Draft National Strategy for Space Environments and Human Spaceflight

August 2014

1. Vision

The UK will be a recognised and valued participant in human spaceflight and space environments research – in low Earth orbit, on analogue platforms and in deep space exploration. Advancing scientific knowledge and technological capabilities as a pathway to growth will positively augment the UK economy and provide measurable societal benefits in sectors such as healthcare, communications and education.

1.2 Introduction

This strategy will help ensure that existing investment is well targeted and be a guide for future investment decisions, providing a framework for further activities. The path towards the achievement of the vision begins with space-analogue and orbital platforms, expands human presence into the solar system, and ultimately leads to human missions on the surface of Mars or other solar systems planets, moons or asteroids. The first steps focus on utilizing the ISS, expanding the synergies between human and robotic missions, and pursuing discovery-driven missions in the lunar vicinity that help to develop capabilities and techniques needed to go further, as described in the Global Exploration Roadmap[1].

1.3 Tim Peake, a former British Army helicopter pilot was selected from thousands of applicants from across Europe to join the ESA Astronaut Corps in 2009. His first mission was announced in May 2013: he will fly on the ISS for a six-month mission commencing December 2015, becoming the first UK government-backed British astronaut, the first British astronaut to visit the ISS, and a very visible demonstration of UK engagement with human spaceflight. This mission presents an excellent opportunity for publicising leading UK science and technology and a unique focus for education.

1.4 The UK Space Agency will lead national activities in space environments research and human spaceflight, coordinating stakeholders and setting a clear national framework. This strategy lays out how the Agency will facilitate UK involvement in these areas, its goals for the sector(s) and how the many interests in this domain will be balanced to deliver one coherent overarching programme.

1.5 The Agency will work closely with partners in academia, industry and government to ensure that the UK exploits opportunities in international programmes to drive research and innovation, building the national research base. It will work closely with international space agencies to secure commercial opportunities for UK companies delivering spaceflight infrastructure and work to identify downstream sectors which

[1] The Global Exploration Roadmap, Version 2, published August 2013 by the International Space Exploration Coordination Group – see http://www.globalspaceexploration .org

will benefit from the vast range of research conducted in space and space-analogous environments.

1.6 UK strengths in biomedicine, fundamental physics, materials research and space science will be advanced through research in space environments. The Agency will identify priority areas consistent with those of the national Research Councils and target these areas in particular, whilst remaining mindful that the unique properties of the space environment may be of interest to research in virtually any discipline and encouraging new and innovative interventions.

1.7 The Innovation and Growth Strategy for space (IGS) and the Agency's Civil Space Strategy (CSS)[2] provide a clear context for UK investment in space. The space environments and human spaceflight programme, as part of this broader national picture, is expected to help deliver the goals set out in the CSS: facilitating excellent science to underpin growth; encouraging growth through innovation; enabling growth from export; and providing a unique context for education for growth.

2. Goals

2.1 Building upon analyses and consultation undertaken in 2012, the following goals have been identified for the National Strategy. It should be noted that these are not specific to the ELIPS and ISS Utilisation programmes, rather they are the goals set by the Agency regardless of the mechanism by which they are delivered. The goals (not in any order of priority) are:

- **To deliver excellent science and technology in line with UK priorities**
  - with fundamental intellectual merit and socio-economic impact
  - utilising a range of space environments platforms, including but not limited to the ISS; parabolic flights; drop towers and bed rest facilities
  - with terrestrial benefit, and downstream application: for example in the areas of healthcare and materials
  - positioning the UK for leadership of technologies for human exploration beyond LEO

- **To exploit the public fascination and enthusiasm for human spaceflight to deliver education**
  - focussed especially on encouraging young people to take up STEM[3] subjects

[2] UK Space Agency Civil Space Strategy 2012-2016 – see http://www.bis.gov.uk/assets/ukspaceagency/docs/uk-space-agency-civil-space-strategy.pdf .

[3] Science, technology, engineering and maths. Increased uptake in these subjects has been recognised as important for the national economy in general, and for providing the skilled workforce needed by the UK's growing space industry in particular. See the Space IGS space Growth Action Plan www.bis.gov.uk/assets/ukspaceagency/docs-2013/igs-action-plan.pdf Pp.23

- in line with the national curriculum and the Agency's existing education strategy[4]

- **To use the interdisciplinary nature of these platforms to foster new collaborations**
  - between and scientific disciplines
  - between industrial and academic partners
  - between the space sector and 'non-space' sectors
  - to increase the speed with which science is taken up and commercially exploited

- **To win contracts for UK industry and attract new investment in the UK**
  - matching at least the value of government investment
  - reflecting the UK's world leading capabilities in telecommunications and propulsion systems and developing capability in new areas where the UK can take a lead
  - to attract inward investment from foreign companies, where this will complement existing UK capabilities.

- **To help prepare the UK for possible future commercial human spaceflight endeavours**
  - by providing a regulatory environment that encourages commercial spaceflight in the UK
  - by enabling research in space medicine and human health

2.2 In line with the pathways to growth defined in the UK Civil Space Strategy, the programme will open up opportunities for **growth from export**; drive **innovation supporting growth;** enable **science to underpin growth;** contribute significantly to **education for growth** and position the UK for **growth through new opportunities.** These criteria will be used to inform future investment decisions.

3. Delivery

3.1 As with much of the UK space programme, delivery will be in cooperation with a range of partners. Primarily, the role of the Agency is to provide funding for access to space infrastructure; other bodies are responsible for the exploitation thereof. As a simple example, the Agency may fund the launch costs and payload development for a science experiment, but a research funder (such as one of the national Research Councils) would fund the utilisation of any data the experiment delivers. The situation with space environments research is slightly more complex as it covers a broad range of facilities and requires interfaces with many different national funders, each with its own policies.

[4] www.bis.gov.uk/assets/ukspaceagency/docs/strategy/uk-space-agency-education-strategy-march-2011.pdf

3.2 Secondarily, due to the cross-disciplinary nature of space environments and human spaceflight research, many organisations may have a stake, and the Agency must effectively coordinate the various interested parties. The division of responsibilities between different national funders necessitates continued communication between the Agency and other bodies; the Agency will effectively follow Research Councils' existing research priorities

3.3 Access to space and space-analogues

The UK does not have the capacity to unilaterally deliver these programmes, and to develop the necessary infrastructure would require unfeasible levels of investment. There are realistically three routes for the delivery of the Agency's principal responsibility of providing access to space:

1. Missions and/or experiment campaigns bilaterally with other nations
2. Procurement of capacity on commercial platforms (ground based, sub-orbital and in LEO)
3. Subscription to ESA programmes

3.4 **Option 1** could have some merit in enabling relatively quick access to partners' existing facilities. However, it would be costly and likely to result in unequal relationships: the UK does not have the infrastructure so will inevitably be the junior partner, thus subject to the whims of the other nation. Some partners may be considered more reliable than others, but there will always be an element of risk involved.

Examples may include cooperating with China, delivering British science on the Shenzhou and Tiangong platforms, or contribution to NASA-led initiatives on the ISS. The high element of risk in doing so, and the inability of the UK to plan a long-term strategy with confidence are impediments to solely pursuing this route. It could however complement a broader programme of activity and the Agency will remain alert to the potential for such partnerships and assess on merit any missions of opportunity that arise.

3.5 **Option 2** is still in its infancy, though great progress is being made. Alongside commercial space on the ISS, the space tourism industry recognises a need to diversify beyond 'merely' tourist flights and to offer a service for scientific payloads[5]. Funding access to facilities such as parabolic flights and bed rest facilities in direct negotiation with providers is a route already taken by other European countries alongside their subscriptions to ESA programmes. However, demand is as yet difficult to ascertain in the UK, and there is a serious risk that the science community

[5] An ISU/IISC workshop *Commercial Solutions for Microgravity Experiments* (London, 04 December 2013) identified several such providers www.isunet.edu/news-and-media-center-2/1284-workshop-commercial-solutions-for-microgravity-experiments . A useful summary may be found in Buckley and Peeters, 2012.

is either unready or uninterested in fully utilising such investment. Further, with few such facilities owned and located in the UK, this approach would not directly support UK industry. It will therefore not be pursued until such a time as demand necessitates it and there is sufficient national supply to meet at least some of this demand.

3.6 **Option 3** is deemed by the Agency as the approach involving least risk and maximum return for UK investment. Contributing to ESA programmes gives the UK a 'seat at the table' in determining their directions and priorities, ensures a certain level of investment back into UK industry (via the ESA principle of 'geo-return'[6]) and opens up access to a whole range of facilities which would otherwise, individually contracted, be many times more expensive. It also allows UK researchers to join their international colleagues in existing funded collaborations and to take stronger roles in ESA's Topical Teams, which set the direction for future research in Europe. ESA has a good heritage of space flight operations and supports design and technical development of experiments in a manner the Agency cannot feasibly replicate in the UK.

Consultation with the scientific community has indicated that bed rest, parabolic flights, drop towers and the ISS are the most important space environments facilities for UK researchers. Subscription to ELIPS provides access to all of these, and contribution to the ISS also permits UK leadership of ISS-borne experiments. Whilst programmatic pressures constrain the degree of access (for example, the multiple scientific and technical reviews required, and limited space available on the ISS mean it can take several years for an experiment to progress from concept to launch), these constraints are offset by the sheer range of facilities available for relatively modest investment.

Contribution to ESA's ISS Utilisation programme is currently the only viable and cost effective route to ensure UK involvement in human spaceflight. Although Tim Peake was selected to join the ESA Astronaut Corps before the UK had any formal involvement in the ISS, without the subsequent investment he would have remained simply an 'ESA astronaut' with no UK government backing and no option for the UK to make use of his flight, either by delivering science and technology or through inspiring children and the public with a tailored education programme.

In summary: option 3 will be pursued and option 1 remains under consideration.

3.7 The ISS will inevitably cease operations in the coming decades[7], and the Agency therefore must consider delivery beyond this. The Agency will proactively consult on national requirements and scope post-ISS scenarios. Specifically, a full assessment

[6] This dictates that whatever a Member States commits to a programme will as far as possible be spent in turn in that Member State, minus ESA overheads

[7] The formal 'end date' for ISS operations at the time of writing is 2020, but all ISS partners are considering extending funding beyond this.

shall be made of option 2 above and the capabilities of small satellites to deliver experiments in both the life and physical sciences. At this stage all options will be considered, including commercial providers should they meet the requirements of the user community.

3.8 Stakeholders and partners

As noted above, the engagement of partners is critical. The Agency's commitment extends only as far as investing in access to space environments facilities and international human spaceflight programmes. Thereafter, others must make use of this investment, though the Agency will proactively lead activities to publicise the opportunities to relevant groups and offer guidance and administrative support.

Key stakeholders are listed in annex 1.

3.9 Highlighted research areas

The Agency prioritises investment in facilities that deliver government strategy. It will identify highlighted research areas:

- which reflect the research priorities of the national Research Councils as formed in response to the needs of their respective science communities;
- considered likely to significantly benefit from space environments and human spaceflight; and
- where the UK has expertise and is well-placed to take a leading role

3.10 These priorities will also be used by the Agency to shape the long-term plans for the programme. Other interests are not excluded and it must be noted that a key strength of human spaceflight and space environments research is the great breadth science and innovation enabled. The highlighted research areas provide some direction and coherence to Agency activities and inform discussions with other funding bodies. The highlighted areas are:

- **Astrobiology and astrochemistry** meeting STFC's Science Roadmap Challenges[8], including 'How do stars and planetary systems develop and is life unique to our planet?'

- **Life and biomedical sciences** aligned to MRC and BBSRC priorities for research into ageing, for example under the Lifelong health and Wellbeing[9] initiative;

[8] Aspects of all four of the 'challenges' may be addressed through work in space environments. See http://www.stfc.ac.uk/challenges

[9] Lifelong Health and Wellbeing (LLHW) is a major cross-Council programme led by MRC. http://www.mrc.ac.uk/Ourresearch/ResearchInitiatives/LLHW/index.htm

- **Fundamental physics** addressing the EPSRC 'Grand Challenges' in Physics[10] and STFC's Science Roadmap Challenges;

- **Materials research** addressing EPSRC's Materials Engineering and 'Manufacturing the Future' research themes[11]

These are well-aligned with the research 'cornerstones' as defined within the ESA programme – specifically, Astrobiology; Human Physiology & Performance; Biology; Fundamental Physics and Material Sciences – and international goals for human spaceflight and space environments research, as defined in the ISCEG Global Exploration Roadmap (GER)[12]. The UK is an active member of the ISECG and uses the GER, which was conceived and agreed by 14 national space agencies, for strategic planning of space exploration in the international context. The Agency will use these as reference points to identify niche areas for the UK to exploit.

3.11 The Agency will work closely with national funders of these areas to ensure that the programme is well understood, that respective remits are clearly defined (of ESA, the Agency and the science funders) and that, where appropriate, specific funding calls are available. The lack of space-based research in some of these fields has led to scepticism about the relevance of space in some quarters; the Agency recognises that it is required to actively promote the benefits of research in space environments and to demonstrate its relevance, both to the science community and on behalf of the science community to other government bodies. This will be done through formal (e.g. submission to advisory boards; memoranda of understanding) and informal (e.g. direct conversations; attendance at relevant conferences and events) channels.

3.12 Industrial research and exploitation of space environments

The Agency will work closely with industrial partners and government bodies responsible for facilitating industrial applications of space – primarily the Technology Strategy Board (TSB) and the Satellite Applications Catapult. The cross-disciplinary nature of space environments necessitates that the Agency also reach out to a broader range of industry than simply the traditional space sector. This will be done through the Knowledge Transfer Network, maintaining a visible presence at industry events and promoting new opportunities through information sessions. Representative bodies of sectors likely to benefit from space environments research will be consulted, including the Institute of Materials Minerals and Mining (IOM3), the UK Space Biomedicine Consortium (IOM3) and UKspace.

[10] such as Quantum Physics for New Quantum Technologies; Emergence and Physics far from Equilibrium; and the study of the Physics of Life.

[11] See http://www.epsrc.ac.uk/research/ourportfolio/themes/manufacturingthefuture/Pages/future.aspx

[12] The GER provides a framework for strategic planning of space exploration, agreed by 14 national space agencies. This is agreed at an inter-agency level and built on consultation and input from governments, scientists and engineers.

3.13 The Agency also has a role to play in representing UK industry in an international context, ensuring that UK industrial capability and interests are reflected in international roadmaps and in the specific programme plans to which the UK subscribes – positioning the UK for long-term opportunities whilst making the most of more immediate plans.

3.14 The Agency will also act as a national point of contact for expert advice on commercial uses of, and access to, space environments; advising industry on the advantages, limitations and technical requirements of different platforms – be these funded privately or through government programmes. To maximise commercial exploitation, scientists engaging with the programme will be encouraged to consider the downstream and commercial uses of their research.

3.15 Education

Space environments and human spaceflight give an exciting context for education. The Agency will exploit the opportunity presented by UK involvement in these programmes to deliver its existing education, outreach and skills strategy[13]. The human angle, and the novelty of science performed in space or space-like conditions, gives these programmes a great attraction and potential to reach people who would otherwise have been uninterested. However, it must also be noted that any educational activity which is seen to be merely novel, or for which the spaceflight angle is unnecessary or contrived, will be rejected and should be avoided.

3.16 As well as using this inspiring context generally, specific opportunities will be exploited as they arise, for example by implementing educational activities tied to specific science experiments, or through programmes of activity tied to astronaut missions. Given the additional publicity generated by space environments research, scientists will be actively encouraged to consider education and outreach opportunities and wherever possible the Agency will support them to deliver these. This may be through direct support or through coordinating with relevant bodies, such as ESERO-UK[14], the National Space Centre or Association of Science and Discovery Centres.

4. Governance

4.1 This strategy is owned by the Chief Executive of the UK Space Agency. The strategy is drafted in consultation with the community and broader public, through official advisory boards and a public consultation. The UK Space Agency Space Exploration Advisory Committee (SEAC) and the Environments Working Group (SEWG) will

[13] www.bis.gov.uk/assets/ukspaceagency/docs/strategy/uk-space-agency-education-strategy-march-2011.pdf
[14] European Space Education Resource Office, UK. Based at the Science Learning Centre in York, this office helps to deliver the Agency space education activities and acts as a national coordinator of educational materials.

review the strategy annually and monitor progress against the stated goals. Due to dependence on other bodies, its content is subject to their approval and this will be sought for each future revision. Delivery of the strategy will be monitored by the SEWG and defined in annual work plans overseen by this group and its parent committee, the SEAC.

4.2 Evidence

National evidence for the impact of work described in this strategy is, in some areas, incomplete or speculative. This is inevitable when participating in new areas; estimates and market analyses are made based on the best data available and reasonable projections. The Agency will proactively gather evidence illustrating the effectiveness of the programme as it progresses. This evidence will be used to shape future iterations of this strategy and inform decisions concerning continued participation space environments and human spaceflight programmes.

Annex 1: Definitions and Background

i Definitions

i.a **'Human spaceflight'** is here used to describe all human presence in space. Practically, this may be via one of two routes: 1. State-funded projects, in particular the International Space Station (ISS)[15], a permanently crewed presence in low earth orbit (LEO). 2. Commercial spaceflight providers – none of these is yet fully operational for human missions, but several are expected to commence flights bearing the first commercial astronauts and 'space tourists' or 'participants' (as distinct from astronauts) in the next few years.

i.b **'Space environments'** is used to refer to all research conducted in space, utilising one or more condition of the space environment – for example, microgravity, radiation, extreme vacuum – or in ground-based facilities which mimic these conditions, such as drop towers simulating microgravity or Antarctic stations providing isolation. As such, 'space environments' essentially describes several related sites of study, rather than a scientific discipline or methodology *per se*. Particular strands of research in fields as diverse as quantum physics, applied psychology and advanced manufacturing may be considered to fall under the umbrella of 'space environments research.'

ii Background, context and timing

ii.a At the European Space Agency (ESA) Council of Ministers in November 2012, the UK committed funding for the first time to the European Life and Physical Sciences (ELIPS) programme and the ISS Utilisation programme: 16M€ was committed to ELIPS over a four year period, and 20M€ to the ISS as a 'one-off' contribution. This marked the first time the UK had been involved in human spaceflight, and the decision was based upon detailed business cases prepared by the UK Space Agency in consultation with scientific and industrial communities and other government bodies. These business cases assessed the costs and benefits in scientific, economic and societal terms. Strategic discussions were held with key stakeholders and areas likely to benefit were identified, based upon robust market analysis, community consultation and research. This forms the basis of the Agency's goals for the programme.

ii.b The present document expands these goals, identifies the challenges in achieving them and presents an overarching strategy for maximising the UK's return from space environments and human spaceflight.

[15] It should be noted that there is also a Chinese human spaceflight programme independent of the ISS, though this currently offers no opportunity for UK participation

Annex 2: List of stakeholders

Stakeholder	Relevant Areas of Interest
Government Bodies	
Biotechnology and Biological Sciences Research Council	The BBSRC is the UK's main public funder of bioscience. It invests in research and training, with the aim of furthering scientific knowledge, to promote economic growth, wealth and job creation and to improve quality of life in the UK and beyond. Of particular relevance is the strategic priority of healthy ageing, which might be addressed through human research in space and space-analogue environments
Medical Research Council	The MRC seeks to improve human health through world-class medical research. To achieve this, it supports research across the biomedical spectrum, from fundamental lab-based science to clinical trials, and in all major disease areas. It works closely with the NHS and the UK Health Departments, giving a high priority to research that is likely to make a real difference to clinical practice and the health of the population. In the frame of this programme, human research in space and space-analogue environments can be used to address a wide range of medical questions. Particularly, research on ageing, human physiology and immunology.
Science and Technology Facilities Council	The STFC supports UK research in a range of fields. Specific STFC 'science challenges' which might be addressed by research in space environments include 'What is the Universe made of and how does it evolve?'; 'How do galaxies stars and planets form and evolve?'; 'What are the laws of physics in extreme conditions?' and 'Are we alone in the Universe?'. The STFC is the principal government funder of astrochemistry and astrobiology in the UK.
Engineering and Physical Sciences Research Council	The EPSRC is the main government funder of research and training in engineering and the physical sciences. Research areas of direct relevance to this strategy are materials research, fluid physics and rheology.

	Work in space environments leads to better understanding of thermophysical properties of materials and novel manufacturing processes – The Agency see synergy here with EPSRC's research themes of 'Manufacturing the Future', 'Energy' and 'Physical Sciences'.
Department for Business Innovation and Skills	BIS is the parent Department of the UK Space Agency.
TSB Satellite Applications Catapult	The Satellite Applications Catapult is an independent innovation and technology company, created by the Technology Strategy Board to foster growth across the economy through the exploitation of space. It helps organisations make use of and benefit from satellite technologies, and bring together multi-disciplinary teams to generate ideas and solutions in an open innovation environment. Together with Scottish Enterprise, the Satellite Applications Catapult ius establishing a 'Space and Life Sciences Centre' which could provide a route for commercialisation of UK research in space environments.
International Bodies	
European Space Agency	The UK Space Agency works closely with ESA for the delivery of programmes. ESA manages European involvement in the ISS and operates the Columbus module. The UK is a member of ESA's ISS Utilisation and ELIPS programmes.
International Space Exploration Coordination Group	The ISECG is an international forum of 14 space-faring nations which seeks to coordinate the long term space exploration goals of its members. The UK is an active member.
Learned societies	
Institute of Materials, Minerals and Mining	IOM3 is a major UK engineering institution whose activities encompass the whole materials cycle, from exploration and extraction, through characterisation, processing, forming, finishing and application, to product recycling and land reuse. It exists to promote and develop all aspects of materials science and engineering, geology, mining and associated

	technologies, mineral and petroleum engineering and extraction metallurgy, as a leading authority in the worldwide materials and mining community.
Astrobiology Society of Britain	The ASB is a learned society dedicated to the understanding and advancement of astrobiology in the United Kingdom.
UK Space Life and Biological Sciences	UK Space LABS is an association of academic and commercial entities and individuals which pursues a unified strategy to draw upon the contributions, knowledge, activities and strengths of its members. It identifies, supports and promotes areas of synergy between space and terrestrial healthcare and conducts translational R&D in support of UK interests.
Institute of Physics	The IOP represents the UK physics community and seeks to advance physics education, research and application. It engages with policymakers and the general public to develop awareness and understanding of the value of physics.
Royal Astronomical Society	The RAS represents the astronomy and space science communities in the UK. It encourages and promotes the study of astronomy, solar-system science, geophysics and closely related branches of science.
Trade bodies	
UKspace	UKspace is the trade association of the UK space industry. It is dedicated to representing the interests of our members, supporting them in growing and developing their businesses. It represents the interests of industry with the UK government, parliament and national and international stakeholders.