

# 72nd International Astronautical Congress 2021

## The Interstellar Papers

John I Davies

This year the International Astronautical Federation will once more hold the International Astronautical Congress in a selected geographical location, this year in Dubai. At the time of writing it is not clear to what extent the proceedings will be available remotely but precedent suggests that registered attendees will have access to videos of presentations, presentation material and full text of papers. Registration is available at [iac2021.org/registration](http://iac2021.org/registration). The catalogue of all technical sessions is at - [iafastro.directory/iac/browse/IAC-21/](http://iafastro.directory/iac/browse/IAC-21/). In this report we attempt to list all the items currently announced 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.

You will find -

- Code & link - the unique IAC code and a link to the Abstract
- Paper title, Speaker, institutional Affiliation and Country
- A brief summary based on the Abstract - credit IAF and authors, errors and omissions my own!

Please contact [john.davies@i4is.org](mailto:john.davies@i4is.org) if you have comments, find discrepancies or have additional items to suggest.

### Session: IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM - Astrobiology and Exploration

[iafastro.directory/iac/browse/IAC-21/A1/6/](http://iafastro.directory/iac/browse/IAC-21/A1/6/)

Code & link	Paper title	Speaker	Affiliation	Country
A1,6,1,x63282 <a href="http://iafastro.directory/iac/paper/id/63282/abstract-pdf/IAC-21,A1,6,1,x63282.brief.pdf">iafastro.directory/iac/paper/id/63282/abstract-pdf/IAC-21,A1,6,1,x63282.brief.pdf</a>	Extended Habitable Zone and biosignature detection of M-dwarf planets	Dr Amri Wandel	The Hebrew University of Jerusalem	Israel
Suggests that the Habitable Zone around M-stars is significantly wider than previously thought and as M-dwarfs dominate planetary systems by number and their small masses and radii make their transiting planets comparatively easy to detect and characterise, in particular to look for bio-signatures.				

### Session: IAF SPACE EXPLORATION SYMPOSIUM - Space Exploration Overview

[iafastro.directory/iac/browse/IAC-21/A3/1/](http://iafastro.directory/iac/browse/IAC-21/A3/1/)

Code & link	Paper title	Speaker	Affiliation	Country
A3,1,3,x65095 <a href="http://iafastro.directory/iac/paper/id/65095/abstract-pdf/IAC-21,A3,1,3,x65095.brief.pdf">iafastro.directory/iac/paper/id/65095/abstract-pdf/IAC-21,A3,1,3,x65095.brief.pdf</a>	Why Space Exploration Will Be Soon Unsustainable, Without a Serious Civilian Space Settlement Programme	Adriano V Autino	Space Renaissance International	Italy
Advocates of further space exploration should advocate space settlement. The differences between exploration and expansion analysed. The socio-economic rationale: if remain closed within the boundaries of our mother planet, the multiple crises that are already jeopardising our economy and culture will likely close the “launch window” sooner than what we could expect until a few years ago.				

**Session: IAF SPACE EXPLORATION SYMPOSIUM - Mars Exploration – missions current and future**

[iafastro.directory/iac/browse/IAC-21/A3/3A/](http://iafastro.directory/iac/browse/IAC-21/A3/3A/)

Code & link	Paper title	Speaker	Affiliation	Country
A3,3A,10,x66846 <a href="http://iafastro.directory/iac/paper/id/66846/abstract-pdf/IAC-21,A3,3A,10,x66846.brief.pdf">iafastro.directory/iac/paper/id/66846/abstract-pdf/IAC-21,A3,3A,10,x66846.brief.pdf</a>	Colonizing Mars: In-Situ Resource Utilization of the Martian Moons	Harshit Goel	University of Petroleum and Energy Studies	India
Futuristic case study of an exploration mission to the Martian Moons - and prospect of utilising minerals on Martian moons.				

**Session: 50th IAA SYMPOSIUM ON THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) – The Next Steps - SETI 1: SETI Science and Technology**

[iafastro.directory/iac/browse/IAC-21/A4/1/](http://iafastro.directory/iac/browse/IAC-21/A4/1/)

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,1,x65248 <a href="http://iafastro.directory/iac/paper/id/65248/abstract-pdf/IAC-21,A4,1,1,x65248.brief.pdf">iafastro.directory/iac/paper/id/65248/abstract-pdf/IAC-21,A4,1,1,x65248.brief.pdf</a>	Breakthrough Listen: Green Bank Telescope Observations, Analysis, and Public Data	Dr Steve Croft	University California Berkeley	USA
Breakthrough Listen (BL) observes as primary user for around 1/5 of the available time on the Green Bank Telescope, to March 2021 almost 14 PB of archival data products. BL have 2 PB available in a publicly accessible archive with an open-source software suite enabling data into Python programs and software search for narrow-band Doppler drifting signals. Also current status of BL’s observing program at GBT, the analysis pipeline, highlighted public datasets, collaborations with academia and industry, and some of the latest science results.				

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,2,x65540 <a href="http://iafastro.directory/iac/paper/id/65540/abstract-pdf/IAC-21,A4,1,2,x65540.brief.pdf">iafastro.directory/iac/paper/id/65540/abstract-pdf/IAC-21,A4,1,2,x65540.brief.pdf</a>	Energy-intensive civilisations and their imprint on astronomical data	Prof Mike Garrett	University of Manchester	UK
A non-exhaustive description of some main anomalies astronomers are currently seeking. How long-baseline interferometry can follow-up observations of the Breakthrough Listen candidates. Astronomers need to broaden their horizons to new possibilities including on-biological forms of intelligence and consciousness.				

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,3,x64350 <a href="http://iafastro.directory/iac/paper/id/64350/abstract-pdf/IAC-21,A4,1,3,x64350.brief.pdf">iafastro.directory/iac/paper/id/64350/abstract-pdf/IAC-21,A4,1,3,x64350.brief.pdf</a>	Interferometric SETI searches with the Breakthrough Listen initiative	Dr Cherry Ng	University of Toronto	Canada
Breakthrough Listen has partnered with the SETI Institute to develop commensal SETI search capabilities on some of the most sensitive radio interferometers, including the Allen Telescope Array (ATA), the Very Large Array (VLA) and MeerKAT - providing a larger field of view, maximizing the SETI survey speed. Presenting updates on these surveys and a refreshed outlook on SETI search using next generation telescope facilities.				

Code & link	Paper title	Speaker	Affiliation	Country
CA4,1,4,x65765 <a href="#">iafastro.directory/iac/paper/id/65765/abstract-pdf/IAC-21,A4,1,4,x65765.brief.pdf</a>	The Breakthrough Listen search for intelligent life: machine learning and artificial intelligence approaches [ML & AI]	Ms Shirley Wang	Berkeley SETI Research Center	USA

The abundance of data generated by the BL program makes it infeasible to examine it with traditional methods. Recent work developing improved RF interference rejection and generic anomaly detectors applying unsupervised learning methods like autoencoders, transfer learning with pre-trained Object Detection models. Latest data collection and processing techniques. Describe applying ML and AI models to improve robustness of software pipelines and increase sensitivity to a wider class of technosignatures. Report on a signal injection and recovery in collaboration with industry partners Google and Kaggle.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,5,x65784 <a href="#">iafastro.directory/iac/paper/id/65784/abstract-pdf/IAC-21,A4,1,5,x65784.brief.pdf</a>	BL@Scale: Scaling Technosignature Search Pipelines to the Cloud	Yuhong Chen	University of California, Berkeley	USA

Technosignature pipelines deployed at telescope sites and UC Berkeley data center but limitations of on-premise, hardware-centric approach constrain ability to ramp up intensive analysis campaigns on demand. BL@Scale (currently in a pilot phase) using cloud technologies like Docker and Kubernetes yields infrastructure able to flexibly scale with computing demands. Everyday workloads using on-premise machines but able to expand to large workloads quickly in the cloud. Reporting on capabilities, structure of platform, and some recent advances.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,6,x65944 <a href="#">iafastro.directory/iac/paper/id/65944/abstract-pdf/IAC-21,A4,1,6,x65944.brief.pdf</a>	Optimal Observing Strategies for Commensal SETI Surveys with Radio Telescope Arrays	Dr Daniel Czech	University of California, Berkeley	USA

Radio telescope arrays using commensal SETI surveys - Ethernet-based architectural approaches by MeerKAT, Jansky Very Large Array and Allen Telescope Array allow multiple commensal users to receive data simultaneously. Breakthrough Listen conducting a commensal SETI survey at MeerKAT, using raw voltage data streams from F-engines[1] with both coherent and incoherent beamforming on the buffered raw voltages. 64 simultaneous beams will be formed on objects of interest within the primary field. Most objects for observation drawn from 26 million stars drawn from Gaia DR2 [2] using reconfigurable processing pipeline. A subset of available stars may be observed ranked according to metrics such as distance and sequencing of observations to maximise results from available observing time + capacity.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,7,x66146 <a href="#">iafastro.directory/iac/paper/id/66146/abstract-pdf/IAC-21,A4,1,7,x66146.brief.pdf</a>	Breakthrough Listen Search for Intelligent Life in the Galactic Plane with the Parkes Telescope	Ms Karen Perez	Columbia University	USA

A primary target of BL is a comprehensive blind survey of the entire Galactic Plane to search for artificial narrowband transmitters from ETIs. From two full scans of the Galactic Plane over 1200–1550 MHz using the Parkes Telescope's 21cm Multibeam Receiver, covering roughly 3000 square degrees over Galactic longitudes  $-174^\circ < l < 60^\circ$  and latitudes  $|b| < 6.5^\circ$  during 1200 hours and observing billions of stars applying the multibeam coincidence rejection technique used for detecting Fast Radio Bursts to narrowband signals to SETI for the first time.

[1] FX architecture (Fourier transform 'F' followed by Cross-correlation 'X'). See *Engineering and science highlights of the KAT-7 radio telescope*, Foley et al, MNRAS, 2016, [academic.oup.com/mnras/article/460/2/1664/2608970](http://academic.oup.com/mnras/article/460/2/1664/2608970)

[2] Gaia telescope [www.cosmos.esa.int/web/gaia/spacecraft-instruments](http://www.cosmos.esa.int/web/gaia/spacecraft-instruments) Gaia DR2 results <https://www.cosmos.esa.int/web/gaia/dr2>

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,8,x66951 <a href="#">iafastro.directory/iac/paper/id/66951/abstract-pdf/IAC-21,A4,1,8,x66951.brief.pdf</a>	How to Build a Commensal SETI Search Engine for Radio Telescope Arrays	David MacMahon	Berkeley SETI Research Center	USA

Commensal observing trades off control of the telescope for greatly increased amounts of telescope time. For radio telescope arrays with relatively large fields of view (eg MeerKAT, ALMA, ngVLA) this is of less consequence. Digital techniques such as coherent beam-forming afford commensal backend control over where to point narrow synthetic beams within the telescope's primary beam. BL has deployed a commensal digital backend on MeerKAT in South Africa to do this. This paper discusses the design and implementation of this commensal SETI search engine and presents data to show its capabilities.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,9,x66549 <a href="#">iafastro.directory/iac/paper/id/66549/abstract-pdf/IAC-21,A4,1,9,x66549.brief.pdf</a>	The Sardinia Radio Telescope in the Framework of the Breakthrough Listen Program: Technical & Scientific Commissioning and First Results	Dr Andrea Melis	INAF - Istituto Nazionale di AstroFisica	Italy

Sardinia Radio Telescope (SRT), a 64-m fully-steerable antenna, surveying the Galactic Center at higher radio frequencies (7 and 22 GHz) to find evidence of artificial transmitters, and following up potential exoplanet candidate announced from the TESS program in collaboration with the BL team. Reporting ongoing activities and in particular the commissioning of the system and first results.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,10,x67003 <a href="#">iafastro.directory/iac/paper/id/67003/abstract-pdf/IAC-21,A4,1,10,x67003.brief.pdf</a>	From Dust to Technosignatures: Searching for Stellar Occulters with Machine Learning	Dr Daniel Giles	SETI Institute (SI)	USA

While no theory provides a perfect explanation for the fading events seen in Boyajian's star, the large volume of imaging data emerging from the TESS mission is now enabling a new search for similar behaviour in additional objects. A SI team has created light curves for 50 million relatively bright stars. Using a combination of supervised and unsupervised machine learning to discover and classify rare fading events with follow up on the most unusual objects with ground-based optical and radio observatories to determine the origin of such variability. Ultimately, this program will either discover or put an upper limit on the frequency of transiting artificial megastructures around main sequence stars in our galaxy.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,11,x66875 <a href="#">iafastro.directory/iac/paper/id/66875/abstract-pdf/IAC-21,A4,1,11,x66875.brief.pdf</a>	Upgrades to the Allen Telescope Array: wide-band, wide-field radio observations	Dr. Wael Farah	SETI Institute	USA

Allen Telescope Array (ATA), a 42-element, fully steerable, interferometer with unique log-periodic feed design provides an impressive spectral coverage ranging from 1 to 12 GHz and four independent digital signal processing (DSP) chains delivering 650 MHz bandwidth each and 2600 MHz of instantaneous bandwidth if processed simultaneously. Describing ongoing refurbishment programme, astronomical observations including pulsars and fast radio bursts - and planned and ongoing SETI surveys to leverage the wide-field and wide-band capabilities of the telescope.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,12,x67028 <a href="#">iafastro.directory/iac/paper/id/67028/abstract-pdf/IAC-21,A4,1,12,x67028.brief.pdf</a>	Searching for Gravitational Lens Probes and Analysis of Tabby's Star Observations using turboSETI Software	Nick Tusay	Pennsylvania State University	USA

KIC8462852, aka Boyajian's Star or Tabby's Star, the artificial nature of this star's dimming is currently disfavoured but analysis developed for this star can be extended to other sources. The graduate SETI course at PennState, has taken observations in X, C and S bands with plans to add L band later to search for signals from potential artificial relay probes positioned to use the gravitational lensing effects of our Sun - as a benchmark for searching for possible probes placed as part of an interstellar communications network.

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,13,x64992 <a href="#">iafastro.directory/iac/paper/id/64992/abstract-pdf/IAC-21,A4,1,13,x64992.brief.pdf</a>	Search for nanosecond optical transients with TAIGA-HiSCORE array for the SETI problem.	Dr Alexander Panov	Skobeltsyn Institute of Nuclear Physics	Russia

The wide-angle integrating Cerenkov array TAIGA-HiSCORE (FOV ~0.6 steradians) includes nearly 100 optical detector stations distributed over an area of ~1 km used to search for nanosecond astrophysical transients in the optical range. The telescope can register signals of distant nanosecond lasers (up to 1000 light-years and more) with moderate energies and sizes, thus of interest for SETI. The report discusses the method of searching for astrophysical transients - demonstrating performance with the example of laser pulses from Earth satellite. Results of the 2018-2019 winter season include a candidate for recurrent transient with the estimated probability of random chance by fluctuation of background EAS (Extended Air Shower) is at least 10%. An upper bound on the event frequency of optical transients with a spectral energy density of more than  $1.5 \times 10^{-3}$  erg/sec/cm<sup>2</sup> and duration of  $\geq 1$  ns has been found to be 0.05 events/ster/day [1].

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,15,x65656 <a href="#">iafastro.directory/iac/paper/id/65656/abstract-pdf/IAC-21,A4,1,15,x65656.brief.pdf</a>	Numerical simulations for possible Galactic Habitable Islands in the Milky Way	Prof Teófilo Vargas	Universidad Nacional Mayor de San Marcos	Peru

The concept of Galactic Habitable Islands (GHI) refers to locations in our Galaxy outside of the "standard" Galactic Habitable Zone (GHZ) [2] that could be favourable to the development of life. Recent numerical simulation models suggest life could have emerged at the outskirts of the galactic disk and recent observations, show some indications that zones suitable to life have emerged in the galactic centre and in the outer part of the Galaxy. This paper presents new numerical simulations compared to observations. If the simulations confirm the indications, parameters from the former will be extracted and changed to identify more zones suitable to life.

[1] events/ster/day = events/steradian/day. Steradians are units of solid angle. They are the angle subtended by a unit area of the surface of a sphere so a whole sphere contains  $4\pi$  steradians and thus 0.05 events/ster/day implies  $.05 * 4\pi = 0.63$  events/day for the whole celestial sphere or 1.59 days between events..

[2] The idea of a galactic habitable zone is based on the observation that some parts of the galaxy are more hazardous to life than others. Some stars are unstable and others emit hostile radiation continuously so it is not safe for life to be near them. Comets from our Oort cloud are likely to be more frequent if other stars pass close to us and perturb their orbits so planets in more densely populated parts of the galaxy are likely to be subject to more comet bombardment. More at [en.wikipedia.org/wiki/Galactic\\_habitable\\_zone](https://en.wikipedia.org/wiki/Galactic_habitable_zone)

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,17,x63320 <a href="https://iafastro.directory/iaac/paper/id/63320/abstract-pdf/IAC-21,A4,1,17,x63320.brief.pdf">iafastro.directory/iaac/paper/id/63320/abstract-pdf/IAC-21,A4,1,17,x63320.brief.pdf</a>	The Drake equation and SETI in the JWST era	Dr Amri Wandel	The Hebrew University of Jerusalem	Israel
Applying earlier analyses of SETI from the Kepler telescope to James Webb Space Telescope whose biosignature analyses can identify biotic exoplanets within the local habitable zone of M-dwarf solar systems giving better values for the relevant terms of the Drake equation, the Fermi-SETI paradox, the Earth radiosphere explanation of the SETI-Fermi paradox and perhaps a further METI paradox.				

Code & link	Paper title	Speaker	Affiliation	Country
A4,1,18,x63279 <a href="https://iafastro.directory/iaac/paper/id/63279/abstract-pdf/IAC-21,A4,1,18,x63279.brief.pdf">iafastro.directory/iaac/paper/id/63279/abstract-pdf/IAC-21,A4,1,18,x63279.brief.pdf</a>	Moon Farside Protection and Astronomy Protection are URGENT	Dr Claudio Maccone	International Academy of Astronautics (IAA) and Istituto Nazionale di Astrofisica (INAF)	Italy
The Moon Farside is the only place where radio transmissions and noises produced by humanity may not reach - the Moon blocks them. In 2010 Dr Maccone advocated the creation of a “Protected Antipode Circle (PAC)”, a circular area at the lunar farside centre. The "new race to the Moon” complicates matters. This paper supports Moon Farside Protection by all scientists working in three areas: Planetary Defence, Cosmology and SETI.				

**Session: 50th IAA SYMPOSIUM ON THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) – The Next Steps - SETI 2: SETI and Society**

[iafastro.directory/iaac/browse/IAC-21/A4/2/](https://iafastro.directory/iaac/browse/IAC-21/A4/2/)

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,2,x62338 <a href="https://iafastro.directory/iaac/paper/id/62338/abstract-pdf/IAC-21,A4,2,2,x62338.brief.pdf">iafastro.directory/iaac/paper/id/62338/abstract-pdf/IAC-21,A4,2,2,x62338.brief.pdf</a>	“The readiness is all” - Understanding Post-Detection Dynamics through Live Action Role Play	Ms Kate Genevieve	University of Sussex	UK
Confirmed detection of extraterrestrial life has the potential to generate considerable societal upheaval and planning for post-detection scenarios should involve stakeholders from across human society, not just scientists and politicians. Collaborators (Genevieve, Dr Arik Kershenbaum - Cambridge U, Prof John Elliott - Leeds Beckett U, Ruth Catlow) developed and prototyped an online LiveAction Role Play (LARP) across video conferencing platforms that simulates a contact scenario for diverse groups of people. The presentation will showcase the post-detection LARP, techniques devised to share learning found through game-play aiming for an open source SETI experiment. Also consider issues of maintenance and creativity imagining post-detection that keeps pace with societal development and a final discussion of recent participatory experiments in the UKSRN ( <a href="https://uksetiresearchnetwork.wordpress.com">uksetiresearchnetwork.wordpress.com</a> ) Post-Detection group and others.				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,3,x64977 <a href="https://iafastro.directory/iaac/paper/id/64977/abstract-pdf/IAC-21,A4,2,3,x64977.brief.pdf">iafastro.directory/iaac/paper/id/64977/abstract-pdf/IAC-21,A4,2,3,x64977.brief.pdf</a>	Use of force against extra-terrestrial life	Matija Rencelj	European Space Policy Institute (ESPI)	Slovenia
This paper will analyse the legality of using force against extra-terrestrial life and potential mechanisms of assigning legal rights to extra-terrestrial life - based on current national and international law. Even though doing so might not be of immediate urgency it might help us better understand our role in the Universe.				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,5,x65530 <a href="https://iafastro.directory/iac/paper/id/65530/abstract-pdf/IAC-21,A4,2,5,x65530.brief.pdf">iafastro.directory/iac/paper/id/65530/abstract-pdf/IAC-21,A4,2,5,x65530.brief.pdf</a>	Other minds in the Universe?	Pauli Laine		Finland
<p>The probability of the emergence of life is unknown - and of complex forms and into intelligence is even more unknown. We can see behaviour in many animal species that can be described as intelligent. We can program computers to behave like intelligent agents. But none of these are capable for (or interested in) interstellar communication. Our own interest arises from need to communicate within a small ancestor group. We do not know what possible evolutionary paths lead to intelligent society and technological culture - we have only one example. It is hard to imagine alternatives. Fermi's paradox questions any claim about how life would evolve to something that could be observable other than biochemically.</p>				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,6,x66778 <a href="https://iafastro.directory/iac/paper/id/66778/abstract-pdf/IAC-21,A4,2,6,x66778.brief.pdf">iafastro.directory/iac/paper/id/66778/abstract-pdf/IAC-21,A4,2,6,x66778.brief.pdf</a>	On the necessary aspect of METI	Dr Carl DeVito	<a href="http://www.math.arizona.edu/~devito/">www.math.arizona.edu/~devito/</a>	USA
<p>Any message we send into space will be, to its recipients, a message from the past; perhaps from very far in the past. It is argued here that, because of this fact, any message we send should have a component that serves as a legacy of humanity; a component that says something about the nature of the intelligent, senescent ["sentient" ?] race that arose near a star in the Milky Way Galaxy. This should serve as at least a partial guide to us in preparing the content of our message.</p>				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,7,x61738 <a href="https://iafastro.directory/iac/paper/id/61738/abstract-pdf/IAC-21,A4,2,7,x61738.brief.pdf">iafastro.directory/iac/paper/id/61738/abstract-pdf/IAC-21,A4,2,7,x61738.brief.pdf</a>	Astropolitics and the Implications of Belonging to an Extraterrestrial Polity	Mclee Kerolle	Space Generation Advisory Council (SGAC)	USA
<p>This paper will address the political implications regarding discovery that Earth belongs to an interstellar polity with several hundred extraterrestrial civilizations, questioning our anthropocentric assumptions and the expectation that more technically advanced civilizations will be more culturally and ethically advanced and would thus not harm human civilization. Are the five main space treaties of the UN consistent with the most famous post detection policy, the First SETI protocol of 1989? And what would the global impact on space law of the discovery of belonging to an interstellar polity have?</p>				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,10,x65430 <a href="https://iafastro.directory/iac/paper/id/65430/abstract-pdf/IAC-21,A4,2,10,x65430.brief.pdf">iafastro.directory/iac/paper/id/65430/abstract-pdf/IAC-21,A4,2,10,x65430.brief.pdf</a>	Benedict XVI and SETI	Dr Paolo Musso	University of Insubria	Italy
<p>Dr Musso wrote to Pope Emeritus Benedict XVI, asking his opinion about some theological issues related to extraterrestrial intelligent life - first of all of course whether it can exist from a Christian point of view. His reply in June 2014 was strictly personal but at the beginning of 2021 Dr Musso requested permission to include the letter as an appendix to a book in preparation. This was granted and here, for the first time, a former Pope has taken an open position to the possible existence of intelligent species other than humanity.</p>				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,12,x61987 <a href="https://iafastro.directory/iac/paper/id/61987/abstract-pdf/IAC-21,A4,2,12,x61987.brief.pdf">iafastro.directory/iac/paper/id/61987/abstract-pdf/IAC-21,A4,2,12,x61987.brief.pdf</a>	Radio bridges of the future between Solar System and the nearest 100 stars	Dr Nicolò Antonietti	INAF - IRA	Italy
<p>Co-author Claudio Maccone published <i>The Sun as a Gravitational Lens: Proposed Space Missions</i> in 1998. But radio bridges between the Sun and any nearby star may also be conceived. Space probes to the nearest stars could be placed behind the star of arrival and along the star-Sun line, thus allowing two gravitational lenses to work together resulting in a power-efficient permanent communication link. The paper studies radio bridges between the Sun and each of the nearest 100 stars, the basis for a Galactic Internet and human expansion to the stars.</p>				

Code & link	Paper title	Speaker	Affiliation	Country
A4,2,18,x62033 <a href="http://iafastro.directory/iac/paper/id/62033/abstract-pdf/IAC-21,A4,2,18,x62033.brief.pdf">iafastro.directory/iac/paper/id/62033/abstract-pdf/IAC-21,A4,2,18,x62033.brief.pdf</a>	The need for a worldwide and international SETI Journal	Dr Claudio Maccone	International Academy of Astronautics (IAA) and Istituto Nazionale di Astrofisica (INAF)	Italy

Acta Astronautica, the official journal of the International Academy of Astronautics (IAA), has also been the preferred journal for SETI-related papers since 1971, when the IAA established the IAA SETI Committee. In 50 years, SETI research grew from a murky sub-field of Astronomy to a self-sufficient branch of science resting on Radio Astronomy, Optical and Cherenkov Astronomy, Astrobiology and the Social Sciences. In recent years SETI scientists have had their SETI Abstracts rejected by Acta Astronautica often without preliminary discussion with Acta Astronautica reviewers. Since SETI scientists now also come from the Social Sciences, concerning themselves with the social impact of SETI discovery and political leaders of the most advanced countries seem to be totally unprepared to face such a “SETI Crisis”, this paper ponders the opportunities of establishing the first SETI Journal capable of preparing Humanity for Contact.

**Session: 24th IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM - session 4-D2.8 Space Transportation Solutions for Deep Space Missions**

[iafastro.directory/iac/browse/IAC-21/A5/4-D2.8/](http://iafastro.directory/iac/browse/IAC-21/A5/4-D2.8/)

Code & link	Paper title	Speaker	Affiliation	Country
A5,4-D2.8,1,x65969 <a href="http://iafastro.directory/iac/paper/id/65969/abstract-pdf/IAC-21,A5,4-D2.8,1,x65969.brief.pdf">iafastro.directory/iac/paper/id/65969/abstract-pdf/IAC-21,A5,4-D2.8,1,x65969.brief.pdf</a>	Design optimisation and analysis of very high power transportation system to Mars	Dr Christie Maddock	University of Strathclyde	UK

Results of 2020 study through ESA to develop preliminary flight vehicle engineering model of a Very High Power Transportation System to Mars for a crewed return mission. Vehicle configuration study with numerical models for structural mass, radiation, propulsion, habitat and consumables, and structural analysis of the separation truss between the spacecraft, including crew habitat module, and nuclear engine. Requirements and assumptions: Earth-Mars one-way journey less than 90 days, minima 50 tons cargo and 3 crew, in-orbit manufacturing and re-fuelling assumed operational around both Earth and Mars. Launch and landing segments of the mission not considered. Two system configurations developed: higher-TRL nuclear thermal propulsion and ESA developed NTER (Nuclear Thermal Electric Rocket). Multi-objective optimisation solver used to examine trade-offs in mission and trajectory with vehicle design parameters including engine sizing, and gross and dry vehicle masses. For a cycler-based mission architecture, single and return legs were analysed independently and together, using continuous and on-off thrust models. Preliminary results show a single leg journey possible (eg 86.0 days for Earth to Mars for a 650.86 t vehicle). Trade-off between total transfer duration against vehicle mass for a 30 day stay on Mars showed total flight times ranging from 295 days (376.8 t out and 668.28 t return) to 541.7 days (111.7 t out and 272.21 t return).

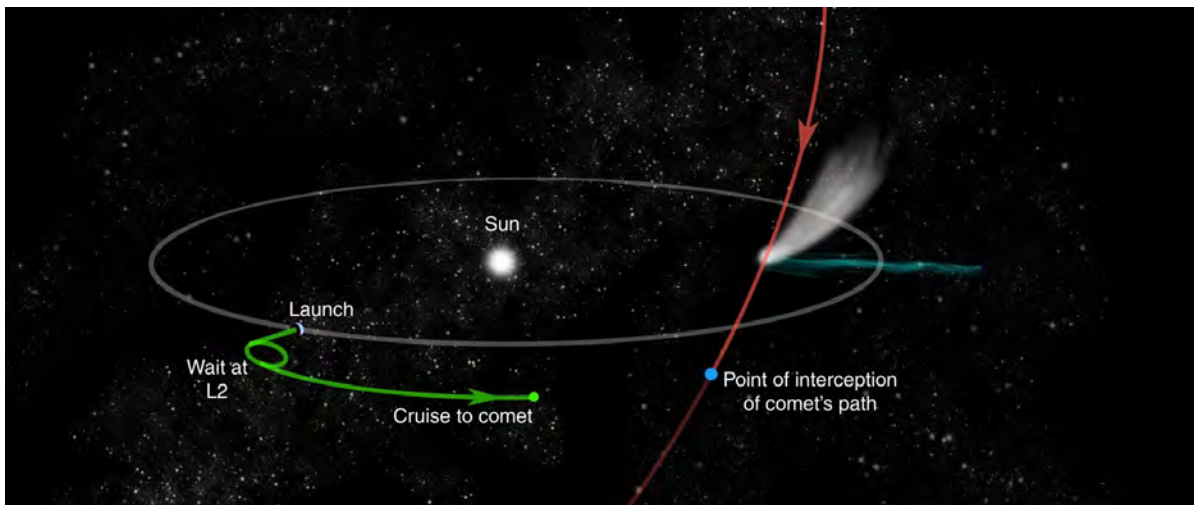


**Session: IAF SYMPOSIUM ON ONGOING AND NEAR FUTURE SPACE ASTRONOMY AND SOLAR-SYSTEM SCIENCE MISSIONS - Technology Needs for Future Missions, Systems, and Instruments**

[iafastro.directory/iac/browse/IAC-21/A7/3/](http://iafastro.directory/iac/browse/IAC-21/A7/3/)

Code & link	Paper title	Speaker	Affiliation	Country
A7,3,2,x67120 <a href="http://iafastro.directory/iac/paper/id/67120/abstract-pdf/IAC-21,A7,3,2,x67120.brief.pdf">iafastro.directory/iac/paper/id/67120/abstract-pdf/IAC-21,A7,3,2,x67120.brief.pdf</a>	Comet Interceptor: A daring mission to a long period comet or an interstellar object	Dr Mohamed Ramy Elmaarry	Khalifa University of Science and Technology (KUST)	United Arab Emirates

Comet Interceptor is an upcoming European Space Agency (ESA)-led mission in partnership with the Japanese Space Agency (JAXA) planned for launch to Lagrange point L2 in 2029 to loiter until a suitable object is found[1]. The mission objective is to explore for the first time a long-period comet, preferably dynamically new and as such, are expected to be much less processed/evolved than comets that have come close to the Sun on multiple occasions. Alternatively, an interstellar object (ISO) with a trajectory that is feasible for Comet Interceptor would provide a chance to explore an ISO in close proximity for the first time. The paper will discuss the mission further, and provide updates on the state of its development..



ESA Comet Interceptor - Launch, Loiter and Flyby.

Credit: Sketch of mission phases from *The European Space Agency's Comet Interceptor lies in wait* Colin Snodgrass & Geraint H Jones, Nature Communications 2019 [www.nature.com/articles/s41467-019-13470-1.epdf](http://www.nature.com/articles/s41467-019-13470-1.epdf).

**Session: IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM**

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Code & link	Paper title	Speaker	Affiliation	Country
B2,5,4,x62574 <a href="http://iafastro.directory/iac/paper/id/62574/abstract-pdf/IAC-21,B2,5,4,x62574.brief.pdf">iafastro.directory/iac/paper/id/62574/abstract-pdf/IAC-21,B2,5,4,x62574.brief.pdf</a>	Gravitational lensing of sun for deep space communication	Ms Bhavana B Rao	Ramaiah Institute of Technology	India

Gravitational lensing by massive objects predicted by the General Theory of Relativity. The sun's mass allows a probe along any radial direction from the sun from 550 AU and beyond. This can be used for a link to an interstellar probe. This paper compares the bit error rate across interstellar distances with and without using the gravitational lens effect of the Sun and the possibility of building radio bridges from the solar system such that data could be transmitted from interstellar probes with minimum power.

[1] See *News Feature: All Comets Great and Small* Principium 25 May 2019 for a summary of the Comet Interceptor mission.

**Session: Joint Session on Advanced and Nuclear Power and Propulsion Systems**

[iafastro.directory/iac/browse/IAC-21/C3/5-C4.10/](http://iafastro.directory/iac/browse/IAC-21/C3/5-C4.10/)

Code & link	Paper title	Speaker	Affiliation	Country
C4,10-C3.5,1,x63502 <a href="http://iafastro.directory/iac/paper/id/63502/abstract-pdf/IAC-21,C4,10-C3.5,1,x63502.brief.pdf">iafastro.directory/iac/paper/id/63502/abstract-pdf/IAC-21,C4,10-C3.5,1,x63502.brief.pdf</a>	Overview of Breakthrough Propulsion Research at TU Dresden	Prof Martin Tajmar	TU Dresden	Germany

Given the limitations of currently feasible means of propulsion to the stars, TU Dresden decided to establish a dedicated breakthrough propulsion group to investigate and test new ideas for propellantless propulsion with three main areas: Theory/model assessments, development of test equipment and experimental tests. Recently developing a suite of measurement devices including torsion thrust balances with nano-Newton resolution, a superconducting levitation thrust stand and a nano-gram weight balance, two thruster claims were tested in detail on different balances: the Mach-Effect thruster and the EMDrive, including a superconducting EMDrive and a laser-based variation. Also investigating complementary and fundamental theories such as claimed anomalous thrust of charged high-voltage capacitors, the influence of temperature on weight or consequences of scalar-tensor 5D gravity theories, which may lead to novel propulsion effects. The paper reviews current progress and summarises activities.

Code & link	Paper title	Speaker	Affiliation	Country
C3,5-C4.10,2,x64835 <a href="http://iafastro.directory/iac/paper/id/64835/abstract-pdf/IAC-21,C3,5-C4.10,2,x64835.brief.pdf">iafastro.directory/iac/paper/id/64835/abstract-pdf/IAC-21,C3,5-C4.10,2,x64835.brief.pdf</a>	Comparative Overview of NEP programs and concepts	Manuel La Rosa Betancourt	Neutron Star Systems UG	Germany

Human space exploration is at the dawn of a new era. Chemical propulsion will not be enough. Nuclear Electric Propulsion (NEP) is more cost-effective and sustainable for interplanetary voyages, combining the megawatt power of a nuclear reactor with the high specific impulse (Isp) of electric propulsion. This paper presents the geopolitical and technological considerations behind different NEP programs worldwide - the two major actors NASA and ROSCOSMOS and other interested space agencies such as CNSA, ESA and UKSA. Gridded Ion Thrusters (GIT) and Hall Effect Thrusters (HET) at low power levels (up to several kilowatts). Superconductor-based Readiness Enhanced Magnetoplasmadynamic Electric Propulsion (SUPREME) could be a better alternative for high power manned and cargo missions. Applied-Field Magnetoplasmadynamic (AF-MPD) Thrusters offer a range of operations wider than any other existing electric propulsion technology.

Code & link	Paper title	Speaker	Affiliation	Country
C4,10-C3.5,3,x65105 <a href="http://iafastro.directory/iac/paper/id/65105/abstract-pdf/IAC-21,C4,10-C3.5,3,x65105.brief.pdf">iafastro.directory/iac/paper/id/65105/abstract-pdf/IAC-21,C4,10-C3.5,3,x65105.brief.pdf</a>	A Cubesat Demonstrator of Quantized Inertia Propulsion	Dr Ryan Weed		USA

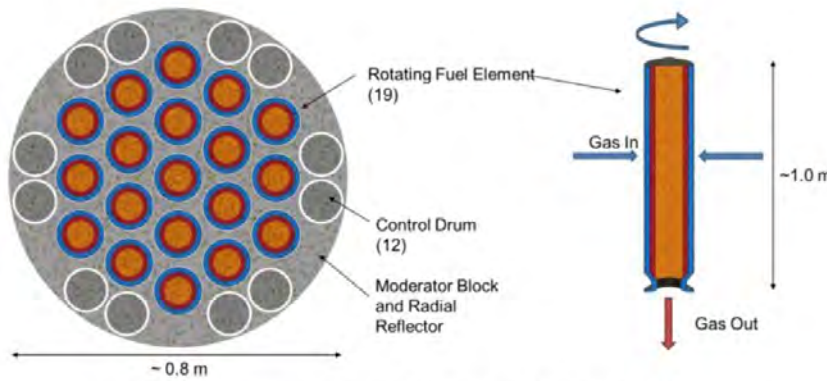
Results of effort to demonstrate a novel propellantless propulsion concept based on the theory of quantized inertia (QI), developed by Prof Michael McCulloch, University of Plymouth, UK [1]. QI theory predicts that a force can be generated in high-Q asymmetric electromagnetic cavities without the use of propellant. For interstellar propulsion, photon-based thrust efficiency is limited to approximately mN/MW. To enable human exploration of the outer solar system and the stars, engineers need a propellantless engine operating at much higher thrust efficiency (>100 N/MW) and an energy source providing high specific power (<10 kg/kW). In a Phase I/II DARPA study, a 3U CubeSat thruster was designed to demonstrate an orbital inclination change under QI propulsion. A lab demonstration at USC Space Engineering Research Center with measurement of the thrust efficiency used a mechanically/electrically isolated/levitated platform in UHV, capable of micro-newton thrust measurements. Main technical challenges were manufacture/coating of the complex optical cavity shapes and isolating the thrust measurement from error sources. CubeSat design challenges included incorporation of unique QI cavity into CubeSat standard geometry, integration of medium power solid state laser, supporting power distribution and thermal design.

[1] See the summary of McCulloch's talk at the second *i4is News Feature: Foundations of Interstellar Studies Workshop 2019 (FISW2)* reported by Patrick Mahon in *Principium* 26 August 2019 page 12. For greater detail see the presentation *Quantised inertia, propellant-less thrust and interstellar travel* by Dr McCulloch video and slides available to i4is members at [i4is.org/videos/fisw2/](http://i4is.org/videos/fisw2/)

Code & link	Paper title	Speaker	Affiliation	Country
C4,10-C3.5,5,x66797 <a href="https://iafastro.directory/iac/paper/id/66797/abstract-pdf/IAC-21,C4,10-C3.5,5,x66797.brief.pdf">iafastro.directory/iac/paper/id/66797/abstract-pdf/IAC-21,C4,10-C3.5,5,x66797.brief.pdf</a>	Overview of the High Performance Centrifugal Nuclear Thermal Propulsion System	Jimmy Allen	Dynetics	USA

Space nuclear propulsion (SNP), and specifically nuclear thermal propulsion (NTP) and nuclear electric propulsion (NEP) show tremendous potential. High Performance NTP (HPNTP) systems can be defined as systems capable of providing ~20,000 N thrust at specific impulse >1300 s. This presentation will focus on one HPNTP concept, the Centrifugal Nuclear Thermal Rocket (CNTR) [1] enabling a relatively short (420 day) round-trip mission to Mars (including 6 weeks at Mars) at an acceptable advancement degree of difficulty (AD<sup>2</sup>) [2].

CNTR uses a combination of flow geometry and centrifugal force to enable a high propellant exhaust temperature (~4000 K) while maintaining structural materials, moderators, and other components at 1000 K. The reactor comprises 19 fuel cylinders, each approximately 1 m in length and 0.1 m in diameter and partially filled with enriched metallic uranium fuel. The first experiment will demonstrate the feasibility of the flow geometry and the second experiment will demonstrate the required compatibility between the cylinder wall, the liquid metallic uranium fuel, and the propellant.



Schematic of 19 cylinders CNTR, Fig. 1 in Allen *et al.*, *Overview of High-Performance Centrifugal Nuclear Thermal Rocket Propulsion System* [1]  
Credit: Allen *et al.*

Fig. 1. Schematic of 19 cylinders CNTR

Code & link	Paper title	Speaker	Affiliation	Country
C4,10-C3.5,11,x65142 <a href="https://iafastro.directory/iac/paper/id/65142/abstract-pdf/IAC-21,C4,10-C3.5,11,x65142.brief.pdf">iafastro.directory/iac/paper/id/65142/abstract-pdf/IAC-21,C4,10-C3.5,11,x65142.brief.pdf</a>	Toward the Engineering Feasibility of the Centrifugal Nuclear Thermal Rocket	Prof Dr Dale Thomas	University of Alabama in Huntsville	USA

In the Centrifugal Nuclear Thermal Rocket, see above ref C4,10-C3.5,5,x66797, the propellant is heated directly by the reactor fuel. This can yield high specific impulse (1800 s) at high thrust but significant engineering challenges must be addressed to establish technical viability: Heat transfer between metallic liquid uranium and the propellant; Accommodation of startup and shutdown transients. Research is on analytical modelling and simulation of the two-phase heat transfer between the liquid metallic uranium fuel and gaseous propellant.

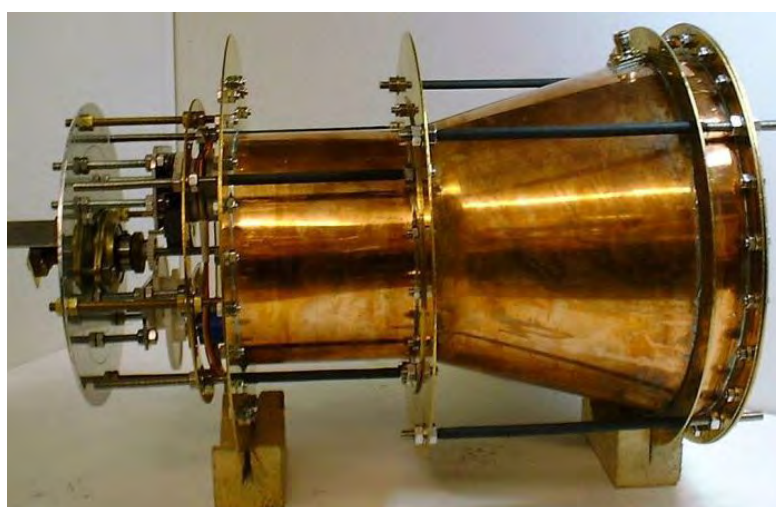
[1] *Overview of High-Performance Centrifugal Nuclear Thermal Rocket Propulsion System*, Jimmy Allen (Dynetics), Michael Johns & Mark Patterson (Southern Research), Michael Houts (NASA Marshall Space Flight Center), Florent Heidet (Argonne National Laboratory), Nicholas V Smith (Idaho National Laboratory), John E Foster (University of Michigan) - 2020 ANS Virtual Winter Meeting [local.ans.org/ne/wp-content/uploads/2021/02/OverviewCNTR-ANS-Winter-2020-summary-paper.pdf](https://local.ans.org/ne/wp-content/uploads/2021/02/OverviewCNTR-ANS-Winter-2020-summary-paper.pdf)

[2] See *Using the Advancement Degree of Difficulty (AD<sup>2</sup>) as an input to Risk Management*, James W Bilbro 2008 [apps.dtic.mil/sti/pdfs/ADA507591.pdf](https://apps.dtic.mil/sti/pdfs/ADA507591.pdf)

**Session: IAF SPACE PROPULSION SYMPOSIUM - Electric Propulsion**

[iafastro.directory/iac/browse/IAC-21/C4/5/](http://iafastro.directory/iac/browse/IAC-21/C4/5/) and [iafastro.directory/iac/browse/IAC-21/C4/6/](http://iafastro.directory/iac/browse/IAC-21/C4/6/)

Code & link	Paper title	Speaker	Affiliation	Country
C4,5,2,x63347 <a href="http://iafastro.directory/iac/paper/id/63347/abstract-pdf/IAC-21,C4,5,2,x63347.brief.pdf?2021-03-31.07:18:11">iafastro.directory/iac/paper/id/63347/abstract-pdf/IAC-21,C4,5,2,x63347.brief.pdf?2021-03-31.07:18:11</a>	A Superconducting EmDrive Thruster. Design, Performance and Application	Roger Shawyer	Satellite Propulsion Research Ltd	UK
<p>Building on work described in a IAC20 paper [1, 2], the author advances that design to a superconducting version. Changes include a new material for the microwave cavity and a passive cooling system, Outline designs of inner and outer solar system missions, 90 kg and 120 kg, use solar power and isotope source power respectively. A specific thrust of 12.3 N/kW at operating temperature 77 K is expected.</p>				



EmDrive Flight Thruster test  
 Credit: Satellite Propulsion Research Ltd  
[emdrive.com/](http://emdrive.com/)

Code & link	Paper title	Speaker	Affiliation	Country
C4,6,7,x64788 <a href="http://iafastro.directory/iac/paper/id/64788/abstract-pdf/IAC-21,C4,6,7,x64788.brief.pdf">iafastro.directory/iac/paper/id/64788/abstract-pdf/IAC-21,C4,6,7,x64788.brief.pdf</a>	Progress in Research and Development of Superconductor-Based Applied-Field Magnetoplasmdynamic Technology	Marcus Collier-Wright	Neutron Star Systems UG	Germany
<p>Applied-Field Magnetoplasmdynamic (AF-MPD) Thrusters have been widely-researched electric propulsion technologies, offering unique characteristics: propellant flexibility, throttleability, high specific impulse, high thrust density, and scalability but research diminished due to issues of electromagnet power consumption and thruster lifetime. There is now a renaissance in research in Germany, Italy, Japan, China, and Russia. Work at University of Stuttgart has achieved the most promising results to date, SUPREME [3], a 100 kW-class SX3 thruster, with thrust efficiencies as high as 62%. This paper reviews the latest advances in AF-MPD and HTS (high temperature superconductor) developments and presents the SUPREME design concept with technological roadmap, subsystem and system level developments and candidate flight missions.</p>				

[1] *An EmDrive Thruster for Cubesats*, Roger Shawyer, IAC-20,C4,6,9,x56845 [www.emdrive.com/IAC20paper.pdf](http://www.emdrive.com/IAC20paper.pdf)

[2] EmDrive Fundamentals [vimeo.com/501195339](https://vimeo.com/501195339)

[3] SUPerconductor based Readiness Enhanced Magnetoplasmdynamic Electric Propulsion thruster, <https://www.neutronstar.systems/the-tech>

**Session: IAF SPACE PROPULSION SYMPOSIUM - New Missions Enabled by New Propulsion Technology and Systems**

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Code & link	Paper title	Speaker	Affiliation	Country
C4,9,10,x61782 <a href="http://iafastro.directory/iac/paper/id/61782/abstract-pdf/IAC-21,C4,9,10,x61782.brief.pdf">iafastro.directory/iac/paper/id/61782/abstract-pdf/IAC-21,C4,9,10,x61782.brief.pdf</a>	The Comet Interceptor Mission - Making a case for Solar Electric Propulsion	Henrique Costa	GMV Innovating Solutions	Portugal
[see A7,3,2,x67120 above for more on Comet Interceptor] Analysis of a Solar Electric Propulsion (SEP) transfer for The Comet Interceptor Mission- possible encounter locations were parametrically defined and mapped according to the $\Delta v$ required to reach them with SEP and compared results to available performance data for the Chemical Propulsion (CP) baseline system, establishing superiority of the SEP option in maximizing both payload mass and reachable locations. Concluded that SEP delivers trajectories requiring less propellant mass and allows savings of more than 125 kilogram for 50% of the comet encounter locations.				
Code & link	Paper title	Speaker	Affiliation	Country
C4,9,11,x61960 <a href="http://iafastro.directory/iac/paper/id/61960/abstract-pdf/IAC-21,C4,9,11,x61960.brief.pdf">iafastro.directory/iac/paper/id/61960/abstract-pdf/IAC-21,C4,9,11,x61960.brief.pdf</a>	Combining Electric sail propulsion and Magnetic propulsion to reduce the time involved in deep space exploration	Ms Zafera Amtul Khader	-	India
We can reduce the mission time of deep space exploration by combining electric and magnetic propulsion. A magnetic sail is more effective at higher velocities whereas an electric sail demonstrates superior performance at low speeds. For deceleration of an interstellar mission the most promising technology the magnetic sail - using the deflection of interstellar matter. Issues: thruster mass, propellant mass, variable specific impulse.				
Code & link	Paper title	Speaker	Affiliation	Country
C4,9,12,x63409 <a href="http://iafastro.directory/iac/paper/id/63409/abstract-pdf/IAC-21,C4,9,12,x63409.brief.pdf">iafastro.directory/iac/paper/id/63409/abstract-pdf/IAC-21,C4,9,12,x63409.brief.pdf</a>	Optimization of interplanetary trajectory for direct fusion drive spacecraft	Prof Giancarlo Genta	Politecnico di Torino	Italy
Direct Fusion Drive (DFD) technology will allow fast and affordable interplanetary travel. To optimize the payload fraction, the thruster should operate in Variable Ejection Velocity (VEV) mode with low thrust interplanetary travel in three phases: first planetocentric, second heliocentric and third planetocentric - optimising thruster mass, propellant mass and variable specific impulse across the three phases. Using IRMA mission analysis code[1] an optimal solution for the duration of planetocentric phases and interplanetary phase, optimal starting and arrival dates can be chosen for any interplanetary journey. Examples of very fast Earth-Mars journeys are computed, showing that DFD allows affordable fast interplanetary travel.				

[1] IRMA: a Graphical Tool for Interplanetary Mission Design, Giancarlo Genta\* and P Federica Maffione, 2018 [www.matec-conferences.org/articles/mateconf/pdf/2018/69/mateconf\\_csc2018\\_02049.pdf](http://www.matec-conferences.org/articles/mateconf/pdf/2018/69/mateconf_csc2018_02049.pdf)

**Session: 19th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE - Innovative Concepts and Technologies**

[iafastro.directory/iac/browse/IAC-21/D4/1/](http://iafastro.directory/iac/browse/IAC-21/D4/1/)

Code & link	Paper title	Speaker	Affiliation	Country
D4,1,7,x66824 <a href="http://iafastro.directory/iac/paper/id/66824/abstract-pdf/IAC-21,D4,1,7,x66824.brief.pdf">iafastro.directory/iac/paper/id/66824/abstract-pdf/IAC-21,D4,1,7,x66824.brief.pdf</a>	An Interactive Model for Space Megastructure Construction	Ms Elizabeth Scott	Colorado School of Mines	USA
<p>An interactive software model to explore the economic and technological conditions needed for the construction of space megastructures, including fuel depots, orbital habitats, space-based solar power satellites, and planetary sunshades intended to assess the technological and economic feasibility of space megastructure construction. Uses a time-driven state machine that virtually transforms various cislunar raw materials into useful resources and finished products, as well as modelling their transportation throughout cislunar space. The paper shows the model’s architecture, demonstrates its use and presents preliminary results for time-, mass-, and cost-efficient construction of space megastructures.</p>				
Code & link	Paper title	Speaker	Affiliation	Country
D4,1,14,x66313 <a href="http://iafastro.directory/iac/paper/id/66313/abstract-pdf/IAC-21,D4,1,14,x66313.brief.pdf">iafastro.directory/iac/paper/id/66313/abstract-pdf/IAC-21,D4,1,14,x66313.brief.pdf</a>	Selection of asteroids which are suitable for collision with Mars for the purpose of terraforming	Neelabh Menaria	Ramaiah Institute of Technology	India
<p>To terraform Mars, methods are devised to augment temperature, water levels, atmospheric composition, and atmospheric pressure. No one approach was found that could tackle all of the requirements and a synergistic approach was taken. One of these approaches includes bombardment of planet from volatile rich asteroids. Importing volatiles is essential step for terraforming Mars since the abundance of nitrogen is currently too low to support Earth life. The paper also lists possible candidate asteroids with suitable mass, density, diameter, composition and other parameters.</p>				

**Session: 49th STUDENT CONFERENCE -**

[iafastro.directory/iac/browse/IAC-21/E2/](http://iafastro.directory/iac/browse/IAC-21/E2/)

Code & link	Paper title	Speaker	Affiliation	Country
E2,2,9,x65326 <a href="http://iafastro.directory/iac/paper/id/65326/abstract-pdf/IAC-21,E2,2,9,x65326.brief.pdf">iafastro.directory/iac/paper/id/65326/abstract-pdf/IAC-21,E2,2,9,x65326.brief.pdf</a>	A first step towards interstellar fusion propulsion	Mewantha Aurelio Kaluthantrige Don	University of Strathclyde	UK
<p>This paper focuses on nuclear fusion processes. Inertial Electrostatic Confinement (IEC) is a method to obtain nuclear fusion reactions by means of strong electrical fields confining plasma. Two concentric spherical electrodes apply voltage to ionize the gas between them and accelerate the ions to initiate fusion. The electrical field geometry causes plasma to be ejected, as in common electrostatic propulsion systems. This paper shows the physics of an IEC by manufacturing and testing a small-scale plasma confining propulsion system and conceivably applying it to a 6U CubeSat. The work is at NASA Ames Research Center, Technological and Educational Nanosatellite department, lead by Marcus Murbach, Principal Investigator, Space Technology division.</p>				