PRINCIPIUM

The Newsletter of the Initiative for Interstellar Studies™

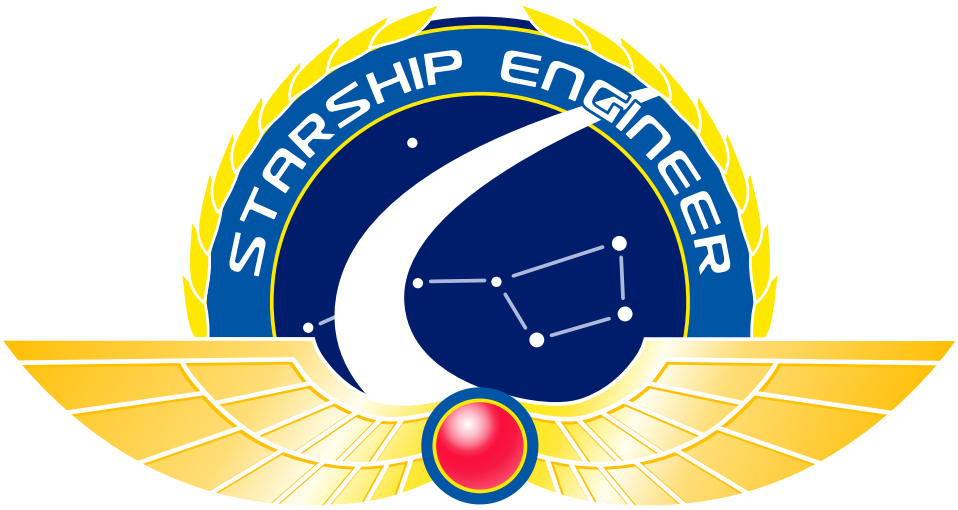
Issue 11 | November 2015

www.I4IS.org

Scientia ad sidera

Knowledge to the Stars

STOP PRESS!



Starship Engineer course at BIS London, 24-25 November 2015

The first running of our Starship Engineer course is happening at the British Interplanetary Society in London, November, 24-25 November 2015, 09.15 through 17.00 hrs.

More details in the advertisement towards the end of this issue.

Not much time to sign up for this eye-opening opportunity!

Editorial

In In this edition we start with a Stop Press announcing the first running of our Starship Engineer course at the British Interplanetary Society in London, 24-25 November 2015. More details in the advertisement towards the end of this issue. This issue of Principium arrives as Rob Swinney and Kelvin Long are polishing their course material. Sign up now!

Our guest introduction is by Robert G Kennedy III, PE. Robert is best known in the interstellar community as co-founder and organiser of the Tennessee Valley Interstellar Workshops. Here he applies his wide understanding of the relevant physics and engineering to suggest a novel approach to the search for extraterrestrial intelligence (SETI). In this issue we also present Robert's report of the i4is SF design workshop from the 2014 Tennessee Valley Interstellar Workshop (TVIW). Robert also contributes a trip report about TVIW 2014 overall - capturing the combination of serious thinking and convivial enthusiasm of these events.

Our News this time includes details of our Project Dragonfly video, a recent meeting of the core team of i4is and the announcement of a new i4is publication, Axiom.

We have a detailed account of the Project Dragonfly competition and workshop by Dan Fries with an addendum on the way forward for the project by Martin Langer. We will be covering Project Dragonfly in yet more detail in later editions.

Our friends Icarus Interstellar held their big Starship Congress and "Hackathon" in Philadelphia last month and one of the TVIW team, Ken Roy, was there and gives us a personal view in his piece "Surviving the Interstellar Hackathon in the City of Brotherly Love". It sounds like he had a great time!

One of the keynotes at the Congress was delivered by Dr Ralph McNutt and he talked about the New Horizons probe to Pluto and the Kuiper Belt - and how we might build interstellar precursor missions. Dr McNutt has kindly given us access to his recent thinking on this and Rob Swinney has written a report for this issue, Pluto and Beyond: Next Steps to the Stars after Voyagers and New Horizons.

As always, we maintain our strong links with the dreamers of Science Fiction. We were at this year's UK national Eastercon. Some of our doings there are captured in an account by John Davies and Rob Swinney.

There have been a number of relatively technically realistic films set in space in recent years and the latest is The Martian, directed by Ridley Scott and based on Andy Weir's novel. Not interstellar but another inspiration to our species to get out there! We have a review by John Davies.

We have to disappoint readers who were expecting a meditation on the interstellar implications of the Rosetta comet probe and its Philae lander. We'll do our best to bring it to you in the New Year.

You may notice that our layout has made a great leap forward to last year - having welcomed back Adrian Mann in this role. He's a massively talented artist and practitioner of digital visual media. Not least he is responsible for many of Reaction Engines videos; take a look at their website. If, like me, you are thrilled at the idea of a take-off and ascent to orbit of their Skylon spaceplane then you will appreciate what Adrian can do.

Our front cover feature is the Daedalus starship of the British Interplanetary Society (BIS) as imagined by Adrian Mann. His imagining is based on the detailed design developed in the 1970s by the team led by Alan Bond and Tony Martin. Daedalus remains the most detailed design yet produced for a starship. It is the starting point for the Icarus project of Icarus Interstellar and the BIS, a new starship design based on fusion principles. We might appropriately have featured Daedalus on the cover of our first issue but it is so well known that we have left it to this, our eleventh issue. We hope to feature a detailed Icarus design well before our 20th issue!

And for the back cover we have the Globular Cluster Omega Centauri (NGC 5139) as imaged by the European Southern Observatory (details at http://www.eso.org/public/images/eso0844a/). At about 16,000 light years distance, it's a tough target for any of our relatively near term starships. But what impressed us, apart from the sheer beauty of the image, is that there is some suspicion that one of our nearest neighbours, Kapteyn's Star, may have originated in NGC 5139. Kapteyn's Star is about 12 light years away and has at least two exoplanets.

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

John I Davies, Editor *Principium*

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Guest Introduction: A Modest Proposal for Photometric SETI

Robert G Kennedy III, PE

Background[1] : For good historical and technological reasons, the SETI (Search for Extraterrestrial Intelligence) community's roots are in radio astronomy (RA).

After all, the Big Bang was discovered at radio frequencies (RF, but technically microwaves (MW)), and people began constructing radios not too long after they built telegraphs and telephone networks. Also, one of the very first applications of computers was to perform what we would now call signal processing (SP) on RF signals during WW2[2].

Thanks to numerous RF transmission windows in the atmosphere, it is far easier to build and use ground-based detectors to observe the sky at RF, than it is at say, ultraviolet (UV), optical, or infrared (IR) frequencies. So there has been some path dependence in the SETI field. However, as a greater fraction of humanity's exponentially increasing data traffic goes by optical fiber or by low-power short-range encrypted wireless comms almost indistinguishable from noise, the world is "going black" from a SETI perspective. Furthermore, teasing out extraterrestrial RF signals from RF noise appears to be a black hole for spare computing power. So Terra's unusual brightness at RF may turn out to be a very-short lived "blip" on a historical timescale, not to mention geologic and cosmologic timescales. How then to find evidence that "*We Are Not Alone?*" Rather than exclusively focusing on RF, what other signatures could we look for? Well, as the late Rod Serling[3] used to say, "*presented here for your consideration*" is a proposal to take a photometric approach to SETI. (nihil sub sole novum: this is not an original idea. Approximately two centuries ago, the mathematician Carl Friedrich Gauss speculated about using giant mirrors and what we would today call terrestrial geoengineering to send optical signals at interplanetary range.[4]). If we decide to do this, what technical capability would we need? At what time could we first expect to spot a civilization like ours (spacefaring terrestrial tool-users[5]) at interstellar ranges using optical astronomy? If we limit ourselves to basic photometry without new-fangled SP techniques, then we are measuring two simple physical phenomena that can be adequately resolved at interstellar range: optical power, i.e. luminosity, and time.

Dr Sara Seager's "Search for Earth 2.0" keynote address (https://www.youtube.com/watch?v=JOvB71mHyNA) at the last Tennessee Valley Interstellar Workshop (TVIW) in Oak Ridge, Tennessee in November 2014 presented the progress in finding extrasolar planets, and one new approach (direct observation using diffractive sunshades). The technical progress in just the last generation is remarkable. Virtually all of these methods are indirect and optical, including:

- radial velocimetry (Doppler wobbles in spectra pioneered by Queloz/Mayor/Marcy/Butler in the late 1980s);
- photometry (variations in brightness by eclipses and transits a la Kepler, plus subtler techniques);
- astrometry (direct measurement of stellar motions);
- gravitational microlensing;
- direct spectral detection during stellar transits of non-equilibrium gases like oxygen and methane as proxies for biological activity.

(Direct imaging, i.e. spatially resolving extrasolar planets directly, is beyond our terrestrial capabilities now, but see Seager's talk for what the future may hold.)

Every year, the lower mass limit of detectability goes down. It seems that if an Earth-like world exists within a reasonable range, then we should find it within the next generation, say 30 years. Later on at TVIW 2014, the "C-for-Commo" working track came to the conclusion that interpretation of an extraterrestrial signal would be a hopeless task without interacting in realtime with the particular somatic embodiment of the intelligence that created the signal. (This also was the conclusion of a SETI conference taking place at the same time on the other side of the North American continent, unbeknownst to the organizers of TVIW.[6]) While the mere detection of an unambiguously artificial signal would be a major world-historical event by itself, understanding means crewed interstellar missions, a very tall order that is at least centuries off[7].

There are two broad classes of candidate stars to look for.[8]

The first class would host societies that have mastered space-based solar power (SBSP), perhaps for geoengineering purposes, on up through Kardashev Type I (defined as using all the available power of their home world). On Earth, about the same amount of sunlight falls on the lit face in one hour (~600 exajoules) as the entire human race uses in one year (8766 hours), a 4-order-of-magnitude ratio. In a 2006 paper, Sandia Labs showed that solar power has by far the most headroom for growth of any energy resource that we know about[9]. A fission economy based on breeding plutonium from ^{238}U, or ^{233}U from thorium is the only other existing energy solution of that scale, yet it is still a distant second. Per unit area, solar power is 3-4 orders of magnitude greater than the third potential source, geothermal power. Presently the primary power of the human race (all sources, oil, coal, gas, nuclear hydro, wind, sun, waves, even burning poop) is equivalent to ~20 thermal terawatts (TW), of which 2 TW is round-the-clock electric generating capacity. Therefore, our energy consumption could grow 4 orders of magnitude, to 160,000 TW, before we exhausted all the solar power available to us terrestrially.

The second class is a solar-system-wide civilization evolving toward a Kardashev

Type II status, defined as using all the available power of their home star. Sol System's Type II would be ~2 billion times as powerful as the Terra's Type I. By definition, a civilization like this could be detected at the same range as Sol itself. (Or even greater, depending on the rarity of 300K IR objects 2 AU in diameter.) However, since Freeman Dyson dealt with this subject well enough 55 years ago[10], we need not explore it further here.

Geoengineering and Luminosity.

In a recent paper in JBIS[11], we proposed using a school of radiation-levitated sunshades in non-Keplerian orbits inside the Sun-Earth L1 point to counteract climate change while generating clean power from space to pay for the scheme. Being roughly the size of Texas in aggregate area (1 million km^2), the school of sails would stop one-quarter of 1% of sunlight falling on Earth, enough to offset global warming with artificial cooling. Think of it as a Mirrored Maunder Minimum like the one five centuries ago. Putting a photovoltaic layer on the sunny side would generate a useful by-product: 10 TW of electric power, beamed to the global grid via a 2-link maser (microwave lasers emitting coherent MW radiation), enough to satisfy total planetary demand for electricity by 2050. Most of the 400 TW of sunlight hitting the sunny side of the sail would be reflected off it. Assume for example that the reflected light-cone subtends a degree of arc. Since Sol's disk is only half a degree wide from the sail's point of view at L1, then most (¾) of the reflected photons go past Sol's limb into deep space—in essence, a lighthouse beacon that rotates exactly in synch with the forever hidden Earth. The intrinsic luminosity of the reflected image is 400 TW absolute. The duration of the light pulse would be directly proportional to the cone's angle; the amplitude would vary as the inverse square of the cone's angle; particular numbers for both would depend on the specific geometry. In this case, a 1-degree searchlight would sweep through its own width in a day, since there are about the same number of degrees in a circle as days in a year (Earth's orbital period). The apparent brightening at the Sun-Earth L3 point on the far side of the Sun in this case would be about +20%, or +300 W/m^{-2}. Any extrasolar observer, far away but at a fixed location also aligned with the ecliptic plane, would glimpse some increase in Sol's apparent luminosity[12]. Unlike a planetary transit of the sort that the Kepler mission looks for, there would be no corresponding occultation a half-period later (ie the secondary eclipse) visible from the outside since the L1 point is always interior to the Earth. The absence of that dimming might itself be considered notable.

Geoengineering, Geology, and Time.

Luna, queen of the skies, is actually a rather dull object, with an albedo of only 0.07. (Charcoal is 0.04.) At full, it only looks so bright because its face is fully illuminated by the Sun against the deep black of space. With clouds, icecaps, light deserts and the glint of sun off the world ocean, Terra is quite a bit brighter, with an albedo of ~0.3. However, three times in the past billion years our planet's albedo has approached 0.9 when the world froze over, most recently 650 megayears. The magnitude of this change in optical power was on the order of 100,000 TW in all directions, but these "Snowball Earths" took millions of years to happen, persisted for 10s of millions, and took more megayears to unhappen.

Though hominids have walked the Earth for several million years, and urbanized civilization has existed for 6,000 or so, virtually all of the gross physical, chemical and ecological changes on the surface of our world due to *Homo sapiens* happened in the last two centuries, and much of that in just the last couple of billion seconds. Hence the neologism "Anthropocene" popularized by Paul Crutzen in climate science[13].
So compared to geologic transitions, these anthropogenic changes in albedo are lightning fast.

Thus, instead of random isotropic changes in albedo every few hundred megayears, this brief 400 TW flash from the sail school at L1 would occur exactly once every year, concentrated in the ecliptic and as regular in amplitude and frequency as a metronome. Over a long enough observing campaign, say several dozen observations in a billion seconds, this anisotropic optical pulsar could be construed as a signal of artificial origin. If the traffic analyst was (fantastically) lucky enough to be watching at the right time, this artefact would emerge from background noise in about a century.

We are not presently able to spatially separate such a source from its host star, but we don't have to; the variation of luminosity on a temporal axis is good enough. Since the Copernican Principle (which amounts to *"everywhere is, pretty much, like everywhere else!"*) cuts both ways, this is the sort of optical signal to look for.

Independent Confirmation at MW/RF.

Science knows of natural masers. The brightest one in our galaxy is the 6.7 GHz (45 mm wavelength) methanol maser in W49. Sol itself emits essentially no radiation longer than 1000 microns. Therefore a regular pulse of monochromatic 60 GHz μwave radiation (5 mm wavelength), also perfectly synchronized to that 1-year period of the optical fluctuation, but exactly 180 degrees out of phase, should stand out brightly. Thus the leakage or side-lobes from the multi-deka-terawatt maser beam from solar sails at L1 could provide independent confirmation of intelligent activity to that extraterrestrial observer.

Luminosity, Time, and SBSP for Sol System.

Once techniques for SBSP have been worked out, perhaps to solve an urgent crisis of climate change with geoengineering, space-based industry will have been given its needful kick in the pants. After this, we see no reason that enterprising Earthlings would discontinue building these useful devices, which can be used for propulsion or power. The next logical places to put large numbers of sails would be the Earth-Moon L4 and L5 points, followed by the Sun-Earth L4 and L5 points. Mirrors at Luna's L4/L5 points will have the same basic annual periodicity as Earth's orbit round the Sun, with a monthly cycle superposed on that basic rhythm. The maximum spatial separation of mirrors at Luna's L4 and L5 points, ~800,000 km, is about that of Sol's diameter itself, which would make them much more visible, perhaps enough to be resolvable spatially with micro-arcsecond instruments just coming online.

Shiny objects at the Sun-Earth L4/L5 points would by definition be separated from each other 400 times as much, or 1 astronomical unit (AU), but still permanently in synch with the home world. One AU separation is enough to be resolved spatially at interstellar ranges with milli-arcsecond instruments.

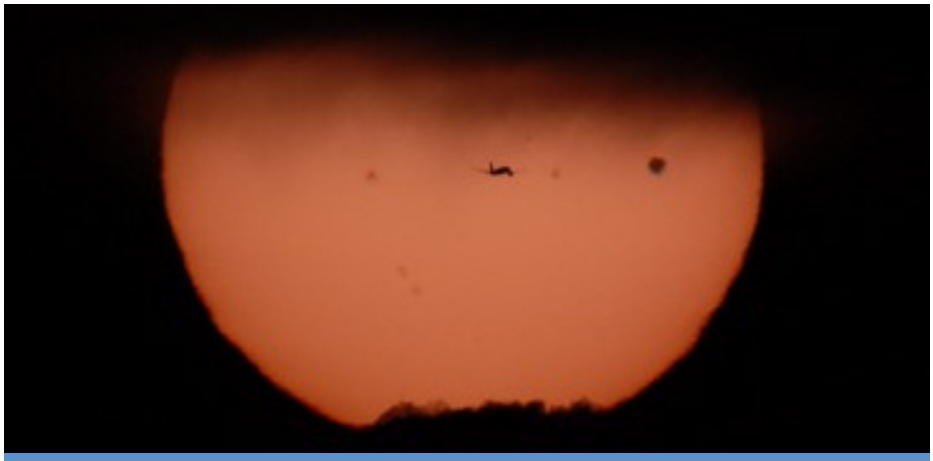
As society back home grows wealthy due to the value created by their

machines, the sheer optical power manipulated and reflected by their sails also grows. *If present trends continue uninterrupted*, and given that humanity's recent appetite for electricity doubles approximately every generation, or an order of magnitude about every century, then people should achieve Type I status in less than a millennium. Not only would this be 3-5 orders of magnitude faster than albedo changes of geologic origin, the anisotropic light reflected into space by a Type I civilization would be of somewhat greater magnitude than any naturally-occurring isotropic albedo fluctuation on Earth. If this power level as measured at the point-of-use were ultimately and entirely generated by space-based solar sails mostly in the ecliptic, then we can predict that something on the order of a million terawatts of optical power in the by-then numerous searchlights sweeping the universe. This would be on the order of parts-per-thousand of Sol's apparent luminosity in the ecliptic, a precision that has been available to optical science for decades now[14], and radio science for a century.

So, in sum, in order for us to optically detect a civilization just embarking on its path to Type I status, we would need instruments possibly of part-per-billion precision, staring at targets long enough to capture events of 10s of kiloseconds duration repeating at 10s of megasecond intervals, over observing campaigns of perhaps a billion seconds. Because of the long stares and long campaigns, we'd need a lot of assets in space. That would take decades and cost a lot of money.

In order to optically detect a civilization that has fully arrived at Type I status, we would only need instruments with perhaps part-per-thousand precision, staring at targets long enough to capture events of varying duration but with periods on the order of a million seconds, over observing campaigns of less than a billion seconds. Because the latter is so much easier to spot than the former, and we already possess the necessary resolution, we might be able to find the fingerprints of a Type I civilization simply by data mining the archives from missions such as Kepler and its successors, using crowdsourcing like that pioneered by SETI@home in the RF region, or, in the visible region, like that which IOTA (International Occultation Timing Association) and the Kepler mission ("Planet Hunters" network) already do. Though it won't be as perfectly synchronized as in the beginning for geoengineering, still there will be anomalies, patterns, rhythm, and structure in the data to be teased out by those observers who didn't get the subtler message the first time.

About the author: Robert Kennedy PE is a Senior Systems Engineer VI who does green energy (mostly solar and geothermal) at what he laughingly calls his "day job". He is the co-author (with Ken Roy) of many papers about "Dyson Dots" and "Shell Worlds", and is also one of the co-founders of the Tennessee Valley Interstellar Workshop.



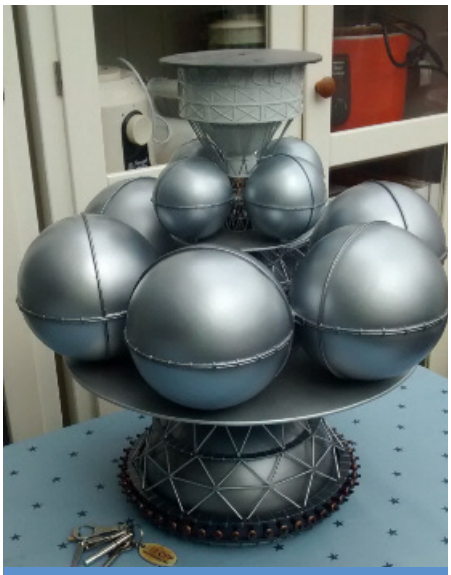
Local Example of Simultaneous Stellar Transits by Natural and Artificial Objects. Venus transiting Sol (left). Passenger jet from Salt Lake City (SLC) transiting Sol and Venus (right). Image acquired in Salt Lake City at 0430 UTC 06 June 2012. Shot bagged 2030 Mountain Time 05 Jun 2012 @ Salt Lake City Museum by Bruce Hugo per loud tipoff by Robert Kennedy & Eric Hughes.

1. I allude to the cracking of the German Enigma system (ULTRA) by the British at Bletchley Park, and the Japanese JN-25 naval codes by American cryptanalysts (MAGIC).
2. Host of an early Space Race-era American television show, *The Twilight Zone*.
3. While I personally think that life evolved from the inside out, starting with chemosynthesis, and that ice worlds are a great place to look for other life, I think that is another subject for another day.
4. *"Communicating Across the Cosmos: Summary of a Workshop on Interstellar Message Design"*, http://www.seti.org/weeky-lecture/communicating-across-cosmos-summary-workshop-interstellar-message-design , accessed 11 Oct 2015.
5. Being pedantic, one could say there's a third class, the Kardashev III civilization defined as using all the available power of the galaxy, which is another twelve orders of magnitude beyond the Type II. But Type III is so far beyond our humble selves, that I doubt we would even recognize it if it existed.
6. Jeff Tsao, et al, "*Solar FAQs*" Working Draft Version, Sandia National Laboratories, 20 Apr 2006, http://www.sandia.gov/~jytsao/Solar%20FAQs.pdf, accessed 19 Sep 2015.
7. F.J. Dyson, "*Search for Artificial Stellar Sources of Infrared Radiation*", Science, 131 (3414), pp.1667–1668, 3 June 1960
8. R.G. Kennedy, K.I. Roy, E. Hughes, and D.E. Fields, "*Dyson Dots & geoengineering: the Killer App Ad Astra*", JBIS, vol.66, no.10-11, Oct-Nov' 13.
9. Even a billionth (-90 dB) should be detectable, if not now, soon. If that sounds tiny to the reader, be advised that the human race is getting very good at measuring very small proportions. Modern atomic timekeeping (the heart of satnav), laser measurement, analytical chemistry, and certain forms of radio science all operate at -90 dB precision or better.
10. W. Steffen, P. Crutzen, J.R. McNeill, "*The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?*", Ambio 36, no.8, pp.614-621, 2007
11. The Kepler spacecraft measures photic fluctuations of less than 1% on a baseline of ~100 million seconds.

News from the Institute

i4is in Cheltenham

The weekend of 2-4 October 2015 saw the first formal Annual General Meeting (AGM) of i4is and one of our regular Progress and Planning meetings. Kelvin Long and Rob Swinney are the directors of our UK-registered not-for profit company but our own board is a little larger and appointed 5 new members at the AGM (Jeremy Clark, Robert Kennedy III, Andreas Hein, Richard Osborne and Professor Rachel Armstrong). Several of our most active members are simply that, ordinary members. So five of us in person, Kelvin, Rob, Gill Norman, Terry Regan and John Davies were at Gill's place in Cheltenham for the weekend and Andreas Hein joined us by Skype from Paris. We plotted our direction for the next few months but then took a very pleasant evening off over dinner. Terry brought his Daedalus model along - he tells me it's nearly finished but I can't see anything missing - judge for yourself!



Terry Regan's Daedalus

Some of us stayed up till the small hours and others enjoyed a walk up the local hill on Sunday. We said farewell after a visit to the local aviation museum, the Jet Age museum. If you are in the Cheltenham / Gloucester area don't miss the brilliant exhibits (sitting in the Vulcan cockpit was my high point!).

Vulcan at the Jet Age Museum

Project Dragonfly - The Movie!

The first cut of our video from the Project Dragonfly symposium is at -

https://www.youtube.com/playlist?list=PL6Bs4IMTm6V4b0AMmINUy6eHwAYhMAYS4

As you will see from the YouTube playlist, it's in five parts. Here they are -

- **Part 1:** Welcome address: Andreas Hein, Chair | WARR ISF, Technical University of Munich Presentation & Q&A
- **Part 2:** University of California, Santa Barbara Presentation & Q&A
- **Part 3:** Cairo University Presentation & Q&A
- **Part 4:** CranSEDS (Cranfield University, Skolkovo Institute of Science & Technology, Paul Sabatier University) Presentation & Q&A | Final Review Panel retires / Informal discussions
- **Part 5:** Prize ceremony | The Future of Project Dragonfly: Andreas Hein

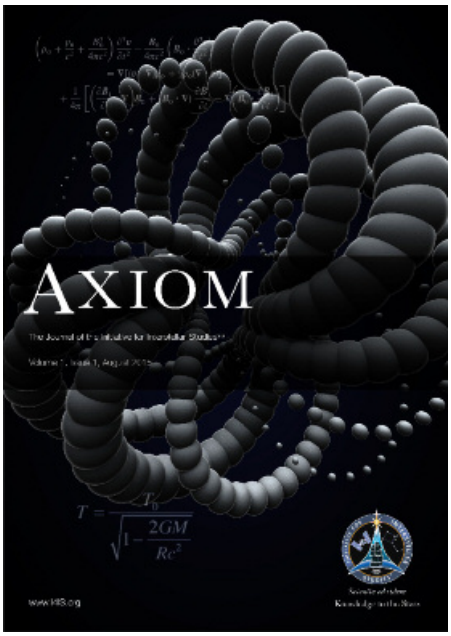
Our good friend Rick Garcia captured the event in quality video and sound. He'll be adding more to a later cut but the whole show is there now. Take a look!

We have a full account of the event in this issue, "*The i4is Project Dragonfly Competition*", by Dan Fries. And Martin Langer adds a summary of the way forward for this project, "*Project Dragonfly – The road goes on…*". Expect Dragonfly to continue to feature strongly in *Principiums* (or is that *Principia*?) to come.

i4is at the SDSO

Rob Swinney and Terry Regan were at the Scottish Dark Sky Observatory (SDSO) in August representing both i4is and the British Interplanetary Society. Rob told a packed meeting about the prospects of real interstellar flight in the near future and Terry talked about his spacecraft models. He builds 'from scratch', no kits, to create some of the historical explorers such as Pioneer, Voyager and Cassini and his own model creation of Daedalus, the BIS starship design. The attendees were amazed at his models and enjoyed hearing some of the trials and tribulations of building them from scratch using various household and other everyday items (from wine glasses to Christmas decorations).

Axiom



This new publication of the Initiative for Interstellar Studies is a technical academic educational journal. It will be published three times per year and will explore ideas, assumptions and paradigms of existing knowledge including papers which explain our current understanding of topics in interstellar studies or offer new insights or new ways of looking at a problem or known solutions. Not new ideas or new technologies (there are other journals for this including the Journal of the British Interplanetary Society). Of you would like to submit a paper to this new journal can do so by emailing us at our regular contact address info@i4is.org. Axiom is a print journal, obtainable via -

http://www.lulu.com/shop/kelvin-long/axiom1/paperback/product-22353814.html

All profits raised go directly towards the activities of our organisation. The first issue contains three papers -

- The 'Invention' of the Starship and Revisiting Tsiolkovsky
  - Kelvin F. Long
- Two-Stage vs. Single-Stage: A Performance Comparison
  - Adam Crowl
- Exponential Growth for Another Thousand Years
  - Stephen Ashworth

2016 i4is Calendar

The Initiative for Interstellar Studies began on 12th September 2012 and we have therefore passed our third anniversary.

To celebrate this we have recently released an i4is 2016 calendar containing images from our various activities. All profits raised go directly towards our not-for-profit organisation and help fund our continued efforts. You can purchase a copy here:

http://www.lulu.com/shop/kelvin-long/my-calendar/calendar/product-22353949.html

A perfect seasonal gift for your interstellar-struck friends and relations!

London Review of Books "Lets all go to Mars"

I note that John Lanchester, author of "Whoops! Why Everyone Owes Everyone and No One Can Pay" and several novels has been discussing Elon Musk's ambitions in the London Review of Books. Here's a quote -

> ***As for human spaceflight, I think it's an inherently progressive activity, not so much in its practical consequences but in the way it changes our species' frame of reference. The modern ecology movement was in effect created by the image of the whole earth, vulnerable and isolated and full of life, sent back by Apollo 8.***

Good to see the London literary intelligentsia getting on board!

A Record Monolith?

The Monolith

For the 2014 Worldcon (Loncon3) in London we built a 4m tall monolith. Our builders, Terry Regan and Paul Campbell, built it to the exact 1:4:9 dimensions of the object in 2001: A Space Odyssey and it was a quite an attraction at the con. It has recently been suggested that it may be the largest in existence.

So do we have a world record? If you think so or you know of another contender then please me know john.davies@i4is.org.

Principium back issues

This is the 11th edition of Principium. If you missed any of our issues 1-10 or have recently joined our mailing list, you can catch up on the back issues at i4is.org/publications.

Pluto and Beyond: Next Steps to the Stars after Voyagers and New Horizons

Presented by Ralph L McNutt, Jr (The John Hopkins University Applied Physics Laboratory, USA)

Reported by Rob Swinney

Keynote speech at the Starship Congress 2015 Interstellar Hackathon, 4th of September, 2015

For those not able to attend this year's Interstellar Hackathon at Drexel University Bossone Research Centre in Philadelphia, YouTube came to the rescue and we were able to watch many of the presentations live via a web cam. Unfortunately for a couple of the key speaker's presentations the technological gremlins prevented the live broadcast and we wait with bated breath for the official edited version taken by the main TV camera to appear. This happened to Dr Ralph McNutt's presentation but for this report he very kindly forwarded the presentation and his related paper submitted for the International Astronautical Congress. Hopefully here we will be able to give a fair interpretation of the presentation for the reader. Without actually having seen it!

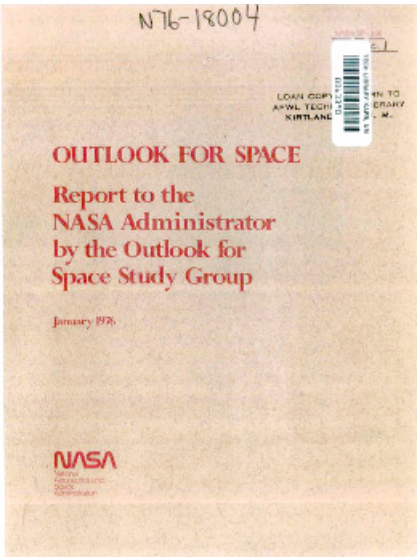
Dr Ralph McNutt is one of the co-investigators at the John Hopkins University Applied Physics Laboratory working on the famous New Horizons mission to Pluto and beyond. This year we were treated to this actual encounter on 14 July, the first to a new planet (okay, ice dwarf planet) for many decades and fortunately, with the fly past on automatic, there were no gremlins on this occasion. During his talk he would give the latest on the fly past but it is what may lie beyond Pluto and New Horizons, and finding out, which provided the main content.

Unlike the devotees of interstellar travel research organisations, like Icarus Interstellar who hosted the hackathon and our own i4is, Dr McNutt started by making it clear that his talk would not be about actual interstellar travel. Or, indeed, another popular dream, colonisation. But it would be about *'The New Frontier'* in deep space exploration: the interstellar medium (ISM) itself. This would be beyond the interaction zone between the ISM and the Sun's heliosphere far exceeding the orbit of Pluto.

He illustrates that the out-flowing solar plasma contained within the heliosphere encounters the ISM at some point in the direction of the Sun's travel first and forms a shock transition and a broader boundary shell around our star, similar to that now observed around distant stars. This had been debated as early as the 1970s and even in 1971 it was known that the final Pioneer probes would leave the solar system and be able to obtain data from the interaction region (if they survived that long).

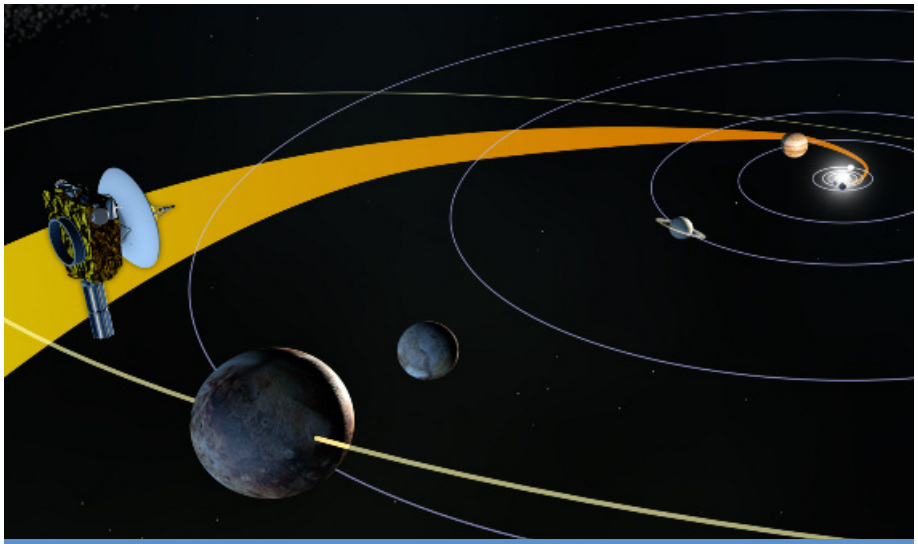
Within a few years there were specific proposals for a mission beyond the planets driven by science and later still many more detailed proposals followed from NASA studies and US National Academy Studies to explore these remote regions.

Speaking of events more recent, Dr McNutt described two workshops at Caltech, known as the Keck Institute of Space Studies (KISS) workshops, which culminated in a final report in July 2015.



At the workshops, some 32 participants discussed the science drivers and enabling technologies for the exploration of the ISM which were led by the three team leaders, Edward C Stone, Leon Alkalai and Lou Friedman. The goal of the workshops was to consider the capability push, such as being able to reach the ISM in 10 to 15 years rather than 36 as in the case of Voyager 1 and 2, and the science pull of identifying the compelling science goals for exploring the ISM between 100 and 300 AU (and other interesting stuff along the way).

The questions were many and varied but the key result of the two KISS



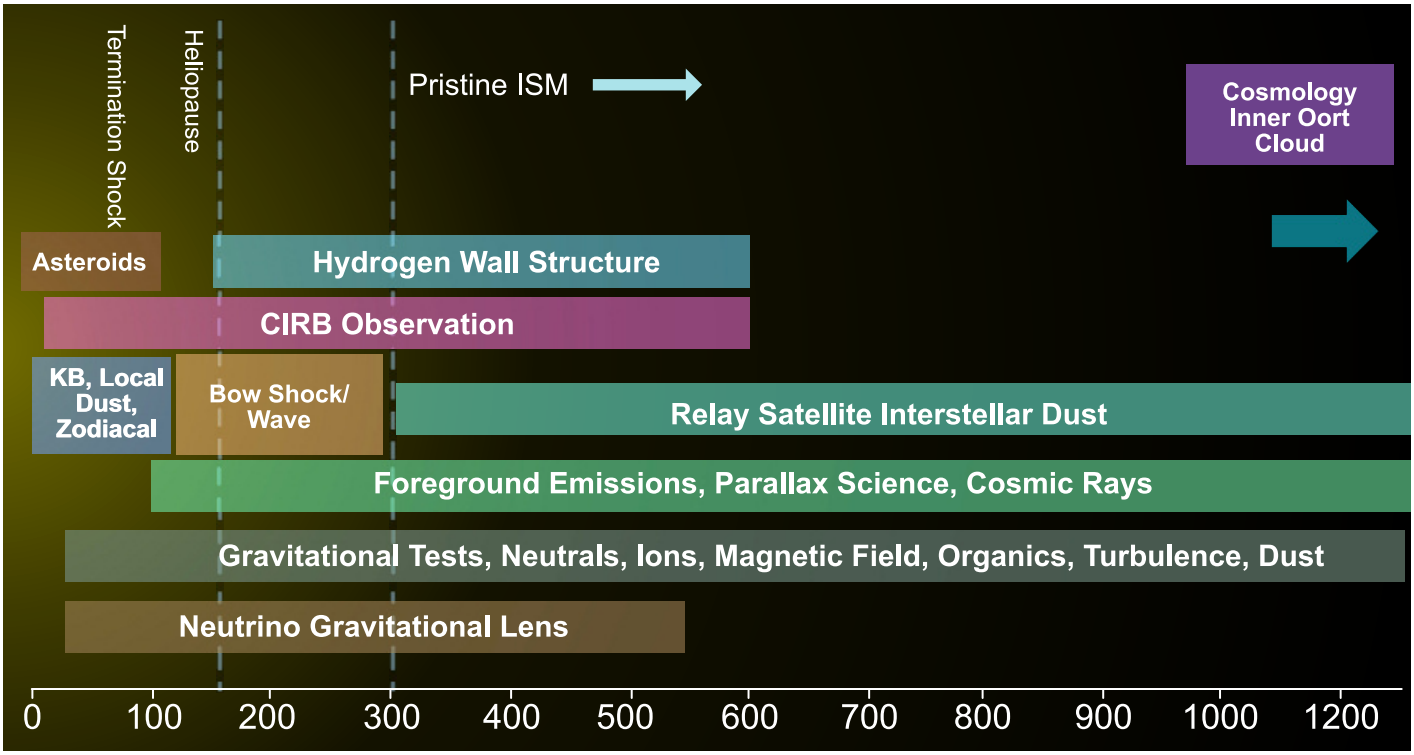
New Horizons journey from the Earth to Pluto, and beyond.

NASA Studies	National Academy Studies
Outlook for Space, 1976	Physics through the 1990's - Panel on Gravitation, Cosmology, and Cosmic Rays (D. T. Wilkinson, chair), 1986 NRC report
An implementation plan for solar system space physics, S. M. Krimigis, chair, 1985	Solar and Space Physics Task Group Report (F. Scarf, chair),1988 NRC study Space Science in the 21st Century - Imperatives for the Decade 1995-2015
Space Physics Strategy-Implementation Study: The NASA Space Physics Program for 1995-2010	Astronomy and Astrophysics Task Group Report (B. Burke, chair), 1988 NRC study Space Science in the 21st Century - Imperatives for the Decade 1995-2015
Sun-Earth Connection Technology Roadmap, 1997	The Decade of Discovery in Astronomy and Astrophysics (John N. Bahcall, chair)
Space Science Strategic Plan, The Space Science Enterprise, 2000	The Committee on Cosmic Ray Physics of the NRC Board on Physics and Astronomy (T. K. Gaisser, chair), 1995 report Opportunities in Cosmic Ray Physics
Sun-Earth Connection Roadmaps, 1997, 2000, 2003	A Science Strategy for Space Physics, Space Studies Board, NRC, National Academy Press, 1995 (M. Negebauer, chair)
NASA 2003 Strategic Plan	The Sun to the Earth - and Beyond: A Decadal Research Strategy in Solar and Space Physics, 2003
The New Science of the Sun - Solar System: Recommended Roadmap for Science and Technology 2005 - 2035, 2006	Exploration of the Outer Heliosphere and the Local Interstellar Medium, 2004
Heliophysics: THE SOLAR AND SPACE PHYSICS OF A NEW ERA; Recommended Roadmap for Science and Technology 2009–2030, May 2009	Priorities in Space Science Enabled by Nuclear Power and Propulsion, 2006

workshops was that there was compelling science on the way to the ISM, at the ISM and from the ISM.

There were five major goals presented on the way; Zodiacal/Cosmic background science, solar wind science, parallax science, radio science and astrometry. Within 50 AU the science of the termination shock, heliopause, bow shock, bow wave, organics and dust composition. There was the science of the pristine ISM beyond 200 AU; the interstellar magnetic field, cosmic ray science, interstellar winds, primordial black holes, WIMPS, organics and dust composition. Even further at greater than 550 AU there was more radio science, the solar lens focus and exoplanets and KBO detection. Finally there was the KBO science itself between about 30 to 50 AU with fast flybys or impactors to the largest trans-Neptunian objects.

It would have been at this point that Dr McNutt must have reflected on the fact that the New Horizons programme in reality had 'just begun' by illustrating some of the latest images received from the space probe flypast of Pluto. From the flypast the downlink phase would take 16 months to download all of the data from the event including the data giving ever increasing resolution. The journey was not over for New Horizons as it was now targeted for an additional flyby of a small



KBO in January 2019. It was also possible to reflect on how it all looked just easy - after New Horizons had phoned home!

At this point in the presentation there was a switch to considering what was titled The Interstellar Probe (although, keep calm, recall that this title describes a probe to go to the nearest ISM not Alpha Centauri). It illustrates a series of potential instrument payloads, resources and different science goals for such a potential probe.

Consideration was then given to physical limits starting with the distance achievable and minimising transit times by maximising speeds. It is clear that there is significant history in this field by looking at previous missions that might be considered prototypes, e.g. Pioneer 10 and New Horizons. Whichever choice you might make for Interstellar Probe, whether ballistic or assisted, a key factor is the initial kick, the launch energy that can be given to your space probe.

A notional model of an Interstellar Probe shows a high gain antenna for communications, radio isotope power supplies for electrical power, a boom for magnetometer and antennas clearly demonstrating earlier heritage. Nevertheless earlier proposed missions that never got off the drawing board had considered Nuclear Electric Propulsion such as the Thousand Astronomical Unit (TAU) mission by Nock in 1987 which would have been an order of magnitude bigger in mass. Other alternatives suggested a return back to smaller designs such as the NASA Interstellar Probe Science and Technology Definition Team which stood up in 1999 and suggested a solar sail for propulsion including a near Sun encounter. This option suggested 200 AU would be achievable in 15 years with a payload requirement similar to that of Pioneer 10. These and other alternative in-space propulsion approaches continue to need significant development.

With the development proposed for the Space Launch System (SLS), which falls back into the more traditional approach, the Block 1B version could be enabling. With increasing difficulty coupled to increasing performance, four notional approaches were considered:

1) High energy launch (known as high C3 launch)
2) Add Jupiter gravity assist
3) Add powered Jupiter gravity assist
4) Use a Jupiter (and other gravity assists) to enable an Oberth manoeuvre close to the Sun

These potential approaches were turned into a one reference mission with goals (for a spacecraft that would fit on an SLS Block 1B launch):

1) Reaching approximately 200 AU in approximately 20 years from launch
2) Travelling at high solar system escape velocity approximately 13 AU/year. Further than 500 AU in 50 years (option 4 above). (Compare to Voyager 1 at approximately 3.5 AU/year and New Horizons at approximately 2.5 AU/year.)
3) Survivability: design for 20 years; good to last for 50 years
4) Cost approximately $1 billion or less excluding launch vehicle and phase E cost

The remainder of the presentation was given over to a Mission Design overview and an investigation of the various options to achieve the mission. Although solar sails and nuclear electric propulsion offered advantages, the required developments to achieve these technologies remained problematic. Whereas using the SLS option with a single solid rocket motor 'perihelion kick stage' and another bi-propellant 'deep space manoeuvre' for extra Delta V prior to the perihelion burn would permit a lower launch energy for a reasonable probe mass. Although there were still some issues, this particular design only required limited technological development in various enabling technologies (thermal protection, instruments and power for example).

Some of these developments would prove to be enablers for many other architectures such as high energy stage affordable launch vehicles, with low specific mass power supply, reliable and sensitive deep space communications and other mission operations and data analysis performance.

Nevertheless, in comparing the options it would still be challenging to meet the initial goal of 15 years to 200 AU with these notional versions of the SLS. But within the achievable science our heliosphere is still the key to 'The Bigger Picture' of the Sun and Earth's place in the universe.

In the presentation it is clear that the Interstellar Probe is a high scientific priority which can be achieved. 2026 is a technically implementable launch date. As a finale there is a confident comment, *"We can do this; it is just a question of how and when."*

It is clear that much effort has been put into this work and study similar to the efforts that were expended in the 70s, 80s, and 90s to give us the Pioneers, Voyagers and New Horizons. The input from many others is recognised by Dr McNutt although there were too many to mention.

In presenting 'Pluto and Beyond: Next Steps to the Stars after Voyagers and New Horizons' Dr Ralph McNutt kindly inspired and enthused a new generation of students, professionals and enthusiasts alike at the Starship Congress Interstellar Hackathon.

I4is would like to thank him for his contribution and also Icarus Interstellar and Drexel University for creating the opportunity.

About the author: Rob Swinney is Deputy Director of i4is.

About the presenter: Dr Ralph L McNutt Jr, is the chief scientist in the Space Department at the Johns Hopkins University Applied Physics Laboratory, which he joined in 1992. In addition to other major roles Dr McNutt is a co-investigator on NASA's New Horizons mission. He has been involved in a range of space physics research projects and mission studies, including studies of the interstellar probe missions for the future.

Surviving the Interstellar Hackathon in the City of Brotherly Love

Kenneth I Roy, PE

Not only did I survive the "Icarus Hackathon" (more properly called, the Icarus Starship Congress of 2015) held on 4-5 September 2015 ("Labor Day" holiday weekend in the USA) on the Drexel University campus in Philadelphia, I actually had a good time.

The event hotel was 4-5 blocks from the event auditorium but the weather was nice so that wasn't a problem. The organizers held a reception the evening before in a small conference room on the Drexel Campus (it was hard to find!). They had several trays of sandwiches and a few bottles of Coke. There were about 20 people there and about half of them were Drexel students. Icarus has a chapter on the university, thus the connection. I met some interesting people and enjoyed the conversations and I got enough food to call it dinner.

On Friday, 4 September, the Congress formally convened. It was somewhat disorganized with about 50 people in attendance, 10 to 15 of them being students. Coffee was from Starbucks in those little coffee containers. The event was held in a large lecture hall with fixed seating and small tables. No food was provided so lunch was "on your own" but the university had a lot of food trucks and nice restaurants around.

Dr Rachel Armstrong gave a good talk on Prototyping Starships. Rachel is a dynamic and fun speaker. John Bucknell gave a nice talk on Nuclear Thermo Turbo Rockets that offers a 20% payload fraction to LEO with a 1000-MW(t) reactor. If the reactor power goes up to 5000-MW(t), the mass fraction goes up to 35%. The concept looks interesting but may have a few problems with contamination in the atmosphere. John is a good speaker.

About 3:00 pm, the event moved upstairs to a large room with many round tables. That was the "Hackathon" part. A number of topics were proposed and several people proposed additional topics, one per table. Folks were allowed to self-select which table they wanted to go to. They were allowed to continue as long as they liked but most (or all) broke up before 7:00 pm. It was actually fun. I chose a table whose topic was "why do we want to go into space and why do we want to go interstellar?" This table included four students, a couple of older folks and one active-duty US Air Force major general. The people who go to these things are fairly passionate about the subject and the resulting conversation was good. The group from our table plans to write this up and submit somewhere. I'm not sure what the other groups were doing or plan to do.

The "why do we want to go" group, Ken is on the left at the back

I met a lot of interesting people and had a number of stimulating conversations. The mix of attendees varied from college students to senior retired engineers and scientists. The event was small enough that it was possible to talk to just about everybody. Finding dinner companions was easy and many people I talked to seemed delighted to have a chance to share their ideas with other folks who shared a common interest. I don't know that anybody was there because their company paid for the conference. Everybody I talked to was there on their own dime because they wanted to be there. Several students, a few professionals, and one writer from the west coast had flown out to this event.

The second day was much like the first with some disorganization and late coffee, some good papers, many not so good, a few not given and a 3:00 Hackathon that actually started at 4:00 but was still fun. There was no formal summation, closing ceremony, or send-off.

A couple of final comments - Mike Mongo did an amazing job with the Kickstarter program and pulled in lots of money and attention. There were a number of good papers, several less so, and several that were advertised but not delivered - without explanation.

That evening I found a great BBQ place (of course) and went out with a lot of the event people and had a great time. I enjoyed myself immensely and hope to stay in contact with some interesting people. Our group continues to work via email after the event and everyone seems excited about it.

PS. By the way, flying is no fun anymore.

About the author: Ken Roy PE, is a professional engineer, the inventor of the Shell World and Dyson Dot concepts, and one of the founders and directors of the Tennessee Valley Interstellar Workshop, Inc and serves on the Board of TVIW. kiroy@tviw.us

What we did at **Eastercon**

John I Davies

The i4is team always enjoy meeting science fiction (SF) people, both enthusiasts and practitioners - and there is a powerful overlap between these two in the SF world. The imagination in SF gives our big brother, the British Interplanetary Society (BIS), its motto "from imagination to reality", most of us are readers of SF and a few of us have written some SF ourselves.

Last year we were at the massive Worldcon, Loncon3, which took over a large part of the Excel centre in London's Docklands. This Easter we were at the more modest annual UK national convention the 2015 Eastercon, titled Dysprosium.

Again we were alongside BIS in the exhibits space. Sadly we didn't have the headroom for our 2001 monolith. Four metres is a "big ask" for a hotel lobby and we would have to have had it lurking at the back of one of the big presentations - so it remained in storage.

We gave two presentations; the first was by John Davies explaining the Tsiolkovsky rocket equation and how it is possible to use a simple spreadsheet to deliver the same result from Newton's Second Law (F=MA). John developed this as part of the i4is educational programme for UK schools. By avoiding using calculus we can reach almost all secondary school students. At the Eastercon, John extended this concept to help a largely adult audience gain a greater understanding of the requirements of rocket propulsion, both for themselves and for schools. This seems to have worked - given the tough questions received from the audience! Given the day and hour, 10 on a Sunday morning, the audience were strikingly numerous and very wide awake.

Kelvin points the way to the Sombrero Galaxy

The second was by i4is directors Kelvin F Long and Rob Swinney and gave a presentation on Reverse Imagineering some SF starships. Rob discussed requirements and some formal studies and Kelvin brought the ideas together, discussing specific SF starships, such as Clarke's Quantum Drive in '*Songs of Distant Earth*' and the Sail Ship in Niven's '*The Mote in God's Eye*'. A packed audience on the last evening of the Con and a great reception.

Thanks to Alistair Scott and Steve Salmon of BIS for their support alongside at the BIS table and to John's "other half", Lindsay Wakeman, for her help on our own table.

We'll be there for the annual Novacon in November 2015 in the UK city of Nottingham so if you are at the Con look out for our table and Kelvin's presentation.

Lindsay talks to Gerry Webb of BIS and CST (www.commercialspace.co.uk)

Sailing to unknown shores:
The i4is Project Dragonfly Competition

Dan Fries

Building spacecraft specifically to leave our solar system and reach out to other stars is a feat yet to be accomplished.

There are many ideas, some of which include the construction of massive generation ships carrying tens of thousands of human beings. Such endeavours would require unprecedented co-operation between individuals, organizations and nations as well as access to resources on a scale that seems almost absurd when looking at the pure numbers. Another approach is to use current advances in technologies aiming at minimizing the size of devices. While this is not suitable for a manned mission, it would enable robotic pre-cursor missions in interstellar exploration. Another issue from a human perspective is travel time. The star system closest to us is Alpha Centauri at 4.3 light years. Using conventional technologies like chemical or electrical propulsion, it would take more than a human lifetime to reach this destination. However, there is a concept derived from solar sails that would allow us to achieve velocities of several percent of the speed of light with near-term technologies; simply termed a laser sail. Project Dragonfly aims at combining miniaturized spacecraft with a laser sail

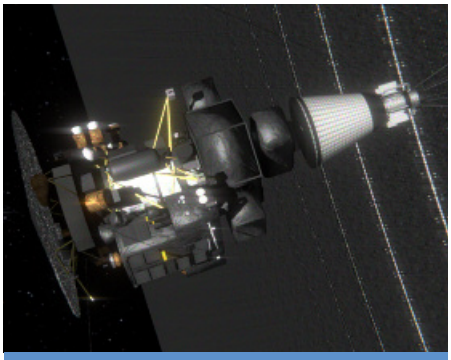


Figure 1: Dragonfly style probe with sail attached, as illustrated by Seth Prichard

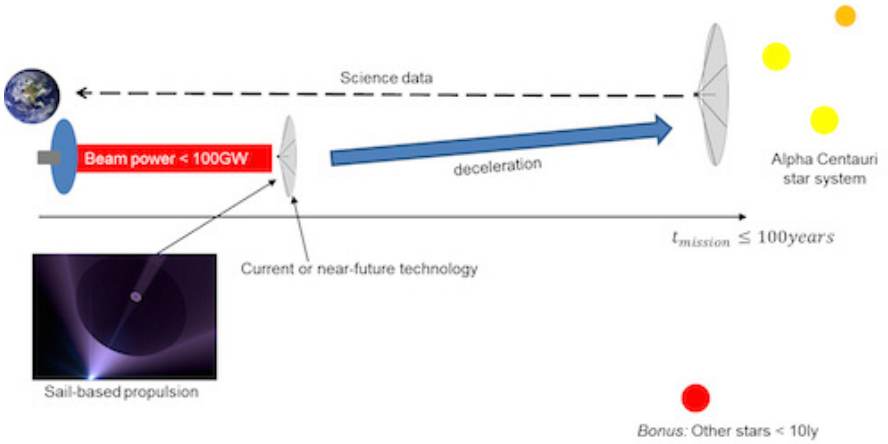


Figure 2: Graphical depiction of the Dragonfly design competition requirements

propulsion system to arrive at an interstellar probe concept realizable within the next few decades.

To collect ideas, develop a feasible technology roadmap and spread the idea of such spacecraft the i4is decided to organize a student design competition and in August 2014, international university teams were invited to participate in this competition. To prepare the student teams, they were given an initial set of specific problems, regarding interstellar exploration and laser sail spacecraft, to prepare them for the independent design of an entire mission and provide them with the framework of a proper systems engineering approach. The teams who were able to complete this initial task were then confronted with the mission requirements. These are depicted in Figure 2 in a graphical fashion and were given as –

1. Design an unmanned interstellar mission that is capable of delivering useful scientific data about the Alpha Centauri System, associated planetary bodies, solar environment and the ISM.
2. The spacecraft will use current or near-future technology.
3. The Alpha Centauri system shall be reached within a century of its launch.
4. The spacecraft propulsion for acceleration must be mainly light sail-based.
5. The mission shall maximise encounter time at the destination.
6. The laser beam power shall not exceed 100 gigawatts
7. The laser infrastructure shall be based on existing concepts for solar power satellites

The 100 GW beam power requirement constrains the design space considerably. For example, it constrains the mass of the spacecraft to tens of tons and is very challenging to generate, but not impossible. The 100 year time constraint sets a minimum average speed of 4.3% of the speed of light. Thus, the spacecraft mass, its sail parameters and the duration of acceleration/deceleration are left as variables. It was the teams' responsibility to navigate within the given design space and make meaningful decisions through trade-offs and careful analysis. Two intermediate deliverables ensured that we could keep track of the teams' progress and give feedback and assistance when needed. We hoped that the staged process would maximize the students' learning experience.

Moreover, it was our desire to increase public attention to the students' hard work, an interstellar exploration topic and reward the participating teams which lead to the organisation of a Kickstarter campaign, aimed at financing the student's travel expenses and bolstering the awards. After some initial research we

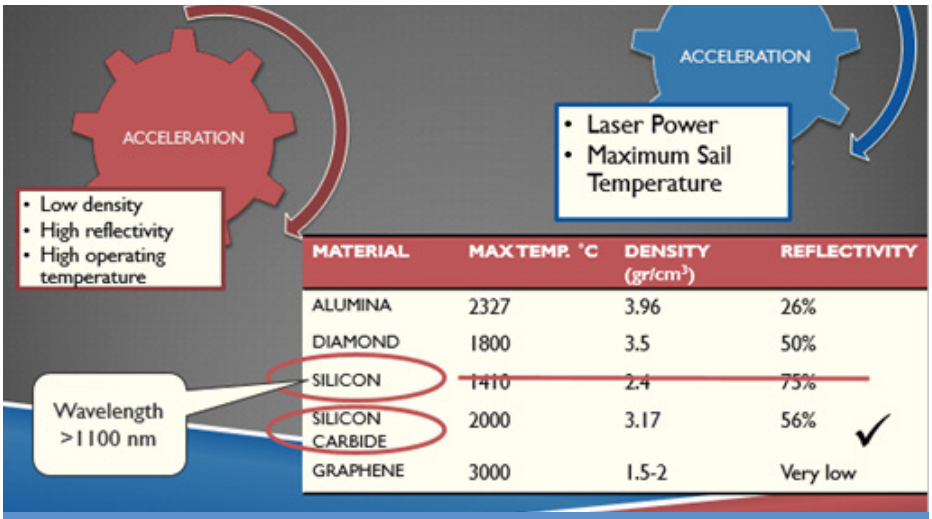


Figure 3: Technology trade-offs are a vital tool in determining optimal solutions for a certain problem. This particular one regards the laser sail material and was conducted by the CranSEDS team.

decided to go with a 30 day campaign and a funding goal of $10,000. Through the relentless efforts of the Dragonfly team and the entire i4is network we managed to exceed that goal, not only enabling us to support the student teams but also proving that i4is has the capabilities to obtain funding for their technology programmes from unconventional sources such as crowdfunding, allowing us to move forward more quickly.

Out of the initial six, four international teams were able to surmount all hurdles, submit a final design report and attend the Dragonfly workshop in London:

- Technical University of Munich
- University of Cairo
- University of California Santa Barbara
- CranSEDS, consisting of students of Cranfield University, UK, the Skolkovo Institute of Science and Technology, Russia, and the Université Paul Sabatier, France

The reports were reviewed by a panel of external and internal experts and on 3 July 2015 the teams were invited to present their design at the final workshop in London at the BIS headquarters. The main purpose of the workshop was to mimic a typical design review in the space sector. Thus, the teams had to give a presentation covering all vital aspects of their design and then answer questions from the audience and review panel.

Of course, the Dragonfly mission includes all typical challenges particular to space mission architectures. That is, restricted payload mass, reliable power supply, lifetime of the mission, communication and controls. However, due to the unique propulsion concept and mission goal, there were some twists. A 100 year lifetime, for example, is unusual in the space sector, especially without any direct maintenance. Moreover, velocities of a few percent of the speed of light lead to a new problem, even in interstellar space, and especially in dust clouds or within our solar system. This adds the risk of high velocity impacts with dust and even smaller particles leading to abrasion of the probe/sail material and eventual failure.

Once the probe arrives at the target star, how is it going to have enough time to make meaningful measurements flying at around 5% of the speed of light? Remember that requirement to maximise encounter time at the destination the probe must be decelerated. Conventional chemical or electrical propulsion systems would require huge amounts of extra mass and there is no experience with storing any type of fuel over such a long period of time. Commanding the probe is even less feasible than current long range probes like New Horizons at Pluto. The command loop delay at arrival is 8.6 years. Thus, command of the probe from Earth is completely impractical. And how is the probe going to find Earth and send a powerful enough signal in the right direction at this distance? In addition, there have been problems sustaining mission support over 10 or 20 years. What is the project management and financing for an endeavour like this going to look like? Are there innovative mission designs to make this more feasible? And the 100 Gigawatt laser that has to be stationed somewhere in the vicinity of Earth with a direct line of sight to the probe. The student teams faced all of these extremely difficult questions and many more in coming up with ideas to turn Project Dragonfly into a reality. This is Science Fiction made into reality by this new generation's bright and adventurous minds.

To give you a brief impression of the amount of thought and diligence that went into solving these problems, here are a few examples of what the teams came

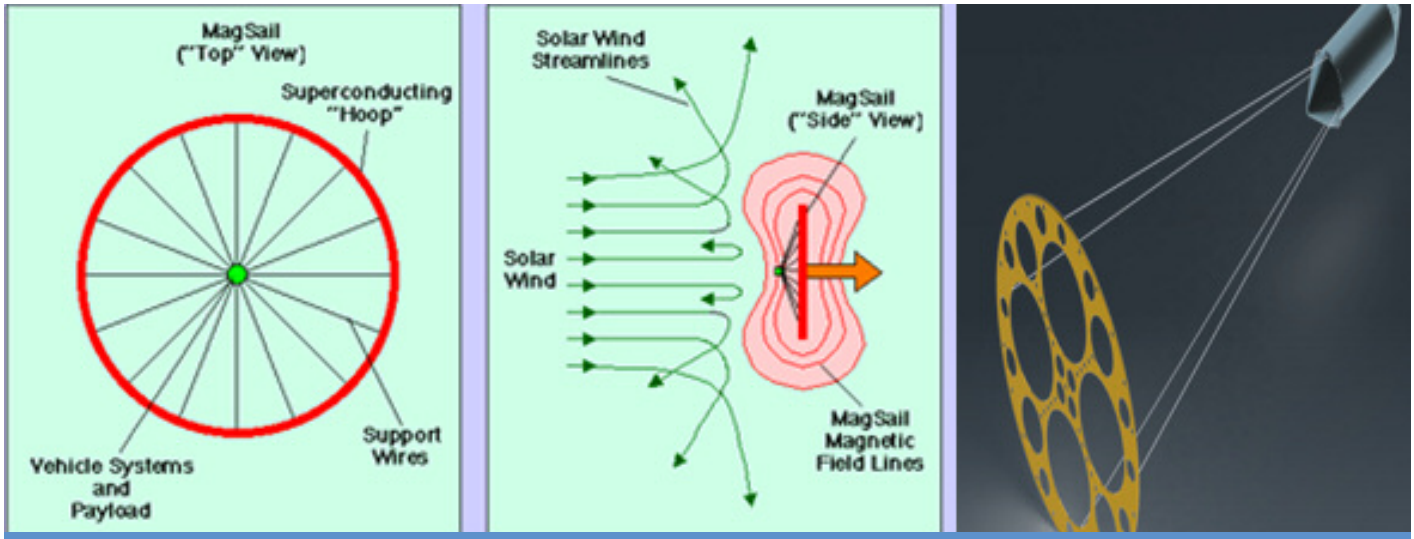


Figure 4: A Magsail as shown in the left two illustrations consists of a superconducting hoop through which a current is flowing. This current will induce a strong magnetic field which results in an opposing force when exposed to a stream of charged particles coming from, eg, a star ahead. On the right, a more sophisticated/optimized Magsail design by the Cairo University team is shown.

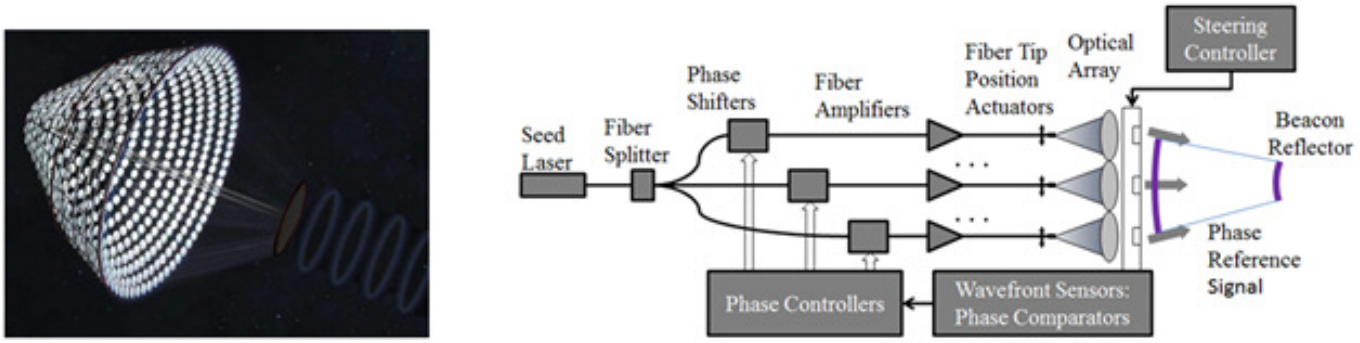


Figure 5: A spaced based solar power infrastructure as illustrated on the left could be used to power Gigawatt lasers in space as well as to supply Earth with energy. To achieve the required output the UCSB team envisage an array structure as on the right.

up with. The Technical University of Munich would accelerate their spacecraft up to a distance of 2.2 light years from Earth at a final velocity of 9% of the speed of light and place the laser infrastructure on the Moon to compensate for the reactive forces of the powerful laser beam (we have to remember here that photons carry momentum and thus a laser is subjected to Newton's third law). Deceleration is enabled by a staged magnetic/electric sail. A magnetic sail is very efficient at high velocities but gets increasingly inefficient at lower velocities. On the other hand an electric sail is capable of decelerating at lower velocities. Their overall spacecraft design is a monolithic approach, resulting in a 14 t spacecraft.

That a single, heavy spacecraft is not the only way was shown by the team from the University of California Santa Barbara. They designed a "wafer-based" design. The spacecraft is imprinted onto a chip with all spacecraft subsystems integrated into it which allows not only miniaturization but also the launch of several 100 or 1,000 small spacecraft to increase the chance that at least one of them succeeds. The sail would consist of a dielectric material with an extremely high reflectivity, in order to withstand the enormous power density of the Gigawatt laser. The latter is based on a "phased laser array" (DE-STAR)[15] concept also developed by the same student group, utilizing many lasers working parallel rather than a single gigantic laser.

The Cairo University Team developed a spacecraft that separates into two sub-probes upon arrival in the target star system. One probe will collect data from Proxima Centauri, the other data from the Alpha Centauri A and B system. Moreover, the team presented an innovative approach for attitude control during the acceleration phase by changing the shape of the sail.

The CranSEDS Team suggested an interesting way to reduce the overall cost and difficulty of keeping a 100 year space programme running: a total of three spacecraft are launched at 33 year intervals. Thus, each subsequent spacecraft acts as a communication relay station for its predecessors and technological advances that have occurred in the meantime can be exploited.

Results of the Competition

The review panel ranked the teams based on the reports, the presentations and the Q&A sessions. The final ranking thus became:

1. Technical University of Munich
2. CranSEDS
3. UCSB
4. Cairo University

All teams presented excellently researched and well thought out ideas, which was reflected in the small point-wise differences between the four places. The first prize, which went to the team of the Technical University of Munich, includes one of the Alpha Centauri Prizes which i4is awards to contributions advancing the field of interstellar travel. All of the teams are currently in the process of polishing the work they have done so far and aim to publish it at conferences and in scientific journals, increasing the return for themselves and the interstellar community.

Without a doubt, it can be said the Dragonfly project has already been a great learning experience for i4is, thanks to the student teams and every single supporter of the Kickstarter campaign who made this possible. Currently, the Dragonfly technology roadmap and strategic partnerships are being developed. We will keep you up to date. Together, we will go to the stars and expand humanities final frontier.

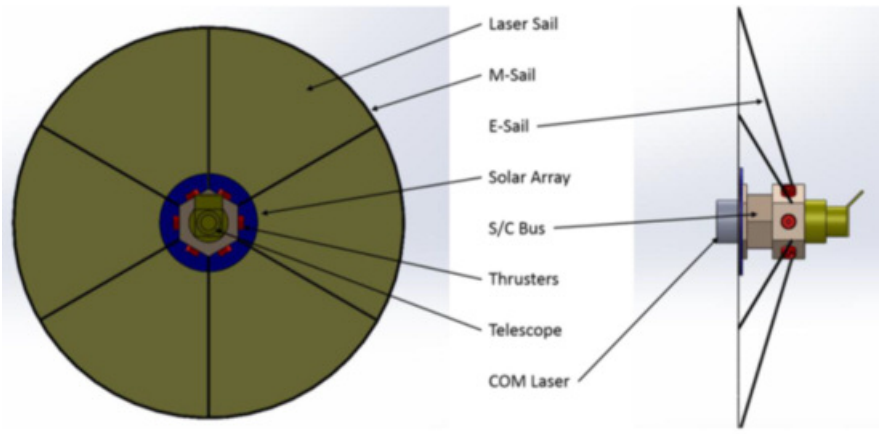


Figure 6: The laser sail spacecraft as imagined by the team from the Technical University of Munich

References:

http://www.centauri-dreams.org/?p=33615

About the author: Dan Fries is currently pursuing a PhD in Aerospace Engineering, dealing with supersonic combustion and turbulence, at the Georgia Institute of Technology. He is interested in advanced forms of propulsion, space utilization/exploration and systems engineering.

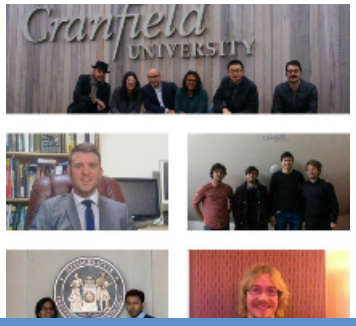
15. Lubin, P, Hughes, G B J, Bible, J, Johansson Hummelgård, I, *"Directed Energy for Planetary Defense and exploRation - Applications to Relativistic Propulsion and Interstellar Communications"* edited by Gerald Cleaver - Journal of the British Interplanetary Society (JBIS) (in press 2015)

Project Dragonfly – The road goes on….

A note on the way forward by Martin Langer.Although the success of our Kickstarter campaign and the workshop in London still amazes and inspires us, the time has come to move on and continue work on Dragonfly. The momentum, the spirit and the creativity is still high and the students involved are still pushing the limits. In the Starship Congress 2015 held 4-5 Sept 2015 at Drexel University, Lukas Schrenk of Team Munich presented their winning design of the laser sail propelled probe. Such presentations, combined with discussion and feedback is a crucial part for our ambitious mission, since we are constantly at the edge of technical feasibility. Therefore, as a planned phase of the student competition, the student teams are now summarizing and condensing their designs into papers with help from the Dragonfly Technical Committee. It is intended to submit these reports to peer reviewed journals or conferences later this year. The Kickstarter Campaign is still ongoing, since all the pledgers around the world (thank you by the way!) more than deserve their rewards in time and regular updates have to be maintained. Furthermore, a "lessons learned" document was created out of the campaign, which will help future projects within i4is.

Now, how do we continue the technological development of a project like Dragonfly? To tackle this question the technical committee created a preliminary technical roadmap, sorting out different technologies and goals, with respect to near-term and future feasibility. Even the near term options offer many opportunities to advance towards our long time goal of sending a laser propelled spacecraft to a nearby star. In our first trade-offs a “minimal ISM” appeared as the best candidate for a starting point. Many things need to done for such a mission – and a lot of research carried out. But there are pieces of the puzzle already out there: miniaturized technology available from space applications (ie CubeSats and SmallSats), research on high power laser systems and widely available commercial-of-the shelf electronic solutions for space; Rideshares into space are carried out on a regular basis and ongoing research on low-energy trajectories may offer opportunities for us to go out there, to reach the edge of our solar system. Right now we are just in the beginning - looking for partners to co-operate and experts to comment on our ideas. But we see the future rising and we feel there is a real chance to launch a minimum ISM in the upcoming decade.

The Cairo Team



The Cranseds Team

The UCSB Team

The TUM Team

About the author: Martin Langer is currently pursuing a PhD at the Institute of Astronautics at the Technical University of Munich (TUM). His research interests cover the reliability of Small Satellites and the influence of high energy radiation on satellite components. He is the current project manager of MOVE-II, a single unit CubeSat, due to be launched in 2017 and was also member of First-MOVE, the first satellite of TUM, launched in 2013.

Starship Congress at Drexel University

TVIW 2014:
i4is SF design workshop

A report from i4is's "D-for-Design" track at the Third Tennessee Valley Interstellar Workshop in Oak Ridge, Tennessee, on 09-12 November 2014.

Andreas Hein (L on dais) and Rob Swinney (R on dais) running the "D-for-Design" track at TVIW-2104.

When TVIW's Program Committee settled on an interdisciplinary suite of workshop tracks (see next article) covering interstellar communication, exploration, and travel, these tracks were: "A-for-Aero/Astro" to identify opportunities in the physical sciences, "B-for-Bio" in the life sciences, "C-for-Commo" in the social sciences, while "D-for-Design" as a pure engineering romp, we knew just who to ask to run that last one.

We were aware of i4is's plans to launch The Journal of Spacecraft Archaeology. "Spacecraft archaeology" means reverse-engineering the conceptual starships imagined by classic science fiction authors into as-credible-as-possible pre-concept design solutions, using known physics and engineering. (This process had previously been demonstrated by reverse-engineering the Enzmann Starship, which was published in JBIS: "The Enzmann Starship: History and Engineering Appraisal", JBIS, 65, pp 185-199, 2012, A Crowl, K F Long, R Obousy.) So, after the participants in the "D" track were briefed by Rob Swinney and Andreas Hein on certain classic ships of science fiction, building on prior reading, they were split into small teams (one per ship) and tasked to work out the physics and an engineering description of their operation. A half-dozen examples were considered (list was compiled by Kelvin Long):

- Laser sail system in Larry Niven's 'The Mote in Gods Eye'.
- Bussard ramjet from Poul Anderson's 'Tau Zero'.
- Archeron nuclear-electric drive from Clarke's 'Earthlight'.
- Sunjammer Solar photon sail from Clarke's 'The Wind from the Sun'.
- Antimatter drive from Ben Bova' 'Queen of Angels'.
- Rama from Clarke's 'Rendezvous with Rama'.

Participants also had to come up with the mission profile, a performance table with focus on the propulsion, vehicle configuration and layout, and a sketch if they had time. The philosophy was to remain as close to the intention of the author's ideas as possible. When the fictional elements clearly conflicted with reality or at least plausibility, then the participants had to make a design decision. Summary results of this friendly design competition were then reported out to the full audience at TVIW.

It is clear that this process can be repeated and many Starship ideas from the Science Fiction literature could be bought to life. "From imagination to reality", indeed.

People from Icarus Interstellar who were at TVIW-2014: L to R: Andy Presby, Lucas Schrenk, Michel Lamontagne, Jim Benford, Rob Swinney, Andreas Hein, Robert Freeland, Buck Field

About the author: Robert Kennedy PE is a Senior Systems Engineer VI who does green energy (mostly solar and geothermal) at what he laughingly calls his "day job". He is the co-author (with Ken Roy) of many papers about "Dyson Dots" and "Shell Worlds", and is also one of the co-founders of the Tennessee Valley Interstellar Workshop and a director of i4is.

Field report from TVIW 2014

The ancient Greeks defined "symposium" as a "drinking party" during which events were celebrated, literary and philosophical works recited, or ideas discussed.

The Roman equivalent was convivium. As quite a few members of i4is who have enjoyed TVIW's "Southern hospitality" already know, our symposia have elements of both: they are certainly convivial, and they do involve some drinking. (Search, for example, the text string "Alpha Centauri Sunrise".) We believe monkey sociability is essential for quality collaboration, so the Sunday Night Reception has become one of the hallmarks of the TVIW. The third symposium which returned to its roots in Oak Ridge, Tennessee, on 09-12 November 2014 was no different. (Early on in the planning, we delayed the opening from the first week of November to the second, in order to synchronize TVIW 2104 with the premiere of the movie Interstellar.)

As in 2011, the Reception took place in Barbara Jackson's and Robert Kennedy's living room. It was co-sponsored by Toni Weisskopf's Baen Books (www.baen.com) and Robert's Russian-American trading company, Ultimax Group Inc (www.ultimax.com). The date is historically noteworthy, for it was 25 years almost on the dot after the Fall of the Wall at 2245 Central European Time (1645 Eastern) on 09 November 1989. It was also in Robert's living room that all the authors of "Dyson Dots" (see JBIS, vol.66, no 10-11, Oct-Nov 2013) finally got to meet J T Early who first came up with the idea of sunshades at L1, also 25 years before, in the pages of JBIS? It is also interesting that Dr Early retired just over the mountains in Kitty Hawk, North Carolina, where powered flight was first demonstrated by the Wright Brothers in 1903. Present as well was Dr Michael Minovitch, the American mathematician and the discoverer of the first numerical solution (aka "gravity-assist trajectory") to the famous unsolved Three-Body Problem in celestial mechanics, the discovery that made possible all of NASA's high energy deep-space multiplanetary missions, such as the Voyagers and the Pioneers. Over 70 other scientists, engineers, space enthusiasts, artists, writers, editors, publishers, and academics gathered for this symposium, which was again held in the Double Tree Hotel in Oak Ridge as it was in 2011. Mostly they came from the American Southeast, in keeping with the Workshop's name, but there was talent from the private-, public-, and military-sectors from as far away as Germany, the United Kingdom, and California. One thing all these participants had in common was thirst, because a number of them had spent all day in two paid Seminars put on by the Workshop, on Terraforming and Space Propulsion respectively. (Despite the fine traditions we are creating, we also innovate. This year the paid Seminars were one such. What we now call "Working Tracks" was another, a fuller expression by Eric Hughes of the Hackers-Conference-inspired "Birds of a Feather sessions" from TVIW 2013.)

Dr. Sara Seager, MIT "The Search for Earth 2.0"

It has been observed by many that *"one thing you don't get a lot of at TVIW and that's free time"*. It's true. We try to design a reasonable schedule every year, and every year we fail. Sigh.

The basic two-day program consisted of a single-track of 19 plenary sessions, all of which were taped by our president and talented videographer John Preston: (https://www.tviw.us/tviw-2014-videos). On Monday morning, we kicked off with an inspiring keynote lecture by Dr Sara Seager of MIT on "The Search for Earth 2.0".

Interleaved with that were four parallel workshop tracks that provided "quality time" for participants to dive into systems engineering for world ships, life sciences, SETI & communications, and design concepts for interstellar travel. Why does TVIW have these funny "workshop tracks"? Because TVIW serves as both a colloquium to present papers of interest to colleagues, and as a workshop to get things done. Interstellar is no small subject we are dealing with; so what can we practically contribute? People say creativity can't be forced, but the conditions to foster creativity certainly can be—so our explicit intention was to engineer the conditions to nurture those things that need doing and promote progress in our field. In regard to interstellar studies in general and SETI in particular, there have been three truly seminal conferences in history, all of them highly interdisciplinary: the 1961 meeting at Green Bank organized by Frank Drake himself, the 1971 "CETI" conference at Byurakan Observatory in old Soviet Armenia jointly organized by the American and Soviet Academies of Science, and 1983's "Interstellar Migration" workshop at Los Alamos. The latter two generated quite remarkable proceedings, one edited by Carl Sagan (Communication with Extraterrestrial Intelligence, 1973), the other by Finney & Jones (Interstellar Migration and the Human Experience, 1985). One salient quote from decades ago has been inspirational to us at the TVIW: *"the form of the discussions was… an initial presentation of a subtopic by a discussion leader and then an*


The pioneering generation was there to inspire the new generations. Left, Michael Minovitch, the discoverer of gravity-assist trajectories. Right, Santosha Havercamp, child of one of this TVIW 2014's essay winners, Noah Havercamp.

Participants and organizers of TVIW 2014

often lively and vigorous range of comments, criticism, and free association" (Sagan, 1973). This gave us the rationale for our workshop-track approach to interstellar communication, exploration, and travel. "A-for-Aero/Astro" was to identify opportunities in the physical sciences, "B-for-Bio" in the life sciences, "C-for-Commo" in the social sciences, while "D-for-Design" was just a pure engineering romp (see Robert's report above in this issue).

A buffet dinner, provided by one of our sponsors, Digital Oilfield Solutions, was held on Monday night around the pool of the Doubletree Hotel. After another day of plenaries and parallel tracks on Tuesday, the respective leaders from each of the four tracks enthusiastically reported out their results to a rather boisterous audience. Track A's 4-by-8-foot illustration panel had so many colored strings on it that Andy Presby quipped, "one more thread and that thing will achieve sentience". (Track A became a story on the Baen website, Track B's and Track C's intellectual products ended up getting published by JBIS, and Track D—which was Kelvin Long's brainchild to begin with—will be a whole day workshop by itself put on by BIS this coming November.) The formal program wrapped up with a bang: a talk by Les Johnson describing his proposed small solar sail mission that could slingshot around the Sun and be flung out of the Solar System entirely, getting to 94 AU out in just a few years. This is a completely credible concept to Go Interstellar with modest funds in short order. Though exhausted by this point, this reporter/organizer can only describe the mood at this point as joyous. (We may add "ending with a bang" as yet another signature event of the TVIW.)

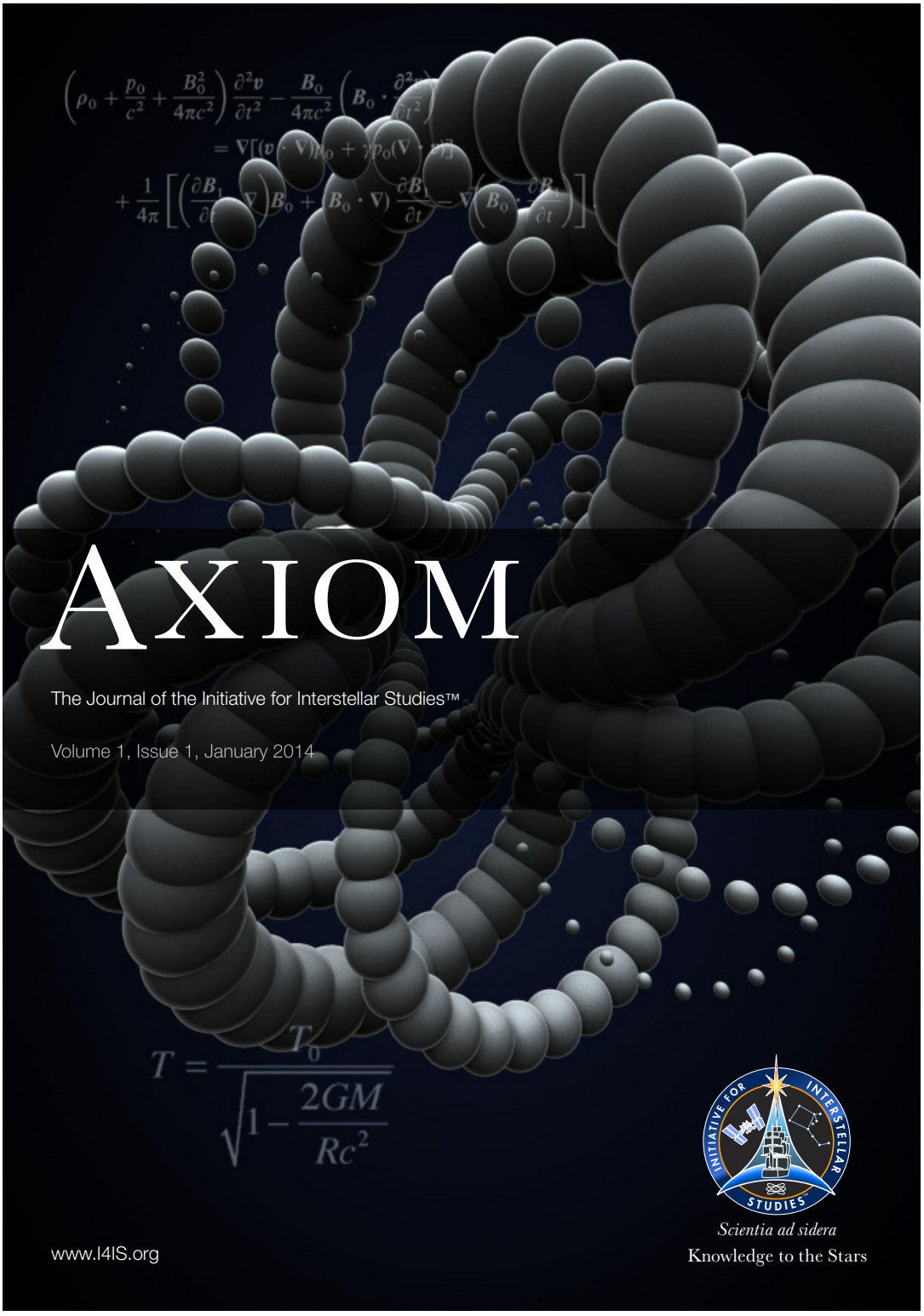
Formal programming concluded Tuesday night with a panel of science fiction writers giving a discussion for our Public Outreach (another signature event), in conjunction with a space/science book sale (including tomes penned by some of our participants) orchestrated by one of our sponsors, Barnes & Noble. That night, our fellow participant Jim Beall got his very first commercial writing gig with Baen Books at TVIW-2014 (as well as a first-time JBIS contributor!), as a direct result of being there. Jim had written detailed notes during Track "A", but then took them in a completely unexpected direction. While discussing the potential of this approach with Les Johnson at the close of the Tuesday Night Public Outreach Event, Toni Weisskopf leaned around the microphone and hired Jim on the spot. This is what she published: www.baen.com/our_worldship_broke.asp .

We began Wednesday with what has become yet another hallmark of the TVIW, the Big Techno Tour. This year, we were conducted all over the Oak Ridge National Laboratory (www.youtube.com/watch?v=hZUE030yMVk), including the Manhattan-Project-era Graphite Reactor and its 1940s control room (old Big Science), the Spallation Neutron Source (multi-billion-dollar new Big Science), and the Supercomputing facility, wherein supernovae are modelled, among other things. The Public Relations Committee felt validated when the tour guide came down the front stairs of the SNS and said, *"Are you from that meeting we've been hearing about on national public radio?"*

Wednesday afternoon followed with a group viewing of the film "*Interstellar*". The mood after this stunning film can best be described as cathartic. Afterward, we closed the TVIW at what's called "the Dead Dog Session" (not a "session" at all) in the "Consuite" (another thing we've borrowed from local science-fiction-conventions), at which those hardy souls who had survived so far consumed all the remaining beverages and victuals. Then we toddled off to do major face plants, because this is why TVIW is a sesquiennial affair: more frequent than that would kill the volunteers.

Remember the admissions process for TVIW-2016 has now opened: https://www.tviw.us/event/tviw-2016/participate. Don't forget to keep checking our website: www.tviw.us for news, and hope to see all y'all in Chattanooga in 2016.

About the author: Robert Kennedy PE is a Senior Systems Engineer VI who does green energy (mostly solar and geothermal) at what he laughingly calls his "day job". He is the co-author (with Ken Roy) of many papers about "Dyson Dots" and "Shell Worlds", and is also one of the co-founders of the Tennessee Valley Interstellar Workshop and a director of i4is.



Axiom is a print journal, obtainable via -

http://www.lulu.com/shop/kelvin-long/axiom1/paperback/product-22353814.html

All profits raised go directly towards the activities of our organisation. The first issue contains three papers -

- The 'Invention' of the Starship and Revisiting Tsiolkovsky
  - Kelvin F. Long
- Two-Stage vs. Single-Stage:
  A Performance Comparison
  - Adam Crowl
- Exponential Growth for Another Thousand Years
  - Stephen Ashworth

Film Review: The Martian

After the distant thrills of "Interstellar" we review a film with its feet very much on the ground. In this case the intrinsically hostile but in the end, surprisingly benign surface of the only planet which some of us may reach within the lifetime of your, admittedly elderly, reviewer.

Director: Ridley Scott

Script: Drew Goddard, based on the novel by Andy Weir

Running time: 141 minutes

Starring: Matt Damon (stranded astronaut Watney), Jessica Chastain (commander astronaut Lewis), Kristen Wiig (NASA PR Montrose), Jeff Daniels (NASA Director Sanders), Michael Peña (pilot astronaut Martinez), Kate Mara (SysAdmin astronaut Johanssen), Sean Bean (Flight Director Henderson), Sebastian Stan (Medic astronaut Beck), Aksel Hennie (German chemist astronaut Vogel), Chiwetel Ejiofor (Mission Director Kapoor)

The premise

Matt Damon, as engineer and botanist astronaut Mark Watney, is stranded on Mars. How can he survive? Can he get back? But this is no "Robinsonade". This is an adventure displaying the Right Stuff, as exemplified by Yeager, Glenn (and the rest of the Mercury Seven), Armstrong - oh, and an obscure fellow named Gagarin.

Alternatively, this is the fairy tale story of how an unpublished author, using technology invented very recently, self-published his carefully researched tale and got Hollywood (and perhaps its greatest SF director) to make it into the film released this year.

Is it right?

I'm not going to attempt to evaluate the plausibility of the story from the astronautical engineering point of view. I'm not an astronautical engineer any more, the issues aren't in the area I used to know and the web will be alive with opinions, well-founded to wonky, for months, if not years to come. Several of my i4is colleagues will have their much more authoritative opinions too!

But let's get that storm on Mars out of the way. Mars does have storms with high wind-speeds and lots of dust flying around but the atmospheric pressure is so low that the chance of the ascent vehicle being blown over is essentially zero (and the dust storms are talcum powder!). This is a plot hole in the book and its author freely admits that he needed a dramatic way to strand his astronaut on Mars and bent the facts to achieve this. So we suspend our engineering judgement if we like the story - which I do!

The cast

More good news, the casting is near perfect. Damon can play the everyman adventurer better than any current star (just look at the Bourne films). Jessica Chastain can play just about anyone and is just right for a mid-21st century mission commander. Chiwetel Ejiofor is another actor who can play virtually any part and does just the right combination of gung ho and gravitas I imagine for a mission director. Again, my more knowledgeable colleagues may correct me here but it works for the story. The lesser parts are all top professionals playing professionals in the space business very well. I'll come to a couple of quibbles later.

Does it work?

The overall tone of the film is almost light-hearted despite the perils. This works because the bantering style is how humans can handle persistent peril without losing sanity - and the 12A certificate widens the audience. Watney's survival on potatoes grown using his own

(and his crewmates) excrement is both plausible and bizarre. The light and shade of tension and humour have carried over very successfully from book to film.

There are moments however, particularly for the central character, where deeper despair would have been more realistic. The skin-of-the-teeth solutions he had to come up with were often glossed over - a judgment about how scary you want to make it. And it's difficult to see how to show the scientific and technical detail without it becoming a physics and chemistry lesson (a possible problem with the book?).

Now some quibbles –

I mentioned the jokes. They are one of the best features of both book and film. They contrast lightness to peril and add humanity to technology. Sadly, one of the best in the book should perhaps have been left out of the film, given the casting. Mission Director Kapoor is asked, at a particularly tense moment, "Do you believe in God?" "Yes, lots of them, I'm a Hindu". Making the mission director an ethnic African with an Indian parent allows him to retain his name, Kapoor, and religious background but deflates the jokes. Asked "Do you believe in God?" he has to respond with an explanation of his mixed ancestry instead of that instant witty response.

In the last major action sequence, the crew on the Hermes carry out their EVA without so much as a safety line or a carabiner in sight. NASA apparently gave the film a lot of support but this looked like rashness bordering on "roller skating in a buffalo herd"!

And in the same sequence, would Watney really have climbed up to the Mars Ascent Vehicle nosecone and hung out there waving about like Tiny Clanger? I was almost expecting to hear a swanee whistle conversation.

OK, enough quibbles, but that last kids TV alien reminds me of some UK TV Martians who really did live on potatoes. Instant mash in this case. Have a look on YouTube for the Smash Martians!

See it!

It's the best space adventure since Gravity - and it looks a lot more plausible to me. But it is not Ridley Scott's best by some distance. You don't walk out of the cinema in a visual and emotional haze.

But will he ever surpass Blade Runner, Alien and Gladiator? And who else can do this better? Ridley Scott's second best is still better than most others greatest work.

It's a hymn to engineering, both planned and "seat-of the pants". The Hermes craft is a beautiful descendant of the Jupiter ship in 2001 and Watney is the engineer as hero in its best form since Apollo 13.

We now know there is running water occasionally on Mars, so maybe Andy Weir wouldn't need that too-strong wind to menace the ascent vehicle - a briny flood would do. Which is intriguing given the rumour that NASA may have held back the news about the running water until the film was released.

About the author: John I Davies is a Senior Researcher with i4is and editor of Principium. He is a retired software engineer and telecoms consultant. He started in the space business but was distracted by computer communications.

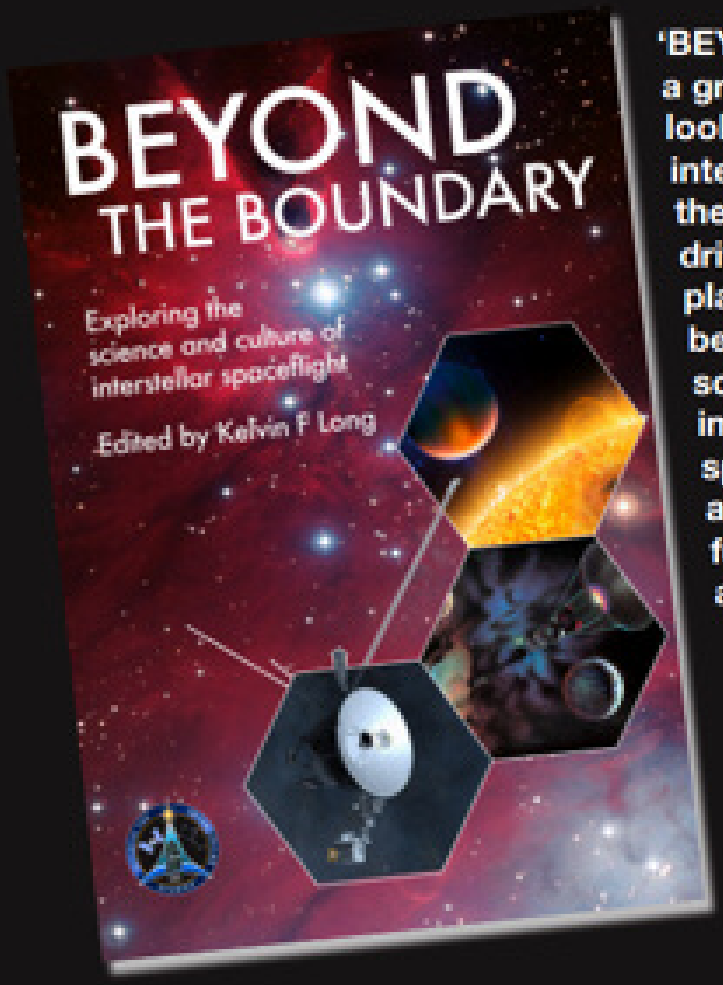
What's in Principium 12

In the next issue of Principium our Guest Introduction will be from our i4is colleague, Gillian Norman. Gill will give us her personal perspective on the why and the how of Interstellar Studies.

We will feature some musings from John Davies on "Transcendence going Interstellar", a recent Centauri Dreams paper by Andreas Hein, and we aim to give you an account of the other keynote from the recent Starship Congress, "Prototyping Starships" by Professor Rachel Armstrong.

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
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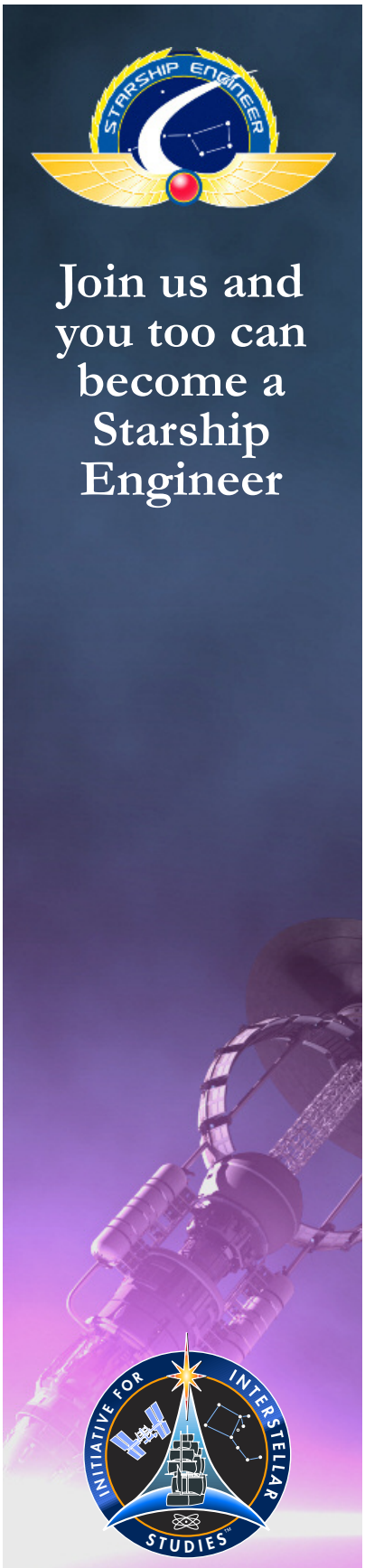

STARSHIP ENGINEER

The Initiative for Interstellar Studies (I4IS), in collaboration with the British Interplanetary Society, Tuesday 24th and Wednesday 25th November, 2015.

To be held in the conference room at the BIS HQ, London SW8 1SZ

This new and innovative educational product is being launched by the Initiative for Interstellar Studies (a not-for-profit organisation incorporated in the UK) in collaboration with the British Interplanetary Society (a registered Charity).

We aim to help raise the educational levels of participants so that they can use some of the tools to start assessing deep space exploration concepts and even designing interstellar vessels. Two one day courses have been arranged, and you can either attend one or both, each will be different and important in their own way.

Tuesday 24th November:

Starship Engineer

This course aims to give you a basic grounding in interstellar studies. We go from considering the essential requirements to giving you an overview of different spacecraft systems. We then take you on a journey through several actual starship design studies, and show you how to calculate and evolve an interstellar machine. We will give a broad set of examples from the literature, but focus on two specific case studies, that of fusion propulsion and laser-sail propulsion, as plausible ways by which we may someday reach the distant stars.

Wednesday 25th November:

Science Fiction Starships

The works of science fiction literature have produced many fascinating starship concepts, but how realistic are they? In this one day course we will examine texts such as laser-sails in "The Mote in God's Eye" (Larry Niven and Jerry Pournelle), Torch Ships in "Time for the Stars" (Robert Heinlein), Quantum Ramjets in "The Songs of Distant Earth" (Arthur C Clarke) and other inspirational examples of interstellar vessels. This course will teach you how to evaluate these ideas from the imagination and how to perform a physics and engineering assessment of their feasibility.

Education Requirements:

The courses are open to everyone and anyone is welcome to attend, but to participate in the design workshops it is recommended that you have some familiarity with basic mathematics and algebra.

Principal Lecturers:

Kelvin F. Long is a physicist and aerospace engineer, Chief Editor Journal of the British Interplanetary Society, author of the book "Deep Space Propulsion: A Roadmap to the Stars" and is the Executive Director i4is.

Rob Swinney is a former RAF Squadron Leader aerosystems engineer and is a Deputy Director of i4is. He, and Long, have both been involved in the creation and running of the only two modern starship design projects, Project Icarus (fusion) and Project Dragonfly (laser-sails).

Pricing:

Normal rate: £59 per day or £99 for the two days.

Discounted rate: £49 per day or £79 for the two days;
includes students and senior citizens. Lunch and coffee will be provided on the day for all attendees.

To join any of the events contact the booking team at: ***info@i4is.org*** or visit ***www.i4is.org*** for more details.

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: “Daedalus Staging”, art by Adrian Mann www.bisbos.com.

Back cover: The Globular Cluster Omega Centauri NGC 5139 - European Southern Observatory Credit: ESO www.eso.org/public/images/eso0844a/

www.I4IS.org

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

Editor: John I Davies
Deputy Editor : Kelvin F Long
Layout: Adrian Mann

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