IAC 2022

72nd International Astronautical Congress 2022
The Interstellar Papers

edited by John I Davies

This year the International Astronautical Federation is holding the 2022 International Astronautical Congress in Paris 18-22 September. Here we report on items which are likely to be of special interest to Principium readers. Some are explicitly interstellar in topic but others are important in contributing to our interstellar goal including innovations in propulsion, exploitation of resources in space, deep space communication and control, enhanced and economical access to space, etc.

Please contact john.davies@i4is.org if you have comments, find discrepancies or have additional items you think we should cover at the Congress.

We will have the first of two reports on the Congress in our next issue, Principium 39, in November. Our congress reports will not necessarily be restricted to this selection.

The overall contents of the technical congress is at iafastro.directory/iac/browse/IAC-22/

A1. IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM

A2. IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM

A3. IAF SPACE EXPLORATION SYMPOSIUM

A4. 51st IAA SYMPOSIUM ON THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) – The Next Steps

A5. 25th IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM

A6. 20th IAA SYMPOSIUM ON SPACE DEBRIS

A7. IAF SYMPOSIUM ON ONGOING AND NEAR FUTURE SPACE ASTRONOMY AND SOLAR-SYSTEM SCIENCE MISSIONS (this item was removed from the IAC22 website around 30 June 2022)

B1. IAF EARTH OBSERVATION SYMPOSIUM

B2. IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM

B3. IAF HUMAN SPACEFLIGHT SYMPOSIUM

B4. 29th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS

B5. IAF SYMPOSIUM ON INTEGRATED APPLICATIONS

B6. IAF SPACE OPERATIONS SYMPOSIUM

C1. IAF ASTRODYNAMICS SYMPOSIUM

C2. IAF MATERIALS AND STRUCTURES SYMPOSIUM

C3. IAF SPACE POWER SYMPOSIUM

C4. IAF SPACE PROPULSION SYMPOSIUM

D1. IAF SPACE SYSTEMS SYMPOSIUM

D2. IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM

D3. 20th IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT

D4. 20th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE

D5. 55th IAA SYMPOSIUM ON SAFETY, QUALITY AND KNOWLEDGE MANAGEMENT IN SPACE ACTIVITIES

D6. IAF SYMPOSIUM ON COMMERCIAL SPACEFLIGHT SAFETY ISSUES

E1. IAF SPACE EDUCATION AND OUTREACH SYMPOSIUM

E2. 50th STUDENT CONFERENCE

E3. 35th IAA SYMPOSIUM ON SPACE POLICY, REGULATIONS AND ECONOMICS

E4. 56th IAA HISTORY OF ASTRONAUTICS SYMPOSIUM

E5. 33rd IAA SYMPOSIUM ON SPACE AND SOCIETY

E6. IAF BUSINESS INNOVATION SYMPOSIUM

E7. IISL COLLOQUIUM ON THE LAW OF OUTER SPACE

E8. IAA MULTILINGUAL ASTRONAUTICAL TERMINOLOGY SYMPOSIUM

E9. IAF SYMPOSIUM ON SECURITY, STABILITY AND SUSTAINABILITY OF SPACE ACTIVITIES

E10. IAF SYMPOSIUM ON PLANETARY DEFENSE AND NEAR-EARTH OBJECTS

GTS. GLOBAL TECHNICAL SYMPOSIUM

LBA. LATE BREAKING ABSTRACTS

Below is how they fit into the week Sunday 18th to Thursday 22nd -

Date	18/09/2022	19/09/2022	19/09/2022	20/09/2022	20/09/2022	21/09/2022	21/09/2022	22/09/2022	22/09/2022
Time / Room Number	15:15-17:45	10:15-12:45	15:00-17:30	10:15-12:45	15:00-17:30	10:15-12:45	15:00-17:30	10:15-12:45	13:45-16:15
N04	A3.1	A3.2A	A3.2B	A3.3A	A3.3B	A3.4A	A3.5	A3.2C	A3.4B
S06	D2.1	D2.3	D2.2	D2.4	D2.5	D2.6	D2.7	D2.8/A5.4	D2.9/D6.2
S05	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C1.7	C1.8	C1.9
S04	A6.7	A6.9	A6.4	A6.3	A6.2	A6.5	A6.6	A6.8/E9.1	A6.1
S03	B3.1	B3.2	B3.3	B3.4/B6.4	B3.5	B3.6/A5.3	B3.7	B3.8	A6.10/E10.2
S02	B4.1	B4.2	B4.3	B4.4	B4.5	B4.6B	B4.7	B4.8	B4.6A
S01	E7.1	E7.2	E7.3	E7.4		E7.6/E3.5	E10.1	E7.5	E7.7
W07	C4.1	C4.3	C4.5	C4.2	C4.6	C4.7	C4.8/B4.5A	C4.9	C4.10/C3.5
W06	C2.1	C2.2	C2.3	C2.4	C2.5	C2.6	C2.7	C2.8	C2.9
W05	A1.1	A1.2	A1.3	C4.4	A1.4	A1.5	A1.6	A1.7	A1.8
W04	A2.1	A4.1	A4.2	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7
W03	D1.1	D1.2	D1.3	A5.1	A5.2	D1.4A	D1.4B	D1.5	D1.6
W02	B1.1	C3.1	C3.2	B1.2	B1.3	B1.4	B1.5	B1.6	C3.4
E04B	E9.2	E3.1	E3.2	E3.3	E3.4	A7.1	E3.6	A7.2	E8.1
W01	E5.1	D5.1	E5.2	D5.2	E5.3	D5.3	E5.4	E5.5	E5.6
731/732	B5.1	B2.1	B2.2	B2.3	B2.4	B2.5	B2.6	B2.7	A7.3
E08B	E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E1.7		E1.9
E06B	D4.1	D4.2	D4.3	D3.1	D3.2A	D4.4	D4.5	D3.2B	D3.3
E03B	E2.1	E2.2	B6.3	E2.4	B5.2	B5.3	B6.1	B6.2	B6.5
W08	B2.8/GTS.3	D6.1	E2.3/GTS.4	D6.3	E6.5/GTS.1	C3.3	B4.9/GTS.5	D5.4	B3.9/GTS.2
733/734		E6.4	E6.3	E6.2	E4.1	E4.2	E6.1	E4.3	
ISZ								E1.8	

Category A: Science & Exploration	A1--> A7	Category C: Technology	C1--> C4	Category E: Space & Society	E1--> E9
Category B: Applications & Operations	B1--> B6	Category D: Infrastructure	D1--> D6		

Rooms versus dates and times

Credit: IAF

- followed by links to Index pages including room, company and author.

The Papers

The Code and link gives the IAF refererence for each paper (prefix "IAC-22," if you want to quote the full reference) and a link to the IAF summary page which includes an onward link to the PDF of the abstract.

Our summary is in the box below each table.

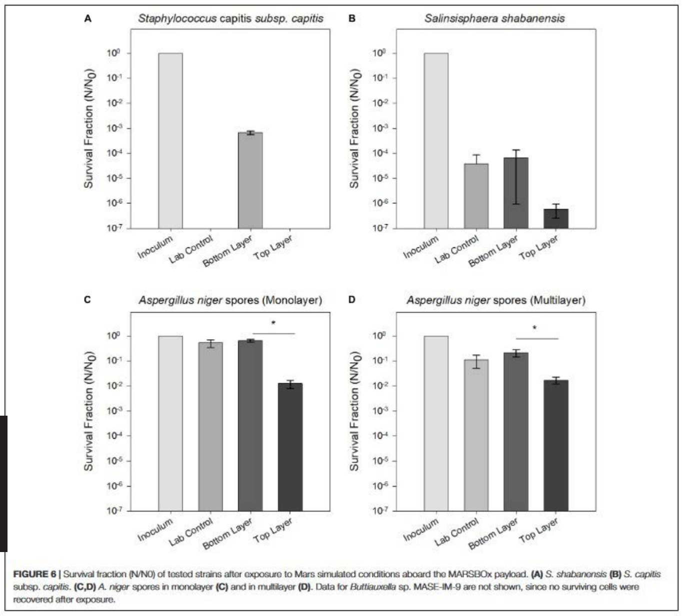
◀ A1. IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM
iafastro.directory/iac/browse/IAC-22/A1/

Astrobiology and Exploration IAC-22,A1,6 iafastro.directory/iac/browse/IAC-22/A1/6/

Code and link	title of talk/paper	presenter	institution	nation
A1,6,2,x68198 iafastro.directory/iac/paper/id/68198/summary/	Salinisphaera Shabanensis - A New Astrobiological Model Organism	Dr Petra Rettberg	DLR [1]	Germany

Having tested the response of a variety of (facultative) anaerobic microorganisms to conditions on current day or on early Mars, Rettberg et al report that Salinisphaera shabanensis, previously isolated from a deep-sea brine, is also radiation tolerant and can survive long periods of desiccation making it a promising new model organism for astrobiology.

The image shows the results of research in survivability of microorganisms in a simulated Mars environment.

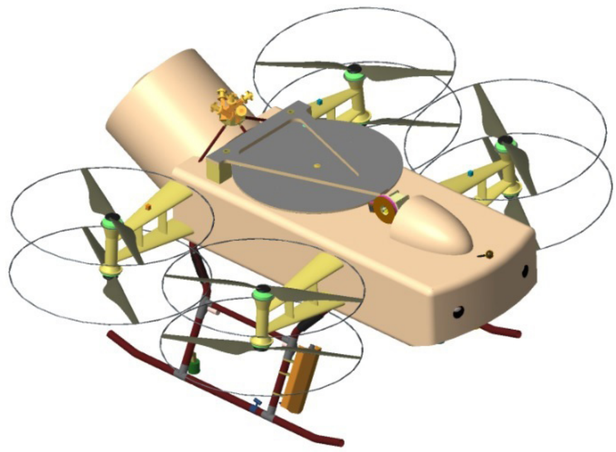


Survival fraction (N/N0) of tested strains after exposure to Mars simulated conditions aboard the MARSBOx payload [2]

Credit(image and caption): Cortesão et al

Code and link	title of talk/paper	presenter	institution	nation
A1,6,4,x73104 iafastro.directory/iac/paper/id/73104/summary/	Space exploration of icy moons to determine their astrobiological potential	Dr Athena Coustenis	LESIA - Observatoire de Paris	France

Jupiter’s Europa and Ganymede show indications of harbouring liquid water oceans under their icy crusts, which, in the case of Europa, may be in direct contact with a silicate mantle floor and kept warm through time by tidally generated heat. Around Saturn, Titan and Enceladus, were found to possess organic chemistries with seasonal variations, unique geological features and internal liquid water oceans. They provide a conceptual basis within which new theories for understanding habitability can be constructed. This talk will focus on the new scientific insights that will be offered by ESA’s JUICE mission and NASA's recently selected Dragonfly mission.



The Dragonfly configuration for atmospheric flight (with the gray circular HGA stowed flat). Note the aerodynamic fairing in front of the HGA gimbal. The cylinder at rear is the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). A sampling drill mechanism is visible in the nearside skid leg, and forward-looking cameras are recessed into the tan insulating foam forming the rounded nose of the vehicle. The rotor wing section and planform are designed for the Titan atmosphere.
Credit (image and caption): Figure 3, Lorenz et al, *Dragonfly: A Rotorcraft Lander Concept for Scientific Exploration at Titan*, 2018
www.jhuapl.edu/content/techdigest/pdf/V34-N03/34-03-Lorenz.pdf

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[1] DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V.
[2] *MARSBOx: Fungal and Bacterial Endurance From a Balloon-Flown Analog Mission in the Stratosphere*, Cortesão et al, DLR, https://www.researchgate.net/profile/David-Smith-251/publication/349495107_MARSBOx_Fungal_and_Bacterial_Endurance_From_a_Balloon-Flown_Analog_Mission_in_the_Stratosphere/links/6033c00a4585158939c130a1/MARSBOx-Fungal-and-Bacterial-Endurance-From-a-Balloon-Flown-Analog-Mission-in-the-Stratosphere.pdf

A1,6,8,x68072 iafastro.directory/iac/paper/id/68072/summary/	Cubesat lunar cycler platform to measure darwinian evolution beyond low earth orbit	Ms Yana Charoenboonvivat	School of Aerospace Engineering, Georgia Institute of Technology	USA

Life can be defined as a "self-sustaining chemical system capable of Darwinian evolution." Biological Exploration Payload 2 (BioX2) is targeted for launch to the International Space Station (ISS) to grow and evolve Bacillus subtilis under selective pressure provided by ultraviolet (UV) radiation. This paper suggests that a subsequent BioX3 cislunar CubeSat mission integrates BioX2's core astrobiology experiment into a lunar cycler to characterize the effects of deep-space radiation on microbial evolution beyond the radiation shielding provided by Earth's magnetosphere.

A3. IAF SPACE EXPLORATION SYMPOSIUM
/iafastro.directory/iac/browse/IAC-22/A3/

Small Bodies Missions and Technologies (Part 2) IAC-22, A3, 4B

iafastro.directory/iac/browse/IAC-22/A3/4B/

A3,4B,10,x70801 iafastro.directory/iac/paper/id/70801/summary/	Mission architecture and spacecraft design for long-term contact studies of the interstellar asteroid 1I/Oumuamua	Dr Olga Bannova	University of Houston	USA

This paper presents an explorative study conducted by a team of more than 100 undergraduate and graduate students and young scientists from Russia, USA, France, Switzerland, Italy and UK who participated in the International Youth Scientific School "Space Development: Theory and Practice - 2021", held at Bauman Moscow State Technical University which developed a technical proposal for a complex of spacecraft for long-term contact study of the interstellar asteroid 1I/Oumuamua. The proposal included braking to rendezvous, detailed surface examination usung a spider robot and guidance to target using a Hubble-class telescope. The paper includes a computational analysis of options for mission architecture and new technology suggestions for small body studies.

The paper has two further co-authors from the Bauman Moscow State Technical University.

Solar System Exploration including Ocean Worlds IAC-22,A3, 5

iafastro.directory/iac/browse/IAC-22/A3/5/

A3,5,2,x71874 iafastro.directory/iac/paper/id/71874/summary/	Exploration of Venus Using Bioinspired Flier, BREEZE	Mr Nicholas Noviasky	University at Buffalo	USA

BREEZE is the Bioinspired Ray for Extreme Environments and Zonal Exploration developed by the CRASHLAB team from the University at Buffalo-The State University of New York combining an inflatable structure with bioinspired propulsion to create a buoyant flyer that could efficiently scan the surface of Venus, map the magnetic field, and analyze the atmospheric composition for signs of life. The concept combines the benefits of both lift and buoyancy-based aircraft. BREEZE can flap to overcome the winds of Venus and traverse a range of altitudes by actively controlling its volume and has the ability to survive without the Sun's power on the dark side of the planet. The team has explored thrust production capabilities of the bioinspired motion, advanced structural analysis techniques of the flexible structure, and proof of concept actuation methods with string actuators.

visualisation of BREEZE. Credit: NASA [1]

[1] www.nasa.gov/directorates/spacetech/niac/2019_Phase_I_Phase_II/breeze/

◀ Note that Venus rotates about twice during each orbit around the Sun - it has a synodic day length of 117 Earth days and a sidereal rotation period (about the Sun) of 243 Earth days.

The apparent detection of phosphine, a potential biosignature, led to several studies of Venus atmospheric vehicles including from a team centred on i4is [1].

A3,5,4,x70283 iafastro.directory/iac/paper/id/70283/summary/	Feasibility study of a robotic space mission for searching trace of life on Europa	Mr Mario Rizzi	Politecnico di Torino	Italy

Europa is the smallest of the four Galilean moons orbiting Jupiter. However it is only slightly smaller than Earth's Moon and has smooth icy surface making it probable that a water ocean exists beneath the surface. Oceans are good at supporting "life as we know it" so missions to explore beneath that surface are very attractive - while remaining highly technically challenging.

This paper describes work performed during the 2nd Level Specializing Master Programme SEEDS (SpacE Exploration and Development Systems), now in its fourteenth edition, to develop a feasibility study for a future space mission to Europa yielding the detailed design of a lander capable of drilling, moving, and employing ice probes with the involvement of three Universities (Politecnico di Torino, ISAE-SUPAERO and University of Leicester), space agencies and industries (ASI, Thales Alenia Space, CNES and ESA) and a team of forty-five students hosted in the cities of Turin, Toulouse, and Leicester during a five-month period.

A4. 51st IAA SYMPOSIUM ON THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) – The Next Steps

SETI 1: SETI Science and Technology IAC-22, A4, 1

iafastro.directory/iac/browse/IAC-22/A4/1/

A4,1,1,x73848 iafastro.directory/iac/paper/id/73848/summary/	KEYNOTE (Pesek Lecture): Breakthrough Listen Search for Intelligent Life in the Galactic Plane with the Parkes Telescope	Ms Karen Perez	Columbia University	USA

The Breakthrough Listen (BL) programme is a 10-year effort to conduct the most sensitive, comprehensive, and intensive search for advanced intelligent life on other worlds ever performed. This will be an update on the programme.

A4,1,3,x72363 iafastro.directory/iac/paper/id/72363/summary/	Automation and target selection for commensal SETI observing	Dr Daniel Czech	University of California, Berkeley	USA

Radio telescope arrays offer exciting opportunities for commensal SETI surveys. Ethernet-based architectural approaches adopted by MeerKAT, the VLA[2] and the Allen Telescope Array allow multiple observers to receive data simultaneously. This paper describes the automation of Breakthrough Listen’s commensal observing at MeerKAT including the optimal automated response of the observing system to different scenarios, along with the associated processing, target selection and survey figures of merit. Practical implementation details are discussed, including the software (in development) [3] written to automate observations - with an evaluation observing performance under different scenarios.

UC Berkeley SETI Program logo

[1] *Precursor Balloon Mission for Venusian Astrobiology*, The Astrophysical Journal Letters, Volume 903, Number 2, April 2020 https://iopscience.iop.org/article/10.3847/2041-8213/abc347/pdf
[2] Hickish et al *Commensal, Multi-user Observations with an Ethernet-based Jansky Very Large Array*, 2019. arxiv.org/abs/1907.05263
[3] github.com/UCBerkeleySETI/commensal-automator

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A4,1,8,x73676 iafastro.directory/iac/paper/id/73676/summary/	SETI India: A search for techno-signatures from extraterrestrial life using uGMRT.	Mr Arun Muraleedharan	Amity University Mumbai	India

Despite the large scale radio SETI activities at numerous observing facilities, there exists a dearth of continuous frequency coverage between 300 MHz and 1 GHz. Upgraded Giant Metrewave Radio


A panoramic view of the GMRT telescope, located near Pune, India. Credit(image and caption): The SKA Project https://www.skatelescope.org

Telescope's (uGMRT) [1] operation capability at these frequencies makes it a desired and complementary instrument with ongoing SETI activities. The GMRT also provides unique opportunities to capture phased array beam voltages parallel with interferometric imaging visibilities. This papers present ongoing efforts in SETI, the first of their kind in India, to capture the raw stream of data products from the uGMRT and conduct searches for novel signals likely to be produced by the activities of advanced ETIs.

A4,1,10,x72939 -iafastro.directory/iac/paper/id/72939/summary/	Extragalactic SETI	Prof Mike Garrett	University of Manchester	UK

Even the largest radio telescopes observing at 1-2 GHz have a field-of-view that spans several arcminutes, and the Breakthrough Listen (BL) surveys therefore often encompass many distant background sources. To appreciate and exploit the presence of extragalactic objects in the field of view, the Aladin sky atlas (aladin.u-strasbg.fr/) and NED (NASA/IPAC Extragalactic Database) were employed to make a rudimentary census of extragalactic objects that were serendipitously observed as part of one of the initial Breakthrough Listen observing campaigns. Using the 100-m Greenbank telescope observing at 1.1-1.9 GHz, 692 fields were originally targeted, each selected to contain a nearby star of known distance. This work examines 469 of these fields. Several nearby galaxies, galaxy groups and galaxy clusters are identified, permitting the parameter space probed by SETI surveys to be significantly extended. It is demonstrated that the recent Breakthrough Listen Initiative, and indeed many previous SETI radio surveys, place stronger limits on the prevalence of extraterrestrial intelligence in the distant Universe than is often fully appreciated.

Mike Garret and the Manchester Mark 1 (aka Lovell telescope)
Credit: @Mike_Garrett/Twitter

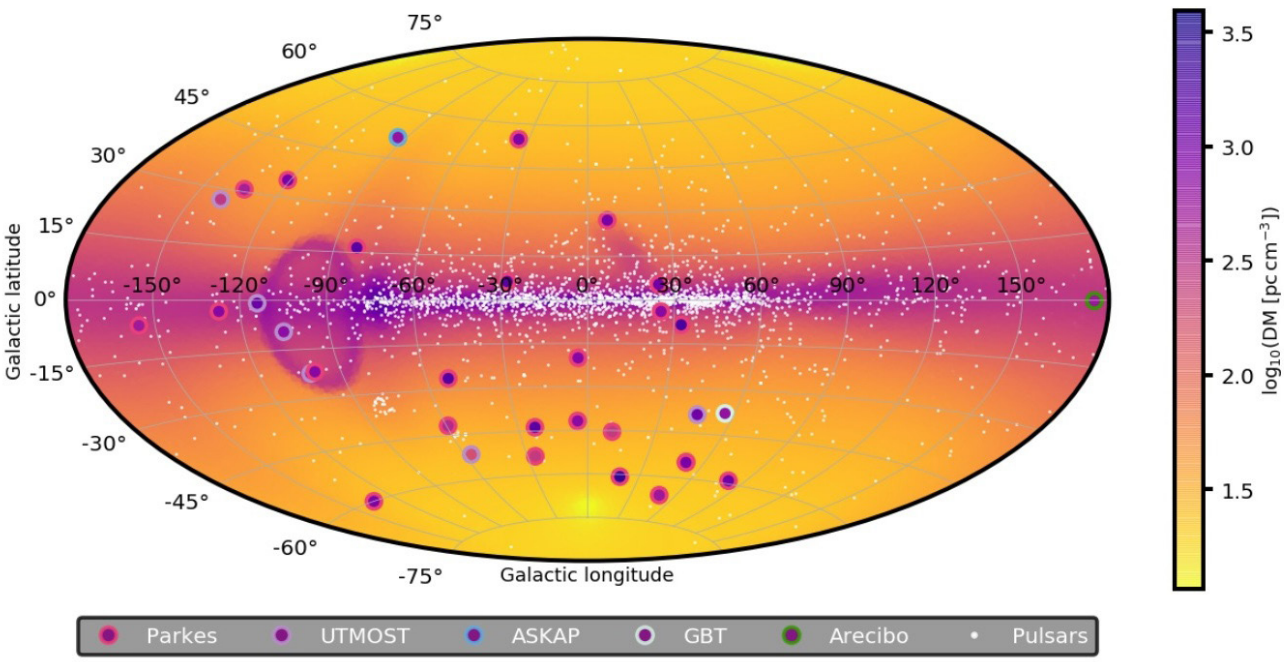
[1] Gupta et al *The upgraded GMRT: opening new windows on the radio Universe*, 2017, https://tstwww.currentscience.ac.in/Volumes/113/04/0707.pdf

A4,1,12,x72537 iafastro.directory/iac/paper/id/72537/summary/	Upper bounds on technoemission rates from 60 years of silence	Mr Claudio Grimaldi	Ecole Polytechnique Fédérale de Lausanne (EPFL)	Switzerland

The lack of detection to date of electromagnetic technosignatures implies either that we have been unable to detect them due to incomplete sampling of the search space or that we cannot detect them because the Earth has been located during the entire history of SETI in a region of space not covered by artificial extraterrestrial emissions. Starting from the latter hypothesis, and assuming that technoemissions are generated in our galaxy at a constant rate. This paper derives probabilistic upper bounds on that rate. In the case of isotropic emissions, it finds a 5% probability that there are more than one to five emissions per century that are generated across the entire Milky Way and that higher emission rates can only be derived by assuming that a significant fraction of all technoemissions are anisotropic and randomly oriented narrow beams.

IAC-22,A4,1,15,x69772 iafastro.directory/iac/paper/id/69772/summary/	An Investigation of Fast Radio Bursts and its Feasibility as Technosignature	Ms Koena Maji	Manipal Institute of Technology	India

Fast radio bursts are astrophysical radio pulses which occur for a fraction of a millisecond to a few milliseconds. They appear sporadically - the first was discovered in 2007. They vary in terms of their periodicity, occurrence, and energy profile (but with unusually high intensity given their expected distance from Earth). Their origins and emission mechanism are unknown. Possible theories to explain them include astrophysical candidates such as magnetars (highly magnetized young neutron stars). But other theories suggest that they are from extragalactic civilisations - technosignatures. This paper studies the energy signature and responsible magnetic field strength for repeater and non-repeater FRBs including the possibility of originating from intelligent life.



The approximate locations of FRBs. The large coloured dots are the FRB positions from FRBcat, the colour of the edge of the dot indicates the observatory that detected the FRB. Credit (image and caption): MeerTRAP, or "more TRANsients and Pulsars", is a project to commensally use the MeerKAT telescope to search the sky for pulsars and fast transients. www.meertrap.org/science-goals/fast-radio-bursts/

SETI 2: SETI and Society IAC-22,A4,2

iafastro.directory/iac/browse/IAC-22/A4/2/

A4,2,2,x73236 iafastro.directory/iac/paper/id/73236/summary/	Fifty Years of SETI in the IAF Digital Library	Prof Claudio Maccone	International Academy of Astronautics (IAA) and Istituto Nazionale di Astrofisica (INAF)	Italy

Claudio Maccone is one of the most-distinguished and most long-engaged researchers in SETI. Here he reports that the IAF Digital Library covers fifty years of progress in SETI begining in 1959 with Giuseppe Cocconi and Philip Morrison [1]. He presents three conclusions:

1) Historians of SETI now have the IAF Digital Library to explore. Popular descriptions of the seventy years of SETI progress could be published and attract widespread attention even among non-technical readers.

2) Young SETI researchers should explore the IAF Digital Library to enrich their philosophical and technical SETI background. Only then will they be able to make good progress towards the future of SETI research.

3) The discovery of a host of exoplanets is now transforming SETI in the search for technosignatures by virtue of space missions like Tess and more. Then, exploring the IAF Digital Library is the best way to merge classical SETI learning with current and future scientific space missions.

Prof Maccone also has *Moon Farside Protection for SETI and Astronomy* (iafastro.directory/iac/paper/id/68273/summary/) in the same session.

A4,2,7,x70624 iafastro.directory/iac/paper/id/70624/summary/	SETI Space Telescope Mission Concepts Designed Around Upcoming Fully-Reusable Launch Vehicles	Mr Eric Michaud	Massachusetts Institute of Technology (MIT)	USA

Space-based radio telescopes would be highly desirable for conducting SETI observations. A primary reason for this is that such telescopes, if placed in a high Earth orbit or ideally on the Moon's far side, would experience far less Radio Frequency Interference (RFI) than ground-based observatories. But radio telescopes are bulky and heavy - think of Greenbank, Parkes and Jodrell Bank as single instruments or the Atacama Large Array (ALMA) and the Square Kilometer Array (SKA) under construction. The James Webb telescope shows how even one of the biggest launchers available, Ariane 5, requires much tricky folding to launch what is, by terrestrial standards, a fairly modest-sized optical telescope.

This paper notes that over the next few years fully-reusable launch systems like SpaceX's Starship may fundamentally change the tradeoffs and costs involved in designing and launching space telescopes. Starship resurrects the idea of the "big dumb booster" but it is re-usable, so not so dumb! The paper suggests that it may soon be cheaper to launch 100 tons of payload with Starship than any amount of mass with any other rocket and thus that we should design space telescopes around the payload capacity of the Starship. The paper discusses possible mission designs for a space-based radio telescope for SETI built around the Starship launch vehicle.

A4,2,15,x73175 iafastro.directory/iac/paper/id/73175/summary/	Romanticism in Science as a form of cognitive bias and SETI	Prof Gabriel G De la Torre	University of Cádiz	Spain

Romanticism was a reaction to the 19th century European Enlightenment driven by nationalism and physical materialism. This paper suggests that this represents the best early example of romanticism within astronomy supported by a perception of the beauties of nature. It suggests some SETI hypotheses may be at risk of suffering from a similar romantic tendency and risks anthropocentric cognitive bias. It will discuss several examples of this form of Neo-Romanticism, cultural implications, cognitive bias in human perception, information processing and science work relevant to SETI.

[1] *Searching for Interstellar Communications*. Nature, vol. 184, no. 4690, pages 844- 846, Sept. 19, 1959 - no open source version found.

◀ A6. 20th IAA SYMPOSIUM ON SPACE DEBRIS

iafastro.directory/iac/browse/IAC-22/A6/

As elsewhere, there is much more on this topic than you see below. This subset seems especially relevant to interstellar since access to space is a prerequisite for a wider solar system culture and economy upon which any major move to interstellar must be built. More at the URL above.

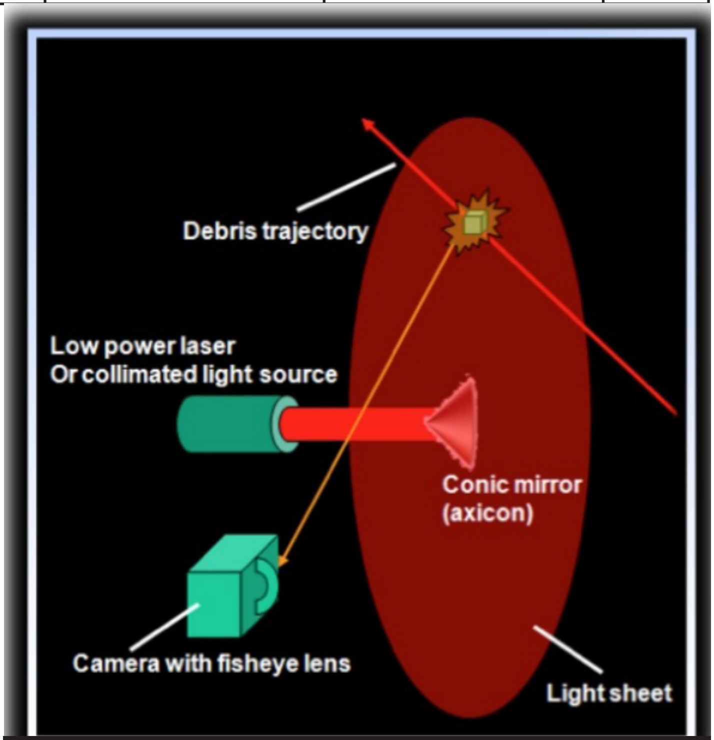
Space Debris Detection, Tracking and Characterization - Space Surveillance and Tracking (SST)

iafastro.directory/iac/browse/IAC-22/A6/1/

A6,1,8,x71592 iafastro.directory/iac/paper/id/71592/summary/	On-orbit Optical Detection of Lethal Non-Trackable Debris	Mr Andrew Nicholas	Naval Research Laboratory	USA

Objects in the size range of 0.1 mm to 3 cm are not currently trackable but have enough kinetic energy for lethal consequences to spacecraft. This paper proposes a light sheet sensor similar to the LARADO concept of the US Naval Research Laboratory (NRL).

Recent technology maturation efforts in an NRL laboratory successfully detected small debris (1.6 mm diameter) moving at 6.38 km/s ready for a flight demonstration on STPSat-7, under the Space Test Program (STP) of the US Department of Defense, in 2024.



LARADO concept [1]

Political, Legal, Institutional and Economic Aspects of Space Debris Mitigation and Removal - STM Security

iafastro.directory/iac/browse/IAC-22/A6/8-E9.1/

A6,8-E9.1,10,x69130 iafastro.directory/iac/paper/id/69130/summary/	Financial Incentives for Debris Removal Services	Mrs Morgane Lecas	Astroscale Ltd	UK

This paper starts from the premise that "Our use of space is already unsustainable". It assesses financial incentives for satellite operators to adopt debris removal services. The challenge is to develop commercially viable debris removal services bringing together mature technological solutions, favourable regulatory environment, and cost-effective solutions that customers are willing to pay for. The problem now is that "As in other sectors, once satellites reach their end-of-life they are no longer providing revenue to the operator, which means funds are not necessarily available for decommissioning at the required time." The paper assesses financial incentives for debris removal services - value to government and space agencies, external sinking or accrual funds, decommissioning guarantees and subsidies.

[1] breakingdefense.com/2019/04/nrls-larado-project-hopes-to-track-tiny-space-debris/

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◀ B2. IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM

iafastro.directory/iac/browse/IAC-22/B2/

Advances in Space-based Navigation Technologies IAC-22, B2, 1

iafastro.directory/iac/browse/IAC-22/B2/1/

IAC-22,B2,1,1,x69864 iafastro.directory/iac/paper/id/69864/summary/	Methods for Navigation in the Nearby Interstellar Medium	Dr John Christian	Georgia Institute of Technology	USA

This paper asserts that navigation is expected to be amongst the most challenging tasks for missions to the nearby interstellar medium (ISM) due to the immense distances involved. The paper presents detailed models for all of the major sources of navigation information, including Earth-based radiometric tracking, visible-spectrum star sightings, X-ray pulsar navigation (XNAV), StarNAV, and others - examining their utility and presenting numerical results to illustrate their efficacy.

C2 IAF MATERIALS AND STRUCTURES SYMPOSIUM

C2, 3 Space Structures - Dynamics and Microdynamics

iafastro.directory/iac/browse/IAC-22/C2/

IAC-22,C2,3,8,x73418 iafastro.directory/iac/paper/id/73418/summary/	Dynamic Stability of Flexible Lightsails for Interstellar Exploration	Dr Michael Kelzenberg	California Institute of Technology (Caltech)	USA

The Breakthrough Starshot Initiative requires stabilised propulsion of flexible membrane-like lightsails via radiation pressure from a high power phased-array laser source which can accelerate the lightsail spacecraft to relativistic speeds. This paper reports the first investigation of flexible, large area lightsail membranes driven by laser radiation pressure using a finite element model to describe the light-matter interactions for flexible ultrathin membranes - with attention to ideas such as spinning lightsails and embedded nanophotonic metagrating structures using anisotropic light scattering, for flat as well as curved membrane shapes.

C3. IAF SPACE POWER SYMPOSIUM

iafastro.directory/iac/browse/IAC-22/C3/

Space Power System for Ambitious Missions IAC-22,C3,4

iafastro.directory/iac/browse/IAC-22/C3/4/

IAC-22,C3,4,1,x73419 iafastro.directory/iac/paper/id/73419/summary/	Power Requirements and Technologies for Gram-Scale Interstellar Spacecraft	Dr Mason Peck	Cornell University	USA

The combination of extremely limited mass budget, long mission duration, and harsh operating environment poses considerable challenges to the development of a power source for gram-scale space probes accelerated to relativistic velocities by an earth-based laser source, as envisaged by the Breakthrough Starshot Initiative. This paper presents the results of an investigation into the suitability of various power generation and energy storage technologies for such missions. Base assumptions include requirements for 20 uW periodically during the 20-year transit phase of the mission, 1 W peak power during launch, flyby, and data return phases of the mission, with a total energy budget of 14 kJ. Topics include thin-film photovoltaics and conversion of kinetic energy through interaction with the interstellar medium, analysis of various energy storage schemes including chemical, electrical, and nuclear technologies, ranking these in terms of viability, risk, and technology readiness level (TRL). And identifying topics for future research and development.

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◀ C3. IAF SPACE POWER SYMPOSIUM C4. IAF SPACE PROPULSION SYMPOSIUM
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Joint Session on Advanced and Nuclear Power and Propulsion Systems

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This session, organized jointly between the Space Power and the Space Propulsion Symposiums, includes papers addressing all aspects related to advanced and nuclear power and propulsion systems for space applications.

IAC-22,C4,10-C3.5,2,x69597 iafastro.directory/iac/paper/id/69597/summary/	Early Progress toward the Feasibility of the Centrifugal Nuclear Thermal Rocket	Dr Dale Thomas	University of Alabama in Huntsville	USA

The Centrifugal Nuclear Thermal Rocket (CNTR) is a Nuclear Thermal Propulsion (NTP) concept designed to heat propellant directly by the reactor fuel [1] potentially delivering high specific impulse (1,800 seconds), similar to ion thrusters at much higher thrust. This paper reports further research progress in analytical modelling and simulation of the two-phase heat transfer between the liquid metallic uranium fuel and the gaseous propellant.

See also - C4,10-C3.5,3,x69402 iafastro.directory/iac/paper/id/69402/summary/ *Experimentally Backed Model of Bubbly Flow in a CNTP Reactor* and C4,10-C3.5,4,x73738 iafastro.directory/iac/paper/id/73738/summary/ *Exploring the Feasibility of a Power-Generating Pulsed Nuclear Magnetic Nozzle*, both from University of Alabama in Huntsville.

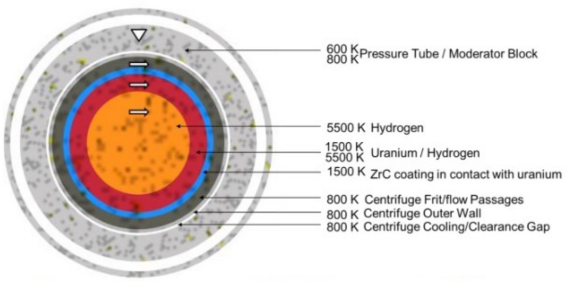

Fig. 2. Cross-section of CNTR Rotating Fuel Element

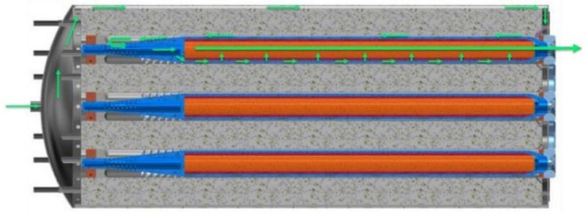
Fig. 3. Propellant Flow Path in the CNTR

Configuration of a Centrifugal Nuclear Thermal Rocket [2]

LBA,C4,3,x74497 iafastro.directory/iac/paper/id/74497/summary/	First laser beam to orbit Demonstrations, Modelling Spacecraft and Reflector, Beam Laser Propulsion Missions	Mr Kolemann Lutz	Mars University	USA

Mars University (MarsU, www.marsu.space) is an international academic and research organisation, a student run organisation and eSchool with a team of 20+ researchers, faculty, and staff. Kolemann Lutz outlines a laser demonstration of beam energy toward a spacecraft in MEO/GEO by Summer/Fall 2023. Using a 3 kW ground-based laser focused into a propellant heating chamber with up to 300-500 kg of hydrogen gas to reach up to 30,000 K achieving 1000 - 3,000 seconds specific impulse (Isp).

[1] See our earlier IAC reports IAC-21, C4.10- C3.5.11,x65142 *Toward the Engineering Feasibility of the Centrifugal Nuclear Thermal Rocket*, by Dr Thomas in Principium 36, page 32. and C4,10-C3.5,5,x66797 *Overview of the High Performance Centrifugal Nuclear Thermal Propulsion System* by Jimmy Allen (Dynetics) in Principium 36, pages 27 & 28. P36 is at i4is.org/wp-content/uploads/2022/02/Principium36-AW-2202191002opt.pdf
[2] from *Overview of High-Performance Centrifugal Nuclear Thermal Rocket Propulsion System*, Allen et al, 2021. local.ans.org/ne/wp-content/uploads/2021/02/OverviewCNTR-ANS-Winter-2020-summary-paper.pdf ▶

◀ D2. IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM
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Future Space Transportation Systems

iafastro.directory/iac/browse/IAC-22/D2/4/

D2,4,9,x67466 iafastro.directory/iac/paper/id/67466/summary/	Interplanetary transfer network design and technology roadmap for a sustainable off-world human community	Mr Koldo Zuniga	Cranfield University	UK

An interplanetary human civilization that expands beyond Earth to settle on other planets of the Solar System will require a transport network to connect the different human outposts via fast transfers and high-capacity spacecraft. This paper reports work to understand the requirements for such fast transfers in terms of engine technology and dry mass fraction, and identify when these capabilities could be available based on current TRLs [1] using models of one-way and round-trip Earth – Mars trajectories and the resulting ΔV requirements compared against minimum viable Isp, spacecraft dry mass fraction and refueling capability. It concludes that nuclear electric propulsion could yield 60 day trips to Mars within 20 years and, later, nuclear thermal propulsion could halve that trip time [2]. The paper identifies key requirements and constraints to be considered when designing and roadmapping an interplanetary transfer network capable of enabling a sustainable off-world human community.

Space Transportation Solutions for Deep Space Missions: D2,8-A5,4

iafastro.directory/iac/browse/IAC-22/D2/8-A5.4/

IAC-22,A5,4-D2.8,1,x68209 iafastro.directory/iac/paper/id/68209/summary/	Interstellar terminal and starship assembly in the Kuyper Belt	Giorgio Gaviraghi	Unispace Exponential Creativity	Italy

If starships carrying humans (or biology based ETIs) are built then it can be assumed that their civilisations will want to go beyond a single destination system. This paper suggests that "shipyards" for such proliferating civilisations might best be situated at the radius of trans-Neptunian objects. This paper aims to define and analyse these "terminal space settlements", their design, assembly and operations as well as the starships that would be built in the facilities including the definition of technologies and capabilities required.

We have visualised a "shipyard" for a first fusion starship for the cover of Principium 22. It would not, of course, accelerate from low Earth orbit!

Cover of Principium 22, Assembly of an Icarus Firefly vehicle in low Earth orbit. Credit: Michel Lamontagne.

A5,4-D2.8,2,x72880 iafastro.directory/iac/paper/id/72880/summary/	NASA Envisioned Future Priorities for In-Space Transportation	Mr John Dankanich	NASA	USA

A high-level overview of NASA's plans for the development of in-space transportation capabilities, a description of the state of the art, capability goals, technical challenges and gaps, and options for partnerships with industry and other agencies towards developing a robust logistics infrastructure to support NASA's objectives. Note this is purely in-space showing that NASA is getting more interested in getting around in space, perhaps leaving the literal "heavy lifting" to the likes of SpaceX, ULA and Blue Origin.

[1] Technology Readiness Level www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level
[2] Compare current missions around 180 days to Mars and note the importance of steam over sail for world trade, 15 knots (32 km/hour), when the wind blew, for a small "racer" cargo sailer like *Cutty Sark* in the 1870s versus the monster*Great Eastern* already achieving that speed in the 1860s.

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D2,8-A5.4,4,x68378 iafastro.directory/iac/paper/id/68378/summary/	Mission to Mars Using Space-Sourced Propellant	Dr Jan Thoemel	University of Luxembourg	Luxembourg

This paper anticipates storing propellant in space, specifically in a lunar orbit and Sun-Earth-Lagrange point 2 (where the James Webb and Gaia telescopes reside). Simulating missions for the 2026, 2028, 2030 departure windows, comparing propellant consumption of a direct mission versus missions refuelling in lunar orbit or at that Lagrange point and concluding refuelling can be cost effective.

D4. 20th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE

iafastro.directory/iac/browse/IAC-22/D4/

Innovative Concepts and Technologies IAC-22,D4,1

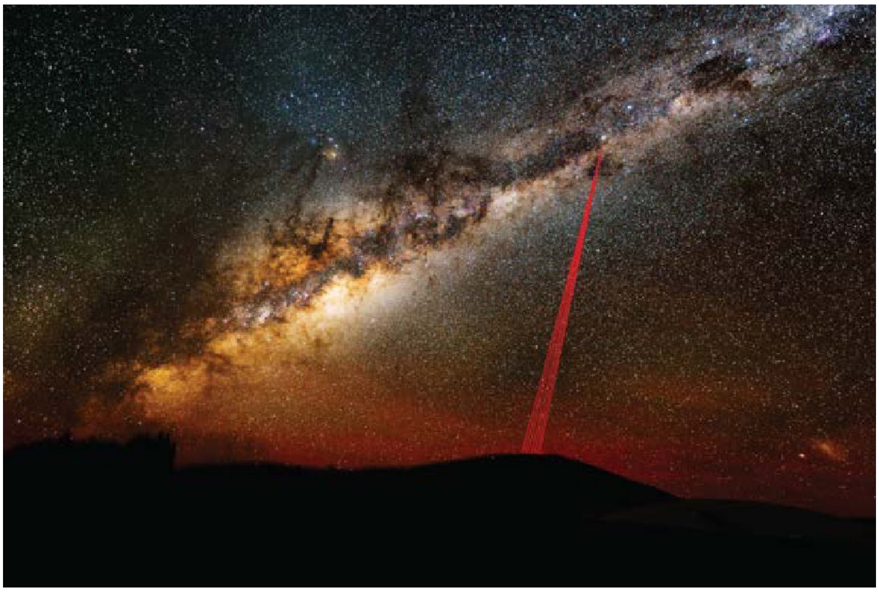
iafastro.directory/iac/browse/IAC-22/D4/1/

D4,1,4,x73256 iafastro.directory/iac/paper/id/73256/summary/	Benchmarking von Neumann's universal constructor architectures for in situ production in space environments	Mr Hussain Bokhari	Space Forward Lab	Sweden

In-situ self-contained resilience, providing redundancy and logistics of spare parts and consumables, is a vital part of long term exploration and exploitation of space. This paper looks at John von Neumann's Universal Constructor, a self-replication machine [1] and finds advantages of reduced costs of transportation by use of self-replicating seed payloads and self-reparation or self-replication in case of malfunction. Advances in synthetic biology, chemical computing, and soft living matter can contribute. It examines architectures of various universal constructor concepts and approximates, discusses and interprets for typical space exploration use cases the minimal thermodynamic costs, energy consumption, production time, external energy supply requirements and constraints of building an incremental unit in different space environments.

D4,1,12,x70259 iafastro.directory/iac/paper/id/70259/summary/	Advancements in laser propulsion for relativistic lightsail missions	Mr Wesley Green	Breakthrough Initiatives	USA

A summary of the Breakthrough Starshot Photon Engine research showing viable paths to create a gigawatt-level, kilometre-scale coherent phased array, including advances in beam control and adaptive optics, fibre amplifiers and nonlinear effects, semiconductor lasers, photonic integrated circuits, and cost estimations. Critical technology areas are highlighted, indicating where advancements are needed and where some technology branches are determined to be incompatible with Starshot.



Header image from Breakthrough Initiatives - Breakthrough Starshot - Photon Engine RFP issued 6 Oct 2017. https://breakthroughinitiatives.org/i/docs/RFP_Photon_Engine_Final.pdf Credit: Breakthrough Initiatives

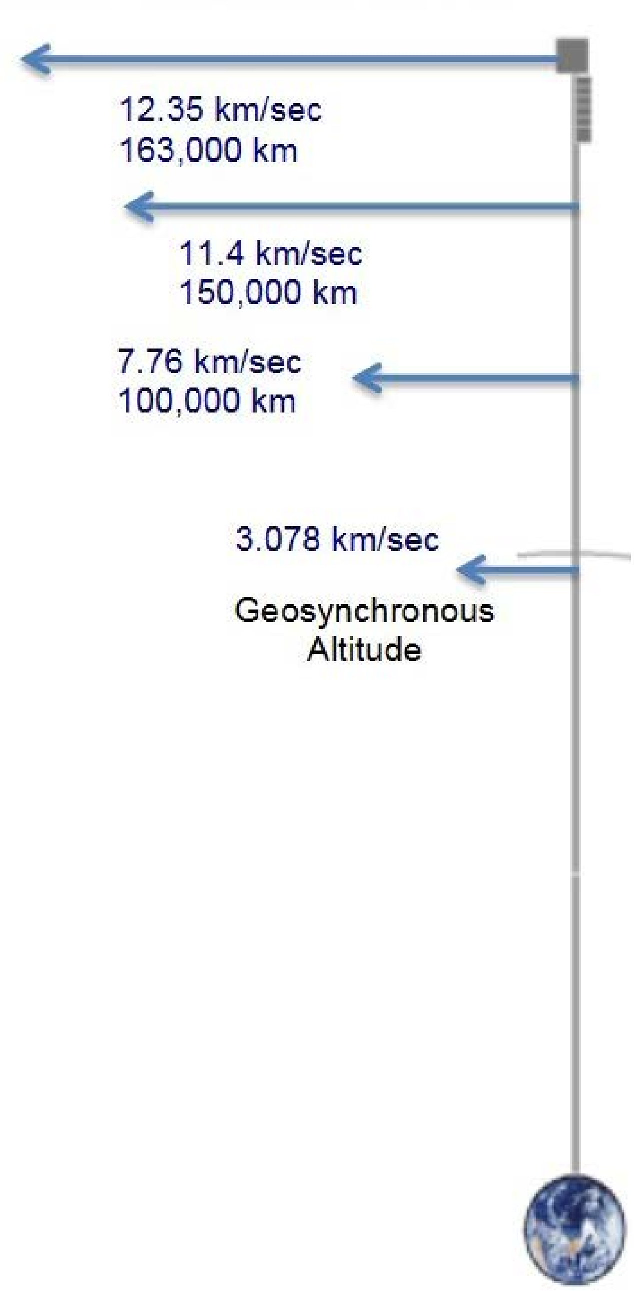
[1] *The Universal Constructor: Theory of Self-Reproducing Automata*. John von Neumann. Edited by Arthur W Burks. University of Illinois Press, Urbana, 1966 also en.wikipedia.org/wiki/Von_Neumann_universal_constructor

Modern Day Space Elevators Entering Development

iafastro.directory/iac/browse/IAC-22/D4/3/

IAC-22,D4,3,1,x67635 iafastro.directory/iac/paper/id/67635/summary/	KEYNOTE: Space Elevators as a Transformational Leap For Human movement off-planet	Dr Cathy Swan	SouthWest Analytic Network	USA

The International Space Elevator Consortium (ISEC) observes that a Permanent Space Infrastructure would enable massive movement of cargo to GEO and beyond in a safe, environmentally friendly, inexpensive, daily and routine way – thus transforming the approach for humanity to escape the Earth's gravity. This supports goals including Space Solar Power, lifting payloads to help to save our atmosphere, lunar villages and, longer term, Lagrange 5 settlements. The paper uses a Mars settlement as an example describing work by ISEC and Arizona State University.



Velocities achievable using a space elevator.
Credit: ISEC Report: Space Elevators are the Transportation Story of 21st Century, **Figure 4.1, Space Elevator Launch Geometries** www.isec.org/s/ISEC2020-2Study.pdf [1]

[1] Torla et al IAC-18-D4.3.4 *Optimization of Low Fuel And Time-Critical Interplanetary Transfers Using Space Elevator Apex Anchor Release: Mars, Jupiter And Saturn.*

D4,3,4,x69339 iafastro.directory/iac/paper/id/69339/summary/	Space Elevator tether materials: An overview of the current candidates	Dr Adrian Nixon	-	UK

Session D4/3 includes 16 papers on both opportunities and technologies for space elevators. For example, the tether is clearly a major technical challenge and this paper reviews manufacturing progress in making materials with the strength necessary to form the tether for the space elevator falling into two categories, nanotubes and 2D materials and concluding that carbon nanotubes are the material of choice for the tether. This paper will detail the current state of the art of manufacturing for these tether candidate materials. See also www.isec.org/tether-materials.

D4. 20th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE

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Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond

/iafastro.directory/iac/browse/IAC-22/D4/4/

D4,4,1,x70268 iafastro.directory/iac/paper/id/70268/summary/	10%: The First 10 Years of The 100 Year Starship™	Mr Jason Batt	100 Year Starship	USA

100 Year Starship™ was funded in 2012 by the US Defense Advanced Research Projects Agency. Mr Batt is editor of the *100YSS Symposium Conference Proceedings*. He will look back at the first ten years of The 100 Year Starship and explore how 100YSS has changed the landscape of interstellar development in the last ten years. What are the results of the activities and initiatives 100YSS has championed? What are the challenges that we must face in the next ten years? What have been the challenges that have arisen in accomplishing the 100YSS mission and what are the challenges to come? And finally, explore what the potential roadmap might be for the next ten years.

D4,4,2,x67412 iafastro.directory/iac/paper/id/67412/summary/	Case Study of a Mission to Epsilon Eridani: Unmanned Interstellar Probe Using Gas Core Nuclear Reactors with Early 21st Century Technology	Dr Ugur Guven,	UN CSSTEAP	UK

UN CSSTEAP is the Centre for Space Science and Technology: Education in Asia and the Pacific (www.cssteap.org/). This paper discusses the possibility of an interstellar mission to Epsilon Eridani by comparing different modes of propulsion and plotting the distance, time and specific impulse for gas core nuclear propulsion system which promises to reach its target in a reasonable amount of time with the existing early 21st century technology presenting the challenges of such a mission in detail with the effects of semi-relativistic speeds, mass expansion and time dilation. Its intention is to become a reference point for similar unmanned interstellar missions in the future.

D4,4,3,x73132 iafastro.directory/iac/paper/id/73132/summary/	Advanced Electric Propulsion Concepts for Fast Missions to the Outer Solar System and Beyond	Mr Angelo Genovese	Initiative for Interstellar Studies	Germany

Electric Propulsion (EP) comprises all types of space propulsion in which propellant is ionized and then accelerated by electric and/or magnetic fields. It allows for much higher specific impulses (order of 5000 seconds) than conventional chemical propulsion resulting in a major reduction of the propellant mass or a considerably higher final speed. This paper suggests that an EP system coupled with an advanced nuclear reactor could enable fast manned missions to Mars (one-way travel times less than 4 months). A breakthrough in power source specific mass is needed in order to enable missions with ultra-high specific impulses (order 10,000 seconds); this could be realised using an external power source, Laser-powered Electric Propulsion (LEP). The on-board power source is now limited to a light-weight photovoltaic receiver/converter. This could enable the most challenging interstellar precursor missions up to the Oort Cloud and beyond. This paper gives an update on the status of these advanced propulsion concepts and provides examples of interstellar precursor missions enabled by advanced EP systems which could be launched before 2040.

D4,4,4,x69452 iafastro.directory/iac/paper/id/69452/summary/	Stella: Europe's contribution to a NASA interstellar probe	Prof Stanislav Barabash	Swedish Institute of Space Physics	Sweden

The Interstellar Probe (ISP) is a potential NASA large strategic mission candidate - concept study report: *Interstellar Probe: NASA Solar and Space Physics Mission Concept Study* [1] has shown that an ISP mission is realistic and can be designed, built, and launched by 2036, at 7.0 au/year it would reach 350 au during its nominal 50-year life-time but system resources could allow traveling to, at least, 525 au. ESA contributions could include scientific instruments, communication system including the 5 m high-gain antenna, an extension of ESA's DSA [2] with a new antenna array and a major contribution to ISP operations. Stella contributes to achieving ISP goals by answering five specific questions:

• What is the composition of the local interstellar medium?

• How is our dynamical heliosphere upheld and how does it change from the Sun to the local interstellar medium?

• What is the origin and role of galactic cosmic rays in the solar system and beyond?

• How does the local interstellar medium become structured when it meets the heliosphere?

• Are there any deviations from the 1/r gravity law on the interstellar scale? [3]

ESA assumes a model European payload including neutral gas mass spectrometer, plasma package, cosmic ray spectrometer, UV spectrograph, and radio science (using the spacecraft radio for that last fundamental physics question).

See also D4,4,9,x69502 below.

D4,4,5,x72336 iafastro.directory/iac/paper/id/72336/summary/	Performance Map for Laser-Accelerated Sailcraft Missions	Dr Kevin Parkin	Breakthrough Initiatives	USA

Dr Parkin has previously delivered key studies on the overall system design of the Starshot mission [4] and in a range of advanced propulsion technologies. This paper maps the wider design space for cost-optimal missions with 0.1 mg to 100 kt payload, 0.0001 c to 0 .99 c (6.3 au/y to 63,000 au/y) cruise velocity, and 10 y to 100 y development time. This mapping is made possible by a simplified system model that swaps numerical trajectory integration for closed-form equations. The new code computes 2-3 orders of magnitude more point designs per unit time than the earlier more general code. Parkin notes that for missions that require only a few gigawatts of laser power or less, an electrical transmission line connected to a regional grid can directly drive the laser instead of, or in addition to, on-site energy storage. This greatly reduces system cost for some precursor missions.

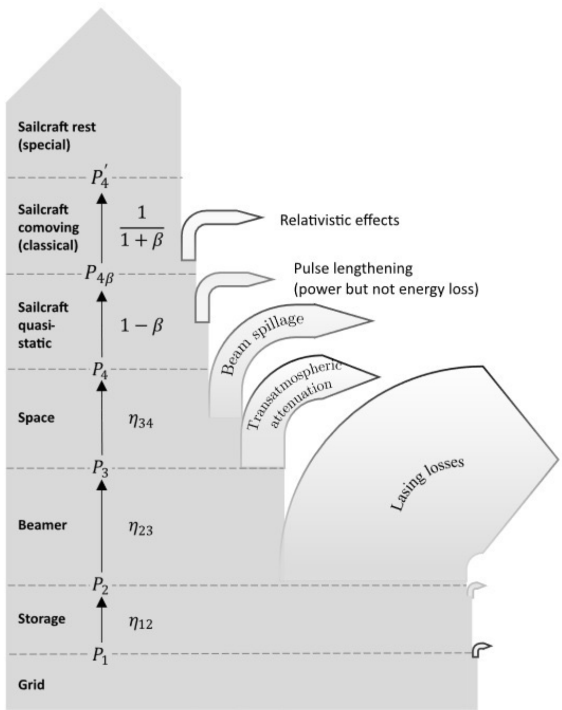


Figure 1: Power and efficiency relationships

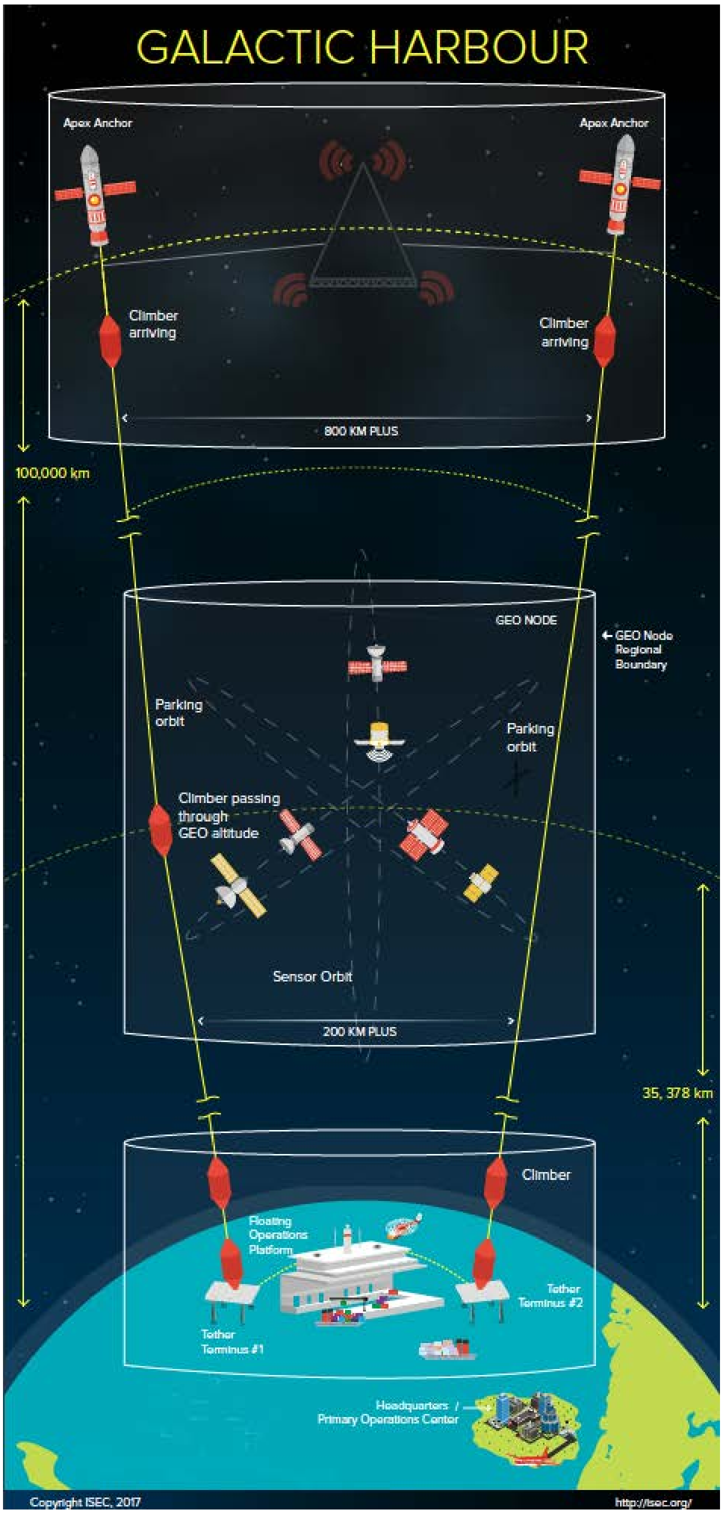
Power and efficiency relationships, Figure 1 in Parkin (May 2022) [5]

[1] Published December 2021. For the full 498 page report - kiss.caltech.edu/papers/ism/papers/Interstellar-Probe-MCR.pdf
[2] ESA Deep space communication and navigation. www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Deep_space_communication_and_navigation
[3] This looks like an error "when I went to school" it was $1/r^2$ but this is probably an IAF re-keying error rather than a mistake by Prof Barabash.
[4] An early example - *The Breakthrough Starshot system model*, Acta Astronautica, Vol 152, November 2018, Pages 370-384 arxiv.org/abs/1805.01306
[5] *Cost-Optimal System Performance Maps for Laser-Accelerated Sailcraft*, Kevin L G Parkin, arxiv.org/abs/2205.13138

D4,4,6,x67947 iafastro.directory/iac/paper/id/67947/summary/	Transformational Release of Scientific Payloads from the Apex Anchor - Any Size, Every Day, Anywhere	Dr Peter Swan	International Space Elevator Consortium	USA

The International Space Elevator Consortium (ISEC) has been working for some years on the challenging but potentially transformational idea of an Earth to GEO orbit tether with cargo vehicles climbing and descending at costs a small fraction of any current or envisaged launchers. The Apex Anchor of such a system would be 100,000 km, about three times GEO height. Contrast current launches from Earth to Mars taking 8-months, separated by 26 months until the next launch window and Mars payload a small fraction of launch mass. The elevator Apex Anchor would enable release towards Mars every day taking around two months and deliver hundreds of thousands of tons at around 8 km/sec. The advantages for deep space and even interstellar missions are obvious. See also D4,3,1,x67635 above.

More about ISEC in reports from IAC21, Dubai, in Principium editions 36 - *A brief on IAC2021: Inspire, Innovate and Discover For the Benefit of Humankind* - Samar AbdelFattah and at this IAC the session D4,3 *Modern Day Space Elevators Entering Development*, iafastro.directory/iac/browse/IAC-22/D4/3/ with presenters from ISEC, Obayashi Corporation and Shonan Institute of Technology (both Japan), Politecnico di Torino, Arizona State University, Royal Institute of Technology (Sweden), National Institute for Space Research (Brazil), the USA National Space Society (Mumbai chapter, India) and York University (Canada).



Galactic Harbour architecture, see P36, *A brief on IAC2021: Inspire, Innovate and Discover For the Benefit of Humankind*, Samar AbdelFattah, i4is.org/wp-content/uploads/2022/02/A-brief-on-IAC2021-Principium36-AW-2202191002opt.pdf

D4,4,9,x69502 iafastro.directory/iac/paper/id/69502/summary/	The Pragmatic Interstellar Probe Study: Results	Dr Ralph L McNutt, Jr	The Johns Hopkins University (JHU)	USA

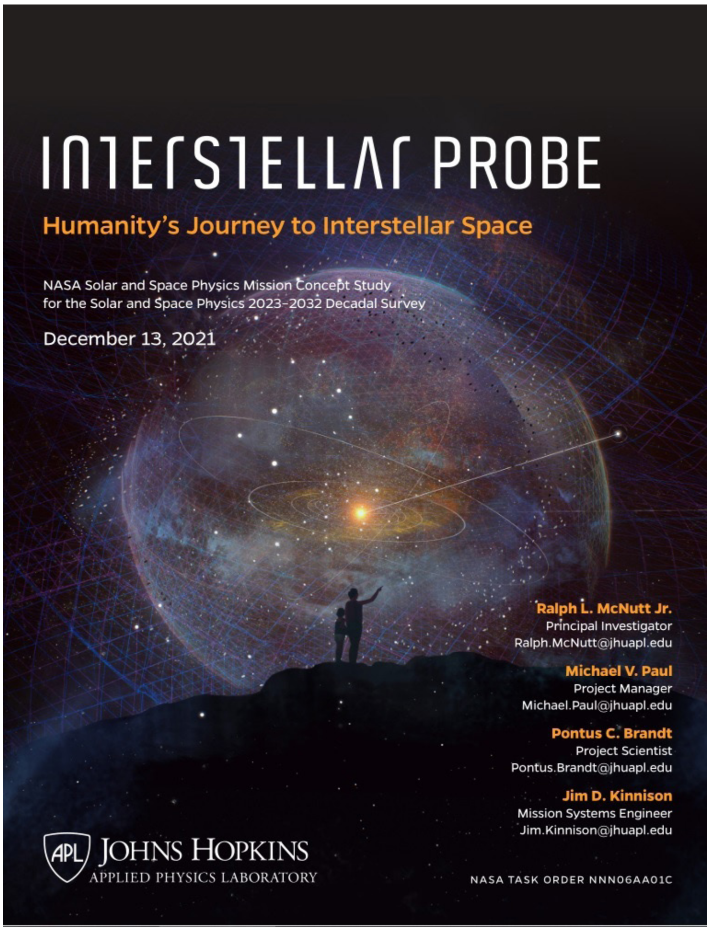
The JHU Interstellar Probe is a proposed NASA mission to the interstellar medium and the heliosphere, in effect a faster and much more capable Voyager probe. Working Groups from within and beyond JHU have refined the science payload. The proposal now suggests a spacecraft of 860 kg (about the same as the 45-year old Voyagers) carrying about 90 kg of instruments launched by a super heavy lift launch vehicle (SHLLV) [1] with additional 3rd and 4th stages. It will now use a Jupiter Oberth manoeuvre rather than a Solar Oberth manoeuvre, trading less impulse for less spacecraft mass since no heatshield would now be required. Later i4is Project Lyra studies have made a similar trade-off.

The paper has co-authors from University of Kiel (Germany), Viterbi School of Engineering-University of Southern California and NASA.

See also -

- summarised above - D4,4,10,x73530, *Stella science for interstellar probe*, Prof Dr Robert F Wimmer-Schweingruber, University of Kiel et al (co-authors from Swedish Institute of Space Physics, JHU, University of Bern, Institut de Recherche en Astrophysique et Planétologie (IRAP) - France, Sapienza University of Rome - Italy, CNRS-LATMOS - France, Mullard Space Science Laboratory-UK). Science for the proposed European contribution to NASA's Interstellar Probe. iafastro.directory/iac/paper/id/73530/summary/
- D4,4,11,x70087, *The Pragmatic Interstellar Probe Study: The Evolutionary Journey of our Habitable Astrosphere*, Dr Pontus Brandt, JHU Applied Physics Laboratory. The paper has 40 co-authors from institutions ranging from JHU to Northumbria University in UK. iafastro.directory/iac/paper/id/70087/summary/

The comprehensive JHU-APL study of December 2021 is at interstellarprobe.jhuapl.edu/Interstellar-Probe-MCR.pdf.



Interstellar Probe, Humanity's Journey to Interstellar Space, JHU-APL December 2021 Report

[1] SHLLV examples include the operational SpaceX Falcon Heavy and the near term SpaceX Starship & NASA Space Launch System (SLS)