Calculating and contemplating the future of humankind among the stars and beyond, through rigorous and reasoned intellectual discourse

FISW-2019 Programme Guide
27 – 30 June 2019
Charfield, United Kingdom
Background to Foundations of Interstellar Studies Workshop

At the start of this new millennium we are faced with one of the greatest challenges of our age – can we cross the vast distances of space to visit worlds around other stars? At the end of the last century the idea of interstellar travel was considered one of pure science fiction. In recent times that has changed and interstellar flight has received much interest, particularly since the discovery of many planets outside of our Solar System around other stars. Indeed, we now know that a planet, of Earth mass size, orbits one of our closest stars, Proxima b. In addition, national space agencies and private commercial industry are beginning to turn their attention to the planets and beyond. It is time to start considering a bold interstellar journey and how we might accomplish it. Yet, this challenge presents many difficult problems to solve and who better to address them than the global physics community. Hence the need for a regular forum to discuss such ideas.

“How many more years I shall be able to work on the problem I do not know; I hope, as long as I live. There can be no thought of finishing, for ‘aiming at the stars’ both literally and figuratively, is a problem to occupy generations, so that no matter how much progress one makes, there is always the thrill of just beginning.”

— Robert H Goddard

Other good conferences or workshops do exist, but some observations have been noted. Such as there is a tendency to sacrifice quality over quantity, or that the large number of attendees prevents any discussion in depth, or that the agendas are so busy and packed with talks and events that participants become exhausted and have no time for actual progress. The Foundations of Interstellar Studies Workshops therefore attempt to address these issues.

Some other observations have identified key needs in the interstellar community, including: (1) a need to raise the academic standard of publications in the field (2) a need to educate academics as to the actual progress that has been made over past decades and create a sea change in perspectives. Essentially, the Foundations of Interstellar Studies Workshop will address these issues and the goal is to not only raise the standard of published papers by emphasis on academic rigour, but also to facilitate further contributions from academic communities towards solving interesting problems that need to be addressed.

At the end of World War II there was a set of outstanding physics meetings that took place in North America. These were the famous Shelter Island conference on the foundations of Quantum Mechanics (1947), and Pocono Conference (1948) and Oldstone Conference (1949). These meetings were known for their informal conversations. To illustrate the structure of these conferences here is one report from a delegate: “It has been found that much of value may be accomplished in two or three days of close association by key workers, who are frequently widely scattered geographically. Concentration on a given topic, the absence of distracting interests and the opportunity of free intimate discussions which is made possible by a small group, are particularly helpful.”

In the early part of the last century the famous Solvay conferences on physics took place, devoted to outstanding preeminent open problems in physics (and chemistry). These were attended by the likes of Albert Einstein, Hendrik Lorentz, Ernest Rutherford, Erwin Schrodinger, Werner Heisenberg and many others. The Solvay conferences still take place today, the most recent being one in 2014 on Astrophysics and Cosmology. The first such meeting was in 1911.
The lessons from these famous meetings are therefore reflected in the *Foundations of Interstellar Studies* Workshop. It is the intention to create an 'interstellar focussed' version, perhaps after several iterations, run jointly between several organisations depending on the host country. Such a workshop is to be run perhaps every two to three years if successful. The idea of this workshop is to do something that nobody has done before in the interstellar community. It is to provide a forum for problem solving on theoretical physics problems focussed on interstellar flight. The aim is to get researchers together and to maximum the social interaction time for idea swapping and information exchange and it is expected that the ideas and discussions (and maybe even calculations) should continue into the evening social sessions. It is the intention to make this one of the most successful scientific meetings relating to interstellar flight that has ever been organised. The *Foundations of Interstellar Studies* Workshop concept was created by the physicist and aerospace engineer Kelvin F Long.

**Purpose of workshops**

To facilitate intellectual discourse in matters relating to the technical challenges of interstellar flight and to promote theoretical and experimental progress towards the attainment of the interstellar vision.

"*Exploration is in our nature. We began as wanderers, and we are wanderers still. We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars.*"

— Carl Sagan

**Publication of Papers**

Post-workshop, all participating authors are encouraged to send in an ‘MS Word’ version of their presented paper or poster to the chairman of the meeting, and their paper will be considered as a part of a group submission to the *Journal of the British Interplanetary Society* for publication in a special issue. For information on the preferred *JBIS* style guide please contact the FISW-2 organising committee. This was done for the 2017 papers and so far a total of nine of the eighteen submitted have appeared in the journal. In any event, post-publication in *JBIS*, all submitted papers will appear in the FISW-2 proceedings document which will be collated a year after the journal submissions have taken place. This is to ensure that the journal receives the benefit of first publication rights. If authors wish to submit their papers to other journals, then we welcome that, but please let us know you have done so, in order for us to keep track of it.
Welcome from the Chairman

Humankind is engaged in the earliest stages of the astronautical endeavour, which began in the 1800s and 1900s, although had its origins in the works of science fiction and also the dreamers like Leonardo da Vinci who imagined we could one day fly in the sky like the birds. The subsequent emergence of our species into space in the 1950s and 1960s set us on a course of destiny that is sure to be accomplished in the near future; that is the exploration and colonisation of the Solar System and the surrounding interplanetary space. After that, comes the pinnacle of the astronautical endeavour, the exploration and colonisation of other star systems many light years away.

At the Foundations of Interstellar Studies Workshops (FISW), we celebrate this amazing potential of human kind, but also take steps to directly work towards it through our meetings. The speakers that present to our delegates cover a range of technical disciplines and all are at the forefront of visionary thinking in their field. They are represented by people that are not just talking about space, but are actually working on projects to make it happen.

The first FISW meeting took place during June 2017 in the city that never sleeps, New York City in the United States of America. That city is a metaphor for the productivity and continued activity of human existence as we construct our Mega Cities and the complex social structures that make them possible. This event was highly successful, and was hosted by the New York City College of Technology at its campus in Brooklyn.

The second FISW meeting is taking place in the village of Charfield, near the town of Wotton-under-Edge, Gloucestershire in the United Kingdom. This area is a part of the Cotswolds, an area of Outstanding Natural Beauty. It is also part of the industrial revolution that took place from around 1760 to 1840. The host for this meeting is the Initiative for Interstellar Studies, at its HQ. With the line-up of speakers we have scheduled for the event, we are confident that this too will be a successful meeting. For FISW-2 we have chosen three themes to focus our discussions.

Living in Deep Space: This includes space habitats on moons or planets. It may also include existing on small exploration vessels, living within medium slow boats or large world ships that travel over interstellar distances. The assumption is that any vessels that require human occupation have travel times which are equivalent to or exceed a human lifetime.

Advanced Propulsion Technology, Missions & Foundational Physics: This includes technologies that will take our probes to the farthest reaches of our Solar System, beyond the Voyagers to interstellar space, and onto nearby star systems. This may include beaming systems, energetic reactions engines such as fusion and also exotic systems such as antimatter. Propulsion concepts which include an application of known physics are considered. Mission application concepts are also discussed that span the gamut of deep space exploration within the solar system, such as human missions to the outer planets, interstellar precursor missions, and missions to nearby star systems. Foundational physics concepts with a proper grounding in understood physics are discussed that may facilitate better understandings of the natural world and hence may provide avenues for more effective power and propulsion approaches that make interstellar aspirations more feasible.

Building Architectural Megastructures: This includes a consideration for constructions that are the size of moons or planets, such as planetary/stellar engineering initiatives like Dyson-Stapledon spheres, Stellar Engines, Matrioska brains, Ring Worlds and other innovative inventions. This may also include the possibility of constructing gravity-based engines from space-time geometry such as worm holes and warp drives.

We welcome all delegates to FISW-2 in the village of Charfield, UK and we look forward to the exciting, enlightening discussions in the days ahead.

Kelvin F Long, Rob Swinney, Harold ‘Sonny’ White
Organising Committee

Co-Chairman:
Kelvin F Long, Interstellar Research Centre, Stellar Engines & Initiative for Interstellar Studies, UK.

Rob Swinney, Initiative for Interstellar Studies, UK.

Harold ‘Sonny’ White, NASA Lyndon B Johnson Space Center, USA.

Secretary:
Samar AbdelFattah, Hyperloop Project Director, Sypron Solutions

Logistical Planning:
John Davies, Initiative for Interstellar Studies, UK.

Promotions:
Alex Storer, Initiative for Interstellar Studies, UK.
Thursday 27 June

Session ZERO:

OPENING RECEPTION NIGHT

<table>
<thead>
<tr>
<th>Time</th>
<th>Item</th>
<th>Description</th>
<th>Further Info</th>
<th>Mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>Arrivals</td>
<td>Final Registration &amp; Delegate Packs, Tea &amp; Coffee</td>
<td>Programme Guide, Badging</td>
<td>60</td>
</tr>
<tr>
<td>18:00</td>
<td>Social</td>
<td>Opening Event for FISW-2, Food &amp; Wine</td>
<td>“Blue Shift”</td>
<td>180</td>
</tr>
<tr>
<td>21:00</td>
<td>Close</td>
<td>End of Opening Event</td>
<td>--</td>
<td>60</td>
</tr>
<tr>
<td>22:00</td>
<td>Exit</td>
<td>Last Stragglers Out</td>
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</tbody>
</table>

All registered delegates should pick up their packs when they enter the venue which is to include their badges which are to be worn throughout the FISW-2 meeting. The evening open reception will feature a catered dinner and drinks and an opportunity to socialise with your friends and colleagues. We hope you have fun and enjoy the evening as our guests.

At the June 2017 workshop in New York, for the opening evening we arranged for a three-piece classical orchestra. We are pleased to announce that the opening evening on Thursday 27 June will be accompanied by the three-piece ‘Blue Shift’ jazz band. Blue Shift is a trio drawn from the thriving community of jazz musicians in Oxfordshire. They play popular standards from the mid-20th century in the styles of the Great American Songbook, including swing, blues, bebop, bossa nova and ballads. The name puns on the Doppler shift of an approaching astronomical body.

The members of the band include Stephen Ashworth, a member of the Initiative for Interstellar Studies and also a long time Fellow of the British Interplanetary Society. The other band members are Simon Feast and Tom Feast, who both work for a company in Oxfordshire which is a commercial effort to develop Single Stage to Orbit Spaceplanes to replace conventional rocket technology.
# LIVING IN DEEP SPACE

<table>
<thead>
<tr>
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<th>Item</th>
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<tr>
<td>08:15</td>
<td>Open</td>
<td>Tea, Coffee &amp; Pastries</td>
<td>--</td>
<td>30</td>
</tr>
<tr>
<td>08:45</td>
<td>Welcome</td>
<td>By Kelvin F Long</td>
<td>i4is &amp; Interstellar Research Centre</td>
<td>5</td>
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<tr>
<td>08:50</td>
<td>Introduction</td>
<td>By Chairman Rob Swinney</td>
<td>Initiative for Interstellar Studies</td>
<td>10</td>
</tr>
<tr>
<td>09:00</td>
<td>Keynote</td>
<td>Philip Mauskopft, “Interplanetary &amp; Interstellar Communication &amp; Navigation”</td>
<td>Arizona State University, USA</td>
<td>40</td>
</tr>
<tr>
<td>09:40</td>
<td>Speaker 1</td>
<td>Mark Hempsell, “Colonies and World Ships”</td>
<td>British Interplanetary Society, UK</td>
<td>30</td>
</tr>
<tr>
<td>10:10</td>
<td>Break</td>
<td>Tea, Coffee, &amp; Biscuits</td>
<td>--</td>
<td>20</td>
</tr>
<tr>
<td>10:30</td>
<td>Speaker 2</td>
<td>Kelvin F Long, “Calculations for a Crewed Interstellar Dysonship Driven by Microwave Beam Propulsion”</td>
<td>Interstellar Research Centre, Stellar Engines &amp; Initiative for Interstellar Studies, UK</td>
<td>30</td>
</tr>
<tr>
<td>11:00</td>
<td>Speaker 3</td>
<td>Angelo Vermeulen, “Evolving Asteroid Starships: A Bio-Inspired Approach for Designing Generation Starships”</td>
<td>Delft University of Technology, Netherlands</td>
<td>30</td>
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<tr>
<td>11:30</td>
<td>Discussion</td>
<td>Communications, navigation, space colonies, world ships, evolving starships, asteroid mining</td>
<td>Interactive</td>
<td>60</td>
</tr>
<tr>
<td>12:30</td>
<td>Break</td>
<td>Catered Lunch</td>
<td>--</td>
<td>60</td>
</tr>
<tr>
<td>13:30</td>
<td>Speaker 4</td>
<td>Samar AbdelFattah, “Hyperloop: Martian Operation 1”</td>
<td>Cairo University, Egypt</td>
<td>30</td>
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<tr>
<td>14:00</td>
<td>Speaker 5</td>
<td>Peter Robinson, “Space Elevators: The Earth, The Moon and Beyond”</td>
<td>International Space Elevator Consortium</td>
<td>30</td>
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<tr>
<td>14:30</td>
<td>Speaker 6</td>
<td>Richard Osborne, “The Use of Near-Term Launch Systems for Developing A Stanford Torus”</td>
<td>StellarDyne, UK</td>
<td>30</td>
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<tr>
<td>15:00</td>
<td>Speaker 7</td>
<td>Patrick Mahon, “Worldships – Some Ecological and Resource Constraints”</td>
<td>Initiative for Interstellar Studies</td>
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<tr>
<td>15:30</td>
<td>Break</td>
<td>Tea, Coffee, &amp; Biscuits</td>
<td>--</td>
<td>20</td>
</tr>
<tr>
<td>15:50</td>
<td>Discussion</td>
<td>Hyperloop, Mars, Space elevators, Stanford Torus</td>
<td>Interactive</td>
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<tr>
<td>16:40</td>
<td>Panel</td>
<td>Chaired by Rob Swinney, “A Near-Term Tactical Discussion on the Build-up of an Interplanetary Infrastructure Toward the Strategic Vision of Interstellar Flight Capability”</td>
<td>Osborne, AbdelFattah, Davis, Vermeulen, White, Ashworth</td>
<td>70</td>
</tr>
<tr>
<td>17:50</td>
<td>Social</td>
<td>Special Poster Session Top Floor (Long, Swinney, Bangs, Kaur, Kokkalis, Mahon, Hein)</td>
<td>Accompanied by Wine, Spirits &amp; Nibbles</td>
<td>100</td>
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<tr>
<td>19:30</td>
<td>Close</td>
<td>End of Poster Session</td>
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<tr>
<td>19:35</td>
<td>Social</td>
<td>Dinner on own or groups</td>
<td>Pay for own meal</td>
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## ADVANCED PROPULSION TECHNOLOGY & MISSIONS

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<th>Time</th>
<th>Item</th>
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<th>Further Info</th>
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<td>08:15</td>
<td>Open</td>
<td>Tea, Coffee &amp; Pastries</td>
<td>35</td>
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</tr>
<tr>
<td>08:50</td>
<td>Introduction</td>
<td>By Chairman Harold ‘Sonny’ White</td>
<td>NASA Johnson Space Center, Texas, USA</td>
<td>10</td>
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<tr>
<td>09:00</td>
<td>Keynote</td>
<td>Alan Costley, “Development for Faster Fusion at Tokamak Energy”</td>
<td>Tokamak Energy Ltd</td>
<td>40</td>
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<tr>
<td>09:40</td>
<td>Speaker 1</td>
<td>Angelo Genovese, “Laser-Powered Electric Propulsion Precursor Mission”</td>
<td>Initiative for Interstellar Studies, UK</td>
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<td>Break</td>
<td>Tea, Coffee, &amp; Biscuits</td>
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<tr>
<td>10:30</td>
<td>Speaker 2</td>
<td>Ryan Weed, “Antielectron Propulsion”</td>
<td>Positron Dynamics, USA</td>
<td>30</td>
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<td>11:00</td>
<td>Speaker 3</td>
<td>Rob Swinney, “Project Icarus Fusion Starship Concept Design Solutions”</td>
<td>Initiative for Interstellar Studies, UK</td>
<td>30</td>
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<tr>
<td>11:30</td>
<td>Speaker 4</td>
<td>Charles Swanson, “Direct Fusion Drive for the Gravitational Lens Mission”</td>
<td>Satellite Systems, USA</td>
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<tr>
<td>12:00</td>
<td>Photo</td>
<td>Workshop Group Photograph</td>
<td>10</td>
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<tr>
<td>12:10</td>
<td>Break</td>
<td>Catered Lunch (2nd viewing of posters opportunity)</td>
<td>--</td>
<td>60</td>
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<tr>
<td>13:10</td>
<td>Discussion</td>
<td>Fusion, antimatter catalysed fusion, laser-electric propulsion, precursor missions</td>
<td>Interactive</td>
<td>50</td>
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<tr>
<td>14:00</td>
<td>Speaker 5</td>
<td>Jeremy Munday, “Engineering Quantum Vacuum Fluctuations”</td>
<td>University of Maryland, USA</td>
<td>30</td>
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<tr>
<td>14:30</td>
<td>Speaker 6</td>
<td>Harold ‘Sonny’ White, “Dynamic Vacuum Model and Casimir Cavity Experiments”</td>
<td>NASA Johnson Space Center, Texas, USA</td>
<td>30</td>
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<tr>
<td>15:00</td>
<td>Break</td>
<td>Tea, Coffee, &amp; Biscuits</td>
<td>30</td>
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<tr>
<td>15:30</td>
<td>Speaker 7</td>
<td>Heidi Fearn, “Advances in Mach Effect Gravitational Assist (MEGA) Drive Experimentation”</td>
<td>CSU Fullerton, California, USA</td>
<td>30</td>
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<tr>
<td>16:00</td>
<td>Speaker 8</td>
<td>Mike McCulloch, “Quantised Inertia, Propellant-less Thrust and Interstellar Travel”</td>
<td>Plymouth University, UK</td>
<td>30</td>
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<tr>
<td>16:30</td>
<td>Speaker 9</td>
<td>Philip Lubin, “Directed Energy – The Path to Interstellar Flight”</td>
<td>University California Santa Barbara, California, USA</td>
<td>30</td>
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<tr>
<td>17:00</td>
<td>Discussion</td>
<td>Quantum vacuum, Mach Effect, inertia drives</td>
<td>Interactive</td>
<td>50</td>
</tr>
<tr>
<td>17:50</td>
<td>Close</td>
<td>End of Session</td>
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<tr>
<td>19:30</td>
<td>Social</td>
<td>Workshop Dinner at the Swan Hotel to include an invited after dinner speech from guest Professor Gregory Matloff</td>
<td>16 Market St, Wotton-under-Edge, GL12 7AE</td>
<td>180</td>
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<tr>
<td>22:30</td>
<td>Close</td>
<td>End of Dinner</td>
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<tr>
<td>22:45</td>
<td>Transport</td>
<td>Cars / Taxis back to Hotels</td>
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### Sunday 30 June  

**Session THREE:**  

**BUILDING ARCHITECTURAL MEGASTRUCTURES**

<table>
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<tr>
<td>08:15</td>
<td>Open</td>
<td>Tea, Coffee &amp; Pastries, Doors open</td>
<td>--</td>
<td>35</td>
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<tr>
<td>08:50</td>
<td>Introduction</td>
<td>Chairman Kelvin F Long</td>
<td>i4is &amp; Interstellar Research Centre</td>
<td>10</td>
</tr>
<tr>
<td>09:00</td>
<td>Keynote</td>
<td>James Schalkwyk, <em>Building Breakthrough Starshot</em></td>
<td>Breakthrough Initiatives, California, USA</td>
<td>40</td>
</tr>
<tr>
<td>09:40</td>
<td>Break</td>
<td>Tea, Coffee &amp; Biscuits</td>
<td>--</td>
<td>20</td>
</tr>
<tr>
<td>10:00</td>
<td>Speaker 1</td>
<td>Remo Garattini, <em>Casimir Traversable Wormholes</em></td>
<td>Bergamo University, Italy</td>
<td>30</td>
</tr>
<tr>
<td>10:30</td>
<td>Speaker 2</td>
<td>Francisco Lobo, <em>Wormholes, Warp Drives and Interstellar Travel</em></td>
<td>Institute of Astrophysics &amp; Space Sciences, University of Lisbon</td>
<td>30</td>
</tr>
<tr>
<td>11:00</td>
<td>Discussion</td>
<td>Starshot, wormholes, warp drive</td>
<td>Interactive</td>
<td>30</td>
</tr>
<tr>
<td>11:30</td>
<td>Speaker 3</td>
<td>Al Jackson, <em>Neutrino Beacons for Interstellar Communications</em></td>
<td>Triton Systems, USA</td>
<td>30</td>
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<tr>
<td>12:00</td>
<td>Speaker 4</td>
<td>Gregory Matloff, <em>Is the Kuiper Belt Inhabited?</em></td>
<td>New York City College of Technology, USA</td>
<td>30</td>
</tr>
<tr>
<td>12:30</td>
<td>Discussion</td>
<td>SETI &amp; interstellar communications</td>
<td>Interactive</td>
<td>30</td>
</tr>
<tr>
<td>13:00</td>
<td>Conclusions</td>
<td>Chairman Kelvin F Long, Summary of Workshop</td>
<td>--</td>
<td>30</td>
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<tr>
<td>13:30</td>
<td>Break</td>
<td>Catered Lunch (<em>light only</em>)</td>
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<td>30</td>
</tr>
<tr>
<td>14:00</td>
<td>Close</td>
<td>End of Workshop</td>
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</tr>
<tr>
<td>14:30</td>
<td>Transport</td>
<td>Cars depart for station and airport</td>
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Biographies of Participating Speakers

Philip Mauskopf, Arizona State University, USA

Professor Philip Mauskopf has a joint appointment at Arizona State University in the School of Earth and Space Exploration and the Department of Physics. His background is in primarily experimental cosmology - in particular designing and building new types of instruments for measuring signals from the most distant objects in the universe. However, he has broad interests that include solid state physics, atmospheric science and quantum communications and cryoptography. He particularly enjoys the opportunity to pursue interdisciplinary projects within the ASU community as well as collaborating with researchers at other universities and research institutions such as Caltech/JPL, University of Pennsylvania, Columbia University, NIST Boulder, Cardiff University (UK) and the Neel Institute and IRAM observatory (France).

Before starting at ASU in 2012, Professor Mauskopf was a professor of experimental astrophysics at Cardiff University in the U.K. since 2000 where he helped to start a world-leading group in the area of astronomical instrumentation for terahertz (THz) frequencies.

"Interplanetary and Interstellar Navigation and Communications Challenges & Constraints"

Abstract: Like the early intercontinental explorers traveling the oceans, two of the major challenges of interplanetary and interstellar exploration are navigation and communication. Today, navigation and communication on the earth benefits from the use of radio communication between networks of satellites. For space missions, star cameras can provide information about orientation but not accurate location and velocity. I will describe a proposal for a network of small satellite beacons distributed throughout the solar system which can provide a similar function for interplanetary and interstellar travel as the earth-based Global Positioning System (GPS). In addition, I will discuss the navigation and communication requirements for interstellar travel.

References:

Mark Hempsell is the current President of the British Interplanetary Society, 2018 and a former editor of the Society’s Journal. Mark has a BSc in Physics and an MSc in Astronomy and Astronautics. He has forty years’ experience as a systems engineer in the space industry and has around a hundred publications. He worked for thirteen years as a spacecraft systems engineer at British Aerospace and then worked for seventeen years at the University of Bristol lecturing in Astronautics. In 2009 he joined Reaction Engines Limited as the Future Programmes Director responsible for the Skylon airframe. In 2013 he left Reaction Engines to form Hempsell Astronautics Limited a systems engineering consultancy and to write science fiction that considers what is possible in spaceflight with the technology we already have.

“Colonies and World Ships”

Abstract: The renewed interest in space colonies, as proposed by O’Neil, led to the concept of world ships by Bond and Martin. The technology of one leading to the other. The Scorpion study has been looking at the reality of what mankind could realise in space with our current technological tools and that includes O’Neil scale Earth orbit colonies with up to a million inhabitants. However unlike the 1970’s colony concepts, which emphasized closed loop sustainability (essential for world ships), the Scorpion study colonies are hubs in a wider space economy and do not require self-sufficiency. This leads to many technical approaches that are dependent upon the colonies’ economic trading links, and, as a consequence, not suitable for a World ship. Although it was always acknowledged there were some clear differences between an Earth orbit colony and a world ship, this work suggests that the technology gap between them may be greater than originally thought. However this gap may in part be filled by interplanetary colonies beyond Earth orbit.

References:

2. A. Bond and A.R.Martin “World Ships – An Effective Assessment of the Engineering Feasibility”, Vol.37, pp254-266, June 1984,
Kelvin F. Long, Interstellar Research Centre & Initiative for Interstellar Studies, UK

Kelvin F Long studied a Bachelor’s Degree in Aerospace Engineering and a Master’s Degree in Astrophysics from the University of London. He was the co-founder, first Executive Director and President of the UK based not-for-profit the Initiative for Interstellar Studies. He is a Chartered Member of the Institute of Physics, a Fellow of the British Interplanetary Society and was formerly the Chief Editor for the Journal of the British Interplanetary Society. He has worked on a 200 AU mission with the International Academy of Astronautics, a 1,000 AU mission with Johns Hopkins University Applied Physics Laboratory and a full interstellar mission with the Breakthrough Initiatives. He is a member of the Breakthrough Starshot advisory committee. Kelvin has published or edited numerous books on interstellar studies and has published dozens of popular articles and academic peer reviewed papers in technical science journals.

“Calculations for a Crewed Interstellar Dysonship Driven by Microwave Beam Propulsion”

Abstract: In this paper we review calculations for a seed colonisation vessel that carries 500 people, propelled by a 1200 TW microwave beam, utilising a solar collecting mirror as the energy source. The concept is to accelerate at 0.98 m/s² for 1 year over a distance of 3,260 AU, reaching a cruise velocity of 30,927 km/s or ~0.1c. It would then reach a nearby star system ~60 years from launch. The calculations for the concept are compared to other microwave driven calculations by Robert Forward for the Starwisp concept using a purpose build Fortran program. Comparisons will also be made to calculations from a NASA workshop study and the Breakthrough Initiatives Project Starshot study. A revised concept for the Dysonship that is more credible is then demonstrated. We will also comment on other elements of the design, including issues such as shielding requirements. Finally, some comments will be made on the design of the concept as compared to other ‘slow boats’, such as the Enzmann starship.

References:

**Angelo Vermeulen**, Delft University of Technology, Netherlands

Angelo Vermeulen is a space systems researcher, biologist, and artist. He works on bio-inspired concepts for interstellar exploration at Delft University of Technology, bringing together a multitude of disciplines. Since 2009 he has been collaborating with the European Space Agency’s MELiSSA program on biological life support. In 2013 he became the first crew commander of the NASA-funded HI-SEAS Mars simulation program in Hawai’i. Vermeulen actively collaborates with commercial space companies such as LIQUIFER Systems Group and ESA spin-off SEMiLLA Circular Systems, and regularly advises young space startups. He also co-founded SEAD (Space Ecologies Art and Design), an international transdisciplinary collective of artists, scientists, engineers, and activists. SEAD’s goal is to reshape the future through critical inquiry and hands-on experimentation. Vermeulen has been (guest) faculty at several universities across Europe, the US, and Southeast Asia, and is passionate about public speaking. Currently, he is designing a series of art+science experiments on board the International Space Station.

**“Evolving Asteroid Starships: A Bio-Inspired Approach for Designing Generation Starships”**

**Abstract:** In order to deal with the deep uncertainty that is inherent to interstellar exploration, a morphogenetically engineered starship concept is being proposed. A starship is attached to a C-type asteroid, and its architecture is evolved over time. The starship gradually mines resources of the asteroid, while at the same time using it as forward shielding. The extracted raw materials are used for expansion of the starship’s modular architecture through mobile 3D manufacturing and cultivation of an on-board regenerative ecosystem. Within the bounds of its sensing horizon, the spacecraft can detect prospective particle collisions and radiation events along its flight path. Subsequently, the starship can adapt itself by reconfiguring its interior and exterior morphology. This constant evolution aims to minimize the spacecraft damage and loss of functionality, and handles the inherent unpredictability of the mission. The TU Delft Starship Team (DSTART) researches this concept by combining a series of different formalisms into a hybrid simulation. The goal is to explore plausible scenarios that the starship would come across by running hundreds of thousands of different combinations of input variables, using sampling techniques, and searching for clusters of probable outcomes. In this presentation, the current state of the hybrid simulation will be presented, and initial results will be discussed.

**References:**

Peter Robinson, International Space Elevator Consortium

Peter Robinson is a member of the International Space Elevator Consortium (ISEC). He presented papers at the ISEC Seattle Conference in 2014 and 2015, with the former titled ‘Space Elevator Simulation, Validation and Metrology’ published in the ISEC ‘CLIMB’ magazine of that year. He has also presented on space elevators at the British Interplanetary Society ‘Future Histories’ Symposium in 2017 and was the co-organiser of the BIS ‘Space Elevator’ Symposium in 2017, also presenting on ‘Solar System Space Elevators’. He has also presented at the IAC/Bremen in 2018 and the ISDC/Washington DC in 2019, in addition to numerous other venues over the last three years. He is a Fellow of the British Interplanetary Society.

“Space Elevators: The Earth, The Moon and Beyond”

Abstract: This paper will summarise the current Earth Space Elevator (SE) and ‘Galactic Harbour’ system concepts as envisioned by the International Space Elevator Consortium (ISEC). It will define material ‘Specific Strength’ and describe some possible tether materials. It will describe the basic operational requirements for the tether and associated climbers. The paper will then describe possible SE systems in other solar system locations, including The Moon, Mars, asteroids and gas giant moons. It will speculate on how smaller-scale systems could support asteroid mining operations whilst also building reliability for later planetary elevators. It will conclude by asserting that multiple Earth Space Elevators will be essential to raise the people and high-technology material from Earth to facilitate the construction of massive crewed interstellar starships and independent space habitats.

References:

Samar AbdelFattah has an Aerospace Engineering background. She currently acts as the Hyperloop project director at Sypron Solutions. She started taking part in space based engineering projects in 2015, when she was part of UNISEC- Global research on “Optimizing Nano- Satellites for Early Predictions of Surface Disturbances” in critical areas in Japan. Later in 2015, she was a participant in the Initiative for Interstellar Studies “Project Dragonfly”. In 2016, she received the “Design Innovation Award” in the SpaceX Hyperloop competition, where her team was able to design and analyse a linear induction propelled Hyperloop capsule. She then published a paper “Conceptional Design of a Hyperloop Capsule Using Linear Induction Propulsion System” in ICAMAME, Berlin. She led the HyperNova team who won the Dubai Government award for designing a Hyperloop capsule and station for the UAE government; then they built their first Hyperloop single- passenger capsule to be tested in SpaceX track. She has acted as a consultant for Smart Mobility solutions and Human- Centered Experience for different projects in the MENA region. She launched the first Hyperloop Summer School ever to happen in Dubai in 2018, and recently filed a patent on the first Hyperloop interactive lab- tested to support her educational vision. She is the Secretary for the second Foundations of Interstellar Studies Workshop which has been organized with the Initiative for Interstellar Studies as the host.

“Hyperloop: Martian Operation 1”

Abstract: Many recent researches have considered the applications of vacuum trains and magnetic levitation on Earth. However, we need to look at the existing environments that welcome such applications and facilitate its operation. The Hyperloop represents a great sample model for possible mobility solution for inhabitants on Mars. In this presentation, we study the effect of surface geography on track and atmosphere composition on operation. In addition, the magnetic levitation options integrated with electromagnetic or complete electric thrust to reduce magnetic drag, although we are already having zero aerodynamic and friction drag. Hypothetically, we can assume a colony of 80,000 people that will need accessibility across the planet equatorial at preferable mean temperature for inhabitants. A design case can be performed with 4 main stations around the equatorial with average track length of 5325 Km. Along, each track multiple exits and/ or small stations are built to provide further accessibility. The system can initially operate with 80 capsules over a two-ways and three- meters width Aluminum track with capacity of 20 passenger or a cargo payload of two tons. The low pressure, low temperature environment will sustain efficient Hyperloop operation without the need for a vacuumed tube, and might even allowing the electromagnetic system to operate efficiently without the risk of heat excess and the need for cooling system. However, we can use the heat generated by the electromagnetic system in the track or on board to warm the air in capsule or station. The main aim of this presentation is to build a mobility case study for inhabitants on Mars. The solar-powered smart stations connecting via an elevated track across the equatorial circumference will provide accessibility for the colonized regions a long with easier payload transfer for further structural projects or exploration missions. Such an implementation needs further studies as it is to be a major aid in colonization and further construction on the red planet.

References:

Philip Lubin, University California Santa Barbara, California, USA

Philip Lubin attended the University of California at Berkeley A.B (Physics and Mathematics), Harvard University, Cambridge (Physics) and the University of California at Berkeley Ph.D (Physics). Philip Lubin is a professor of Physics at UC Santa Barbara whose primary research has been focused on studies of the early universe in the millimeter wavelengths bands as well as applications of directed energy for planetary defense and relativistic propulsion. His group has designed, developed and fielded more than two dozen ground based and balloon borne missions and helped develop two major cosmology satellites. Among other accomplishments his group first detected the horizon scale fluctuations in the Cosmic Microwave Background from both their South Pole and balloon borne systems 20 years ago and their latest results, along with an international team of ESA and NASA researchers, are from the Planck cosmology mission which has mapped in exquisite detail the structures of the early universe. He is a co-I on the Planck mission. His group has worked on applications of directed energy systems for both small scale single launcher solutions as well as large standoff systems for planetary defense and on applications to allow small interstellar probes to achieve relativistic speeds for the first interstellar missions. He is director of the NASA Starlight program, currently in a Phase II whose goal is to use directed energy for humanity’s first interstellar missions. He is also concept director for the Breakthrough Starshot program whose goals are also to achieve relativistic flight with miniature spacecraft. He is co-recipient of the 2006 Gruber Prize in Cosmology along with the COBE science team for their ground breaking work in cosmology as well as the 2018 Gruber Prize in Cosmology along with the Planck science team for their determination of fundamental cosmological parameter. He has published more than 400 papers.

“Directed Energy – The Path to Interstellar Flight”

Abstract: High power directed energy solutions offer a radically different approach to both space propulsion and long range power applications. All current propulsion systems that leave the Earth are based on chemical reactions. Chemical reactions, at best, have an efficiency compared to rest mass of 10-10 (or about 1eV per bond). All the mass in the universe converted to chemical reactions would not propel even a single proton to relativistic speeds. While chemistry will get us to Mars it will not allow rapid interplanetary nor interstellar capability. Barring new physics we are left with few realistic solutions. None of our current propulsion systems, including nuclear, are capable of the ultra-high speeds needed for rapidly exploring the solar system and for the future capability of relativistic flight to enable interstellar exploration. However, recent advances in photonics and directed energy systems now allow us to realize the ability to project the high power over vast distances that is needed for space applications. When operated in direct drive photon momentum exchange, extremely high speeds including relativistic flight become possible. When used in indirect drive mode where the beamed power is converted to electrical power to drive high Isp ion engines, we can realize high mass missions in our solar system at vastly higher speeds than chemistry. These approaches allow missions using direct photon drive from wafer-scale spacecraft capable of speeds greater than 0.25c that could reach the nearest star in 20 years to 10 kg spacecraft travelling at 0.02 c to large missions using beamed energy driven ion engines, including human capable, that enable rapid interplanetary capability including very rapid missions to Mars. Photonics, like electronics, and unlike chemical propulsion is an exponential technology with a current double time of about 20 months. The same core technology can be used for many other purposes including planetary defense, stand-off asteroid composition analysis, space debris mitigation, power beaming to long range spacecraft and other distant assets, LEO and GEO power beaming from Earth and space among many others applications. This would be a profound change in human capability. We will discuss the many technical challenges ahead, our current laboratory prototypes and recent data on kilometer baseline arrays, long coherence length amplifiers, low cost large aperture optics as well as the many transformative implications and complexities of this program. We are currently in three Phase II NASA NIAC R&D programs. We discuss the roadmap ahead, the short term and long term milestones that allow for a logical and cost effective approach.

References:

Harold ‘Sonny’ White, NASA Johnson Space Center, Houston, USA

Dr. White holds a Ph.D. in Physics from Rice University, a Master’s of Science in Mechanical Engineering from Wichita State University, and a Bachelor’s of Science in Mechanical Engineering from University of South Alabama. He currently serves as the Advanced Propulsion Theme Lead for the NASA Engineering Directorate and is the JSC representative to the Nuclear Systems Working Group. In his role, Dr. White is serving to help the Agency incorporate high TRL advanced power and propulsion technologies into near and mid-term human exploration architectures. He is also pursuing theoretical and laboratory research on developing lower TRL advanced propulsion and power technologies in the advanced propulsion physics laboratory known as Eagleworks that is located at the Johnson Space Center.

“Dynamic Vacuum Model and Casimir Cavity Experiments”

Abstract: This paper will summarize the pilot wave interpretation of quantum mechanics and provide an overview of a recent pilot wave model approach known as the dynamic vacuum model. Some of the recently published findings for the dynamic vacuum model approach are discussed and the implications of these findings lead to some possible new insights associated with the Casimir force phenomenon. The implications resulting from the hypothesis that there is structure to the quantum vacuum in the Casimir cavity are discussed and some conceptual experiments are presented. Some general sizing calculations related to these experiments are provided to determine the possibility of being able to measure the phenomenon in the lab.

References:

**Charles Swanson**, Princeton Satellite Systems, USA

Dr. Charles Swanson is a plasma physicist at Princeton Satellite Systems. He completed his Ph.D. thesis, "Measurement and characterization of fast electron creation, trapping, and acceleration in a high-mirror-ratio, low-beta magnetic mirror" at Princeton University in September 2018. His B.S. in physics is from Carnegie Mellon in 2011. Prior to beginning his graduate work, he interned at SpaceX, working on Electromagnetic Interference for the Dragon and Falcon spacecraft. Before settling into his thesis work, he modeled and studied the re-capture of secondary electrons by complex surfaces, such as fibrous and fractal materials. He wrote a Monte-Carlo simulation code and an analytic model to predict the amount of secondary electron suppression. Dr. Swanson has mentored eight undergraduate interns at the Princeton Plasma Physics Laboratory. The projects included: diagnosing plasmas using Langmuir probes, fast-framing cameras, and x-ray detectors; developing high efficiency RF amplifiers for fusion; and simulating the DFD rocket using UEDGE. Dr. Swanson was the assistant instructor for the graduate-level course "Laboratory in Plasma Physics" at PPPL. He coached two middle- and high-school robotics teams to compete in FIRST Tech Challenge.

"**Direct Fusion Drive for the Gravitational Lens Mission**"

**Abstract:** Direct high-resolution investigations of a potentially habitable exoplanet may result in finding extra-terrestrial life, arguably the raison detre of space exploration. This can be achieved, if a modest astronomical telescope is delivered to the focal region of the Solar Gravitational Lens (SGL), some 650 AU from the Sun. The payoff from such a novel space-based facility would be enormous: it is the only practical way to achieve a multi-pixel image at a kilometers-scale resolution on the surface of a potentially habitable exoplanet. Instrument requirements are a telescope, a coronagraph and a spectrometer. The Direct Fusion Drive (DFD), based on the Princeton Plasma Physics Laboratory’s Princeton Field Reversed Configuration machine, is a rocket engine that has the potential to propel a spacecraft for a mission to the gravitational lens point and arrive there in 13 years or less. The paper begins with an introduction to DFD, then continues with a discussion of the gravitation lens mission. The spacecraft must be kept on the focal line for best results. The spacecraft will also power a set of small spacecraft that will fly in formation with the main spacecraft for the gravitational lens mission. This is followed by a discussion of the nuclear fusion propulsion system including the latest results from the NASA NIAC study and a NASA Phase II STTR on superconducting coils for the machine. This includes new work on the power recycling system and the plasma drive. Results from an ARPA-E project to demonstrate ion heating are discussed. The design of the fusion engine and the spacecraft is presented in detail. The laser power transfer system for powering the small spacecraft and their design is also discussed.

**References:**

**Alan Costley**, Tokamak Energy Ltd, UK

Alan Costley, a PhD graduate of the Physics Department at Imperial College, has worked in fusion for more than 40 years holding senior positions at the JET project, Culham Laboratory, and on the international ITER project in Cadarache. He was awarded the Charles Vernon Boys Prize of the Institute of Physics for distinguished research in experimental plasma physics by a young researcher, and is an elected Fellow of the American Physical Society. He has published more than 300 papers including about 40 invited papers at international conferences mainly in the areas of plasma diagnostics and compact fusion. He retired from ITER in 2009 and is now a consultant for government and private organisations in the UK and USA.

“**Development for Faster Fusion at Tokamak Energy**”

**Abstract:** System code and analytical studies have shown that in addition to the conventional large size, high aspect ratio approach to realising fusion energy, there could be an approach based on low aspect ratio spherical tokamaks at much smaller size. Tokamak Energy Ltd, a privately funded company in the UK, is pursuing a development programme that aims to realise this alternative route. The development programme includes the construction and exploitation of spherical tokamaks with increasing performance; parallel R&D on key enabling technological elements, for example magnets made with high temperature superconductors; physics and engineering design of compact fusion modules based on the spherical tokamak. In this presentation, we present the key modelling methods and results, and give an overview of the development programme.
Jeremy Munday, University of Maryland, USA

Jeremy Munday received his PhD in Physics from Harvard in 2008, his BS in Physics from Middle Tennessee State University in 2003, and was a postdoctoral scholar at Caltech until 2011 when he came to the University of Maryland. He is currently an Assistant Professor of Electrical and Computer Engineering with affiliate appointments in the Institute for Research in Electronics and Applied Physics (IREAP) and the Chemical Physics Graduate Program. His research endeavors range from near field optics, photonics, and plasmonics for solar energy conversion to quantum electromechanical phenomena (such as the Casimir effect) for actuating micro- and nanomechanical devices. He has received a number of recognitions, including the NASA Early Career Faculty Space Technology Research Award.

“Engineering Quantum Vacuum Fluctuations”

Abstract: Deep space may be mostly void of particles, but that does not mean that it is empty. Quantum electromagnetic fluctuations are omnipresent and are responsible for a number of observed effects including the Lamb shift and the Casimir effect. The presence of matter gives rise to boundary condition on the quantum electromagnetic fluctuations, which change the total energy density. This energy density is sometimes referred to as the zero-point-energy of vacuum. For the case of two charge-neutral parallel plates, the energy is reduced as the plates are brought closer together, causing an attractive force between them. With specially designed materials, the interaction can be either attractive or repulsive and can even lead to rotations. In this talk, I will overview our experiments to engineer the boundary conditions on the vacuum fluctuations, which have resulted in measurable forces and torques between objects. I will also try to provide some perspective on what may or may not be possible in future experiments.

References:

Heidi Fearn, CSU Fullerton, California, USA

Heidi Fearn received her PhD in the UK at the University of Essex, working with Rodney Loudon in quantum optics 1989. She worked for two years as a post doc with Marian Scully and Willis Lamb, then joined the faculty at CSU Fullerton in the fall of 1991 and has been there ever since. She visited Los Alamos National Laboratory for several years, in the summer, to work with Peter Milonni. She also spent two years as a distinguished visiting professor at the US Air Force Academy. She is currently a full professor of physics. She has been teaching physics for nearly 30 years both undergraduate and graduate all courses. She has been working with Jim Woodward since 2012 on Mach effect gravity assist drives. She has always been a fan of space exploration and is keen to see gravitation used for something as practical as a space drive.

“Advances in Mach Effect Gravitational Assist (MEGA) Drive Experimentation”

Abstract: The Mach Effect Gravitational Assist (MEGA) device is an electronic propulsion system which employs Mach’s principle and utilizes fluctuations in the internal energy of an accelerating object to produce a force. Mach’s principle states that the inertia of a body is due to the gravitational interaction with all matter and energy flow in the universe. The accelerating objects we use are capacitor stacks of PZT (lead zirconate titanate) disks, which are powered by an AC voltage. The usual frequency used is between 30-50 kHz. These capacitors are bolted between a cylindrical brass mass and an aluminum mass. The PZT stack pushes against the brass to create a force of the order of micro Newtons (μN). The observed force may be used as a propulsion method which has zero propellant which is why the MEGA drive has been proposed as a space drive. The experimental apparatus is based on a very sensitive force balance which we are currently upgrading. We shall also discuss the ENI amplifier and other new equipment which in turn allows for new measurements to be made. These new measurements help to physically characterize the stacks and thus our understanding of what tweaks will increase the force.

References:

Mike McCulloch, Plymouth University, UK

Mike McCulloch took a BSc in Physics at the University of York in 1991, and a PhD in Physical Oceanography at the University of Liverpool in 1995. He worked as a scientist at the Met Office between 1998 and 2008 and is now a lecturer in geomatics (the maths of positioning in space) at the University of Plymouth. In 2007, he suggested a new model for inertia (called Quantised Inertia or QI) which predicts galaxy rotation without dark matter and cosmic acceleration without dark energy, and has been in trouble ever since. He has published over 20 journal papers on QI, and a book called ‘Physics from the Edge’. Quantised inertia predicts a new kind of propellant-less thruster (an electric rocket) which could replace chemical rockets and make interstellar travel possible. He has just won $1.3M in funding from DARPA (Defence Advanced Research Projects Agency) to test this experimentally. As well as being curious about the cosmos, he likes drawing, playing the flute, family life, reading, hill walking, sci-fi, and attending interstellar workshops.

“Quantised Inertia, Propellant-less Thrust and Interstellar Travel”

Abstract: According to standard physics interstellar travel is impossible within a human lifetime because speeds close to the speed of light are needed and the amounts of rocket fuel required to achieve these speeds are impractical. Nuclear propulsion is a possibility but presents some extreme engineering challenges. A new approach to physics has been proposed called Quantised Inertia or QI (McCulloch, 2007). It assumes that inertia and gravity are due to the effect of horizons on the quantum vacuum. QI predicts galaxy rotation without dark matter (McCulloch, 2017), cosmic acceleration without dark energy and other anomalies, so it has empirical support. Quantised inertia predicts that propulsion can be achieved by making information horizons in the vacuum using conductive metamaterials (McCulloch, 2008, 2018), a form of propulsion for which no heavy fuel is needed, only an energy source. $1.3M has recently been won from DARPA to build & test QI-thrusters (with collaborators in Germany and Spain) and experiments are in progress. If QI is confirmed then interstellar travel within a human lifetime becomes possible. This talk will present the QI theory, the evidence for it, the experimental thruster results so far and an outline of the likely configuration of a QI-based interstellar propulsion system.

References:

Rob Swinney, Initiative for Interstellar Studies, UK

Rob Swinney was one of the first to join the design study for an interstellar probe, Project Icarus and he is the current Project Leader. He is also a director of the not-for-profit UK based Initiative for Interstellar Studies and former director of Icarus Interstellar Inc, the US based non-profit co-founded by original members of Project Icarus. He completed his BSc in Astrophysics at the University of Newcastle and MSc in Radio Astronomy at the University of Manchester. After several years teaching he returned to his studies and graduated from Cranfield University with a further MSc in Avionics and then undertook a rewarding career in the RAF as an engineering officer. He completed his commission in 2006 having attained the rank of squadron leader and has been working as an independent consultant in the space industry since. He was inspired by the Apollo adventure and the Grand Tours of the Voyager spacecraft. Today, he believes the ‘planets are aligning’ again, and organisations like the British Interplanetary Society, Breakthrough Initiatives, Icarus Interstellar and the Initiative for Interstellar Studies will prove that, although still extraordinarily difficult, real steps to interstellar exploration are being taken.

“Project Icarus Fusion Starship Concept Design Solutions”

Abstract: At FISW 1 in New York 2017, the workshop was introduced to the plasma dynamics of the Project Icarus’ Firefly fusion engine. Firefly, with its Z-pinch fusion engine, is the most developed variant of the Project Icarus study, a theoretical study to design a credible fusion powered starship capable of travelling to nearest stars within a target 100-year timeframe. The other Project Icarus concept designs are compared and explored here. Although not as detailed as the Firefly design their proposed fusion propulsion solutions are worthy of note for the record. There is also limited experimental evidence which makes it difficult to differentiate between options that might eventually prove successful. The team are currently compiling the Project Icarus final report presenting the key technical details which, having identified over 20 potential fusion mechanisms, resulted in several Icarus fusion driven variants primarily separated by their propulsion/ignition systems and fuels. Variants Ghost and Resolution/Endeavour are nearest to the Daedalus-style engine design and versions of Inertial Confinement Fusion (ICF). UDD is another variation of ICF-like fusion but with Deuterium/Deuterium fuel in a pre-compressed state of ‘Ultra Dense Deuterium’. The remaining variant, Zeus, was quite different and based on Plasma Jet Magnetised Inertial Fusion. Earlier designs such as the multi-mode Leviathan and precursor missions Pathfinder and Starfinder are summarised. An aim of the Project was to update and progress the renowned Project Daedalus fusion starship study and not necessarily advocate for fusion as the definitive solution. Other non-fusion powered interstellar solutions are available. The sheer challenge of utilising fusion revealed during this study led some to suggest alternatives and beamed sails now seem a plausible interstellar mission candidate within the near future. Still possible, fusion propulsion appears likely to be longer term.

References

Angelo Genovese, Initiative for Interstellar Studies, UK

Angelo Genovese received a Master’s Degree in Aerospace Engineering (specialising in Space Propulsion) at the University of Pisa, Italy, in 1992. He started to work as Electric Propulsion Engineer in the Italian space propulsion research centre “Centrospazio” in Pisa, developing Field Emission Electric Propulsion (FEEP) ion thrusters for ultra-precise positioning of scientific spacecraft. In 2000 he moved to the Austrian Research Centres in Vienna, Austria, where he contributed to develop an Indium FEEP Micro-propulsion System from breadboard to qualification level for the ESA Spacecraft LISA Pathfinder. Since 2009 he has been working at Thales Deutschland, Ulm, Germany, on the development and qualification of the innovative ion thruster HEMPT, suitable for new-generation GEO satellites, for the upcoming LEO/MEO smallsat constellations, and for advanced scientific missions. Angelo has published more than 50 papers in conferences and scientific journals, and he contributed to two patents on Indium FEEP ion thrusters. Deeply interested in advanced space propulsion systems for interplanetary exploration and interstellar precursor missions, he is the Director Experimental Programs of the non-profit international organisation Initiative for Interstellar Studies (I4IS). He has contributed to the I4IS book “Beyond the Boundary” with a chapter on advanced electric propulsion. Angelo is a visiting lecturer at the International Space University (ISU), Strasbourg, France, and he is regularly invited at international workshops including TVIW, Breakthrough Discuss, Mars Society and FISW.

“Laser-Powered Electric Propulsion Precursor Mission”

Abstract: Voyager 1 is the fastest human-made object and the first to venture into interstellar space; it crossed the heliopause, the boundary separating solar and galactic plasmas, in August 2012 at 120 AU from the Sun, 35 years after the launch from Cape Canaveral in 1977. It is now at 145 AU from the Sun with a speed of 17 km/s. The New Horizons spacecraft was launched in 2006, 30 years after Voyager 1. New Horizons has been built with far more advanced technology than Voyager 1, however its present speed is even lower than Voyager 1’s speed, “just” 14 km/s. It is clear that a real breakthrough propulsion technology is needed in order to enable reasonable interstellar precursor missions (>> 200 AU). The Thousand Astronomical Unit (TAU) mission was an interstellar precursor mission concept, studied by JPL scientists in the late 1980s, which could have reached 1000 AU within a 50-year trip time. The challenging ΔV needed (> 100 km/s) could be achieved with a nuclear electric propulsion system including a nuclear fission reactor in the 1-MWe class with a specific mass of 12.5 kg/kWe and advanced ion thrusters with a specific impulse of 12,500 s. While The NASA’s HiPEP ion thruster has demonstrated a specific impulse of ~ 10,000 s, the needed lightweight nuclear reactor still exists only on paper. This paper proposes an advanced propulsion concept for challenging interstellar precursor missions, Laser powered Electric Propulsion (LEP). A high-power laser beam is aimed at a lightweight photovoltaic (PV) collector on the target spacecraft, where it is converted to electric power for an ultra-high specific impulse EP system. The PV collector/converter on the spacecraft can be tuned to the laser wavelength, thus achieving high monochromatic conversion efficiencies, currently ~50% with the potential to reach 70% in the near future. The TAU mission could greatly profit from the LEP concept. Instead of a heavyweight nuclear reactor we could have a monochromatic PV collector with 50% conversion efficiency and a specific mass of just 1 kg/kWe; such a lightweight power source could pave the way to challenging missions beyond the heliopause like FOCAL and the exploration of the Oort Cloud, with travel times well within a scientist career lifetime

References:

Ryan Weed, Positron Dynamics, USA

Ryan Weed has a BA from Wesleyan University, a BS in Engineering and Applied Physics from Columbia University in the City of New York and a PhD in Antimatter Physics from the Australian National University. He previously worked as an Engineer for Team Frednet GLXP on Thermal and Structures system design, propulsion and other areas. His work with the Center for Antimatter-matter studies at the Australia National University was to develop variable energy pulsed positron beamline using neon moderator and surko buffer gas trap. He has also worked as an Instrumentation and Controls Engineer for Blue Origin on designing an instrumentation laboratory for cryogenic fuels and sensors. In 2011 he was the founder of Positron Dynamics in California, and is developing positron technology for advanced propulsion and non-destructive testing of critical components in aerospace and defense sectors. He is also a pilot in the United States Air Force.

“Antielectron Propulsion”

Abstract: The primary challenge of an antimatter propulsion system is conversion of the annihilation products into propulsive force. Early concepts relied on reflection of annihilation gamma rays to produce thrust at the theoretical maximum specific impulse (3x10^7 secs). Unfortunately, fundamental properties of high energy photon scattering limit the feasibility of gamma ray reflection. The next generation of antimatter propulsion concepts relied on exhausting propellent heated by absorption of annihilation photons or the catalysis of fission or fusion reactions. The utilization of ‘on-board’ regenerated radioisotope sources of antimatter has also been suggested to eliminate the trapping challenges. While these hybrid approaches lower the amount of antimatter required to produce meaningful propulsive force, their specific impulse is limited by the velocity of the nuclear fission or fusion reaction products (<10^6 secs). Here, we present a possible mechanism for producing thrust at the maximum specific impulse using non-reflected annihilation gamma rays, while also utilizing the benefits of hybrid antimatter/nuclear fuel cycle to regenerate radioisotope, thus eliminating the trapping difficulties that are typical of antimatter propulsion systems.

References:

Born and raised in Cape Town, South Africa, James Schalkwyk’s professional interest in interstellar travel began in 2011 with DARPA’s 100-Year Starship program, which focussed on how to encourage private investment in interstellar space travel, and where he became interested in how governments and the private sector work together to achieve technological and social breakthroughs. After DARPA, he joined NASA’s Ames Research Center where he worked variously in the Communications and New Ventures Directorate, the NewSpace-focused “Space Portal” and in the Strategic Partnerships Division. During this time, his work ran the gamut, ranging from SmallSats to low-cost lunar settlements, and from policy and government relations to off-Earth resource extraction. After completing a graduate degree in Public Administration at Columbia University in 2018 he joined the Breakthrough Initiatives to help manage the growing Starshot program, bringing him back into the business of building starships.

“The Scale of an Interstellar Mission: Microphotonics to Megastructures”

Abstract: The scale of the mission architecture of Breakthrough Starshot spans an extraordinary range: from the ultralight Sailcraft weighing in at a single gram to the Photon Engine, a laser array that will cover an area several kilometers across. But even within these structures there is a marriage of the large and the small. An 6m² sail may stably ride a 100GW laser thanks to subwavelength-scale textures built into the material; the photon engine itself is not a gargantuan single laser feeding a 2.8 km diameter collimator but rather an array of perhaps millions of individual collimators. This talk will examine the Starshot components from small to large and show how the design of the largest structures are informed by individual, modular components. Further, it will begin to explore how such structures might actually be built, powered, and operated in the coming decades with an eye to both the technical requirements and geopolitical realities.

References:

Richard Osborne, StellarDyne, UK

Richard Osborne is Programme Manager for the Skyrora Private Launch Company, as well as an independent launch vehicle and strategic foresight consultant. He is the I4IS Director of Technology and Strategic Foresight, chaired the Technical Committee of the British Interplanetary Society (BIS), chaired the UK Rocketry Association (UKRA) Safety and Technical Committee, and has served on the BIS Council for 11 years, and previously UKRA Council for 13 years. He has a B.Sc(Hons) in Physics, M.Sc in Remote Sensing and Planetary Physics, studied for a PhD in Solar Astrophysics, and is a Chartered Physicist and Fellow of both the Royal Astronomical Society and the BIS. He previously worked for companies including Reaction Engines, Airborne Engineering and Commercial Space Technologies for whom he produced spaceport studies for the British National Space Centre and UK Space Agency, as well as providing consultancy for 3 of the UK spaceport bids. He was also engaged in systems engineering and science consultancy for space projects including an ESA payload to the Mir space station, Cubesats, picosats, to NASA and Russian Mars missions. He specialises in launcher technology, rocket propulsion, planetary landers, technological and strategic forecasting, including developing technological and strategic roadmaps for spaceflight and associated technologies, and long range forecasts for clients including the British Government’s Cabinet Office and Department of Business.

“The Use of Near-Term Launch Systems for Developing A Stanford Torus”

Abstract: Abstract Large scale astroengineering is widely seen as being a very long term proposition for humanity, due to the advances in technology required and the sheer cost. This paper seeks to show that rather than advances in technology or cost preventing development, to some extent, it is failure of imagination and belief in humanity’s current capabilities that is holding back the start of large scale astroengineering. Using the currently under development SpaceX BFR and Blue Origin New Glenn as baseline launch systems, it is shown that with the breakthrough of reuseable first stages, the ability to build a modest astroengineered structure, the Stanford Torus design, is possible, and would enable duplication of the astroengineered structure at other locations within the solar system. This would then leverage a faster build-out to scale of space infrastructure, which in turn would help enable the more timely construction of true astroengineering structures on a much larger scale, such as Bishop Rings, Orbitals and Ring Worlds.

References:

**Remo Garattini**, Bergamo University, Italy

Remo completed his first degree in Theoretical Physics at the University of Milan and later completed his PhD at the Mons-Hainaut University in Belgium with a thesis on Space Time Foam with Professor P Spindel and R Brout as supervisors. He has a permanent research position at the University of Bergamo, Faculty of Engineering. His research activities are in Quantum Gravity and Quantum Cosmology (Inflation, Dark Energy, Space Time Foam) and the Casimir effect. He is editor in chief for Astrophysics and Cosmology of the MDPI Journal “Entropy” (www.mdpi.com/journal/entropy)and Guest Editor for Galaxies and Quantum Reports of MDPI - which delivers scholarly open access publishing (www.mdpi.com/about). In April 2017, Remo was qualified by the Italian Abilitazione Scientifica Nazionale (ASN - rio.jrc.ec.europa.eu/en/library/national-scientificqualification-asn) to be Associate and Full Professor in Theoretical Physics.

“**Casimir Traversable Wormholes**”

**Abstract:** After a brief description of what is a traversable wormhole we describe the connection between traversability and the Casimir effect. With the help of an equation of state we also discuss different form of solutions generated by the Casimir source. A connection with the Quantum Weak Energy Condition is also presented.

**References:**

Francisco Lobo, Institute of Astrophysics and Space Sciences, University of Lisbon, Portugal

Francisco S. N. Lobo is a Principal Investigator at the Institute of Astrophysics and Space Sciences (IA) of the Science Faculty of the University of Lisbon, and has previously led the Cosmology Group at the IA. His research is focused on gravitational physics, and several of his publications have received extensive news coverage from publications including the New York Times, Scientific American, and National Geographic. His impact factor, h, in the scientific community is presently 52. To the present date, he has published two books and over 170 articles in high-impact international research journals and conference proceedings.

“Wormholes, Warp Drives and Interstellar Travel”

Abstract: We consider the possibility of multiply-connected spacetimes, ranging from the Flamm-Einstein-Rosen bridge, geons, and the modern renaissance of traversable wormholes. A fundamental property in wormhole physics is the flaring-out condition of the throat, which through the Einstein field equation entails the violation of the null energy condition. In the context of modified theories of gravity, it has also been shown that the normal matter can be imposed to satisfy the energy conditions, and it is the higher order curvature terms, interpreted as a gravitational fluid, that sustain these non-standard wormhole geometries, fundamentally different from their counterparts in general relativity. We explore interesting features of these geometries, in particular, the physical properties and characteristics of these ‘exotic spacetimes’.

References:

Al Jackson, Triton Systems, USA

Albert Allen Jackson IV was born in Dallas, Texas, October 1940. Grew up in Dallas but graduated from high school at Texas Military Institute in San Antonio in 1959. Received my Bachelor and Master in Mathematics and Physics from University of North Texas in Denton Texas, 1965. Entered the US civil service with NASA in January of 1966 as a crew training instructor on the Gemini Crew Trainer, worked on a simulator for the Lunar Landing Training Vehicle and then became full time Apollo crew trainer on the Lunar Module Simulator, subsystem the Abort Guidance System until late 1970. I took up graduate work in physics in late 1970 gaining my Ph.D. in physics in Jan 1975 from the Relativity Center at the University of Texas at Austin. I returned to the Johnson Space Center 1975 working for MacDonnell Douglas, Computer Science Corporation and Lockheed-Martin developing flight planning software, Orbital Debris modeling and finally engineering simulation. I retired in 2010. Independent research and publication in interstellar flight and SETI. I was a Visiting scientist at the Lunar Planetary Institute for 30 years. I am now at Triton Systems LLC in Houston.

“Neutrino Beacons for Interstellar Communications”

Abstract: Observational SETI has concentrated on using electromagnetism as the carrier, namely radio waves and laser radiation. Michael Hippke [1] has pointed out that it may be possible to use neutrinos or gravitational waves as signals. Gravitational waves demand the command of the generation of very large scale amounts of energy, Jackson and Benford [2]. This paper describes a beacon that uses beamed neutrinos as the signal. Neutrinos, like gravitational waves, have the advantage of extremely low extinction in the interstellar medium. To make use of neutrinos an advanced civilization can use a gravitational lens as a focus and amplifier. The lens can be a neutron star or a black hole. Using wave optics one can calculate the advantage of gravitational lensing for amplification of a beam and along the optical axis it is exceptionally large. Even though the amplification is very large the diameter of the beam is quite small, less that a centimeter. This implies that a large constellation of neutrino transmitters would have to enclose the local neutron star or black hole. This implies that such a beacon would have to be built by a Kardashev Type II civilization.

References:

Dr. Greg Matloff is a leading expert in possibilities for interstellar propulsion, especially near-Sun solar-sail trajectories that might ultimately enable interstellar travel, and is a tenured astronomy professor with the physics department of New York City College of Technology, CUNY, a consultant with NASA Marshall Space Flight Center, a Hayden Associate of the American Museum of Natural History and a Corresponding Member of the International Academy of Astronautics. He co-authored with Les Johnson of NASA and C Bangs Paradise Regained (2009), Living Off the Land in Space (2007) and has authored Deep-Space Probes (edition 1: 2000 and edition 2: 2005). As well as authoring More Telescope Power (2002), Telescope Power (1993), The Urban Astronomer (1991), he co-authored with Eugene Mallove The Starflight Handbook. (1989). His papers on interstellar travel, the search for extraterrestrial artifacts, and methods of protecting Earth from asteroid impacts have been published in JBIS, Acta Astronautica, Spaceflight, Space Technology, Journal of Astronautical Sciences, and Mercury. His popular articles have appeared in many publications, including Analog and IEEE Spectrum. In 1998, he won a $5000 prize in the international essay contest on ETI sponsored by the National Institute for Discovery Science. He served on a November 2007 panel organized by Seed magazine to brief Congressional staff on the possibilities of a sustainable, meaningful space program. He currently serves as an Advisor to Yuri Milner’s Breakthrough Initiative Project Starshot and directs the Science Board for the Institute for Interstellar Studies. Professor Matloff is a Fellow of the British Interplanetary Society and a Member of the International Academy of Astronautics and a Fellow of the Explorers Club. He has chaired many technical sessions and is listed in numerous volumes of Who’s Who. In 2008, he was honored as Scholar on Campus at New York City College of Technology. His most recent book, co-authored with Italian researcher Dr. Giovanni Vulpetti and Les Johnson, is Solar Sails: A Novel Approach to Interplanetary Travel, Springer (2008). In addition to his interstellar-travel research, he has contributed to SETI (the Search for Extraterrestrial Intelligence), modeling studies of human effects on Earth’s atmosphere, interplanetary exploration concept analysis, alternative energy, in-space navigation, and the search for extrasolar planets. His website is www.gregmatloff.com

“Is the Kuiper Belt Inhabited?”

Abstract: The Sun’s Kuiper Belt (located about 30–50 Astronomical Units from the Sun) is a volatile-rich region containing very many objects in the ~10–20 km size range. An expedition to our solar system would encounter this region before it reached the Sun’s habitable zone. It has been speculated that alien space habitats in this region could be detected by infrared or visible light transmissions. Recent data from the Gaia space observatory reveals that our solar system is approached very closely by Sun-like stars at intervals of ~ one million years. Properly timed expeditions to Sol might be less time consuming than commonly believed. It is argued here that the probability of our outer solar system being colonized during the distant past is not small. Even if alien space habitats no longer exist, artifacts of failed or abandoned colonization attempts might be discovered. Recent exploration of the Kuiper Belt has revealed fascinating anomalies. It is not impossible that humans are not the first technological terrestrial civilization. Evidence for such a possibility might also be searched for among small Kuiper Belt Objects.

References:

List of Non-Speaker Poster Presentations

C Bangs (and Greg Matloff), Central Booking NYC Art Space, & New York City College of Technology, CUNY , USA

C Bangs is a professional artist whose work has been exhibited throughout the United States and in Europe, South America, and Australia. Her art is included in the permanent collections at the Brooklyn Museum, MoMA’s library collection, Library of Congress, New York City College of Technology, NASA Marshall Space Flight Center, Chrysler Museum (Norfolk, Virginia), the Mint Museum (Charlotte, North Carolina), and the Natural History Museum and the Panterra Contrade Museum (both in Siena, Italy). A 2017-2019 artist residency recipient at the New York Academy of Medicine and Brooklyn Botanical Garden with CENTRAL BOOKING Art Space her work is included in several group exhibitions at these and related locations. Artist’s books include Biosphere Extension: Solar System Resources for the Earth, Star Bright? and Decade and a half Dialogue. Her art is included as chapter frontispieces for Paradise Regained, Living Off the Land in Space, Deep-Space Probes 2nd ed., More Telescope Power, Telescope Power, The Urban Astronomer and The Starflight Handbook, coauthored or authored by Gregory Matloff. Her work has also been included in exobiology issues of the Journal of the British Interplanetary Society (a modified version of the “man and woman” Pioneer 10/11 plaque), MotherBoard, Zenit and in Analog, Science Fiction and Fact. She served as a NASA Marshall Space Flight Center summer Faculty Fellow from 2002-2004, and worked under a NASA grant in 2001 to create a holographic prototype interstellar message plaque. BFA (University of the Arts, 1970), MFA (Pratt Institute, 1975) and a Jerome Fellowship to Bob Blackburn’s Printmaking Workshop (1982). She has contributed chapter frontispiece art to two recent books by Gregory Matloff. Starlight, Starbright: Are Stars Conscious? (Curtis Press, 2015) and Stellar Engineering (Curtis Press, 2019.) Her website is www.cbangs.com

“Potential Application of Holographic Photon Sails to Project Starshot Interstellar Probes”

Abstract: Project Starshot, conducted by Yuri Milner’s Breakthrough Initiative, seeks to develop the technology capable of projecting wafer-thin ~1-gram sailcraft at solar-system exit velocities approximating 0.2c. Boosted by a ~50 GW terrestrial laser, the sail must sustain ~5,000g accelerations for minutes and remain within the beam over a distance of ~10 million km. A holographic image of a highly reflecting optical filter embossed on a metamaterial base, shaped to remain stable within the moving beam is a possible approach. Author Bangs, in collaboration with Martina Mongrovius of the Holocenter, is creating holograms that are scheduled to fly on a CubeSat under development by Mason Peck at Cornell University to test some of these concepts in the near future. The history of holographic sail concepts is also reviewed in this paper.
**Kelvin F Long**, Interstellar Research Centre, Stellar Engines Ltd, UK

(1) “*The Apkallu Initiative: A Minilithic Artefact in the Event of Global Cataclysm, Interstellar Research Centre.*”

**Abstract:** The Apkallu Initiative is a project to consider how to plan for long-term survival of the human race through knowledge preservation so that in the event of global cataclysm human kind can once again get started. The concept takes its inspiration through historical ancient megalithic archaeological sites which are also encoded with knowledge and sacred geometry. The name Apkallu originates from the sages of wisdom that taught knowledge to man according to the mythological stories of ancient Sumerian. This project is dedicated to all those geologists, historians, archaeologists, linguists and anthropologists that uncover our past; all those writers, architects, diplomats and peacemakers that create the conditions of harmony in the present; and all those technologists, futurists, space explorers that plan for a prosperous human future in all the domains of reality upon which our spirits may become embodied. The goals of the information content imprinted onto the artefact: Goal 1: The continued survival of the human species at peace. Goal 2: The accelerated technological, social-cultural growth of human civilization from an assumed stagnated level. Goal 3: The preservation of knowledge, moral and ethical philosophy.

**References:**

(2) “*The Interstellar Research Centre*”

**Abstract:** The Interstellar Research Centre is an entity that has been set up to consider some of the deepest questions of human existence in the Cosmos. A part of its scope of interest includes the potential of sending spacecraft over interstellar distances, but also finding intelligent life. In this poster we set out the key research questions that the research center is focused on and explain how they tie together. The Centre is a division of Stellar Engines Ltd, an aerospace consultancy company that has been operating in the UK since 2011.

**References:**
John Kokkalis, McGill University, Quebec, Canada.

John Kokkalis is an Honours Undergraduate Mechanical Engineering Student at McGill University. As a child, he always had an interest in space exploration and hoped one day to pursue an education in that domain. To enrich his knowledge within the field, he has completed multiple astrophysics courses and has spent an ample amount of time reading scientific literature and hopes to attend multiple conferences around the world. His current area of research involves analyzing the plausibility of laser ablation of interplanetary media during the acceleration phase of a laser-driven spacecraft.

“Laser-Ablation of Interplanetary Media During the Acceleration Phase for Laser-Driven Interstellar Travel”

Abstract: In the context of laser-driven interstellar travel, the inevitable impact of dust grains from the interplanetary media on the lightsail is considered. These impacts may cause the low absorptivity of the sail to be compromised, allowing a large amount of laser flux to be absorbed and resulting in the vaporization of the sail. Thus, the potential use of the laser in order to provide laser-ablation of the dust grains prior to impact during the acceleration phase could be highly advantageous and warrants further investigation. The spatial intensity beam profile of the main 100 GW-class phased-array laser will be modeled as a coherent Gaussian beam, focused onto a 1 m by 1 m lightsail. The problem will be bounded by comparing a fully transparent sail vs a fully reflective sail. Assuming idealized conditions, the diffraction profile of the reflective sail will describe the geometry and intensity of the laser light interacting with the dust grains. In the second case, a single transparent dielectric layer is considered, permitting the main drive laser to directly interact with the dust ahead of the sail. The laser-dust particle interaction of both sail types will be treated via accepted models of continuous laser-driven ablation. Analyzing the ablation times of a perfect spherical 1 μm graphite and silicon dioxide grains will provide two representative materials, with graphite representing the greatest enthalpy of vaporization of known materials in the interplanetary dust medium. Differences presented in the laser-ablation time of both sail types will be examined and compared. The possibility of shielding of the grain due to plasma cloud formation during the ablation process will also be examined. The analysis of these factors could provide a preliminary assessment of the feasibility of laser ablation of dust grains during the acceleration phase of the lightsail.

References:


Navneet Kaur, McGill University, Quebec, Canada.

Navneet Kaur is an undergraduate student at McGill University pursuing a Joint Honors degree in Physics and Math with a Computer Science Minor. She is currently working on investigating the stability of a thin laser powered light-sail using Photonic Doppler Velocimetry. This technique provides a strong foundation for an accurate and detailed study of the dynamics of the sail, which can be implemented in laser driven interstellar space travel. She has also previously worked on encrypting radio frequencies. Her passion for Physics is also heavily weighted on quantum mechanics and she hopes to make a significant contribution to the field one day. When not working on a physics problem she usually finds herself still playing with light on a long walk with her camera capturing and contemplating the complexities of human behavior.

“Investigating the Stability of a Thin Laser Powered Lightsail using Doppler Velocimetry”

Abstract: The revolution in photonic measuring technologies has led to the development of impressive systems permitting the evaluation of absolute position and velocity to extreme precision. Photonic Doppler Velocimetry (PDV) is a technique that blends Doppler-shifted light with non-Doppler-shifted light, resulting in beat frequencies, which can be used to analyze transverse surface velocities in thin materials. In the context of laser-driven interstellar space travel, the use of PDV to provide a means for an accurate and detailed study of the stability of candidate lightsail materials is considered. The effect of photonic pressure onto a lightsail in a vacuum will be modeled by differences in gas pressure within an experimental setup consisting of a shock tube, where the lightsail material will be subjected to shock waves. A high-power and a low-power laser of different frequencies will form a heterodyning setup, making the observation of interference fringes for a sail during moving and stationary phases possible. The laser beam incident to the sail will be split into four distinct channels, allowing for the measurement of surface velocities at different points on the target. The experiment will be replicated with several materials, including thin metal foils and glass, with varying thicknesses down to 200 nm. Different optical elements will be introduced in the setup as a means to modify the spot size of the incident laser beams. Changes in the shock pressure and their effect on the response of the materials will also be studied. The collected data will consist of two arrays describing velocity time and voltage, which will then be processed in the frequency space using Fast Fourier Transform (FFT) analysis. The obtained results will allow for the comparison of different velocity distributions for each experiment, contributing to the modeling of the response of different materials to shock loading.

Keywords: Laser powered lightsail

References:

Andreas Hein, Initiative for Interstellar Studies, UK

Andreas received his master’s degree in aerospace engineering at the Technical University of Munich. He obtained a PhD at the same university in the area of space systems engineering, focusing on the application of heritage technologies to space systems, doing part of his research at the Massachusetts Institute of Technology (MIT) System Architecture Lab. He also worked at the European Space Agency Strategy and Architecture Office on stakeholder analysis for future manned space exploration. Andreas has published over 30 articles on interstellar travel in peer-reviewed international journals and conferences. He is a member of the International Honor Society for Systems Engineering – Omega Alpha Association, a Fellow of the British Interplanetary Society, and a member of INCOSE. He is the current Executive Director of the Initiative for Interstellar Studies.

(1) “Project Lyra: Near-term Exploration of Interstellar Material Via Interstellar Asteroids”

Abstract: The first definitely interstellar object 1I/’Oumuamua (previously A/2017 U1) observed in our solar system provides the opportunity to directly study material from another star system. Can such objects be intercepted? The challenge of reaching the object within a reasonable timeframe is formidable due to its high heliocentric hyperbolic excess velocity of about 26 km/s; much faster than any vehicle yet launched. This poster presents the results of potential near-term options for a mission to 1I/’Oumuamua and potential similar objects. We identify a trajectory to 1I/’Oumuamua with a launch date in 2033, a total velocity increment of 18.2 km/s, and arrival at 1I/’Oumuamua in 2048. With an additional deep space maneuver before the powered Jupiter flyby, a trajectory with a launch date in 2030, a total velocity increment of 15.3 km/s, and an arrival at 1I/’Oumuamua in 2052 were identified. Both launch dates would provide over a decade for spacecraft development, in contrast to the previously identified 2020-2021 launch dates. Furthermore, the distance from the Sun at the Oberth burn is at 5 Solar radii. This results in heat flux values, which are of the same order of magnitude as for the Parker Solar Probe. Further technology options are outlined, ranging from electric propulsion, and more advanced options such as laser electric propulsion, solar and laser sails. To maximize science return, decelerating the spacecraft at ’Oumuamua is highly desirable, compared to the minimal science return from a flyby. Electric and magnetic sails could be used for this purpose. It is concluded that although reaching the object is challenging, there seem to be feasible options based on current and near-term technology.

References:

“Project Glowworm: First Steps Towards an On-Orbit Verification of Laser Sail Propulsion”

Abstract: The currently most realistic interstellar mission concept is based on the use of a massive ground-based laser infrastructure, pushing a gram-sized laser sail spacecraft. One of the prerequisites for such a mission is the successful on-orbit verification of a prototype of the spacecraft and laser infrastructure. Project Glowworm aims at increasing the maturity of a laser sail-based interstellar mission by developing and testing gram-sized spacecraft on-orbit and elements of the laser infrastructure. As a first step, we have studied prototype mission concepts for testing laser sail propulsion in space, ground-based laser sail testing, and have started developing gram-sized spacecraft, so-called ChipSats for in-space testing. This poster provides an overview of these activities that are currently being conducted within the Initiative for Interstellar Studies (i4is).

References:

“Artificial Intelligence for Interstellar Travel”

Abstract: The large distances involved in interstellar travel require a high degree of spacecraft autonomy, realized by artificial intelligence. The breadth of tasks artificial intelligence could perform on such spacecraft involves maintenance, data collection, designing and constructing an infrastructure using in-situ resources. Despite its importance, existing publications on artificial intelligence and interstellar travel are limited to cursory descriptions where little detail is given about the nature of the artificial intelligence. This article explores the role of artificial intelligence for interstellar travel by compiling use cases, exploring capabilities, and proposing typologies, system and mission architectures. Estimations for the required intelligence level for specific types of interstellar probes are given, along with potential system and mission architectures, covering those proposed in the literature but also presenting novel ones. Finally, a generic design for interstellar probes with an AI payload is proposed. Given current levels of increase in computational power, a spacecraft with a similar computational power as the human brain would have a mass from dozens to hundreds of tons in a 2050-2060 timeframe. Given that the advent of the first interstellar missions and artificial general intelligence are estimated to be by the mid-21st century, a more in-depth exploration of the relationship between the two should be attempted, focusing on neglected areas such as protecting the artificial intelligence payload from radiation in interstellar space and the role of artificial intelligence in self-replication.

References:
Patrick Mahon, Initiative for Interstellar Studies, UK

Patrick Mahon completed a BSc in Maths and Physics in 1990 and an MSc in Environmental Decision Making in 2006, and in between studied for a PhD in Theoretical Physics, specialising in condensed matter physics. He has worked in the civil service and for a trade association and now works for a national charity focused on environmental sustainability. He is a Member of the British Interplanetary Society, and on the Board of the Initiative for Interstellar Studies, as well as the Deputy Editor of its magazine, *Principium*.

“Worldships - Some Ecological and Resource Constraint”

**Abstract text:** We consider some of the ecological and resource considerations that are relevant to the design and operation of a worldship intended to travel to interstellar destinations over journey durations longer than a century. We identify several of the resource challenges that are likely to arise during the journey, including the dissipation of critical raw materials, and explore a number of potential strategies for addressing these problems. We conclude with some recommendations for areas requiring further study.

**References:**

John Davies, Initiative for Interstellar Studies, UK

John is a lifelong engineer who has been fascinated by space travel ever since he read the Dan Dare stories in the Eagle in the 50s. He studied Electronics at Liverpool University. He joined Hawker Siddeley Dynamics Space Projects Division in 1968 and worked on the latter stages of the most substantial launch vehicle ever built in UK, Bluestreak. He also worked on satellite projects including a design study for a large space telescope which acquired the name Hubble about 12 years later. He was fascinated by digital technology and moved to Edinburgh University where he wrote some very early communications software. He took a year off to study Computer Science more formally at Manchester University, taking his M.Sc. back to Edinburgh before moving on to London University doing similar work. He re-joined the commercial sector as a consultant and in technical sales support. He was involved in the early stages of SMS messaging and in packet radio long before we all started using it, as GPRS, for our smartphones. His last full-time job was running the IT volunteering programme for the Information Technologists livery company of the City of London. He’s now retired but busier than ever with educational outreach to schools for the Initiative for Interstellar Studies, coordinating work on i4is website and email including the membership scheme, and editing Principium, the quarterly newsletter of the Initiative for Interstellar Studies.
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This meeting was mainly supported and sponsored by Stellar Engines Ltd and the Interstellar Research Centre, with contributions from Terra Altair Ltd, The Initiative for Interstellar Studies, The British Interplanetary Society and Space Excess.