The Journals

John I Davies

Here we list recent interstellar-related papers in the Journal of the British Interplanetary Society (JBIS), published since the 1930s, and Acta Astronautica (ActaA), the commercial journal published by Elsevier, with the endorsement of the International Academy of Astronautics.

JBIS

4 issues of JBIS (May, June, July, August 2022) have appeared since the report in our last issue, P38.

Title (open publication)	Author	Affiliation
Abstract/Précis/Highlights		

JBIS VOLUME 75 NO.5 MAY 2022		
Utilising a Nuclear Transport System as an Earth Orbit Transfer Vehicle	Mark Hempsell	Hempsell Astronautics Limited, UK
The Scorpion is a multi-role crewed transport vehicle designed to extend the human space infrastructure beyond low Earth orbit. One of these roles is as an orbit transfer vehicle to reach higher Earth orbits. The payloads to circular orbits between geostationary to one and half million kilometres from a 400 km altitude orbit using Hohmann transfers were found to range between 465 to 640 tonnes, with the minimum around 100,000 km. Orbits above that, in High Earth Space, have increased payload as the altitude increases. This highlights a little appreciated fact that most of High Earth Space is easier to reach than geostationary orbit. Geostationary, Earth/Sun L2 and various lunar support missions are looked at in more detail. An example geostationary payload was created which suggests the payload provisions on the Scorpion have difficultly handling cargo at its maximum mass. So, for most missions the Scorpion would probably be used well below its capability but this does not introduce any serious inefficiency. A comparison is also made with an orbit transfer vehicle called Taurus which repackages the Scorpion's propulsion system into a simpler rocket stage. This increases the payload by a third but requires spaceports to operate and is therefore more suited to increasing the capability of an architecture already established by the Scorpion.		

Toward the Engineering Feasibility of the Centrifugal Nuclear Thermal Rocket	Dale Thomas et al	University of Alabama in Huntsville
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 viable near-term human Mars exploration by reducing round-trip times to ~420 days. 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. Significant engineering challenges must be addressed to establish the technical viability of the CNTR. Research is presently underway to determine resolutions for these engineering challenges. In particular, research has begun on the analytical modeling and simulation of the two-phase heat transfer between the liquid metallic uranium fuel and the gaseous propellant. Subsequent research will progressively address the remaining CNTR engineering challenges.		

VOLUME 75 NO.6 JUNE 2022		
Space-Based Solar Power: a Literature Survey from The Journal of the British Interplanetary Society	Griffith J Ingram	British Interplanetary Society
A literature survey of past papers in the Journal of the British Interplanetary Society that have in some way considered the use of space generated energy to meet terrestrial power demand has been performed, in order to make past work on this topic more accessible.		

VOLUME 75 NO.7 JULY 2022		
Comparative Overview of Nuclear Electric Propulsion Programs and Concepts	Manuel La Rosa Betancourt et al	NeutronStar Systems UG, Köln
Human space exploration is at the dawn of a new era. The desire to establish a permanent presence beyond low Earth orbit (LEO) has never been higher. The Moon and Mars are first targeted to demonstrate our ability to extend our expanse. As of today, the alternatives offered by the likes of SpaceX, Blue Origin and others are not sustainable. Chemical propulsion will not be the solution for humanity to explore other worlds. Other forms of propulsion offer a more compelling and sustainable alternative: Nuclear Electric Propulsion (NEP) is the key to unlock more cost-effective and sustainable space transportation for interplanetary voyages. NEP combines the unmatched megawatt level of power provided by a nuclear reactor with the high specific impulse (Isp) of electric propulsion. This would enable cargo missions to the Moon, Mars and beyond, on a larger scale than the low Isp chemical propulsion would allow and at a higher cost-efficiency. The development of such technologies is at the core of the new space race. It dictates the direction and evolution of NEP programs and concepts. This paper presents an overview of the geopolitical and technological considerations behind different NEP programs worldwide. While the two major actors remain NASA and ROSCOSMOS, other space agencies such as CNSA, ESA and UKSA have shown extended interest in the progress of NEP. Amongst the various types of electric propulsion systems, Gridded Ion Thrusters (GIT) and Hall Effect Thrusters (HET) are usually the first considered for NEP use due to their high space heritage at low power levels (several kilowatts). However, GIT and HET present a number of fundamental drawbacks at higher power levels: scalability limitation, number of thrusters needed and lifetime concerns. Superconductor-based Readiness Enhanced Magnetoplasmadynamic Electric Propulsion (SUPREME) could be a better alternative for high power manned and cargo missions from LEO to the Moon or to Mars. Applied-Field Magnetoplasmadynamic (AF-MPD) Thrusters have been around since the 1960s, they offer a range of operations wider than any other existing electric propulsion technology. Recent developments achieved by the Institute of Space Systems at the University of Stuttgart have proven thrust efficiencies over 62% with the use of LaB6 hollow cathodes. This paper reviews current concepts and programs for NEP, and underlines the possibilities offered by MPD thrusters, especially by Neutron Star Systems' SUPREME thruster, for these NEP programs and concepts.		

Active Debris Removal - Policy and Legal Feasibility	Josef Koller et al	The Aerospace Corporation, USA
Over the last few decades, the complexity of space operations has grown, the number of commercial entrants into the space economy has increased, and the amount of space debris has inflated to a degree that threatens space operations and often requires satellites to maneuver to avoid collisions. Such maneuvers are becoming more common in certain orbital regimes. Preventing the creation of new debris is one way to preserve the space operational environment; removing debris is another. Yet viable options for Active Debris Removal (ADR) remain elusive due, in part, to technical, economic, and legal challenges. Without diminishing the technical and economic challenges of ADR, this paper focuses on the legal questions associated with ADR which are often described as seemingly insurmountable. Our proposed framework aims to resolve these legal questions by applying a simple, bottom-up approach based on mutual consent, regulatory approval, and contractual agreements between participants. Our approach contrasts against the often-discussed comprehensive approach that promotes multilateral agreements and the establishment of international institutions as a necessary means. Recognizing that building a comprehensive, international framework is fraught with challenges, our framework instead centers not on what is difficult, but on what is achievable: (1) removing debris involving only one nation or (2) removing debris where the service provider and the debris owner share the same interests and recognize the need for active debris removal. Further, this framework offers an initial first step towards establishing that active debris removal is indeed legally feasible, leading the way to eventually building more comprehensive debris removal agreements between states at a future time.		

A Potential Legal Basis for Harvesting Orbital Debris Without the Owner's Prior Consent	George A Long	Legal Parallax LLC, USA
Outer Space Treaty Article VIII is construed as prohibiting the salvage of orbital debris as it expressly provides perpetual ownership of a space object and its component parts. Pursuant to Article VIII, ownership of a space object and its component parts is "unaffected by their presence in outer space or on a celestial body or by their return to Earth." This concept impedes orbital debris removal as it is construed as requiring a third party to obtain the debris owner's prior consent as a prerequisite for touching the space junk. This legal obstacle necessitates an analysis of the space law treaty regime which will allow orbital debris removal without the owner's prior consent. Accordingly, Rescue Agreement Article 5 can be read and interpreted as providing a potential legal avenue for a third party harvesting orbital debris without obtaining the owner's prior consent.		

A Technical Description of Some Scorpion Derivatives	Mark Hempsell	Hempsell Astronautics Limited UK
The Scorpion is a general purpose nuclear powered transport system that can operate from low Earth orbit out to Venus and Mars orbits and can prepare for missions by directly interfacing with the launch system without any other in orbit support. In an extension to the initial outline of the basic spacecraft, the study explored three specialist derivatives of the Scorpion that can transport cargo (Taurus), propellant (Aquarius), and people (Zibanna). It was found that significant improvements in performance could be achieved with these specialist systems without advancing technology. However, this approach to establishing a compete infrastructure requires much higher acquisition investments, both in new system level developments and the establishing of supporting spaceports. Such investments can only be justified if there is a mature and extensive level of activity that has evolved from the initial programmes in high Earth orbits and lunar environment. But in the expectation of such expansion and evolution it makes sense for the very high value investments, like the nuclear rocket engines, to include the likely requirements for the next generation specialist systems to be included in their initial development for the first generation system.		

VOLUME 75 NO.8 AUGUST 2022 Special Interstellar Issue		
Galactic Crossing Times for Robotic Probes Driven by Inertial Confinement Fusion Propulsion	Kelvin F Long	Stellar Engines Ltd, UK
In the future it is possible that spacecraft may be constructed that can travel to the nearby stars and beyond to the wider galaxy. The speed of those spacecraft will depend on the type of reaction engine adopted for the mission. This work considers the transport of replicating robotic probes across the galaxy driven by Inertial Confinement Fusion propulsion (ICF) engines. This includes an examination of a range of possible wave speeds with the addition of stopping time for material mining acquisition and self-replication. The work also discusses reducing cruise velocity for probe random walk pathways as a function of percentage performance degradation with each n generation where the distance attained per crossing is proportional to $\sqrt{n}$. For probes in the engine pulse frequency range of ~100-1,000 Hz it is found that galactic crossing times of order ~1-4 million years may be feasible depending on the average cruise speed of the spacecraft over the range 0.05-0.15c. This will require a total of 20,000-40,000 separate individual probes or star hops to accomplish the full crossing of the galactic diameter. Dispersal calculations are also performed for both exponential population growth and exponential population decay of robotic probes. Some implications for the Fermi paradox are discussed as a spatial-temporal variance model. It is then estimated that for robotic probes a galactic crossing may be possible in ~1-2 million years through the galactic disc, or may be as low as ~0.5-1 million years assuming a central starting position of the probe population since it is a spherical dispersal wave, or assuming multiple seed populations of probes. It is argued that an exploration strategy of this form may have a high dependence on the ability of the probe to maintain its design specification and performance and may exhibit pathway dissipation and random walk along the trajectory. Finally, we give a brief discussion on search strategies for the detection of robotic probes. It is concluded that such probes are likely already here within the vicinity of our solar system despite the limited performance constraint of using ICF propulsion technology. In addition, probability favours that they would likely originate from a star system of less than ~200 ly distance from Sol which is suggestive of search priorities for their detection.		

Self-Replicating Interstellar Probes and Runaway Growth Reconsidered	Stephen Ashworth	Oxford UK
The idea of a robotic interstellar probe which, after arrival in the planetary system of a nearby star, constructs a copy of itself and launches it towards a star more distant from its point of origin, has been a popular one in the technical and science-fiction literature. Some recent papers have claimed that such machines will necessarily fail after a certain number of generations, and thus the volume of space explored by them will remain small on a galactic scale. The question is reconsidered taking into account the likely growth rates, propulsion methods, sizes of seed economy, and motivations of actors in the launching civilisation as well as of the machines themselves. It is concluded that self-replicating probes are indeed likely to emerge as a natural consequence of interstellar exploration and that they may spread freely on a galactic scale, given favourable initial conditions. Their observational absence in the Solar System is a constraint on the abundance of industrial life in the Galaxy, but only a weak one: one or a very few instances of such civilisations are not ruled out.		

Acta Astronautica

Title	Number+date	Author	Affiliation
Abstract/Précis/Highlights			

Design of impulsive asteroid flybys and scheduling of time-minimal optimal control arcs for the construction of a Dyson ring (GTOC 11)	Volume 201, December 2022	Carlos Ortega Absilet et al	Thales Services Numériques, France
This paper describes the approach used by the team named the Eccentric Anomalies to obtain the sixth best solution to the problem of the eleventh Global Trajectory Optimization Competition, whose futuristic scenario of Dyson sphere building remained mathematically relevant for current space mission design and engineering in general. As usual for this recurring challenge, it involved large-scale combinatorics at a high level and a multitude of optimal control problems at a lower level. Furthermore it proposed additional layers of complexity by adding a strong scheduling component to the usual flyby sequencing, and by featuring both impulsive and continuous-thrust trajectories. The authors took advantage of modern theoretical techniques and open-source tools to put together a sequential process including analysis based on analytical trajectory models, tree searches using efficient data structures, global and local finite-dimensional optimization and multi-objective trade-offs. The optimal control part was both tackled with direct transcription as well as indirect shooting methods, and the mixed-integer scheduling reformulated as a bi-level optimization. From a programming point of view, the main framework was set in an interpreted language whilst using as much as possible dependencies written in compiled ones for speed.			

High-temperature superconductor-based power and propulsion system architectures as enablers for high power missions	Volume 201, December 2022	Marcus Collier-Wright et al	Neutron Star Systems UG, Germany
The increasing competitiveness of electric propulsion systems (EPS) for primary spacecraft propulsion has paved the way for higher payload mass fractions by offering significantly higher specific impulses than chemical systems. Concurrently, High-Temperature Superconductors (HTS) have reached an unprecedented level of industrial maturity in recent years, and considering their low masses, compactness, and high current densities, they offer the potential to act as a disruptive technology in several spaceflight applications such as power management systems, re-entry and radiation shielding as investigated in the EU-funded MEESST project, as well as EPS. In the latter case, efforts are already ongoing to develop an HTS-enhanced Applied-Field Magnetoplasmadynamic (AF-MPD) thrusters for high power mission applications. The Tsiolkovsky equation infers that the payload mass fraction increases indefinitely with increased Specific Impulse (I_{sp}), however, in the case of electric propulsion, the dependence of thrust on the available power complicates this issue when transfer time is a primary driver. Here, the Tsiolkovsky equation becomes inadequate and considering a non-dimensional version of the Tsiolkovsky equation in terms of the mission ΔV and transfer time, the EPS thrust efficiency, and the specific mass of the power system becomes necessary. This paper first discusses the recent advances in HTS and their suitability for spaceflight, before reviewing. The development of power system technologies is reviewed and a conceptual power system architecture incorporating HTS is presented. These technologies are analysed using a non-dimensional Tsiolkovsky approach and their impacts on the overall payload mass fraction are assessed. For high-power missions (>100 kW), the use of HTS is shown to have a highly beneficial impact on the mass of the power system. Correspondingly, this enables higher payload mass fractions achievable at increased specific impulse operation, thus strengthening the case for high-power, high-I_{sp} EPS technologies such as AF-MPDT.			

Structural stability of a lightsail for laser-driven interstellar flight	Volume 201, December 2022	Dan-Cornelius Savu, Andrew J Higgins	McGill University, Canada
The structural stability of a lightsail under the intense laser flux necessary for interstellar flight is studied analytically and numerically. A sinusoidal perturbation is introduced into a two-dimensional thin-film sail to determine if the sail remains stable or if the perturbations grow in amplitude. A perfectly reflective sail material that gives specular reflection of the laser illumination is assumed in determining the resulting loading on the sail, although other reflection models can be incorporated as well. The quasi-static solution of the critical point between shape stability and instability is found by equating the bending moments induced on the sail due to radiation pressure with the restoring moments caused by the strength of the sail material and the tension applied at the edges of the sail. From this quasi-static solution, analytical expressions for the critical value of elastic modulus and boundary tension magnitude are found as a function of sail properties (eg thickness) and the amplitude and wave number of the initial sinusoidal perturbation. These same expressions are also derived from a more formal variational energy (virtual work) approach. A numerical model of the complete lightsail dynamics is developed by discretizing the lightsail into rectangular finite elements. By introducing torsional and rectilinear springs between the elements into the numerical model, a hierarchy of models is produced that can incorporate the effects of bending and applied tension. The numerical models permit the transient dynamics of a perturbed lightsail to be compared to the analytic results of the quasi-static analysis, visualized as stability maps that show the rate of perturbation growth as a function of sail thickness, elastic modulus, and applied tension. The analytic theory is able to correctly predict the stability boundary found in the numerical simulations. The stiffness required to make a thin lightsail stable against uncontrolled perturbation growth appears to be unfeasible for known materials, however, a relatively modest tensioning of the sail (eg via an inflatable structure or spinning of the sail) is able to maintain the sail shape under all wavelengths and amplitudes of perturbations.			

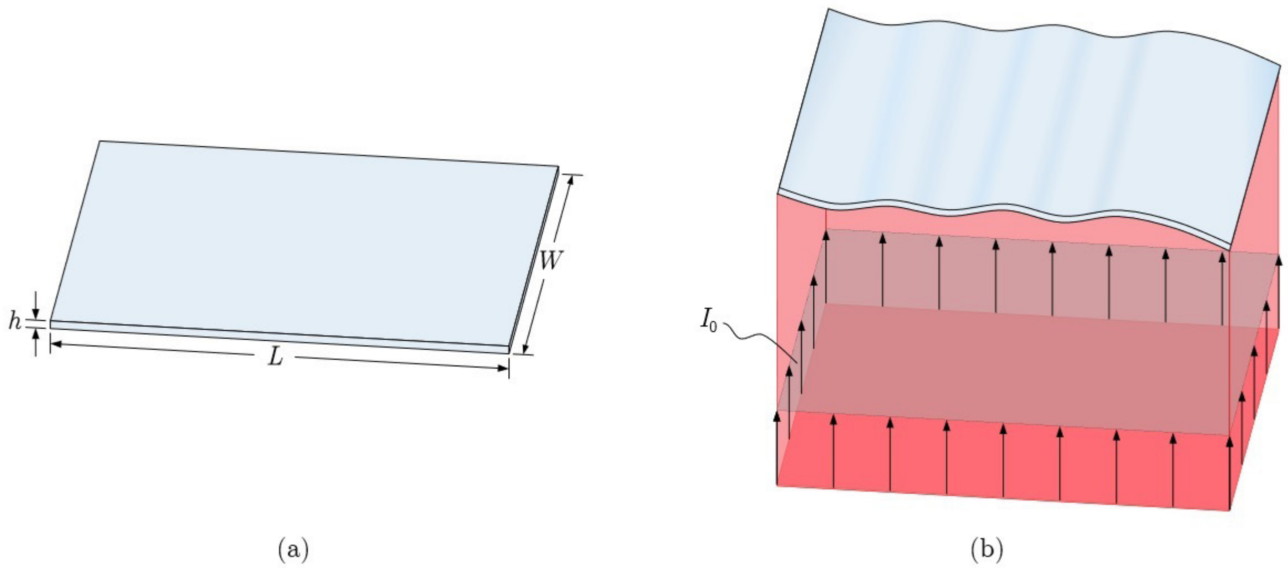

Figure 1: Three-dimensional analytical (plate) model of the lightsail; (a) the lightsail, flat; (b) the lightsail, smoothly perturbed with an incident uniform laser beam.
The problem here considered is whether the perturbations will grow in amplitude or not under the large laser loads
Credit (caption and image): Savu and Higgins, arxiv.org/abs/2210.14399