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Comments on the BNSC Space Exploration Solicitation

Dear Sirs,

Thank you for the opportunity to respond to the BNSC solicitation on UK Space Exploration policy. Here, briefly, are my comments.

Exploration AND Development

Space exploration should not be separated from considerations of space *development:* the harnessing of the energy and material resources of space for the economic benefit of humanity, with the ultimate goal of permanent human expansion into space.

In a speech given at the Goddard Memorial Symposium in March 2008, John Marburger, Director of the White House Office of Science & Technology Policy (OSTP), said the following **[1]**:-

> **"The one big question any vision of space exploration must answer is "Are we going to do it at all?" As I put it in my speech two years ago, "Questions about the vision boil down to whether we want to incorporate the Solar System in our economic sphere, or not." If we are serious about this, then our objective must be more than a disconnected series of missions, each conducted at huge expense and risk, and none building a lasting infrastructure to reduce the expense and risk of future operations. If we are serious, we will build capability, not just on the ground but in space. And our objective must be to make the use of space for human purposes a routine function."**

The question for any appraisal of UK space exploration priorities is therefore: Does the UK want to incorporate space into its economic sphere, and if so, what is it going to do about developing the kind of infrastructure that Marburger describes? If not, is the UK willing to pay the economic and social cost of being left behind as other nations move to develop space?

Global space activities are presently in a state of flux. Space tourism is now a reality, while conventional government programmes labour under heightened budgetary pressures. Independent commercial manned orbital launch, and commercial space stations appear a likely prospect in the next decade. Advocates of "NewSpace" and commercial spaceflight claim that this will lead to lower-cost and more frequent access to space, and consequent new economic opportunities. If there is to be a "gold rush" of commercial space development, the United Kingdom should position itself to be in the business of making and selling shovels.

Space Policy Goals

The United Kingdom's space policy should aim to be:-

- **Innovative:** The UK space policy should harness the best and brightest in British science and engineering. Entrepreneurial activities in space engineering and development should be actively and specifically fostered. Space "incubators" similar to the eSpace Center for Space Entrepreneurship at the Unversity of Colorado **[2]** should be established and actively promoted.
- **Agile:** The UK should be ready and able to respond to rapid technological and economic change in the space marketplace. Governmental "five-year plans" which essentially say 'keep on doing the same old thing because it appears to work' are too little, too late.

- **Relevant:** The UK space policy should be seen to deliver goals which the electorate feels are worthwhile and relevant. The BNSC needs to be become much more visible and proactive in the “explanation mission” of presenting the scientific, economic and educational value of space. The man in the street has heard of NASA. He has not, sadly, heard of BNSC.
- **Sustainable:** British companies undertaking aerospace research and development should be helped and encouraged to produce marketable products as early as possible. A company with a steady sales revenue stream is more likely to survive (and re-invest in expanded R&D) than one which solely depends on intermittent and unreliable government funding.

Technology Strategy Goals

- **Propulsion, Propulsion, Propulsion**

  In the late 1950's and 1960's, the United Kingdom was a world technology leader in liquid-fuelled rocket engines, with the development of the Armstrong-Siddeley Gamma series of kerosene-HTP (High-Test Peroxide) rocket engines which powered the Black Knight and Black Arrow launch vehicles. The engines were structurally simple and highly reliable – of the 22 Black Knight and 4 Black Arrow launchers, involving 128 Gamma engines, there were *no* engine failures **[3]**. That technological lead has long since been lost. The Vulcain and HM7-B engines for ESA's flagship launcher, the Ariane 5, are manufactured by SNECMA (*Société Nationale d'Étude et de Construction de Moteurs d'Aviation,* now part of the SAFRAN group). The most advanced liquid-fuelled rocket engines in commercial use today are typically of American, Russian or French design.

  Although there is some early-stage research work in the UK in advanced rocket propulsion which shows great promise **[4][5]**, the overall level of commercial activity in space propulsion systems in the UK appears depressingly low. The availability of domestic space propulsion engineering expertise would facilitate vertically-integrated assembly of main spacecraft structures and propulsion by the same engineering team – bringing propulsion, structures and most avionics fabrication in-house has provided SpaceX with significant cost and time savings in constructing its Falcon 1 and Falcon 9 launch vehicles, for example.

  I would suggest an active British effort to construct an **advanced, multiply-reusable commercial cryogenic rocket engine**, along the lines of the development work currently being undertaken by XCOR **[6]** and others in the United States. A fully reusable, deeply-throttleable liquid-methane/liquid-oxygen electrically-pumped rocket engine in the 1000-5000 kgf class would have a variety of applications, from small reusable suborbital research vehicles and space tourism systems akin to the XCOR Lynx **[7]**, to commercial cargo vehicle propulsion/service busses like the OSC Cygnus **[8]**, which could be replenished from on-orbit propellant depots (q.v.) to reusable lunar landers which could be resupplied with liquid oxygen manufactured in-situ from lunar regolith.

  Grand Prix Rocket Racing: The new British rocket engines could also be fitted to high-performance racing aircraft, in a similar manner to the Rocket Racing League **[9]** in the United States. The UK already enjoys a strong technological lead in Formula One motor racing, and this would seem a logical extension and an excellent showcase for British aerospace engineering. I note that the Red Bull Air Racing aerobatic races held at London Docklands regularly attract over 50,000 spectators.

  New Schneider Trophy: A regular competition (along the lines of the Schneider Trophy of the 1920's and 1930's in which British teams were remarkably successful) could be organised for small manned aerospaceplanes, with prizes given for maximum speed/maximum altitude with a given propellant load and structural mass ratio. The prize would encourage the design of highly efficient propulsion systems including air-breathing rockets.

- **Inexpensive Modular Spacecraft with Open Interfaces**

  The United Kingdom already has an exemplary record in the innovative development of small, low-cost satellites, thanks to the activities of Surrey Satellite Technology Limited (SSTL)**[10]**. The UK should continue to enhance that lead by developing a common modular commercial spacecraft bus architecture, with fully standardised power, data and cryogenic fluid interfaces that allow external modules to be plugged and unplugged at will (including on-orbit servicing/repurposing). Since the UK is not directly constrained by the US ITAR technology transfer legislation, the UK could freely publish these interface specifications using open (or at least RAND) licenses to third-party and international collaborators. The goal would be to turn spacecraft systems into a (UK-defined!) commodity architecture, in the same way that the first generation of IBM PC's created an open platform using the ISA (Industry Standard Architecture) motherboard bus.

- **Space-based Infrastructure**

  As Marburger states, if we are serious about exploring space, we need to make a positive commitment to create the necessary technological infrastructure which will support this. This includes, but is not limited to: reuseable launch vehicles; low-maintenance reusable thermal protection systems; aerobraking; propellant depots/on-orbit spacecraft refuelling/replenishment; on-orbit assembly and construction; closed-cycle life-support; space tugs/“prox-ops” teleoperation systems; in-situ resource utilisation; artificial gravity and bioscience of partial gravity; tethers (momentum exchange and electrodynamic). Many of these can be addressed with inexpensive, small-spacecraft programmes.

- **Satellite Solar Power**

  Satellite Solar Power (SSP), the harnessing of sunlight in space to generate electrical power to supply markets on Earth, was first proposed in 1968 by Dr Peter Glaser, but with recent heightened concerns over continued fossil energy supply and climate change, SSP has received renewed attention.

  With apologies to its strongest advocates, I am not yet fully convinced about the ultimate economic viability of SSP for providing significant quantities of baseload electrical power. However, I do feel that it is a strategically important area of technology which the United Kingdom should be actively interested in. In any event, highly-efficient and ultralightweight photovoltaic systems have a wide variety of useful economic applications on Earth, even if their space-based deployment is more problematic.

  SSP may well make a useful contribution to human space exploration/development goals. One could envision ultralightweight SSP systems in the low megawatt class (much smaller than the multi-GW behemoths envisioned for baseload applications) being positioned at the EML-1 and EML-2 Earth-Moon Lagrange points, to supply beamed electrical power to human Lunar expeditions during the 14-day Lunar night. Such systems would be less politically sensitive than the alternative of compact nuclear reactors for manned lunar bases, and the availability of excess electrical power at EML-1 and EML-2 and their relatively easy accessibility in delta-V terms may form a kernel for future space industrial/manufacturing applications in those locations.

  British provision of Lunar SSP would provide an effective method of buy-in to a future international human Lunar programme, along the lines of NASA's Project Constellation or its successor, as well as providing technological leadership in a potentially strategic area of sustainable energy generation.

- **Space Activity Suits**

  Mechanical Counterpressure Space Suits, otherwise known as Space Activity Suits, represent a potentially superior technology for protecting humans against the environmental extremes of space. Originally investigated by Paul Webb of NASA in 1968-1971**[11]**, Space Activity Suits provide pressure to the wearer's body via elastic garments, rather than pressurising the entire suit with breathing gas, as is done with conventional spacesuits. A SAS spacesuit would be significantly lighter and more mobile and less fatiguing to the wearer, and punctures would not affect the operation of the suit as a whole. The remaining issues with implementing the SAS are primarily mechanical – smaller joints such as the hands pose difficulties, and the tight elastic garments can be difficult to don and remove. Dava Newman's BioSuit group at MIT has recently made progress towards a fully practical SAS spacesuit**[12]**.

  Development of a commercial SAS spacesuit prototype would represent a relatively “easy” and low-cost, yet publicly visible and high-value project for a UK group. The suit could embody advanced materials such as electroactive polymers, and technologies such as embedded wireless biosensors, to provide a spacesuit that would “shrink to fit” on command, and continuously monitor the astronaut's vital signs.

- **Cheap Access To Space (CATS)**

  Last, and most importantly, lowering the cost of access to space should be a primary concern for every national space agency. Movement towards CATS represents not just good value for taxpayer money, but feeds a potential virtuous circle of lowered payload costs, and new markets whose increased economic activity would fund further R&D, lowering launch and payload costs still further. British engineer David Ashford **[13]** sets out a cogent argument for the “spaceplane” route, using fully-reusable winged aerospacecraft employing near-term technology to reduce launch costs by a factor of up to 1,000 within 15 years. The United Kingdom has a world-leading CATS technology in the form of the Reaction Engines Skylon **[14]**, a single-stage fully-reusable spaceplane which would take off from a conventional runway, and reach orbit using advanced air-breathing rocket engines. Initial engine tests are already under way.

For the UK not to fund CATS research & development would be, to put it kindly, “penny wise and pound foolish”. The superficial savings made now would cost greatly in lost economic opportunities in the years and decades to come.

Human Spaceflight

The scope document for the Space Exploration Review suggests that the Canadian model of involvement in human spaceflight in return for in-kind contributions of relevant technology (such as robotic teleoperations systems) may be a useful template for a British programme. I would agree, and would point to some of the areas discussed above as possible collaborations. I would also strongly suggest that the UK consider looking beyond the conventional route of joining the ESA manned programme when looking for the most cost-effective route to human spaceflight. Commercial actors such as SpaceX and Bigelow Aerospace are likely to welcome British collaboration. The UK should ask NASA whether it could assist with funding the COTS-D commercial human spaceflight development programme, in return for British astronaut involvement. Suborbital flights on Virgin Galactic would provide astronaut training, and could form the basis of a British “Teachers In Space” programme of compelling science and engineering education and outreach (see Law-Green 2007 for further discussion)**[15]**.

Conclusion

The United Kingdom has a singular opportunity to create an innovative, agile, compelling and economically rewarding space programme, should it decide to take it.

References

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[4] http://www.reactionengines.co.uk/

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[7] http://www.xcor.com/press-releases/2008/08-03-26_Lynx_suborbital_vehicle.html

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