shape it to construct a traversable wormhole.

While theoretical research on traversable wormholes continues to evolve and address old and new technical issues, it will be important to focus that research on developing optimal technological sources of scalable negative vacuum energy or other forms of exotic matter, and simultaneously develop optimal technical solutions for the construction of traversable wormholes and their navigation, guidance and control laws for interstellar travel. This remains a rich area for multidisciplinary engineering-physics studies in academia and industry, which could bear much fruit in the future if more effort could be expended on developing traversable wormholes for interstellar flight.

About the author: Eric W Davis, Ph.D., FBIS, AFAIAA, is a senior research physicist at the Institute for Advanced Studies at Austin, in Austin, Texas, USA.

Cover Story: i4is Goes Stratospheric

Kelvin F Long

In January of 2015, a team planned to launch a balloon to high altitude; the mission was called Shackleton 2. The project was led by Sam Harrison and Daniel Parker.

The mission was launched on Sunday 11th January from Enniskillen airport in Northern Ireland, after negotiating CAA launch approval, with the aim to take a 'selfie' of the external display at around 120,000 ft, the target altitude. We are pleased to report

that the launch was a huge success and the balloon flew from Northern Ireland to Oxfordshire. The balloon drifted 100 miles off course but the team was able to recover it. The total flight time was around 3.5 hours.

The probe maxed out at 89,000 ft (27 km, 17 miles) after a frozen helium fill line burst due to the extreme cold caused by the expanding gas which meant they couldn't fill it up enough to reach its

maximum height. The on-board electronic heating system they designed and built worked "like a charm" and kept their iPod fully working at minus 70 degrees Celsius. They did have a tracking link to the probe but the software failed and they couldn't get that working. The i4is logo was loaded onto the probe and was one of the images taken by Shackleton 2 before the camera battery ran out.



Shackleton 2 Flight Path (left) and science payload (right)

The probe went to 89,000 ft which is 27.13 km or 16.86 miles above sea level, which placed it firmly into the stratosphere, the second major layer of the Earth's atmosphere just above the troposphere and below the mesosphere. The temperature at this height is around -50 degrees Celsius or 223.8 K and the pressure is around 20 millibars. The air

density drops to 0.028 kg/cubic meter. The speed of sound drops from its sea level value of 340 m/s to 299.9 m/s.

This is also the point in the atmosphere where the temperature is layered because ozone (O₃) absorbs high energy UVB and UVC energy waves from the Sun and is broken down into atomic oxygen (O) and diatomic oxygen (O₂). Atomic

oxygen is prevalent in the upper stratosphere due to the bombardment of UV light and the destruction of both ozone and diatomic oxygen. The mid stratosphere has less UV light passing through it; O and O₂ are able to combine. This is, therefore, where the majority of natural ozone (O₃) is produced.



Preparing for launch of Shackleton 2 (left) and the mission flight Team Sam Harrison and Daniel Parker (right)



Shackleton 2 went above the cruise altitudes of both the supersonic commercial airliner Concorde and the SR-71 Blackbird spy plane.

The height that the probe went to is above the altitude of commercial airliners (typically 30,000-39,000 ft) and is above the operational height of the supersonic jet Concorde (typically 59,000 ft). It is even above the ceiling the legendary Lockheed SR-71 Blackbird spy plane (typically 85,000 ft).

A huge congratulations to Sam Harrison and his team. It may not

be 4.4 light years away, to our nearest star, but getting our logo to 89,000 ft has to count as a tangible starting point. The photos clearly show the i4is logo with the curvature of the Earth in the background, inspiration for the future.

The i4is team are very excited about this achievement which shows we are starting to put our minds not just to theoretical

achievements, but real world tangible steps to the practical realisation of interstellar flight. Demonstrating transport through the atmosphere, and eventually beyond it, is an essential prerequisite for any space aspiring team.



Shackleton 2 at 89,000 ft with the i4iS logo and the curvature of the Earth clearly visible on the horizon



Shackleton 2 at 89,000 ft high up in the Stratosphere with the Sun in the distance, our closest star.

Icarus interstellar: Project Voyager - planning interplanetary and interstellar missions

Zachary Fejes

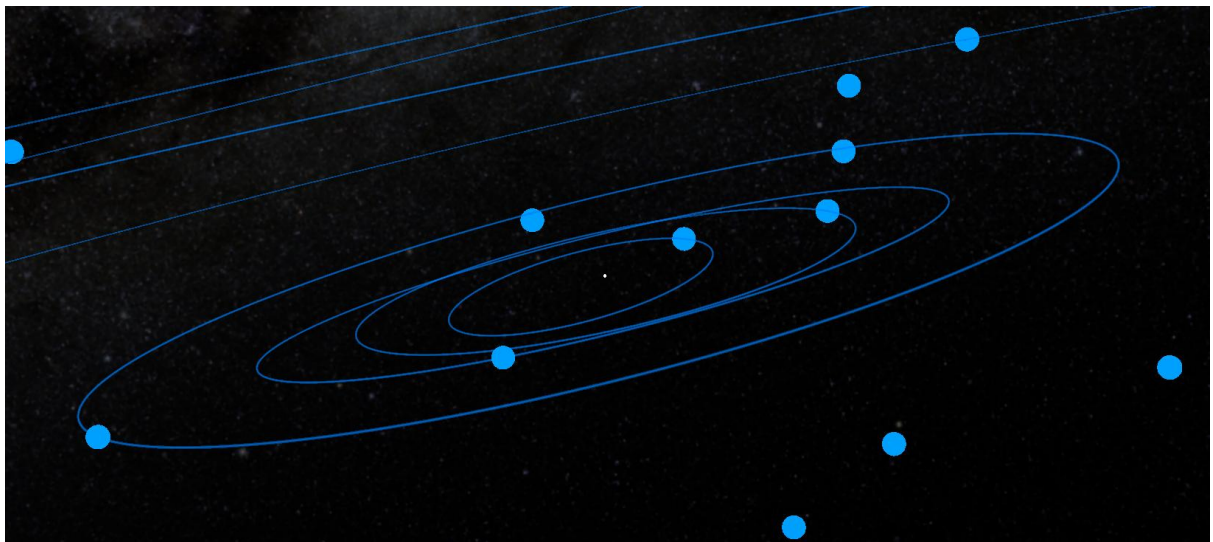
Project Voyager, associated with Icarus Interstellar, surrounds the development of an interplanetary and interstellar mission planning tool. This is being built as a next generation tool for space agencies, academic institutions, and space enthusiasts the world over.

Voyager is in essence a map which will allow users to plan missions to other planets, asteroids, comets, and even other star

systems. Mission planning will be beautifully intuitive, taking cues from modern video game design. Mission simulation will be at least as detailed and accurate as the best software on the market, and we aim to make it even better.

The software has three major components: the space map, mission planning, and mission simulation. Mission planning is done in real time, as the map

continuously updates a rough approximation of your trajectory based on the manoeuvres you lay out. Mission simulation takes this approximation, calculates a more accurate path, and overlays it on the map. By seeing the difference, it becomes much simpler to correct trajectories and iterate through mission designs.



The inner planets are the first things we have to deal with.

Space Map

Voyager features a detailed, high definition, and visually stunning space map which will include all planets, asteroids, and other bodies within our solar system - as well as all star systems and known exoplanets within 15 light-years. The map is dynamic, with all objects positioned in their actual locations at any time between the years 2000-

2050 AD. Time can be altered and the entire map re-positions instantly, and accordingly.

Each object has a vast store of relevant information for planetary scientists, spaceflight engineers, and science students which can be accessed with the click of a button.

The map is also extendable which allows for the addition of newly discovered asteroids, satellites, or exoplanets on the fly.

One of the most interesting challenges facing the development of the software is the approximation of the trajectories of nearby stars. This subject has been researched in the past, but an accurate approximation of relative position vs. time has not been documented. We are currently researching and developing our own algorithm for this approximation and will be utilizing our finding is the space map.

Mission Planning

Voyager is being built around the concept of real-time mission planning - which means that as soon as you modify an orbit, you see the change. Using modified patched conics, it is possible to quickly and easily proof out mission ideas while maintaining the accuracy expected of first order mission plans. Voyager

will support mission planning for a variety of different propulsion systems - from classical rockets to ion thruster systems.

Mission planning is designed to be quick and intuitive, providing the user with not only instant feedback, but with self-updating mission documentation as well. Important

metrics, including Delta-V usage and orthographic projections, are calculated automatically with each new manoeuvre. Mission planning with Voyager is designed to be painless and straightforward, while maintaining the accuracy and data analysis required for even the most demanding of space missions.

Mission Simulation

Beyond first-order mission planning, Voyager makes use of a powerful set of simulators to enable detailed assessment of trajectories and manoeuvres. Once a mission has been prepped, the simulator can take over and assess the plan in order to create a much clearer idea of what happens. As the calculations finish, a visual output of the simulation is overlayed on the space map, along with an expanding cone to indicate mathematical divergence of accuracy. This powerful tool allows for iterative mission design. The user lays out a basic plan, the simulator responds with the realistic result, and the user can iterate their design as required.

Our Mission is to accelerate the

space agencies, and enable more hands-on space science education for budding scientists and engineers all over the world. Voyager can be used for initial mission planning, detailed analysis, and potentially even as in-flight mission software for modern spacecraft.

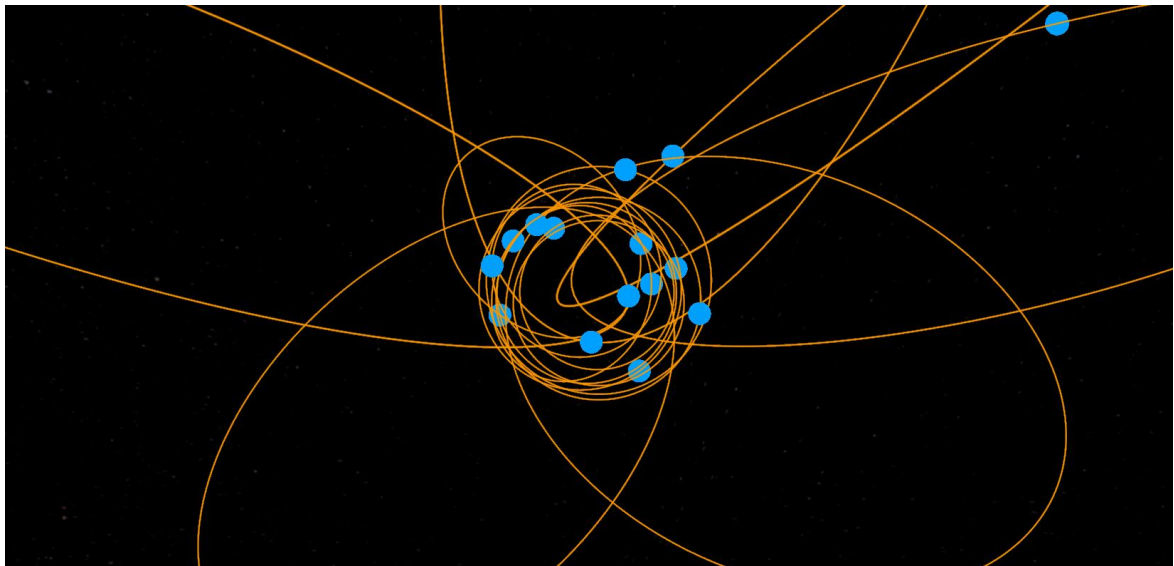
Younger space companies will benefit from having access to accurate, flexible, and powerful mission planning software - giving them a better chance of success in the market, and enabling them to play on the industry stage much faster. It is a perfect platform to give young space organizations a boost into orbit.

Voyager is also intended for established space organisations in the private or public sectors, which

documentation, reporting, and mission analysis.

Voyager has been built from the beginning to make use of a modern 3D interface, stunning visuals, and an accessible learning curve which - along with its accuracy and capabilities - makes it a powerful educational tool. The software is designed to be accessible by students from elementary, to post-graduate levels of education. Further, the accuracy of the software makes Voyager fit for academic research as well.

For younger students, it acts as an interactive space map - excellent for both teaching, and for hands-on learning. For high school and university students, it is a powerful physics tool, ready for use in both



Asteroids can be tricky!

growth of the space sector by providing better tools to all levels of this industry. Through the development of novel mission planning and analysis tools we can boost the success rate of young space companies, enhance the capabilities of mature government

can benefit not only from the above mentioned system capabilities, but the ease of integration into existing environments. Our software can provide a standardized system for mission planning, which can export data into a variety of formats. It also provides complete capabilities for

lecture and laboratory settings. As an educational tool, Voyager can provide an incredible tool for educators the world over. The core functionality of the software will be completed this month, and general development will be continuing through the year.

We are looking forward to showcasing an early version of the software at Icarus Interstellar's Starship Congress this September in Philadelphia. If you are interested in trying out the software in its development stage, please join us at the conference.

About the author: Zachary Fejes is the Project Lead for Project Voyager at Icarus Interstellar. <http://www.icarusinterstellar.org/team/zachary-fejes/>. Zach's piece for Discovery magazine "Project Voyager: A Map to Navigate Our

Dynamic Universe" is at <http://news.discovery.com/space/project-voyager-a-map-to-navigate-our-dynamic-universe-141209.htm>

How do we survive on a distant world?

Roger Dymock

Before departure

Having read a number of books and articles on the subject of interstellar travel I noted that these were almost, if not totally, concerned with the voyage and not the end result. By 'end result' I mean establishing a colony on a distant world (exoplanet in astronomical language). I then happened across Lewis Dartnell's book 'The Knowledge – How to rebuild our world from scratch'.

This described how the survivors of some disaster might reboot civilisation on planet Earth. It seemed to me that this was a good

starting point for populating another world – let's call it Earth II.

I write this on the basis of what we know today – the distant future may of course be very different. Human life on this world could end abruptly in a number of ways - that it will end is without question. Our Sun has another five billion years to live until it runs out of hydrogen at its core but in a billion years the Sun will have warmed so as to make the Earth a very unpleasant place. All life will have been extinguished so hell on Earth it will truly be.

Let's take a step back from arriving on Earth II to consider what

its characteristics need to be for our survival there. I am not considering terraforming as I am assuming we can find a suitable planet without going down that road. It is much beloved of those who wish to live on Mars but, unless you can find a way of stopping the solar wind ripping away the atmosphere, generating a magnetic field and stabilising the axial tilt of that planet, your efforts will be in vain. Prior to arrival we need to know (possibly via a robotic sample return mission or advanced observation from Earth) for example;

- the evolutionary state of its Sun-like star
- Earth II's orbital period, rotational period, axial tilt and stability thereof
- the presence and strength of the planet's magnetic field
- its atmospheric make-up
- its geology (land, water, presence of ores, vegetation)
- its biosphere (microbial and larger life, soil chemistry)
- the presence and evolutionary state of intelligent life

It would seem reasonable to choose an Earth II which had a similar year and day to our present home. Our bodies and any plants and animals we take with us might

struggle to adapt to different cycles and environments so we don't need to present ourselves with unnecessary difficulties, although it may be that we will develop the

ability to genetically modify the human body to cope with different environments.

On arrival

As far as the evolutionary state of intelligent life on Earth II - what would be in our best interests? If we talk of colonisation (in Earth's history that has meant invasion) then our previous Earthly adventures have not necessarily

been in the best interests of the local inhabitants but perhaps we can do better. Perhaps 'settlement' is a better word. Most likely only a relatively small number of Earth's inhabitants could be transported to Earth II so what of those who would

be left behind? There is no need for this to be too painful as just by preventing any new births all human life would be extinct in a hundred years or so.

So let's jump to Earth II. On arrival, priorities for the settlers will

be the same as they always have been - shelter, food and water. Possibly with very advanced robotics we could (as has been suggested for Mars) prepare the ground prior to our arrival. So where would we touch down? Assuming we have chosen an Earth II similar to Earth then, as did early European man, on the coast and near a river mouth and a forested area would be a good place to put down roots.

The sea and river are good sources of food and water and, as exploited by early man, highways for exploring the planet. The landing site would need to be in the planet's temperate zone to avoid climatic extremes. Even if robots do prepare the ground and make available some of our needs we would very soon need to live off the land. Food – deciding what is edible and what is not, would not be an easy task. Growing Earth crops on Earth II becomes essential for our survival – if they are to have a good chance of surviving on Earth II that planet needs to be very much like Earth particularly in terms of climate and seasons.

Simple cooking and preservation skills may need to be re-learned. For agriculture, and much else, we need to know the time and date. This may seem obvious but on a new world it will be essential to establish an accurate calendar. Water too –

Conclusion

I hope that the points I have raised show that settling on an exoplanet is a task of size and complexity that mankind has never yet undertaken. It seems to me that we can't sensibly entertain the idea of journeying to and settling on a distant planet using today's technology (a bit like attempting to go to the Moon by building a better sailing ship).

Rocket scientists won't like it but generational starships or any form of reaction propulsion and/or suspended animation don't cut the mustard – the 'right stuff' just ain't right enough anymore.

We just cannot send people off to Earth II and expect them to fend for

which is why living near a river is essential.

Maintaining good health poses many difficulties. We know about Earthly diseases but will know nothing about what is rife on Earth II. Setting up and maintaining the complex medical facilities we are used to will not happen overnight. A small colony would be very prone to being wiped out by a single infection so it might be advantageous to split the new arrivals into a few groups.

This has its problems as, knowing how we behave today; all sorts of differences and rivalries might soon arise. This leads to government – what would work initially and for the future? Do we yet have an ideal form on Earth one might ask?

On Earth we take good and immediate communication for granted. We need that facility on Earth II to link separate colonies and those exploring this new land. It might take a while to set up the instant forms of electronic communication we have become used to.

For some time modes of transport would be fairly basic – hence the need to locate near water so that boats could be used. It will take a while to develop modern day methods of transport and the means to fuel them. Maybe we will have to revert to horse power if we can find

themselves without any support from back home so we need to look at a transit time of months rather than hundreds if not thousands of years. In that way we should be able to come and go pretty well as we please. Why months – well that is how long it used to take to travel to any destination on Earth using sailing ships so it is as good as anywhere to start.

That takes us into the realm of time travel and wormholes. Professor Kip Thorne thinks using wormholes is a possibility so that, and faster than light travel, are where we should be putting our money. Even if such possibilities are realised we will still have to

horses or similar beasts that are there!! We also will need to know where we are so mapping and defining a coordinate system will need to be a high priority activity.

We will need to generate electricity – solar, wind and water power are possible for starters but we will initially have to rely on whatever tools and technology we take with us or send ahead and set up by robotic means as mentioned earlier.

Finding raw materials and processing them will be a key factor in enabling the settlers to progress. Stone, wood, clay may be the easiest to obtain and work so they may satisfy the settler's initial needs for shelter for example. Longevity of technology is absolutely key – nothing (yet) lasts forever. Star Trek's replicator would be useful – a facility which would accept any material as input, break it down into protons, neutrons and electrons, and rebuild those into any element required. Where science fiction leads science fact might do well to follow.

We have amassed a vast collection of knowledge so we would want, need, to transport that to our far off planet. Some is public and some is not (both government and business data). In what form, as technology is going to be fairly basic for a while?

overcome the challenges discussed here but being able to fairly quickly transport materials and infrastructure to our new world will surely be of significant help.

We have a few billion years to go so these methods may not be as fanciful then as they seem now. Our primary goal must be settlement – the journey is a means to an end.

About the author: Roger Dymock is a Fellow of the Royal Astronomical Society and the author of 'Asteroids and Dwarf Planets and How to Observe Them' ISBN 978-1-4419-6439-7, Springer 2010.

What we did at the WorldCon in August 2014

John Davies

The World Science Fiction Convention was the first really big event for The Initiative for Interstellar Studies. We told you how it happened in the last issue of Principium, number 9, in May 2015. But, as you can imagine, it took some organising. Here are a selection of the "thrills and spills" on the way to the Con, as told by one of the project managers, John Davies.

How we got started

When I joined i4is in late 2012 I asked Kelvin (that's Kelvin F. Long, our co-founder and chief exec) what I could usefully do. My spacecraft design experience was 40 years out of date but my enthusiasm was undiminished! At that stage we were still an unincorporated Institute under foundation. We cooked up the idea of being at the 2014 World Science Fiction Convention. After all it was happening in London, our home base, for the first time since

1965, and most of us were old SF fans. The SF community have always taken an interest in space and the cross-town traffic between the two would fill a book!

We made a start with some planning over an excellent meal at Gerry Webb and Mali Pereira's place. Gerry is both a long-term space entrepreneur and a keen SF fan. Both i4is and BIS would be there and Gerry was keen for us to be alongside. The company was

illustrious and influential. Greg Matloff, emeritus professor of physics at New York City College of Technology, was there. He's chair of the i4is Advisory Committee and is the guy who wrote The Starflight Handbook back in the 1980s. And Kelvin and I met Shana Worthen, one of the principal organisers of the Con. So thanks to Gerry and Mali for inviting us to a very pleasant and very useful gathering.

The Monolith

The Worldcon organisers offered of an 8m square space, which meant we had to show something spectacular. Professor Rachel Armstrong is Director of Sustainability & Development at i4is. She took an active interest in the early Con planning.

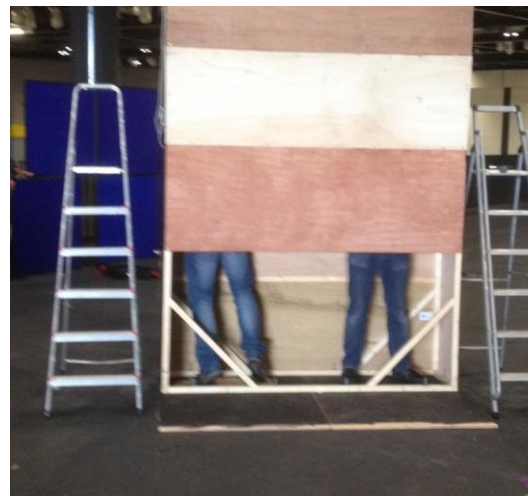
Rachel and I were discussing how the stand should look in early 2014 and we thought showing video would be a good idea. Rachel invited her sister, Esther, a stage designer, and Frank Da Silva of DMT Lab™ to meet us for a coffee and we dreamed up the idea of a 2001-style monolith with a sinister black sheen like the original and a screen for video on the back. I talked to Terry Regan, i4is model maker and all-round practical

engineer, about how we might build a 4m high monolith and he told me "I will build it!". The proportions had to be 1^2 by 2^2 by 3^2 ($1*4*9$), as the original.

By then, early 2014, I was overloaded with Loncon3 preparation and Gill Norman agreed to share the load. The monolith needed a build and test location. Gill and I hunted high and low but all were expensive or hard to reach. Around the same time I happened to be having a pint with an old friend and colleague, Paul Campbell, and he spoke the fatal words "We don't use our basement much, you can use that". He claims to regret this but he's joined the i4is team as our Website Manager so we suspect crocodile tears!

A hundred hours work or so later, Paul and Terry, now close working friends, rolled it outside, assembled it, and Terry attempted to tip it over! It was over 100kg in total but half of that was the base board so my calculations showed it would not topple unless we tilted it beyond 40 degrees. But Terry does these things by "rack o'th eye" and we all trusted his judgement - maybe more than my maths! We rehearsed the delivery, assembly and projection in a north London community hall.

We hired a van which was (just) big enough and delivered to Excel the day before. Paul and Terry had some "fun" as we assembled the monolith at the Excel centre.



Paul, as they say, “Lived to tell the tale” (left). They made it strong – Terry is no lightweight (top right). Spot which legs are Terry and which are Paul! (bottom right).



Here's the Clarke/Kubrick monolith towards the end of the film. Ours is a bit bigger, 4m, but not as big as the one on the moon!

Films, Video, Design, T-shirts and Posters

We worked with Frank Da Silva and Louis Savy (of SCIFI London) on a film competition but we didn't get any suitable entries so we concentrated on film clips, both real and fictional, showing weightless scenes on our vertical screen. You can see NASA and 2001 scenes in our report in Principium 9.

Attracting the big names

We already had people with world reputations - Kelvin and Rachel - for our conference slot but we wanted more. We contacted our old friend Professor Chris Welch at the International Space University in Strasbourg and he not only agreed to speak but also offered to sponsor our stand. The sponsorship from the ISU lead to Chris being on our stand to show the ISU to the world SF community. But we needed writers and our board

We worked with Frank Da Silva of DMTlab on the "look and feel" of the stand and he came up with our design for "The Interstellar Space" and that other essential item, tshirts for the Con!

member Keith Cooper of Astronomy Now magazine contacted Alastair Reynolds, my favourite interstellar writer, and he agreed to speak. Kelvin contacted Greg Benford who turned out to be coming over anyway and he added his name to our programme. And when Stephen Baxter, another major writer, agreed to join the panel "our cup runneth over!". More about all of them in Principium 9.



Frank's brilliant banner

How it all turned out

Very well, as it happened, but take a look at Principium 9, May 2015, for that story



The Monolith – end result of our teams hard work



Rob Swinney's picture of Vidyasagar Ananthan, John, Paul and Terry in front of the screen side of the monolith - looking tired in rough proportion to age!



We are up and running! Our Project Managers, John & Gill, delighted and relieved.



TECHNICAL ADVANCES TOWARD INTERSTELLAR SPACE EXPLORATION

New work currently underway with near term applications in technical fields relating to systems and methods relating to deep space exploration. Ideal papers would be actionable by student and stakeholder involvement, employment and participation in the fields of:

- **Power and Propulsion for deep space exploration** (e.g. fusion, fission, ion, plasma, solar systems used i.e. for power plants, batteries, primary and secondary propulsion, etc.).
- **Materials advances with Aerospace Applications** (e.g., graphene uses in space industry, structural materials and components, heat pipes, radiators, etc.).
- **Communications and Navigation systems** (e.g. inflatable antennas, communications relays, astronavigation, algorithms, interplanetary internet).
- **Spacecraft Design and Mission Planning** (e.g. Kuiper and Oort cloud object probes, CubeSat's, waystations, exoplanet imagers, asteroid and deep space dwarf planet explorers).

OUR WORLD IN THE INTERSTELLAR ERA: CIVILIZATION AND CULTURE

Future studies relating to trends in civilization and culture as we approach the "Interstellar Era", where interstellar exploration is feasible and interplanetary travel is accessible and commonplace. Ideal papers examine the human perspective of "a future worth believing and worth hoping for" (Nick Nielsen), as the world undergoes rapid, sometimes dangerous changes:

- **Interstellar Space Exploration and Earth Society** (e.g. utopian or dystopian? how society might motivate the broad settlement of space, the desire or need for space migration).
- **Future Earth History** (e.g. examining social trends which lead to a future where humanity is able to inhabit ours and other star systems, realizing the Earth's future by acting in the present).
- **The Arts of Space** (e.g. space inspired art and design, connecting space and arts, space art in science fiction and science fact, video demonstrations and animations welcome).
- **Living and Working in Space** (e.g. living and thriving on a worldship, how we open up space to the job market, industrialization of space, generating sustainable space jobs).

About Starship Congress: Interstellar Hackathon

Starship Congress is a biennial, two-day fest, organized by Icarus Interstellar—a non-profit dedicated to starship research—that brings together deep-space science superstars, interstellar mavens, thought-leaders, technologists, and enthusiasts alike, to brainstorm cutting-edge concepts. This year's event is being hosted by Drexel University (home to the first collegiate chapter of Icarus Interstellar) in Philadelphia, Pennsylvania, on September 4 and 5. Starship Congress 2015 @ Drexel University aims interface students, companies developing innovative technologies, artists and thinkers contemplating the future of our civilization as we approach the Interstellar Era.

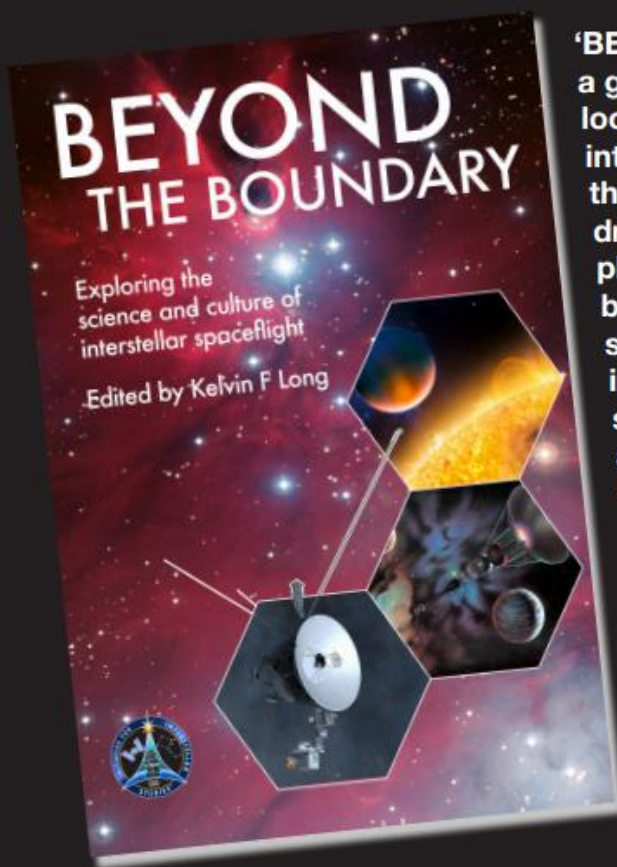
Registration for Starship Congress: <http://www.icarusinterstellar.org/starship-congress-2015-interstellar-hackathon-drexel-university-philadelphia-sept-4-5-2015/>

Support the Hackathon on Kickstarter

<https://www.kickstarter.com/projects/1468630926/starship-congress-2015-interstellar-hackathon>

THE INITIATIVE FOR INTERSTELLAR STUDIES

PRESENTS



'BEYOND THE BOUNDARY' is a ground-breaking new book looking at the possibilities of interstellar flight, including the technology that will drive our starships, the planets and stars that will be our destinations, the sociological basis and impact of becoming a space-faring civilisation and how our interstellar future is depicted in art and culture.



- Over 350 pages
- Including more than 20 chapters
- Topics as diverse as propulsion technology, exoplanets, art and SETI
- Published October 2014
- info@i4is.org



www.i4is.org

Get your copy via Lulu.com

<http://www.lulu.com/shop/kelvin-long/beyond-the-boundary/hardcover/product-21884350.html>

What's in Principium 11

In the next issue of Principium we will be strongly featuring Project Dragonfly, reporting in detail from the workshop in July and explaining the future of this major new i4is programme. And we'll also report more from the UK national science fiction Eastercon. Showing that even Heathrow can be a fun place! We also hope to have our promised meditation on Rosetta and Philae. And we'll have more thinking about the significance of the New Horizons successful mission to Pluto, celebrated on the back cover of this issue. Our guest introduction will be by Robert Kennedy III, chief sponsor, co-founder and co-organiser of the Tennessee Valley Interstellar Workshops.

More about our front and back covers

Sam Harrison and Daniel Parker provided the image from their balloon, Shackleton 2, at 89,000 ft with the i4iS logo and the curvature of the Earth clearly visible on the horizon

Charon and Pluto in their austere magnificence show what humanity can reach with the technology of more than 10 years ago. The New Horizons team inspire us all to reach for the stars.

The image is a composite of two images -

-  <http://www.nasa.gov/image-feature/charon-s-surprising-youthful-and-varied-terrain>
-  <http://www.nasa.gov/image-feature/pluto-is-dominated-by-the-feature-informally-named-the-heart/>

- resized to show their approximate relative size, based on a single lower definition image of both, also from NASA

Mission Statement

The mission of the Initiative 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: "i4is logo at 89,000 ft", credit: Sam Harrison and Daniel Parker
Back cover: Charon and Pluto from New Horizons, credit: NASA-JHUAPL-SwRI

Editor: John I Davies
Deputy Editor : Kelvin F Long

www.i4is.org

We'd love to hear from you, our readers, about your thoughts on Principium, the i4is or interstellar flight in general.
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