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Interstellar Probes

How can
we do it?



An Astronomical Question: What is 1I/`Oumuamua?

- Long (about 5:1) and tumbling but not breaking up
- Accelerating away from Sun but tumbling motion unchanged
- Who said (of another astronomical discovery) – “That’s funny....”?
- We will return to this...



A probe to nearby stars

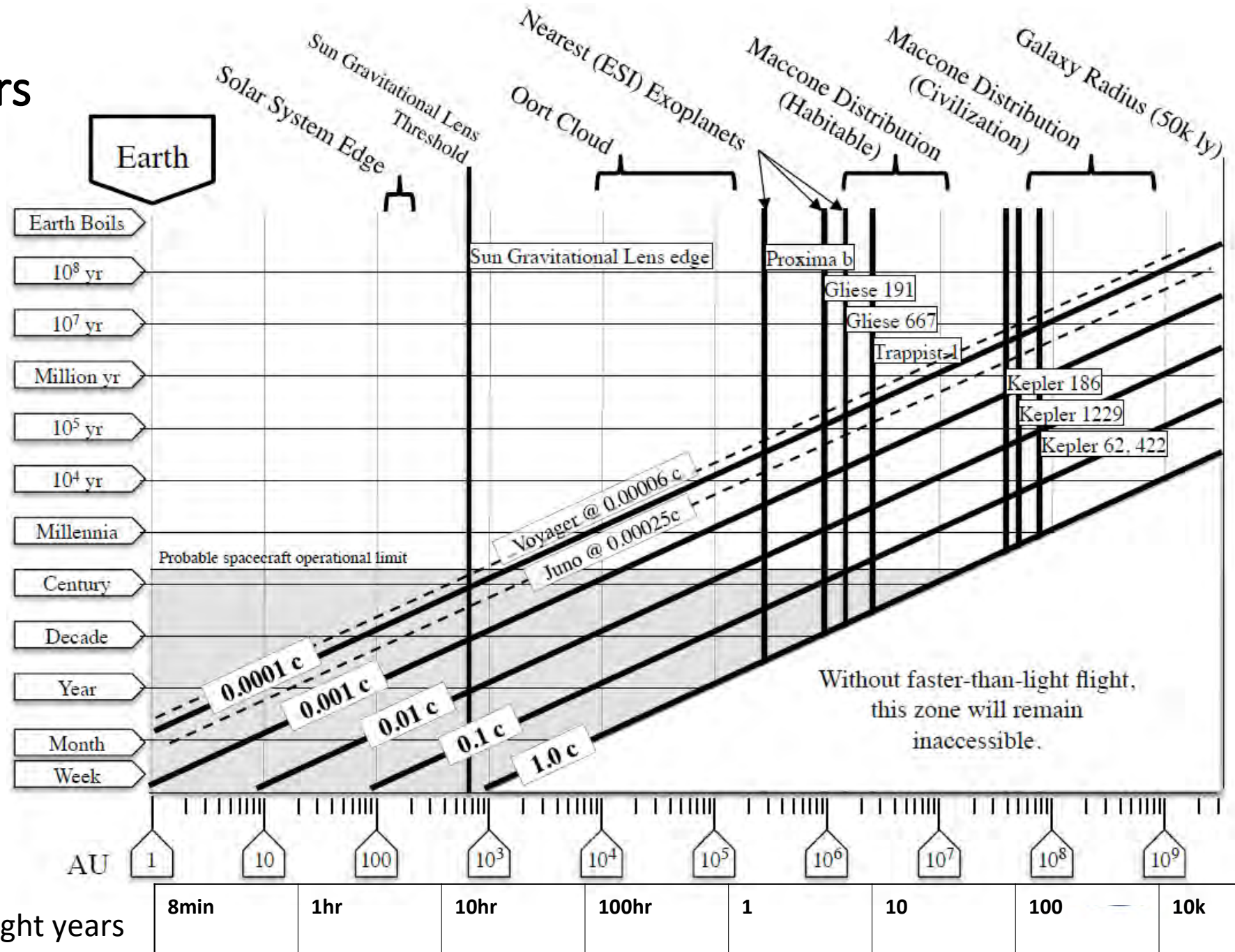
Scaling the problem

credit - Tau Zero Foundation -
NASA Breakthrough
Propulsion Study 2018

“Maccone Distribution” in C
Maccone*, “The Statistical
Drake Equation”, 59th
International Astronautical
Congress, Glasgow, 2008

*i4is.org/who-we-are/advisory-
council

approx light years



The Heavy Way – The Rocket Equation

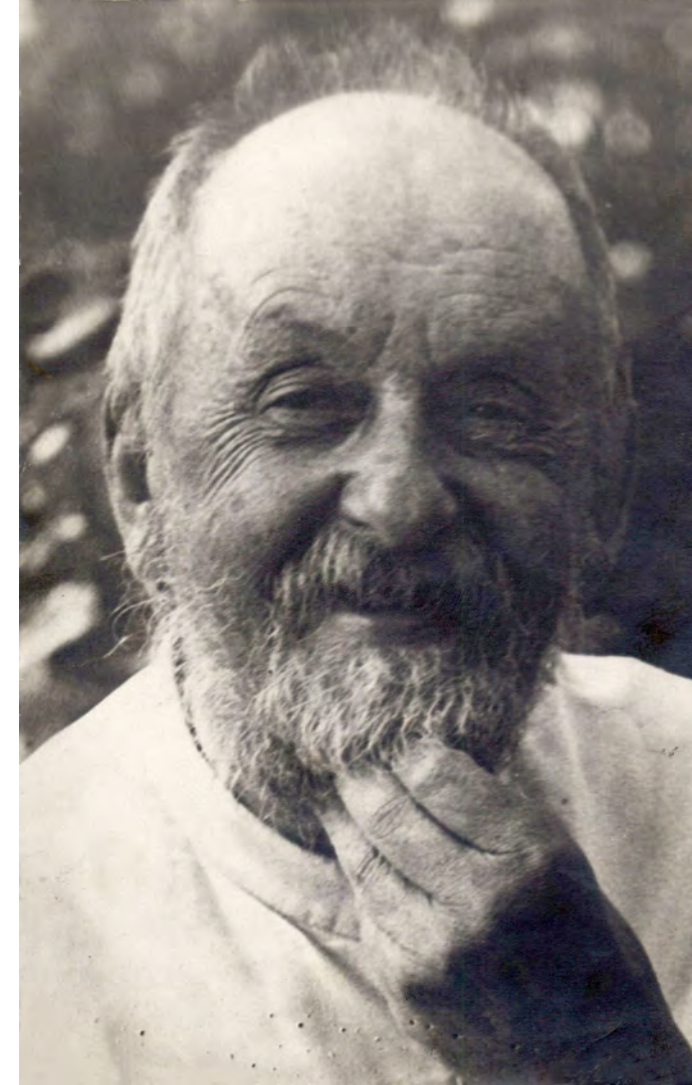
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ΔV is the change in rocket velocity (possibly from zero)

v_e is the velocity of the exhaust coming out of the rocket

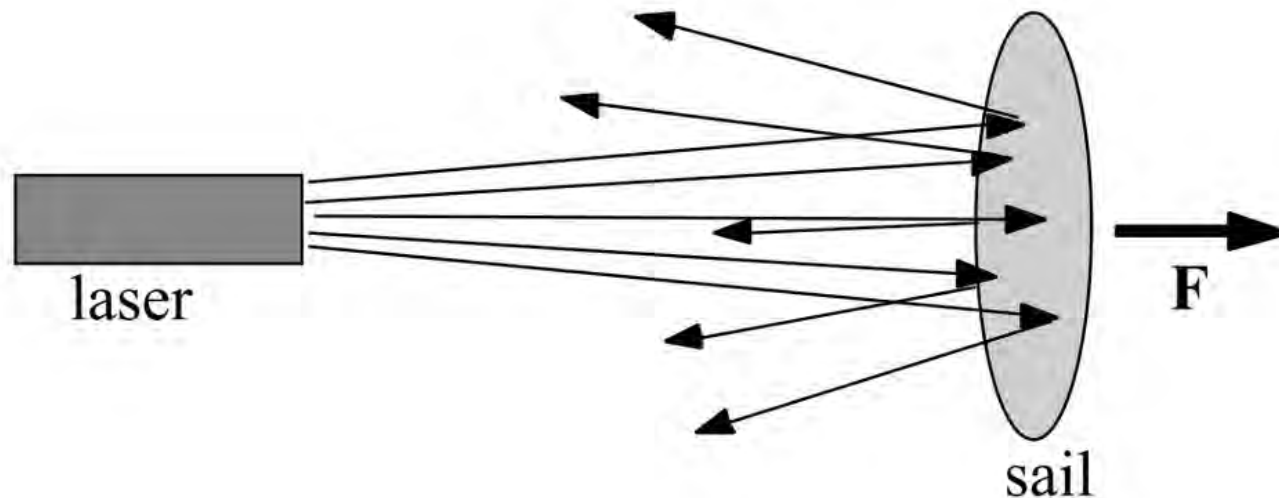
m_0 and m_f is the mass of the rocket when it starts and m_f is its mass with all the fuel gone.

The function \ln is just the natural log which results from integrating $1/x$



The Light Way – Laser Sail Propulsion

- Subset of Light Sail propulsion
- Solar photons already used – Ikaros and LightSail 2
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“The acceleration α of a vehicle of mass M and reflectance η driven by an incident laser power P is -

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

where c is the velocity of light and the factor 2 comes from the double momentum transfer to the sail by the reflected photons. “

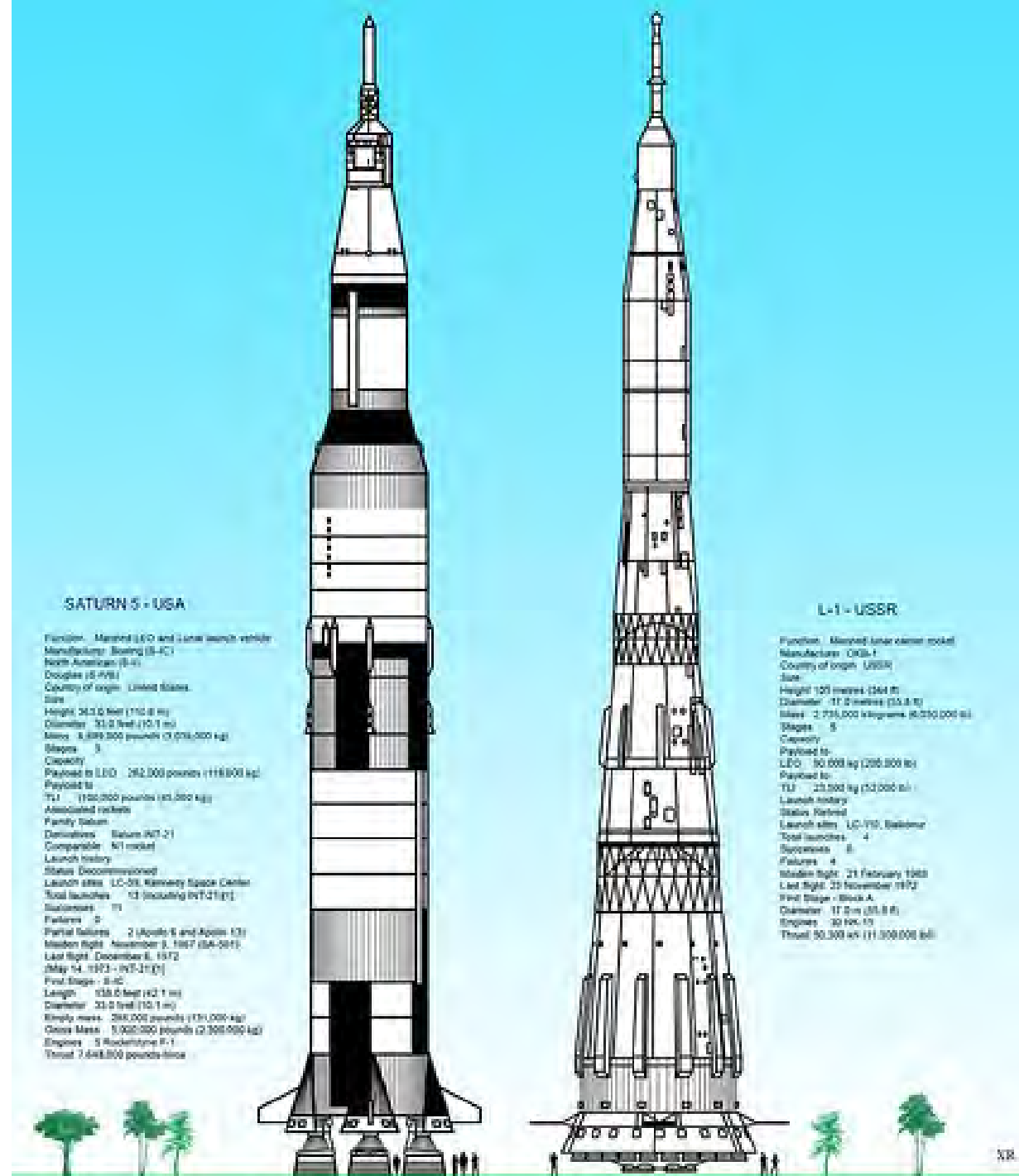
Forward 1984 - arc.aiaa.org/doi/abs/10.2514/3.8632

pdfs.semanticscholar.org/25b2/b991317510116fca1e642b3f364338c7983a.pdf

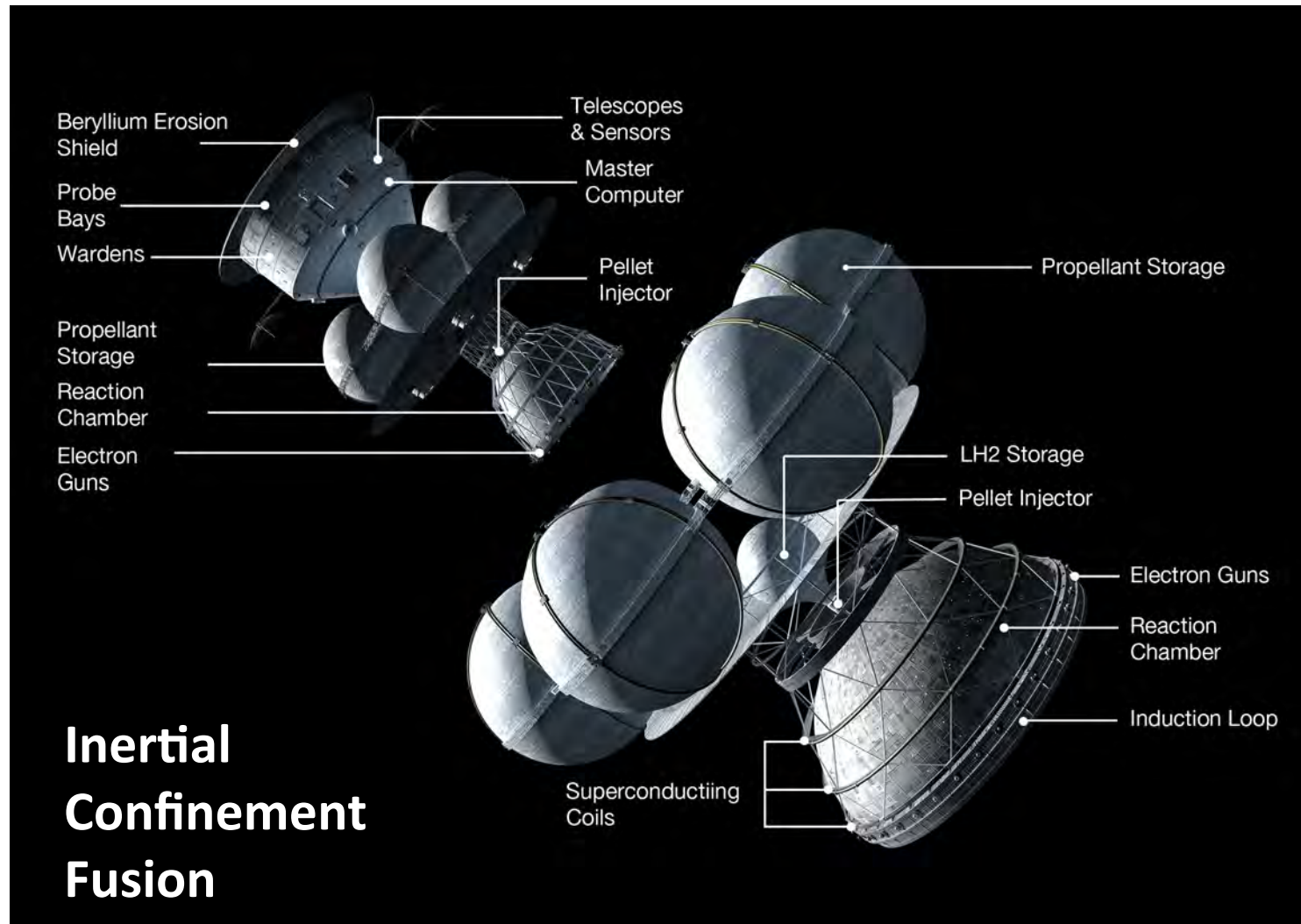


Moon rockets and people

Saturn 5 launch mass
3,500 tons (US)



Daedalus and Icarus – the heavy family



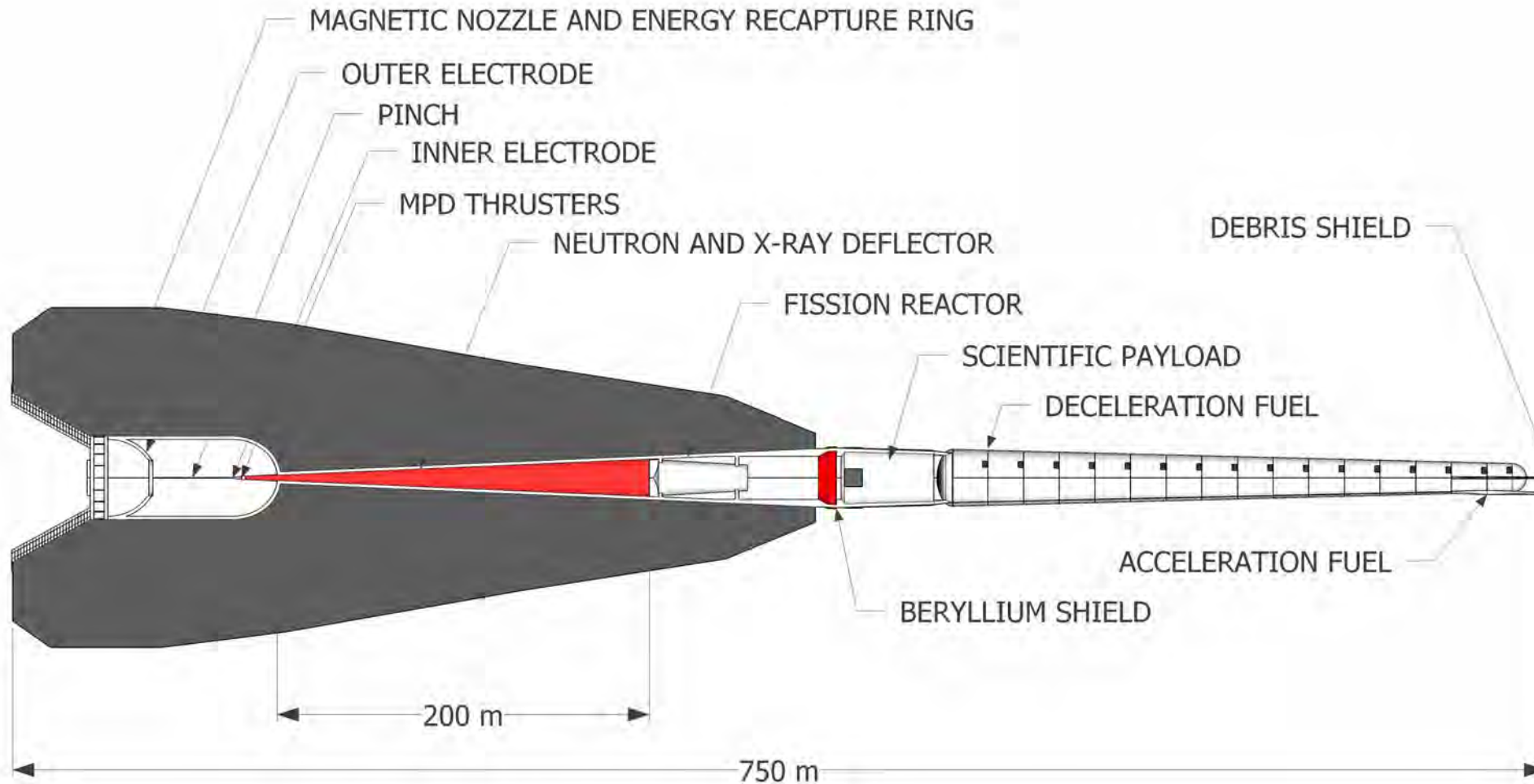
**50,000
tons**

BIS Daedalus 1978
credit: Adrian Mann





Daedalus and Icarus – the heavy family



**Icarus
Firefly
2018**

credit: Michel
LaMontagne

**Z-Pinch
Fusion**

i4is.org/reaching-the-stars-in-a-century-using-fusion-propulsion/



Laser Sails - The i4is Andromeda study

- Commissioned by Breakthrough Initiative Project Starshot - 2016
- *Initial Considerations for the Interstellar (Andromeda) Probe: A Three Day Study* i4is.org/what-we-do/technical/andromeda-probe/
 - laser sail propulsion – space-based – about 1 GW
 - 50 year time of flight
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All accessible via Google Scholar

The LGM factor – lessons from - Jocelyn Bell Burnell,
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What is 1I/'Oumuamua?

i4is Project Lyra – missions to ISOs

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- A Hibberd, AM Hein & TM Eubanks. *Project Lyra: Catching 1I/'Oumuamua-Mission Opportunities After 2024.* Acta Astronautica, 170, May 2020 arxiv.org/abs/1902.04935
- A Hibberd et al. *Feasibility of a Mission to Interstellar Comet C/2019 Q4 (Borisov)* September 2019 arxiv.org/abs/1909.06348
- A Hibberd & AM Hein. *Project Lyra: Catching 1I/'Oumuamua -- Using Laser Sailcraft in 2030*, arxiv.org/abs/2006.03891v1

Also – The Feasibility and Benefits of In Situ Exploration of 'Oumuamua-like Objects, Seligman and Laughlin (Yale) 2018, Astro J v55 #5, 2018 – first published April 2018 arxiv.org/pdf/1803.07022.pdf



1I/Oumuamua and 2I/Borisov — the unexpected and the half-expected interstellar visitors - Leeds Astro Soc – 10 June 2020

i4is.org/videos/the-unexpected-and-the-half-expected-interstellar-visitors/

The screenshot displays a simulation titled "Project Lyra" showing the trajectory of an interstellar object. The object's path is a complex loop that passes near Jupiter and Earth. Key data points are provided:

- 2035 SEP 11 14:00:21**
DISTANCE FROM SUN = 2.8AU
SPEED = 16.7km/s
- Jupiter 2034 JUL 12 11:54:56**
CLOSEST APPROACH = 262748.90km
DeltaV at Jupiter = 0.1km/s
CUMULATIVE DeltaV = 8.2km/s

The simulation also shows the orbits of Jupiter and Earth. A vertical sidebar on the right contains five video thumbnails of participants in a virtual meeting. In the bottom right corner, there is a circular logo for the "INITIATIVE FOR INTERSTELLAR STUDIES" featuring a stylized interstellar probe and a star.

Interstellar Studies – books, web, films

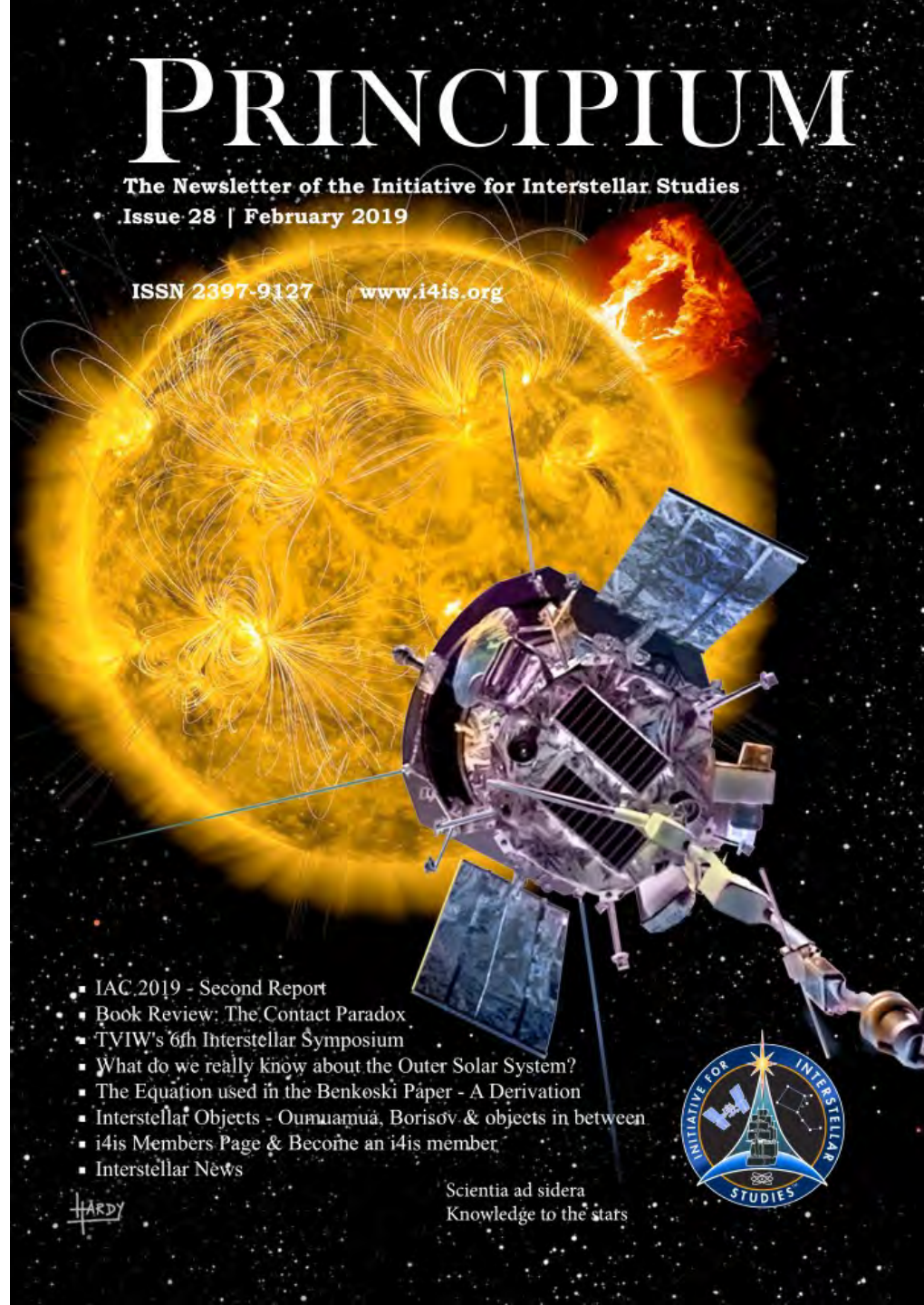
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- WEB - i4is.org, tviw.us, www.bis-space.com, tauzero.aero,
breakthroughinitiatives.org/initiative/3, www.esa.int/gsp/ACT/acta_futura/issue12/
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 - ***Interstellar*** - Prof Kip Thorne (Caltech) envisages a wormhole -
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The i4is
quarterly

PRINCIPIUM
magazine is free!

i4is.org/Publications/Principium



PRINCIPIUM

The Newsletter of the Initiative for Interstellar Studies
Issue 28 | February 2019

ISSN 2397-9127 www.i4is.org

- IAC 2019 - Second Report
- Book Review: The Contact Paradox
- TVIW's 6th Interstellar Symposium
- What do we really know about the Outer Solar System?
- The Equation used in the Benkoski Paper - A Derivation
- Interstellar Objects - Oumuamua, Borisov & objects in between
- i4is Members Page & Become an i4is member
- Interstellar News



Scientia ad sidera
Knowledge to the stars

HARDY



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- To the Stars in a Century:
Z-Pinch fusion & Firefly Icarus
- IAC 2018 Bremen - interstellar & i4is
- Breakthrough Propulsion Physics
- Book Review: Exoplanètes
- Interstellar News
- News Features
 - Moon, Mars & beyond - an RI debate
 - Catching A Little Bit of Heaven
 - i4is HQ Symposium & Lecture
 - Wormholes & Time Machines
 - How far have we come?



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John I. Davies - The Initiative & Institute for Interstellar Studies, email: John.Davies@i4is.org

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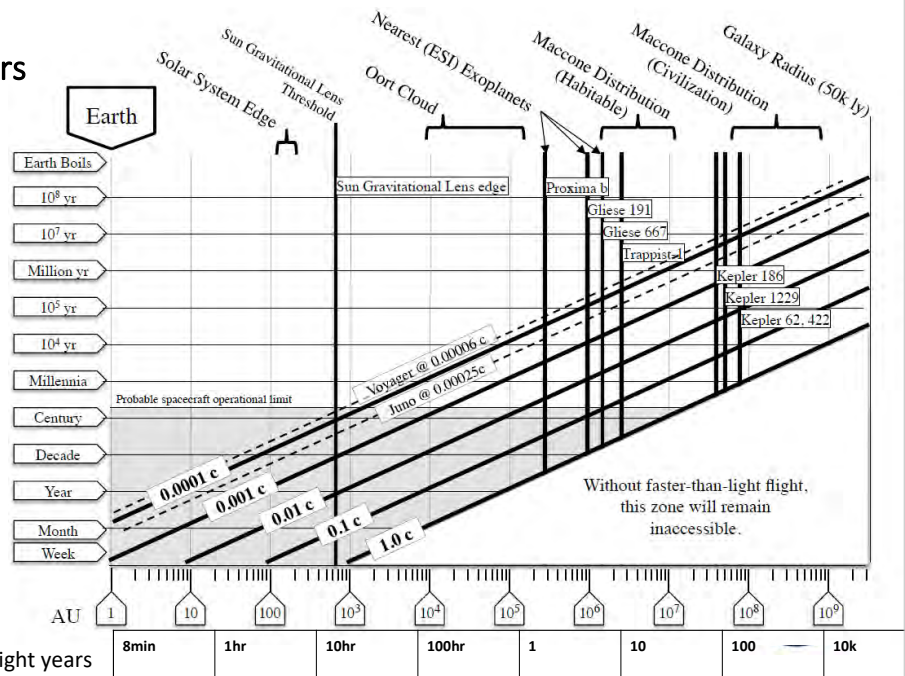
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Tau Zero Foundation-Breakthrough Propulsion Study - Assessing Interstellar Flight
Challenges and Prospects - NASA Grant No. NNX17AE81G

First Year Report- Prepared by: Marc G. Millis, Jeff Greason, Rhonda Stevenson

June 2018

Fig. 2. Correlating Interstellar Distances with Human Timescales and Flight Speeds

Figure Caption: This figure shows the correlation between long timescales, interstellar distances, and average flight speed. Both the distance and timescales are logarithmic. The horizontal scale spans the radius of the Milky Way galaxy (50,000 ly), while the time scale extends all the way to the certain end of Earth's habitability (~1 billion years [35]). The assumed upper limit for the operational duration of a space probe (200 years) is shown. The diagonal lines represent different speeds, starting on the left with Voyager's 0.00006 c. The faster Juno spacecraft (0.00025 c) is also shown. The other diagonal lines are in terms of fractional lightspeed, shown in increasing factors of 10 all the way up to lightspeed. For each factor of 10 increase in speed, the required energy goes up by at least a factor of 100.

The Heavy Way – The Rocket Equation

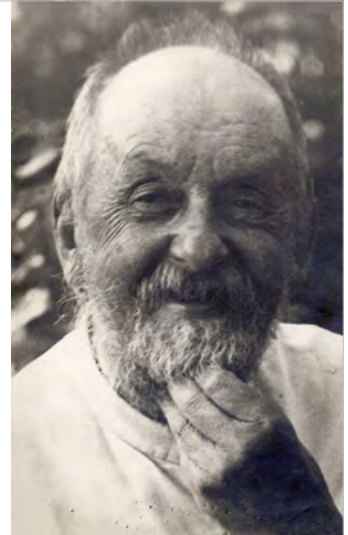
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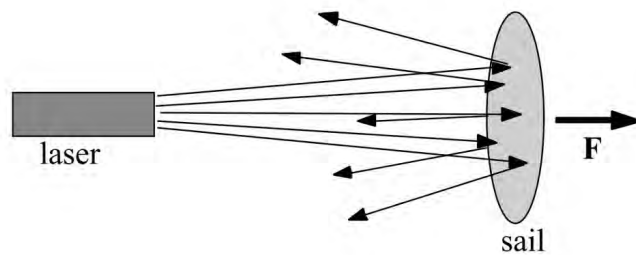
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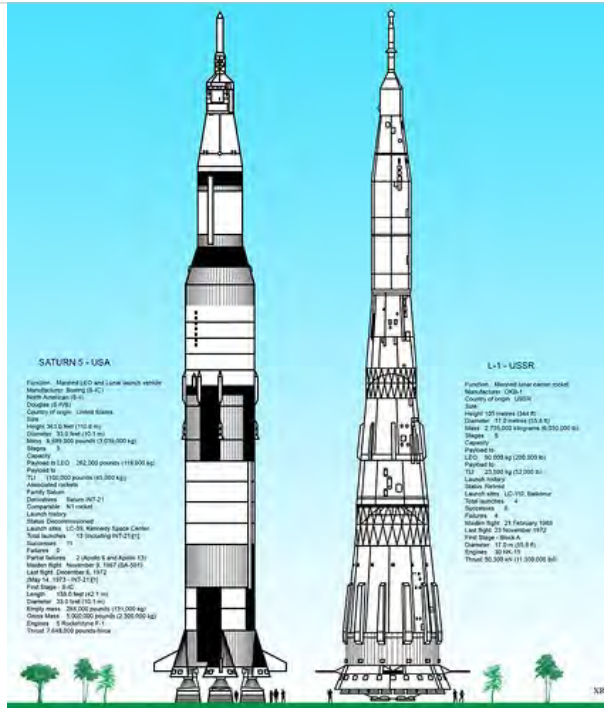
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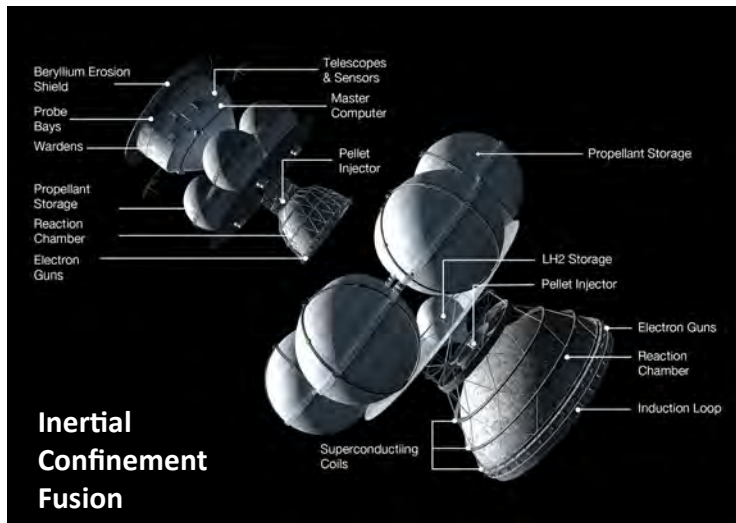


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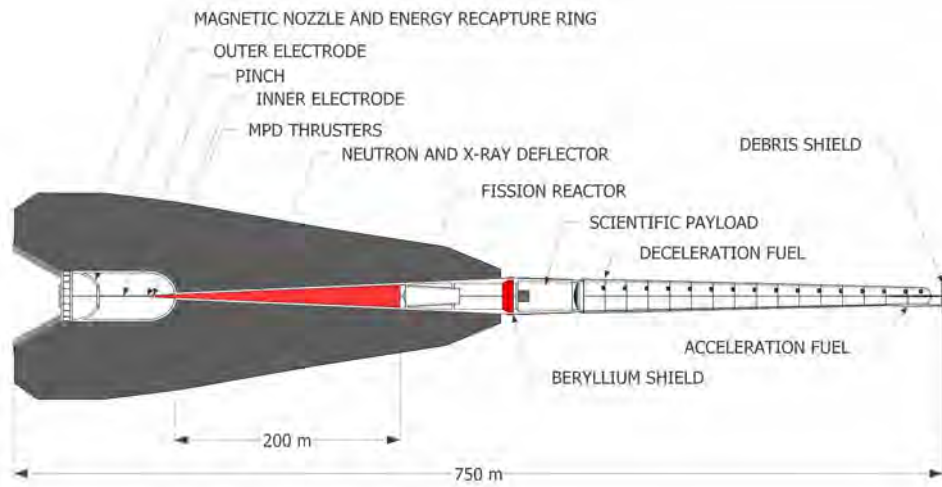
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credit: Adrian Mann





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i4is.org/reaching-the-stars-in-a-century-using-fusion-propulsion/

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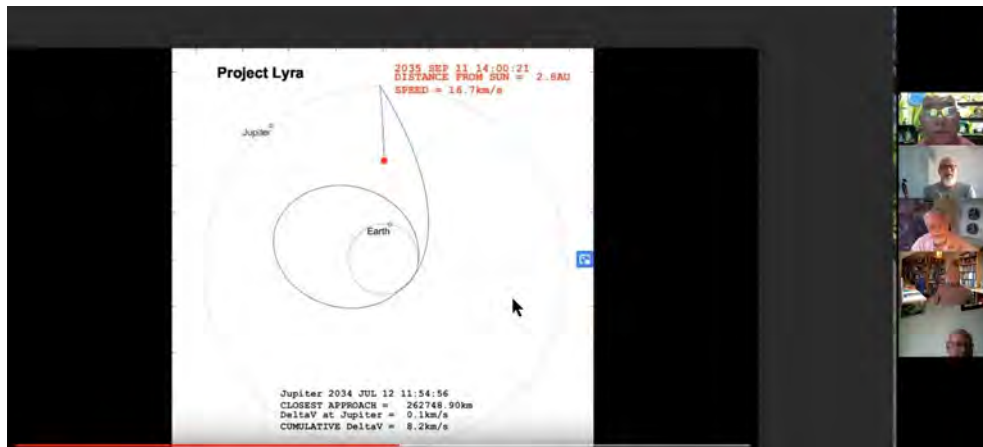
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About our Logo The logo for the Initiative for Interstellar Studies was designed jointly by Kelvin F. Long and Adrian Mann during the summer 2012, with input from George Abbey Junior, Rob Swinney, Richard Osborne, Stephen Ashworth, Gemma Long and Jonathan Brooks.

HMS Challenger ([en.wikipedia.org/wiki/HMS_Challenger_\(1858\)](http://en.wikipedia.org/wiki/HMS_Challenger_(1858))) ... scientific expedition that set out in 1872... Can we build ships which also venture to explore the ocean of knowledge before us, and so cross the technological horizon, and build similar vessels which cross the sea of Suns – Starships.. **the star at the top of the logo represents the stretch goal that ‘interstellar flight’ provides** to develop ... capabilities to explore interplanetary space, interstellar space and the voids in between. **The International Space Station** is .. the first great modern wonder of space made by human hands, and is an example of what can be accomplished when peaceful co-operation between nations is embraced **Pegasus is a constellation of the stars, with 51 Pegasi being indicated as the first exosolar planet to be discovered orbiting another Sun-like star**, some fifty light years away. Pegasus . . . the Greek mythological winged horse, an artefact of our imagination. Starships too, are considered pure fantasy by many, ... Pegasus symbolises our quest to turn imagination into reality ...

... **the logo ... four key sides of the interstellar square**. Firstly, the need to **develop the science and the technology, symbolised by the atom**, Second, the **motivation for discovery and the political and cultural courage to embrace ... opportunities within our grasp, symbolised by the ship**. Third, ... develop ... **capabilities ... to support such missions, symbolised by the ISS**. Fourth, ... **a destination ..., symbolised by the constellation of Pegasus**. Finally, the **ship can be viewed as our quest to explore Earth (our past), the ISS as our quest to explore interplanetary space (our present) and the constellation as our quest... to explore interstellar space (our future)** and ultimately evolve to an interstellar civilization.