BPSC Workshop – Session 1: Welcome and Introduction

Conference Room at Space Park Leicester

Tuesday 18th June 10:00 – 11:00

How to get your instrument selected and into space

Sue Horne

Key Points: Tips on getting your exciting idea for a new space instrument into a reality, covering politics, finances and partnerships.

This presentation provides the perspective of the retired Head of Space Exploration on progressing an idea, through selection to eventual operations. Concentrating on navigating your way through international politics, UK finances and what to look for when developing partnerships.

An introduction to space projects: Case study on BepiColombo MIXS

Adrian Martindale (University of Leicester)

I will describe the structure of space projects in the European system, using examples from the development of the BepiColombo Mercury Imaging X-ray spectrometer (MIXS). It is intended to give new scientists and engineers who are entering the space industry some insight into how projects are structured, managed and reviewed in the ESA system. I will describe the phasing of projects, the review sequence and the objectives of each phase and I will discuss how things often change and become more complicated in real projects.

BPSC Workshop – Session 2

Conference Room at Space Park Leicester

Tuesday 18th June 11:30 – 13:00

Accelerating space system development through the application of space 4.0 technologies

Piyal Samara-Ratna (University of Leicester)

Piyal is the Principal Engineer for the Manufacturing, Engineering, Technology, Earth Observation, Research (METEOR) centre at Space Park Leicester. He is a Chartered Mechanical Engineer with an MEng in Mechanical Engineering from UCL and over 17 years experience working in the space sector. He is a senior mechanical engineer for the James Webb Space Telescope Mid-Infrared instrument, with a leading role within the instrument systems team, leading instrument assembly and integration activities at NASA. He has also worked on numerous projects spanning deep space exploration, planetary exploration, space nuclear power and Earth observation. He is interested in technology transfer and has achieved particular success with medical device development. His current role is focused on accelerating space system development through the application of space 4.0 technologies including digital twins, concurrent design, model based systems engineering, artificial intelligence, automation and advanced modelling.

The Double Walled Isolator, A Modern Approach to Mars Sample Containment.

John Holt (University of Leicester)

A key challenge for a Mars Sample Return mission is to develop technologies that enable the safe handling, movement (transfer), analysis and curation of Planetary Protection Category V, restricted samples. While it is expected that a dedicated Sample Receiving Facility (SRF) will offer BSL-4 type containment, contamination control processes need to be in place to protect the scientific integrity of precious samples such that they are not compromised by our terrestrial environment. Unlike typical primary barrier technologies and industry specific isolators (e.g. pharmaceutical or Class III bio-safety cabinets), the planetary science community requires containment and ultra-cleanliness, along with analytical capability inside the cabinet. The Double Walled Isolator (DWI) is a unique multi-barrier solution to the problem where a negative pressure inert gas working environment utilises a “double wall” feature and a positive pressure interstitial volume to meet these fundamental requirements.

BPSC Workshop – Session 3

Conference Room at Space Park Leicester

Tuesday 18th June 14:00 – 15:35

SNUG: A Self-Reconfigurable Undulating Grasper for Asteroid Mining

Mini Rai (University of Lincoln)

Co-authors: Suzanna Lucarotti (University of Surrey), Simon Hadfield (University of Surrey)

Key points: Asteroid mining, Robotics

Rapid advances in In-Situ Resource Utilisation are crucial for cost-effective and long-term scientific exploration of the solar system. A key enabling feature for this is mining raw materials off-Earth, but previous research has focussed on low-gravity regolith mining, primarily on the Moon. This conventional mining technique is suitable for very large asteroids and minor planets and relies on lower gravity Earth analogue methods to manipulate fine regolith. Recent missions to asteroids have shown that many have rubble surfaces, which current extra-terrestrial mining techniques are unsuited for. In this talk, Prof. Rai will present a new generation of bio-inspired asteroid mining robots - the Self ReconNfigurable Undulating Grasper (SNUG) - capable of the helical caging and grasping of surface rocks. This novel concept exploits rotational symmetry and homogeneity to form a cage to grasp a target of uncertain properties safely. This talk will cover the design engineering of this modular space robot and its distinct mobility in low-gravity Eenvironments.

Updates on the development of European Radioisotope Power systems: Radioisotope Thermeoelctric Generators (RTGs) and Radioisotope heater Units RHUs

Emily Jane Watkinson (University of Leicester)

Co-authors: Richard Ambrosi (UL, SPL, UK), Ramy Mesalam (UL), Alessandra Barco (UL), Hannah Sargeant (UL), Christopher Bicknell (UL), Tony Crawford (UL), Gareth Bustin (UL) and Duncan Ross (UL)

Key points: University of Leicester are developing Radioisotope Thermoelectric Generators and Radioisotope Heater units for the European Space Agency. This presentation will provide updates to the community on their development.

Radioisotope power systems enable the exploration of dark, distant and cold locations of the solar system that are not possible with solar array based electrical power systems e.g. far locations in the solar system or in cratered regions. They can also enable greater flexibility of operations. They utilise the heat generated from a radioisotope. Radioisotope Thermoelectric Generators (RTGs) convert this heat into electrical power. Radioisotope Heater units (RHUs) can be used for thermal control. The University of Leicester have been developing radioisotope power systems, namely, RTGs, RHUs and a large heat source known as the European Large Heat source (ELHS) for the European Space Agency since 2010. These utilise 241Am as the radioisotope that has a 432 year half-life. This presentation will provide updates to the community on their development.

Thermal Design and Performance of the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission the Soft X-ray Imager (SXI)

Yasir Soobiah and Andy Cheney (University of Leicester)

Co-authors: Dr Steve Sembay, Dr Jenny Carter

SMILE is a joint European Space Agency (ESA) and Chinese Academy of Sciences (CAS) mission due for launch 2025. The SMILE payload consists of the SXI and Ultraviolet Imager (UVI) and two in-situ instruments, the Light Ion Analyser (LIA) and Magnetometer (MAG). SMILE will build a more complete understanding of the Sun-Earth connection by X-ray imaging of the Earth's magnetosheath and cusps, to measure the solar wind and its dynamic interaction with the magnetosphere.
The SXI is a UK-led instrument (PI: S. Sembay, University of Leicester), with contributions from a Europe-wide consortium. The SXI and its application in the mission concept has benefited from novel technologies adapted for the detection of X-rays in space.
The capabilities of the SXI, its role in the mission, and key challenges in thermal design and performance will be presented.

BPSC Workshop – Posters

Main atrium, Space Park Leicester

Tuesday 18th June 15:35 – 17:00

Surface Enhanced Raman Spectroscopy for Detection of Trace Biosignatures

Donald Bowden (University of Southampton)

Co-author: Hanna Sykulksa-Lawrence (University of Southampton)

Key points: We present possible designs for a SERS substrate for use in space missions by activation of a silver chloride substrate in-situ.

Raman spectroscopy has been adopted as a tool for investigating planetary materials, with deployment of the Mars 2020 SuperCam and SHERLOC instruments, and development of the ExoMars Raman Laser Spectrometer. These instruments can distinguish between mineral species and may be able to detect bulk quantities of organic matter in the Martian regolith. However, potential organic content in the Martian regolith has been predicted to be on the order of 1 ppm [1], below the detection limits of such instruments.

Surface enhanced Raman spectroscopy (SERS) has the potential to greatly improve these detection limits. SERS exploits the interaction between the analyte molecule, incoming laser radiation, and an electrically conductive surface. Ag surfaces provide high levels of enhancement, but practical deployment is limited by the effective lifespan of such surfaces which are subject to tarnishing[2].

We investigate possible designs for a SERS substrate for use in space missions, utilising AgCl to avoid tarnishing of silver. AgCl can be activated using the same laser wavelength as used for Raman spectroscopy (e.g. 532nm), producing silver nanoparticle surfaces [3].

We present preliminary development of AgCl substrates, including coated nanopillar structures, which may help to produce the required SERS enhancement under laser radiation. The substrate geometries are characterised using scanning electron microscopy, and their SERS enhancement is verified and analysed using probe biosignature molecules.

1. McKay, C.P., et al., Astrobiology, 2013. 13(4): p. 334-353.

2. Matikainen, A., et al., Scientific reports, 2016. 6(1): p. 37192.
3. Matikainen, A., et al., Scientific Reports, 2015. 5(1): p. 8320.

An early X-ray instrument concept for in-situ Jovian observations

Natasha Carr (University of Leicester)

Co-authors: C. H. Feldman (UOL, UK), S. T. Lindsay (UOL, UK), A. Martindale (UOL, UK)

Key points: We present an early concept of an X-ray instrument for a Jovian mission, with applications for other outer planets. This concept draws on the extensive heritage of lobster eye telescopes developed at the University of Leicester.

ESA's Voyage 2050 and NASA's Planetary Decadal Survey 2023-2032, include an emphasis on outer planetary missions; particularly on the Jovian system. Science objectives include measuring the surface compositions of the Galilean moons and their interactions with the Jovian magnetosphere. An X-ray telescope could address both objectives.

X-ray spectrometers have been used to study the Moon and Mercury, but have not been deployed to an outer planet system. As such, the processes driving X-ray emission in these systems are largely unexplored. X-ray emission from processes including particle interactions with the Jovian moons has already been observed from Earth orbit, but our knowledge would be vastly improved by an in-situ X-ray instrument. This study aims to specify the fundamental scientific objectives to derive an instrument specification suitable for X-ray observations in the Jovian system. These include measuring surface composition, the intensity and dynamics of the charged particle environment, and the processes relating them.

The recent development of Micro Pore Optics in lobster eye arrangements, has enabled the creation of smaller, lighter X-ray telescopes with wider fields-of-view. An instrument similar to BepiColombo MIXS or SMILE SXI could perform in-situ X-ray observations within the outer planetary systems allowing science observations that have not been possible with the high mass of traditional X-ray telescopes or from Earth orbit.

We present an early concept of an X-ray instrument for a Jovian mission, with applications for other outer planets. This concept draws on the extensive heritage of lobster eye telescopes developed at the University of Leicester.

The case for a meteor counter at Venus

Apostolos Christou (Armagh Observatory and Planetarium)

Co-authors: Maria Gritsevich (U. Helsinki, Finland; Ural Federal U., Russia)

Key points: The distribution of large meteoroids has to-date only been measured at 1 au from the Sun. To extend that knowledge to other locations, we propose to use Venus's thick atmosphere as a meteor detector.

While much is now known about the distribution of solar system dust, the flux of mm-sized or larger grains is largely unconstrained by direct observation outside of the Earth's immediate vicinity. Measuring the flux of those larger meteoroids requires using the surface area of an entire planet, catching those particles as meteors burning up in the atmosphere. A case in point is Mini-EUSO, a nadir-pointed optical-transient detector successfully recording meteors from the International Space Station since 2019 (Bacholle et al, ApJSS, 2021; Coleman et al, APh, 2023). The concept of an orbital meteor survey is particularly suited to the planet Venus, where the harsh surface environment and thick, opaque atmosphere preclude the use of ground-based assets for this purpose.
Here we use physics-based modelling to assess the detectability of meteors in the upper atmosphere of Venus and to compare the efficiency of meteor surveys at Venus vs the Earth. Application of our ablation model to Venus confirms earlier findings that Venus meteors would be brighter but shorter-lived than Earth meteors due to the different density scale heights. Meteors at Venus would typically appear at 85-125 km altitude, meaning an orbital survey would be unimpeded by the presence of the cloud layers. Finally, we consider the performance of a hypothetical meteor detector similar to the Mini-EUSO instrument on the ESA EnVision mission. We find a Venus detection rate of 1.5x-2.5x the Earth rate, more than sufficient to characterise the meteoroid population at 0.7 au from the Sun.

Instrument design proposition for the optimised high resolution measurements of negative ions

Anna Parsec-Wallis (Mullard Space Science Laboratory, UCL)

Co-authors: Andrew Coates (MSSL,UK), Georgios Nicolaou

Key points: Ahead of the announced large-class ESA mission with mission targets being Enceladus and Titan, where negative ions were found, we present a preliminary definition for the instrument requirements for detection and analysis of negative ions, and present an initial design.

One of the unexpected measurements of the Cassini-Huygens mission was the discovery of heavy negative ions in Titan’s upper atmosphere (Coates et al., 2007, 2009, 2010). Anions were also discovered

near Enceladus, Rhea and Dione, and appear to be a feature of icy moons with subsurface oceans, signalling the potential for prebiotic chemistry. The primary focus of our research is to resolve the composition of icy moon atmospheres and to understand the prebiotic chemistry involved. Ahead of the announced large-class ESA mission with mission targets being Enceladus and Titan (ESA, 2024), it is important to analyse existing data with the most advanced methods available to unravel further details on the processes at work. Negative ions were detected by the Cassini electron spectrometer (CAPS-ELS) which was designed to detect electrons. In this poster we will present results from CAPS-ELS and identify outstanding questions based on these data. We will also present a preliminary definition for the instrument requirements for detection and analysis of negative ions, and present an initial design.

Computationally Simulating Spectral Sensing of Planetary Surface Composition

Roger Stabbins (Natural History Museum, London, UK)

Co-authors: Peter Grindrod (NHM, UK), Matt Gunn (Aberystwyth University, UK), Shingo Kameda (Rikkyo University, Japan), Andrew Coates (MSSL/UCL, UK)

Key points: We describe a number of methods and computational tools for simulating the measurement of reflectance spectra of planetary surfaces, and showcase the use of these tools in the development of upcoming spectral sensing systems for the ESA ExoMars Rosalind Franklin Rover and the JAXA Martian Moons eXploration spacecraft.

Reflectance spectroscopy and spectral imaging are efficient methods for exploring the distribution of materials across a planetary surface. To be spectrally distinct, the materials of a given set must have distinct chemical and crystalline properties that result in statistically distinct signals across the spectral range and resolution of the sampling instrument. The statistical distribution of a material signal can depend on a number of properties, some intrinsic to the material (e.g. variation of grain size and chemical composition), some intrinsic to the instrument (e.g. counting and electronic noise), some intrinsic to both (e.g. scale of macroscopic mixing of materials compared to the instrument spatial sampling), and some extrinsic to both (e.g. atmospheric scattering, illumination incidence angle). This large parameter space of mostly uncontrollable properties is a challenge to the task of evaluating the ability of a spectral sensing system to distinguish a set of materials. We showcase a number of computational tools and methods we have developed for simulating spectral sensing, toward comprehensive controlled exploration of this large parameter space, for investigating the capabilities and defining the requirements of spectral sensing systems for planetary surface exploration. We showcase applications of simple Gaussian-distributed 1D resampling of laboratory-measured pure mineral reflectance spectra, for establishing and demonstrating fulfilment of requirements of forthcoming instruments (ExoMars Rosalind Franklin Enfys spectrometer, MMX OROCHI spectral imager), and for comparing the performance of equivalent systems (e.g. ExoMars RF PanCam vs. MSL

Mastcam & M2020 Mastcam-Z spectral imagers), and more comprehensive 3D spectro-radiometric physically-based ray-tracing for simulating image formation.

Synchrotron X-ray diffraction for sealed Mars Sample Return sample tubes

Lukas Adam (Space and Planetary Instruments group, School of Physics and Astronomy, University of Leicester, UK)

Co-authors: John Bridges (UoL, UK), Candice Bedford (Purdue U, USA), John Holt (UoL, UK), Elizabeth Rampe (NASA JSC, USA), Michael Thorpe (NASA Goddard, USA), Kashauna Mason (Texas A&MU, USA), Ryan Ewing (Texas A&MU, USA)

Key points: We have investigated the use of a synchrotron for powder X-ray diffraction of sealed Mars Sample Return samples in titanium sample tubes for quantification of modal mineralogy and found it to be feasible, with the tube causing only a few narrow diffraction peaks.

The joint NASA-ESA Mars Sample Return campaign aims to return approximately 30 sample tubes containing drilled rock cores and regolith. X-ray computed tomography and magnetometry will be carried out on the still sealed titanium alloy sample tubes in the Pre-Basic Characterization phase of sample investigation, which informs later analysis decisions. Powder X-ray Diffraction (XRD) in this phase would enable mineralogical analysis of returned samples without opening the samples tubes and the potential changes to the sample that entails, allowing investigators to better plan subsequent, more specialised analysis. [2,3] However, XRD using conventional sources is infeasible due to the size and thickness of the sample tubes. We show that powder XRD analysis can be successfully carried out on sealed samples using 54 keV monochromatic X-rays at the I12 beamline of the Diamond Light Source synchrotron. [3] Our experiment used an analogue sample tube and a Martian regolith analogue (Icelandic basaltic sediment). Measurements were taken with and without the sample tube, and were compared to data from a conventional laboratory diffractometer using powdered sample. A 0.5 × 0.5 mm square beam profile and 30 s exposure time were used. The tube walls give strong but few diffraction peaks, making identification of the major constituent mineral phases using Rietveld refinement feasible. A more significant constraint on phase quantification by this technique is likely to be the grain size of the material. Future work involves similar testing of analogues inside a purpose-built high-containment vessel with X-ray transparent windows.

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[1] Meyer M. A. et al. (2022) Astrobiology, 22(S1), 5–26. [2] Tait K. T. et al (2022) Astrobiology, 22(S1), 57–80. [3] Ewing R. et al. (2020) LSPC LI, Abstract #JSC-E-DAA-TN78511. [4] Adam L. et al. (2023) Meteoritics & Plan. Sci., 59(1), 40-54.