A New British Space Age

A Response to the Royal Astronomical Society Report on Human Spaceflight

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3 Jan 2007

Artist's impression of the Virgin Galactic *SpaceShipTwo* suborbital spaceplane and *WhiteKnightTwo* carrier aircraft in flight. Image © Virgin Galactic.

Summary:
The recent Royal Astronomical Society report on human spaceflight *("Report of the Commission on the Scientific Case for Human Space Exploration"*, Close et al. 2005) highlighted the scientific and cultural value of human spaceflight, and noted that this is a field of endeavour that has historically been neglected in the United Kingdom. It recommended that the UK Government invest sufficient additional funds in the European Space Agency to allow the training of a small number of UK astronauts. Total additional expenditures in the range of £50 million to £120 million over five years have been quoted.

This author agrees with the positive assessment of Close et al. of the value of human spaceflight to the United Kingdom, but disagrees with the emphasis of the policy recommendations made so far. A number of relatively modest investments in UK commercial spaceflight would potentially deliver the same or greater scientific, cultural and economic returns, more promptly and at less overall expense than the proposed ESA funding.

This document outlines a number of potential projects to: enhance the UK's space technology base, improve cooperation with allied nations on commercial spaceflight, increase outreach and public involvement with UK space projects, preserve and protect the UK's space history, benefit UK science education and enhance the UK's international reputation in innovation and engineering excellence.

Introduction:

The Royal Astronomical Society recently published a report (Close et al. 2005) discussing the scientific and cultural merits of human spaceflight. The report concluded that human spaceflight has significant positive potential value for the United Kingdom, and recommended that the UK invest a modest additional sum (in the range of £50M to £120M) in the European Space Agency, to allow for the training and flight of a small number of British astronauts. The report was timely and generally well received, and created significant media interest around UK involvement in space, and the possibility of a UK manned space programme. As a result, the British Interplanetary Society (BIS) began an active online campaign for British involvement in the ESA astronaut programme.

However, Close et al. did not give a great deal of attention to the rapidly-developing field of commercial human spaceflight and its implications for the UK; something which I feel is a notable omission, and which I hope to address in this paper.

Commercial Human Spaceflight

The defining event for the development of commercial human spaceflight was the series of successful suborbital flights made by Burt Rutan's *SpaceShipOne* in Sep/Oct 2004 to win the $10 million Ansari X-Prize. This served as an existence proof that a small, innovative company operating on a relatively limited budget could develop and deploy capable manned spaceflight technology. The effects of this revelation have been profound. The SpaceShipOne technology has been licensed by Richard Branson for his passenger suborbital spaceline project *Virgin Galactic*. Several other companies in the United States, Canada, UK, Europe, Russia and South Korea are actively working on competing suborbital manned spacecraft. First test flights are expected to start around 2008. A "second tier" of companies is now developing to supply the spacecraft builders with products and services: examples include Frontier Astronautics (engines, attitude control systems) **[1],** Orbital Commerce Project (vehicle simulators, astronaut training) **[2]**, Orbital Outfitters (spacesuits) **[3].**

In December 2005, the X-Prize Foundation proposed a new competition for manned orbital spaceflight: the Human Orbital Vehicle Challenge **[4]** with prizes in the range of $50 million to $150 million.

NASA itself has taken note of developments in commercial spaceflight and instituted the *Commercial Orbital Transportation Services* (COTS) programme **[5]**. COTS is a $500 million project to use commercial launchers to resupply the International Space Station with cargo (and eventually crew) once the Space Shuttle is retired in 2010. Contracts were awarded to the companies SpaceX and Rocketplane-Kistler in August 2006.

At least two companies (Bigelow Aerospace **[6]** and Excalibur Almaz) are actively working on commercial manned space stations. Bigelow is working with the major US aerospace/defence contractor Lockheed-Martin on a design study to adapt their *Atlas V* rocket to carry passengers to and from Bigelow stations. Two companies (Constellation Services International and Space Adventures) have proposed systems to take paying passengers on circumlunar flights.

In December 2006, an editorial in the Wall Street Journal proposed that NASA funding of $100 billion for the establishment of a permanent moonbase be replaced with a $50 billion prize for the first private company to construct and man such a base. Although

there is no indication that such a prize will be established, it demonstrates the extent to which commercial spaceflight has fired the popular imagination.

A timeline of possible developments in government and commercial spaceflight over the period 2007-2014 is shown in the Appendix.

A UK Astronaut Corps?

To evaluate properly the proposal for ESA astronaut funding, we need to consider the timescale necessary for implementing the plan: selecting and training the astronauts and launching them into space; and what competition this will face from parallel developments in commercial spaceflight.

It is an unpalatable fact, but it bears pointing out: the European Space Agency *currently does not have an independent manned spaceflight programme*. While it has launch vehicles which would in principle be capable of carrying people into orbit (the Ariane-5 **[7]**), it does not have manned spacecraft to launch on them. ESA currently "borrows" passenger space from NASA and the Russian Space Agency when it wishes to fly its astronauts. NASA has announced plans under its Vision for Space Exploration to retire the Space Shuttle in 2010 following the completion of International Space Station assembly. The majority of the remaining Shuttle flights already have crew manifests. It is very unlikely that a British ESA astronaut would get to fly on the Shuttle before it is retired. Operations would therefore be dependent on Soyuz launches from Baikonur. The first Soyuz launch from Kourou is expected in 2008, but there are currently no plans to upgrade the Kourou pad to support manned spaceflight. The proposed joint ESA/Russian successor vehicle to the Soyuz, the Crew Space Transportation System (CSTS) is currently expected to be operational in the 2012-2014 timeframe **[8].**

Individual ESA astronauts often face quite lengthy delays between their initial appointment and their assigned mission, and there is no indication that British astronauts will be allowed to "jump the queue". The Swiss astronaut Claude Nicollier waited fourteen years from his initial appointment to his Shuttle flight on STS-46 in 1992. Christer Fuglesang, the Swedish Space Agency astronaut aboard STS-116 Discovery, waited thirteen years between joining ESA and his first flight. On that basis, if a British ESA astronaut were to be appointed as soon as possible in 2007, it would potentially be as late as 2020 before he/she actually got to fly into space!

The benchmark survey of projected commercial space activity is the Futron study of 2002, which forecast that by 2021, the commercial spaceflight market would be 5,000 people (suborbital flights) and 60 people (orbital flights) per year **[9]**. Estimates of the importance of the commercial spaceflight market continue to grow. In a speech given in February 2006, Burt Rutan estimated that 100,000 people will have travelled into space on commercial flights by 2021 **[10]**. If these optimistic forecasts of commercial space development come to pass, a British investment in the ESA manned programme runs the risk of appearing *irrelevant*, as the main centre of activity would long since have moved from the government to the commercial sector.

This is not a plea for the abandonment of a possible British ESA manned programme. The advantages of such a programme are well documented by Close et al., and I fully endorse those conclusions. It is a plea for proper consideration of both government and commercial spaceflight development. For example, if political commitments given by the British Government to ESA over use of the Columbus module on the International Space Station, blocked them from supporting British involvement in

commercial space stations, that in my opinion would constitute a significant mistake. ESA deserves to be supported, but not at the expense of other very promising developments in space.

In response to the question "Should the UK have its own astronaut corps?", my answer is "Yes, absolutely. By the way, we *already have one*. They work for Richard Branson."

ESA Support for Commercial Human Spaceflight

The European Space Agency has taken note of recent developments in commercial human spaceflight, instituting a grant scheme as part of its 'Survey of European Privately-Funded Vehicles for Commercial Human Space Flight' **[11].** The scheme, part of the ESA General Studies Programme, is expected to run for 9 months in 2006/7 and will fund studies into the technical and business viability of individual European commercial human spaceflight projects. An analogous study funded by the European Commission aims to assess commercial suborbital activities worldwide, and the necessary changes to regulatory frameworks.

This development is most welcome, and demonstrates that ESA understands the challenges and opportunities of commercial human spaceflight. However, it runs the significant risk of being *overtaken by events*. Several companies in the US (and two based in the UK!) are already at the stage of "bending metal", building fully flight-capable prototypes. The viability of commercial spaceflight will not be proven by design studies. It will be proven by real spacecraft performing successful flights.

> *"In all that time, they [NASA] let me go to space just five times… Gee, when this thing gets to be operational, I'll probably be able to go to space two or three times a day."*
>
> --- Robert "Hoot" Gibson, former NASA shuttle commander, now chief operating officer and chief test pilot for Benson Space Inc., speaking about the Dream Chaser spaceplane currently under development. **[12]**

UK Space Entrepreneurs

The UK need not be a "poor cousin" to its international competitors in space. We are home to a range of innovative entrepreneurial companies currently working on technology to transform our access to and use of space. Some notable examples are listed below:-

- **Virgin Galactic:** Virgin Galactic **[13]** is the current world leader in the development of commercial suborbital human spaceflight. The company, founded by British entrepreneur Richard Branson, has licensed the suborbital spaceplane technology developed by Burt Rutan's Scaled Composites for the X-Prize-winning *SpaceShipOne*. They are currently developing *SpaceShipTwo,* a fully-reusable suborbital spaceplane which will carry two pilots and six passengers to 100km altitude and back. Two carrier aircraft and five spaceplanes are currently under construction at the Scaled Composites plant in Mojave, California. SpaceShipTwo is expected to enter commercial service in

2009, with a per-seat ticket price in the region of $200,000.

British firms are contributing to the Virgin Galactic engineering effort: the defense contractor Qinetiq is working on modelling the re-entry system **[14]**. However, closer collaboration is affected by the US ITAR rules on technology transfer (see proposal 1.d below).

British pilots will be leading the way in the development of the SpaceShipTwo suborbital vehicle. In an announcement made in March 2006, Virgin Galactic stated that they expect to recruit about 30 astronaut pilots, mostly from Virgin Group airlines. Steve Johnson (chief astronaut pilot) and Alistair Hoy (head of astronaut training) are ex-RAF Red Arrows pilots **[15]**. Flight tests are expected to start from Mojave Spaceport in 2008. Virgin Galactic is expected to make around 50 flights in its first year of operation. It is worth noting that ESA currently has a corps of 16 professional astronauts **[16].** In full operation, Virgin Galactic will employ *twice as many astronauts as the entire European Space Agency.*

Virgin Galactic is collaborating with the New Mexico state government on the funding and construction of Spaceport America **[17]**, a $225 million project to build the world's first purpose-built commercial passenger spaceport. Construction is expected to start following environmental approval in late 2007, with the spaceport becoming operational around 2010.

- **Starchaser:** Starchaser Ltd originated in a project of the University of Salford. Starchaser is engaged in the development of large liquid-fuelled rocket engines, for use in their *Skybolt* sounding rocket, and *Thunderstar* suborbital space tourism capsule. They also have longer-term plans for the development of an eight-passenger suborbital spaceplane. They have recently been conducting extensive rocket engine tests at RAF Spadeadam, the site for many similar tests during the Blue Streak/Black Arrow era in the 1960's **[18].**

  Starchaser will be a major tenant at Spaceport America once it becomes operational. They have also purchased 120 acres of land near Las Cruces, New Mexico, with a view to developing a "Rocket City", with manufacturing centres, astronaut training facilities, hotels and restaurants **[19].**

  In January 2007, Starchaser was the recipient of a €150,000 study grant from the European Space Agency as part of its 'Survey of European Privately-Funded Vehicles for Commercial Human Space Flight' to evaluate the economic and technical feasibility of European space tourism ventures **[20]**.

- **Surrey Space Technology Limited (SSTL):** SSTL **[21]** is the world leader in the design and construction of microsatellites, having produced a wide range of successful communications, navigation and earth observation spacecraft for government and commercial customers over the past 20 years. SSTL is involved in US "NewSpace" developments through its alliance with Space Exploration Technologies Inc. (SpaceX), a US company engaged in the development of low-cost orbital launch vehicles **[22]**.

  The company's ambitions continue to grow: a consortium including SSTL recently proposed two microsatellite missions to the Moon; Moonlight (a lunar orbiter/penetrator mission) and Moonraker (a lunar lander mission) **[23]**.

- **Reaction Engines Ltd:** Reaction Engines **[24]** design and develop advanced space propulsion systems. Most notable among their projects is an innovative *hybrid airbreathing/rocket engine*, which will use ambient oxygen in the air to enhance fuel combustion and reduce the mass of oxidiser to be carried by the rocket vehicle. The company has designed single-stage-to-orbit reusable launch vehicles (Skylon) and hypersonic passenger transports (LAPCAT) which would use such engines. They have received funding under the EU Framework 6 programme for the development of the LAPCAT concept.

- **Microlaunch Systems:** Microlaunch proposes a radically new design of inflatable single-stage launch vehicle **[25]**. The designer Mohan Ahad has developed a lightweight rocket with inflatable Kevlar bladders for fuel and oxidiser, held in a carbon-fibre truss structure. Development work is being undertaken by the University of Leicester Space Research Centre, and the University of Stuttgart's flight dynamics institute. Microlaunch Systems was the first UK company to receive a DTI grant for a launch vehicle. In 2003, they received £30,000 to study the commercial feasibility of the project, and the use of mass-produced components.

- **Excalibur Almaz Ltd:** Excalibur Almaz is a joint US, Russian and Japanese collaboration incorporated in the Isle of Man for tax and regulatory purposes. Their objective is to use already existing Russian hardware (the Almaz space station module and reusable crew capsules) to establish a commercial manned space station for space tourism and research **[26].** In the longer term, they intend to study the feasibility of mining asteroids for valuable metals.

  The Manx government has been proactive in encouraging the development of the space industry, including setting a zero rate of corporate income tax for space-related activities. Inmarsat, Boeing, Sea Launch, Loral and SES Global (the world's largest satellite operator) all have operations on the island. In December 2005, the Manx government appointed a Director of Space Commerce specifically to support the growth of the space industry **[27].**

Proposals

This section describes a number of Government policy initiatives and projects which may be undertaken to benefit the UK entrepreneurial space industry, and enhance science and engineering education in the UK.

1. Policy initiatives

a. **Space Agency Policy:** The British National Space Centre or its successor in interest should as soon as possible issue a clear public policy statement supporting UK human spaceflight, *both government and commercial*. **[28]**. The agency should state as a long-term policy goal the *human settlement and utilisation of space:* the harnessing of energy and raw material resources in space for the economic benefit of citizens of the United Kingdom. The name of the agency should perhaps reflect this shift in long-term focus (e.g. *United Kingdom Space Development Agency).*

b. **Spacecraft Licensing:** The BNSC or its successor in interest should work with the Civil Aviation Authority to develop procedures for licensing commercial spacecraft flight operations in UK airspace (both test flights of unmanned prototypes, possibly developed under sections 3 and 4 of this proposal, and

routine flights of fully-fledged passenger spaceliners, such as Virgin Galactic's *SpaceShipTwo*). The safety of the general public should be paramount, but the regulations should not prove unnecessarily burdensome and bureaucratic to the vehicle developers. The US FAA regulations on civilian spaceflight currently under development may be a useful guide in this respect.

c. **Tax incentives:** The Government should take note of the success enjoyed by the Isle of Man administration (Tynwald) in attracting and encouraging space-oriented businesses via the mechanism of tax and regulatory incentives.

   It is timely to consider whether such measures as *zero-gravity, zero tax* would be helpful in aiding the development of the entrepreneurial space industry in the UK. These measures would cover both ground-based research and development for the UK space industry, and work undertaken by UK firms *in space*. If, for example, AstraZeneca were to lease lab space on a commercial orbital station such as that being developed by Bigelow Aerospace **[6]**, and send their own astronauts to conduct pharmaceutical experiments there, would the Government actively support and encourage this through appropriate financial incentives?

d. **ITAR:** The UK Government should petition the United States to review its current policy regarding the International Traffic in Arms Regulations (ITAR) as they affect technical cooperation between US and UK companies on spaceflight projects. Simplified ITAR rules for the sharing of spaceflight technology with most trusted allies would enable closer cooperation between the US and the UK in space to mutual economic benefit. These rules currently have a disproportionate effect on small entrepreneurial companies which cannot necessarily afford their own dedicated legal staff to ensure ITAR compliance.

2. Projects

a. **UK Space Prize Fund** (£10 million over 3 years, with an option to extend): The Government should institute a fund for a series of monetary prizes to encourage technical accomplishments in spaceflight and related technologies, modelled on the Ansari X-Prize for commercial human spaceflight **[29]**, and the NASA Centennial Challenges programme **[30]**. The prizes should be awarded for the demonstrable achievement of specific technical goals defined in advance, and open to UK companies, educational institutions and private individuals. Prizes not awarded in one year should be rolled over, and made available in the following year. The organisers will likely find it useful to consult with the X-Prize Foundation on the choice of appropriate prize goals, and the rules and requirements for judging and awarding prizes. Commercial companies may be invited to contribute to the prize fund and/or the costs of administering the scheme, in return for name-branding of the prizes (as with the Northrop Grumman Lunar Lander Challenge **[31]**).

b. **DTI Spaceflight Grant Line** (£30 million over 3 years, with an option to extend): The Department of Trade and Industry should ring-fence a significant sum of money for the declared purpose of promoting the development of commercial spaceflight (manned and unmanned) in the United Kingdom. Grants should be awarded for the development of technology which can be readily commercialised: it should be a strict condition of grant awards that applicants demonstrate at least matching funding from commercial sources. Monies should be awarded on the basis of the demonstrable achievement of specific technical milestones. In the case of the development of novel propulsion systems (e.g.

rocket-based combined-cycle engines), awards should be given to projects directly resulting in flight-capable, recoverable hardware. **Grants should not be awarded simply for design studies and the development of yet more "Powerpoint spaceships".**

c. **HighJump** (£1 million over 3 years): Current rapid advances in the field of commercial suborbital spaceflight raise the interesting possibility that a large-scale programme of launching suborbital payloads for educational and research purposes may soon be feasible at relatively modest cost. The "HighJump Project" would act as a national coordinated programme, purchasing suborbital launches from commercial providers and allowing a large number of UK schools, colleges and universities to provide payloads for those launches. The payloads would be of a standard size and mass, around 300 grams (similar in size to a soft drinks can, a format known as a "CanSat"). There is considerable opportunity for commercial sponsorship of such a programme – UK manufacturers and retailers of suitable components (such as data acquisition computers, CCD cameras, pressure and radiation sensors, accelerometers etc.) could subsidise the production of a standard "kit of parts" for payload assembly, in return for co-branding of programme materials, and possibly launch vehicles.

   The baseline project would call for 100 payloads, possibly as 10 launches of 10 payloads each. As an example, Masten Space Systems **[32]** of Mojave, California, is currently developing the XA-1.0, a fully reusable, vertical take-off, vertical landing (VTVL) unmanned suborbital rocket, with first flight expected in 2008/9. They quote prices of $99 for the launch of a "CanSat"-type payload to 100 kilometres and intact return. On that basis, the total launch costs for a HighJump campaign would be $9900 (£5100) before discounts for launch purchase in volume. Should an individual HighJump payload fail in flight, since the marginal costs of launch are so low, it would be a trivial matter to simply re-fly it.

   High-speed internet links may allow real-time download of experiment data and video from spacecraft in flight to a HighJump "mission control" facility, where students could monitor their payloads. A suitable location for such a mission control may be the National Space Centre in Leicester.

   To re-emphasise: HighJump would not develop any rocketry or launch systems itself. It would purchase suborbital flight opportunities from commercial providers by a standard process of competitive tendering.

d. **Teachers in Space** (£2 million over 3 years): The Government, through the DfES and the DTI should establish a programme to select and train five UK schoolteachers as "teacher-astronauts". The candidates will go through an abbreviated form of astronaut training, including multiple parabolic flights, culminating in suborbital spaceflights purchased from commercial launch providers. Lesson plans should be constructed in advance to exploit each stage of the training and flights for science and technology education.

   This parallels an existing programme currently under development in the United States. It is worth noting that several commercial suborbital launch companies have expressed their intention to provide flight opportunities to teacher-astronauts free of charge under the US Teachers in Space programme, in order to benefit from the resulting positive publicity **[33]**. The UK programme may be able to take advantage of similar arrangements. The interest and excitement created by a well-organised and publicised Teachers in Space programme would be of significant

benefit to the recruitment and retention of science teachers in the UK.

e. **Blue Streak Archive** (£1 million over 3 years, with extension to cover costs of long-term curation): Information relating to the early history of the British space programme, from 1945 to the launch of the Prospero satellite on Black Arrow R-3 in 1971, should be compiled, digitised, and placed in a properly-curated online archive. This would include photos, documents, engineering blueprints, proposals for future developments which were never adopted, archive film footage, and video interviews with surviving participants. The archive can build on the existing work on oral history by members of the British Interplanetary Society. The archive will form a valuable historical reference on the first Space Age, a suitable tribute to the gifted scientists and engineers who took part in the project, and a source of information and inspiration for the UK general public. Possible locations for the physical component of the Archive include the Science Museum, the British Library, and the National Space Centre in Leicester.

f. **UK Spaceflight Exhibit** (£1.5 million over 3 years): Efforts should be made to keep the British public informed of all stages of the developments described in previous sections of this proposal. An exhibit dedicated to current commercial spaceflight, with an emphasis on British progress in the field, should be established at the National Space Centre in Leicester. The exhibit may, for instance, include a full-scale mockup of the fuselage and interior of the Virgin Galactic SpaceShipTwo vehicle. A full-scale interior mockup already exists, and has been publicly displayed at events in the United States. **[34]**

Artist's impression of the Reaction Engines Ltd. *'Skylon'* spaceplane in orbit.
Image © Reaction Engines Ltd.

Conclusions:

The development of entrepreneurial spaceflight is by its nature a highly speculative venture. It should be regarded as a high-risk, potentially high-reward endeavour. Critics will charge that developments in commercial spaceflight are inherently fragile: that the viability of the market is still unproven and that significant investment is premature. I would argue that a number of modest and well-targeted investments in the UK commercial spaceflight industry could reap considerable economic and scientific benefits. Events are moving so rapidly at the moment that if we fail to support UK companies, we are at serious risk of losing our early lead in this field to our competitors.

Commercial spaceflight development will help to engage and inspire the UK public in science and technology. The rapid pace of progress towards clearly-defined goals (as opposed to the "20-year plans" of government space agencies); the feeling of personal engagement, that "some day soon, I can go too"; the demonstrable benefits to high-technology employment; the positive role models of British entrepreneurs, engineers and spacecraft pilots; all of these will bolster public support and feed back benefits for UK science and commerce.

When speaking on recent developments in spaceflight, UK scientists tend to discuss them purely in terms of the benefits to scientific research. This is wholly understandable, as it is after all their particular domain of expertise. However, it somewhat *misses the point*. It is akin to speakers in 1905 discussing these

remarkable new flying machines purely in terms of their possible benefits to the study of meteorology. The social and economic implications of cheap and routine access to space in the long term are *far larger* than the direct implications to pure scientific research. Speakers need to be aware of these wider aspects of spaceflight and willing to discuss them.

A debate on the future of human spaceflight in the United Kingdom must engage the engineering and business communities as much as the scientific community, as they have expertise in domains crucial to its development. The BNSC stakeholder meetings on the future of the UK space industry are a welcome and wholly encouraging start to this process.

Britain's future in space need not be that of some "poor cousin" to our European neighbours and industrialised competitors. We are well placed to play a leading role in the future of entrepreneurial spaceflight, in which British-funded and British-engineered manned spacecraft will regularly fly into space with British pilots at the controls. We have the opportunity to create a British Space Age: one of which we as a nation can feel justifiably proud.

Acknowledgements:

The author gratefully acknowledges Clark Lindsey of *RLV News* **[35]** for his dedicated and meticulous compilation of online information regarding commercial spaceflight. The online journals of John Carmack (Armadillo Aerospace) **[36]** and Jonathan Goff (Masten Space Systems) **[37]** on the subject of commercial rocket development made compelling and enlightening reading. The publications *Flight International*, and *MSNBC Cosmic Log* **[38]** by Alan Boyle, were invaluable references.

Notes & References:

Close et al. (2005): Close F., Dudeney J., Pounds K., 2005, *Report of the Commission on the Scientific Case for Human Space Exploration,* special publication by the Royal Astronomical Society, http://www.ras.org.uk/images/stories/ras_pdfs/Final%20Report%20October%202005.pdf

[1] http://www.frontierastronautics.com/

[2] http://www.orbitalcommerceproject.com/

[3] http://www.orbitaloutfitters.com/

[4] http://www.space.com/news/051208_xprize_hov.html

[5] http://www.nasa.gov/mission_pages/exploration/news/COTS_selection.html

[6] http://www.bigelowaerospace.com/

[7] From the point of view of available payload capacity, at least. Considerations such as maximum G-loading and safe abort scenarios involved in "man-rating" a space launcher are outside the scope of this discussion.

[8] http://www.flightglobal.com/articles/2007/01/23/211685/esas-crew-vehicle-study-shapes-up.html

[9] http://www.futron.com/pdf/resource_center/white_papers/SpaceTourismRevisited.pdf

[10] Speech given at TED2006 in Monterey, California in February 2006. Video available online at http://www.ted.com/tedtalks/tedtalksplayer.cfm?key=b_rutan&flashEnabled=1

[11] http://www.esa.int/SPECIALS/GSP/SEMR2Q8ATME_0.html

[12] http://cosmiclog.msnbc.msn.com/archive/2006/12/14/20846.aspx

[13] http://www.virgingalactic.com/

[14] http://www.flightglobal.com/articles/2005/11/15/202884/ss2-faces-major-design-decisions.html

[15] http://www.flightglobal.com/articles/2006/03/31/205761/virgin-galactic-to-use-virgin-atlantic-pilots-as-astronauts-for.html

[16] http://www.esa.int/esaHS/ESA75G0VMOC_astronauts_0.html

[17] http://www.spaceportamerica.com/

[18] http://www.starchaser.co.uk/index.php?view=gallery_storm_firing_1106

[19] http://www.starchaser.co.uk/index.php?view=pr_nm_dev_announce_060706

[20] http://www.starchaser.co.uk/index.php?view=pr_esa_press_release_uk_0107

[21] http://www.sstl.co.uk/

[22] http://www.sstl.co.uk/index.php?loc=27&id=789

[23] http://news.bbc.co.uk/1/hi/sci/tech/6246513.stm

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

[25] http://www.flightglobal.com/Articles/2005/12/20/Navigation/200/203670/Inflatable+launcher+more+than+hot+air.html

[26] http://www.thelawyer.com/cgi-bin/item.cgi?id=118450

[27] http://www.gov.im/lib/news/treasury/treasuryannounce.xml

[28] The British Interplanetary Society's webpage campaigning for a UK Human Spaceflight programme states that the BNSC should *drop its policy of opposition to human spaceflight.*

http://www.bis-spaceflight.com/sitesia.aspx/page/1191/l/en-us

In the opinion of the author, this is being somewhat unfair to the BNSC – they are currently actively collaborating with NASA on developing their Global Exploration Strategy on plans for continued manned exploration of the Moon, and establishment of a permanent moonbase.

[29] http://www.x-prize.org/

[30] http://exploration.nasa.gov/centennialchallenge/cc_index.html

[31] http://www.spaceref.com/news/viewpr.html?pid=21029

[32] http://www.masten-space.com/

[33] http://www.teachersinspace.org/

As of Sept 2006, Armadillo Aerospace, Rocketplane-Kistler, XCOR Aerospace, Planetspace and Masten Space Systems have announced their support for the US Teachers in Space programme. See http://cosmiclog.msnbc.msn.com/archive/2006/09/20/4507.aspx

Also see: Northrop Grumman Weightless Flights of Discovery: http://homework-help.aol.com/zero-g

[34] http://www.flightglobal.com/articles/2006/09/28/209313/pictures-first-pictures-of-virgin-galactic-spaceship2-tourist-spacecraft-interior-unveiled-in-new.html

[35] http://www.rlvnews.com/

[36] http://www.armadilloaerospace.com/

[37] http://selenianboondocks.blogspace.com/

[38] http://cosmiclog.msnbc.msn.com/

Appendix: Space Development Timeline 2007-2015

NOTE: All dates given are purely indicative, and may change due to financial, engineering or political constraints.

	Commercial suborbital	Commercial orbital	Government orbital
2007	Blue Origin *Goddard* flight tests continue. Rollout of Virgin Galactic *SpaceShipTwo*. Spaceport America construction starts. Other "NewSpace" companies continue engine development and flight tests.	SpaceX *Falcon-1* test flights. Launch of Bigelow Aerospace space station test module *Genesis-II* Construction of Kistler spaceport at Woomera starts.	ISS assembly continues. Launch of European and Japanese lab modules to ISS First flight of European ATV cargo carrier to ISS Development of Indian manned programme starts.
2008	*SpaceShipTwo* flight tests start. *Rocketplane XP* flight tests start. *Dream Chaser* flight tests start.	SpaceX *Falcon-9* test flights. Kistler *K-1* test flights.	ISS assembly continues. Final Hubble servicing mission.
2009	*SpaceShipTwo* enters service. *Rocketplane XP* enters service. *Dream Chaser* enters service.	SpaceX *Dragon* capsule test flights. First flight of Orbital Recovery *CXV* space tug. Launch of Bigelow Aerospace *Sundancer* space station. Launch of *Excalibur Almaz* space station?	ISS assembly continues. First test flight of *Ares-I* first stage. Launch of Chinese space station?
2010	Blue Origin *New Shepard* enters service. Virgin Galactic moves centre of operations from Mojave Spaceport to Spaceport America.	SpaceX, Kistler demonstrate cargo delivery to ISS. COTS Phase-I complete. Contractors bid for COTS Phase-II, for crew/cargo transport to ISS. *DSE-Alpha* manned circumlunar mission?	ISS assembly complete. Space Shuttle decommissioned.
2011		Launch of Bigelow Aerospace *BA-330 "Skywalker"* space station. Permanently manned facility? Commercial launch providers compete to resupply Bigelow stations.	
2012	Virgin Galactic starts operations at RAF Lossiemouth. Planetspace *Silver Dart* demonstrates fast suborbital point-to-point travel.	*More orbital RLVs enter service.* *Bigelow launches additional habitat modules as market demand requires.* *Development of habitat designs for Earth-Moon Lagrange Points, Lunar surface*.	First all-up test flight of *Ares-I* booster. Russian/ESA CSTS operations to ISS start.
2013	*Development continues of second-generation designs for point-to-point travel.* *Evolution of suborbital to orbital RLVs.*		First manned flight of *Orion* capsule.
2014			First Indian manned flight? 2 flights/yr of *Orion* capsule.