Report of the UK Space Exploration Working Group - Summary

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The UK Space Exploration Working Group

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The Group was set up in January 2007 as an *ad hoc* committee to:

- review current global plans for space exploration;
- assess what opportunities and benefits exist for UK participation; and
- provide advice to BNSC and partners as to which areas the UK should focus on if it wishes to engage in space exploration.

This analysis is on behalf of BNSC partners for input to UK Space Board, BNSC Space Advisory Council, PPARC Science Committee (or its successor), BNSC Space Technology Advisory Board and other relevant advisory committees. The views expressed are those of the members of the Group and not necessarily of their institutions.

Executive summary

The UK Space Exploration Working Group recommends that the United Kingdom takes maximum advantage of the unique opportunities presented by the Global Exploration Strategy. It should play a full and active role in these programmes and the endeavours that will define space exploration in this century.

Involvement in both robotic and human elements of space exploration should be strategically targeted to develop new capabilities by building on existing UK strengths. Such activities will generate scientific knowledge and return value to the UK economy through technological challenges, innovations and new commercial ventures. Furthermore they will engage British society in the full excitement of space exploration and help to inspire a new generation of scientists and engineers.

We recommend early investment in a demonstration programme that would build both on current areas of strength and engage in preparatory human spaceflight activities. This will in due course enable the UK to judge the value of a stronger involvement up to a level commensurate with our GDP.

The recently published Global Exploration Strategy outlines the ambitions of the world's space-faring nations and their part in a new era of space exploration: one that will see humans and robots working in partnership on the surfaces of the Moon and Mars, while unmanned probes venture out across the far reaches of our solar system. These efforts will seek answers to fundamental questions including the nature and origin of life in the universe.

Participation in the 'grand challenge' of space exploration provides key opportunities for the UK to:

- shape and participate fully in programmes of space science;
- build on its history of excellence in science, technology and innovation;
- form valuable new collaborations with international partners;
- inspire the next generation of scientists and engineers; and
- exploit the direct and indirect commercial opportunities that will be created.

Studies of the solar system may be divided into four stages with increasing levels of sophistication: observation from Earth; observation from spacecraft (including fly-by); robotic landing and exploration; human space exploration *in situ*. The increasing levels of technical challenge have inevitably set the order in which these activities have been tackled. Observation from Earth has a history that is as old as astronomy, while remote observation from spacecraft has been used to great effect during the last 40 years. These endeavours will continue to offer excellent returns by making use of advances in technology.

So far all four stages have been applied to exploration of the Moon, though somewhat superficially given its relative accessibility. In contrast, exploration of the other planets and their moons with landers has begun only recently, and a natural next step, rich in opportunity, is to extend this strategy to Near Earth Objects. Exploration of extraterrestrial surfaces using humans is a goal for the future. While offering the most profound impact for scientific knowledge and human culture, it is also the most costly. It is however a challenge that reaches beyond just science: human exploration of space promises to impact society, medicine and commerce and when the economic assessment is made, these wider issues will have to be taken into account.

Mission planning for a detailed lunar exploration programme involving both machines and humans is already underway. Human space exploration of more remote sites, such as Near Earth Objects and Mars, may be carried out in a longer timeframe, but a return to the Moon will come first. This is the context that has inspired the Global Exploration Strategy and created both opportunities and challenges for the UK.

Having considered these issues, we recommend that the UK should maintain and extend its significant roles in planetary science and robotic exploration through its participation in relevant ESA programmes and in collaboration with other international partners. It should build on its strengths in these areas through international collaboration in a programme of space exploration, taking an active role in selected aspects from the outset.

Further, we recommend that the UK should initiate a technology demonstrator programme focused on current areas of strength, consider joining ESA's microgravity programme, build capacity in relevant science communities across the UK and engage in preparatory human spaceflight activities. These will enable the UK to evaluate the benefits of increasing our involvement in space exploration to a level commensurate with our GDP.

In order to gain maximum benefit from these programmes the UK should develop a formal strategy for exploiting the substantial, wider benefits of space exploration to science education, commerce and culture. This should include funded programmes of public engagement and education.

We believe that space exploration is a strategic activity, with both tangible and intangible benefits across a range of areas. Until now, this has been driven by pure science, but the human exploration of space is a broader ambition. This will require new funding mechanisms to which the science budget should only contribute where appropriate and justified.

'Earthrise' photographed from the Command Module of Apollo 11 (NASA)

A UK vision for space exploration

The recently published *Global Exploration Strategy: The Framework for Collaboration*[*] outlines the future ambitions of the world's space-faring nations and their part in what promises to be one of this century's most ambitious programmes of science and discovery. This is the dawn of a new era in space exploration; one that will see humans and robots working in partnership on the surfaces of the Moon and Mars, while unmanned probes venture out across the far reaches of our solar system. These efforts will seek answers to questions of fundamental importance to science.

Humanity faces many challenges at the beginning of the 21st Century. The exploration of the solar system offers a much-needed opportunity for the peaceful co-operation of all the nations of the world, which in addition to bringing technological advancement and economic growth, may also help to build a sense of global solidarity and fellowship.

We envisage a programme of space exploration in which this country plays a prominent role in the activities described by the Global Exploration Strategy. This will generate new scientific knowledge, increase excitement for science and technology in the young to build the workforce of the future, and provide a grand challenge to invigorate the UK economy.

While science and technology lie at the core of such activities, the wider benefits span the boundaries between society, commerce, culture and education and appeal to the sense of discovery and inspiration experienced by ordinary people from all backgrounds.

In our opinion it is important that the UK investigate new opportunities to collaborate with other nations that exploit our strength in planetary exploration. Our objective should be to target our participation on areas that have the greatest potential to yield benefits to science, technology, industry and the wider public. We believe that this balanced approach will benefit the UK economy and our quality of life through increased scientific knowledge, commercial opportunities, novel technologies, and inspiration in the field of science education. Cultural benefits will also flow from our collaboration in what seems set to become one of the international grand challenges of the 21st Century.

It is important that a commitment, in principle, to the long term programme of human and robotic exploration is made now, and that preparatory programmes should commence immediately, since many of the key international players are actively developing plans and offering partnership opportunities that may not remain open for long. By being involved in this first wave of development, the UK will secure a position of influence. This will enable us to take our full share in both scientific discoveries and in any commercial developments which exploit opportunities in the neighbourhood of Earth that may take place in both the near and more distant future. The UK has a long and noble tradition for exploration across our planet. It is now time for a new vision and a more distant voyage.

Recommendation:	**Our key recommendation is that the UK should pursue a programme of space exploration in which an active role is played in both the robotic and human elements of the Global Exploration Strategy.**

[*] *The Global Exploration Strategy: The Framework for Coordination*, May 2007, agreed and published by ASI, BNSC, CNES, CNSA, CSA, CSIRO, DLR, ESA, ISRO, JAXA, KARI, NASA, NSAU, and Roscosmos, http://esamultimedia.esa.int/docs/GES_Framework_final.pdf

Synthesis of findings

There are scientific questions of great interest that can only be answered through the continued exploration of space. To date much of this science has been achieved through the use of unmanned spacecraft and robotics – in the UK exclusively so. However it is clear that in the coming epoch of space exploration there will be many questions that can only be answered if humans are present. This is especially true for the exploration of the Moon and Mars. Human lunar exploration will re-start around 2020, while a human Mars mission is not expected until the 2030s. A permanently crewed lunar outpost will enable areas of science well beyond the study of the Moon itself.

The debate as to whether or not humans or robots are best suited to space exploration is now redundant. Just as there are scientific questions of profound importance to space science that for the foreseeable future can only be addressed by using automated platforms, so there are those that can best be addressed through human presence.

Future UK space exploration strategy should acknowledge this and, while building upon our tradition of excellence in the field of remote sensing and satellite technology, we should prepare for a future role in programmes of human space exploration.

Exploration of the Moon

The primary scientific importance of the Moon arises from the fact that it has an extremely ancient surface, mostly older than 3 billion years, with some areas extending almost all the way back to the origin of the Earth-Moon system 4.5 billion years ago. It therefore preserves a record of the early geological evolution of a terrestrial planet, which more complicated bodies such as Earth, Venus and Mars have long lost, and a record of the inner solar system environment from billions of years ago. The Moon is thus a museum of the history of the solar system, and contrary to public perception, its surface, with its varied geology, remains largely unexplored. The surface can be surveyed by orbiters, but access to subsurface will require a programme of field geology and geophysics (including drilling to c. 100 m to km depths) that will require a mix of robotic and human presence. In addition to its scientific value, a thorough geological survey of the Moon will enable its long-term commercial and economic potential to be assessed and protected.

The Moon is also a vantage point from which to undertake new and challenging observations. A lunar observatory will revolutionise many areas of astronomy. These will include searches for evidence of life elsewhere in the universe, our understanding of the origins of life on Earth, and of climate change with its implications for the future of life on our planet:

(i) We are now starting to discover large planets in other star systems. But to study Earth-like planets we may need a stable observatory on the airless Moon, since the accuracy we require may well be beyond the expected ability of free-flying telescopes of missions such as Darwin. Moreover, spectroscopic observations of Earth from the Moon will provide knowledge that we will require in order to interpret the spectra of extra-solar Earth-like planets when and if these are discovered.

(ii) Understanding the dynamics of the connection between the Sun and the Earth is vital for predicting climate change. This is one of the most urgent challenges facing humanity and a stable lunar observatory could prove invaluable. It would also provide us with essential knowledge about space weather, which we are going to need if we are to protect astronauts on future missions beyond Earth.

Exploration of Mars

Mars is also an important target for exploration, especially in the context of our search for life elsewhere in the solar system. Mars' surface has been mapped by orbiters at 10-100 m scale but the absolute chronology of its surface features is unknown. Existing knowledge from Mars hints that geological changes affect the habitability of a planet. The history and nature of its lost atmosphere are unknown and may have important lessons for our own planet. Mars is a laboratory where we can learn about the habitability of planets and the prospects for life elsewhere.

Before humans can visit Mars to complete the above, we need to understand the environmental hazards, be able to predict dust storms and measure the UV and cosmic radiation at the surface and to identify the most attractive locations. These require explorations with robotic sensors and the ability to return rocks from the surface, a venture which requires technical advances.

Human exploration of Mars will also require that we gain operational experience on hostile planetary

surfaces, and a better understanding of the physiological and psychological consequences of long-term human exposure to the space environment. This knowledge and experience will be gained through precursor activities on the Moon and the International Space Station.

Humans and robots

Exploration on the Moon offers unique information on the history of the solar system (including the early Earth's atmosphere and dynamo) and the evolution of our Sun. Recovering that evidence left on and beneath the lunar surface by the solar wind, and bombardment by comets and cosmic rays will require collection of material at depths of 100 metres or more in a variety of different geological settings on the surface of the Moon. We agree with the RAS Commission, which concluded that a robotics approach alone could not deliver this now or in the foreseeable future.

Technology and knowledge exchange

Space exploration of the Moon, Mars and beyond offers unique opportunities for the UK economy through development of a generation of skilled engineers, products and services. Today the UK has secured a positive position in such exploration technology and KT through its involvement in robotic exploration of the planets. It is sensible to build upon this by seeking wider opportunities for such partnerships since these would have the greatest potential for UK industrial leadership.

In the short–term we can therefore expect technology to focus on lunar and Mars initiatives that address communications, precision landing, smart roving, sample collection and surface operations. There are in addition new opportunities; from novel sources of energy and their management to drilling and construction. These bring together needs that can exploit already established UK terrestrial expertise in transport, aeronautics, materials, energy conservation and biomedicine.

Commerce

Human society is now at a 'tipping point' where real business cases are being identified space bases services beyond relay of information around the Earth. We feel that commercial markets could complete, through mechanisms such as public-private partnerships, the government funding necessary to launch such new space ventures. Exploitation and enhancement of an initially government-stimulated infrastructure could enable highly profitable commercial applications in the same way that data-relay, GPS and reconnaissance have developed around the Earth. We have explored an example of data relay from a likely growing number of robotic and human lunar explorers and concluded that value can be extracted, although risk and customer commitments do need further study.

The UK is fortunately a leader in numerous areas of technology and science which lend themselves to innovative services linked to exploration. Government commitment to supporting the academic and industrial base in the UK should continue, coupled with revision of the UK space regulatory framework to maximise opportunities for entrepreneurs. High profile opportunities involving launch vehicles and low cost space missions are noteworthy, and will also serve to increase public interest with benefits to the future UK workforce. Commerce, along with education and society also stand to gain strong positive benefits from a UK presence in human space exploration and we endorse the recommendation to introduce a new programme to quantify these benefits.

Finally, if the UK does not act to secure these clear opportunities in space exploration, others will fill the void. Significant economic gains as well as benefits to the quality of life in the UK will not occur.

Society

The benefits associated with increased UK involvement in the exploration of space are truly wide-ranging – from the international standing of the UK, through education and training in subjects vital to future wealth creation, to the public view of the UK as a world leader.

It is widely accepted that there is a crisis in education in the UK, with the numbers of youngsters enrolling in science and technology subjects dropping at all levels. Space exploration can help, offering an outstanding opportunity to motivate a whole new generation of young people to study science.

There is no doubt that space is awe inspiring for the public and especially the young, who are the seed-corn for our future technology. Motivational factors are stronger where human astronauts are involved.

Planning for a renewed and enlarged programme of human space exploration is well advanced in several space-faring nations. Europe, through ESA, is actively involved and expects to begin recruiting a new astronaut corps next year.

Implementation and scenarios

Reviewing the current involvement of the UK in robotic planetary science, we have concluded that this has yielded good scientific return and has helped build a capable technology base in universities, national laboratories and industry. It has also contributed to the UK's 'innovation engine' through the training of skilled individuals and by creating technology which has terrestrial application. The UK's present involvement in the ESA science programme and also in the robotic exploration of Mars (primarily through the ESA Aurora programme) is to be commended.

We have concluded that there is immediate scope to yield increased benefit to the UK through a targeted, near term involvement in exploration of the Moon, emphasising UK science interests and expertise in small satellites and robotics and likely to be undertaken through international cooperation on a bilateral/trilateral basis. A first mission could be launched as soon as 2012. Such involvement would make the UK an early contributor to the Global Exploration Strategy.

There does not presently exist a compelling rationale for the UK to immediately join the current ESA human spaceflight programme at a GDP level, as this is focused on completion and exploitation of the International Space Station. In particular, there would be little or no technological return and, *a priori*, the UK cannot be certain of securing astronaut places given the expectations of other member states.

However, we have concluded that there will be excellent scientific opportunities in a range of disciplines in the period beyond 2020 when the US intends to establish a permanently crewed lunar outpost, and also there exist significant wider societal benefits in participation in human spaceflight. This means that aiming to participate in the human exploration of the Moon (and later, of Mars) is a valid and important objective for the UK. Such involvement would build on the existing UK capabilities strengthened through early involvement in robotic lunar exploration.

In order to bridge the gap between the UK's present activities and capabilities and this mid-term goal of human exploration, it is necessary to develop a detailed plan for a preparatory phase of UK involvement in human spaceflight. This plan should be implemented in the decade beginning 2010 and involve a well-structured mix of scientific, technological and educational goals using the International Space Station as the destination as set out in Appendix D of the full report, a range of approaches seem feasible and a first astronaut flight in 2012 is quite conceivable.

In summary, we advocate a targeted and step-wise UK space exploration strategy based on both robotic and human activities. This national strategy should be implemented through negotiation with international partners in the context of the Global Exploration Strategy. Using this approach, it will be possible to demonstrate the scientific, technological, commercial and societal benefits as each milestone is implemented.

Recommendations

In order to make the most of emerging opportunities in the field of space exploration, maintain existing standards of excellence and develop new capabilities that ensure a prominent role in future international space activities the UK should:

1. Pursue a programme of space exploration in which an active role is played in both the robotic and human elements of the Global Exploration Strategy.
2. Develop a strategy for exploiting the substantial, wider benefits of space exploration to science, education, commerce and culture. This should include co-ordinated, properly funded and sustained programmes of public engagement and education.
3. Maintain leading UK involvement in planetary science within ESA Programmes and, where appropriate, in collaboration with other international partners. This must include continued involvement in the robotic exploration of Mars, especially through ESA's Aurora programme.
4. Initiate a targeted UK robotic lunar programme based on the use of low cost satellites, rovers and resulting operational services, ideally in collaboration with other partners while keeping control of some key technologies.
5. Identify and exploit opportunities for mutually beneficial, bilateral activities with NASA and other prospective partners. The Global Exploration Strategy and the recently signed NASA-BNSC Joint Statement of Intent create narrow windows of opportunity during which agreements of high value might be secured.
6. Take appropriate early steps to prepare for a future role in human space exploration efforts by securing flight opportunities for British astronauts within the next decade to conduct science research and advance science education.
7. Build capacity in relevant UK scientific and technological communities by funding and establishing academic chairs, fellowships, post-doctoral and doctoral positions at UK centres of excellence. These positions should cover the full range of life and physical sciences relevant to the exploration programme, and would expand upon the success of the existing Aurora Fellowship scheme.
8. Engage with research and industrial communities across a broad range of sciences and technology to assess the opportunities that may be raised in the new era of space exploration. This should extend beyond the existing BNSC core partners (DIUS, STFC, NERC) to include MRC and EPSRC and industrial sectors such as mining, prospecting, media and entertainment.
9. Investigate the current opportunities offered by a modest focused subscription to ESA's life and physical sciences programme (ELIPS) which could facilitate UK access to ESA's microgravity facilities in order to build up the UK life and physical sciences microgravity community in preparation for the longer term opportunities that will arise from participation in the GES.
10. Initiate a substantial and sustained national technology R&D and demonstrator programme focused on those areas of technology which underpin the UK's goals within the GES and strengthen the UK position in related ESA programmes. Knowledge exchange opportunities should be embedded in the programme from the start.
11. Survey and identify customer commitments, and quantify value added business for the exploration-related services identified in this report – from near term (e.g. lunar communications relay) to long term (e.g. exploitation of planetary mineral rights).
12. Review and update the UK licensing regime to encourage high value added activities such as space tourism and related activities such as inexpensive, regular and reliable launch of scientific payloads and small spacecraft which build on existing UK strengths and support proposed UK efforts in exploration.

These strategic recommendations would allow maximum benefit to the UK by focused incremental funding in national, ESA and other international bilateral initiatives. The proposed programme represents a broader ambition than the current science-driven exploration of space and so additional funds will be needed to promote the necessary activities in education, science, technology and knowledge exchange.

We believe this will generate new scientific knowledge, increase excitement for science and technology in the young to help build the workforce of the future, and provide a grand challenge to invigorate the UK economy.