UK Space LABS

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Why Space?

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The opportunity for Health and Life Science Innovation

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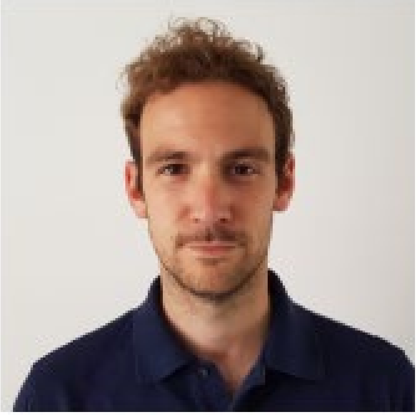

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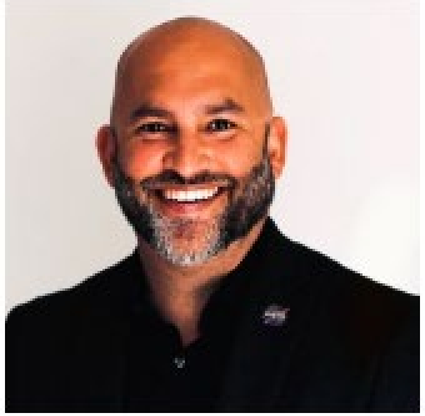

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Why Space? Context

As the global community seeks to recover post covid-19, the opportunity to galvanise our excellence in health and life sciences, and the strong investments in developing sovereign space launch capability, could be a catalyst for future innovation and strengthen existing global ties.

Without funding, infrastructure, relationships and agreements, it is challenging for UK scientists to develop/sustain long-term collaborative research programmes with international agencies, principally ESA, and other commercial partners.

Image Credit: NASA

Why Space? Process

Two space health and life science community workshops attended by government, industry, clinical and academic stakeholders, along with surveys, and one-on-one interviews.

Process of peer-review for all the case studies submitted was carried out by the working group assisted by a panel of independent experts (who are listed below):

Professor Hagan Bayley (University of Oxford),

Dr Tim Etheridge (University of Exeter),

Libby Jackson (UK Space Agency),

Dr Michael Adeogun (National Physical Laboratory),

Dr Barbara Ghinelli (UKRI-STFC),

Dr Noriane Simon (UKRI-BBSRC)

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Why Space? Process

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Open call for papers gathered >50 authored contributions from the research community, which helped broaden our horizons of untapped potential for cross-sector innovation.

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Case Study: Example

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"Human spaceflight research and sport & exercise science: interactions and synergies"

Exercise is a crucial part of human spaceflight; used as a countermeasure against the negative physiological impact of prolonged stays in micro- and reduced-gravity environments.

Reloading of musculoskeletal and cardiovascular systems after spaceflight and in 'return-to-play' scenarios in sport both offer an opportunity to address the reduced physical fitness

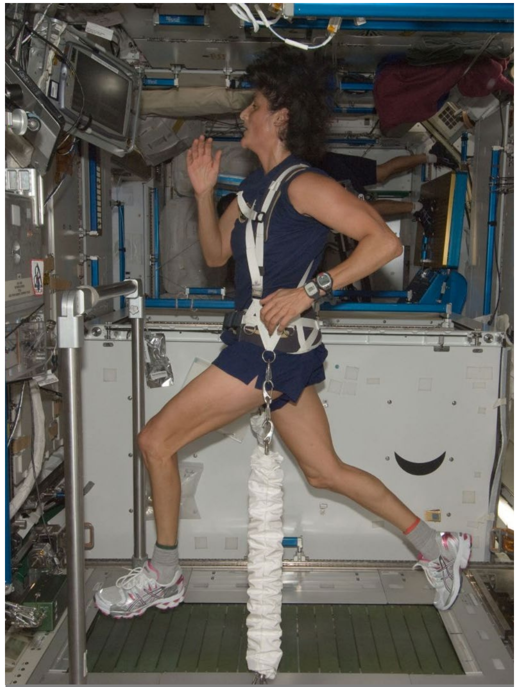

Image Credit: NASA

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Solent University Case Study

Solent University staff are currently involved in a variety of projects that would benefit from the opportunity to be further involved in space-related research.

Exposure to reduced gravity levels during rehabilitation from lower-limb injuries

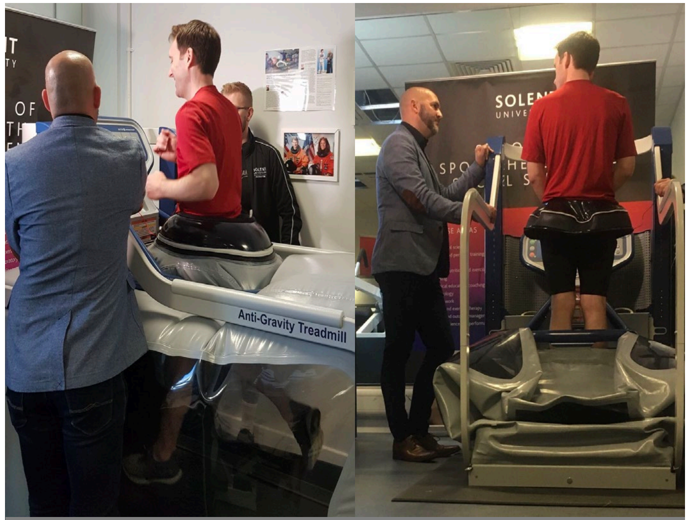
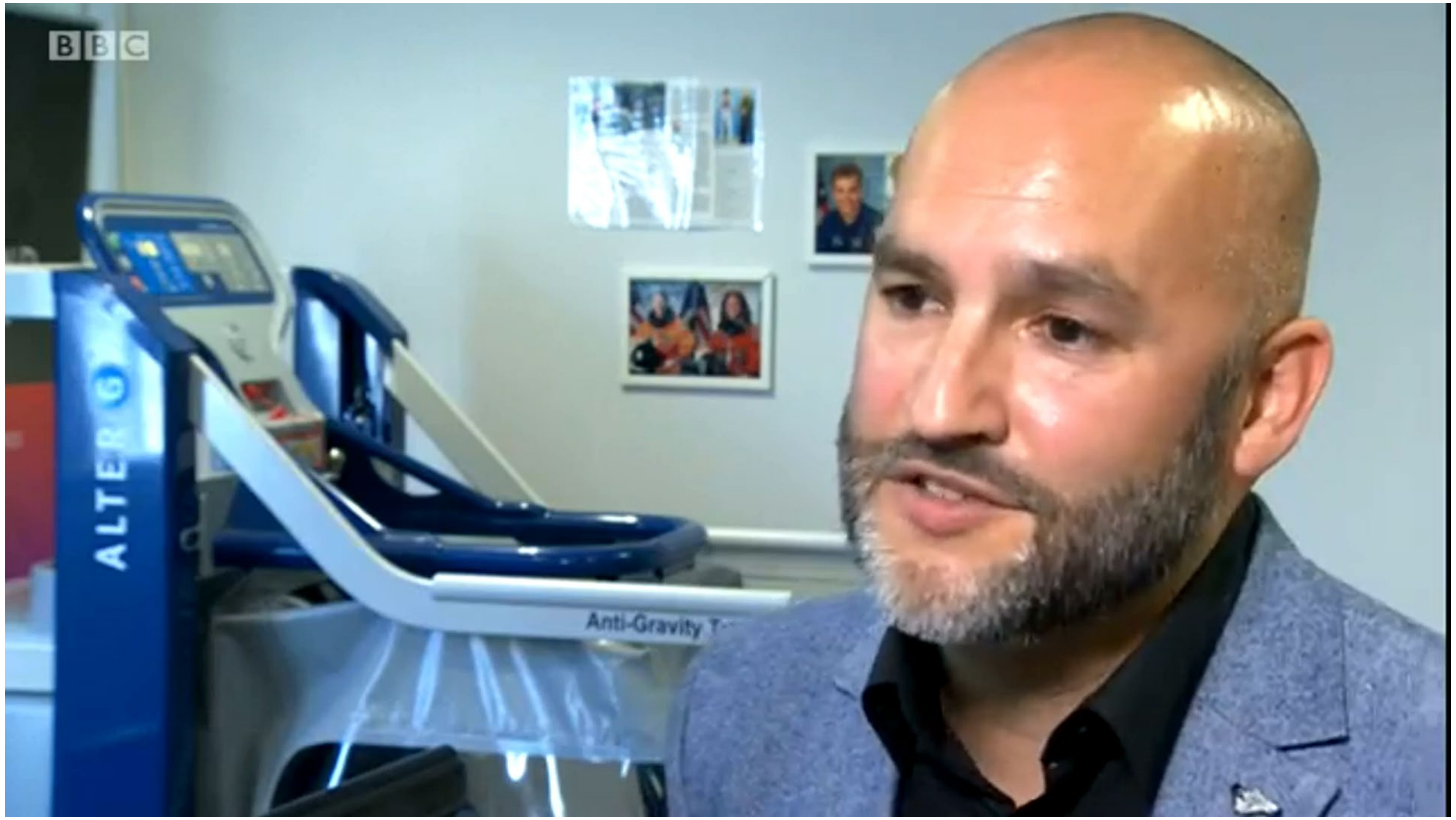


Image Credits: Dr Adam Hawkey



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Solent University Case Study

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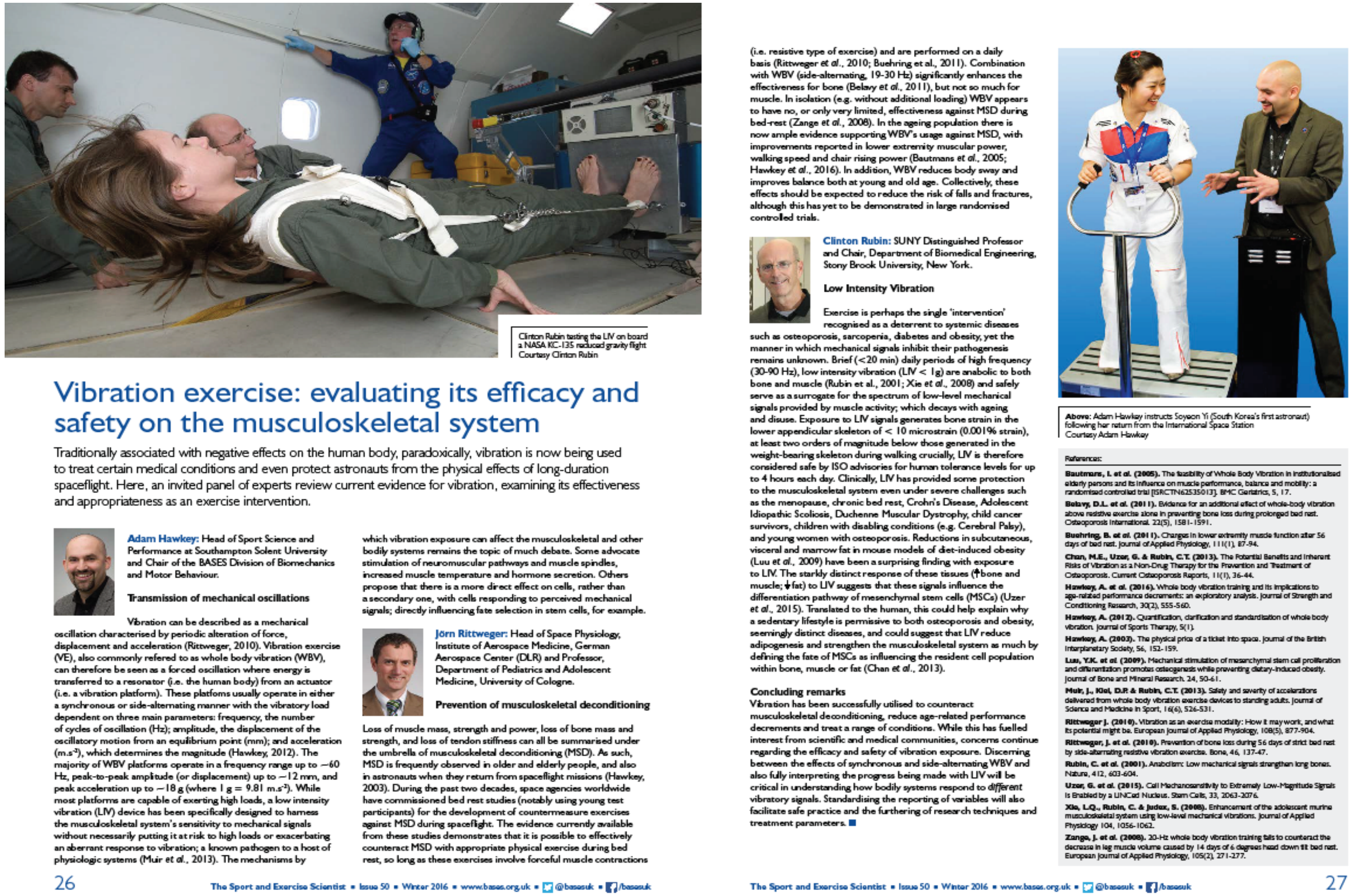
Application of whole-body vibration training (WBVT) for health and athletic performance



Clinton Rubin testing the LIV on board a NASA KC-135 reduced gravity flight
Courtesy Clinton Rubin

Vibration exercise: evaluating its efficacy and safety on the musculoskeletal system

Traditionally associated with negative effects on the human body, paradoxically, vibration is now being used to treat certain medical conditions and even protect astronauts from the physical effects of long-duration spaceflight. Here, an invited panel of experts review current evidence for vibration, examining its effectiveness and appropriateness as an exercise intervention.

Adam Hawkey: Head of Sport Science and Performance at Southampton Solent University and Chair of the BASES Division of Biomechanics and Motor Behaviour.

Transmission of mechanical oscillations

Vibration can be described as a mechanical oscillation characterised by periodic alteration of force, displacement and acceleration (Rittweger, 2010). Vibration exercise (VE), also commonly refered to as whole body vibration (WBV), can therefore be seen as a forced oscillation where energy is transferred to a resonator (i.e. the human body) from an actuator (i.e. a vibration platform). These platfoms usually operate in either a synchronous or side-alternating manner with the vibratory load dependent on three main parameters: frequency, the number of cycles of oscillation (Hz); amplitude, the displacement of the oscillatory motion from an equilibrium point (mm); and acceleration ($m.s^{-2}$), which determines the magnitude (Hawkey, 2012). The majority of WBV platforms operate in a frequency range up to ~60 Hz, peak-to-peak amplitude (or displacement) up to ~12 mm, and peak acceleration up to ~18 g (where 1 g = 9.81 $m.s^{-2}$). While most platforms are capable of exerting high loads, a low intensity vibration (LIV) device has been specifically designed to harness the musculoskeletal system's sensitivity to mechanical signals without necessarily putting it at risk to high loads or exacerbating an aberrant response to vibration; a known pathogen to a host of physiologic systems (Muir *et al.*, 2013). The mechanisms by which vibration exposure can affect the musculoskeletal and other bodily systems remains the topic of much debate. Some advocate stimulation of neuromuscular pathways and muscle spindles, increased muscle temperature and hormone secretion. Others propose that there is a more direct effect on cells, rather than a secondary one, with cells responding to perceived mechanical signals; directly influencing fate selection in stem cells, for example.

Jörn Rittweger: Head of Space Physiology, Institute of Aerospace Medicine, German Aerospace Center (DLR) and Professor, Department of Pediatrics and Adolescent Medicine, University of Cologne.

Prevention of musculoskeletal deconditioning

Loss of muscle mass, strength and power, loss of bone mass and strength, and loss of tendon stiffness can all be summarised under the umbrella of musculoskeletal deconditioning (MSD). As such, MSD is frequently observed in older and elderly people, and also in astronauts when they return from spaceflight missions (Hawkey, 2003). During the past two decades, space agencies worldwide have commissioned bed rest studies (notably using young test participants) for the development of countermeasure exercises against MSD during spaceflight. The evidence currently available from these studies demonstrates that it is possible to effectively counteract MSD with appropriate physical exercise during bed rest, so long as these exercises involve forceful muscle contractions (i.e. resistive type of exercise) and are performed on a daily basis (Rittweger *et al.*, 2010; Buehring et al., 2011). Combination with WBV (side-alternating, 19-30 Hz) significantly enhances the effectiveness for bone (Belavy *et al.*, 2011), but not so much for muscle. In isolation (e.g. without additional loading) WBV appears to have no, or only very limited, effectiveness against MSD during bed-rest (Zange *et al.*, 2008). In the ageing population there is now ample evidence supporting WBV's usage against MSD, with improvements reported in lower extremity muscular power, walking speed and chair rising power (Bautmans *et al.*, 2005; Hawkey *et al.*, 2016). In addition, WBV reduces body sway and improves balance both at young and old age. Collectively, these effects should be expected to reduce the risk of falls and fractures, although this has yet to be demonstrated in large randomised controlled trials.

Clinton Rubin: SUNY Distinguished Professor and Chair, Department of Biomedical Engineering, Stony Brook University, New York.

Low Intensity Vibration

Exercise is perhaps the single 'intervention' recognised as a deterrent to systemic diseases such as osteoporosis, sarcopenia, diabetes and obesity, yet the manner in which mechanical signals inhibit their pathogenesis remains unknown. Brief (<20 min) daily periods of high frequency (30-90 Hz), low intensity vibration (LIV < 1g) are anabolic to both bone and muscle (Rubin et al., 2001; Xie *et al.*, 2008) and safely serve as a surrogate for the spectrum of low-level mechanical signals provided by muscle activity; which decays with ageing and disuse. Exposure to LIV signals generates bone strain in the lower appendicular skeleton of < 10 microstrain (0.001% strain), at least two orders of magnitude below those generated in the weight-bearing skeleton during walking crucially, LIV is therefore considered safe by ISO advisories for human tolerance levels for up to 4 hours each day. Clinically, LIV has provided some protection to the musculoskeletal system even under severe challenges such as the menopause, chronic bed rest, Crohn's Disease, Adolescent Idiopathic Scoliosis, Duchenne Muscular Dystrophy, child cancer survivors, children with disabling conditions (e.g. Cerebral Palsy), and young women with osteoporosis. Reductions in subcutaneous, visceral and marrow fat in mouse models of diet-induced obesity (Luu *et al.*, 2009) have been a surprising finding with exposure to LIV. The starkly distinct response of these tissues (↑bone and muscle; ↓fat) to LIV suggests that these signals influence the differentiation pathway of mesenchymal stem cells (MSCs) (Uzer *et al.*, 2015). Translated to the human, this could help explain why a sedentary lifestyle is permissive to both osteoporosis and obesity, seemingly distinct diseases, and could suggest that LIV reduce adipogenesis and strengthen the musculoskeletal system as much by defining the fate of MSCs as influencing the resident cell population within bone, muscle or fat (Chan *et al.*, 2013).

Concluding remarks

Vibration has been successfully utilised to counteract musculoskeletal deconditioning, reduce age-related performance decrements and treat a range of conditions. While this has fuelled interest from scientific and medical communities, concerns continue regarding the efficacy and safety of vibration exposure. Discerning between the effects of synchronous and side-alternating WBV and also fully interpreting the progress being made with LIV will be critical in understanding how bodily systems respond to *different* vibratory signals. Standardising the reporting of variables will also facilitate safe practice and the furthering of research techniques and treatment parameters. ■

Above: Adam Hawkey instructs Soyeon Yi (South Korea's first astronaut) following her return from the International Space Station
Courtesy Adam Hawkey

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Image Credits: Dr Adam Hawkey

Why Space? Process

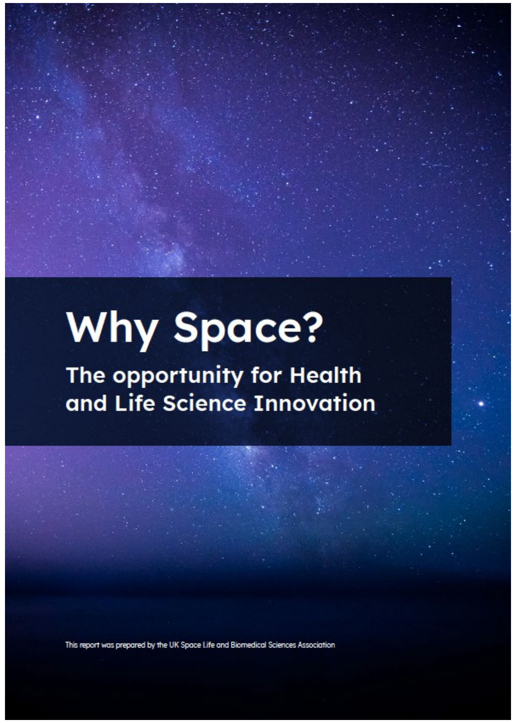
These case studies highlighted the need for bridging mechanisms between capability and access to overcome the barriers to conducting space-related research, for both exploration and terrestrial benefit

UK Space Life and Biomedical Sciences Association

To aid this process, contributions were amalgamated into five Thematic chapters, each with an assigned editor from the paper’s working group

Why Space? Thematic Chapters

- Life Science
- Human Factors, Psychology & Neuroscience
- Bio-Medical and Clinical Considerations
- Engineering, Robotics, Data and AI
- Education and Knowledge Exchange



Why Space? Key Recommendations

- Harness the innovation opportunity from existing research portfolios:

  Establish dedicated funding pilots with funders of Health and Life science research, to galvanise existing scientific capital on translational activities with space. For example, following the 2020 UKRI deep dive into space research funding, the establishment of a cross-UKRI (UK Research and Innovation) Space working group, provides an opportunity to consider how funding in this area might be better supported and extended to include space related Health & Life Science research.

- Create a proof of concept/ catalyst program for Industry:

  To de-risk industrial R&D, facilitate the growth of the market opportunity and the commercialisation activity with space, a catalyst-like programme is recommended to drive an innovation pipeline. This would in turn stimulate the UK's launch and provider network, working with the UK Space Agency, by growing a sustainable customer base.

Why Space? Key Recommendations

- Fund high-risk high-reward thematic centres:

TRANSLATIONAL RESEARCH INSTITUTE FOR SPACE HEALTH ™

A GiantLeap Deep Dive
Advanced Research and Invention Agency

In keeping with the UK Government's renewed interest in high-risk, high-reward research and innovation and inspired by the success of NASA's Translational Research Institute for Space Health, we propose setting up at least three UK challenge-led R&D centres. These would provide opportunities to support Government priorities to deliver an R&D based future economy, contributing to the UK's position as a science superpower and in line with ambitions articulated in the creation of the Advanced Research & Invention Agency.

- Inspire careers in the Health & Life Sciences:

Develop educational programs and outreach opportunities to promote new and existing career pathways in the Health and Life Sciences, particularly those associated with the Space Sector. These activities will further encourage and enthuse the next generation of scientists, engineers, teachers, healthcare professionals, and astronauts.

Why Space? Key Recommendations

- Establish a dedicated knowledge exchange infrastructure:

  Enabling knowledge exchange activities at various stages, from early research through to potential commercial and industry applications. This will support engagement with a broad customer base who might benefit from accessing knowledge in relation to space economies and terrestrial benefit, growing customer base for future space and lunar economies.

- Join the International Space Life Sciences Working Group (ISLSWG):

  Currently several of the major international space agencies (Including NASA, ESA, DLR etc) sit on this group. By lobbying for the UK Space Agency to join, this will raise the UK's International Profile, connect its global leading expertise in Health and Life science research and foster other opportunities to enhance our representation with international groups, future exploration activities, and roadmaps.

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