IAC 2023
The Interstellar Presentations

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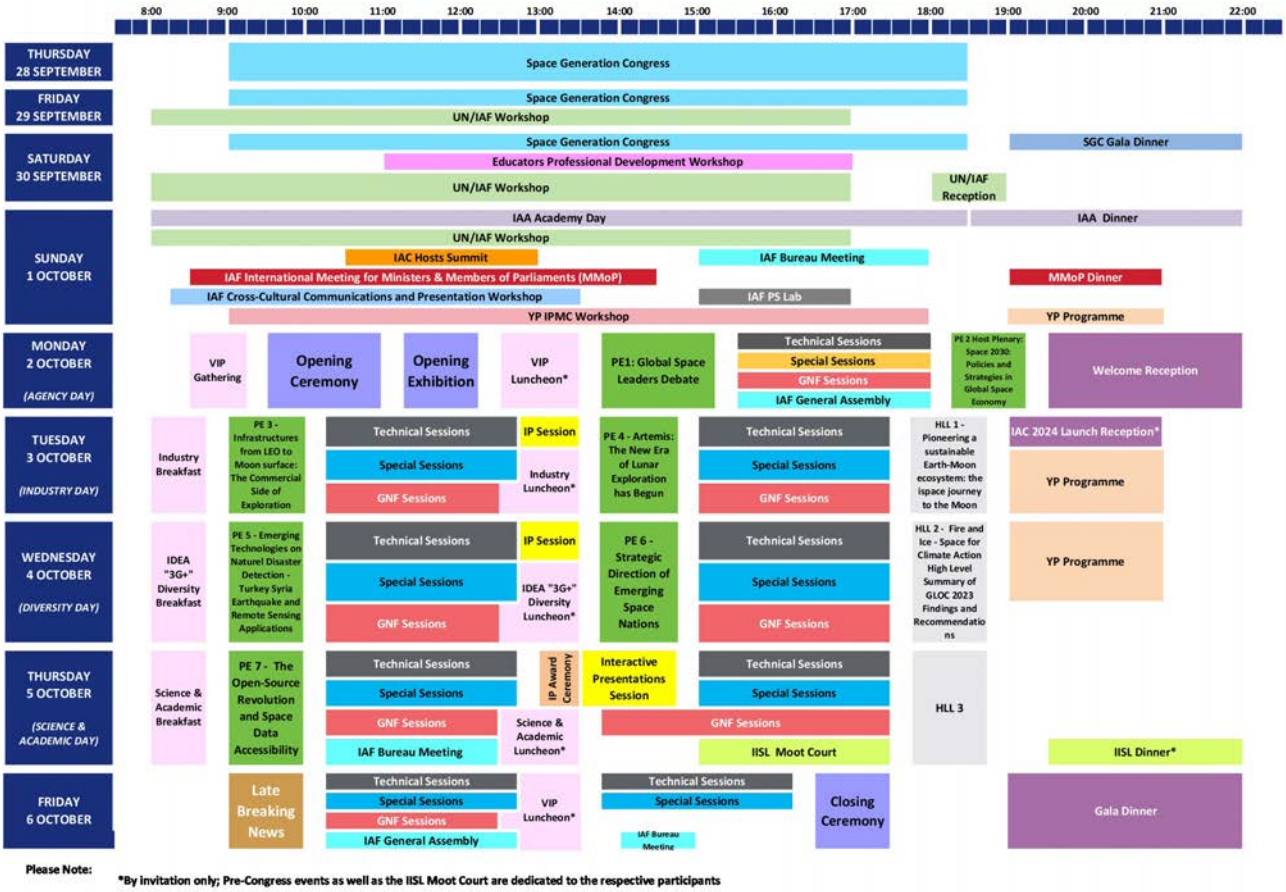
This feature identifies items related to interstellar studies which are listed to appear at this year's International Astronautical Congress, IAC23.
If you spot anything we miss then contact principium@i4is.org and we will endeavour to cover it in our news feature following the congress, for the November edition P43. All of the programme items listed here are visible via iafastro.directory/iac/browse/IAC-23/.



The Programme

Here is the programme with IAF identifying codes for the symposium sessions.

A1.	IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM
A2.	IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM
A3.	IAF SPACE EXPLORATION SYMPOSIUM
A4.	52nd IAA SYMPOSIUM ON THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI) – The Next Steps
A5.	26th IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM
A6.	21st IAA SYMPOSIUM ON SPACE DEBRIS
A7.	IAF SYMPOSIUM ON ONGOING AND NEAR FUTURE SPACE ASTRONOMY AND SOLAR-SYSTEM SCIENCE MISSIONS
B1.	IAF EARTH OBSERVATION SYMPOSIUM
B2.	IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM
B3.	IAF HUMAN SPACEFLIGHT SYMPOSIUM
B4.	30th 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.	21st IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT
D4.	21st IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE
D5.	56th 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.	51st IAF STUDENT CONFERENCE
E3.	36th IAA SYMPOSIUM ON SPACE POLICY, REGULATIONS AND ECONOMICS
E4.	57th IAA HISTORY OF ASTRONAUTICS SYMPOSIUM
E5.	34th IAA SYMPOSIUM ON SPACE AND SOCIETY
E6.	IAF BUSINESSES AND 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

The Interstellar Programme Items

Shown alphabetically by IAF identifying code. Access them all via iafastro.directory/iac/browse/IAC-23/.

C4,10-C3.5,1,x80575	KEYNOTE: Nuclear Thermal Propulsion – Progress and Potential	Dr Dale Thomas	University of Alabama in Huntsville	United States

This keynote address will describe the current research and development efforts currently underway within the United States on Nuclear Thermal Propulsion (NTP), with a particular focus on the Demonstration Rocket for Agile Cislunar Operations (DRACO) project, a joint effort of the United States Defense Advanced Research Projects Agency (DARPA) and the National Aeronautics and Space Administration. The impact of NTP propulsion on both human and scientific exploration of the Solar System will also be discussed. And finally, the topic of advanced NTP propulsion will be addressed, including liquid fuel NTP engines.

C4,10-C3.5,2,x79343	Deployment of the large size solar sail	Dr Vladimir Ya Kezerashvili	New York City College of Technology	United States

A solar sail presents a large sheet of low areal density membrane and is a propellant-less propulsion system for future exploration of the Solar System and beyond. One of the important objectives of the propulsion using a solar sail is the development of the mechanism for the deployment and stretching of large membranes in space. In this work we present a comparison of two novel concepts for deploying and stretching of the large size solar sail:
i. the deployment and stretching of the thin circular membrane attached to the superconducting current loop [1,2],
ii. the deployment and stretching of the thin circular membrane attached to the inflatable toroidal shell [3].
In the framework of a strict mathematical approach based on the theory of elasticity elastic properties of a circular solar sail membrane, inflatable toroidal shell, and superconducting wire loop are analyzed. Within classical electrodynamics it is predicted the magnetic field induced by the Bi-2212 superconducting wire with today achievable engineering current densities can deploy and stretch the large membrane. The formulas for the superconducting wire and sail membrane stresses and strains caused by the current in the superconducting wire are derived. It is predicted that by introducing the gas into the inflatable toroidal shell one can deploy and stretch a large size circular solar sail membrane. The formulas for the toroidal shell and sail membrane stresses and strains caused by the gas pressure in the toroidal shell are derived. The analytical expressions obtained for both type of the deployment mechanism can be applied to a wide range of solar sail sizes. Numerical calculations for the sail of radii up to 100 m (10,000 m^2) made of CP1 membrane are presented. We demonstrate the feasibility of deployment and stretching of a solar sail with a large size circular membrane attached to superconducting wire loop or the inflatable toroidal shell.
References
1. V Ya Kezerashvili and R Ya Kezerashvili, *On deployment of solar sail with superconducting current-carrying wire*, Acta Astronautica 189, 196–198 (2021).
2. V Ya Kezerashvili and R Ya Kezerashvili, *Solar sail with superconducting circular current-carrying wire*, Advances in Space Research 69, 664–676 (2022).
3. V Ya Kezerashvili, R Ya Kezerashvili, and O L Starinova, *Solar sail with inflatable toroidal shell*, Acta Astronautica 202, 17–25 (2023).

C3,5-C4.10,4,x75360	Application of Nuclear Power and Propulsion Systems of High Power Level for Space Transportation	Dr Vladimir Koshlakov	Keldych Research Centre	Russian Federation

Realization of new research and exploration space missions requires a qualitative increase of spacecraft (SC) power and propulsion capabilities. Because of that high power space tug [1,2] based on nuclear power system (with power level up to hundreds of kW – MW) and electric propulsion system, is mainly considered as a new transport vehicle for near-Earth and deep space missions realization. Nuclear power systems are characterized by significantly greater compactness than solar panels, independence of the generated power from the distance to the Sun, light conditions, and increased radiation resistance. The use of electric propulsion (EP) thrusters for such tasks as inserting a spacecraft into orbit, keeping a spacecraft in orbit, interplanetary flights and missions in deep space provides significant savings in the used propellant mass in comparison with traditional chemical propellant thrusters due to the high specific impulse of EP thrusters. Projects aimed at development and application of space vehicles based on nuclear power propulsion system (PPS) of high power level have been conducted since the very beginning of the space exploration Era. Interest in such projects [1] arises as human activity in space grows, for example: project Prometheus (NASA, USA), project Transport Power Module (Russia) and European-Russian projects DEMOCRITOS and MEGAHIT [2]. New projects of SC with nuclear PPS continue to appear due to the development of new designs and technological solutions for the main parts and subsystems of high power level nuclear PPS. One of the promising options is a nuclear power and propulsion consisting of a gas-cooled reactor, a closed Brayton cycle Power Conversion Unit (PCU) and an Electric Propulsion (EP) thrusters [1]. Efficiency of nuclear power and propulsion systems application for transport missions to Moon, to Mars and to Europa (Jupiter's satellite) is analyzed in comparison with conventional chemical propulsion systems. It is shown that high power level power and propulsion systems can have significant advantage in comparison with conventional chemical propulsion, so their application is actual for realization of near-Earth and deep space transport missions.

References

1. A S Koroteev, et al, *The Nuclear Power Propulsion System for the Spacecraft*, Izvestiya RAS, Energetica, 5, 2015, Moscow, Akademkniga Publ., pp. 45-59, (in Russian).
2. Jansen, F et al, '*NPPS Flagship: Cluster of Electric Thrusters*, IAC-19,C4,4,12,x52152, 70th International Astronautical Congress, Washington DC, United States, 2019, 21-25 October.

C4,10-C3.5,8,x77652	Development of a high power Nuclear Electric Propulsion System for interplanetary missions	Mr Vlad-George Tirila	University of Southampton	UK

There is a renewed interest in the development of nuclear fission power sources for space applications. With the large growth in the space sector, missions requiring nuclear fission reactors are again being considered, as demonstrated by NASA planning to fly a prototype nuclear thermal propulsion system 2025. Example missions include: to the Moon, as part of human's return to the lunar environment, space tugs for heavy cargo transport, and missions exploring the far solar system where solar power is unfeasible. Many of these missions require a nuclear fission power system for operating a high power electric propulsion system (ie an ion thruster) that drives the spacecraft towards these distant endeavours. As part of a UK Space Agency funded consortium, through its enabling space exploration call, this paper presents our work to develop a cohesive and concurrently designed nuclear electric propulsion system, with the electric propulsion system designed from outset for integration of a space suitable nuclear fission reactor, and vice versa. Within the minimum year-long project, a Hall ion thruster has been developed for operation at high power, with a power requirement of at least 10 kW. The Hall ion thruster is designed for operation with a variety of different propellants, including both standard gaseous propellants and also condensable propellants such as magnesium. These propellants require heating into a vapour phase, which can be completed using excess heat available from

the nuclear fission reactor system. This thruster has been designed, and will be manufactured for testing to be completed within the University of Southampton facilities in the summer of 2023. From the nuclear reactor perspective, we will develop a nuclear reactor concept within the 10 – 100 kW range that can be integrated with the electric propulsion system. We will make use of Low Enriched Uranium (LEU) Tri-structural Isotropic (TRISO) fuel particles, and through partners expertise previously developed components wherever possible. Two power conversion system options will be considered: Stirling Engines and static Thermo-Electric (TE) methods. Using our broad computational tools for the analysis of the proposed reactor type and associated power conversion systems, core physics, including both neutronic and thermal, will be assessed with tools that are computationally efficient, allowing the use of global optimisation methods. This enables the effective exploration of the many trade-offs that exist to find fission power systems that have minimal mass and volume whilst meeting mission requirements.

C4,10-C3.5,9,x76895	Research Progress toward Engineering Feasibility of the Centrifugal Nuclear Thermal Rocket	Dr Dale Thomas	University of Alabama in Huntsville	United States

The Centrifugal Nuclear Thermal Rocket (CNTR) is a Nuclear Thermal Propulsion (NTP) concept designed to heat propellant directly by the reactor fuel. The primary difference between the CNTR concept and traditional NTP systems is that rather than using traditional solid fuel elements, the CNTR uses liquid fuel with the liquid contained in rotating cylinders by centrifugal force. If the concept can be successfully realized, the CNTR would have a high specific impulse (1,800 s) at high thrust, which may enable (i) viable near-term human Mars exploration by reducing round-trip times to 420 days and (ii) direct injection orbits for scientific missions to the Solar System outer planets and Kuiper Belt objects. The CNTR could also use storable propellants such as ammonia, methane, or hydrazine at an Isp of 900 s, enabling long-term in-space storage of a dormant system. Research is presently underway to determine resolutions for the significant engineering challenges that the CNTR concept presents. Papers were presented at the 2021 and 2022 IACs which described these challenges, the study plan to address them, and progress to date. In particular, the 2022 paper highlighted the challenge of neutronics driving the heat generation gradient in the liquid uranium annulus, which results in the greatest heat generation on the outer wall of the annulus, where the maximum temperature of the containment wall is constrained to maintain structural integrity. This constraint was resulting in performance projections well below the theoretical projection. This paper provides a follow-on update which summarizes progress of the overall research effort, including strategies and key results to date on leveling the heat generation gradient in the liquid uranium annulus. The paper will also summarize the 3D modelling of the gaseous hydrogen bubbles in the liquid uranium and experimental results on gaseous and liquid analogs to validate the analytical models. Finally, estimates of engine key performance parameters including specific impulse, thrust and thrust to weight ratio will be given, and mission analyses of scientific missions to various solar systems destinations including Kuiper belt objects.

C4,10-C3.5,10,x76665	System Design Optimization for a Centrifugal Nuclear Thermal Rocket	Mr Mitchell Schroll	Propulsion Research Center	University of Alabama in Huntsville	United States

A Centrifugal Nuclear Thermal Rocket (CNTR) is a high-performance engine concept utilizing a liquid uranium fuel to achieve a theoretical specific impulse of 1,800 seconds. The design is a modification of traditional Nuclear Thermal Propulsion (NTP) in that it utilizes a high energy density uranium reactor to heat a propellant gas, eliminating the need for mass hungry oxidizers. While the concept of a CNTR dates back to the early 60's and 70's in work conducted by Nelson, Grey, and Williams, no significant advancement has been made in the modelling of the system since then. Research conducted in the interim based the system design around the work by Nelson, utilizing the same geometry and system performance assumptions since deemed the baseline design. Recently, efforts by Keese et al have shown that this initial baseline design had erroneous assumptions and the newly calculated values show a significantly reduced performance of the engine than previously thought, giving rise to the need to determine the optimum design configuration for future work. A comprehensive systems model was developed incorporating the propellent tanks, turbomachinery, regenerative cooling systems, centrifugal fuel element turbines, core fluid dynamics, nucleonics, and nozzle dynamics. The systems model was then overlain with a thermodynamics module allowing for various propellent and materials properties to be considered. Finally, a multidisciplinary design optimization framework was implemented within the code to iteratively solve the optimum geometry and operating conditions for various use cases, such as: long duration loiter, deep space scientific missions, and manned planetary missions. The results from the optimization study found that each use case has similar geometries but differing operating conditions. This result was expected since the main difference between the cases is the propellent used and therefore a function of their thermodynamic properties as they relate to the gas dynamics and turbomachinery and less so their nucleonic heating profiles. The new optimized designs improve upon the existing work done by Nelson et al by using higher fidelity models and more modern techniques, reducing the need for high level assumptions previous models used as well as increased confidence in the design configuration. These new configurations can now serve as a baseline for future work into further design improvements and mission trade studies with significantly improved fidelity.

C4,IP,5,x78557	Fusion-Enabled Plasma Propulsion for Enabling Interstellar Missions	Mr Ravinder Singh	Concordia University	Canada

This proposal introduces a disruptive propulsion technology concept that utilizes fusion-enabled plasma propulsion to enable interstellar missions. Fusion-enabled plasma propulsion is a type of advanced propulsion technology that combines the principles of nuclear fusion and plasma thrusters to generate propulsion. The proposed system would use magnetic fields to confine and compress hydrogen isotopes to induce fusion reactions, generating high-energy plasma that is expelled out of a nozzle to provide thrust. This technology has the potential to enable interstellar missions by providing significantly higher specific impulse than conventional chemical propulsion, enabling higher velocities and shorter travel times. Additionally, the fusion fuel used in this system is abundant and readily available in space, reducing the need for costly and complex refueling operations. The proposed fusion-enabled plasma propulsion system also has potential applications for in-space propulsion, including high-power electric propulsion for manned and robotic missions to Mars and other destinations in the solar system. This paper will provide a detailed description of the proposed fusion-enabled plasma propulsion system, including its key components, performance characteristics, and potential applications. The paper will also discuss the technical and engineering challenges associated with developing and implementing this technology, and will explore potential pathways for technology maturation and integration into future space missions.

D4,4,1,x80088	Communications receiver designs for interstellar probe missions	Prof Philip Mauskopf	Arizona State University	United States

We describe the designs of the ground station communications receiver system for the Breakthrough Starshot mission and other interstellar probes. Past interplanetary missions within the solar system such as the New Horizons mission to Pluto and the Kuiper belt use the NASA deep space network (DSN), a system of large radio dishes distributed around the world, to downlink data obtained during flybys. The next generation NASA probes such as the Psyche mission will test higher capacity optical communications systems. Future interstellar probes will require larger collecting areas and use of optical communications to overcome the signal loss over interstellar distances. We describe four concepts for large area ground receivers: i) an array of 1 meter diameter low cost incoherently combined reflecting apertures, ii) an array of 1 meter diameter low cost reflecting apertures coherently combined into 50 meter diameter optical receivers, iii) a space-based collecting aperture based on low mass nanophotonic reflectors similar to the Breakthrough Starshot lightsail design and iv) a crowd sourced citizen science initiative to produce small receivers for "backyard" collection of communications signals. We also describe astronomy projects which can be carried out using these receivers.

D4,4,2,x75652	High Temperature-superconductor material (HTSM) used for electronics in Radio-isotropic Thermal heat generator(RTG) where Thorium rods are being used as cells for source.	Mr Abhishek Singh	National Space Society (USA) -Mumbai chapter	India

Since launch of Voyager 1 we have that the exploration of deep space has become one of the primary aspect of space missions, but sending a satellite that far often cause an issue with the power management which is caused in traditional electronics being made on silicon board. The idea in this paper is to use a high temperature superconducting material with RTGs which will help in conserving the power since we know that the decay in power of the system will be much less than the traditional system as the power output of any superconducting material is to be given by the V=IR but since we have that the net power output of any supercomputer is zero the net resistance will also be zero in theoretical sense but on practical ground can be assured that this power decay will be far less on a logarithmic scale. Also we have that the RTGs choice for fuel rods can be thorium as we have that the thorium being least radioactive we won't be looking too seriously with the fact that all the electronics on board will be affected by the radioactivity.

D4,4,3,x79329	High-Speed Scientific Spacecraft Launches with Commercial Launch Vehicles	Dr Ralph L McNutt, Jr	Johns Hopkins University	United States

Reaching the outer solar system and interstellar space beyond has always been challenging due to the long distances and long travel times. Initial work on planetary gravity assists in the early 1960s by Minovitch and Flandro laid the basis for expanding reachable space with then-existing launch vehicles. Such gravity assists have been key enablers for orbital exploration missions to Mercury (MESSENGER), Jupiter (Galileo, Juno), and Saturn (Cassini-Huygens) by trading higher mass for lower launch energy from Earth (C3). They have also enabled close passes to the Sun (Parker Solar Probe) and moderately rapid solar system escape, coupled with fast flybys of various planetary-sized bodies: Mariner 10 (Mercury via Venus), Pioneer 10 (escape via Jupiter), Pioneer 11 and Voyager 1 (escape via Jupiter and Saturn), Voyager 2 (escape via Jupiter, Saturn, Uranus, and Neptune: the "Grand Tour"), and New Horizons (escape via Jupiter and Pluto). Two of these missions hold the first and second places for the most energetic launches (New Horizons: C3 = 157.7502 km^2/s^2; Parker Solar Probe: C3 = 152.222 km^2/s^2). Disadvantages in using Earth and Venus gravity assists to increase spacecraft injected mass to Jupiter and beyond include the time

penalty and the need for a customized propulsion system to provide a deep-space maneuver (DSM). For "timely" transits to Neptune with a large orbiter or rapid solar system escape with an Interstellar Probe, more capable launch vehicles can be enabling by pushing the injected mass versus C3 curves "to the right." While the most extreme speeds asymptotically away from the Sun (7 to 8 au/yr) can be achieved with fast Jupiter gravity assists and super-heavy lift launch vehicles (SHLLV) such as the Space Launch System (SLS) surmounted by multiple upper stages, solar system escape speeds larger than those achieved by Voyager 1 are possible with existing and upcoming large commercial launch vehicles. Such vehicles include the Falcon-Heavy, New Glenn, and Vulcan Centaur. Better performance accrues with the fully expendable versions of these vehicles and/or with "refueling" in a low-Earth orbit, with performance versus launch cost as a central trade. Even better performance can be projected with SHLLVs in development, such as the Starship Super Heavy and Long March 9. We discuss some of the possibilities and trades such newer vehicles can enable in the near term for continued – and more distant – exploration of the solar system and beyond.

D4,4,5,x79852	The Next Ten Years: 100 Year Starship's Second Decade	Mr Jason Batt	100 Year Starship	United States

The next ten years of the 100 Year Starship (100YSS) are poised to be transformative, driven by ongoing advancements in space propulsion technology, public-private partnerships, and the development of life support systems for long-duration space missions. However, 100YSS is not just about technological advancements; culture, purpose, and the human experience are increasingly important areas of focus. At the recent Nexus Nairobi 2023 event, leaders from various fields came together to explore the intersection of culture, purpose, and space. The event emphasized the ways in which space exploration can inspire new approaches to cultural and societal challenges. The tagline for Nexus Nairobi 2023, "Space. Radical. Vital. Down to Earth," reflects the idea that developments in space technology have the potential to improve our lives here on Earth. Health technologies developed for long-duration space travel could have applications for improving healthcare in remote or underserved communities on Earth. Remote imaging and sensing technologies developed for space exploration can be used to address environmental issues on Earth, such as deforestation, water scarcity, and climate change. Education programs developed for space missions can inspire and engage students around the world in STEM fields. Moreover, the cultural impact of space exploration cannot be overstated. Art, music, and literature inspired by space exploration can promote a sense of wonder, curiosity, and imagination, which can inspire innovation and creativity in other fields. The next ten years of 100YSS will be a time of rapid change and innovation, driven by advancements in technology and the intersection of culture, purpose, and space. By fostering collaboration and dialogue across disciplines and cultures, we can build a more inclusive and holistic vision of the future of space exploration, one that recognizes the potential of these developments to improve our lives here on Earth. Ultimately, 100YSS can inspire a new approach to space exploration, one that recognizes the importance of culture, purpose, and the human experience. As we look ahead to the next ten years of 100YSS, it is clear that the intersection of culture, purpose, and space will be increasingly important. By working together across disciplines and across borders, we can build a brighter future for all of humanity, one that is rooted in a deep sense of wonder, curiosity, and imagination.

D4,4,6,x77432	Interstellar Exploration Using "EXPLORER" Spacecraft - Building The Foundation	Mr Aditya Prakash	Indian Institute of Technology Kanpur	India

Humanity's quest for exploration and discovery has driven our progress for thousands of years. Our ancestors, who ventured out on boats in search of new lands, continue to inspire us to pursue this legacy. In this spirit, we propose the development of a self-sustaining ecosystem spacecraft (EXPLORER) capable of interstellar exploration and human settlement. This research paper lays the foundation for the development of EXPLORER and identifies the areas of research required to make this vision a reality. The proposed spacecraft is designed to travel millions of light-years in search of habitable zones, containing a nuclear energy-based ecosystem that gets its energy from a nuclear reactor (or artificial sun). This miniaturized version of Earth will contain only the necessary resources, recycling mass to ensure sustainability. The EXPLORER will be protected by a shield to protect it from interstellar dust, debris, and radiations, and will use gravitational pull and advanced propulsion technology with the least mass consumption to reach its destination. One of the biggest challenges in interstellar exploration is to find the most dense place in the universe with habitable zones and the least energy path to it. A large part of the universe remains unknown and the journey will be purely based on exploration. Hence, the transportation technology must be advanced enough to handle these challenges. Our solution is to develop technology that can map the universe ahead of us and chart a path that minimizes energy consumption while maximizing speed and efficiency. The EXPLORER will be designed as a self-sustaining ecosystem capable of supporting human life for generations. The explorers on the spacecraft will grow, develop, reproduce, and pass down their knowledge and experiences, just as our ancestors did. Our ultimate goal is to establish human settlements on habitable planets and carry on the legacy of exploration and discovery that our forefathers started. The development of EXPLORER will require substantial time, resources, and knowledge, making it a task for future generations. Nevertheless, it holds the potential to expand human presence in the universe, establish new civilizations, and bring humanity closer to a sense of brotherhood in this vast universe. This research paper highlights the technological challenges and solutions for the development of EXPLORER and sets the direction for future research. It aims to bridge the gap between reality and science fiction and is a continuation of the legacy of our ancestors.

D4,4,7,x75821	Interstellar Exploration: from Science Fiction to Actual Technology	Prof Giancarlo Genta	Politecnico di Torino	Italy

The exploration of the solar system has already started: robotic probes reached all the planets and many minor bodies, and the plans to land humans on Mars are being developed. The technology for even the most advanced missions in the solar system doesn't need advances in basic science. Traveling through the solar system can be described through what is called 'hard science fiction,' ie science fiction strictly based on scientific knowledge. Interstellar exploration is completely different. Robotic flyby missions to the nearest stars using nanoprobes can be performed using technologies based on known science, while anything beyond this requires advances which we don't know how to implement, but even we are not sure whether they are possible at all. Here the point is not only the technological aspects but even the scientific bases on which the relevant technologies may rest. The missions requiring less scientific-technological advances, are slow missions, like space arks (generation ships) or missions based on hibernation with travel times up to hundred years. To implement both, the uncertainties are more related to the advances in space medicine and biology than in propulsion and physics. The fastest travels allowed by the current interpretations of the relativity theory are relativistic missions in which the time contraction at speeds closing the speed of light is exploited to decrease the travel time for the astronauts, although the travel time seen by those who remain on Earth is close, in years, to the distance travelled expressed in light years. However, the energy required for this type of travel is large and grows drastically with the increase of time contraction. FTL travel, which seems to be possible following some interpretations of relativity involving either wormholes or

warp drive, requires substantial advances in fundamental physics. A symptom of this is that the novels dealing with interstellar travels belong more to the space opera than to the hard science fiction subgendres, not following strictly scientific credibility. No novels of this kind explain in some detail how the relevant machinery works, and even less scientifically realistic are the movies and TV series of this kind. Moreover, to achieve a travel time allowing to reach distant star systems in reasonable times using warp drives, the authors of Star Trek had to resort to the Warp Factor which is essentially an exponential scale. This makes the requirements for FTL travel even more difficult to achieve.

D4,4,8,x79861	Exploring Interstellar Travel in Video Games: Shaping Public Perceptions and Support for Future Initiatives	Mr Jason Batt	100 Year Starship	United States

Interstellar travel is a subject of great interest to scientists and the public alike, and video games have become a popular medium for exploring this topic. From procedurally generated galaxies to rich storytelling, video games have the potential to both accurately represent the scientific and technological challenges of interstellar travel and inspire players to learn more and support future initiatives. This interactive presentation will explore the trends in the industry and analyze what interstellar travel video games get right and wrong. It will examine the challenges of balancing realism with creative freedom and the trade-off between scientific accuracy and storytelling. It will also analyze specific games and how they handle interstellar travel, from simulating the challenges of engineering to offering a fantastical vision of the future. The presentation will discuss how games like No Man's Sky and Elite Dangerous use procedural generation to create vast, seemingly infinite universes for players to explore, inspiring a sense of wonder and discovery, but also leading to limitations in terms of scientific accuracy. Games like Mass Effect and the Outer Worlds create rich, immersive worlds with engaging characters and compelling narratives but also take liberties with science and technology to serve the story. The presentation will also analyze specific interstellar travel video games, such as Kerbal Space Program and Space Engineers, which aim for scientific accuracy and realism, allowing players to simulate the challenges of space travel and engineering. Other games, like Star Citizen and EVE Online, offer a more fantastical vision of interstellar travel, incorporating alien races and futuristic technologies. One of the key themes of the presentation will be how video games can encourage or discourage public support for interstellar initiatives. By portraying interstellar travel in a positive light and emphasizing the potential benefits, video games can inspire interest in science and technology and encourage critical thinking and problem-solving skills. However, if video games perpetuate misconceptions or present a negative view of interstellar travel as a tool of conquest, they may discourage public support for future initiatives. The presentation will conclude by examining the potential benefits of interstellar travel video games and their role in shaping public perceptions and support for future initiatives. Overall, interstellar travel video games represent a fascinating and growing subgenre, and this presentation will provide an overview of the industry, analyze its trends and examine specific games, and consider the potential benefits and drawbacks of this genre.

D4,4,9,x79839	The Canopus Award for Excellence in Interstellar Writing: Celebrating Fiction and Nonfiction that Champions the Dream of Interstellar Travel	Mr Jason Batt	100 Year Starship	United States

The Canopus Award for Excellence in Interstellar Writing is a prestigious literary award that recognizes outstanding works of fiction and nonfiction that promote and celebrate the dream of interstellar travel. Established in 2015 by 100 Year Starship, the Award seeks to honor those who contribute to this field through their writing. A panel of experts in the fields of science, engineering, and literature evaluates each nominated work based on its scientific accuracy, literary quality, and overall contribution to the field of interstellar travel. The judges also consider the work's impact on public awareness and engagement with the concept of interstellar travel.

The Canopus Award seeks to inspire and encourage new writers to explore the themes of interstellar travel and the possibilities it holds for humanity's future. It also recognizes established authors who have made significant contributions to the field of interstellar writing. Past winners of the award include Kevin J Anderson and Rick Wilber for "The Hind," Jeff Lemire and Gabriel Hernandez Walta for Sentient, and Alex McKenzie and Punske for "Language Development During Interstellar Travel." These works represent some of the best writing in the field of interstellar travel, inspiring readers to think about the possibilities of space exploration and to imagine a future where humanity is a spacefaring species. In addition to recognizing outstanding writing, the Canopus Award also helps to broaden public awareness and support for interstellar travel initiatives. By highlighting the importance of interstellar travel in popular culture, the award encourages public engagement with space exploration and fosters a sense of excitement and wonder about what lies beyond our planet. The award also helps to bring attention to the challenges and opportunities associated with interstellar travel, inspiring researchers and innovators to pursue new technologies and solutions to the challenges of space exploration. The Canopus Award celebrates the power of imagination and creativity in our quest for knowledge and understanding of the universe. Through recognizing exceptional works of fiction and nonfiction, the award inspires us to think about the possibilities of space exploration and to imagine a future where humanity is a spacefaring species. By promoting public awareness and support for interstellar travel initiatives, the Canopus Award helps to shape a brighter future for all of us.

E7,IP,8,x80109	Interstellar Investments: A Legal Odyssey of Space Law and International Investment Law	Mr Anmol Dhawan	International Institute of Space Law (IISL)	The Netherlands

The rapid proliferation of commercial activities in Outer Space and the subsequent expansion of private investments poses a significant challenge to the traditional international space law framework. The current regime needs to adapt to the modern commercial reality and regulate the legal issues that arise from the increasing involvement of the private space sector. This paper examines the intersection between international investment law and space law to address these challenges and evaluate avenues for more robust protection to space investors. This paper firstly analyzes whether investments in space activities - particularly in the satellite industry - could fall within the purview of Bilateral Investment Treaties (BITs) and Article 25 of the International Centre for Settlement of Investment Disputes (ICSID) Convention. If so, investors may enjoy broader substantial protection by benefiting inter alia from the requirements of Most-Favoured Nation (MFN), Fair and Equitable Treatment (FET), and Full Protection and Security (FPS). Further, the current state of space law does not provide self-exercisable remedies to private actors who rather depend on their home state to obtain compensation for damage suffered, based on the concept of diplomatic protection. In this context, the authors examine how the investor-state dispute resolution (ISDS) regime could address the specificities of space-related disputes and provide further incentives for space investments. Private operators can resort to arbitration under investment treaties, which can offer more efficient and effective dispute resolution mechanisms than national courts. Indicatively, investors can benefit from awards that grant compensation for losses suffered due to state actions, such as the denial or revocation of licenses. To this end, we discuss significant cases, such as Devas, which exemplify the benefits of the potential of ISDS, if used for space disputes. In conclusion, this paper highlights the relevance of international investment law in addressing some of the practical challenges that arise from the growing involvement of the private space sector in space activities and in strengthening the global rule of law. To that end, the authors examine how the use of international investment law standards could contribute towards mitigating space debris, ensuring space safety and sustainability, and promoting the peaceful use of Outer Space. Based on the findings, this paper calls for more comprehensive and coherent policies and regulations that could accommodate the evolving nature of the space industry and encourage more investments in Outer Space.