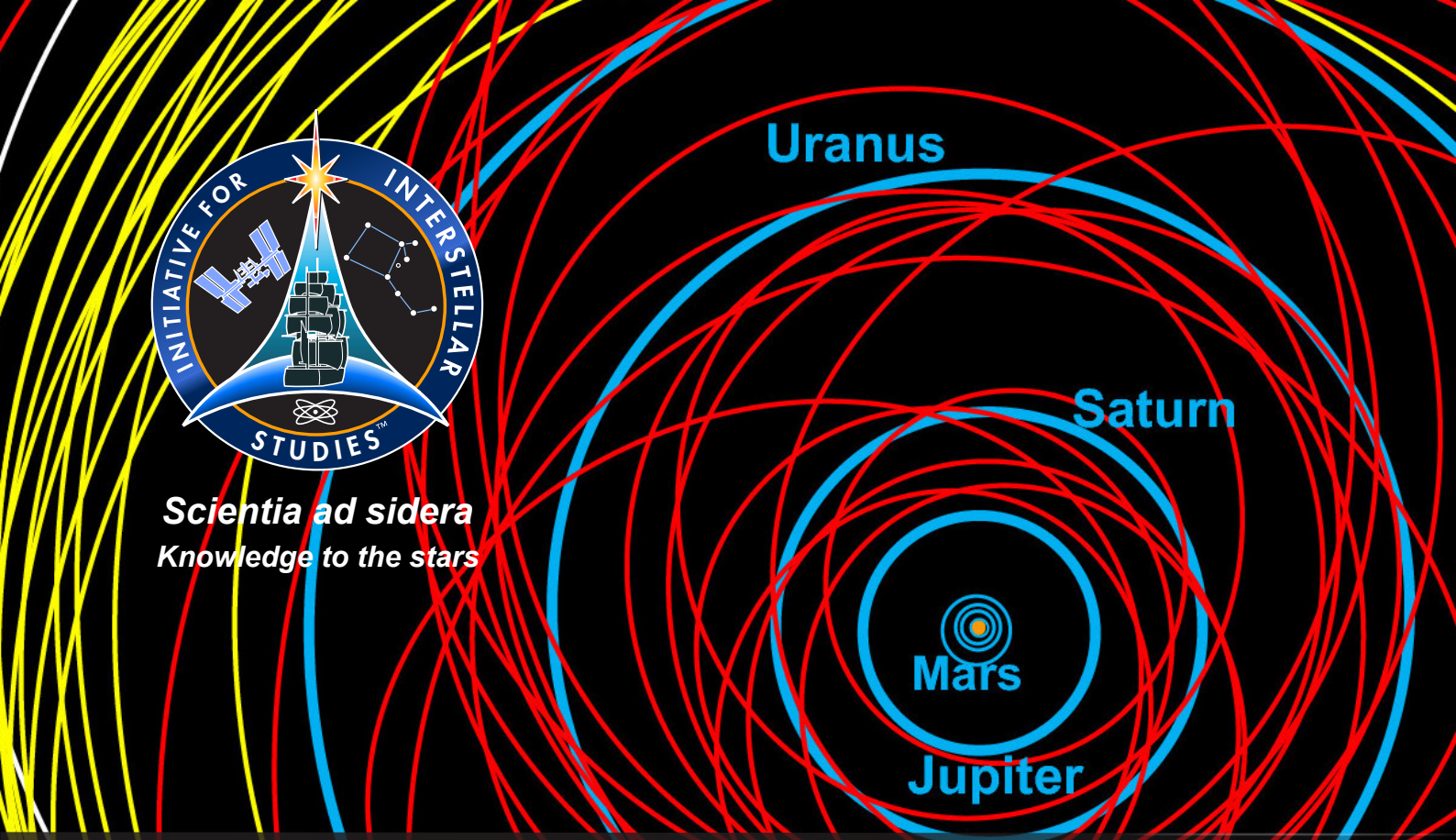
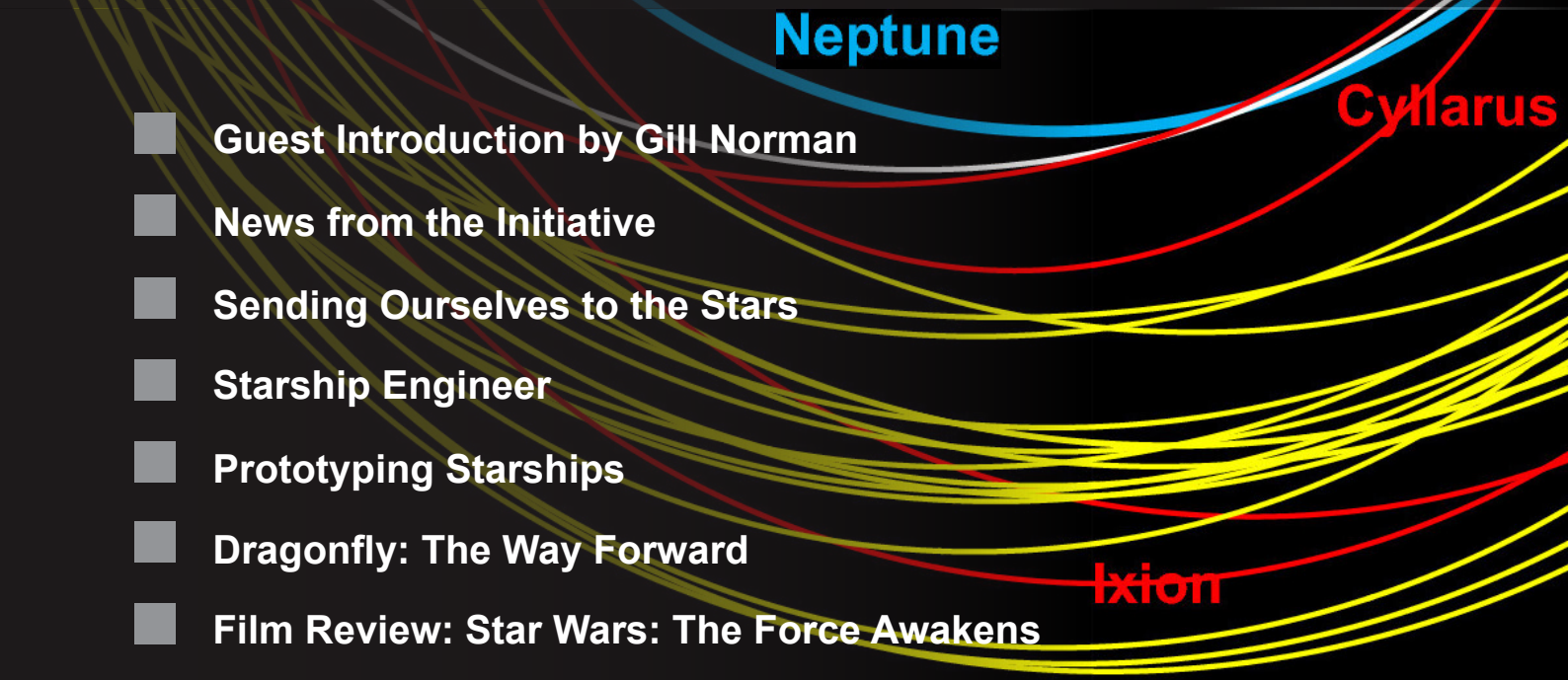


Scientia ad sidera
Knowledge to the stars

PRINCIPIUM

The Newsletter of the Initiative for Interstellar Studies™

Issue 12 | February 2016



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Editorial

In this edition our guest introduction is by Gill Norman. Gill is a former director of i4is. She has helped us become the reasonably well organised body that we now are. Her thoughts here are on the necessity of human engagement in Interstellar Studies and space in general, *Space: It's all about people*. She tells us how we need to engage resources and talents from all who feel our outward urge. Scientists and engineers are essential but so are entrepreneurs, PR experts and, of course, the best administrators we can find!

Gill has been appointed Executive Secretary at the British Interplanetary Society (BIS) where she will, we are sure, display even more of the organisational abilities which have so helped i4is. More in our news section.

In addition to this our News section this time includes a short report on our Starship Engineer course, a sad farewell to David Bowie, a Starman we shall miss, our continuing engagement with the SF community, at UK Novacon, the publication of the massive ISU/i4is world ship study and continuing work with others from the Tennessee Valley Interstellar Workshop (TVIW) to our involving of UK schools in the interstellar endeavour.

Last time we had a detailed account of the Project Dragonfly competition. This time Andreas Hein looks at how Project Dragonfly will build on the solid work of our student teams to expand the idea of a small laser-pushed interstellar probe.

We follow up the Icarus Interstellar Starship Congress and 'Hackathon' in Philadelphia with an account of the first keynote at the Congress by our Professor Rachel Armstrong. Rachel has kindly given us access to her thinking on this and Kelvin F Long has written a short report for this issue. Rachel's thinking will appear in more detail in a future issue of our print journal, *Axiom*. You can find more information about *Axiom* in an advert towards the end of this edition, while you can purchase a subscription here.

Our i4is Deputy Director, Andreas Hein, has been thinking for some time about how Digital Persons might travel to the stars more easily then their biological ancestors. Inspired by his most recent thinking on the *Centauri Dreams* website, John Davies muses on 'Sending Ourselves to the Stars'. Note that the views of Nick Beckstead (Research Fellow, Future of Humanity Institute, University of Oxford) appear in the thinking here and in Professor Armstrong's presentation also reported in this issue.

Following our review of *The Martian* last month we move to a more fantastic genre, *Star Wars*. Another review by myself is somewhat less complimentary of this new incarnation of the long running series.

Our front cover feature is by Duncan Steel. It is a diagram of the outer Solar System from a Royal Astronomical Society press release announcing 'Centaurs as a hazard to civilization' in the December issue of *Astronomy & Geophysics* (A&G), the journal of the Royal Astronomical Society. Our thanks to Duncan for his permission to use this striking image reminding us of the complexity of the outer regions of our own Solar System and the existential hazards we face as a species until we move out into our solar system and the galaxy.

For the back cover we celebrate the International Space Station (ISS), which reached its 15th anniversary just after we published the last *Principium*. It's our first vehicle assembled in space. We'll have to do that for starships and probably for any serious manned missions to the planets. The ISS is a symbol of cooperation amongst our perennially squabbling species. In the UK we celebrate our first ISS astronaut, Tim Peake, but also lament our national sluggishness in space – France and Germany have had many astronauts on the ISS.

As always, give me your views on both form and content.

John I Davies, Editor, *Principium*
john.davies@i4is.org

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You can also become part of our professional network on LinkedIn.

And take a look at the I4IS blog, The Starship Log.

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And seek out our followers too!

Contact us directly on email via info@i4is.org.

Space: it's all about people

Gill Norman

Two hours before I started writing this article, Tim Peake safely boarded the International Space Station (ISS), heralding a new first for the UK Space Industry.

We are extremely fortunate to live in this time with such a bright future in store for the exploration of space. This last year has seen some incredible excursions to parts of the solar system we have been hard pushed to describe adequately, until going there, even with our finest science fiction authors. Our imagination, however, knows no bounds and will not be content with reconnaissance of our own cosmic back garden. As is well documented in this magazine, that doesn't mean it's plain sailing to the stars.

Let me state first: I haven't had a career in the space industry. My perspective comes from a rather more mundane background in finance, people and organisational development - along with a healthy passion for astrophysics and spaceflight.

We continue to face widespread challenges as a species, with disturbing events on a daily basis, highlighting the difficulties that some humans have with communications and cooperation. Our evolutionary path has ensured that humanity has traditionally been a territorial species, with a high degree of significance placed on our land and borders. However, it can also be argued that the desire to conquer or protect that land and those borders has often led to tremendous technological advances through our history.

For advancement's sake?

Is most scientific progress now made primarily for the sake of satiating shareholders? This is simply a more sophisticated form of our territorial instincts to guard and expand our assets. Or are we finally at a stage where we can sometimes pursue advancement for the sake of advancement alone? I'm firmly in the camp of the latter. And we have some wonderful evidence supporting this case in the gleaming laboratory for weightless science that orbits the Earth 16 times a day. It's brilliant proof that our intellectual endeavours can transcend borders and conflicts. So is it really too far-fetched to believe that we can traverse the interstellar seas in the next few centuries? I don't think so. And neither do the wonderful people working for this organisation or those working for our peer organisations, such as Icarus Interstellar and TVIW, to name but two.

The determination and collaborative skills that designed and built Tim Peake's temporary home are the same attributes that will get humans to the stars.

However, aside from the vast engineering demands required to construct a vehicle that can reach our nearest stellar neighbour, we have another noteworthy matter to consider: people. Ultimately, the success of any project – regardless of the scale – is decided by the aptitude and attitude of the people involved. Their hopes, dreams and behaviour; their ability to interact, manage or lead; all of these aspects have a significant impact on progress.

I urge all of our interstellar community to do your best to get the right people into the right places within your organisations. This is much harder than it sounds. No matter how complicated 'rocket science' is, it's not nearly as complex as the human brains responsible for creating it – and the rest of our culture. And establishing effective organisations is even tougher when there just aren't enough resources of the human kind to go round.

Every space related organisation needs their visionaries to have the dreams, to inspire the teams and to motivate others to join the cause. They also need effective leaders that can turn those dreams into tangible outcomes. Competent managers are required to run the outfit, the teams or projects successfully. Public relations and media expertise are essential for communicating the vision and the journey. And don't get me started on administration!

Successful corporations have been doing this for years; we would do well to follow some of their examples of how to lead, manage and organise. Examine what makes them successful: remarkable spokespersons, exceptional leaders, excellent directors of people and processes, highly proficient engineers.

▲Tim Peake photographed while getting his final suit check before his first space walk on 15 January. Image credit: ESA/NASA.

Cold hard cash

Whilst we are not yet primarily concerned with lining shareholders' pockets, it is an undeniable fact that our normal currency of goodwill will not suffice for all of our planned undertakings. At some point, this community will need hard cash to begin envisaging our dreams. We are unlikely to be gifted all the components for a robotic probe, although it's not beyond the bounds of possibilities that we might acquire willing and able volunteers to build some of it in their spare time. And, alas for the Daedalus project cashflow forecasts, nobody is going to mine the upper atmosphere of Jupiter, on its behalf, for free. But a cheap lift to lower earth orbit sometime in the next two decades, for some precursor mission components, wouldn't go amiss! So we have an additional requirement for financiers and people adept at business and commerce.

We could also take the bold step of enlisting countries that are at different stages in their spaceflight development programmes. If it's problematic to engage our own governments and local space agencies, how can we bring, say, the Chinese or Indians on board? Can we make the first interstellar mission a truly global accomplishment? Perhaps we also need skilled diplomats, linguists and facilitators.

I don't claim to have any answers for these dilemmas; just a desire to raise awareness of the need to focus effort on the development of people and organisations. Like-minded individuals coming together can achieve monumental tasks if we can organise ourselves in the right way.

And that brings me to my last point. All voluntary societies always need more people – always! Many of the skills that you possess could be useful to us if applied in the right place. Even if you think you 'just love space', then that could be enough. It's interest and passion that count, not necessarily letters after your name. We are continuing to build new ways of working and collaborating within our small but growing interstellar populace. Ways that aren't necessarily built on our normal ideas of compensation. Some time ago, in a history not so far away, there was a system of living that didn't involve dollars, pounds, rupees or yen. What it did involve though, was the exchange of skills. Imagine being part of the first endeavour to send a human-made object to another star. That's compensation enough for me.

If you, too, are looking for a new avocation, please get in touch via info@i4is.org and become part of something wonderful.

About the Author

Gill Norman is a programme and project manager. She has extensive experience in the financial sector, having held a senior role at Morgan Stanley. She has been responsible for much of the financial and business management of i4is. She is about to take up the post of Executive Secretary at the BIS. Gill has a degree in maths from the University of Bath and a masters in astrophysics from Queen Mary University of London.

Interstellar News

John Davies with the latest interstellar-related news.

Starship Engineer course

The first run of the i4is 'Starship Engineer' course took place at the British Interplanetary Society (BIS) in London on 24–25 November 2015. Kelvin F Long and Rob Swinney gave the participants a basic grounding in interstellar studies, including the basic requirements to achieve interstellar flight, an overview of interstellar spacecraft systems and several existing starship design studies. Your editor became a humble student again for the two days and learned a lot!

We learned how to do the essential calculations, concentrating on fusion and laser-sail propulsion – perhaps two of the most plausible technologies at the moment. We also looked at a number of starship concepts from science fiction, examining their technical plausibility. Writers like Larry Niven and Jerry Pournelle, Robert Heinlein and Arthur C Clarke have devised inspirational examples of interstellar vessels. There were 21 course participants on this first day one dedicated to the basics of 'real' interstellar starship design.

The second day, dedicated to looking at science fiction starships and how they might work using known principles, featured 13 participants

Kelvin also brought along some of his large collection of interstellar artefacts and drawings.

▲The 21 participants on the first day of i4is' 'Starship Engineer' course with their certificates of achievement.

A group exercise showed how much we had all absorbed and a happy and enthusiastic crowd ended up in the Riverside pub!

Globular Clusters

Our friend, Paul Gilster, has a fascinating article on his Centauri Dreams website entitled 'Globular Clusters: Home to Intelligent Life?'

Paul reported on the work of Rosanne Di Stefano (Harvard–Smithsonian Center for Astrophysics, USA) and her colleague Alak Ray (Tata Institute of Fundamental Research, India), who have produced a paper entitled Globular Clusters as Cradles of Life and Advanced Civilizations, which Stefano presented at the January 2016 meeting of the American Astronomical Association.

Globular clusters contain between 100,000 and a million stars in a volume typically about 100 light-years across. So interstellar distances are orders of magnitude less than in our neighbourhood. We live in the sticks by comparison to these stellar 'cities'. However, globular clusters are a long way away; the nearest of them are thousands of light years from us. So globular clusters are targets for SETI rather than any possible chance to visit them.

This discussion reminds us of the back cover image in *Principium 11*, showing the globular cluster Omega Centauri (NGC 5139). We remarked at the time that there is some suspicion that one of our nearest neighbours,

◀Omega Centauri (NGC 5139), from where Kapteyn's Star has originated. Image credit: ESO/INAF–VST/ OmegaCAM.

Kapteyn's Star, may have originated in Omega Centauri. Kapteyn's Star is about 12 light years away and has at least two exoplanets. Should we be looking more closely at Kapteyn's Star?

David Bowie, Starman

As we were putting the final touches to this issue of *Principium* we heard of the untimely death of David Bowie at the age of 69.

David Jones was a boy from just down the road from the British Interplanetary Society's HQ, in the London district of Brixton. When David was born the capital was slowly recovering from the Second World War and the London Blitz. He was a multi-talented lad. He went to Bromley Technical High School, became David Bowie, and ended up as the iconic pop star of the seventies and a great cultural innovator of the era since.

We mourn and celebrate him, especially in *Principium* for his perennial interest in other worlds and other ways of living. He was a striking presence in a number of films based on powerful science fiction novels. Walter Tevis wrote *The Man Who Fell to Earth* and Bowie personified the alien in the film. He played the weird genius inventor and engineer, Nikola Tesla, who was the pioneer of alternating current electrical engineering, in *The Prestige*, based on the novel by Christopher Priest. But most of all he played a continuously re-invented David Bowie. If you have the chance, see the Victoria and Albert Museum exhibition *David Bowie Is*, which is on a world tour.

I nearly forgot to mention the music. There's a 'Starman' waiting in the sky and we need to be 'Heroes' to seek him out. Bowie's spirit will be with us when that encounter happens.

What we did at Novacon

Last November i4is was at Novacon in Nottingham, UK. This is an annual SF convention run by the Birmingham Science Fiction Group. It aims for a fan-driven rather than academic or writer-centred content. Kelvin F Long, our Executive Director, was at the convention to present 'The Physics of Starships in Science Fiction.'

Kelvin and Rob Swinney hosted our table at the con and we met lots of enthusiasts and several old friends including space artist David Hardy and artist and musician Alex Storer. Both have been involved with i4is since the beginning and this was a great opportunity to meet them again in person and engage with their friends in the SF fan community. Thanks to all for a great con and a special thanks to people who bought t-shirts and our book, *Beyond the Boundary*. We'll be at Eastercon at the Hilton Deansgate in Manchester on 25–28 March 2016 and we'll continue to engage with the dreamers of SF worldwide.

ISU/i4is Worldship study

A team of graduate students at the International Space University (ISU) spent much of 2014 and 2015 working on the possibility of interstellar travel using a slower-than-light, self-sustaining worldship to carry humans over many generations to other star systems and, in particular, the preparations needed to launch such a ship in a nominal 100-year timeframe. The ISU/i4is worldship final report, bearing the logos of both the ISU and the Initiative for Interstellar Studies, has now been published as the Astra Planeta Final Report.

You can meet the team on YouTube (Roadmap to an Interstellar Worldship – Astra Planeta).

▲**Rob Swinney at the I4IS stand at Novacon.**

New BIS Exec Secretary

The British Interplanetary Society (BIS) is the granddaddy of space advocacy and research organisations, and is i4is' own direct ancestor.

▼**The i4is/ISU joint worldship report.**

All the most active i4is people are members of the BIS and some of us have been with the BIS for decades. The Executive Secretary of the BIS is its chief executive. The current Executive Secretary, Suszann Parry, is retiring and the BIS has appointed Gill Norman as her successor. Gill is a past director of i4is and has been largely responsible for organising both our processes and our events. She has written the guest introduction to this edition of *Principium*, giving us her personal vision of how we can bring people together to advance the cause of interstellar flight. We wish Gill and the BIS great success as she takes over from Suszann. Suszann has helped i4is to maintain a very effective and friendly relationship with the BIS and we wish her all the best in her retirement

i4is at TVIW

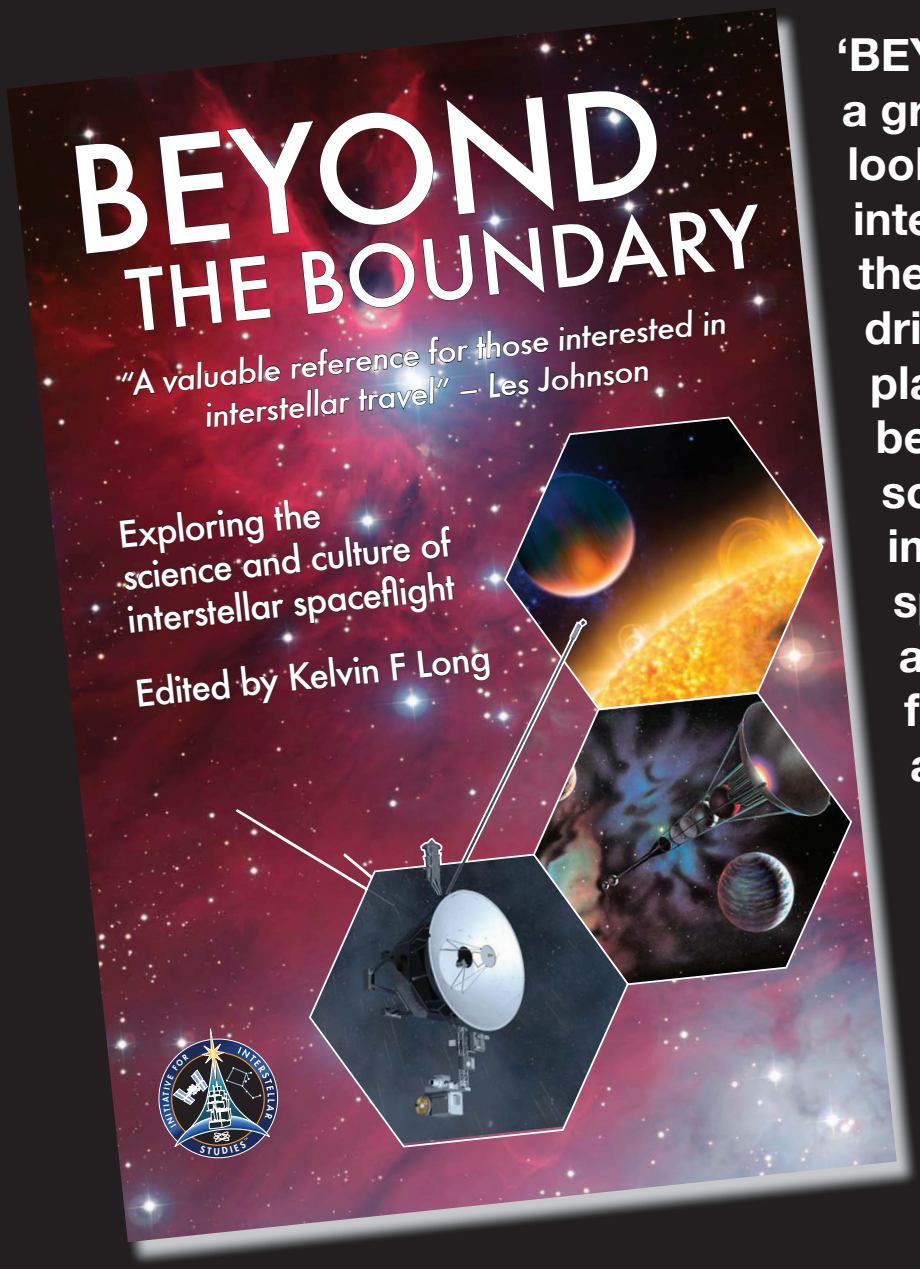
Kelvin F Long, our Executive Director , and Rob Swinney, Deputy Director, will be at the Tennessee Valley Interstellar Workshop (TVIW) between 28 February and 2 March 2016 at the Chattanooga Choo-Choo Hotel in Chattanooga, Tennessee, USA. The workshop is subtitled 'From Iron Horse to Worldship: Becoming an Interstellar Civilization' and tickets are available at www.tviw.us. Come along and meet Kelvin, Rob, Angelo Genovese (new i4is Director Space Mission Development) and Stefan Zeidler (new i4is Director of the Enterprise Committee) – and lots of other interstellar people.

i4is Education in Schools

In addition to university level work, such as the supervision of masters projects at the International Space University (ISU), i4is has been active in outreach to schools in the UK, including the rocket club at Greig City Academy (GCA) in north London and years 10 and 12 (ages 14 and 16) at the new Space Studio West London (SSWL). We'd like to extend outside London so please get in touch from any part of the UK right now or contact us to discuss how we can reach you through i4is members in other countries around the world.

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.

- 448 pages, hardback edition
- Featuring 21 chapters written by i4is' interstellar experts
- Topics as diverse as propulsion technology, exoplanets, art and SETI
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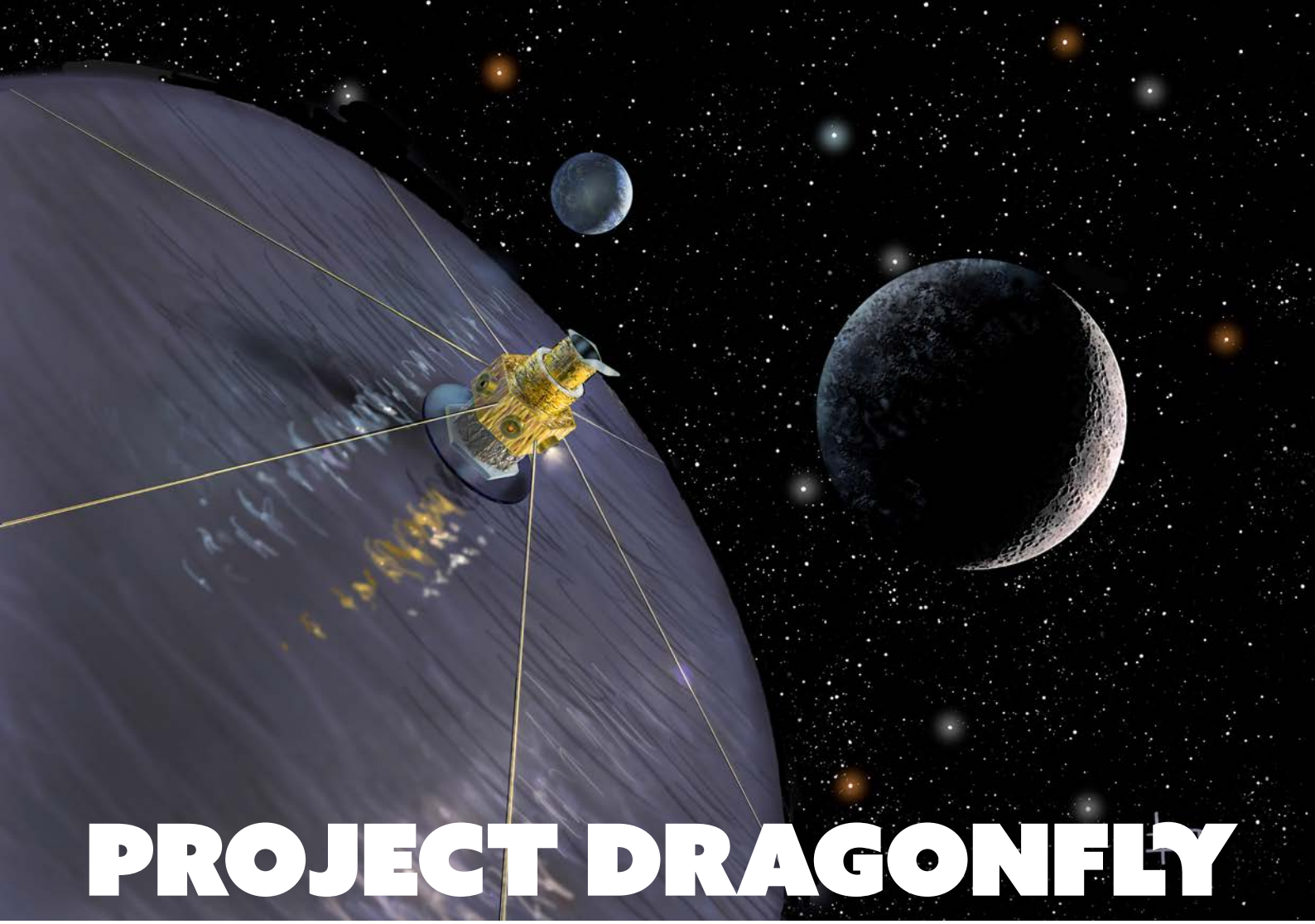


PROJECT DRAGONFLY

the way ***forward***

Andreas Hein explores some of the latest exciting developments surrounding i4is' flagship project: Dragonfly.

'To the stars in our lifetime' – this is our philosophy. What does it actually mean? Does it mean we are actually visiting another star within our lifetime? Or does it mean that we launch a probe to the stars in our lifetime? In this article, I will elaborate on the latter possibility and how i4is is planning to address it by working on three types of missions, based on near-term technology: Project Dragonfly works towards an interstellar mission that can reach another star within 100 years, the TAU mission aims at reaching 1000 astronomical units (AU) within 50 years, and the 'minimal interstellar mission' aims at being the first ever spacecraft that is launched towards another star.

In 2015 we accomplished a major step: we concluded the Project Dragonfly Design Competition. Our student teams were able to generate four different concepts for a laser-propelled interstellar spacecraft, able to reach Alpha Centauri within 100 years (T Brashears, P Lubin, G B Hughes, K McDonough, S Arias, A Lang ... & Zhang, 2015; Gutsmiedl et al., 2016; Ismaiel and Fattah, 2016; Testore et al., 2015). They started with the constraint that the laser beam power is limited to 100 GW. Yes, this is still the equivalent of dozens of large power plants and with all the inefficiencies of the system; we are talking about a laser infrastructure that probably needs to generate power in the terawatt range. However, this is huge progress compared to existing interstellar design studies, where the whole power output of humanity is needed to propel the probe. Furthermore, we do not use any technology that is not achievable during the next 10-20 years. By contrast, alternatives such as fusion propulsion are very challenging technology-

▲**David A Hardy's superb artistic impression of the Dragonfly probe. Dragonfly's design is based on the work of a team at the Technical University of Munich.**

wise and it is by far not clear if they will ever reach the performance levels required for "fast" interstellar travel. By "fast", we mean reaching another star within 100 years. Hence, both in terms of required resources and the maturity of the technologies on which the mission is based, we have made a large step forward.

Minimal mission

However, one of the caveats of a laser-propelled mission is the laser infrastructure. We are still talking about a space-based infrastructure that generates about 10% of the current power output of humanity. It is rather unlikely that such an infrastructure will be available during the next decades. So how can we then stay with our motto "to the stars in our lifetime"? We will actually use a trick. The advantage of interstellar travel is that it has a fuzzy definition. "Interstellar travel" means that we travel between the stars. Furthermore, we add the requirement that at some point our spacecraft needs to reach a star. We call such a mission that would be feasible with the technology of the next 5-10 years, can enter interstellar space, and will likely reach another star at some point in time a "minimal interstellar mission".

This definition for an interstellar mission does not constrain us on how quickly we need to reach a star. Of course, we still need to leave our Solar System, which is challenging, as we have to be fast enough. With current technology, it is only possible by using a rocket with a powerful upper stage for leaving the gravitational attraction of Earth and additional manoeuvres such as gravity assists where the spacecraft passes close to a planet and is accelerated by interacting with its gravitational field. Other existing technologies are ion drives, solar sails, and potentially electric sails that are capable of accelerating a spacecraft out of the Solar System.

Out of the plane

The other challenge is actually to target another star. This is a challenge, as most stars are actually not in the plane of our Solar System. For example, the Alpha Centauri star system is inclined strongly and is only visible from the southern hemisphere. Note that the Earth itself is inclined about 23° relative to the Solar System plane. Why is this a problem? Because for aiming at a star that is highly inclined with respect to the Solar System, we need much more energy as we cannot expect to use standard manoeuvres such as gravity assists. Furthermore, when the spacecraft leaves Earth, it is already on an orbit around the Sun and on this orbit the spacecraft has a velocity of roughly 32 km/s. For leaving the Solar System, you only have to accelerate the spacecraft from this velocity to the escape velocity from the Solar System. If you would like to escape the Solar System perpendicular to the plane in which the planets are located, you would need to accelerate from 0. Hence, the more a star is located close to the Solar System plane, the less additional velocity and hence energy we need for leaving the Solar System. For example, the Voyager 2 probe was only able to leave the Solar System with an inclination of 79° relative to the Solar System plane with the help of a Neptune gravity assist. Which stars are actually close to the Solar System plane and that are furthermore close to the Sun? There are quite a few up to a 10 light year distance and a declination (elevation) of less than 10°, as listed in Table 1.

Note that the Alpha Centauri star system is not among the options, as it has a declination of –22°. Further, note that these considerations are rather interesting for a mission that uses current technologies where a velocity requirement of 70 to 100 km/s is difficult to achieve. If we

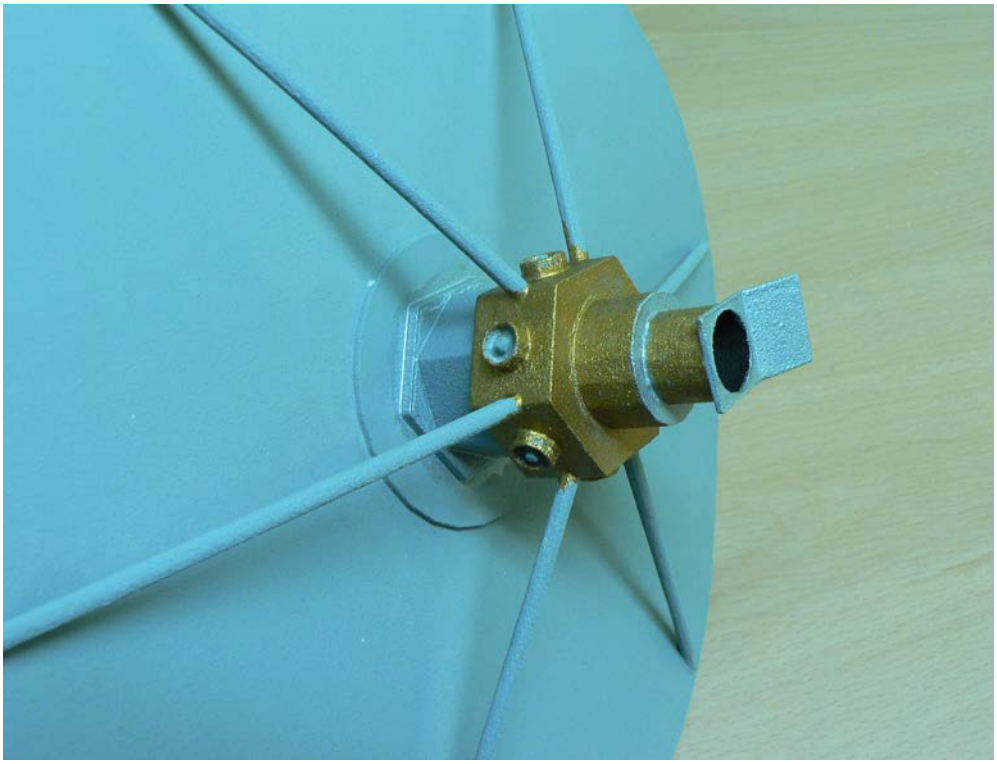
Table 1: Nearby stars located close to the Solar System ecliptic based on data from (Astronexus, n.d.)

Star System name	Distance from Sun (light years)	RA relative to ecliptic	Declination relative to ecliptic	Exoplanets?	Flight time with Voyager-type probe (years)	Flight time with TAU-type probe (years)
Barnard's Star	5.9	–7.1°	0.88°		104,033	18,726
Gliese 406	7.79	–8.45°	0.49°		136,541	24,577
Lalande 211	8.31	–37.1°	3.89°		145,554	26,200
Gliese 65A	8.56	17.66°	1.62°		150,027	27,005
Sirius	8.6	15.9°	–0.02°		150,616	27,111
Gliese 729	9.69	22.9°	–5.36°		169,743	30,554
Epsilon Eridani	10.5	8.99°	0.55°	At least 1	183,798	33,084

talk about more advanced propulsion technologies such as fusion and laser propulsion, we expect velocities of several thousands and even ten-thousands of km/s. In such a case the savings from choosing a star close to the Solar System plane does not make a big difference. It only makes a difference for a minimal interstellar mission. To conclude, there are a number of stars that we could target with a minimum interstellar mission.

vicinity. We want to develop a small spacecraft and benefit from interplanetary cubesat technologies that are going to be available in a 5-10 year timeframe. Furthermore, we are not only looking at the technological feasibility of such a mission but also at potential financing options.

A second, more challenging, step is the Thousand Astronomical Unit (TAU) mission. The TAU mission aims at reaching a distance of 1000AU within



▼Detail of Terry Regan's model of the Technical University of Munich's winning Dragonfly design.

The i4is Technical Committee has initiated work on a minimal interstellar mission. Our objective is twofold: To send the first private spacecraft out of the Solar System and to launch the first spacecraft targeted at another star. Note that past spacecraft such as the Voyager and Pioneer probes will reach other stars at some point. However, none of these probes will fly past a star in its immediate

50 years and was originally introduced by NASA researchers (Etchegaray, 1987; Nock, 1987). This translates into an average velocity of 20 AU/year which is more than 10 times faster than the Pioneer probes. Such a mission would be possible by extrapolating existing technologies such as advanced nuclear ion propulsion or solar sails. However, it would also be the test case for using a laser infrastructure.

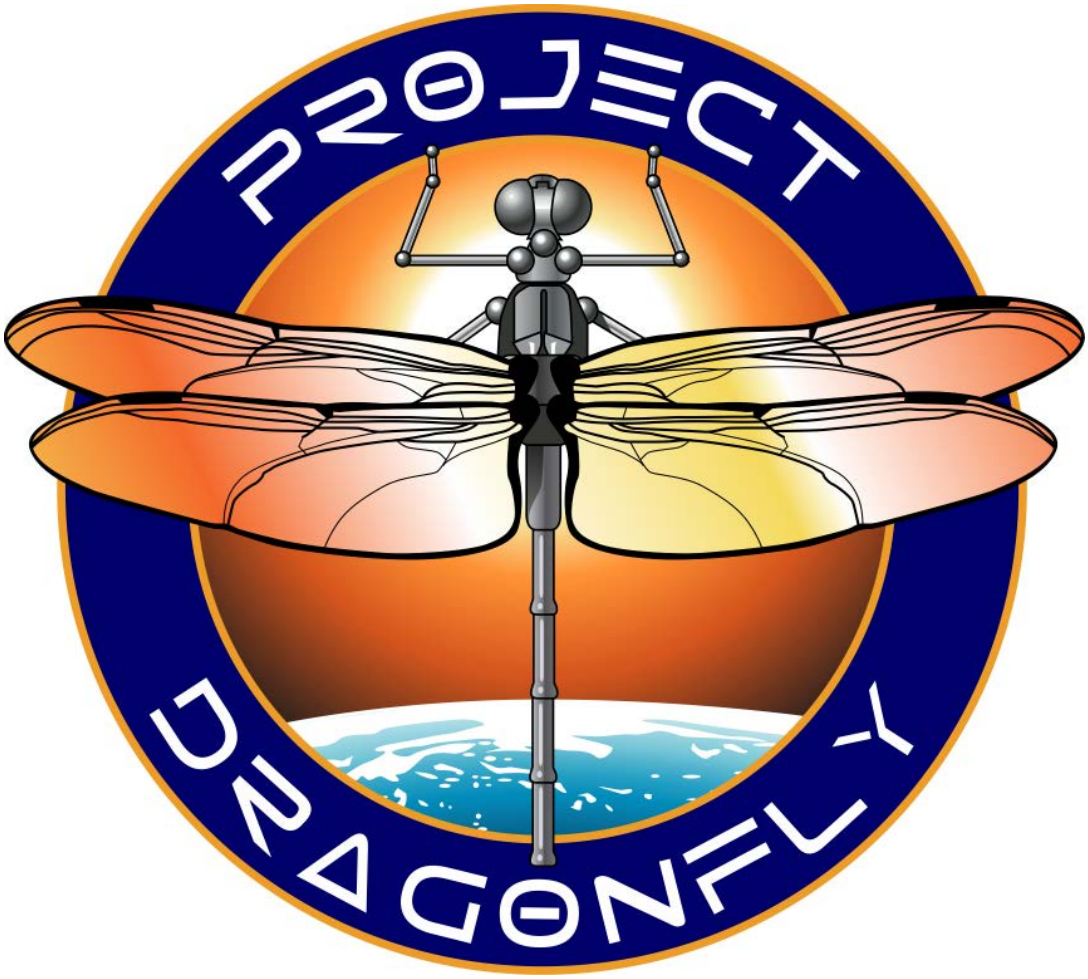
I4is is currently looking into how a TAU mission could be realized by using laser propulsion. We would like to know the size of the laser infrastructure that would be necessary for such a mission and how it could be the first step towards a fast interstellar mission.

Steps on the road

These three missions form the first poles in our roadmap divided into near-term (minimal interstellar mission), mid-term (TAU), and long-term (Dragonfly). There is a forth project related to Project Dragonfly we are working on and which is the only project that does not work directly on a mission. It is the 'von Neumann' project. The von Neumann project works towards the vision of self-replicating space systems. As the literature on self-replicating space infrastructures shows, such a capability would be a huge leap in what we could do in space: large-scale manufacturing of space systems. Such a capability could enable the construction of a large laser infrastructure in space such as required for the Dragonfly mission. However, in order to realize this vision, we need to start small. Our first step is assessing what could be done with technologies available within the next 5-10 years. We are particularly looking into areas where manufacturing technologies such as 3D-printing could be used for creating new business opportunities. We think this is a promising research path as 3D-printing have capabilities

that are a good fit for space systems: to manufacture highly-customized, small-lot products with complex geometries. We are currently developing concepts for spacecraft components that could be manufactured via 3D-printing and which new business models would be enabled by these new capabilities.

To summarize, i4is currently works on three projects that could represent incremental steps towards a laser-propelled interstellar exploration. The minimal interstellar mission as the first privately funded probe to fly towards another star, the TAU mission as a mid-term concept, and Dragonfly as the first fast interstellar mission (less than 100 years trip duration). Finally, the von Neumann project intends to develop the technological capabilities for manufacturing large infrastructures in space.



About the author

Andreas Hein is a Deputy Director of i4is and Director of i4is' Technical Research Committee.

Table 2: Existing probes that are flying towards other stars

Existing probe	Speed (AU per year)	Star system they reach	Time to reach star system
Pioneer 10	1.6	Aldebaran	2 million years
Voyager 1	3.6	Gliese 445	40,000 years
Voyager 2	3.3	Sirius	296,000 years

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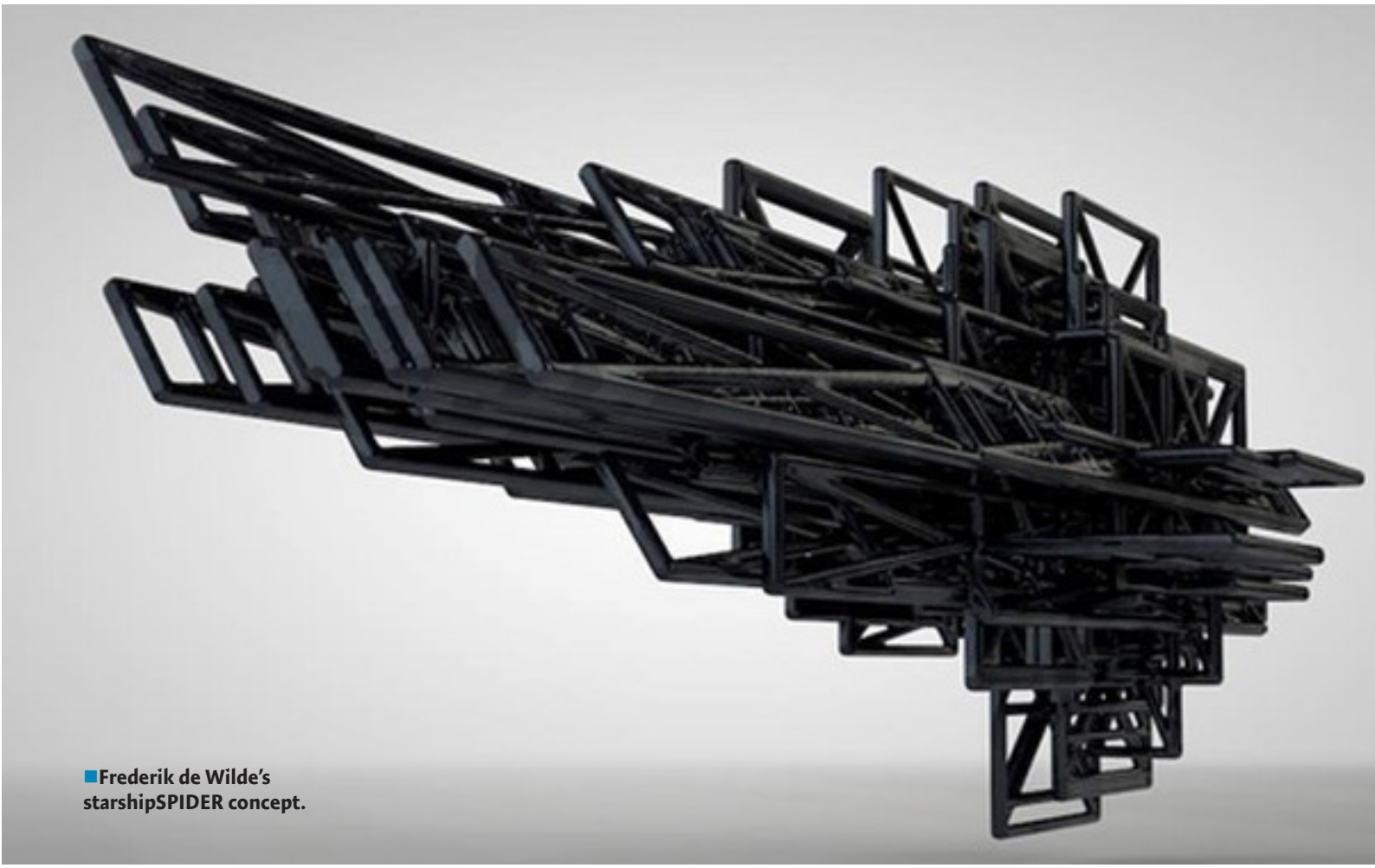
Prototyping STARSHIPS

Kelvin F Long reports on the keynote speech at 2015's Starship Congress by Professor Rachel Armstrong.



Frederik de Wilde's starshipSPIDER concept.

On 4 September 2015 Professor Rachel Armstrong of the University of Newcastle gave a rousing keynote speech to delegates attending the Icarus Interstellar Starship Congress and Hackathon at Drexel University, Philadelphia. Rachel intended to set the tone for this event and future events of this kind, and she did not disappoint.

Rachel opened her talk arguing that the interstellar question is not one that can be broken down into a set of solvable steps, but it is more of a conundrum or manifold that harbours many overlapping and related concepts that change with context and over time. To date the challenge has largely been addressed by academics and professionals making grand proposals for starship blueprints based on the physics of the cosmos and knowledge of engineering. Yet these designs make significant assumptions about the advent of those technologies that may take them from concept to reality – for example the kind of propulsion systems available.

She examined a criticism by Nick Beckstead (Research Fellow, Future of Humanity Institute, University of Oxford) of the interstellar movement, who argues that bias exists in that interstellar advocates already believe in its possibility and fail to engage with relevant counter arguments. Other critics of the interstellar movement include science fiction writers Kim Stanley Robinson and Charles Stross. Robinson's recent novel

Aurora has a plot ending with the implication that interstellar journeys won't succeed. But, overall, it has been argued by Beckstead that there are no major voices insisting on the fallacy of the enterprise. However, Rachel suggested that the approach adopted by Beckstead is deterministic. It assumes the results are calculable or finite now.

Ecosystem entanglement

One of the most visionary moments of Rachel's keynote was a screen into which our ideas are projected. Many civilisations have offered solutions to the interstellar question – some are religious, others magical. The current preference is to provide technical responses. Yet the proposed ideas point towards the mutable nature of the question itself. Rachel cautions that, since the Space Age, we have held a largely industrial view of our civilisation which shapes our expectation. We translate this into modes of thinking in new territories. Yet we are moving from an industrial age of development to an ecological view of reality. The growing realisation that our species is not simply an isolated entity but deeply entangled in, and dependent upon, its ecosystems is changing the way we live on Earth and therefore the way we address the interstellar question.

The production of prototypes is an open and a contingent venture. Prototyping proposes an open, bottom-up approach to the production of an interstellar culture, thus enabling the development of a vessel that will take colonists to the stars. Making a transition from a top-down blueprint to an emergent design, the interstellar question is no longer a deterministic but a probabilistic venture.

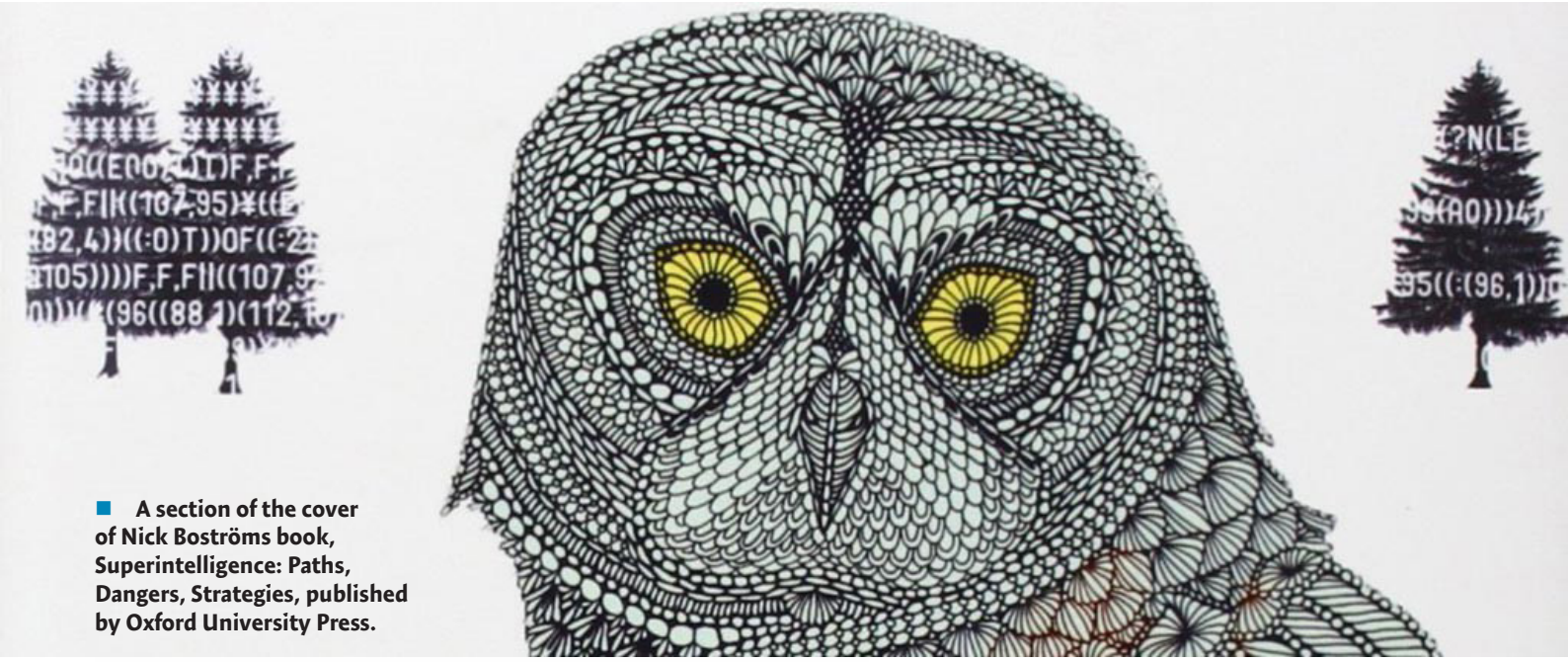
Rachel cited the StarshipSPIDER concept of Frederik de Wilde, a craft that is more than an inert hull moving through interstellar space. It is a concept that engages with the strangeness of matter between the visible and dark universes. Harvesting scant matter such as photonic winds and buckyball carbon atoms, it synthesizes cosmic scaffoldings that can become the infrastructure for future space ecologies. StarshipSPIDER is pitilessly black. Its artistic roots arising from deep within the 'satanic mills' of the industrial revolution that spewed black carbon into Earth's atmosphere and marked the urban environment with dark scars. An absolute rejection of the depiction of objects in favour of pure expression, evoking moods that range from joy to chaos. The concept of StarshipSPIDER is a very long way from being buildable. How it may influence starship design is as yet unknown. But this concept can be turned towards everyday machines, such as cars and planes, and asks what might happen if they repaired rather than destroyed environmental relationships and created opportunities for ecodiversity rather than biospherical scars. These are the leaps of imagination that our society needs if we hope to survive this planet and explore the next. Rachel argues that we are currently reverse terraforming our own planet, and we do not yet know how to make life or ecology from scratch. She closed by saying that prototyping the interstellar question does not pretend to be classical science, nor a substitute for engineering practices. It is an adjunct and inspiration for these endeavours.

The full text of Rachel's presentation will be published in issue 2 of the i4is journal *Axiom,* out soon. You can find more about *Axiom* on the next page.

Professor Rachel Armstrong gives her keynote speech at the Starship Congress.

Sending ourselves to the stars?

If sending our physical bodies to other worlds proves too impractical, could a solution be to send out digital selves? John Davies considers this 'Transcendence meets Interstellar' scenario and finds that there may be more to it than just fiction.



■ A section of the cover of Nick Boström's book, Superintelligence: Paths, Dangers, Strategies, published by Oxford University Press.

Overture from the 2500s

I met my twin brother, Jack, again today. He's very like me but he's been away for 25 years doing the early work of our species in the Ran star system (they used to call it Epsilon Eridani up to 2015). We have a base on Eldir, one of the moons of the planet Ægir.

It's not that unusual these days to have an electronic twin. In the old days biological cloning and downloading was dreamed of but it's much easier for a Digital Person to simply have a twin who shares your memories of youth.

Meeting Jack again after all these years was great and hearing the tales he tells of the Eldir station and the Ran system at first hand, rather than from ancient emails, is fascinating.

The big question is, what does he want to do next? He's already 20 years younger than me by the normal measure (though we have defeated the tyranny of Tsiolkovsky's equation we haven't got past that horrible little letter, c, yet).

But Jack and I can be virtually (good word!) immortal if we want to be. First, Jack wants to get to know all the family he has acquired while he's been away and then decide if he wants another of those long trips. I might go with him next time...

There are almost certainly profound implications for interstellar studies in the fields of artificial intelligence (AI) and the convergence of machine and biological intelligence. Thinking has ranged from interstellar spacecraft AI systems, for example the Wardens of Project Daedalus[1], to the transmission of artificial persons which is the subject of this article - though not necessarily in the form described in the Overture to this article.

I first thought of exploring this subject, in the overlap between Computer Science, Philosophy and Interstellar Studies, on reading Andreas Hein's piece on the noted interstellar studies website, Centauri Dreams, 'Transcendence Going Interstellar'. More about this below. This is the first of a two part exploration of some topics inspired by Andreas Hein's thinking.

Another i4is thinker in this area is Jeremy Clark. He addressed the issue in a chapter of the i4is book, *Beyond the Boundary* (BTB)[2], entitled 'An Introduction to Artificial Intelligence as applied to Space Exploration':…. This describes approaches to AI, especially neural networks and

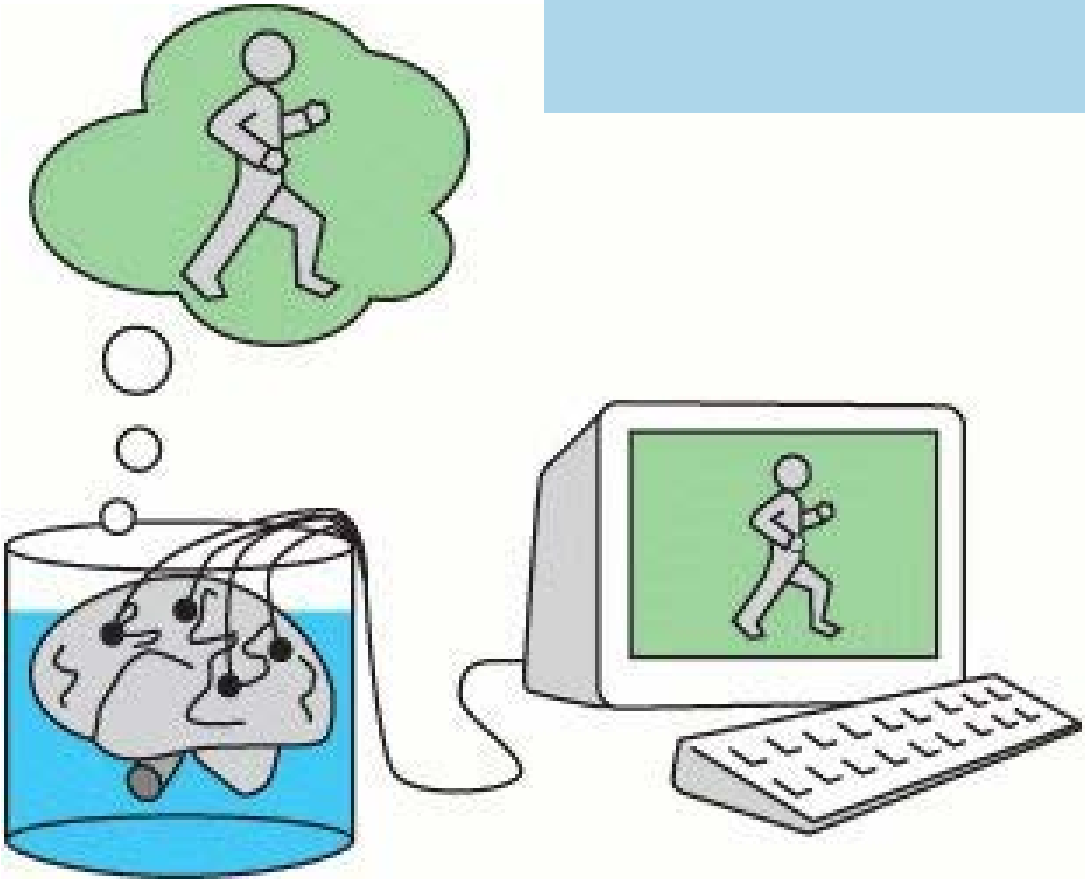
their descendants, and the decision problems which have confronted long distance missions.

Another chapter in the *Beyond the Boundary* calls the problem of getting humans to the stars 'The Greatest Challenge'[3]. Here Andreas Hein identifies four ways of achieving this:

- Worldships, human beings in a large self-sufficient habitat, akin to the O'Neill colonies of The High Frontier, and earlier ideas;
- Human hibernation, either with slowed metabolism or as in the controversial "cryonic" storage of humans at cryogenic temperatures;
- Zygotes (fertilised eggs) and Embryos, possibly as an adjunct to one of the other methods;
- Digital Persons

Most recently Andreas has speculated that a digital equivalent of a human mind, Whole Brain Emulation (WBE), would, if achieved, be almost trivially capable of being transmitted by electromagnetic means, probably at light frequency or higher (to achieve maximum bandwidth). His piece on the noted interstellar studies website, Centauri Dreams, 'Transcendence Going Interstellar'(TGI)[4] is the primary inspiration for the present article.

But how close are we to achieving this digital equivalent of a human consciousness? What are the possible steps to achieve it? How might it be transmitted? Once it is achieved, what would be the status of such 'digital persons' and could/should/would the traveller ever be merged back into the biological consciousness? How does this possibility relate to the wide field of Artificial Intelligence (AI) research and development and the more ambitious objective of Artificial General Intelligence (AGI)? This article will explore only some of these topics.



This article is a series of musings on the above and especially on Andreas Hein's Transcendence article (TGI). Dip into this piece. Read Andreas Hein's TGI again. Pick up your copy of *Beyond the Boundary* (BTB) and read Jeremy Clark's discussion of AI applied to space and Andreas Hein's Greatest Challenge- and send me your own thoughts. This writer is a seriously interested layman (see 'About the Author' at the end of this article) and would welcome comments from both professionals in the areas discussed and from others with a serious interest in this means of achieving interstellar objectives.

What is Artificial General Intelligence?

'Artificial General Intelligence' (AGI hereafter) refers to AI being general in the sense that it is designed not for particular tasks but for being capable of learning various skills (definition by Arakawa et al[5]).

It differs from much software currently labelled Artificial Intelligence – which is designed for specific purposes such as analysis of medical imaging or driving a car. Elements of AGI may be achieved either before or after various levels of emulation of human consciousness. There is clearly a dialogue between AI, especially AGI, and WBE[6].

Nick Beckstead of The Future of Humanity Institute at the University of Oxford asks 'Will we eventually be able to colonise other stars?'[7] and gives a tentatively positive answer based on interviews with Anders Sandberg, Geoffrey Landis, Robert Zubrin and Charles Stross,

supported by his own judgement "that advances in AI and robotics will make it possible for machines to substitute for humans in building a civilization, even in environments that would be very inhospitable to humans"[8].

Nick Beckstead's interviewees were:

• Anders Sandberg—Research Fellow, Future of Humanity Institute, who has a background in computational neuroscience;

• Geoffrey Landis—NASA scientist and science fiction author, works at the NASA John Glenn Research Center on Mars missions and on advanced concepts and technology for future space missions;

• Robert Zubrin, founder and President of the Mars Society is an aerospace engineer holding several patents in space propulsion technologies;

• Charles Stross, science fiction writer, was initially a technical author and programmer.

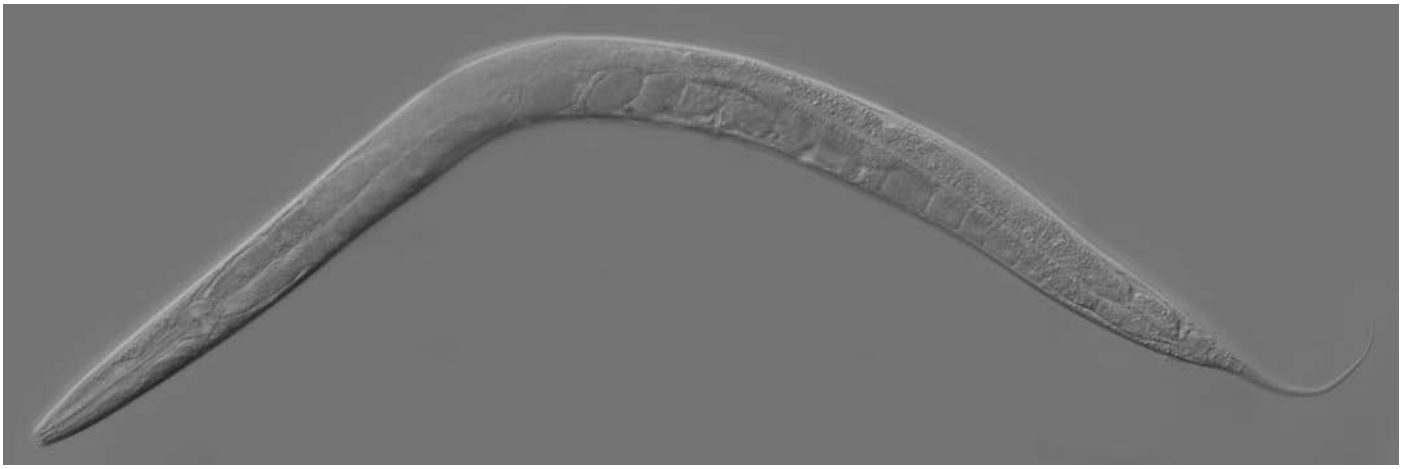
Means of achieving Transcendence

How close are we to achieving this digital equivalent of a human consciousness? Sandberg & Bostrom (2008), "Whole Brain Emulation - A Roadmap"[9] describe a hierarchy of possible approaches from top-down to bottom-up with many steps in between. Theirs is a substantial study of the subject of Whole Brain Emulation (WBE) as a route to AGI. To achieve something similar to Andreas Hein's Transcendence may be significantly less challenging.

Let's look at what has been achieved and might be achieved from the bottom up and from the top down.

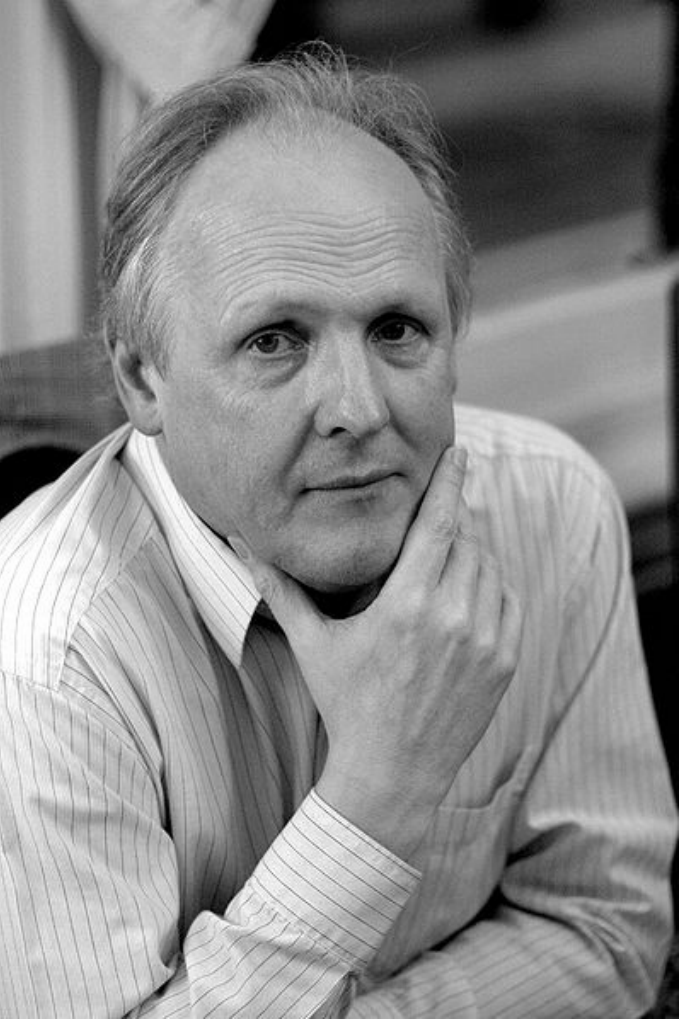
Bottom up – Simulation of Nervous Systems

Perhaps we can map a very simple organism first and then scale up and generalise? The simple worm *Caenorhabditis elegans*, usually called *c elegans*, has a nervous system consisting of exactly 302 neurons. A number of simulations of this simple creature have been proposed and attempted[10]. However, we are still some way from understanding the way in which even this 302 cell brain is connected and how each neuron functions. Alarmingly, this may involve processes which take the biochemistry down to the level of protons, see Sandberg & Bostrom, cited above.



▲**The c elegans worm with its 302 neurons.**

So perhaps we can build an analogue of a nervous system and see how it works? ARM and Acorn pioneer Steve Furber leads a team centred on the University of Manchester, building the SpiNNaker (Spiking Neural Network Architecture) system. This is "...a million-core computing engine whose flagship goal is to be able to simulate the behaviour of aggregates of up to a billion neurons in real time"[11]. The project relies on the speed of processors and communication across its electronic topology being several orders of magnitude faster than propagation in biological nervous systems. But as Furber says himself[12] – the complete SpiNNaker system will make a number of simplifying assumptions to achieve only 1% of the capacity of the human brain. If capacity were the only limitation and Moore's law applied then WBE will be achievable less than 14 years later![13] I don't think Furber or anyone else would take this literally but it's certainly food for thought.[14]



◀Steve Furber leads the SpiNNaker team.

Furber's team are not alone, the Blue Brain project is (of course!) an IBM-based project at the École Polytechnique Fédérale de Lausanne to create a synthetic brain by reverse-engineering mammalian brain circuitry - and the Human Brain Project at the same institution is using both bottom up and top down strategies[15].

Top Down: Simulation of Human Behaviour

The most successful general simulation technique achieved so far is probably the use of neural networks and this has been so for at least 30 years. Neural networks simulate biological learning by weighting interconnections to achieve a desired output based on a series of trials, for example to perform character recognition. The author worked at a major UK software house, Data Logic (part of US company, Raytheon) in the 80s. The company had an AI department which was heavily involved in the use of neural networks. They remain of great interest in AI generally and specifically in spacecraft applications[16]

Much work has been done on simulation of human behaviour. A lot of it relates to the behaviour of large groups, such as crowd behaviour in emergency situations. Simulation of individual human behaviour looks at lot harder to achieve. Much AI work, including the pioneering development of neural networks, has concentrated on supervised learning, again see Jeremy Clark's chapter, already cited, in *Beyond the Boundary*.

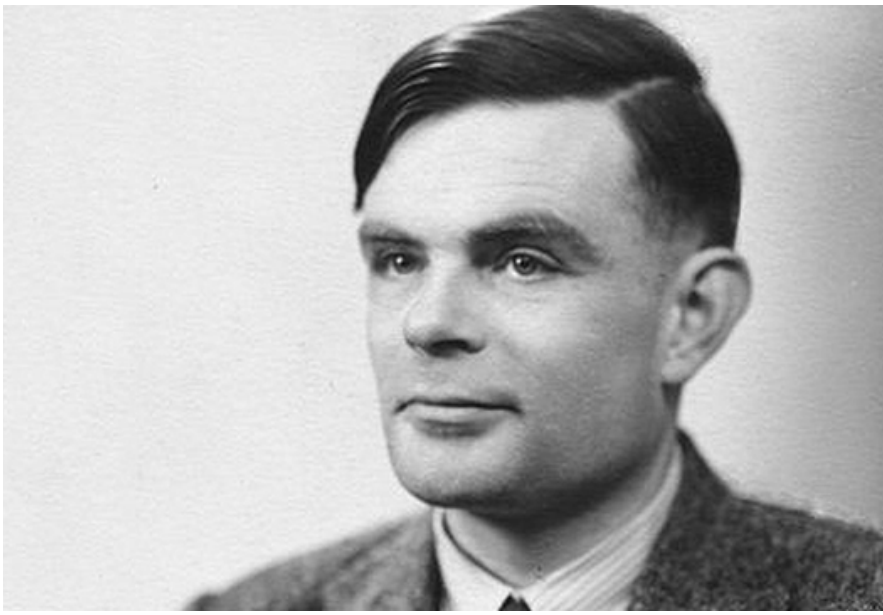
Alan Turing is most famous for war time code breaking but he was also perhaps the first serious practitioner of theoretical Computer Science. He had two ideas which are relevant here. One is the Church-Turing Thesis[17], shared with Alonzo Church. The other is the Turing Test for AI.

The first demonstrates that all "computers", including humans following an algorithm, are capable of computing the same things - be it the sum of two integers or the fluid dynamics of the earth's atmosphere.

The second of Turing's ideas is his "polite convention" that any system capable of convincing human conversation should be regarded as exhibiting intelligence. His paper in the journal, Mind, in 1950[18] asked "Can machines think?" Only a few years later another great computing thinker thought this was a silly question, as we will see.

To demonstrate WBE it seems to me that we 'only' need to achieve the latter, or some variant of it, not the equivalent of the former, which would be a mathematical proof that the WBE and a human were equivalent. Sandberg and Bostrom call this 'Social role-fit emulation'/'Person emulation'[19].

▼Alan Turing developed much of the groundwork for computing systems and AI.

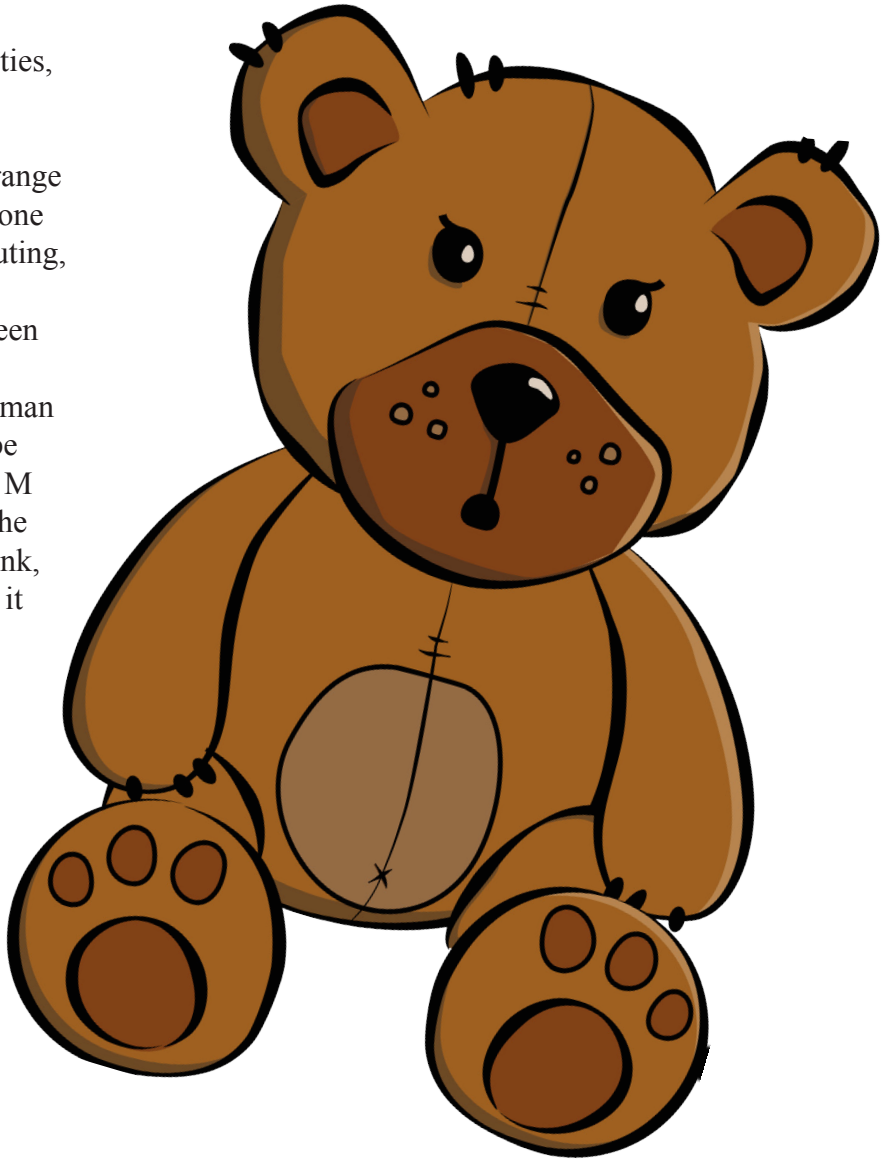


However, there are some further subtleties, as suggested in 'The status of Digital Persons' below.

Computer Science includes a wide range of views on AI. A typical dismissal by one of great 20th century thinkers in computing, Edsger W Dijkstra, is the following:

"The Fathers of the field [AI] had been pretty confusing: John von Neumann speculated about computers and the human brain in analogies sufficiently wild to be worthy of a medieval thinker and Alan M Turing thought about criteria to settle the question of whether Machines Can Think, a question of which we now know that it is about as relevant as the question of whether Submarines Can Swim."[20]

Closer to home, one of my i4is colleagues, Stephen Ashworth, has discussed "Technological Singularity, or Plateau? The case for anti-singularitarianism"[21]. He argues that human-like intelligence requires "emergent properties of the brain-body system rather than qualities which can be programmed in terms of specific lines of code".



This is allied to his technological pessimism; Ashworth wonders if "... technological progress has reached an inflection point and is starting to decelerate towards a plateau. This is already apparent in such areas as nuclear fusion research, space travel, medicine and fundamental physics and cosmology."

I am a technological optimist but Ashworth's paper is a powerful antidote to the wilder dreams[22], and nightmares[23], of the advocates of the idea that "the singularity is near" or that machines will transcend human intelligence in the near future. More about the history of AGI under - A Warning - 'False Dawns' of AGI in the next issue of *Principium*.

Parenting an AI - The Teddy Bear Technique

Most of the above means of achieving AGI are "bottom up" or model humans "en masse". An alternative appears from robot development, Learning by Imitation[24] [25], either using computational neuroscience, neural networks and the like - or by learning from adaptive behaviour in animals. There are obvious parallels with child development[26], specifically infant learning.

A Teddy Bear is a natural means of interaction with young humans and has been proposed as a user interface[27]. This may be a possible way of constructing a human-like artificial intelligence by bringing up the teddy bear in a "normal" human domestic environment. The resultant entity may exhibit similar behaviour to a human child while remaining wholly digital. This is, of course, a highly speculative idea and the practical means of achieving it - not to mention the moral issues relating to the child who is given this rather spooky device as a toy and companion - are distinctly non-trivial. Modern toys do this in a limited way but imagine a teddy bear that grows up with you right through your childhood and into adolescence!

In the next issue

In the next issue *Principium* I'll look at some of the philosophical implications of Digital Persons and their implications for interstellar travel. And finally I'll take a look at some related ideas arising in Science Fiction.

Endnotes

[1] Project Daedalus: Demonstrating the Engineering Feasibility of Interstellar Flight,
[2] *Beyond The Boundary*, published 2014 by the Initiative for Interstellar Studies, edited by Kelvin F Long.
[3] *Beyond The Boundary*, Chapter 18, 'The Greatest Challenge: Manned Interstellar Travel'.
[4] Transcendence Going Interstellar: How the Singularity Might Revolutionize Interstellar Travel.
[5] An Overview of Artificial General Intelligence as of 2014. Arakawa, Naoya/Yamakawa, Hiroshi/Ichise, Ryutaro – an expanded version of an article written in Japanese as an introduction to AGI for the audience at the 2014 conference of the Japanese Society for Artificial Intelligence. Contact john.davies@i4is.org in case of difficulty.
[6] But we might all be in a simulation anyway (see Sandberg & Bostrom below and here.
[7] Will we eventually be able to colonize other stars? - Notes from a preliminary review, June 22, 2014.
[8] This is an old topic. Arthur C Clarke discussed it in *Profiles of the Future: An Inquiry into the Limits of the Possible*, Gollancz, 1982.
[9] Sandberg, A., & Bostrom, N. (2008), Whole Brain Emulation: A Roadmap, Future of Humanity Institute, Oxford University.
[10] Oscillatory transepithelial h+ flux regulates a rhythmic behavior in c. Elegans, Pfeiffer J, Johnson D, Nehrke K.
[11] IEEE Transactions On Computers, Overview of the SpiNNaker system architecture, Steve B. Furber et al.
[12] Overview of the SpiNNaker system architecture (video), Steve Furber.
[13] Moore's Law implies a doubling of IC density every two years 2^7=128 and 2 × 7 = 14
[14] SpiNNaker topology: The interconnect topology of Spinnaker is a torus, beautifully illustrated in SpiNNaker toroidal structure visualisation for a planned art exhibition at Manchester Art Gallery part of Manchester's role as European City of Science in 2016. Contact john.davies@i4is.org in case of difficulty.
[15] 'Can we understand the brain using only a bottom-up strategy?'
[16] See *Beyond the Boundary*, chapter 15, Jeremy Clark, especially pages 280–293.
[17] The most often-quoted paper is Turing's 'On Computable Numbers, With an Application to the Entscheidungsproblem' (1936). I have tried and failed to understand it. I haven't tried 'An Unsolvable Problem of Elementary Number Theory' (1936) by Alonzo Church. Have a go at both if you think you are (mentally) tough enough!
[18] Computing Machinery and Intelligence, A. M. Turing, Mind, Vol. 59, No. 236 (Oct 1950), pp. 433–460, Oxford University Press.
[19] Sandberg & Bostrom (2008) Page 11, table 1, row 6a .
[20] 'The Threats to Computing Science', Edsger W. Dijkstra
[21] 'Technological Singularity, or Plateau? The Case for Antisingularitarianism', Stephen Ashworth.
[22] *The Singularity Is Near: When Humans Transcend Biology*, Ray Kurzweil, Viking, 2005.
[23] *Superintelligence: Paths, Dangers, Strategies*, Nick Bostrom, Oxford University Press, 2014.
[24] Robot Learning By Demonstration, Aude Billard and Daniel Grollman (2013), Scholarpedia, 8(12):3824.
[25] 'Infant Learning by imitation', Gergely, G, Bekkering, H. and Király, I. (2002), Rational Imitation in Preverbal infants, *Nature*, 415(6873) p. 755-755." and Carpenter, Malinda; Call, Josep and Tomasello, Michael (2002). Understanding 'Prior Intentions' Enables Two-Year-Olds to Imitatively Learn a Complex Task. *Child Development* 73(5): 1431-1441.
[26] See the above Scholarpedia entry and specifically the chapter on 'What to Imitate'.
[27] 'A Teddy Bear-Based Robotic User Interface', Noriyoshi Shimizu et al, ACM - *Theoretical and Practical Computer Applications in Entertainment*, [Vol. 4, No. 3].

About the author

John I Davies is a retired software engineer and mobile telecommunications consultant. He was briefly part of the UK space industry and played a small part in an early design study for the Hubble telescope and an even smaller part in a much larger enterprise, the later stages of the unsuccessful European ELDO launcher project. His main experience has been in communications software and the development, both technical and commercial, of mobile data communications. He retired in 2008 and has been active with the Initiative for Interstellar Studies since soon after its foundation in 2012. He is a career-long member of the British Interplanetary Society and has dabbled in philosophy via the UK Open University and latterly, the University of the Third Age.

FILM REVIEW

Star Wars: The Force Awakens

After the (almost) hard realties of *The Martian,* we come to the latest episode of the prodigal child of the Saturday matinee, *Star Wars: The Force Awakens*. Despite it being hot on the heels of *Avatar's* box office records, John Davies saw it at the BFI IMAX in London and had some reservations. Watch out for spoilers below!

I probably saw some of the matinee science fiction adventures that inspired George Lucas. My father's generation remembered *Flash Gordon* but does anyone of my generation remember *The Strange World of Planet X?* It made my 11-year-old flesh creep! I guess a lot has been written about the mythic and media sources of the *Star Wars* serial (a recent example in *Slate* is *Star Wars* Is a Postmodern Masterpiece). But maybe there's a bit of soap (grand?) opera in *Star Wars* too. We found out all about the dysfunctional Skywalker family in *Return of the Jedi* and we also found out how they got like that in the awful (and I don't mean awe-full!) prequel trilogy 20 years later.

A familiar story

So how does the story continue in this seventh episode? It does it again! The plot of *The Force Awakens* is so close to the original *Star Wars* that you can almost guess what happens next in many scenes. Remember the boast about the speed of the Millennium Falcon (complete with incorrect use of parsecs). It's there! With added irony. Remember the first space battle and "Don't get cocky kid!"? It's there, though somewhat rephrased. Remember the working class guy who fancied the princess, now it's an interstellar janissary fancying a female version of Luke. I could go on – and others have. Now imitation is the sincerest form of flattery but what is self-imitation? Or how bored are you with the *Rolling Stones'* touring repertoire – some of it 50 years old? Or, to put it personally, I was bored for at least part of that two hours plus.

The cast did a workmanlike job with a retread plot and a patchy script – Daisy Ridley (Rey), John Boyega (Finn) and Carrie Fisher (Leia) were particularly poorly scripted. Little or no wit, little or no repartee. And there was little or no teenage yearning for the two young leads, Rey and Finn. Remember Luke and the twin setting suns in *A New Hope*? Contrast Rey in *The Force Awakens*, with 'tough kid' self-reliance but no angst. A little light self-plagiarism would have worked here.

Harrison Ford and Lupita Nyong'o (motion captured as a wise old alien, Maz Kanata) got the Han Solo wisecracks and the Yoda wit and wisdom respectively and used them well but

nobody else got much. Adam Driver had the advantage of being the interesting villain (as proto-Darth Vader, Kylo Ren) and delivered all his lines, good and bad, with just the right combination of evil and internal conflict.

Despite following the well worn path of previous films, does it work? Actually, as an adventure, yes! If you like moderately intelligent space adventure then I think you might love it. If your strongest memory is the awfulness of the prequel trilogy then you'll be pleasantly surprised. If like me, you thought the very first *Star Wars* was a bit derivative, but fun, at first release and then saw it again and recognised that it paid a multitude of homages to Saturday morning cinema in the fifties, the swashbuckling in the 1930s and 40s, RAF heroics from the *Dambusters* to *617 Squadron*, *Casablanca*, westerns (and 'easterns' like *The Seven Samurai*) and even good old *2001* – then perhaps not. On the whole *The Force Awakens* suffers from excessive hype and critical gushing (uncritical gushing?). This ancient cinemagoer was disappointed but you may not be.

Interstellar fantasy

Does it say much that is interstellar? As ludicrous as the Starkiller super-weapon was, there is an analogy with a Kardashev type II society utilising the entire energy of a star. Most of the rest of the film, and *Star Wars* in general, is even purer space opera and fantasy. E E 'Doc' Smith would be proud! The planets were all of a type – a desert planet, a forest planet, an ice planet – but exoplanets are going to be even more varied and alien than the supporting non-human characters of *Star Wars*. And notice they can all breathe the same atmosphere as humans! The scale of the *Star Wars* universe implies that the hyperspace drives required by all spacecraft are capable of effective speeds that are beyond Miguel Alcubierre's wildest dreams.

Maybe we need inspirational fantasy – which 10-year-old wouldn't want to be Luke Skywalker, Han Solo, Finn or Rey flying through space? *Star Wars* remains a great inspiration for the spirit of space travel. I wonder if, in 10 or 20 years time, we will hear from female astronauts, engineers or scientists who became interested in space because the character of Rey inspired them. Carl Sagan told us he was inspired by John Carter of Mars – pure hokum but the adventures still spoke to him. So you need to cast aside your 'technical tosh' filter for the *Star Wars* mythos in general. You *can* do the Kessel run in 12 parsecs!

About the author

John Davies is the Editor of *Principium*.

Credits

Director: J J Abrams. Script: Lawrence Kasdan, J J Abrams, Michael Arndt, based on characters and plot by George Lucas. Starring: Harrison Ford (Han Solo), Mark Hamill (Luke Skywalker), Carrie Fisher (Leia Organa), Daisy Ridley (Rey), John Boyega (Finn), Oscar Isaac (Poe Dameron), Adam Driver (Kylo Ren), Max von Sydow (Lor San Tekka). Running time: 2 hours, 15 minutes.

NEXT ISSUE

In the next issue of *Principium* we will feature a detailed account of the i4is 'Starship Engineer' event reported in this issue. There will be further musings from John Davies on 'Sending Ourselves to the Stars'. We also hope to have something about that most distinguished member of our Advisory Board, Professor Freeman Dyson of Princeton University. If you have only heard of Dyson spheres and Project Orion you have merely scratched the surface of the work of this creative colossus! Closer to home, we also hope to have a progress report on lowering the cost of access to low Earth orbit, which is a vital precursor to an interplanetary, and thus an interstellar, civilisation.

▼**Construction of a Dyson sphere. Image credit: ASTRON.**

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.

We'd love to hear from you, our readers, about your thoughts on Principium, the Initiative or interstellar flight in general. Come along to Facebook, Twitter (@I4Interstellar) or LinkedIn to join in the conversation.

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Front cover: Visualisation of the outer solar system by Duncan Steel (www.duncansteel.com) from a Royal Astronomical Society press release announcing 'Centaurs as a hazard to civilization' in the December issue of *Astronomy & Geophysics* (A&G), a publication of the Royal Astronomical Society. Back cover: The International Space Station reached its 15th anniversary just after we published the last Principium. JAXA astronaut Kimiya Yui photographed the station's Japanese Experiment Module, named 'Kibo', which means 'hope' in Japanese. Image: NASA.

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