72nd International Astronautical Congress 2021
The Interstellar Papers

edited by John I Davies

This year the International Astronautical Federation once more held the International Astronautical Congress in a geographical location, this year in Dubai. In this first of two pieces 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.

Our onsite reporter was i4is Contributing Editor Samar AbdelFattah of DM TECH (www.disruptivemobility.com).

Here you will find -

■ Code - the unique IAC code and a link to the Abstract

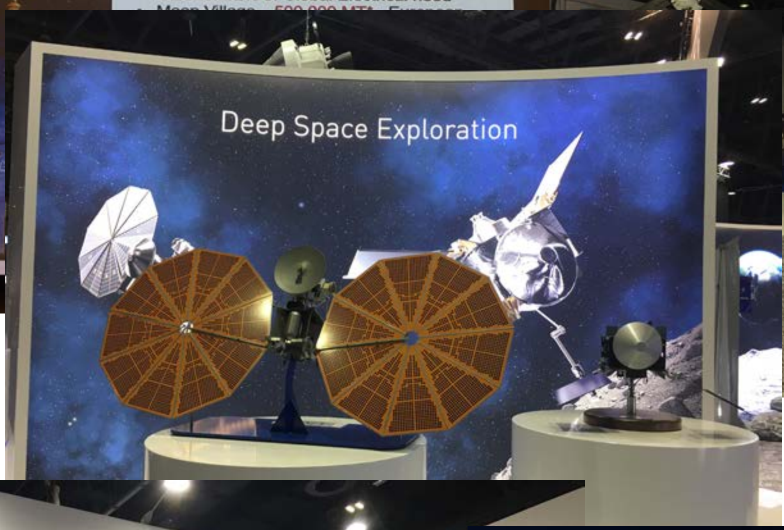
■ Paper title, Speaker, institutional Affiliation and Country

■ Links to papers and videos on the IAF website (login required) and to open publication where found

■ Remote reports by - Adam Hibberd & John I Davies

Please contact john.davies@i4is.org if you have comments, find discrepancies or have additional items to suggest.

We will have more reports and background in our next issue, Principium 36.



At IAC 21

Images credit: Samar AbdelFattah

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,A3,IP,58,x65239	Optimum Location to Intercept Interstellar Objects with Build-and-wait Missions	Laia Lopez Llobet	International Space University (ISU)	France

IAF cited paper:

dl.iafastro.directory/gallery/file/IAC-21/A3/IP/IAC-21,A3,IP,58,x65239.pdf

IAF cited presentation video:

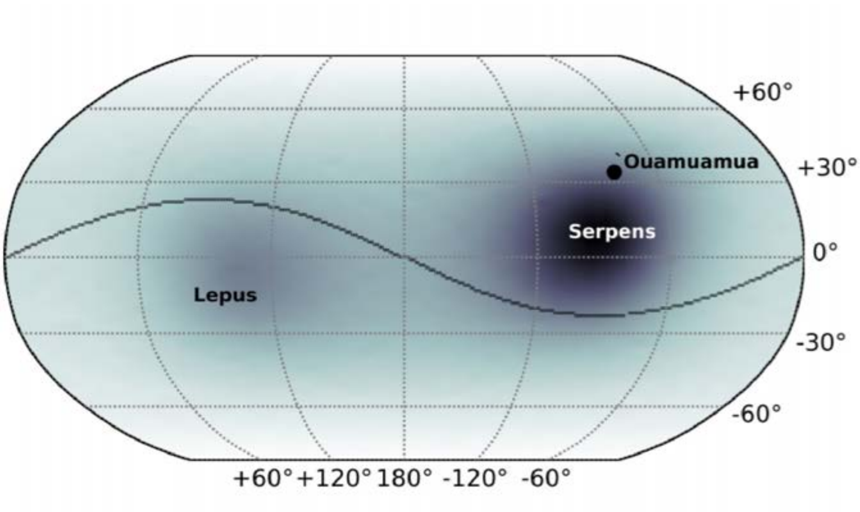
dl.iafastro.directory/gallery/file/IAC-21/A3/IP/IAC-21,A3,IP,58,x65239.lecture.mp4

Open paper: none found

Reported by: John I Davies

The ESA Comet Interceptor mission will launch in 2028 to the Sun-Earth Lagrange 2 position (joining the existing Gaia astrometry mission, the James Webb space telescope and others at this convenient quasi-stable point in the Earth-Sun system [1]). The Comet Interceptor will "lurk" until a suitable object, possibly an interstellar object (ISO), is spotted by one of the increasingly capable telescopes in place and planned for that time.

This study aims to generalise the problem of where best to locate a vehicle specifically intended to reach an ISO. It uses numerical analysis to simulate the potential trajectories of ISOs through the Solar System and calculates where they will intersect the ecliptic plane. The most likely incoming vectors are at the solar apex and anti-apex.



Entire caption credit: Lopez Llobet-

Fig. 3. Probability map from a heliocentric perspective representing the likelihood of ISOs approaching with a velocity vector parallel to the vector pointing from the Sun to a particular position in the sky. A higher probability is indicated with darker colors. The ecliptic is represented by a black line. The positions of 1I/'Oumuamua entering the Solar System and the constellations Serpens and Lepus have also been represented. These constellations are in the solar apex and anti-apex, respectively.

It uses MATLAB (in common with the work of Adam Hibberd for i4is Project Lyra - see multiple issues of Principium) to create the ISOs' trajectories. The trajectories are all hyperbolic with respect to the Sun, eccentricity >1, and the study considers eccentricities up to 9.

The study also examines the probability of ISO impact on the Earth and concludes that ISOs will average a hit every ten million years but with the caveat that only objects around the size of 1I/'Oumuamua or above are considered (so don't relax yet, an object half the size of 1I could do a lot of damage!). In fact the study suggests that Earth is near-optimally placed to intercept an ISO supporting the hypothesis that prebiotic molecules could have been brought to Earth by an ISO.

The study looks at costs and logistics and suggests that an ISO interceptor should probably be space-based, like the already planned ESA mission, but Earth based build-and-wait missions have advantages and should not be ruled out.

Authors: Laia Lopez Llobeta (ISU), Chris Welch (ISU), Andreas M Hein (i4is)

[1] To be clear, L2 is a dynamically unstable Lagrange point. A useful analogy is the top of a hill rather than the bottom of a valley. For example Gaia is not stationary but is in a "figure of eight" Lissajous-type orbit around the L2 point of the Sun-Earth system.

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,C3,IP,x65677	High-Temperature Photovoltaic Cells for Near-Sun and Interstellar Precursor Missions: State of the Art and Future Developments	Corentin Guemene	International Space University (ISU)	France

IAF cited paper:

dl.iafastro.directory/gallery/file/IAC-21/C3/IP/IAC-21,C3,IP,x65677.pdf

IAF cited presentation video:

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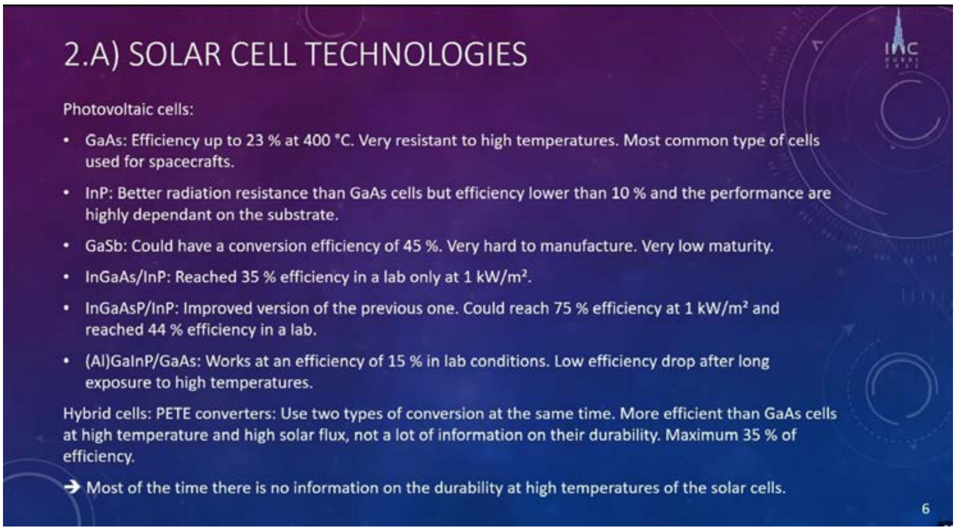
Open paper: none found

Reported by: John I Davies

Missions close to the Sun are conveniently powered by the light of our local star. However, at the orbit of Mercury and closer, temperatures are challenging for current solar cells [1]. This study focuses on both these applications and on high-power electric propulsion with an external laser power source. Three missions are considered -



- Mercury orbiter
- Solar probe to study the Sun from close orbit
- Interstellar precursor mission to the outer Solar System and beyond

Solar cell technologies
Credit: Guemene

Existing material technologies examined include GaAs (Gallium arsenide), InP (Indium phosphide), GaSb (Gallium antimonide), multi-layer technologies (InGaAs/InP, InGaAsP/InP. (Al)GaInP/GaAs) and Hybrid Photon-Enhanced Thermionic Emission (PETE) converters (for example with a GaAs absorption layer and a GaAs photovoltaic cell).

Powering a spacecraft via external lasers is attractive because the craft need not carry large solar arrays (and can reach targets distant from the Sun) or a radioisotope thermal generator (RTG). The study identifies some challenges including a single optimum frequency (ie monochromatic) source, precise pointing and possible need for even larger photovoltaic arrays and laser sources, especially at low frequencies (ie long wavelengths).

The past MESSENGER craft, the current BepiColombo mission to Mercury and the projected Solar Probe+ are examples of the high temperature solar power application. The projected Solar Probe+ would study the Sun from 8.5 solar radii.

The study concludes with a discussion of the Technology Readiness Levels (TRLs) [2] of the various materials against several possible missions: Mercury, near-Sun, and interstellar precursor.

Authors: Corentin Guemene (ISU), Chris Welch (ISU), Rob Swinney (i4is), Angelo Genovese (i4is)

[1] Mercury is about 75 solar radii out, but probes which aim closer either for research reasons or to achieve gravity-assisted acceleration are planned to get much closer.

[2] Technology Readiness Level (TRL) - The ESA Science Technology Development Route sci.esa.int/web/sci-ft/-/50124-technology-readiness-level.

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,D3,1,7,x63937	Advanced Propulsion as a Cornerstone for Space Exploration and Interstellar Living	Tommaso Tonina	International Space University (ISU)	France

IAF cited paper:

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IAF cited presentation video:

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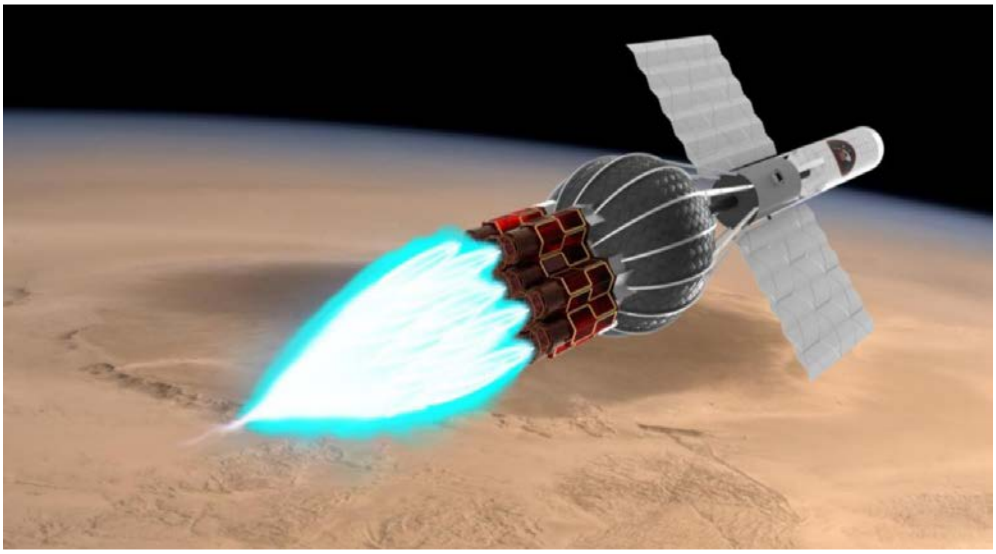
Open paper: none found

Reported by: John I Davies

Mission patch

Credit: ISU *Space Studies Program Team Project, Fast transit: Mars and beyond*

The bold ambition of this paper is missions accelerating at 0.2 g with a mid-journey flip to decelerate. Implying missions to Mars in 4-10 days using rocket having specific impulse (Isp) of 19,000 seconds a thrust/weight ratio of 2.94 using either Magnetic Inertial Confinement Fusion (MICF) with current TRL 2-3, or Antimatter Catalysed Fusion (ACF) with current TRL 2. They propose a large initial investment, likely through a Public Private Partnership (PPP), to demonstrate feasibility, delivering quick access to abundant raw materials as the return on investment. Achieving this would lead to a change in perception about accessibility of space travel. The team conducted interviews and discussions with key experts and a systematic review of the literature. They considered orbital mechanics and trajectories including an Earth-Mars cycler and the use of Lagrange points but settled on a direct Earth-Mars trajectory using the advanced rocket technologies MICF or ACF, settling on ACF and calling this "Fast Transit spaceflight". They also considered human factors, social ethical implications, the business implications of such a major undertaking and the legal issues - notably the dangers presented by such powerful rocketry. They present a highly ambitious roadmap and spin-off benefits for research missions and commercial applications.



Proposed spacecraft in transit near Mars - from -

International Space University Space Studies Program Team Project, Fast transit: Mars and beyond, Illkirch-Graffenstaden (France), 2019. -

:isulibrary.isunet.edu/index.php?lvl=notice_display&id=10798

Authors: Tommaso Tonina (ISU), Hamda Alshehhi (UAE Space Agency), Jason Dowling (CSIRO Australian e-Health Research Centre), Gustavo Jamanca-Lino (Colorado School of Mines), Erin Kennedy (Robot Missions Inc, Ontario), Yelyzaveta Kucher (ISU), Rijin K V (Indian Space Research Organisation), Itai Norber (ImageSat International NV, Israel)

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,E5,3,7,x66226	Virtual futuristic analogue missions to drive methodological innovation for clinical research for space mission and earth	Mona Nasser	University of Plymouth	UK

IAF cited paper:

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IAF cited presentation video:

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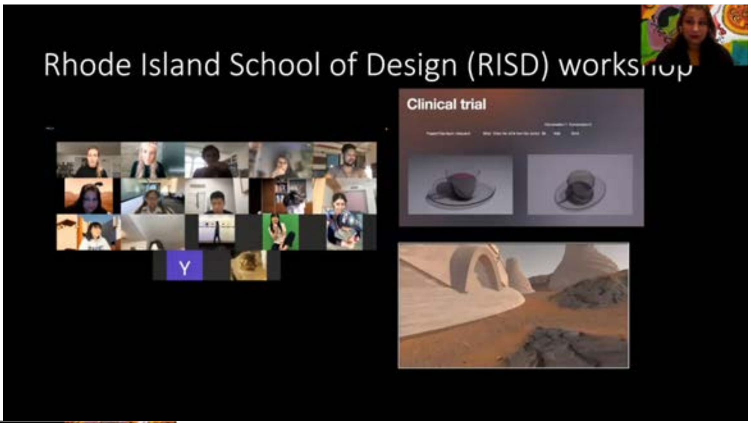
Open paper: none found

Reported by: John I Davies



The team piloted a series of virtual workshops using a futuristic sci-fi scenario for interplanetary and interstellar missions adapted for a virtual environment. They aimed for innovative approaches to the methods of clinical research in this context. In 2019, and 2020 they first conducted small groups of pilot hybrid workshops and moved on to four workshops with 20-30 people (engineers, lawyers, artists, clinical researchers, medics, geologists, other sciences and professionals). Having identified several limitations in current space medicine literature they immersed participants in a futuristic scenario, modulating participant tendencies to reinterpret the scenario presented into something more familiar. The team included a layer of meta-research which they termed "forensic backcasting" of scientific methods.

Some interesting results included participants starting to take an ecological approach to design clinical research and participants' confusion between risk and uncertainty. The team aim to extend their exercise to an interstellar scenario.

Venues included Torbay Hospitals (UK), the Cochrane Colloquium in Edinburgh, the office of Transtech (Plymouth, UK), the EDGE clinical trial conference in Southampton (UK), the International Space University and Rhode Island School of Design

Authors: Mona Nasser (University of Plymouth), Jacqui Knight (University of Plymouth), Agatha Haines (Rhode Island School of Design), Diego Maranan (University of the Philippines),

Ann Peeters (Space Ecologies Art and Design, Belgium), Prashanti Eachempati & Sumanth Kumbargere Nagraj (Manipal University, Malaysia), Mr Joshua Bernard-Cooper (UK)

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21, A7,3,2,x67120	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

IAF cited paper:

dl.iafastro.directory/gallery/file/IAC-21/A7/3/IAC-21,A7,3,2,x67120.pdf

IAF cited presentation video:

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Open paper: None found

Reported by: Adam Hibberd

This is an audacious combined ESA and JAXA F-class mission with a serious British involvement in the form of the Mullard Space Science Laboratory. Its whole raison d'etre is based on statistical predictions on three counts:

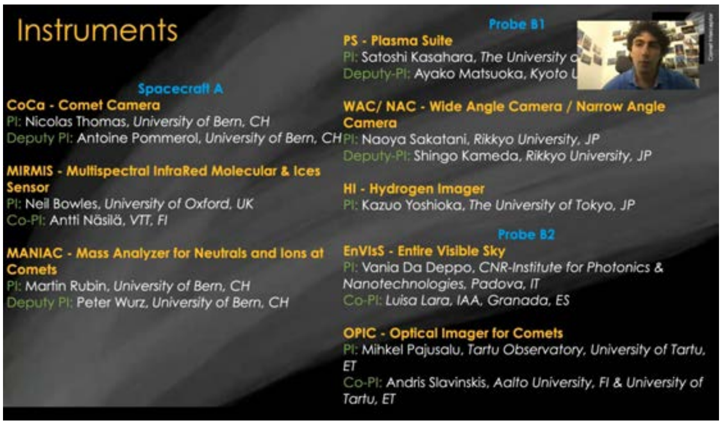
1. there are a sufficient number of dynamically new comets encountering the inner solar system
2. when the Vera C Rubin telescope comes into operation, it will be able to detect a sufficient quantity of them
3. there will be at least one which will be reachable by the spacecraft during its 3 year mission.

There is however a failsafe to the mission in that there are several short period comets which the mission designers have in mind and which would serve as a back-up if the statistical calculations are off-beam.

In simple terms Comet-I is a spacecraft capable of waiting in space for up to three years at a planned point, the Sun-Earth Lagrange 2 Point to be precise. There it will tag a free ride shadowing the Earth as it orbits the sun, counterbalanced perfectly by the forces from these two celestial bodies.

Once an appropriate 'dynamically new comet' (a comet possibly new to the inner solar system so in a relatively pristine condition - not eroded by the sun) is found by the Vera C Rubin, then at a suitable juncture the spacecraft will be sent a dispatch command from Earth to intercept this comet.

Relative velocities as high as 70 km/s are possible. Generally speaking, optimal intercept happens when the comet crosses the ecliptic, meaning the spacecraft need not apply much – or any – ΔV out of the ecliptic plane, where the Sun/Earth L2 lies of course. This 70 km/s figure makes sense because a comet arriving from approx. infinity would have a speed at 1 AU of 42 km/s. If one further supposes this is the worst case scenario (ie retrograde) and the s/c is travelling at Earth’s speed of 30 km/s prograde, then these two speeds are additive, giving the 70 km/s (approx) stated in the paper.



Just before intercept, two smaller probes will be detached from the mother craft and study the comet in detail separately yet simultaneously and an image of the comet can be generated.

The relevance to i4is is the possibility that an ISO might be found in this three year span. If this happens then it would truly be a jackpot with implications regarding the potential scientific return which would result.

Authors: Mohamed Ramy El-Maarry, Geraint H Jones, Colin Snodgrass, Cecilia Tubiana, and the Comet Interceptor Team

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,A4,1,17,x63320	The Drake equation and SETI in the JWST era	Amri Wandel	Hebrew University of Jerusalem	Israel

IAF cited paper:

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IAF cited presentation video:

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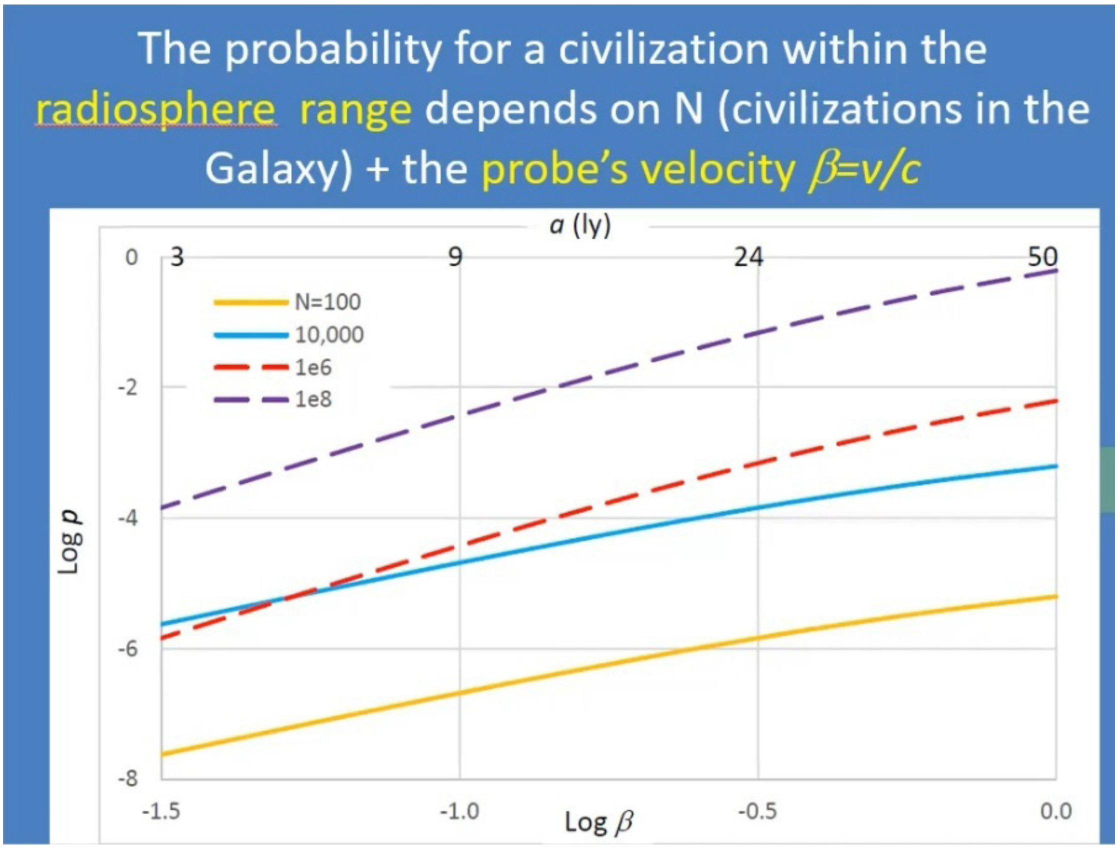
Open paper: None found

Reported by: John Davies

In another paper at this congress (IAC-21-A1.6.1 Extended Habitable Zone of M-dwarf planets) the presenter suggests that "the Habitable Zone around M-stars is significantly wider than previously thought". Arguing that, with current receiver technology, we can only detect signals deliberately aimed at our solar system. Therefore our "radiosphere" (the radius reached by our unintentional signals) may represent the maximum distance from which we might expect to receive such signals. Wandel also considers probes sent by such ETIs, assumes that they would have two-way communication with their home world and that signals from the home world would be powerful enough for us to detect. He also argues we should look for such signals in the Earth's "transit zone" since we may be detected by analysis of our atmosphere as it intercepts light from the Sun. Overall he concludes that the Fermi Paradox and "The Great Silence" may be attributed just to the sluggish velocity of light!



Plot of (log) probability of civilisations within Wandel's "radiosphere" range against (log) velocity of a probe sent to our Solar System as a fraction of the velocity of light, c.

Suggesting that negative SETI results apply only to that radiosphere.

Credit: Wandel

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,A4,1,18,x63279	Moon Farside Protection and Astronomy Protection Are Urgent: Asking For A “Farside Science Treaty” Also Called “Switch-Off-Treaty” (“SOT”)	Dr Claudio Maccone	International Academy of Astronautics (IAA) and Istituto Nazionale di Astrofisica (INAF)	Italy

IAF cited paper: dl.iafastro.directory/gallery/file/IAC-21/A4/1/IAC-21,A4,1,18,x63279.pdf

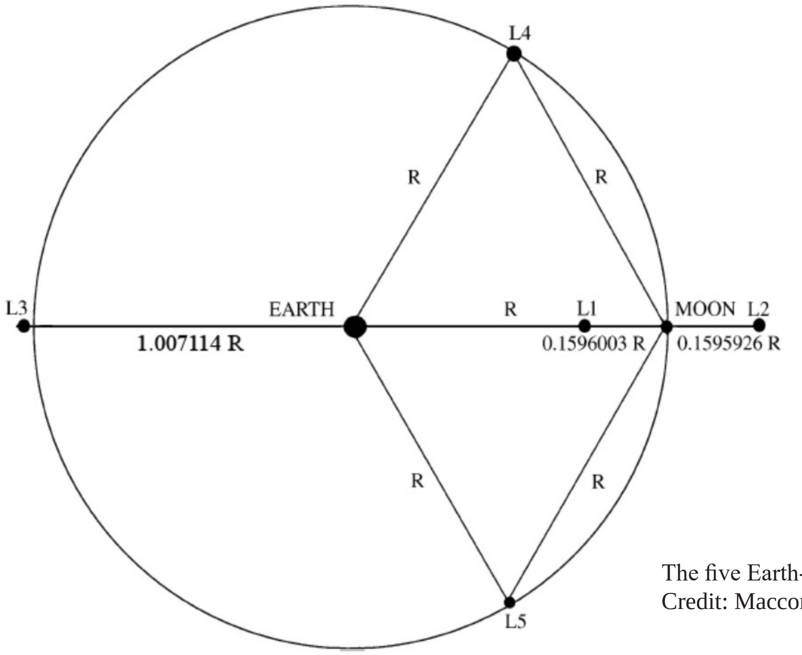
IAF cited presentation video: dl.iafastro.directory/gallery/file/IAC-21/A4/1/IAC-21,A4,1,18,x63279.lecture.mp4

Open paper: None found

Reported by: John Davies

Claudio Maccone is one of the greatest and most long-engaged researchers in SETI. Here he argues that, since the Moon Farside is the only place where radio transmissions and noises produced by Humanity on Earth may not reach, the legal protection of the Moon Farside from all kinds of non-scientific future exploitations (real estate, industry and military) has long been a concern. The current "race to Moon" adds to the threat. The farside must be reserved for radar watch (for Earth-impact warning), cosmology and SETI. He proposes the signing of a “Farside Science Treaty” or “Switch-Off-Treaty” by all space-faring Nations under the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). He gives some history of past farside proposals and notes the recent Chinese relay satellite Queqiao in the Earth-Moon Lagrange 2 (L2) point (beyond the Moon) as the first of what may be many transmitters above the farside. Queqiao would "blind" any future radio telescope on the farside.

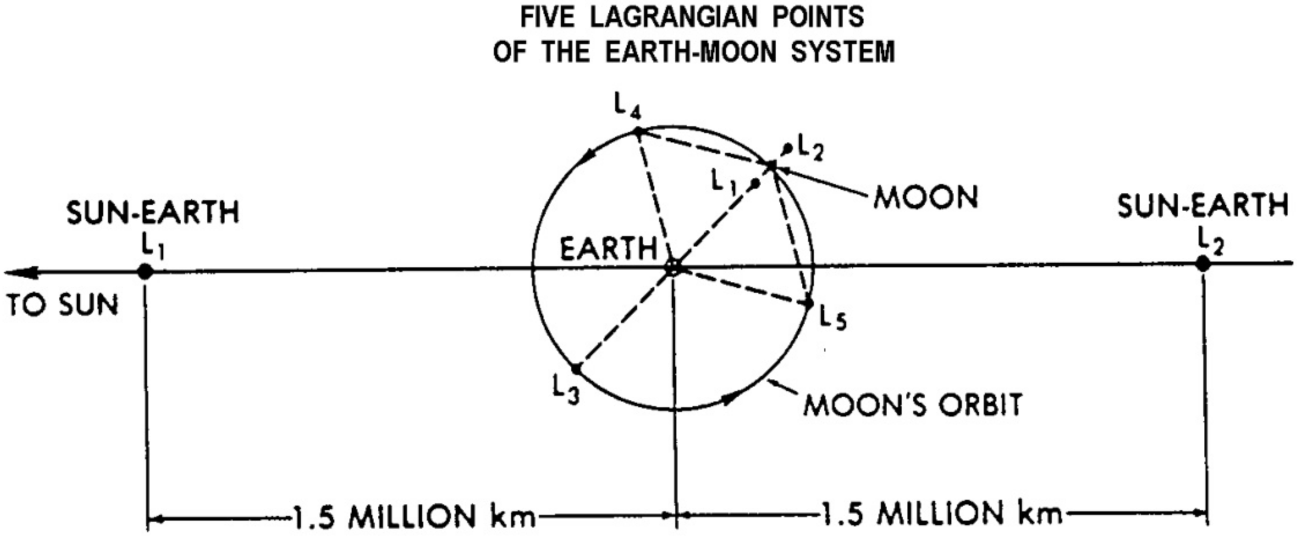
Maccone proposes a Protected Antipode Circle in the centre of the farside protected from radiation coming from L2 and even L4 and L5 (equivalent to the Trojan positions in the Jupiter-Sun system).



The five Earth-Moon Lagrangian Points
Credit: Maccone

There is clearly a "quiet cone" where transmission from Earth and our satellites do not reach [1]. As a flat surface near the centre of the farside area defined by the "quiet cone", Maccone proposes the crater Daedalus for a radio observatory in what may be the quietist place in the near solar system.

[1] Since geostationary satellites are 42,000 km from the centre of the Earth the cone diameter is 84,000 km and the sides are tangents to the Moon's surface



[credit Maccone] "(Courtesy of the late Dr Robert “Bob” Farquar, Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA). In addition to the five Lagrangian Points of the Earth-Moon system (already described in Figure 4) the next two closest Lagrangian Points to the Earth are the Lagrangian Points L1 and L2 of the Sun-Earth system. These are located along the Sun-Earth axis at the distances of about 1.5 million kilometers from the Earth toward the Sun (L1) and outward (L2). Unfortunately, spacecrafts located in the neighborhood of these L1 and L2 Sun-Earth Points do send electromagnetic waves to the Farside of the Moon. Examples are the ISEE-III and Soho spacecrafts, already orbiting around L1, and more spacecrafts will do so in the future around both L1 and L2."

Other places polluting radiation are the Earth-Sun Lagrange points L1 (between Earth and Sun) and L2 (beyond Earth). These are already occupied and are polluting the Moon's "quiet cone" (during new moon and full moon and times around them).

Maccone lists and characterises a number of other pollution source both human and natural and exhorts all with authority and influence to support the proposed Farside Science Treaty.

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,A4,2,12,x61987	Radio Bridges of the Future between Solar System and the Nearest 50 Stars	Claudio Maccone & Nicolò Antonietti	International Academy of Astronautics & Istituto Nazionale di Astrofisica	Italy

IAF cited paper: dl.iafastro.directory/gallery/file/IAC-21/A4/2/IAC-21,A4,2,12,x61987.pdf

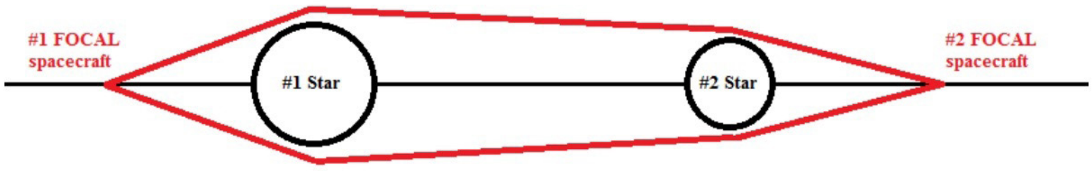
IAF cited presentation video:

dl.iafastro.directory/gallery/file/IAC-21/A4/2/IAC-21,A4,2,12,x61987.lecture.mp4

Open paper: None found

Reported by: John Davies

Dr Maccone (see report IAC-21,A4,1,18,x63279 above) discusses the 50 potential radio bridges between the Sun and each of our nearest 50 stars using the Solar Gravitational Lens (SGL) positions which exist for all massive bodies such as stars. In the coming centuries he envisages a communications network using these radio bridges as energy-efficient relay points. He gives a quick introduction to the SGL concept and goes on to suggest scenarios with and without the SGL. He suggests a gain of about 70 db for the SGL (meaning $10^{7.0}$ = 10 million). This advantage makes his proposed network feasible at greatly reduced transmitter powers. He suggests that "a Civilization much more advanced than Humans in the Galaxy might already have created such a network of cheap interstellar radio links: a true Galactic Internet". If we want to join it we must build relays at SGL points oriented towards our neigbours.



Maccone's illustration of the transmit and receive gain at the end of a SGL relay.

Using his 70 db gain per SGL this would be 70+70=140 or $10^{14.0}$ = 100,000,000,000,000 or 100,000 billion.

Image credit: Maccone

He gives numerical examples of bridges between the Sun and Barnard's star (about six light years), the Sun and Sirius-A, between the Sun and another sun-like star located at the galactic bulge and finally between the Sun and another sun-like star located inside the Andromeda galaxy (M 31). He tabulates the relevant parameters of 50 stars [1] and estimates to potential channel capacities for relays between each of them and the Sun.

This is a very long term vision but Dr Maccone believes that the present paper will still be useful in a few centuries to set up his Roadmap of the Human Expansion into the Galaxy.

IAF reference	title of talk/paper	presenter	institution	nation
IAC-21,A4,2,18,x62033	The Need for a Worldwide and International SETI Journal	Dr Claudio Maccone	International Academy of Astronautics (IAA) and Istituto Nazionale di Astrofisica (INAF)	Italy

IAF cited paper: dl.iafastro.directory/gallery/file/IAC-21/A4/2/IAC-21,A4,2,18,x62033.pdf

IAF cited presentation video:

dl.iafastro.directory/gallery/file/IAC-21/A4/2/IAC-21,A4,2,18,x62033.lecture.mp4

Open paper: None found

Reported by: John Davies

Dr Maccone observes that Acta Astronautica (ActaA) is the official journal of the International Academy of Astronautics (IAA). The publisher Elsevier believes there is insufficient audience for a specialised SETI journal but Maccone has found that SETI papers are often rejected by ActaA and a SETI journal would need a wider cultural scope than ActaA. He suggests that SETI needs to become more "political", helping the world to become ready for a possible “SETI Crisis” in case of first contact with ETI. Maccone gives some history of SETI and identifies 12 current SETI programmes. The limitations of ActaA are, to an extent, made up by the IAF Digital Library set up last year.

Dr Maccone concludes by asking "is the time ripe for the creation of a New International Journal devoted to SETI Only ?"

[1] Proxima Centauri, Barnards star, Wolf 359, Lalande 21185, Sirius A, BL Ceti, Ross 154, Ross 248, Epsilon Eridani, Lacaille 9352, Ross 128, EZ Aquarii A, Procyon A, 61 Cygni A, Gliese 725 A, GXAndromedae, Epsilon Indi A, DX Cancri, Tau Ceti, Gliese 1061, YZ Ceti, Luyten star, Teegarden star, Kapteyn star, Lacaille 8760, Kruger 60 A, Ross 614 A, Gliese 628, Gliese 35, Gliese 1061, Wolf 424 A, TZ Arietis, Gliese 867, LHS 292, Gliese 674, Gliese 1245 A, Gliese 440, Gliese 1002, Ross 780, Gliese 412 A, Groombridge1618, Gliese 388, LHS 288, Gliese 832, LP 944-020, DENIS/DEN02554700, Gliese 682, 40 Eridani A, EV Lacertae, 70 Ophiuchi A