The Journals

John I Davies

Here we list recent interstellar 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

Five issues of JBIS (February, March, April, May & June 2022) have appeared in our last issue, P37 in May.

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

JBIS VOLUME 75 NO.2 February 2022		
Revisiting Voyager 2's Trajectory	K ARNOTT & B CHANDRA	University of the West of England
This paper presents a reconstruction of Voyager 2's trajectory to examine how the mission was optimised for fuel and Time of Flight (TOF), as well as to find out if there is a more efficient trajectory for the full Earth-Jupiter-Saturn-Uranus-Neptune (EJSUN) sequence. Variable TOFs between each interplanetary maneuver for launch dates ~1 year from the original were considered. Brute force search algorithms were developed to find optimized trajectories, the solution to Lambert's problem for fast computation, and a patched conic integrator to plot the optimal trajectories. Multiple 'unpowered' gravity assist trajectories were found: the minimum total change in velocity (ΔV) at perigee found was less than 0.0035 km/s for a total TOF of 4,978 days (13.64 years), the shortest TOF trajectory found spanned 3,299 days (9.04 years), with a total ΔV at perigee requirement less than 0.11 km/s. With consideration to the trajectories found, it was determined that the Voyager 2 trajectory was likely to have been optimized for TOF.		

JBIS VOLUME 75 NO.4 April 2022		
Cultural Evolution and Minimal Crew Size to Maintain Culture Level During Interstellar Travel	Sano Satoshi	Japan Aerospace Exploration Agency
Designing multigenerational interstellar ships requires defining the capacity of a spaceship first, which affects many variables, including food production, air/water circulation systems, electric power and propulsion. A published Monte Carlo code called EVOLVE (Sano, 2021) first suggested a minimal crew size of 2,000 people to maintain a genetically healthy crew, including genetic parameters such as genetic mutation rate and natural selection on interstellar travel, and that the speed of human evolution on interstellar travel would be approximately 10 times higher than that on Earth due to a higher mutation rate in space. However, cultural change must be considered in addition to biological change when considering multigenerational human space travel, because culture is one of the most uniquely human traits and deeply related to the survival and evolution of Homo sapiens. Therefore, EVOLVE was updated to version 3, which includes cultural parameters to estimate adequate crew size to maintain an appropriate technological level during multigenerational interstellar travel. This paper shows that a minimal crew size of 1,500 people for simple technologies and 11,000 people for complex technologies is necessary to maintain a human technological level for interstellar travel. Finally, this paper shows that the genetic evolution rate and cultural evolution rate during interstellar travel would be approximately 10 times and 5 times higher, respectively, than those on Earth due to the high mutation rate in space.		

On the Application of Pulse Propulsion Frequency in Inertial Fusion Space Mission Design	Kelvin F Long	Interstellar Research Centre
The transport of a spacecraft using an Inertial Confinement Fusion (ICF) based propulsion engine exhibits an acceleration and thrust profile which depends on the pulse unit detonation frequency, propellant mass, capsule mass, mass flow rate and exhaust velocity. This paper discusses how the pulse frequency depends on the overall mission parameters and explores the limit of a small mass and high mass capsule design. It is argued that in the limit of a high pulse frequency (>1,000 Hz) and low capsule mass (<<mg) the engine will tend towards an analogue for a continued thrust design (interstellar ramjet), whereas in the limit of a low pulse frequency (1-50 Hz) and high capsule mass (>10 kg) the engine will tend towards a nuclear propelled pulse engine (bomb propulsion) similar to the historical Project Orion. Therefore propulsion from ICF methods with a pulse frequency (10-1,000 Hz) and capsule mass (1-10,000s mg) represents a compromise between these two regimes. Spacecraft driven by an ICF engine are likely realisable in the later part of this century using mg scale capsule designs driven by MJ scale laser beamers to produce GW jet powers at MW/kg specific powers. This may enable interplanetary missions at 0.001-0.0015 c in trip durations of weeks to months to ~100s AU by around 2070, interstellar precursor missions at 0.01-0.015 c in trip durations of months-years to ~1,000s AU by 2110, and interstellar missions at 0.05- 0.15 c in trip durations of decades to ~ly distance by around 2150. Some of the critical technological roadmap steps required are presented leading up to the early part of the 22nd century where all of these missions may become feasible.		

Engineering an Interstellar Communications Network by Deploying Relay Probes	John Gertz & Geoff Marcy	Zorro Productions, Berkeley, CA & Space Laser Awareness, Santa Rosa, CA
We develop a model for an interstellar communication network that is composed of relay nodes that transmit diffraction-limited beams of photons. We provide a multi-dimensional rationale for such a network of communication in lieu of interstellar beacons. We derive a theoretical expression for the bit rate of communication based on fundamental physics, constrained by the energy available for photons and the diffraction of the beam that dilutes the information by the inverse square law. We find that meter-scale probes are severely limited in their bit rate, under 1 Gbps, over distances of a light year. However, that bit rate is proportional to the 4th power of the size of the optics that transmit and receive the photons, and inversely proportional to the square of the distance between them, thus favoring large optics and short separations between nodes. The optimized architecture of interstellar communication consists of a network of nodes separated by sub- light-year distances and strung out between neighboring stars. (https://arxiv.org/abs/2204.08296)		

Interstellar Photon Sailing: Trajectory Errors Due to Sail Unfurlment Timing Delay	Gregory Matloff	New York City College of Technology, CUNY
One method of launching space probes towards interstellar destinations is the application of solar-photon sails unfurled from the near-Sun perihelion of an initially parabolic solar orbit. One issue with this technique is trajectory direction errors caused by sail-unfurlment timing delays. This paper quantifies such delays in a manner that can be readily applied by mission planners. A number of possible techniques that could be applied to the correction of these errors are also briefly considered.		

◀ Acta Astronautica

Title	Number+date	Author	Affiliation
Abstract/Précis/Highlights			

Title	Number+date	Author	Affiliation
How to decode interstellar messages	192, March 2022	M Matessa et al	METI International (San Francisco), Pacific Lutheran University (Tacoma), Dalhousie University (Canada), University of Arizona

How can we determine the meaning of a message from a distant civilization if we do not have a common language? This paper presents a general technique and principles for decoding interstellar messages: First, find the dimension of the message. Prime numbers may be useful in determining the proportions of messages. Next, find the symbols. This can be done considering symbol types: delimiters, values, relationships, and functions. Then, find the symbol meanings. Features that can help in determining meaning include sub-symbolic type, redundant symbols, expression consistency, physics ratios, and physics expression patterns. Concepts in this paper can be used when a message from another civilization is received, or they can be used to create messages, which can teach communication theory concepts.

Title	Number+date	Author	Affiliation
Interstellar Probe: Humanity's exploration of the Galaxy Begins	200, July 2022	Pontus C Brandt and 22 others	Johns Hopkins University, University of California Berkeley, University of Iowa, University of Bern (Switzerland), University of Kiel (Germany), University of Colorado, Weslayan University (CT, USA), Boston University

During the course of its evolution, our Sun and its protective magnetic bubble have plowed through dramatically different interstellar environments throughout the galaxy. The vast range of conditions of interstellar plasma, gas, dust and high-energy cosmic rays on this "solar journey" have helped shape the solar system that we live in. Today, our protective bubble, or Heliosphere, is likely about to enter a completely new regime of interstellar space that will, yet again, change the entire heliospheric interaction and how it shields us from the interstellar environment. Interstellar Probe is a mission concept to explore the mechanisms shaping our heliosphere and represents the first step beyond our home, into the interstellar cloud to understand the evolutionary journey of our Sun, Heliosphere and Solar System. The idea of an Interstellar Probe dates back to the 1960's, when also the ideas of a probe to the Sun and its poles were formed. An international team of scientists and a team of engineers at the Johns Hopkins University Applied Physics Laboratory (APL) are funded by NASA to study pragmatic mission concepts that would make a launch in the 2030's a reality. The ground breaking science enabled by such a mission spans not only the discipline of Solar and Space Physics, but also Planetary Sciences and Astrophysics. Detailed analyses including the upcoming SLS Block 2 and powerful stages demonstrate that asymptotic speeds around 7 Astronomical Units (au) per Year are already possible with a Jupiter Gravity Assist. Here, we give an overview of the science discoveries that await along the journey, including the physics of the heliospheric boundary and interstellar medium, the potential for exploration of Kuiper Belt Objects, the circum-solar dust disk and the extra-galactic background light. The scientific rationale, investigations and implementation of an Interstellar Probe are discussed including also example payload, trajectory design and operations.

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<tr><td>Defining and characterizing self-awareness and self-sufficiency for deep space habitats</td><td>198 June 2022</td><td>AE Rollock, DM Klaus</td><td>University of Colorado Boulder</td></tr>
<tr><td colspan="4">Future deep-space crewed exploration plans include long duration missions (>1,000 days) that will be constrained by lengthy transmission delays and potential occultations in communications, as well as infrequent resupply opportunities and likely periods of habitat unoccupancy. In order to meet the high level of autonomy needed for these missions, many essential capabilities and knowledge previously accomplished through ground support and human operators must now be designed into onboard systems to enable increasing self-reliance. Emergent technologies, including autonomous systems, have the potential to be mission enabling in deep space; however, as these technologies are often low-TRL and without defined mass, power, or volume, their net impact to the design must be assessed through alternative means, especially during the early planning phases. This paper proposes the concept of designing for self-reliant space habitats as the foundation for assessing potential contributions from the integration of emergent technologies. The term 'self-reliance' can be thought of as a combination of the spacecraft system and onboard crew's knowledge (self-awareness) and capabilities (self-sufficiency) independent of external intervention. In order to provide context for human spaceflight, these terms are first derived from related terrestrial applications. Subsequently, a methodology for characterizing the degree of self-awareness and self-sufficiency in a space habitat is outlined to provide designers with logic for assessing the contributions of emergent technologies to the overall self-reliance of the habitat as needed to allow future Earth-independence. The definitions and characterization logic provided in this work offer a systematic process for designing toward self-reliance in future deep space missions.</td></tr>
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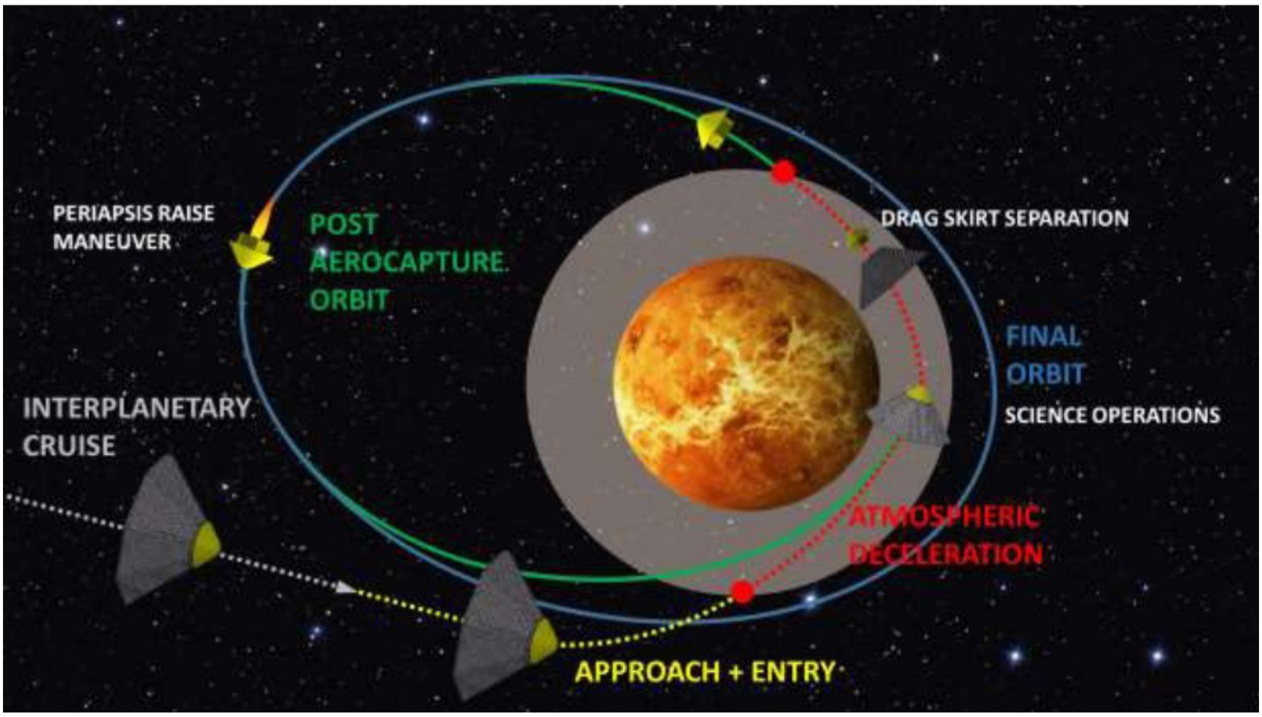

An example of earlier work by AE Rollock, University of Colorado Boulder - "Fig. 3. The aerocapture maneuver, with all of the critical steps to enter orbit" from *SmallSat Aerocapture: Breaking the Rocket Equation to Enable a New Class of Planetary Missions*, lead author Alex Austin. NASA Jet Propulsion Laboratory, Caltech.

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<tr><td>Searching for technosignatures in exoplanetary systems with current and future missions</td><td>198 September 2022</td><td>Jacob Haqq-Misra and 10 others</td><td>Blue Marble Space Institute of Science (Seattle), University of California Riverside, Instituto de Astrofísica de Canarias (Spain), Universidad de La Laguna (Spain), NASA Goddard Space Flight Center, ETH Zürich,, University of Arizona, Leibniz-Institut für Sonnenphysik (Germany), Catholic University of America, NASA Ames Research Center, University of Cadiz, The University of Arizona</td></tr>
<tr><td colspan="4">Technosignatures refer to observational manifestations of technology that could be detected through astronomical means. Most previous searches for technosignatures have focused on searches for radio signals, but many current and future observing facilities could also constrain the prevalence of some non-radio technosignatures. This search could thus benefit from broader participation by the astronomical community, as contributions to technosignature science can also take the form of negative results that provide statistically meaningful quantitative upper limits on the presence of a signal. This paper provides a synthesis of the recommendations of the 2020 TechnoClimes workshop, which was an online event intended to develop a research agenda to prioritize and guide future theoretical and observational studies technosignatures. The paper provides a high-level overview of the use of current and future missions to detect exoplanetary technosignatures at ultraviolet, optical, or infrared wavelengths, which specifically focuses on the detectability of atmospheric technosignatures, artificial surface modifications, optical beacons, space engineering and megastructures, and interstellar flight. This overview does not derive any new quantitative detection limits but is intended to provide additional science justification for the use of current and planned observing facilities as well as to inspire astronomers conducting such observations to consider the relevance of their ongoing observations to technosignature science. This synthesis also identifies possible technology gaps with the ability of current and planned missions to search for technosignatures, which suggests the need to consider technosignature science cases in the design of future mission concepts.</td></tr>
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Searching for technosignatures in exoplanetary systems with current and future missions, Jacob Haqq-Misra et al, https://arxiv.org/abs/2206.00030

Figure 1: A concept image illustrating various types of technosignatures described in this paper, including atmospheric, optical, and radio technosignatures. Atmospheric technosignatures may include obviously artificial molecules such as sulfur hexafluoride (SF6) in addition to common molecules expected for an inhabited terrestrial planet, such as oxygen (O2), carbon dioxide (CO2), and methane (CH4). The top left inset shows the absorption cross-sections of S6. Optical technsignatures include highly collimated laser pulses that can outshine the host star at narrow wavelengths (i.e., Optical SETI). The middle left inset illustrates the narrow power distribution of an optical (green) laser pulse. Active radio beacons or passive radio leakage from the planetary surface, orbit, or elsewhere in the stellar system would be recognizably artificial (i.e., traditional SETI). The bottom left inset illustrates the narrow distribution of power versus frequency anticipated for an artificial radio signal. Additional potentially detectable technosignatures in this planetary system include artificial lighting on the planetary nightside, recognizable spectral breaks from solar arrays on the planet's moon, and anomalous transit signatures from the orbiting habitats and satellite arrays.

A glint in the eye: Photographic plate archive searches for non-terrestrial artefacts	194, May 2022	B Villarroel et al	KTH Royal Institute of Technology and Stockholm University, Instituto de Astrofísica de Canarias, Centro de Astrobiología (Spain), Spanish Virtual Observatory, Gran Telescopio Canarias, Center for Basic Space Science (Nigeria), Durham University (UK)
In this paper, we present a simple strategy to identify Non-Terrestrial artefacts [NTAs; Haqq-Misra and Kopparapu (2012)] in or near geosynchronous Earth orbits (GEOs). We show that even the small pieces of reflective debris in orbit around the Earth can be identified through searches for multiple transients in old photographic plate material exposed before the launch of first human satellite in 1957. In order to separate between possible false point-like sources on photographic plates from real reflections, we present calculations to quantify the associated probabilities of alignments. We show that in an image with nine "simultaneous transients" at least four or five point sources along a line within 10x10 arcmin^2 image box are a strong indicator of NTAs, corresponding to significance levels of 2.5 to 3.9σ. This given methodology can then be applied to set an upper limit to the prevalence of NTAs with reflective surfaces in geosynchronous orbits. (see also the Members Page in this issue and Members Newsletter May 2022)			

A glint in the eye: Photographic plate archive searches for non-terrestrial artefacts, B Villarroel et al http://export.arxiv.org/abs/2110.15217
Figure 5: Triple glints. An example of a triplet glints in a red POSS-I image from 1950s. The left column shows the POSS-I image, and the right column the Pan-STARRS image (> year 2015). The example is from Villarroel et al. (2021) [1]and uses the VASCO citizen science web interface

[1] *Exploring nine simultaneously occurring transients on April 12th 1950*, Beatriz Villarroel et al, 2021
https://www.nature.com/articles/s41598-021-92162-7