News Feature: The 2020 ISU Masters Elective Module

Part 2 of 2

John I Davies

This year the i4is team again led an Elective Module on Interstellar Studies for students of the Master of Space Studies at the International Space University Strasbourg. Here we summarise the rest of the presentations by the i4is team which preceded them.

The current situation meant that this was all conducted online. We missed the personal element of being in Strasbourg with students and faculty at the ISU and we hope to be back in person next year.

The i4is Interstellar Studies Elective Module was run ‘virtually’ for the two weeks 27th April to 7th May. 23 students took part, we delivered 17 lectures and the four student teams each submitted a report.

The theme this year was Worldships and their implications.

The Lectures

This is a brief summary of the rest of the lectures which introduced the two-week elective. The presentations and videos are available in the member's area of the i4is website at - i4is.org/videos/isu-interstellar-studies-module/. The videos are at - i4is.org/videos/isu-interstellar-studies-module- and presentations are linked from the section headings - marked `IMPRESS`

Lecture	Reported
M8-ISR-L01 Introduction to Interstellar Studies Elective	Principium 30 (last issue)
M8-ISR-L02 Background to Interstellar Studies and Scaling the Problem	Principium 30 (last issue)
M8-ISR-L03 Introduction to Worldships	Principium 30 (last issue)
M8-ISR-L04 Introduction to Assignment	Principium 30 (last issue)
M8-ISR-L05 Precursor Missions	Principium 30 (last issue)
M8-ISR-L06 Destinations	Principium 30 (last issue)
M8-ISR-L07 Spacecraft Systems	Principium 30 (last issue)
M8-ISR-L08 Worldship Conceptual Design	Principium 30 (last issue)
M8-ISR-L09 Artificial Intelligence for Worldships	Principium 31 (this issue)
M8-ISR-L10 Worldships in Science Fiction	Principium 31 (this issue)
M8-ISR-L11 Advanced Propulsion Systems 1	Principium 31 (this issue)
M8-ISR-L12 Advanced Propulsion Systems 2	Principium 31 (this issue)
M8-ISR-L13 Artificial Intelligence on Worldship Missions	Principium 31 (this issue)
M8-ISR-L14 Worldship Population Dynamics	Principium 31 (this issue)
M8-ISR-L15 Interstellar Travel using Einstein Physics	Principium 31 (this issue)
M8-ISR-L16 Worldship Documentary	Principium 31 (this issue)
M8-ISR-L17 The Case for Interstellar	Principium 31 (this issue)

2.9 M8-ISR-L09 Artificial Intelligence for Worldships VIDEO IMPRESS

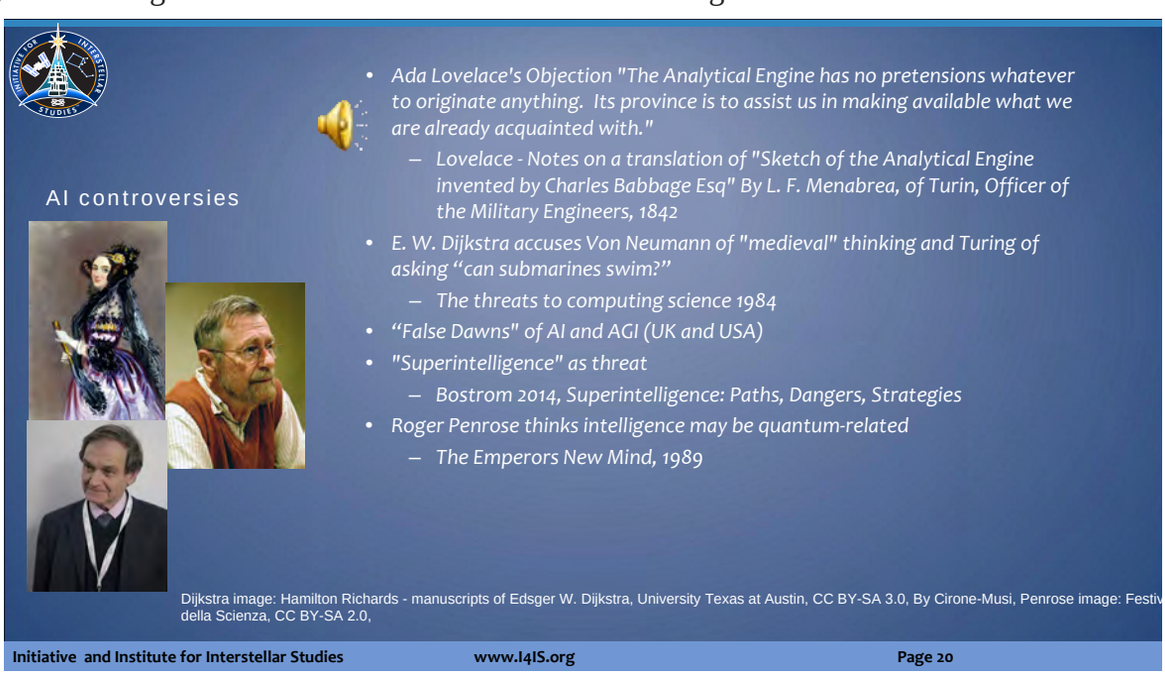
John Davies introduced the first of two presentations on AI applied to worldships. He began with a three minute video dramatisation by Holly Spence[1] raising questions which will arise if and when we create artificial intelligences sophisticated enough to be arguably human.

John asked why we should apply AI to interstellar and pointed to spacecraft become increasingly “intelligent" (however defined) and to the greater need for autonomy as spacecraft go further from humans. But given "good enough" AI, need humans go at all?

However if we want to send biological humans then unless FTL can be achieved then we will need worldships. He quoted from a 2016 paper by Andreas Hein "Given current levels of increase in computational power …a payload with a similar computational power as the human brain would have a mass of hundreds to dozens of tons in a 2050 –2060 timeframe" [2] but asked - What is Artificial General Intelligence (AGI)? Current AI is designed for specific purposes such as analysis of medical imaging, driving a car or playing games. AGI implies a capability for learning a variety of skills rather than for accomplishing particular tasks.

Views differ as to the need for AGI for interstellar missions. An early proponent Arthur C Clarke said "Creatures of flesh and blood such as ourselves can explore space and win control over infinitesimal fractions of it. But only creatures of metal and plastic can ever really conquer it, as indeed they have already started to do. The tiny brains of our Mariners and Pioneers barely hint at the mechanical intelligences that will one day be launched at the stars.“ [3]. An early sceptic was Ada Lovelace - "The Analytical Engine has no pretensions whatever to originate anything. Its province is to assist us in making available what we are already acquainted with." [4].

John cited a number of investigations by Andreas Hein, including a detailed study jointly with Stephen Baxter[5] and some wider sources on subjects including AI implications of Fermi’s Paradox, space colonisation and brain simulation. What sort of AGI is achievable? "Mind uploading" as in the film Transcendence (directed by Wally Pfister, 2014) has been much discussed (and much dismissed!). More plausibly an AGI might arise out of advances in machine learning.



[1] Based on Overture from the 2500s from the article - Sending ourselves to the stars? in Principium issue 12, February 2016 (video: i4is.org/videos/sending-ourselves-to-the-stars).

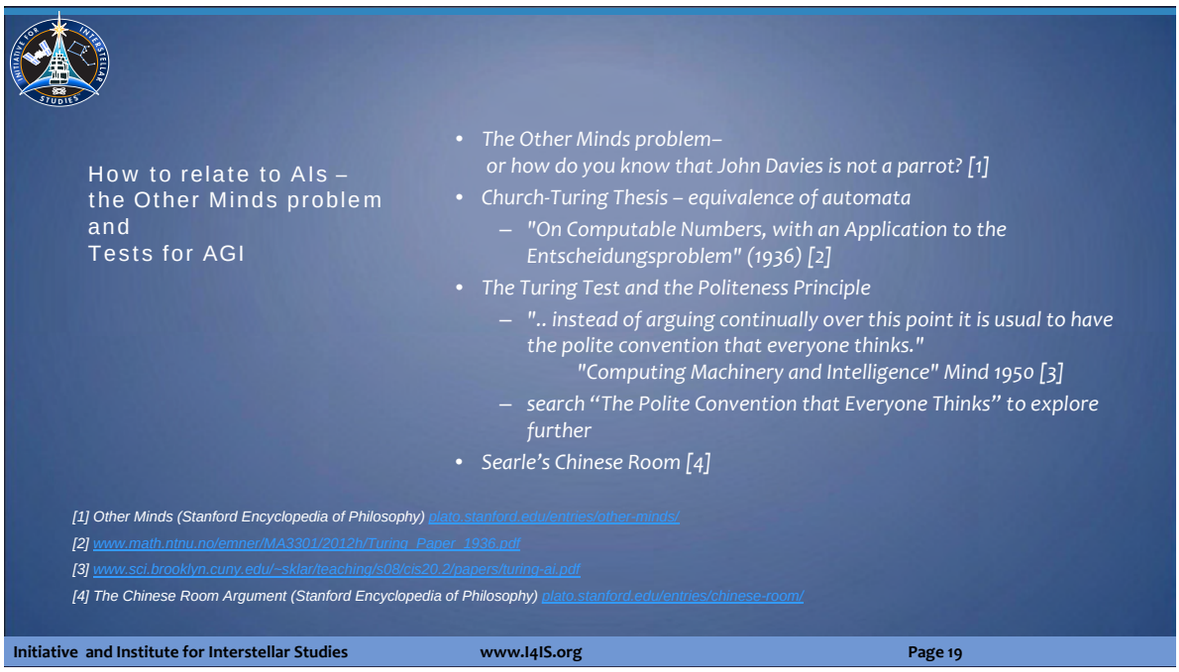
[2] Artificial Intelligence Probes for Interstellar Exploration and Colonization, arxiv.org/abs/1612.08733.

[3] In "The Obsolescence of Man" in the book "Profiles of the Future: An Inquiry into the Limits of the Possible", Gollancz, 1962.

[4] Notes on a translation of "Sketch of the Analytical Engine invented by Charles Babbage Esq" By L F Menabrea, of Turin, Officer of the Military Engineers, 1842 scan: repository.ou.edu/uuid/6235e086-c11a-56f6-b50d-1b1f5aaa3f5e text: pdfs.semanticscholar.org/b61b/9248dfd112b282e116c7bfaa21a681d2ecad.pdf.

[5] Artificial Intelligence for Interstellar Travel, Andreas M Hein & Stephen Baxter, JBIS v72 April 2019 arxiv.org/abs/1811.06526.

Whichever route is taken how are we to regard these apparent peers to biological humans? John introduced the long established philosophical issue, the Other Minds problem[1].



In any case Hein's conclusion in his 2016 paper cited above is that AGI will likely require very massive craft, not the chipsat-sized probes implied by early laser propulsion.

John next considered what worldship configurations might we expect and how AI and/or AGI could contribute to their mission. Citing a paper given by philosopher James Schwartz at TVIW 2017, Worldship Ethics 101: The Shipborn [2], we need to make life en route as desirable as possible, learning from successful and unsuccessful human settlements in the Solar System but he noted that we don't yet know the fate of liberal democratic governance beyond Earth (or even on Earth given recent history!). But might AI or AGI assist the worldship travellers with problems which happen too fast (eg projectiles can easily be dealt with but sabotage would be much harder), are too complicated (eg ethical dilemma such as a food shortage are much harder), too unknown (eg pathogens, political instability or loss of key skills) or pure Black Swan events (imagine your own!)

How can AI/AGI help with planning for worldships? Clearly we first need to simply "run the numbers" as in the Hein Acta Futura paper cited in 2.3 M8-ISR-L03 Introduction to Worldships and elsewhere in this report. Agent-based simulation is the classic way of dealing with these sorts of issues (eg building evacuation, traffic flow). AI via machine learning has already been used to investigate human behaviour and working with agent based models to attempt to solve social dilemmas like the El Farol Bar problem. Human "guinea pigs" have already been both proposed and used to simulate isolated communities and, in typical Ballardian fashion, fictionalised as unknowing guinea pigs in Ballard's "Thirteen to Centaurus" [3].

If AI and/or AGI are to have significant onboard responsibilities then the ethics and politics of their relationship with humans must be considered. How far will we have progressed with AI/AGI at the point of worldship launch? The degree of trust, responsibility and authority given to AI and/or AGI might vary enormously dependent on how far this has progressed by that point in time. John examined two broad scenarios, moderate and advanced AI/AGI and issues in administration, health, justice and vehicle control.

Finally John summarised and offered some speculations on the emergence of AGI "Superintelligence" and the possibility of AI proxies (eg "AI-Attenborough" brought to our sitting rooms).

[1] *Other Minds* in the Stanford Encyclopedia of Philosophy plato.stanford.edu/entries/other-minds/

[2] www.academia.edu/34432202/Worldship_Ethics_101_The_Shipborn see also Worldship Ethics Obligations to the Crew James S J Schwartz, JBIS V71 #2 February 2018, TVIW video Worldship Ethics 101: The Shipborn at - https://www.youtube.com/watch?v=dIpXINcQixE&feature=youtu.be

[3] Discussed in Thirteen to Centaurus by Paul Gilster www.centauri-dreams.org/2016/03/25/thirteen-to-centaurus

2.10 M8-ISR-L10 Worldships in Science Fiction IMPRESS

Simone Caroti of Full Sail University, Florida, introduced the history of the worldship in science fiction including story patterns, speculative content transferable to the discipline of interstellar studies and material for thought experiments applicable to academic studies.

Dr Simone suggests that we currently try to avoid Earth-bound ships becoming technologically, logistically or socially autonomous. We want them to remain nationals of their countries rather than "people of the ship". But this tendency will be hard to resist on worldships.

He identified early exponents of worldship thinking including rocket pioneers Robert Goddard ("The Last Migration," 1918) [1] and Konstantin Tsiolkovsky ("The Future of Earth and Mankind," 1928) - and J D Bernal (The World, the Flesh, and the Devil, 1929 [2]). Dr Simone identified five periods of SF and examined the treatment of worldships in each -

1. The Gernsback period (1920s-early 1940s)

Hugo Gernsback, publisher of Amazing Stories, who britannica.com describes as "largely responsible for the establishment of science fiction as an independent literary form".

worldship themes in the Gernsback period Credit: Caroti

2. The Campbell/Astounding period (1940s-1960s)

John W Campbell editor of Astounding Science Fiction and "responsible for setting a tone for science fiction that haunts this genre to this very day" according to the last winner of the annual award conferred by the same magazine (now called Analog Science Fiction and Fact) before its name was changed to reflect repudiation of his political views.

worldship themes in the Campbell period Credit: Caroti

The founder of modern interstellar studies, Leslie Shepherd (see 2.2 M8-ISR-L02 Background to Interstellar Studies above) commissioned art for his piece Interstellar Flight (JBIS, 1952). Simone commented that Shepherd's text is revealing of the biases of the time: propulsion systems, engineering, and logistics - but that the accompanying Frank R Paul artwork addresses the psychological, cultural and human elements.

worldship studies meets SF art
credit: Caroti / Frank R Paul

[1] Discussed in The Ultimate Migration, David Baker - www.bis-space.com/2012/03/23/4110/the-ultimate-migration

[2] The World, the Flesh & the Devil: An Enquiry into the Future of the Three Enemies of the Rational Soul www.quarkweb.com/foyle/WorldFleshDevil.pdf

3. The New Wave (1960s-late 1970s) the “inner space” era

Epitomised by New Worlds magazine under the editorship of Michael Moorcock.

Aldiss (1925-2017), Harrison (1925-2012) and Brunner (1934-1995) all imagined worldships - the first two having inhabitants who did not know they were on the ship!

three new wave era worldship novels Credit: Caroti

4. The Cyberpunk – or modern – period (1980s-1990s)

When the information age "washed over science fiction" [1].

Wolfe's novel series and a novel from the Cyberpunk era Credit: Caroti

Gene Wolfe took the dystopia of the Book of the New Sun series onto a worldship. Richard Paul Russo imagined another worldship with governance gone wrong.

5. The contemporary period (2001-today).

Simone suggests we now recast the narrative modes of the past into new shapes.

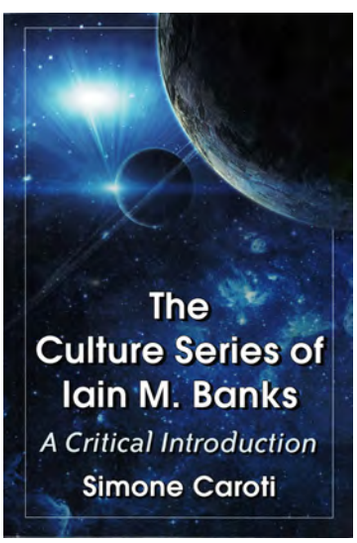
two novels and a collection of papers bring us almost up to date Credit: Caroti

Ken Macleod uses a worldship in a first contact story; Kim Stanley Robinson creates a worldship disaster story, though in this case the travellers knowing exactly what is going on!

Dr Simone wrapped up with some examples of worldships in other media.

- Original series Star Trek episode "For the World Is Hollow and I have Touched the Sky" [2]
- The Starlost was a single 1973 TV series [3]
- Metamorphosis Alpha (TSR) 1976 - a worldship-based role playing game
- Phoenix Without Ashes. IDW, 2011 is a graphic novel/comic by Harlan Ellison
- Pandorum 2009, a film by Christian Alvart, again most aboard no longer know they are on a worldship

Dr Simone Caroti is Course Director in Creative Writing at Full Sail University, Florida. He is the author of of *The Culture Series of Iain M Banks: A Critical Introduction* and of *The Generation Starship in Science Fiction: A Critical History, 1934-2001* - which we will be reviewing in the next issue of Principium. Dr Simone has degrees from Purdue University and the University of Trieste.



The Culture Series of Iain M Banks: A Critical Introduction, McFarland 2015.

In your reporter's opinion the finest introduction to Banks' seminal series yet published.

[1] Writer Bruce Sterling characterised cyberpunk as a "combination of low-life and high tech"

[2] Which has the Enterprise team rescuing another unknowing crew of a worldship

[3] Again the travellers on a worldship forget their situation. Despite the involvement of Douglas Trumbull, Ben Bova, Harlan Ellison and even Keir Dullea from *2001: A Space Odyssey,* the series flopped.

2.11 M8-ISR-L11 Advanced Propulsion Systems 1 VIDEO IMPRESS

Rob Swinney delivered the first of his two briefings on the core problem of interstellar travel : propulsion.

He covered of -

Advanced Propulsion 1:

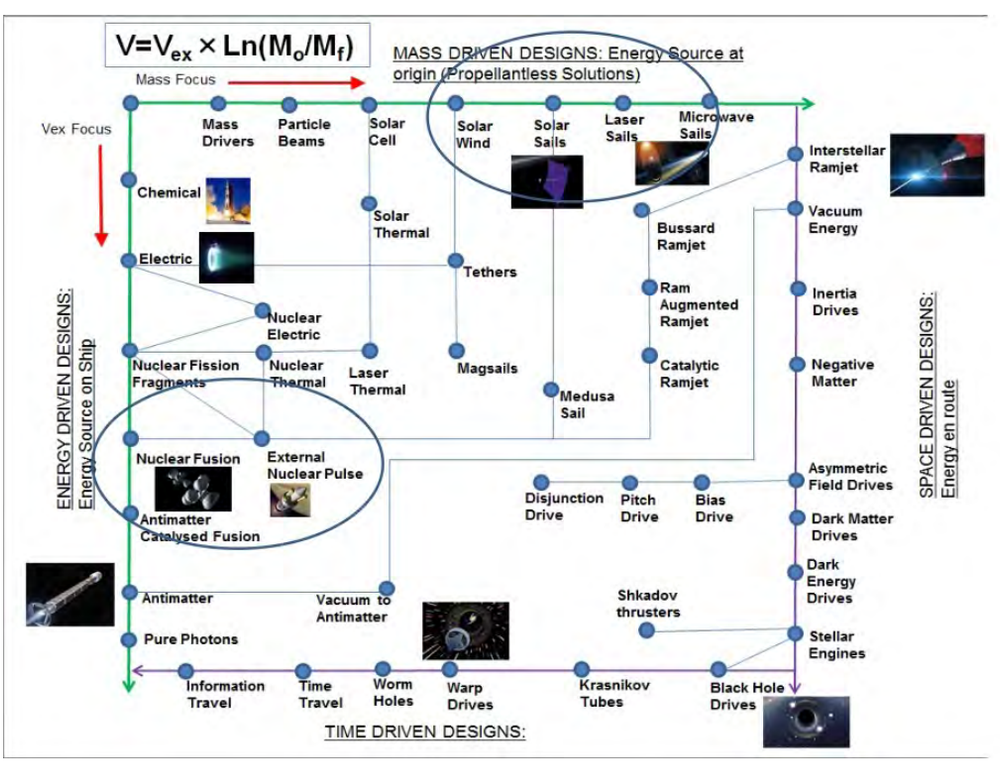
- Solar Sails
- Laser Sails

Advanced Propulsion 2:

- Nuclear Fission/Fusion
- Interstellar Ramjets
- Antimatter

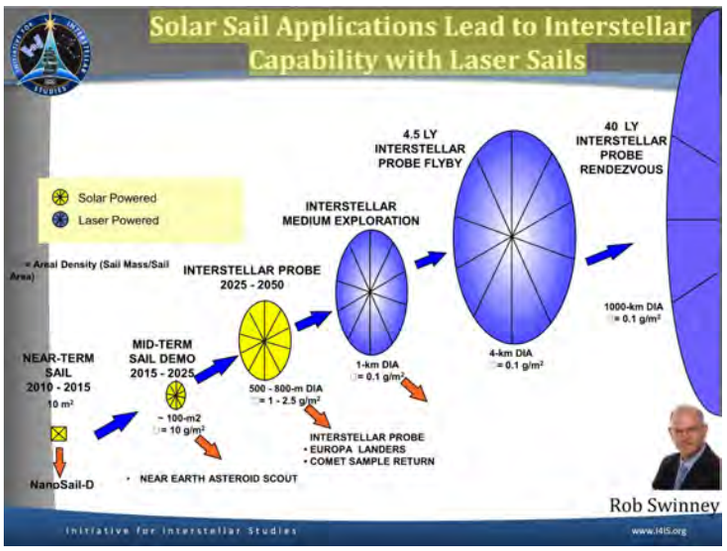
He recommended 18 texts from Les Shepherd's JBIS paper in 1952 to Kelvin Long's 2012 book Deep Space Propulsion: A Roadmap to Interstellar Flight and a taxonomy of propulsion solutions showing where his two lectures would concentrate.

- Matloff, G. L., ***Deep Space Probes, to the Outer Solar System and Beyond***, second edition, Springer Praxis, ISBN 3-540-24772-6, 2005.
- Mallove, E., and G. Matloff, ***The Starflight Handbook: A Pioneer's Guide to Interstellar Travel***, John Wiley & Sons Inc, 1989.
- Wright, J. L., ***Space Sailing***, Gordon & Breach Science Publishers, 1992 (2nd printing 1993).
- Long, K. F., ***Deep Space Propulsion: A Roadmap to Interstellar Flight***, Springer, 2012.
- Dyson, G., ***Project Orion: The Atomic Spaceship 1957-1965***, Allen Lane The Penguin Press, 2002.
- Kondo, Y., F. C. Bruhweiler, J. Moore and C. Sheffield (editors), *Interstellar Travel and Multi-Generation Space Ships*, Apogee Books, 2003.
- Gilster, P., ***Centauri Dreams: Imagining & Planning Interstellar Exploration***, Copernicus Books, 2004
- Millis, M. G., and E. W. Davis (editors), ***Frontiers of Propulsion Science***, Progress in Astronautics and Aeronautics, Volume 227, The American Institute of Aeronautics & Astronautics, ISBN 978-1-56347-956-4, 2009.
- Shepherd, L, *Interstellar Flight*, JBIS, 11, pp.149-167, 1952.
- Nock, K.T, **TAU – *A Mission to a Thousand Astronomical Units***, Presented at 19th AIAAIDGLR/JSASS International Electric Propulsion Conference, 1987.
- Forward, R.L, ***Starwisp: An Ultra-Light Interstellar Probe***, 22, 3, pp.345-350, May /June 1985.
- Landis, G.A, ***Beamed Energy propulsion for Practical Interstellar Flight***, JBIS, 52, pp.420-423, 1999.
- Bond, A et al., ***Project Daedalus: The Mission Profile***, Final Study Report, JBIS Special Supplement, pp.S37-S42, 1978.
- Crowl, A, **The Enzmann Starship: History & Engineering Appraisal**, JBIS, 65, 6, June 2012.
- Bussard, R.W, ***Galactic Matter & Interstellar Flight***", Astronautica Acta, 6, Fasc.4,1960.
- Sagan, C, ***Direct Contact Among Galactic Civilizations by Relativistic Interstellar Spaceflight***, Plan[illegible] Sci, Vol, 11, 1963.



Sailing and reaction methods identified in a taxonomy of propulsion solutions.
Credit: Swinney / Long

Sailing in space has similar benefits to sailing on the oceans - no fuel load - and similar difficulties - finding a strong enough wind! The Sun provides a solar "wind" in the form of photon pressure. The first such probe was Japan's IKAROS: Interplanetary Kite-craft, launched in 2010, and extrapolations of the idea to interstellar probes have been suggested. Rob showed some characteristic equations for solar photon propulsion and gave the example that pressure at 1 astronomical unit (AU) from the Sun, ie where the Earth is, amounted to about 9 Newtons per square kilometre of sail or $9*10^{-6}$ Newtons per square metre. This drops off by the inverse square law leaving $5.8*10^{-9}$ Newtons per square metre at Pluto, 39.54 AU from the Sun.



Solar sailing has limits but leads to laser sails & interstellar capability. Credit: Swinney

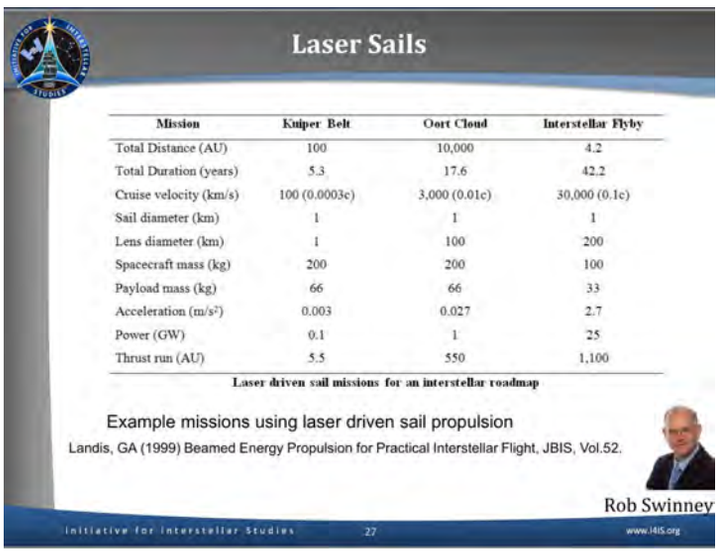
Rob derived and presented a basic equation for a photon-driven sailcraft the photon power required, in watts -

$$P_s(W) = \frac{mca}{2\mu}$$

- where m=spacecraft mass, μ= sail reflectivity, α =absorption coefficient, c = speed of light [1].

Rob showed us Robert Forward's Starwisp ideas, using a microwave beam (Starwisp) and his laser alternative in 1984 and 1985 - and the results of a 1999 study by Geoff Landis.

> Example missions using laser driven sail propulsion
>
> Landis, GA (1999) Beamed Energy Propulsion for Practical Interstellar Flight, JBIS 1999, Vol.52.



Most recently laser sail ideas have again come to the fore with the i4is Dragonfly study and the later Project Andromeda study delivered to Breakthrough Starshot.

Yuri Milner's Breakthrough Starshot initiative exploits recent progress in microminiaturisation, nanotechnology materials science and fibre optics. A fully functional "chipsat" weighing less that one gram is now close to feasibility. Very low mass and highly reflective sails and phase locking of multi-gigawatt laser arrays complete the proposed propulsion approach with the aim of reaching Alpha Centauri in 20 years at 20% of lightspeed. Rob listed 19 areas of challenge to be overcome, not all of them technological.

Summing up, Rob concluded -

1. Solar sails are flight tested and are an option for the inner solar system.
2. Beamed sailing looks viable for further distances away from the sun and for higher velocity.
3. Breakthrough Starshot is a live project backed by $100M over 10 years to solve the challenges posed.
4. Sails appear to have limits to their use in terms of payload/crewed missions...but given future developments?

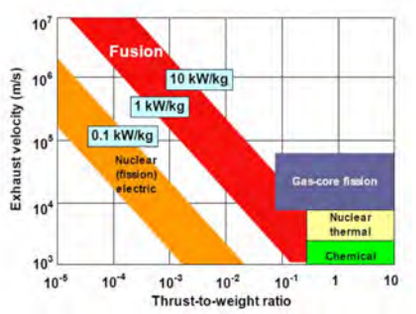
[1] Robert Forward's equation from his 1984 paper, *Roundtrip Interstellar Travel Using Laser-Pushed Lightsails*, states that "The acceleration α of a vehicle of mass M and reflectance η driven by an incident laser power P is - where c is the velocity of light and the factor 2 comes from the double momentum transfer to the sail by the reflected photons."

$$\alpha = \frac{2\eta P}{Mc}$$

2.12 M8-ISR-L12 Advanced Propulsion Systems 2 VIDEO IMPRESS

Rob Swinney continued his propulsion briefing by considering reaction-based propulsion : rockets. He considered -

- Nuclear Fission/Fusion - All carrying their fuel onboard rather than being pushed by external forces[1]
- Interstellar Ramjets - Using material scooped up from the interstellar medium (ISM)

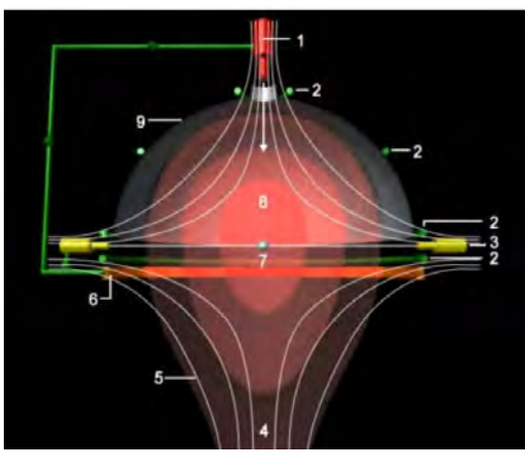


Fusion has the clear advantage.
Credit: Swinney

Nuclear Fission/Fusion

Fusion requires very high pressures and temperatures. Three confinement methods are classified as - gravitational (as in the Sun and other stars), magnetic (as in the Tokamak reactors under development for power generation) and inertial (ICF) using the inertial mass of material to confine the plasma. Rob outlined a number of possible reactions using Deuterium, Tritium, Helium3 and isotopes of Lithium and gave us an equation for the Lawson criterion - comparing the power generated by fusion to the rate of energy loss to the environment.

Reaction propulsion is clearly best suited to large probes or human carrying starships. The probes of the Daedalus (1970s) and Icarus (2010s) studies - and for proposed colony ships and world ships.



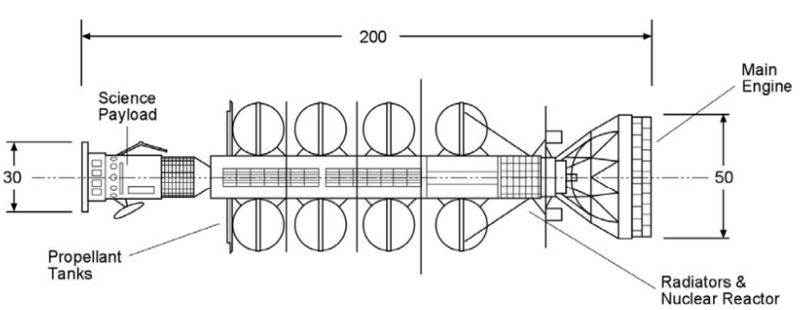
Inertial Confinement Fusion: Daedalus style

1 Pellet injection gun
2 Superconducting field coils (4)
3 Electron beam generators
4 Plasma exhaust jet
5 Magnetic field
6 Energy extraction coils
7 Frozen nuclear pellet
8 Nuclear explosion
9 Reaction chamber
Credit: Adrian Mann www.bisbos.com/space_n_daedalus_prop.html

The pioneering Daedalus study proposed deuterium/helium-3 pellets as fuel and ICF using electron beams. About $3*10^{10}$ pellets would be required. Rob took us through the mass/energy/thrust/exhaust velocity equations noting that the Daedalus reaction yields 42.4 Megawatts per kilogram.

Rob is the long-established Project Director of Project Icarus, the study to build on Daedalus applying new technology and achieving a rendezvous rather than a flyby mission but with a relaxed mission time of 100 years. He noted that a number of intermediate studies were carried out between the publication of the Daedalus results in the late 70s and the inception of Icarus in 2009. Several teams worked on parallel designs within the Icarus programme. They also addressed a number of issues arising from Daedalus including fuel source, pellet rate and use of electron beams to achieve ICF.

Here are the concepts Rob introduced -

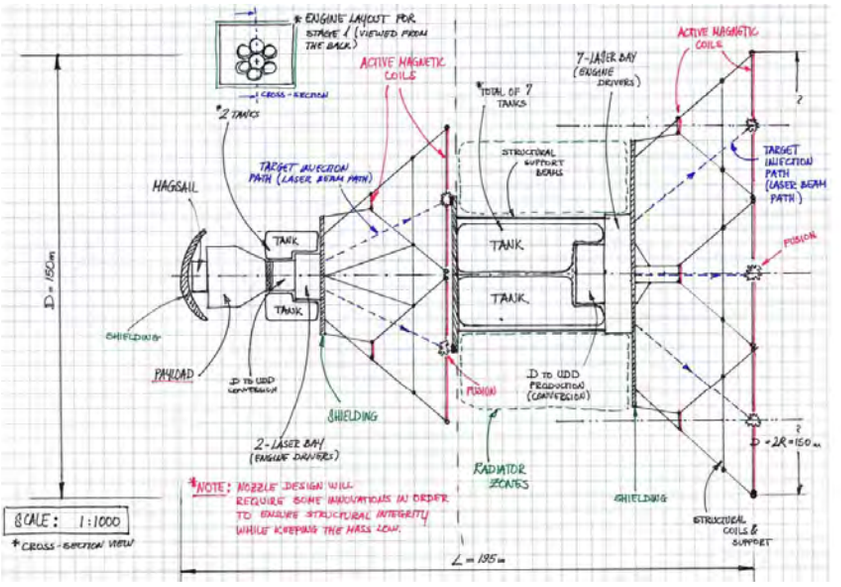


Icarus: Resolution 2013 configuration. Dimensions in metres. Note the similarity to Daedalus.
Credit: Swinney

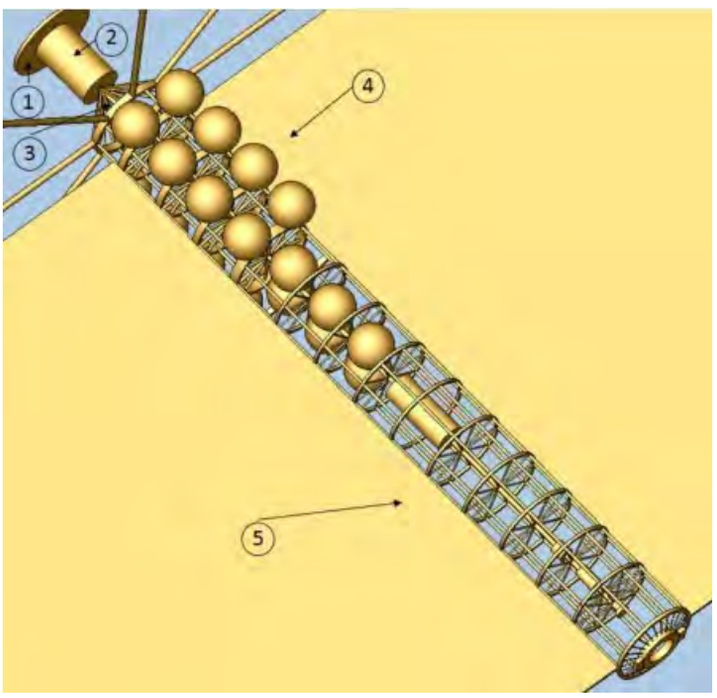
Icarus: Resolution was revised as Icarus: Endeavour with more engines and a faster boost phase.

[1] Thus being subject to the Tsiolkovsky rocket equation DeltaV=ExhaustVelocity*ln(OriginalMass/FinalMass) - a direct consequence of Newton's second law, transposed as Acceleration=Force/Mass.

Icarus: UDD Concept. Credit: Swinney



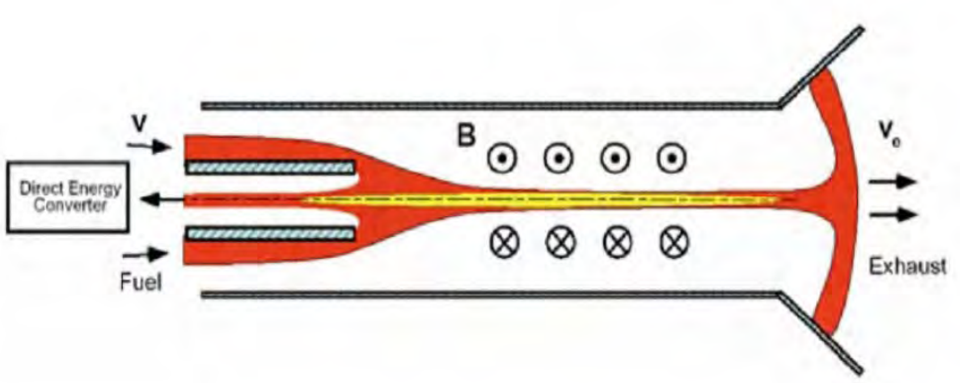
The UDD Concept, based on use of Ultra Dense Deuterium as fuel, offers advantages including simpler reactions, less mass, abundant fuel source and added system robustness and reliability. However producing this fuel in a usable form remains a challenge.



Project Icarus: Ghost Configuration
1.Dust Shield
2.Payload
3.Magnetic Sail
4.Tank Sections
5.Radiators
Credit: Swinney

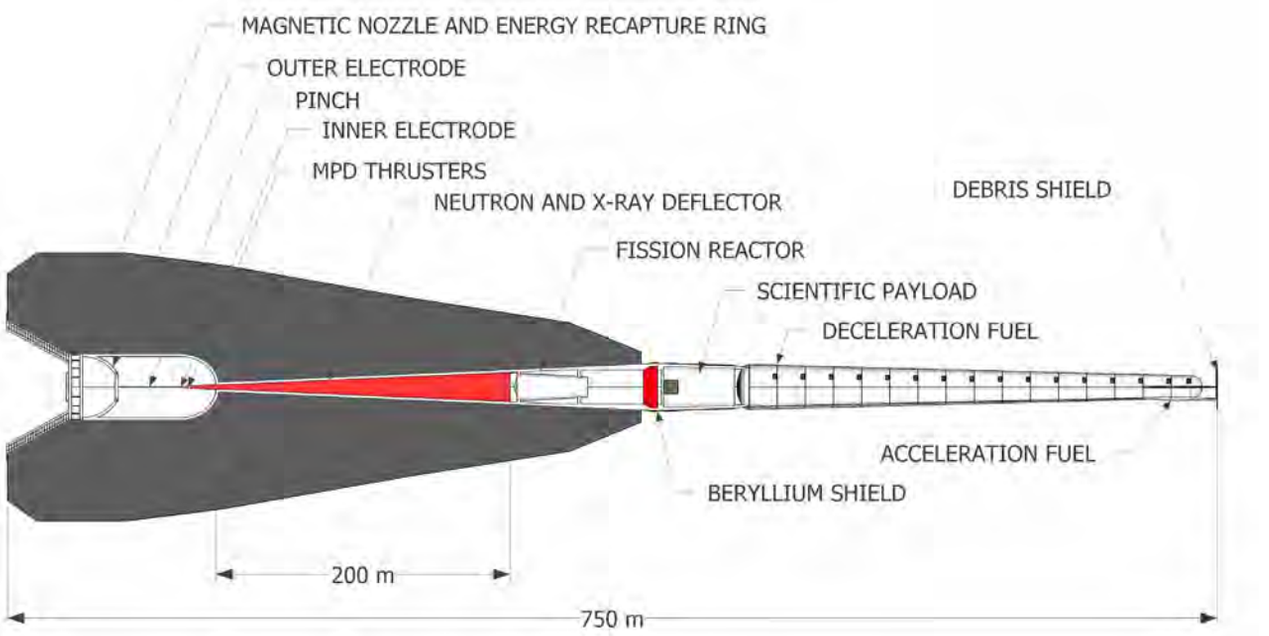
The Ghost team have revised their study, relaxing mission duration to 118.5 years and deriving a new mass budget.

Perhaps the most active and well defined of the Icarus projects has been Icarus: Firefly. This uses a variant of magnetic confinement called a Z-Pinch, relying on the circular magnetic field around any current-carrying conductor. In this case a plasma flow carrying a very substantial current thus producing an inward magnetic force sufficient to achieve fusion-



Simple Z-pinch thruster design by Shumlak. The cylindrical magnetic field is towards (above the plasma) and away (below) from you.
Credit: Shumlak / Swinney

The developed Firefly design has wing-like radiators with a sophisticated liquid metal coolant conveying heat away from the central Z-pinched plasma.

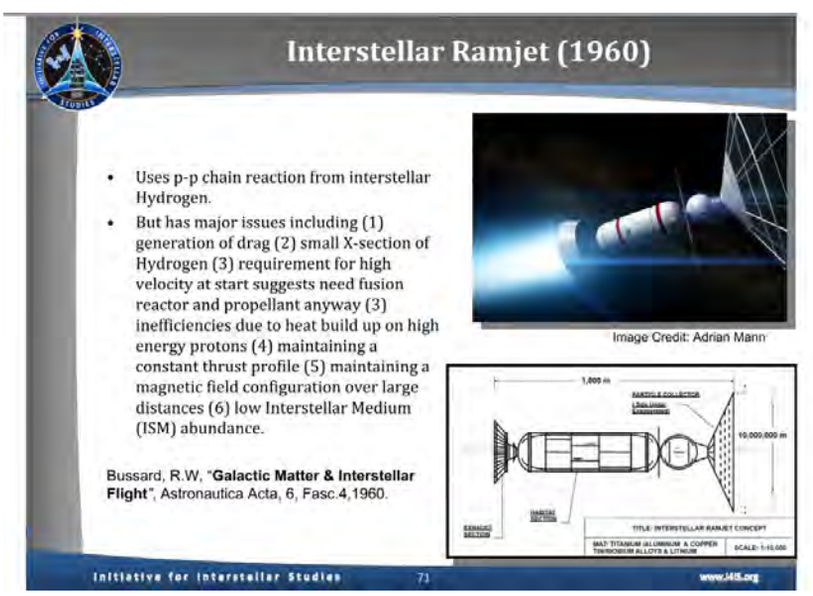


Developed Firefly design (not in the presentation). [1]
Credit: Michel Lamontagne

Another idea under the Icarus programme is Icarus: Zeus - Plasma Jet Magneto-Inertial Fusion (PJMIF) using magnetic confinement fusion.

Interstellar Ramjet

The 1960 Interstellar Ramjet idea of Robert Bussard avoids carrying fuel by using interstellar hydrogen scooped up by the craft's magnetic field. This very attractive idea has been found to have a number of technical flaws which Rob outlined.



Bussard's orginal concept :
Bussard, RW "Galactic Matter & Interstellar Flight", Astronautica Acta, 6, Fasc.4,1960.

Two of them are easily stated - there is not enough interstellar hydrogen and, like terrestrial ramjets, the process only starts to work after a high initial velocity has been achieved.

Rob summed up by reiterating that the BIS Project Daedalus study remains the only full starship "design" and all others are concepts at best. In conclusion, though interstellar travel is very difficult technically, these studies show that it is certainly possible.

[1] Reaching the Stars in a Century using Fusion Propulsion A Review Paper based on the 'Firefly Icarus' Design Patrick J Mahon, Principium | Issue 22 | August 2018.
Also at - i4is.org/reaching-the-stars-in-a-century-using-fusion-propulsion/

2.13 M8-ISR-L13 Artificial Intelligence on Worldship Missions VIDEO IMPRESS

John Davies introduced the second session on the application of Artificial Intelligence (AI) and Artificial General Intelligence (AGI) to worldships.

“Vanilla” AI is all we have now. Much has been achieved, especially by machine learning in recent years but there have been false dawns before.

Artificial General Intelligence is “... designed not for particular tasks but for being capable of learning various skills” Arakawa 2014[1]. AGI approaches take two routes-

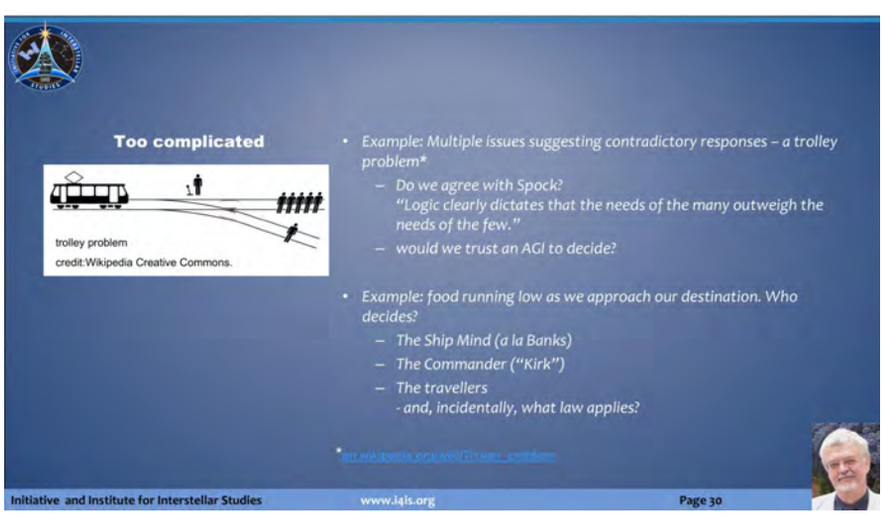
- Bottom up – Simulation of Nervous Systems such as the SpiNNaker - simulation of a billion neurons (maybe 1% of human brain?) of Steve Furber's team at the University of Manchester and its second generation at TU Dresden. Also the Blue Brain and Human Brain Projects at EPFL, Lausanne.
- Top Down: Simulation of Human Behaviour - machine learning via deep neural networks - recently in gaming and pattern recognition notably Google Deepmind.

The theoretical background to simulation is the Church-Turing thesis of 1938 proving that all computers[2] are equivalent and Turing’s 'polite convention' of 1950 - that if an entity seems human then treat it as such[3]. What would be the status of Digital Persons- how can we know that a digital "person" is a real person? – If “uploaded” from a biological human ("Transcendence") how can we know that the copy is identical? – If “educated” how to determine their "personhood"? And finally if only Digital Persons go to the stars, will we feel that the human race has really visited another stellar system?

However there have been false dawns of AGI (USA 1966, UK 1973) and sceptics include a legend of computer science, Edsger W Dijkstra (who dismissed the AI optimism of both Alan Turing and John Von Neumann) and polymath Roger Penrose (The Emperor's New Mind, OUP 1999).

John asked what Worldship configurations should we expect and how can AI/AGI contribute to the mission? The sociology and ethics of worldship societies have been considered recently by Hein et al in the ESA journal Acta Futura (www.esa.int/gsp/ACT/resources/acta_futura) and by James Schwartz, Wichita State University[4].

John considered the following premise - that humans plus AIs (and maybe AGIs) can fix whatever is fixable on a worldship. But what might not be fixable in this way? He gave examples where the occurrence may be too fast, too complicated, too unknown or was a Black Swan event - and what AI or AGI can do in these cases.



The "Too complicated" case illustrated by the Trolley Problem in moral philosophy [5] and Mr Spock's utilitarian response, and exemplified by a worldship scenario.

[1] Planning with Brain-inspired AI, Naoya Arakawa arxiv.org/abs/2003.12353

[2] Strictly speaking finite state automata

[3] Computing Machinery and Intelligence, A M Turing, Mind, Volume LIX, Issue 236, October 1950

academic.oup.com/mind/article/LIX/236/433/986238

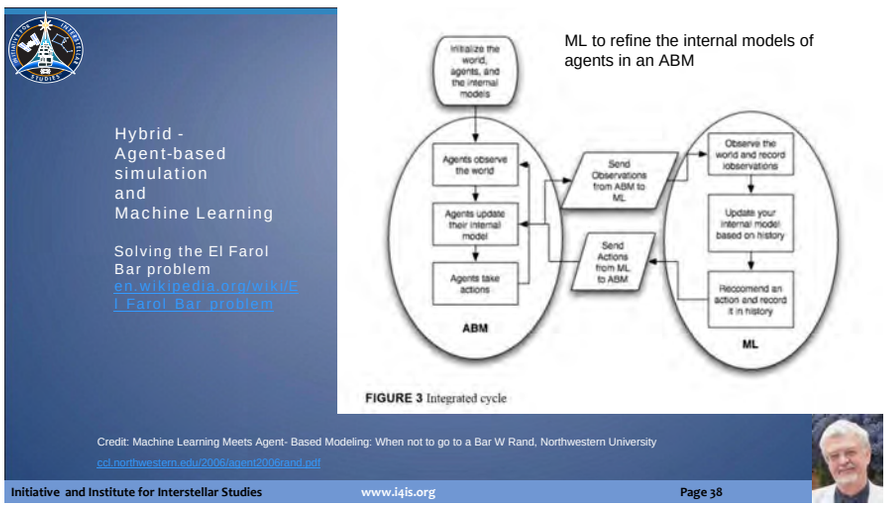
Some key quotes “Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's?” “We cannot expect to find a good child machine at the first attempt. … experiment with teaching one such machine and see how well it learns… then try another and see if it is better or worse.” and refuting The Argument from Consciousness "it is usual to have the polite convention that everyone thinks"

[4] Worldship Ethics Obligations to the Crew James S J Schwartz, JBIS V71 #2 February 2018, TVIW video Worldship Ethics 101: The Shipborn at -www.youtube.com/watch?v=dIpXINcQixE&feature=youtu.be

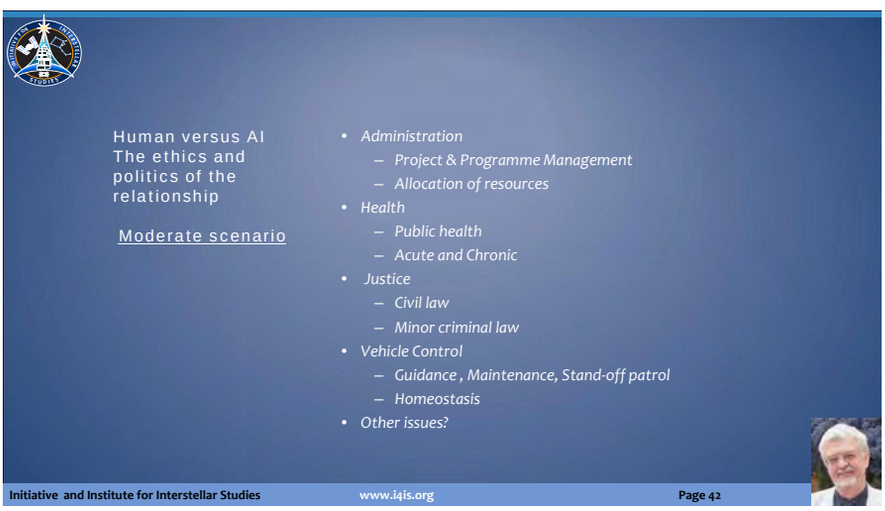
[5] Doing vs Allowing Harm - 2. Distinguishing Distinctions plato.stanford.edu/entries/doing-allowing/#DistDist

So can simulations of worldships help us to think about missions well before launch? We can simply “run the numbers” as in Andreas' Acta Futura paper. If numbers and statistics don’t work then can we simplify and thus simulate human societies? Agent based simulations are used for situations such as building evacuation and road traffic. Can AI, and in particular machine learning, help? And there are also hybrids of these two approaches.

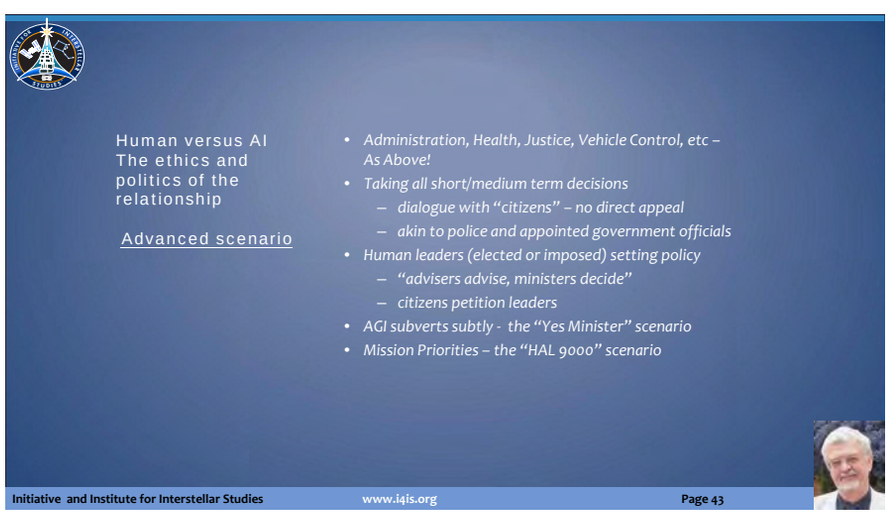
Hybrid - Agent-based simulation and Machine Learning Solving the El Farol Bar problem
Credit: *Machine Learning Meets Agent- Based Modeling: When not to go to a Bar* ,W Rand, Northwestern University
ccl.northwestern.edu/2006/agent2006rand.pdf



On the ship itself how do we balance onboard roles – human versus AI? How far will we have progressed with AI/AGI at the point of launch? John considered moderate and advanced scenarios, with a human only setting policy in the latter case.



moderate (above) and advanced (below) scenarios for worldship AI / AGI



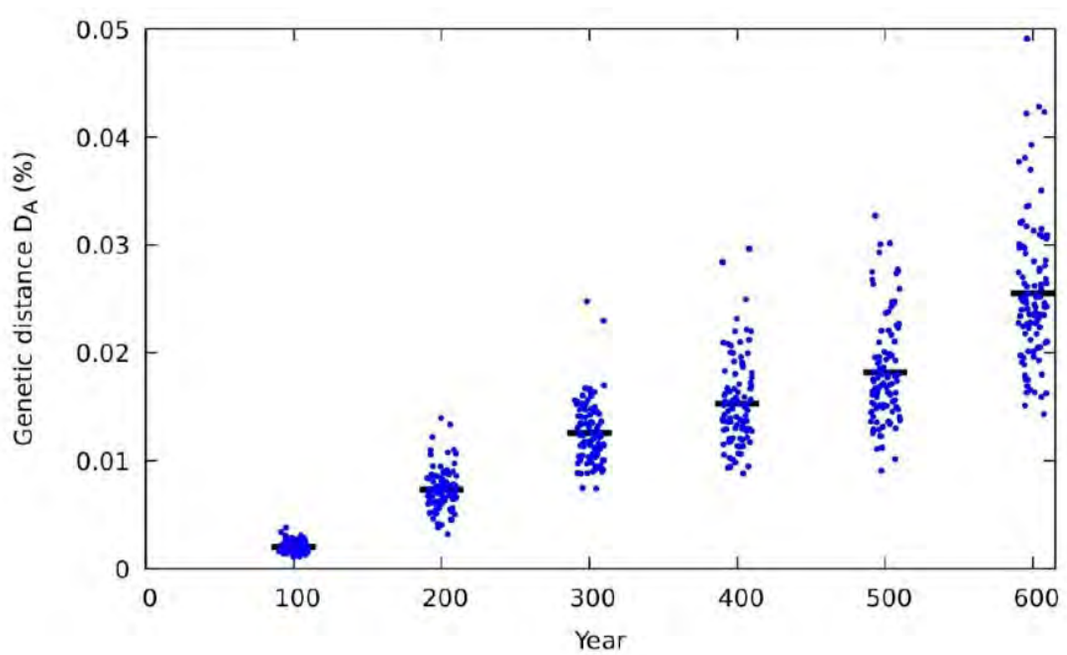
A safe assumption is probably that worldships will adopt current technological practice (as did the Apollo and Shuttle programmes for their computer architecture).

2.14 M8-ISR-L14 Worldship Population Dynamics IMPRESS

Dr Frédéric Marin took us inside the worldship to consider how the human population might fare on their long journey. He introduced us to the early worldship thinking of Robert Goddard and Konstantin Tsiolkovsky, the NASA/Stanford ideas in the 70s. There has been a limited amount of work so far from the population point-of-view [1].

Dr Marin introduced us to the international HERITAGE project, based at the University of Strasbourg, to simulate evolution of a population of digital humans in a closed system (a Moon colony, a space station, an interstellar spacecraft) for hundreds to thousands of years [2]. An example is a simulation of a 600 year interstellar journey with a starting population of 50 people, gender balanced, leading to an exponential-growth population to about 8,000 at journey's end so he aims to limit growth to 1200 people. This initial simulation leads to inbreeding but artificially limiting consanguinity to prevent this leads to population collapse. Simulations starting with 100 people and the same population and consanguinity limits show problems with the lower figure of skills transfer and resilience to widespread diseases or disasters. Starting with 500 people leads to a stable outcome, addressing the issues of skills transfer and resilience.

Dr Marin considered the population sizes from a genetic point of view. The population size considered appears to be adequate in terms of Hardy-Weinberg equilibrium (ie the frequency of alleles[3] should tend to be stable over long periods). However genetic evolution will naturally occur and the population will drift away from the genotypes seen at the start of the journey.



Evolution of the Nei's minimum genetic distance D_A as a function of time for a given HERITAGE parametrization. Each point (at a given time-step) represents the outcome of one out of one hundred simulations. The averaged genetic distance is highlighted by a black bar. The annual equivalent dose of cosmic ray radiation is similar to the Earth radioactivity background at sea level (0.3 mSv).

Credit (image and caption): Marin

Radiation is clearly a threat both genetically and in causing disease, notably cancers. The solar storms especially feared for astronauts outside the Earth's Van Allen belts will naturally be less significant as the journey progresses but Dr Marin identifies cosmic ray radiation as a major issue.

[1] *Evaluating Five Models of Human Colonization*, John H Moore 2001 www.jstor.org/stable/683473

J H Moore. *Kin-Based Crews for Interstellar Multi-Generational Space Travel* - in Kondo, Bruhweiler, Moore and Sheffield (eds). Interstellar Travel and Multi-Generational Space Ships, pages 81–88. Apogee Books, Wheaton, Illinois, USA, 2003

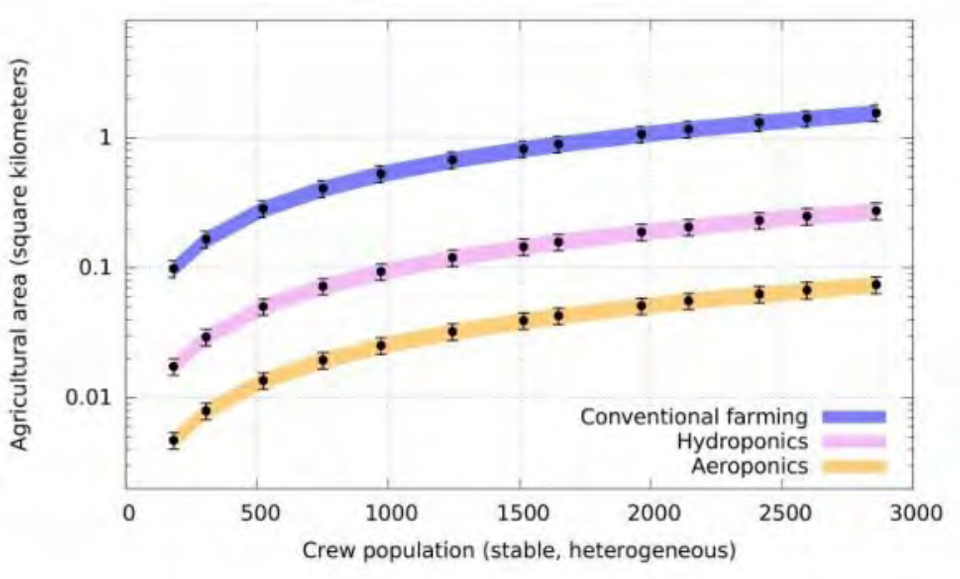
C M Smith, *Estimation of a genetically viable population for multigenerational interstellar voyaging: Review and data for project Hyperion*, Acta Astronautica, 97, pp.16–29, 2014. doi:10.1016/j. actaastro.2013.12.013 open at:tinyurl.com/CMSmith2014

Jean-Marc Salotti, *Minimum Number of Settlers for Survival on Another Planet*, Scientific Reports volume 10, Article number: 9700 2020, www.nature.com/articles/s41598-020-66740-0

[2] The HERITAGE project is entirely voluntary (no specific funding so far). The team would welcome any expert with ideas to improve the code or exploit the data. Human science experts would be especially welcomed as would female academics. More at - astro.u-strasbg.fr/~marin/HERITAGE.html.

[3] en.wikipedia.org/wiki/Allele_frequency

The HERITAGE simulation shows the requirements for food, water and breathable gases. Food requirement is set by the BMR, basal metabolic rate of an individual and physical activity (PAL). The sum of these sets the total energy expenditure. A stable population of 1,100 leads to a requirement of 1 billion kilo-calories per year (equivalent to about 1.15 billion tonnes of potatoes per year!). This is clearly not a practical cargo mass so agriculture is required. The choices are Geoponics (old-fashioned soil-substrate farming), Hydroponics (using inert substrate irrigated with a nutrient solution) and Aeroponics (above-ground with sprays, a fog, of water and nutrients in a closed circuit). The latter requires no substrate and has been shown, on the ISS, to be insensitive to gravity. It is also the most space-efficient of the three.



Required agricultural surface area (in square kilometers) as a function of the crew size for a single-food diet (sweet potatoes). The colors highlight the different, farming techniques used.

Credit (image and caption): Marin

However, considerations of dietary diversity including some provision for animal and orchard sources suggests a proportion of geoponics and thus with a population of 1,100 people, 0.95 square km of agricultural area.

Water is a major challenge - both for human and agricultural use - so both production and recycling will be required. Dr Marin suggests two possible reactions for production the Sabatier reaction (as on the ISS [1]) and the Bosch reaction [2].

Air, and specifically oxygen, is required of course. About 180 million litres of oxygen must be produced per year. Chemical reactions on the ISS cannot be reproduced where there are no incoming supplies so the only way to provide enough breathable gases and recycle gas wastes is to mimic the Earth system and rely on agriculture.

Along with genetic drift there will be social drift. Isolated populations evolve new traits such as (in approximate order) new vocabulary and accents, body language, value scales, artistic expression, philosophy and religious beliefs, language and finally ethnogenesis - the formation of a new culture or nation.

Dr Frédéric Marin is at the Astronomical Observatory of Strasbourg, part of the University of Strasbourg. His scientific interests include both astrophysics (theory and modelling of black holes, polarisation and radiative transfer, galactic nuclei and quasars) and anthropology of space (interstellar travel, multi-generational populations, and worldship design and reliability studies) - more at -astro.u-strasbg.fr/~marin/. He has published a number of papers in JBIS since 2017 [3]. He has degrees in physics and in a variety of astrophysical topics from the universities of Dublin, Annecy-le-Vieux, Montpellier and Strasbourg (PhD).

[1] en.wikipedia.org/wiki/Sabatier_reaction#International_Space_Station_life_support

[2] en.wikipedia.org/wiki/Bosch_reaction

[3] JBIS papers : see *Recent Interstellar Papers in JBIS* in Interstellar News in this issue and earlier -

Computing the Minimal Crew for a multi-generational space journey towards Proxima Centauri b - V71 #1 2018, pages 45-52 V71 #2 February 2018

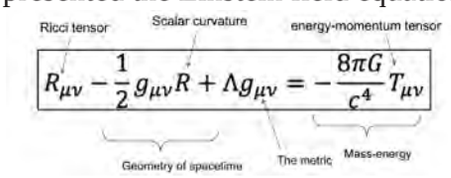
Numerical Constraints On The Size Of Generation Ships from total energy expenditure on board, annual food production and space farming techniques - V71 #10, pages 382-393 October 2018

Heritage: A Monte Carlo Code To Evaluate The Viability Of Interstellar Travels Using A Multi-Generational Crew, V70 # 5/6 May/June 2017, pages184-195

2.15 M8-ISR-L15 Interstellar Travel using Einstein Physics VIDEO IMPRESS

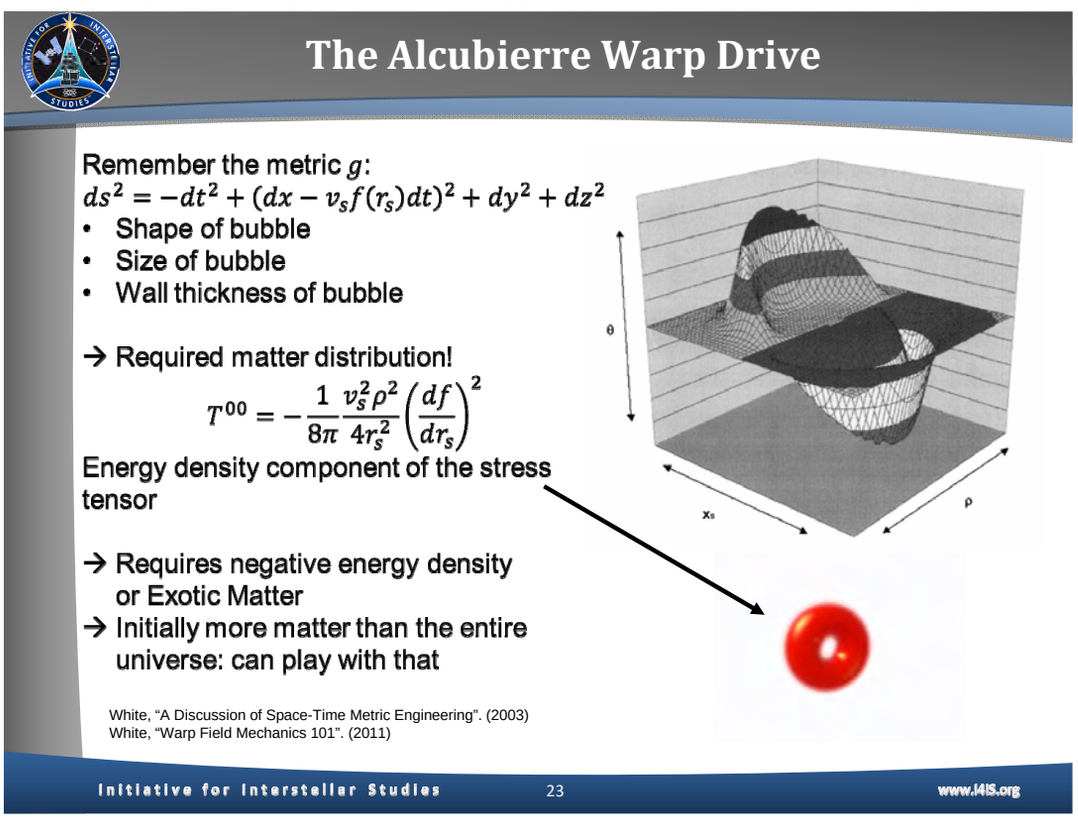
Dan Fries, Deputy Director of the i4is Technical team, examined how some more advanced propulsion technologies might become possible whilst remaining within the framework of Einstein physics - special relativity, general relativity, the Mach-effect thruster, faster than light travel, black holes and wormholes. Special relativity gives us the equivalence of all inertial (non-accelerated) observers and the invariance of c leading to indeterminacy of simultaneity and space-time dilation (with effects on mass, length, time and velocity).

Dan startled us with the assertion "GRAVITY IS NOT REAL". Gravity only appears to be 'the force of attraction between two bodies at rest or in motion' as Newton asserted (and as the everyday world testifies). Einstein's general relativity theory of gravitation teaches us that acceleration and gravity are equivalent. Dan presented the Einstein field equation -



Propellantless space flight is an attractive prospect. Dan illustrated this by citing the payload mass fraction of launchers from Soyuz to Saturn 5. Typical payload is just a few percent of total mass. The hypothetical Mach-effect thruster applies Mach's principle, that "local physical laws are determined by the large-scale structure of the universe" originated by Einstein to deal with phenomena such as the ability of gyroscopes to establish what seems to be a fixed frame of reference. Experimental rigs have yet to show incontrovertible results but if we could find an "inertialess drive" then it might revolutionise how we get around the universe.

Faster than light (FTL) travel has long been a dream of SF and ideas have included slowing down light, using light spots and shadows, aspects of quantum mechanics, hyperspace, superfluid theories and tachyons. However a glimmer of possibility only appeared with the Alcubierre warp drive[1].

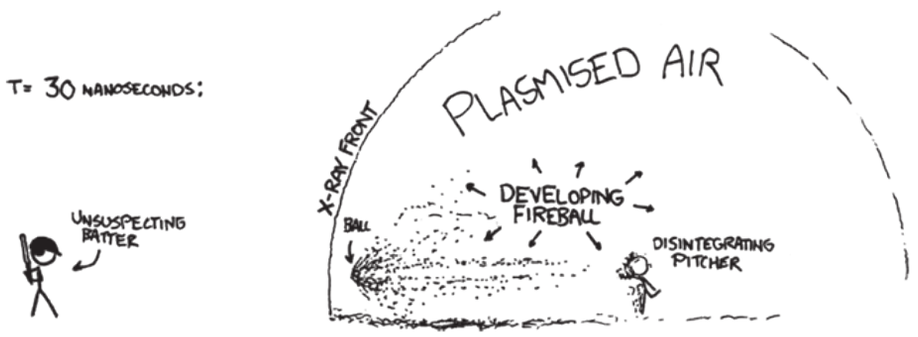


Dan's summary of Alcubierre mathematics

[1] The warp drive: hyper-fast travel within general relativity, Miguel Alcubierre, Classical and Quantum Gravity, Volume 11, Number 5 1994 - synergetics.io/docs/Alcubierre-Warp-Drive-Hyperfast-Travel-With-General-Relativity.pdf

But Dan outlined some problems with FTL - causal violations and energy condition violations, navigation, various forms of radiation and time dilation (the twin paradox). He cited a nice physics joke about just 90%c velocity applied to baseball -

The awful consequences of playing near-light-speed baseball
Credit: what-if.xkcd.com/1/



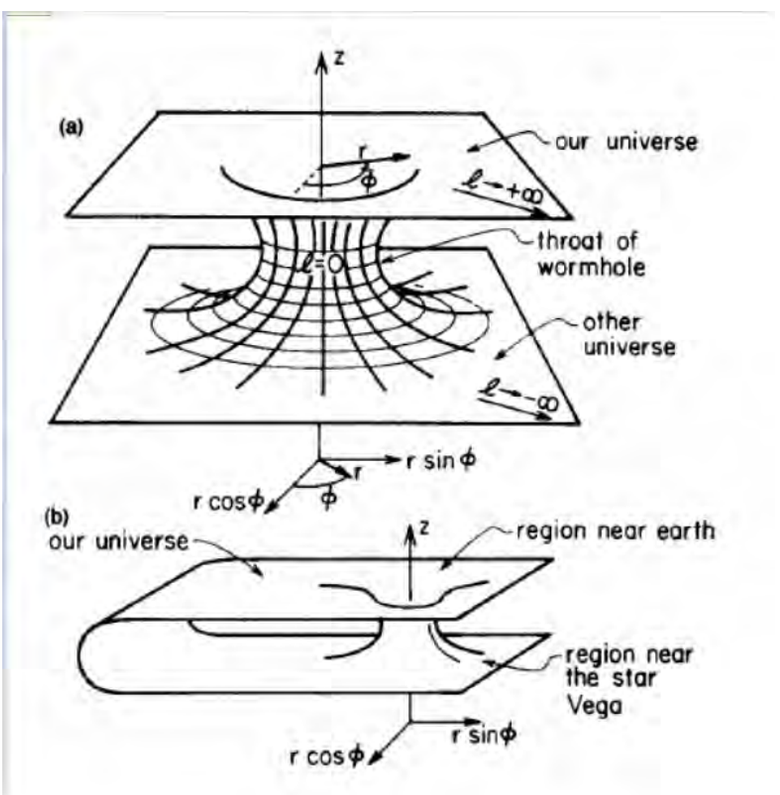
Black holes and wormholes also offer interesting, though somewhat far-fetched, possibilities. Dan gave us a tour of black hole physics - static vs rotating, Schwarzschild and Kerr solutions, the “No hair” theorem (the only parameters black holes have are mass, charge and angular momentum - they are otherwise featureless and indistinguishable).

For propulsion the interesting possibility is the extraction of energy from black holes - for example as Hawking radiation or the Penrose process to extract angular momentum from a rotating black hole. Another possible exploitation of black hole energy is a Black Hole Interstellar Ramjet (BAIR)[1].

Wormholes offer a tempting bypass to the problem of achieving FTL. Dan summarised the work of Albert Einstein and Nathan Rosen (1935), Wheeler & Fuller (1950’s) and Morris & Thorne (1980’s).

Dan showed us an example from a Morris and Thorne paper [2].

Morris and Thorne, “Wormholes in spacetime and their use for interstellar travel: A tool for teaching general relativity”. American Journal of Physics 56, 395 (1988)



As always there is a "BUT": a wormhole requires exotic matter with negative energy.

Dan concluded with a warning to be careful with grand claims and grandiose promises!

His presentation includes two pages of futher learning resources (see the members area of the i4is website - linked from the heading of this article).

[1] i4is.org/what-we-do/technical/black-hole-engine

[2] Thorne also advised on black holes and wormholes for the Christopher Nolan film, Interstellar. His ideas were part of the initial inspiration for the film. He also worked with the effects team at Double Negative (www.dneg.com) gaining new insights into the physics via the detailed CGI work required. Thorne's book *The Science of Interstellar* is a fairly deep dive into the physics. The film and the book were reviewed by Keith Cooper in Principium | Issue 9 | May 2015 Page 19 and Page 22.

2.16 M8-ISR-L16 Worldship Documentary

Michael Madsen's tells us that his documentary is being further refined. It will be reviewed in a later issue of Principium

2.17 M8-ISR-L17 The Case for Interstellar VIDEO IMPRESS

John Davies tackled the issue of how to convince people that interstellar travel and communications deserve their attention and support, in short - How can we convince our fellow human beings to commit to interstellar?

John started with some quotations from three visionaries of interstellar studies -

> *Earth is the cradle of humanity, but one cannot live in a cradle forever.*
>
> Konstantin Eduardovich Tsiolkovsky 1911
>
> *Our exploring ships will spread outwards from their home over an ever-expanding sphere of space. It is a sphere which will grow at almost - but never quite - the speed of light.*
>
> Arthur Charles Clarke, Profiles of the Future - 1962
>
> *…interstellar travel will always be difficult and expensive, but it can no longer be considered impossible.*
>
> Robert Lull Forward, 1996

John listed arguments against interstellar - technical (too far, takes too long, fuel demands, impact hazards) and human (space and zero gravity, life support, radiation, the wait calculation, relativistic effects) and arguments in favour - all human (long term survival of our species given finite age of Sun, over population, energy limits, find habitable worlds & life, the simple Outward Urge, scientific advancement, possible cultural interactions with intelligent life and spiritual - our place/purpose in the Universe).

Sceptics argue that we have enough to do on Earth and many of them are technology pessimists. Arguments range from accusations of technological hubris all the way to technological eschatology - the theology of end times. The tension between -

- technological optimists from Samuel Smiles in the 19th century via Konstantin Tsiolkovsky, Isaac Asimov, Raymond Kurzweil, Nikolai Kardashev to Neil De Grasse Tyson and others in the present day.
- technological pessimists from E M Forster in the early 20th century [1] to today's James Lovelock.

Lovelock suggests “an orderly withdrawal to live in harmony with Gaia” and there are even those who suggest our end times are coming, from religious eschatologists to the extreme technological pessimism in fictions from E M Forster's novel, *The Machine Stops,* to the *Terminator* films.

Revisiting some arguments in favour - and adding commercial drive, civilisation life-cycles (Spengler) and avoiding intellectual stagnation[2]. John asked - are any of these are specific to interstellar? He mused that successful SETI might be “the joker in the pack”. Further negative issues include the human tendencies to isolationism (and even autarky - the motivation to simply "pull up the drawbridge") and general purposelessness. Will we simply decide that the solar system is sufficient or anticipate incessant obsolescence as characterised by the Wait Equation [3].

So who has made "the case for space" and who is doing so now? In the USA Robert Goddard and the American Rocket Society were the 1920s pioneers. More recently the Planetary Society and its founder Carl Sagan - who himself was an early interstellar advocate. In more recent times the interstellar champions have been the Tennessee Valley Interstellar Workshop (tviw.com) and, from 2016, Yuri Milner at Breakthrough Starshot, with supporters as diverse as Mark Zuckerberg and Stephen Hawking [4]. Russia and the USSR of course, had the early vision of Tsiolkovsky and the later engineering leadership of Sergei Korolev but John could see no clear advocates currently.

[1] Also anti-industrialists in the 19th century such as John Ruskin and William Morris and - to an extent - Gandhi in the 20th

[2] See Avoiding Intellectual Stagnation: The Starship as an Expander of Minds, I A Crawford, JBIS, V67, #6 June 2014, pp.253-257, 2014, www.homepages.ucl.ac.uk/~ucfbiac/Starship_philosophy_paper.pdf

[3] See "Interstellar Travel: The Wait Calculation and the Incentive Trap of Progress" JBIS, V59, July 2006 tinyurl.com/kennedywait

[4] Most recently the Limitless Space Institute (www.limitlessspace.org) - President Brian “BK” Kelly, Director of Advanced R&D Dr Harold “Sonny” White, formerly of NASA Eagleworks)

In Europe we had the German Rocket Society, founded by Herman Oberth in the 1920s, and the British Interplanetary Society (BIS) - with Arthur C Clarke as its most famous founding member in the early 1930s. German engineers produced the V2 short range ballistic missile and went on to enhance the space programmes of the USA and USSR. More recently Alan Bond and the BIS Daedalus team produced the first serious interstellar probe design and only last year the Advanced Concepts Team of the European Space Agency held its first Interstellar Workshop, 20-21 June 2019. China is now a major spacefaring nation with Ouyang Ziyuan of the Chinese Academy of Sciences a prominent public advocate. India already has a Mars orbiter probe and has had major space advocates including Vikram Sarabhai, founder of ISRO, and A P J Abdul Kalam, perhaps the first aerospace scientist to be president of a major country.

How will we take our first steps towards interstellar? Can we first build near Earth demonstrators like the i4is Glowworm laser-push demonstrator? How can we fund these? Is faster interplanetary the way to start? Will tourism followed by space habitats be stepping stones?

There are lots of potential destinations with new exoplanets being identified daily and missions to do more in the Kuiper belt and Oort cloud being planned for the coming decade.

Worldships need travellers and the inhabitants of space colonies may be the most likely enthusiasts. In the longer term there may be migration programmes like those for Australia in the 20th century.

Fiction continues to suggest both optimistic and pessimistic scenarios varying from the limping, returning, starship in Aurora by Kim Stanley Robinson to the long-term optimism of Iain Banks' Culture stories - "… to live in a fundamentally rational civilisation"[1].

The ISU Astra Planeta report advocated an "International Interstellar Fund (IIF)" (isulibrary.isunet.edu/doc_num.php?explnum_id=731). This is very long term finance and there may be another fictional parallel, "slow money" in the novel *Neptune's Brood* by Charles Stross.

Andreas Hein has suggested that long-term economic development will "close the gap" in funding [2].

Inevitably we must create an interstellar focussed society "Starships must first conquer people's hearts and minds before they can conquer space." [3]. We must be serious about marketing interstellar with inclusive processes & methods, diplomacy, ethics and leadership.

Robinson's limping starship versus Banks' optimistic Culture. Credit: Barnes and Noble / Livre Poche

[1] See *A Few Notes on The Culture* by Iain M Banks, www.vavatch.co.uk/books/banks/cultnote.htm

[2] Evaluation of Technological/Social and Political Projections for the Next 300 Years and Implications for an Interstellar Mission, A M Hein, JBIS, v65, 2012

[3] Future Geopolitical Scenarios, Their Dominant Schools of Thought and the Impact Thereof on the Promotion of Deep Space Exploration, F Ceyssens et al. (2014), JBIS, 67