**GLOBAL BRITAIN TO GALACTIC BRITAIN: ISRU CAPABILITIES ACROSS THE VALUE CHAIN.** J.N Rasera[1], H. Sargeant[2], P. Harkness[3], S. Mosteshar[4], N. Bowles[5], M. Cosby[6], K. Smith[7], D. Hawkins[8], D. Gray[9], A. Fouto[10], I. Crawford[11], J. Martin-Torres[12], and A. Morse[13], [1]Department of Earth Science and Engienering, Imperial College London, j.rasera@imperial.ac.uk, [2]Space Park Leicester, University of Leicester, [3]James Watt School of Engineering, University of Glasgow, [4]London Institute of Space Policy and Law, University of London, [5]Department of Physics, University of Oxford, [6]Goonhilly Earth Station Ltd., [7]Department of Mechanical, Aerospace & Civil Engineering, The University of Manchester, [8]Metalysis, [9]Added Value Solutions (AVS) UK, [10]Added Value Solutions (AVS) UK, [11]Birkbeck College, University of London, [12]School of Geosciences, University of Aberdeen, [13]School of Physical Sciences, The Open Univeristy.

**Introduction:** In-situ resource utilisation (ISRU) has been identified as a national priority for the United Kingdom's space sector, highlighted in the 2021 *National Space Strategy* [1] and the 2023 *Space Exploration Technology Roadmap* [2]. In response, the UK ISRU Representative Group (ISRU-UK) was formed in 2023 at the request of the UK Space Agency (UKSA) to coordinate and represent the UK's ISRU community. Operating independently of UKSA, this group aligns academic, industrial, and research organisations to advance ISRU capabilities across the entire value chain, from prospecting and extraction to manufacturing, infrastructure, and governance. Its mandate is to advise government on ISRU strategy, policy making, and funding, update UKSA on community R&D activities and needs, and promote collaboration across the UK's ISRU ecosystem.

**Prospecting and Resource Evaluation:** The UK community contributes planetary science and instrumentation expertise to prospecting activities. UK scientists lead the ProSPA analytical laboratory, part of ESA's PROSPECT (Package for Resource Observation and In-Situ Prospecting) package, which will drill and analyze lunar polar soil for water ice and volatiles in the late 2020s [3]. PROSPECT will use a 1 m class drill (ProSEED) to collect samples in the Moon's south polar region and a miniaturised lab (ProSPA, designed at The Open University) to heat and examine those samples for trapped volatiles like $H_2O$ and $CO_2$. In parallel, researchers are developing remote sensing and machine-learning techniques to prospect for resources from orbit and rover data. By applying advanced data analysis to missions like NASA's Lunar Reconnaissance Orbiter and ESA's upcoming Argonaut landers, UK teams help pinpoint rich resource deposits [4, 5]. These contributions ensure that the UK plays a crucial "front-end" role in ISRU, from identifying required lunar resources to characterizing their distribution.

**Extraction and Processing Technologies:** The UK's chemical engineering and minerals processing sectors are driving innovations in ISRU extraction techniques. A notable example is the molten salt electrolysis method for oxygen production from lunar soil. Researchers at the University of Glasgow with the European Space Agency and Metalysis demonstrated that nearly all (~96%) oxygen can be extracted from simulated lunar regolith by electrolyzing it in molten calcium chloride, leaving behind metallic alloy powders as by-products [6]. Metalysis has continued to develop this capability, and is working in a consortium with funding from UKSA and ESA to demonstrate this technology on the Moon [7].

Others have developed alternative systems to extract oxygen from regolith by reduction using hydrogen, to be demonstrated on the lunar surface with the PROSPECT instrument [8], as well as microwave heating for ice mining [9] and sintering [10]. Beyond oxygen extraction, teams are investigating other resource processing techniques. In the area of lunar regolith handling, UK engineers contribute to rover-mounted digging systems and regolith handling studies. Researchers at the University of Manchester have informed the design of lightweight lunar excavators for granular regolith [11]. Further along the value chain, researchers at Imperial College London are developing capabilities in beneficiation, namely size classification and mineral enrichment [12, 13].

**Manufacturing and Construction:** The UK is investing in advanced manufacturing techniques to utilise the outputs of resource extraction for building a sustained human presence in space. Several UK groups are already involved in developing 3D printing processes in lunar gravity or vacuum conditions in conjunction with international partners [14, 15]. For example, experiments have been conducted on sintering regolith simulants into ceramic tiles and using binder jetting to form bricks from regolith [14]. The metallic alloys produced as a by-product of oxygen extraction could be directly leveraged as feedstock for 3D printing spare parts or habitat components on the Moon. Furthermore, Metalysis have received funding to explore methods to 3D print metal alloy powders produced from lunar regolith [7]. The UK's materials science and robotics expertise, supported by initiatives like the *High Value Manufacturing Catapult*, is being applied to space: new alloys and composites are being tested for durability in the lunar environment, and robotic assembly techniques are being refined for autonomous construction.

**ISRU Infrastructure and Support Systems:** Implementing ISRU at scale on the Moon or Mars requires robust supporting infrastructure, notably energy systems, mobility, and operational autonomy. The UK is addressing these enabling technologies as part of its comprehensive approach to ISRU. Power is a critical requirement for off-world resource utilization, and the UK is leveraging its strengths in energy innovation to meet this need. In 2023, the UKSA invested £2.9 million in a project with Rolls-Royce to develop a lunar modular nuclear reactor for surface power [16]. This compact fission reactor concept is intended to provide continuous, reliable power to lunar operations, enabling ISRU devices to run through the lunar night or in shadowed regions where solar power is impractical. Meanwhile, researchers at the University of Leicester are developing Radioisotope Power Systems that could provide lunar night survival to landers and rovers performing prospecting and demonstrator missions [17, 18]. In parallel, UK companies and research labs are advancing fuel cell and battery technologies for space: fuel cells can efficiently convert in-situ produced fuels like hydrogen into electricity, providing steady power for ISRU rigs.

Mobility and excavation infrastructure is another focus. Drawing on its experience in planetary rover development (e.g. ExoMars), the UK is contributing to the design of autonomous robotic miners and haulers that could gather and transport regolith. This includes R&D on traction systems for lightweight lunar excavators and methods to deal with abrasive dust [19]. British engineers have evaluated auger-based drilling and conveyor mechanisms to continually excavate soil for processing [20-22]. The UK is also active in developing the communications and navigation infrastructure needed to support ISRU operations, such as lunar telecommunications relays and precision navigation systems [23]. Together, these infrastructure contributions form the backbone that makes ISRU feasible. They ensure that prospecting instruments, extraction plants, and construction robots have the energy and control needed to operate reliably in harsh off-world environments. By investing in such enabling systems now, the UK is positioning itself as a key supplier of "infrastructure services" for future international lunar missions.

**Governance and Planetary Protection:** The National Space Strategy commits the UK to championing safe and sustainable exploration, working through the UN and other forums to develop norms for activities like resource extraction. Researchers at institutions such as Northumbria University and the Open University (AstrobiologyOU) are actively studying the legal, ethical, and planetary protection aspects of exploiting extraterrestrial resources [24]. Cheney et al. (2020) discuss frameworks for planetary protection in the new space era, examining how space governance can evolve to address the environmental impacts of ISRU and ensure compliance with treaties. By integrating governance and regulatory considerations from the start, the UK can help legitimise ISRU activities globally and foster international partnerships. ISRU-UK provides contextual advice from practicing experts in support of this endevour. This approach echoes the UK's broader goal of "Global Britain becoming Galactic Britain" [1], taking a leading role on the international stage to set standards for the responsible and sustainable use of space.

**Conclusion:** The UK's coordinated focus on ISRU across policy and technology showcases its commitment to enabling a sustainable human presence on the Moon and Mars. The UK ISRU community has made significant strides in recent years: from developing prospecting instruments that will fly to the Moon, to pioneering oxygen extraction techniques, and laying the groundwork for construction and power systems. These efforts leverage the UK's diverse expertise to tackle the full ISRU value chain. Critically, the UK's work is highly collaborative: domestically, it brings together universities and companies under a common vision, and internationally, it contributes to missions and working groups alongside partners like ESA, NASA, and others. By maintaining this momentum, ISRU-UK aims to position UK innovators at the forefront of upcoming lunar missions, whether that be prospecting missions in the mid-2020s or demonstration ISRU plants on the Moon's surface in the 2030s. Moving forward, the UK ISRU group will continue to guide strategic investments and collaborations, ensuring that the UK remains a key player in humankind's return to the Moon. This holistic and responsible ethos will be the cornerstone of the UK's contributions to the next era of space exploration.

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