CATAPULT Satellite Applications

UNIVERSITY OF OXFORD

SAID BUSINESS SCHOOL

UK SPACE AGENCY

SPACEPORT UK: FORGING AHEAD WITH COMMERCIAL CONFIDENCE

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Spaceport UK: A pillar of growth for the UK and European space industry, enabling lower cost access to space, and creating economic benefit far beyond its perimeter fence. A spaceport will unlock economic growth and jobs in existing UK industries and regions, while positioning the UK to take advantage of emerging demand for commercial human spaceflight, small satellite launch, microgravity research, parabolic flights, near-space balloon tourism, and eventually high-speed point-to-point travel. Without a specific site selected and looking at the economic impact of a spaceport generically, this report expects the spaceport to deliver approximately £2.5bn and 8,000 jobs to the broader UK economy over 10 years.

1 Executive Summary

"Our plan is for Britain to have a fully functional, operating spaceport by 2018. This would serve as a European focal point for the pioneers of commercial spaceflight using the potential of spaceflight experience companies like Virgin Galactic, XCOR and Swiss S3 to pave the way for satellite launch services to follow. It would also create a centre of gravity for related technology and service businesses."

- Robert Goodwill MP, Parliamentary Under Secretary, Department for Transport

The UK has a firm ambition to have a commercial spaceport in operation by 2018 to take advantage of the coming era of space tourism and act as a satellite launch centre. This report aims to demonstrate that the case for a UK spaceport is supported by direct demand for the spaceport's services, as well as the benefits to the existing commercial satellite market and the wider economy. This report is intended to complement and build upon the work already done by the UKSA and CAA. As the CAA's technical report has already recommended, the National Space Flight Coordination Group will work across government and with delivery partners to build the economic business case for investment in a UK spaceport and attract spaceplane services that secure economic benefits for the UK at best value for money.

This report delivers important findings from primary research, as well as key insights derived from a combination of existing research, to provide the aforementioned economic business case and support decision making going forward. This report contributes to the above recommendations by investigating the following areas in detail:

UK Capability: A spaceport will build upon the UK's heritage in launch and will strengthen its position in satellite and high-value manufacturing industries.
The spaceport can act as a facilitator for the rest of the space industry in the UK, in particular small satellite manufacturing. Operators of re-usable spaceplanes have indicated that they hope to reduce satellite launch costs by as much as 80% when their systems are fully mature[1]. This could serve as a substantial benefit to UK based satellite manufacturers, particularly because a domestic launch capability can also offer dedicated launch services and reduced transportation costs. It would also mean the UK leading in Europe in terms of offering a launch option that could support a growing European space sector. Despite having no launch site at the moment, the UK does have advanced industrial capabilities in several key aspects of space launch, including rocket motors, high-pressure storage and pumps, low-weight structures and autonomous control systems[2]. The development of commercial spaceplane operations from a UK spaceport would offer the chance to exploit these capabilities further.

Demand: Sources of current and future tenant and customer demand for a spaceport. Whilst space tourism as a revenue stream for spaceplane operators has received much of the focus, this report identifies a number of other

[1-2] CAA, "UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.32" July, 2014

potential users. These include small satellite launch, microgravity research, spaceflight simulation, zero gravity flights, tours and exhibits, and near-space activities like high altitude balloons. In addition, a spaceport can generate revenue from the leasing of its facilities, rental of land, landing fees, etc. The more diversified a spaceport's revenue sources are, the stronger the business case is for a long-term, self-sustaining spaceport.

> *"A spaceport's operating model should be diversified. There should be other sources of revenue besides space launch if the spaceport is to be self-supporting. Examples include tourism, educational venues, energy source generation like a solar farm, or alternate transportation like an airport [3]."*

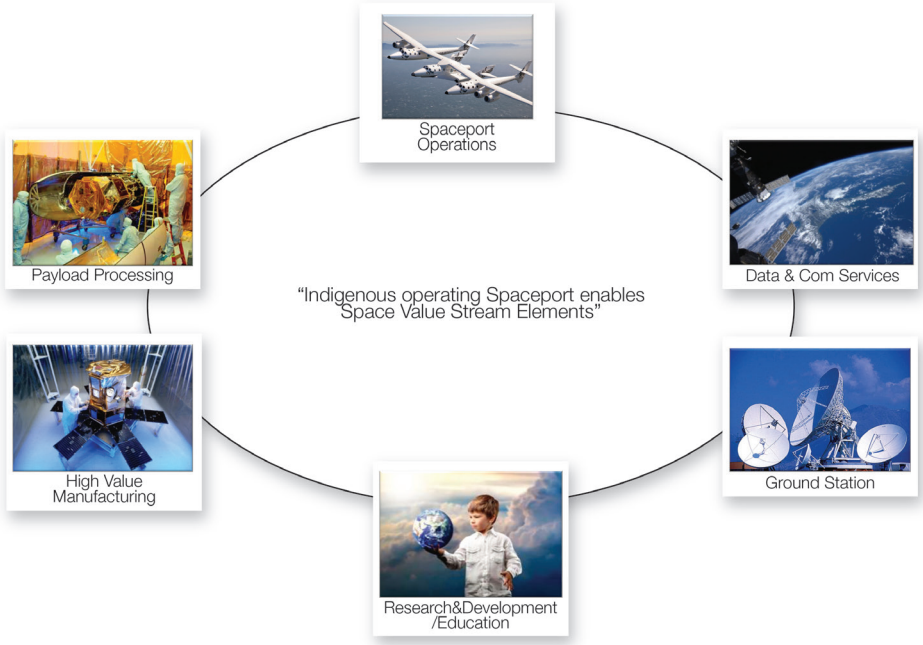
The two dominant spaceport operating models for consideration are[4]:

1. Rent existing land/facilities to tenants, leaving them to invest in and develop their own facilities/ improvements
2. Build new, dedicated facilities and lease them back in an effort to attract tenants

Facilities: Core spaceport infrastructure and activities to attract tenants, customers, and visitors. If the lowest capital cost is desired then it is advisable to select an existing facility with minimal upgrade requirements and multiple synergies in terms of cross-over between spaceplane and other military/ commercial operations. Using an existing facility reduces the potential for development costs to spiral (and therefore higher rates charged to operators) because many of the core facilities for spaceplane operators will already be available at the aerodrome. Consideration has been given to the differences between commercial/private and military aerodromes in terms of core facilities and co-ordination with spaceplane operations. There is a difference of opinion in regards to spaceplane operations co-existing with commercial or military traffic, which will be explored in this report.

Economic Impact: Benefits of a spaceport to the wider economy. As the following illustration highlights, a spaceport can create value far beyond its perimeter fence:

SPACEPORT OPERATIONS CAN ENABLE AN AMBITIOUS UK SPACE STRATEGY



[3] Interview, Christine Anderson, Executive Director NMSA, Spaceport America, August 2014
[4] Interviews, Stuart Witt, CEO Mojave Air and Space Port & Christine Anderson, Executive Director NMSA, Spaceport America, August 2014

R&D spill-over of the space industry is very high compared to other sectors. As a close example, it is estimated that the aerospace sector creates around 70% R&D spill-over[5]. A spaceport will enable the creation of skilled jobs in the wider supply chain, benefits to local economies through tourism, and a deeper interest in STEM subjects because of the growing public appeal of the commercial space industry.

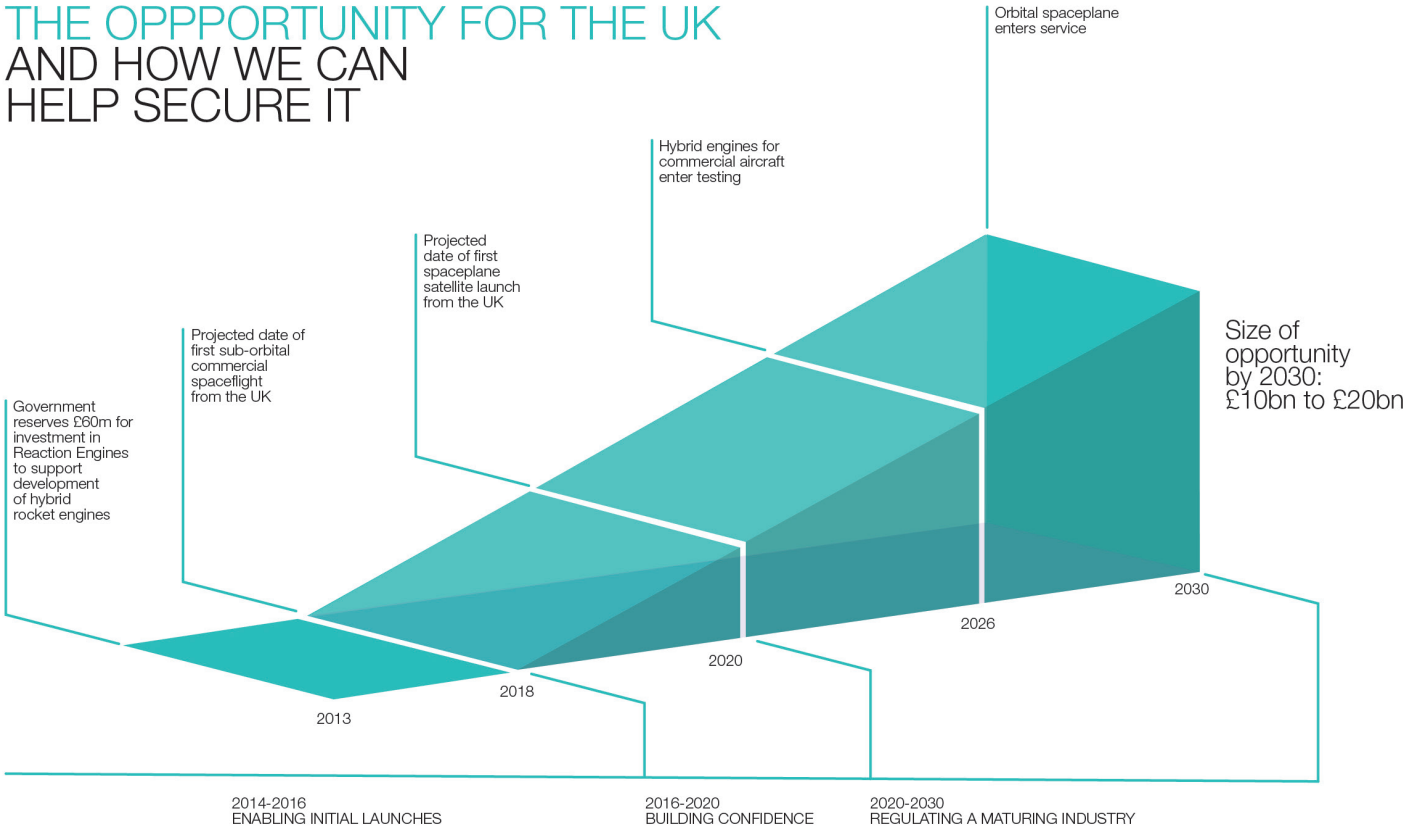
The spaceport has the potential to cumulatively realise a baseline of £320M of additional economic activity and approximately 2,000 new jobs from sub-orbital human spaceflight, satellite launch, regional tourism and microgravity research by 2028. The principal driver of this economic impact is the growing sub-orbital space tourism market and the increasing number of small satellite launches. Tourism related additional economic impact is gauged to range from £20M-£30M and 250-400 new jobs.

Finance & Regulation: Potential funding sources for spaceport development and the importance of clear legislation to enable private investment and innovation.

Government funding will likely be required to develop certain aspects of a spaceport by 2018, in particular for runway extension requirements. As demonstrated by the experience in the US, private capital will flow to a spaceport only after a stable and clear regulatory framework is fully implemented for spaceplane operations. We have seen how legislation in the US, written with the help of industry players, has increased access to space at lower cost, driven the pursuit of commercial spaceflight and much more. Until there is full clarity around whether more regulations will be required under UK law, it is difficult for operators to plan their expansion to the UK.

However, the UK's twin-track approach to a regulatory framework for sub-orbital spaceplane operations can enable the UK to act as the European hub for space tourism, small satellite launch and microgravity research. Operators are aware of the intent and steps the UK is taking to build such a framework and this puts the UK in a strong position to attract operators and tenants to a spaceport.

THE OPPPORTUNITY FOR THE UK AND HOW WE CAN HELP SECURE IT



[5] Oxford Economics, "The Case for Space: The Impact of Space Derived Services and Data.", July 2009

SPACEPORT UK

2 Demand Forecast

This section of the report will assess the core areas of demand for launch services at a UK spaceport, including commercial human spaceflight and very high speed point to point travel, satellite deployment and microgravity research. It will also identify alternative streams of demand for flights from a spaceport, like zero g experience flights, scheduled commercial flights, and high altitude balloon rides.

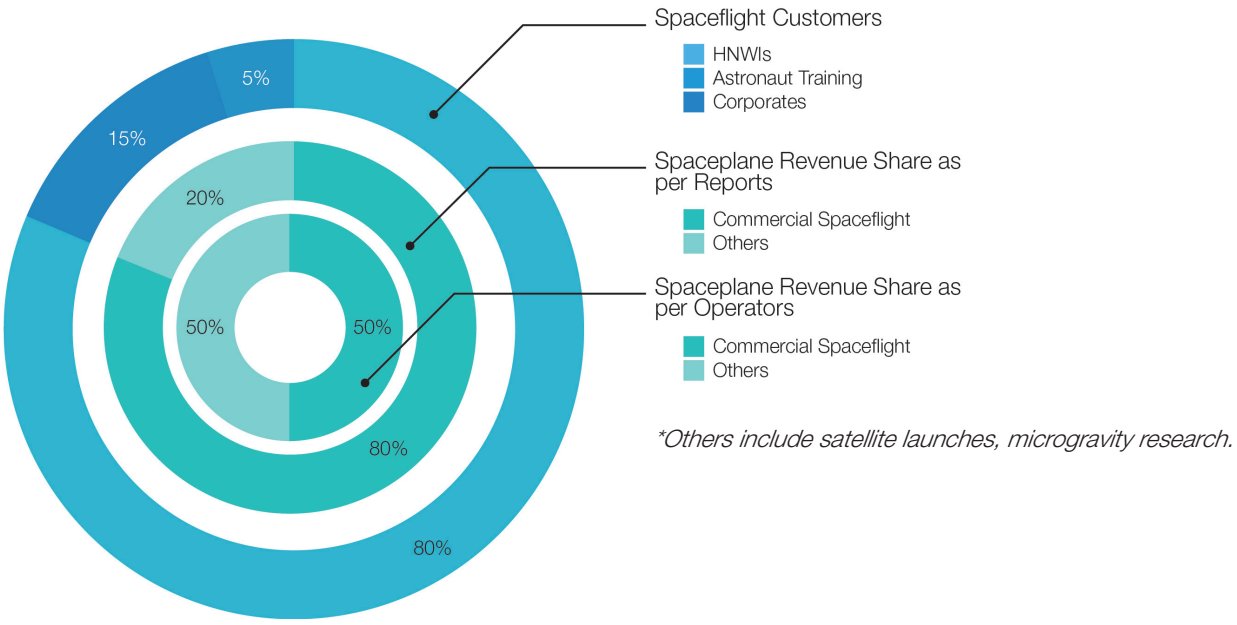
> *"You have to have a spaceport focused on more than just space tourism. A dedicated facility is a dangerous game*[6]*."*

COMMERCIAL HUMAN SPACEFLIGHT

In its report, "The Plan for Growth 2011", the UK Government stated that it:

> *"Wants the UK to be the European centre for space tourism*[7]*."*

This report considers commercial human spaceflight to be the near-term revenue generator for spaceplane operators and a UK spaceport can benefit from that. Whilst many reports suggest spaceflight experience could contribute between 70-80% of a spaceplane operator's total revenue, a longer term view is that revenue sources will be split 50-50 between commercial spaceflight and other operations (including small satellite launch and microgravity research)[8]. The target customers for a spaceflight are[9]:



**Others include satellite launches, microgravity research.*

[6] Interview, PJ King, COO Firefly Space Systems, August 2014
[7] Department for Business Innovation & Skills, "Plan for Growth", March 2011
[8] Surrey Satellite Technology Ltd, "Sub-orbital Reusable Vehicles Market Analysis: UK Spaceport Demand", June 2013
[9] Based on interviews with various spaceplane operators

Demand Projection Model

Demand projections form an integral part of the feasibility study for a spaceport. They are more difficult for a new market that is untested and not yet operational. Market studies have already been conducted to gauge the demand for commercial spaceflight tourism. There are limitations to such studies – many are on a global scale and most are dated. However they can be used as guidelines, and are used to benchmark this report's projections against.

This report generates a model to look at the demand projections for a spaceport in the UK. Over ten years, we expect the baseline cumulative number of spaceflight tourists to be approximately **5,000** and revenue for spaceplane operators of **£500M** from this activity. This is based on the assumptions that the target customer is a HNWI with investable assets > $2.5M. As per the World Wealth Report 2014, high net worth individuals (HNWIs) have a propensity to spend ~8% of their net worth on leisure or sports. The potential customer base is further narrowed down to those who are inclined to undertake a spaceflight and are willing to make such a one-time purchase.

These figures are based on non-US citizens/ residents as we assume the majority of US residents and citizens would undertake spaceflight from the US. Another assumption is that ticket prices will decline from $250k-$100k over the period. While not expected to decline significantly in the next five years, it is assumed that ticket prices will reduce over time with economies of scale.

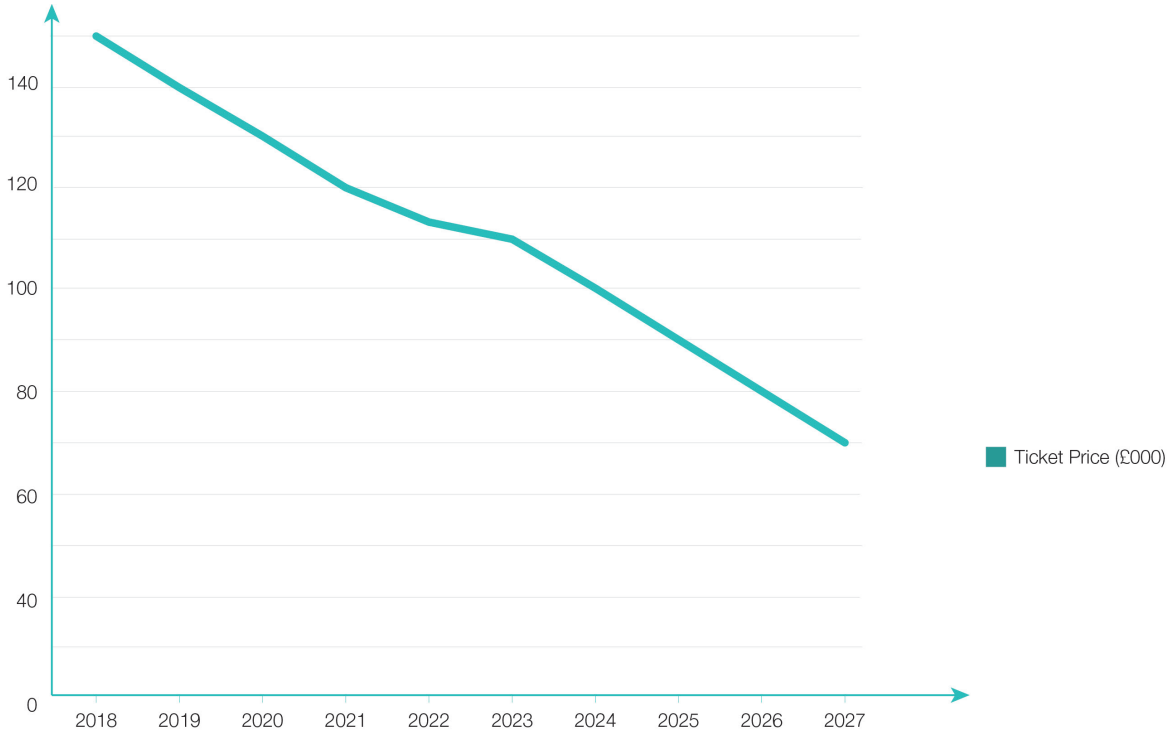
Further details on assumptions and methodology can be referred to in *Appendix A*.

Ticket Pricing

Three price points are considered[10]:

- Ticket price taken as an average over 10 years ($185k or £111k), assuming the ticket prices reduce marginally over the 10 year period.
- Ticket prices assumed to reduce more after 5 year period of operations ($133k or £80k)
- Ticket prices assumed to reduce further **over** 10 year period due to economies of scale and increase in demand ($100k or £60k)

Using Virgin Galactic's ticket prices, the starting price will be approximately $250k (£150k) per seat. The expected decline in price, because of economies of scale, is expected to drive an overall increase in demand. However the prices are not expected to reduce significantly in the short to medium term. In the analysis, it is assumed that ticket prices will reduce by 5% p.a. in the 5 years after operation commences, and will reduce by 10% thereafter.



Projection for sub-orbital spaceflight ticket prices.

[10] For further explanation of ticket pricing, please see Appendix A

The following tables provide a range of revenues based on different ticket prices and market share of a UK spaceport in the overall non-US spaceflight market:

Sensitivity analysis based on 50% of potential customers		
Ticket Price	UK Market Share	
	25%	50%
£111k	£281M	£562M
£80k	£202M	£404M
£60k	£152M	£303M

Sensitivity analysis based on 75% of potential customers		
Ticket Price	UK Market Share	
	25%	50%
£111k	£421M	£842M
£80k	£303M	£607M
£60k	£227M	£455M

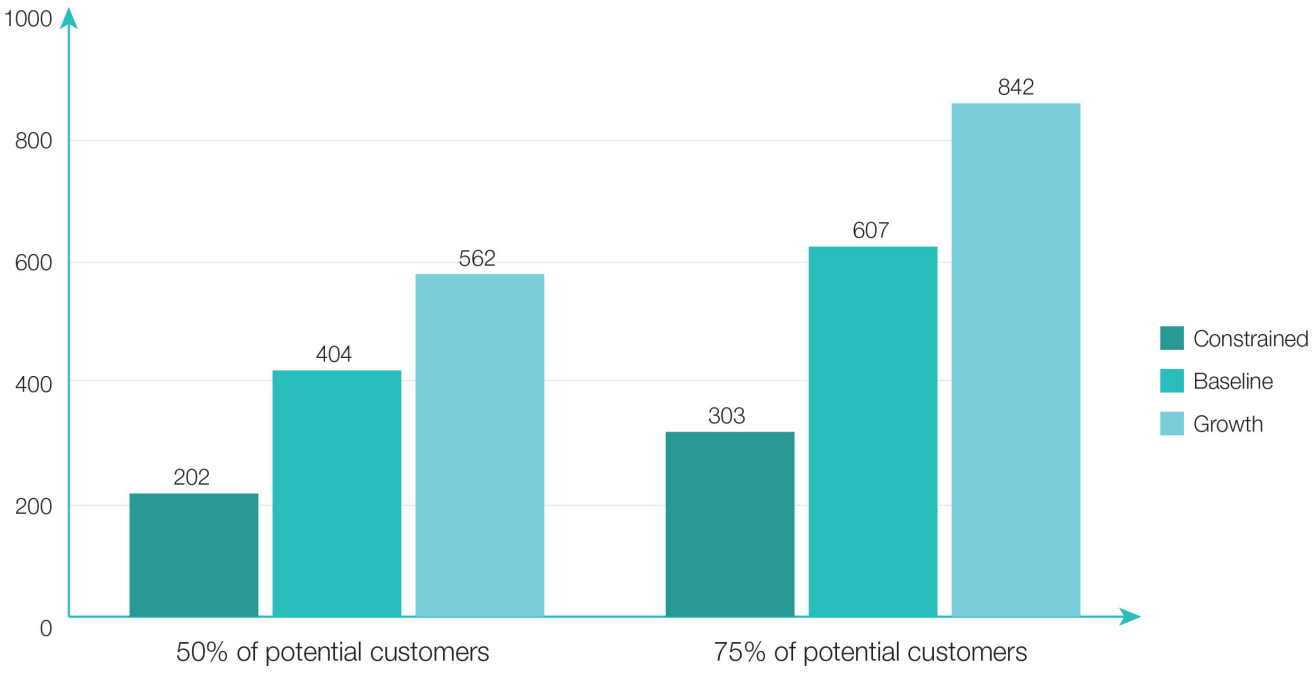
Revenue Projections

1) Based on the assumption that 50% of the potential customers will buy a spaceflight experience, the min/max range for cumulative revenue from UK spaceflight experience is approximately **£150M/£560M** over 10 years.

2) Based on the assumption that 75% of the potential customers will buy a spaceflight experience, the min/max range for cumulative revenue from UK spaceflight experience is **£225M/£840M** over 10 years.

N.B. Any change to assumptions made would affect the above figures.

The revenue projection from human spaceflight experience has been split into three scenarios: constrained, baseline and growth:

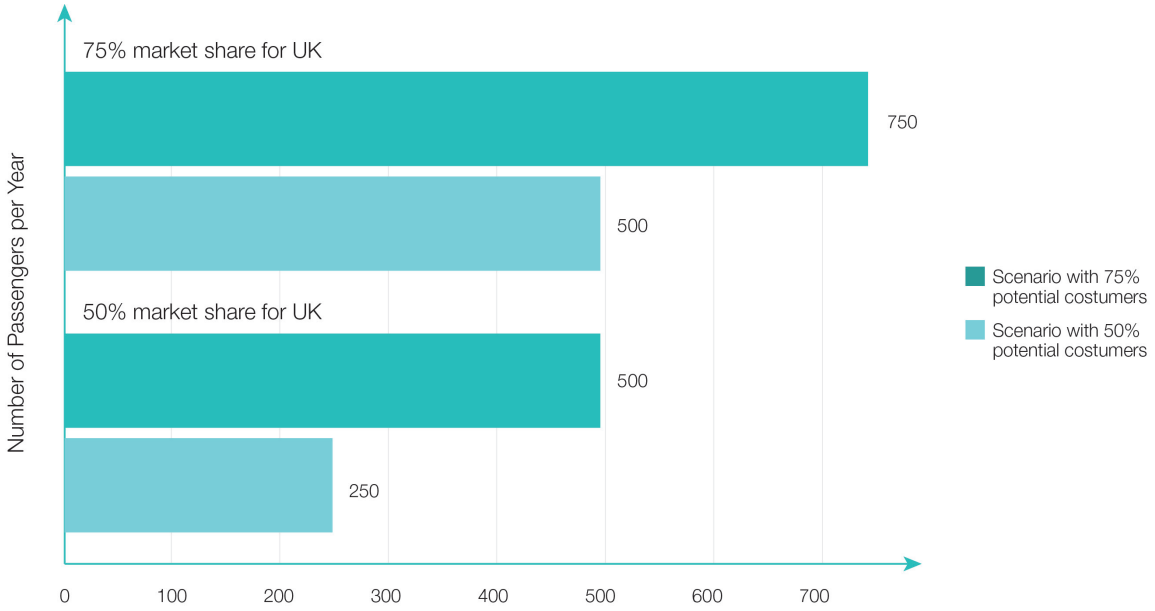


N.B. All figures in £M.

3) Baseline estimate of cumulative revenues is therefore **£500M**[11]

Passenger Projection per year:
The number of passengers for commercial spaceflights is dependent on two factors:

1. What proportion of potential customers would actually buy a ticket?
2. What will be the share of a UK spaceport for the above customer base?



N.B. Any change to assumptions made would affect the above figures.

It is also possible that:

- Some US citizens/residents would prefer to take a spaceflight outside of the US, due to unique regional experience packages
- More non-US spaceports are built, taking market share from the UK, eg Spaceport Sweden or Abu Dhabi Spaceport
- Chinese nationals represent a growing share of HNWIs and an increase in demand from this group may support spaceports outside of the US, particularly the UK. However, reported rumours of restrictions on civilian Chinese nationals flying on US spaceplanes are incorrect. Even if that was the case in the past, it is believed any such ban has been lifted by the US State Department[13].

Publicly available data for current spaceflight experience bookings (from the most likely operators by 2018)[14]:

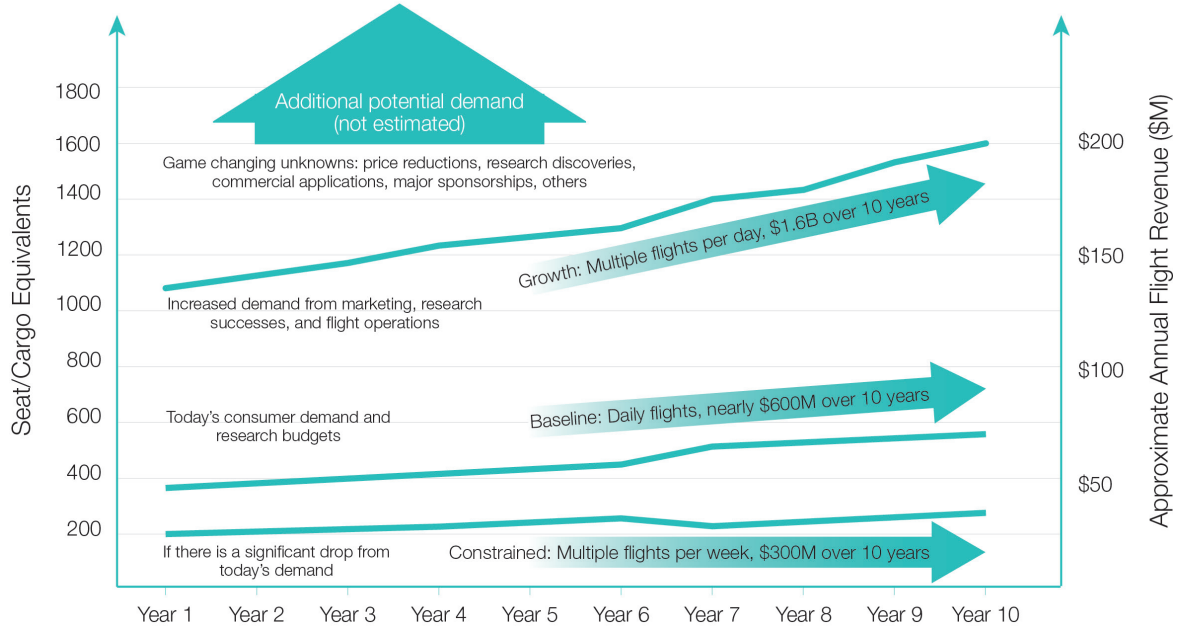
Company	Sub-orbital Vehicle	Planned Start	Number of Reservations
Virgin Galactic	SpaceShipTwo	2015	700+
XCOR	Lynx Mark II	2016	300+
		Total Reservations	**1000+**

Existing Demand Models
Three existing market studies have been analysed as part of this report, to understand the demand projection for human spaceflight from the context of a UK spaceport and to compare and contrast with the analysis done previously. These studies include:

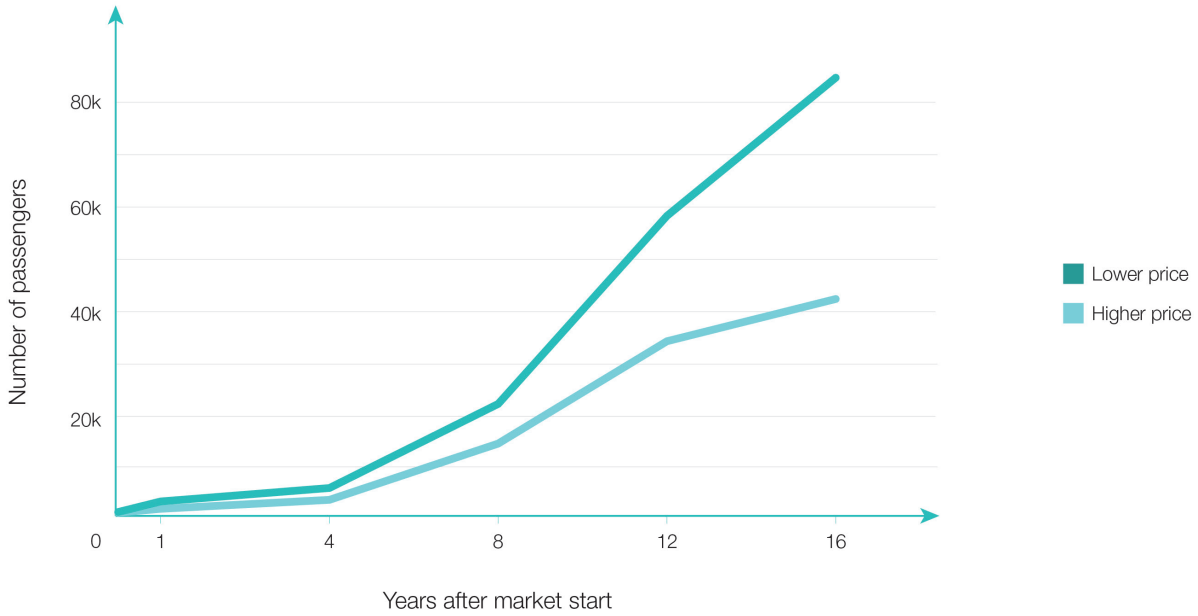
[11] Baseline: £404M + £607M / 2 = ~£500M
[12] See www.edition.cnn.com/2014/01/29/travel/virgin-galactic-chinese (accessed 8th August 2014)
[13] See www.seradata.com/SSI/2014/07/farnborough-air-show-eight-candidates-for-uk-space-port-make-the-cut-and-most-are-in-scotland (accessed 15th August 2014)
[14] Tauri Group, "Sub-orbital Reusable Vehicles a 10 Year Forecast of Market Demand", 2012

Tauri Group [14] : Study conducted for the FAA and released in September 2012. It projects the demand for commercial spaceflight over a 10-year period, and listed three scenarios for its model:

Scenario	Flight Frequency	Seats per Year	Revenue over 10 Years
Constrained	Multiple per Week	200-250	$300M (£175M)
Baseline	Daily Flights	400-550	$600M (£350M)
Growth	Multiple per Day	1100-1600	$1.6B (£940M)

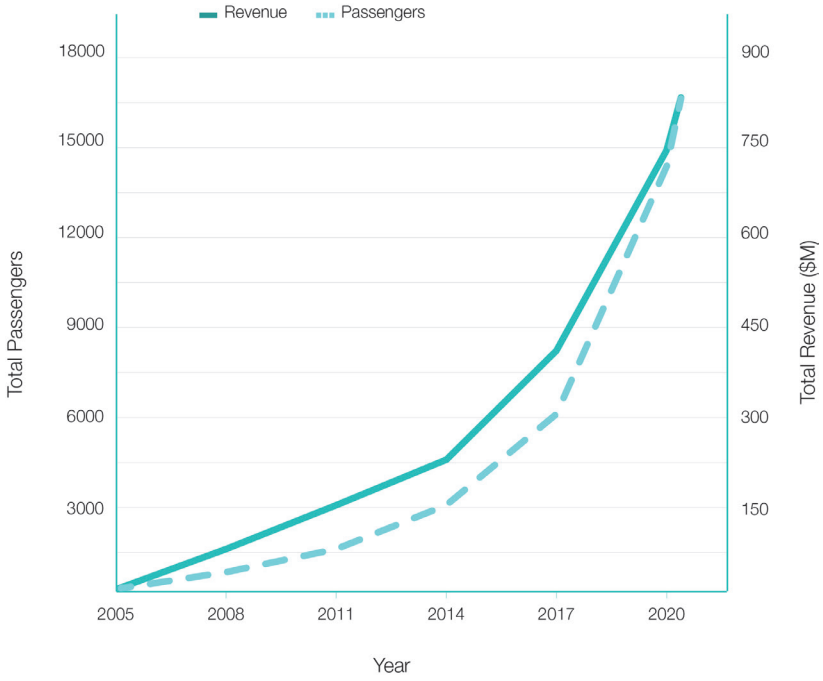


IPSOS/Astrium Study [15] : conducted by IPSOS for Astrium, released in 2007 with updated results in 2011. Study included research with HNWIs before 2007 and then later in 2010 after the financial crisis. It generated a regression model to project demand on various price points over a 16 year period. The projected numbers are significantly higher than other market studies:



[15] IPSOS/Astrium, "*Demand Analysis of Sub-Orbital Space Tourism*", 2012

Futron Report [16]: released in 2002, and updated in 2006. It performed an extensive survey with HNWIs and followed the Fisher-Pry Model to arrive at the demand figures for a 20-year period. It assumed the ticket price to be constant for the first 5 years, and then a straight-line reduction for the rest of the period. The demand projections from this report are global and predict up to 15k passengers by year 10 of operations, with revenues in the range of $700M -$800M per annum.



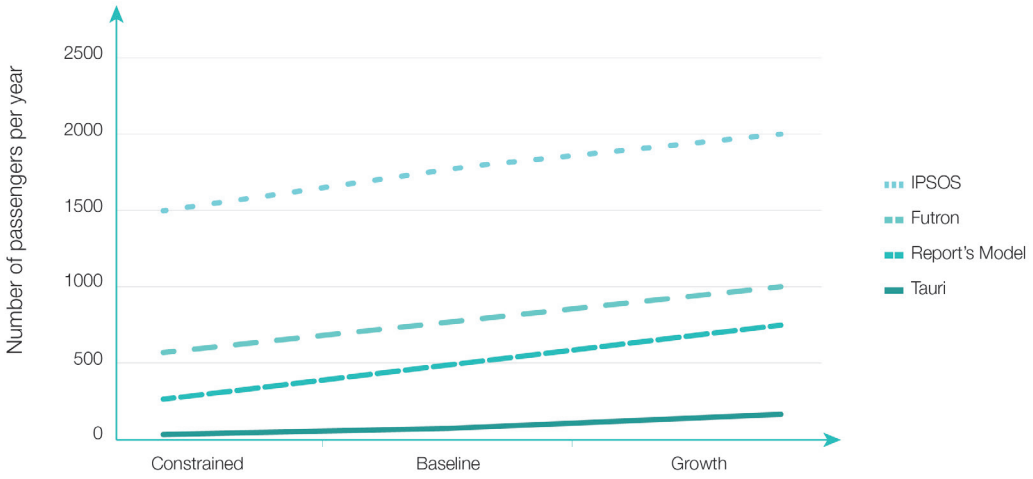
Limitations of existing models

- Reports are up to 10 years prior and so are not fully relevant in the current market context.
- They are based on a global level and thus don't give the relevant numbers for the UK, so assumptions need to be made for a UK market share.
- Many of these reports expected spaceflight experiences to already be operational by 2014, and thus demand would increase in subsequent years. As the first commercial spaceflight hasn't taken off yet, there is a need for a revision to these numbers.

Comparison of demand projections across studies

Though all other spaceflight demand studies were on a global scale, if it is assumed that a UK spaceport takes a 10% share[17] of the projected demand, the total demand can be compared as follows:

UK COMMERCIAL SPACEFLIGHT DEMAND PROJECTION COMPARISON ACROSS REPORTS



[16] Futron/Zogby, "*Space Tourism Market Study*", 2006
[17] Based on UK's target of 10% share of global space industry

Supply of spaceplanes

There are only a few spaceflight operators in the world, and currently all space plane manufacturers are based in the US. By the time a UK spaceport comes on-line in 2018, Virgin Galactic and XCOR are likely to be fully operational. Due to ITAR[18] restrictions, a UK spaceport will probably use a wet lease agreement[19] with these operators in order to provide the necessary supply of spaceplanes for the UK market. Spaceplane operators referenced during this report have expressed their confidence in meeting demand at more than one spaceport location.

KEY FINDINGS

- Taking the mid-point range from the demand projection model, the UK could expect 500 passengers per year for spaceflight experiences.
- The cumulative revenue projections from UK commercial spaceflight will be approximately £500M (baseline scenario) over the 10-year period.
- More high net worth individuals live in London[20] than any other city in the world, this is an important source of demand for those who want the spaceflight experience and for others that may want to partake in alternative activities that a spaceport can offer (highlighted later in this report).

[18] International Traffic in Arms Regulations (ITAR) is a set of United States government regulations that control the export and import of defence-related articles and services on the United States Munitions List (USML). Manned sub-orbital and orbital spacecraft are on the USML.

[19] A wet lease means a company does not purchase the vehicle; rather, it purchases the right to lease the vehicle and pays spaceflight operators to operate it. [8] Surrey Satellite Technology Ltd, “Sub-orbital Reusable Vehicles Market Analysis: UK Spaceport Demand”, June 2013

[20] Knight Frank, “World wealth Report 2014” see www.thewealthreport.net (accessed 14th August 2014)

VERY HIGH SPEED POINT TO POINT TRAVEL

In an increasingly fast-paced digital world, the average speed of air travel has been stagnant around Mach 1 for 50 years. The current interest in sub-orbital commercial spaceflight, be it for space tourism or other applications, is likely to be an initial stepping stone towards markets that are technically more challenging but also more lucrative. Included in this vision is point-to-point (PTP) very high speed transportation.

Point to point sub-orbital travel on a commercial passenger transport scale is unlikely for a few decades given the issues around training required to cope with g forces experienced during flight, and thermal protection systems needed for re-entry[21]. Once there is a database with large and broad data points in relation to the design, manufacture and operation of spaceplanes, there will be enough traceable performance flight data to test sub-orbital flight profiles for mass transit, but that is a long way away at this point[22].

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Hypersonic Flight

Spaceports will lead the way for PTP hypersonic travel (speeds of mach 5 and above), and will likely form the first global network of destinations to be followed later by commercial airports. This therefore represents an opportunity for the UK to capture a share of the market in future years and collaborate with other spaceports around the world.

Industry, government and academia are looking at the common issues related to high-speed commercial PTP transportation (including passenger travel and fast cargo delivery). An example of this is the "FastForward Project" which is an all-volunteer study group with around 25 active member organisations, consisting of major aerospace contractors, emerging new space companies, spaceports, key federal government agencies, and academia[23].

Hypersonic systems could be capable of carrying cargo for medical uses like organ transplant. A spaceport that is located conveniently to distribute such cargo to medical facilities will be an important consideration. Hypersonic flight could also have military applications; the ability to rapidly transport a small team of troops or vital military cargo around the world would be of interest to military organisations. A spaceport that is co-located with a military base may be more appealing for military customers therefore.

PTP very high speed travel (within the Earth's atmosphere) has its share of challenges, from the technology needed for such vehicles to questions about the economics, and uncertainties about the international regulatory environment. In 1962, Concorde was projected to cost £160M, by 1975, the year before commercial launch, more than £1.2B had been spent[24]. Industry experts suggest

[21] Interview, Andrew Nelson, President XCOR Aerospace, Farnborough Air Show, July 2014
[22] ibid
[23] See www.fastforwardproject.com/meetings/pdf/FastForward_March2013_StatusBriefing_v1.pdf (accessed 23rd July 2014)
[24] See www.news.bbc.co.uk/1/hi/business/2935337.stm (accessed 18th August 2014)

that hypersonic flight is a long way off commercial viability for passenger transportation. Logistically and operationally, travelling at such high speeds would likely need training for passengers based on the g-forces experienced during flight. There is also the sonic boom issue (the FAA bans all supersonic flights over land).

Supersonic Flight

The cost benefit of reducing travel times from the UK to Australia from 22 hours to just two hours has been estimated at over £160M per year[25]. This can bring improvement in productivity as a result.

There is a possibility, within the next decade, of a supersonic business jet carrying between 8-12 passengers that could reach Mach 2 and cut down travel times for PTP travel. Andrew Nelson, President of XCOR Aerospace believes:

> *"There would be demand that could facilitate between 40 and 50 of these kinds of jets*[26]*."*

Aerion Corp, which has proposed a mach 1.6 capable business jet called AS2, already has 50 letters of intent to buy according to its CEO Doug Nichols[27]. However Aerion is still awaiting the formation of an industrial partnership and it has indicated that deliveries would not begin until 5-6 years after a formal programme launch.

© Hypermarch Aerospace's SonicStar Supersonic Business Jet

The CEO of Hypermach Aerospace Ltd, a company designing a mach 4 supersonic VVIP business jet capable of carrying 24-36 passengers at a cruising altitude of 65,000 ft[28], believes that such a jet could be a user of a spaceport. UKTI's Global Entrepreneurship Programme (GEP) announced in 2011 that it was working with Hypermach to explore ways that the company could take advantage of the UK's unique aerospace infrastructure and network, including its expertise in aero engine design and manufacturing[29].

Hypermach's CEO noted that the business environment for his sector in the US has been more conducive to investment and support for prototype development and testing. However, he mentioned that UK partners are under consideration by Hypermach for some elements of engine testing and design, and that the government had sent a positive message to the industry in relation to the UK's support for Reaction Engines. He believes his supersonic business jet technology is about 10 years away from a go-live date[30].

[25] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.39*" July, 2014
[26] Interview, Andrew Nelson, President XCOR Aerospace, Farnborough Air Show, July 2014
[27] See www.aviationweek.com/ebace/aerion-unveils-larger-supersonic-jet (accessed 17th August 2014)
[28] See www.hypermach.com/?page_id=66 (accessed 5th August 2014)
[29] See wwww.hypermach.com/wp-content/uploads/2012/11/HyperMach-launches-SonicStar.pdf (accessed 5th August 2014)
[30] Interview, Richard Lugg, CEO Hypermach Aerospace, August 2014

The fledgling renaissance of supersonic commercial flight faces challenges however, including the fact that a supersonic jet will carry a high price tag ($100M plus). In addition, the industry must grapple with the resulting sonic boom (although Hypermach says its design doesn't encounter this issue). In 1973, the FAA banned supersonic flights over land. In order to overcome FAA limits, Boeing and Lockheed Martin have been working with NASA since 2010 on ways to muffle the sonic boom. According to Peter Coen, manager of NASA's High Speed Project, the partners have reached a point where quiet, low-boom overland supersonic passenger service is achievable. However he doesn't expect those designs to fly the skies before 2025[31].

KEY FINDINGS

- Whilst point to point is only one long term element of a spaceport's business plan, it could also be an important one for the wider economy given the potential for time savings that can be made, improving productivity.
- Spaceports could be the likely choice for operators of supersonic, and later hypersonic, point to point travel.
- Hypersonic systems capable of carrying high value cargo would appeal to both industry and government customers.

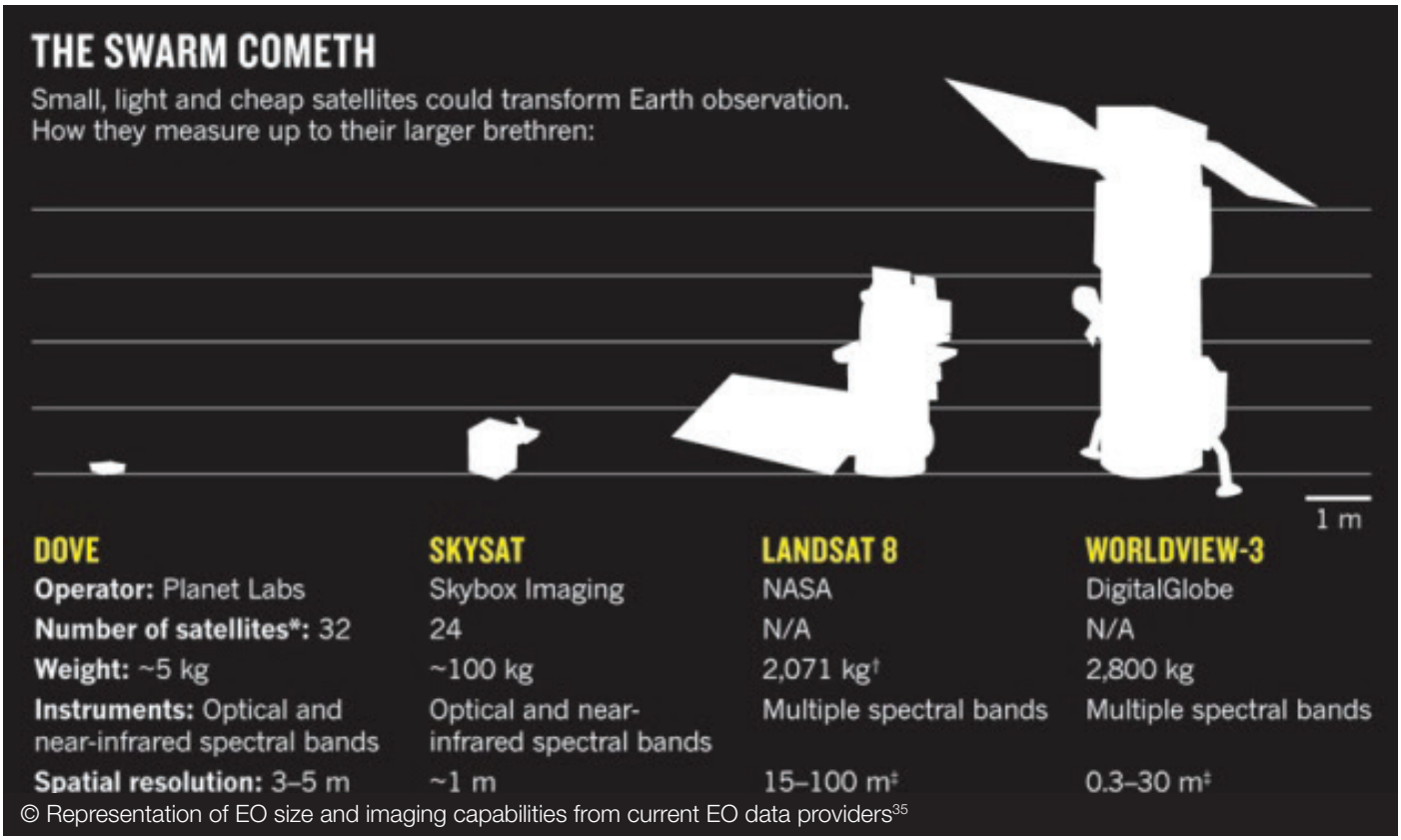
[31] See www.bloomberg.com/news/2014-06-13/mach-5-anyone-supersonic-flight-is-poised-for-takeoff.html (accessed 18th July 2014)

SATELLITE DEPLOYMENT

Traditional Satellite Market
The biggest customers of conventional commercial imaging satellites are governments, in particular intelligence agencies and military. These high cost, high capability products are priced far out of reach for many other potential users, including researchers, in areas as diverse as farming, forest carbon management, regional and local planning, and environmental stewardship.

Paradigm Shift
Miniaturisation of technology, standardisation and reduced launch costs are driving increased interest in small satellites[32]. Progress in electronics and other satellite component advancement has enabled spacecraft innovation. A higher quantity of nano/microsatellite missions will result in an expected 79% decrease in average spacecraft mass from 2012 to 2016[33]. The way ahead for satellite technology is clear:

> *"You can now, with a single chip, create most of the capabilities that you would have found in Sputnik, but, of course, orders of magnitude faster*[34]*."*

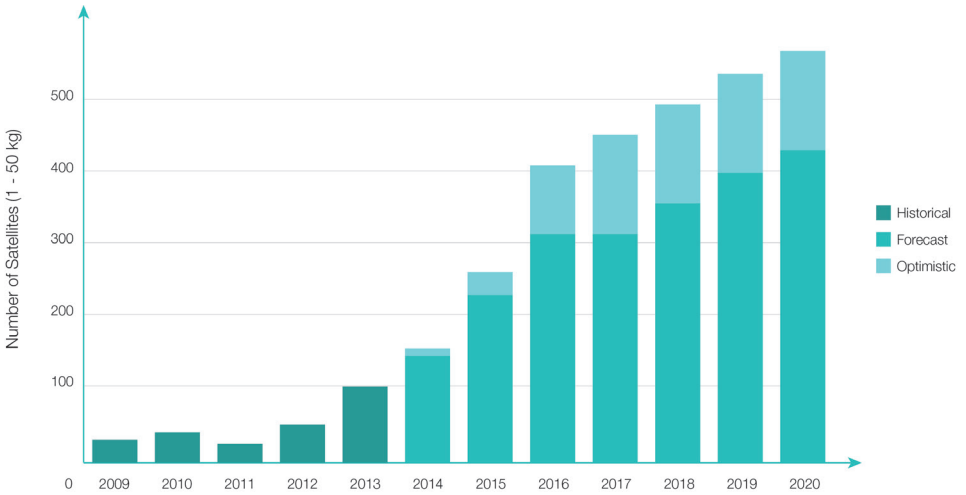


© Representation of EO size and imaging capabilities from current EO data providers[35]

[32] Generally accepted definition of satellite classes: small-satellites from 500kg to 100kg, micro-satellites from 100kg to 10kg, nano-satellites from 10kg to 1kg, pico-satellites less than 1kg
[33] Spaceworks, "*Trends in Average Spacecraft Launch Mass*," June 2014
[34] Economist, see www.economist.com/news/technology-quarterly/21603240-small-satellites-taking-advantage-smartphones-and-other-consumer-technologies (accessed 16th August 2014)
[35] Nature International Weekly Journal of Science

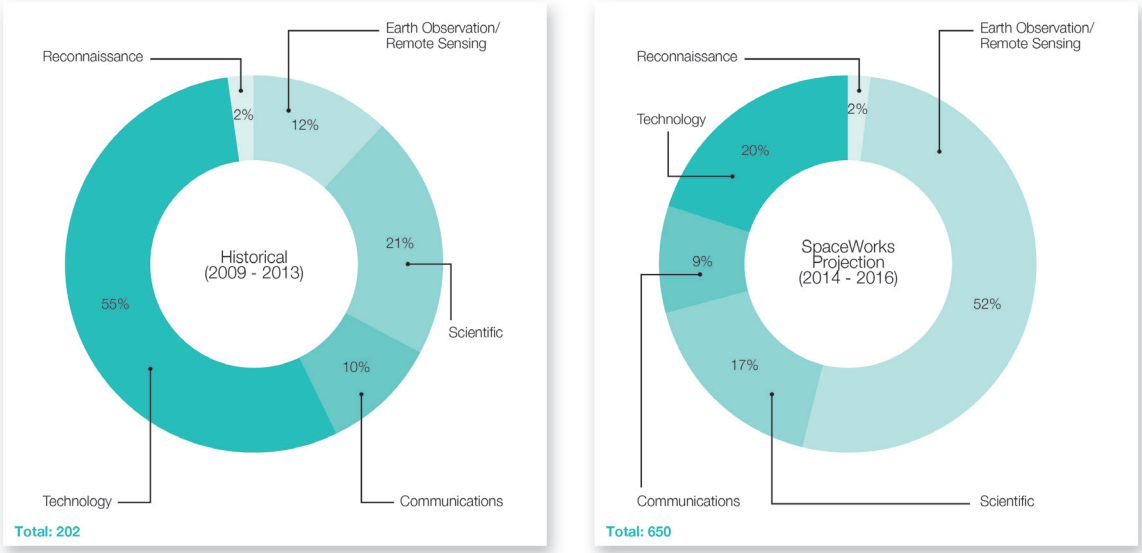
The focus of the analysis has been on the nano/microsatellite categories as, according to SpaceWorks, this is where a relatively large amount of satellite activity is taking place[36]. In 2013 the number of small satellites (weighing less than 50kg) launched was nearly as many as in the previous three years.

The adoption of constellations by new businesses intent on activities including monitoring terrestrial assets, is driving a forecast of 2,000-2,750 small satellites to be launched from 2014-2020, more than four times the number launched in the 2000-2012 period.



Nano/ Microsatellite Launch History and Projection [37]

By bringing the cost down and accessibility up, new entrants in this marketplace aim to spur a proliferation of innovative uses. In addition, applications for nano/microsatellites are diversifying, with increased use in the future for EO and remote sensing missions. The most likely domain to be disrupted by the small mission technology trend is EO - over half of future nano/microsatellites will be used for EO and remote sensing purposes (compared to 12% from 2009 to 2013), with the commercial sector contributing 56% of nano/microsatellites over the next three years[38]. The size of the commercial EO data market by 2020 is estimated to be £1.8B – the nano/microsatellite share is estimated at £970M[39].



Nano/Microsatellite Trends by Purpose [40]

36-37-38-40 SpaceWorks, "*2014 Nano/Microsatellite Market Assessment Overview*", Jan 2014, see www.sei.aero/eng/papers/uploads/archive/SpaceWorks_Nano_Microsatellite_Market_Assessment_January_2014.pdf (accessed 22nd July 2014)

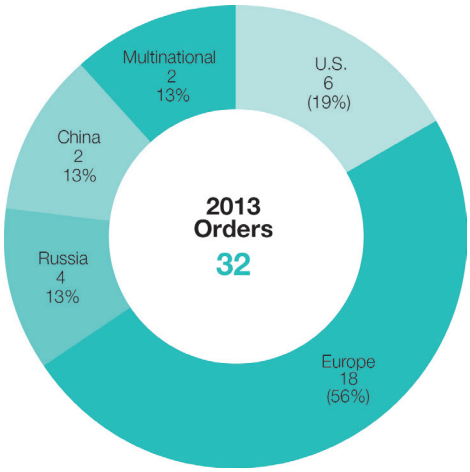
39 Satellite Applications Catapult, "*Small is the New Big: Nano/Micro-Satellite Missions for Earth Observation and Remote Sensing*" May 2014

UK Strengths
Satellites and commercial applications of space have been identified as one of the UK's eight great technologies[41]:

> *"The UK is once more seen as a leading space science nation. Companies have focused on making satellite technology more affordable with smaller, lighter-weight satellites that lower the cost of commercial launches. Surrey Satellite Technology Ltd (SSTL), one of the UK's single most successful university spin-outs, is the world leader in high-performance small satellites. Roughly 40 per cent of the world's small satellites come from Guildford – and now even smaller nano-satellites are coming from SSTL and Clyde Space in Glasgow."*[42]

With such world-leading small satellite manufacturers, the UK is well positioned to capture a significant portion of this market and build on its competitive advantage. Based on a representative cost per nano/microsatellite satellite of £250k[43], if the UK was to achieve a 40%[44] market share of, say, 2,500 small satellite launches during the 2014-2020 period, it would equate to a UK market size of **£250M**[45].

European Strengths
According to the Satellite Industry Association, the trade association representing the commercial satellite industry, orders to launch 32 satellites were placed in 2013 and Europe retained the largest share of those commercial launch orders:



Commercial satellite launch orders [46]

A UK launch capability would not only serve UK satellite manufacturers but it could also capture small satellite launch demand from the rest of Europe, given there is no continental European launch option at the moment.

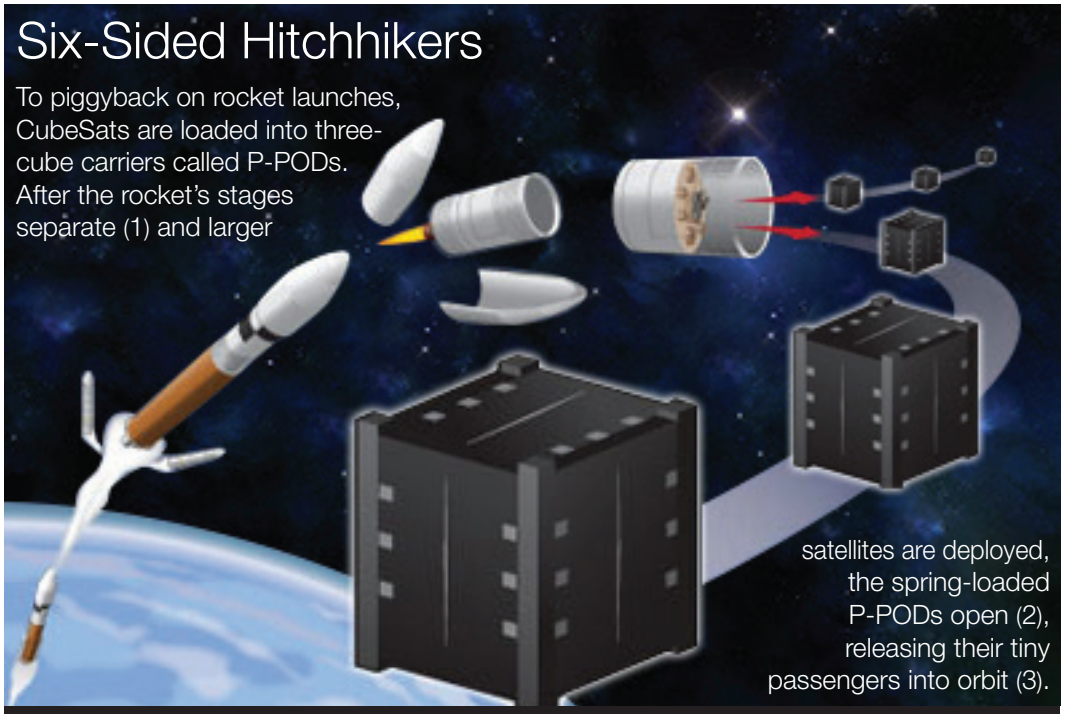
Small satellite solutions are also being developed in Europe, with Dutch firm Innovative Solutions in Space (ISIS) focused on the nano and micro-satellite segment of the market. The firm is a vertically integrated small satellite company, focused on providing high value, cost effective space solutions by making use of the latest innovative technologies. As one of Europe's leaders in the nanosatellite domain, ISIS offers contract research, satellite systems and turnkey space solutions to a broad range of customers for small satellite missions and applications.

[41] Department for Business, Innovation & Skills, Eight Great Technologies, see www.gov.uk/government/uploads/system/uploads/attachment_data/file/249255/eight_great_technologies_overall_infographic.pdf (accessed 22nd July 2014)
[42] David Willetts MP, see www.gov.uk/government/speeches/eight-great-technologies (accessed 16th August 2014)
[43] Based on a survey of existing small satellite manufacturers
[44] Based on a speech by David Willetts MP, see www.gov.uk/government/speeches/eight-great-technologies (accessed 16th August 2014)
[45] 1,000 satellites x £250,000 = £250M
[46] Satellite Industry Association, "*State of the Satellite Industry Report*" May 2014

Launch

> *"Why is hitch-hiking a ride to space the only option[47]?"*

Launch is a key dependency for satellite manufacturers. Smaller microsats and nanosats, are launched as "piggyback" payloads - multi-manifested with satellites of a similar class using excess launch capacity on a rocket. Piggyback launching allows operators to place their spacecraft in orbit at a significantly lower cost than launching as a primary payload.



© Forbes

The current Scenario for small satellite operators
Over 90% of very small satellites (15 kg or less) have been deployed as piggyback payloads on existing launch vehicles[48]. This is currently the only strategy for smaller projects, with rockets like the Falcon 9 and Soyuz bundling nano and cube satellites alongside their primary cargo payloads. There are multiple drawbacks to this approach:

- The requirement of the primary payload might change, putting the small satellite's mission in jeopardy and creating long delays.
- The primary payload may go to a crowded orbit, or may not go to the inclination desired for the small satellite. Therefore the satellite manufacturer has to make do with a second best, or worse, solution than what it was hoping for[49].
- Costs incurred to transport satellites to international launch locations, negotiate customs and other export regulations, and transport team members to remote sites. These can represent a significant proportion of the cost of a launch campaign.
- Geopolitical situation – given the increasing number of sanctions being imposed on Russia by western governments, there is a risk to the supply of lower cost launches in case of any retaliatory sanctions imposed by Russia on non-Russian friendly payloads.

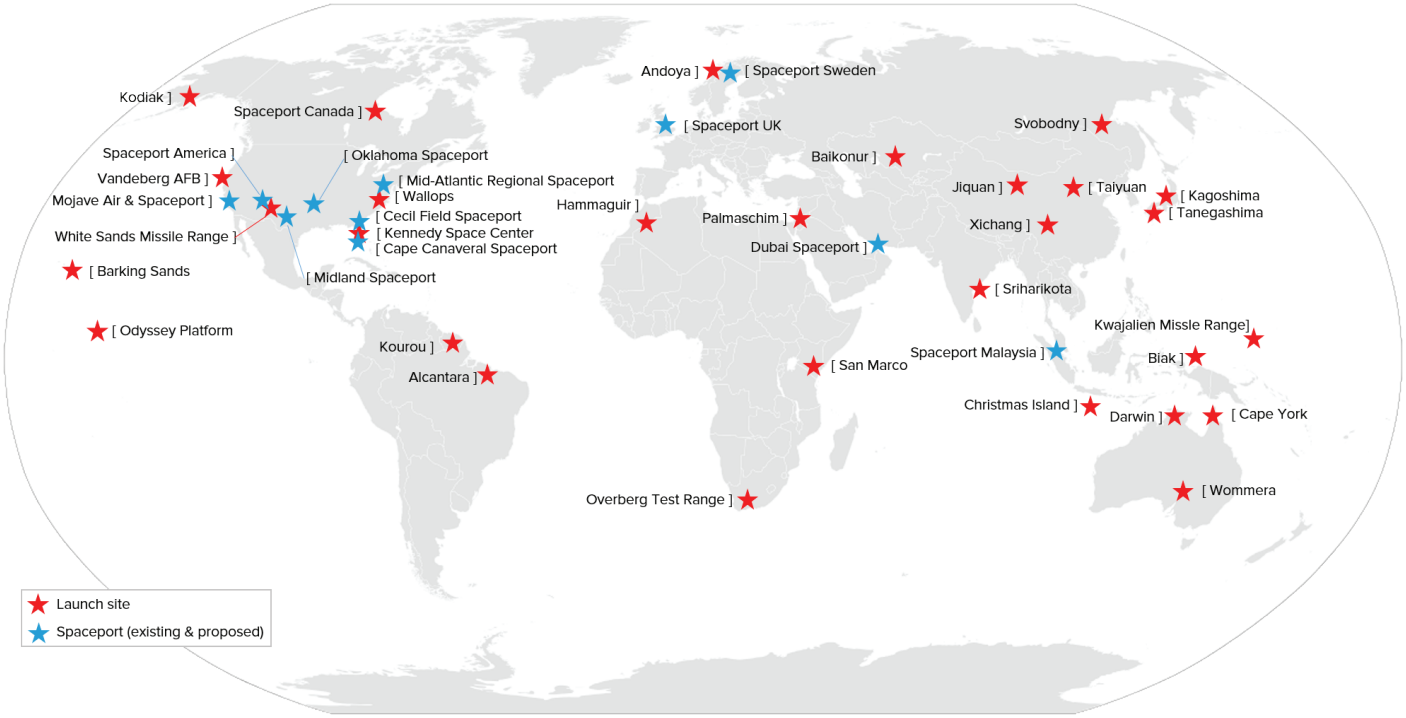
These are some of the main issues that are affecting launch demand for small satellite manufacturers and reducing the opportunity to access space for some firms, particularly in the cubesat segment.

[47] Generation Orbit, Videos, see www.generationorbit.com/videos.html (accessed 16th August 2014)
[48] Tauri Group, "*Sub-orbital Reusable Vehicles: A 10-Year Forecast of Market Demand*", August 2012
[49] See www.space.com/17984-spacex-private-rocket-glitch-satellite.html (accessed 1st August 2014)

> *"As traditional launch vehicles focus on serving the growing spacecraft masses with geosynchronous Earth orbit (GEO) destinations, the challenges of rideshare opportunities will increase and may be unable to keep up with the growing demand in the emerging small payload sector*[50]*."*

Launch Sites and Spaceport Locations[51]

There are multiple countries expressing interest in hosting a spaceport and a number of emerging space nations, in SE Asia for example, are asking operators for launch of cubesats, with the potential for larger satellite missions in years to come[52]. There are opportunities to develop regional sub-orbital operational hubs, including for the UK in Europe.



[50] SpaceWorks, "*Trends in Average Spacecraft Launch Mass*" June 2014
[51] Various sources. N.B. includes some launch sites no longer operational
[52] Interview, Richard Joye, Head of Business Development, Swiss Space Systems, August 2014

Current and future launch options[53]

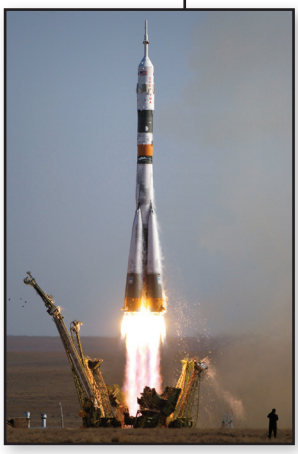
AIRBUS DEFENCE AND SPACE
ARIANE 5
Max payload capability: varies
In service
Likely launch location: Kourou, French Guiana
No dedicated launch
Geopolitical stability: stable

UNITED LAUNCH ALLIANCE ATLAS V/DELTA IV
Max payload capability: varies
In service
Likely launch location: Cape Carnaveral, FL, Vanderburg, CA
No dedicated launch
Geopolitical stability: stable

ORBITAL SCIENCES
PEGASUS XL
Max payload capability: 450kg
In service
Likely launch location: Vanderburg, CA
Dedicated launch
Geopolitical stability: stable

ISC KOSMOTRAS
DNEPR
Max payload capability: varies
In service
Likely launch location: Baikonur, Yasny
No dedicated launch
Geopolitical stability: questionable

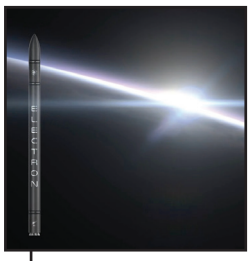
SPACE X FALCON 9
9.1, HEAVY
Max payload capability: varies
In service
Likely launch location: Cape Canaveral, FL, Vandenburg, CA
No dedicated launch
Geopolitical stability: stable



RUSSIAN FEDERAL SPACE AGENCY
SOYUZ
Max payload capability: varies
In service
Likely launch location: Baikonur and Kourou
No dedicated launch
Geopolitical stability: questionable

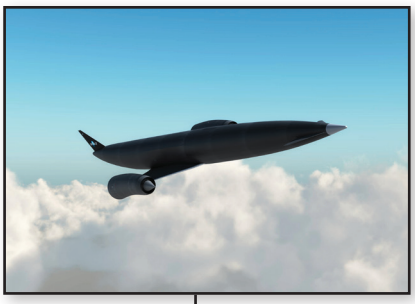
[53] Based on publicly available data from launch providers

ROCKET LAB ELECTRON
Max payload capability: 110kg
In service in 2015
Likely launch location: NZ, US
Dedicated launch
Geopolitical stability: stable



GENERATION ORBIT
GOLAUNCHER2
Max payload capability: 45kg
In service in 2016
Likely launch location: Cecil, FL
Dedicated launch
Geopolitical stability: stable

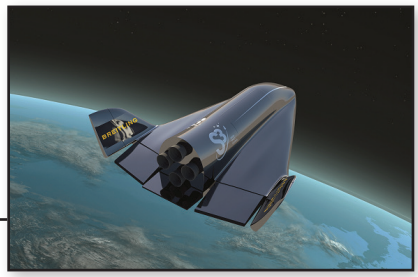
REACTION ENGINES
SKYLON
Max payload capability: 12000kg
In service in 2022
Likely launch location: UK?
Dedicated launch
Geopolitical stability: stable



VIRGIN GALACTIC
LAUNCHERONE
Max payload capability: 225kg
In service in 2016
Likely launch location: New Mexico
Dedicated launch
Geopolitical stability: stable

2015 2016 2017 2018 2022

XCOR
LYNX III
Max payload capability: 650kg
In service in 2017
Likely launch location: Midland, TX
Dedicated launch
Geopolitical stability: stable



SWISS S3
SOAR
Max payload capability: 250kg
In service in 2018
Likely launch location: Colorado
Dedicated launch
Geopolitical stability: stable

FIREFLY ALPHA
Max payload capability: 400kg
In service in 2017
Likely launch location: TX, CA
Dedicated launch
Geopolitical stability: stable

STRATOLAUNCH
SYSTEMS PEGASUS II
Max payload capability: 6000kg
In service in 2018
Likely launch location: UK?
Dedicated launch
Geopolitical stability: stable

The benefit of spaceplane launch does not come in the form of lower cost, at least initially, but rather in the form of dedicated launch. The way spaceplanes will be able to reduce cost over the medium to longer term is fly more often, spread development costs out over a number of flights, and therefore benefit from economies of scale.

> *"Price should not be the sole criteria to focus on. The opportunity to reduce risk, have control over the mission and have frequent access to launch is also very important for small satellite manufacturers*[54]*."*

Spaceplane Launch
Launch vehicle providers like XCOR, Virgin Galactic and Swiss S3 highlight the following operational advantages over the status quo:

1) **Flexibility** – spaceplanes/air-launch vehicles can offer a wider range of orbits and an orbit that is specific to the manufacturer's requirements.
2) **Speed to market** – launch cycle times reduced to 6 months[55], from the current waiting time equating to years for some satellites
3) **Frequency** - Spaceplanes/air-launch vehicles can be used multiple times per day to meet demand
4) **Dedicated launch** – focused on the needs of that specific satellite manufacturer

Also significant are the cost savings involved in transportation and logistics during a launch campaign for satellites. Satellite manufacturers may sometimes need a team of up to 5 people at a launch site, a month before the launch date. That costs money, potentially hundreds of thousands of pounds, and it's a big part of the cost when talking about an overall £5M launch project[56].

> *"A UK location is more preferable - transporting a satellite internationally is expensive and there are a number of additional issues to consider like customs and logistics, which can delay a satellite's journey to a launch site. However, this is just one part of the overall launch cost equation*[57]*."*

> *"Some customers are just stuck, they want to launch this year but they don't want to send the satellite to the other side of the planet. By coming to the customer, integrating the satellite and then launching it will reduce the lag time*[58]*."*

[54] Interview, Richard Joye, Head of Business Development Swiss Space Systems, August 2014
[55] Generation Orbit, Videos, see www.generationorbit.com/videos.html (accessed 16th August 2014)
[56] Interview, Andy Bradford, Surrey Satellite Technology Ltd, August 2014. As an approximation, a figure of $5M to launch a 150kg satellite into LEO, is seen as a reasonable benchmark
[57] ibid
[58] Interview, Richard Joye, Head of Business Development Swiss Space Systems, August 2014

© Designboom

Virgin Galactic, for example, has announced its intention to support the small satellite launch market via its privately funded LauncherOne vehicle (pictured above) and it expects LauncherOne to be operational in 2016[59]. At the Farnborough Air Show in 2012, the company announced that four private firms had already put down deposits to be future LauncherOne customers, expressing their intent to purchase a total of several dozen launches[60]. LauncherOne customers already signed up include Skybox Imaging, GeoOptics Inc, Spaceflight, Inc. and Planetary Resources. Furthermore, SSTL's US division signed a Memorandum of Understanding with Virgin Galactic in 2012 to collaborate on optimising satellite platforms for LauncherOne:

> *"SSTL has long been working on making space more accessible by dramatically lowering the cost of space missions and the company welcomes Virgin Galactic's dedicated launcher service for small satellites, looking forward to a higher degree of flexibility and frequency of launch opportunities when LauncherOne debuts. Making satellite launches more affordable and flexible will accelerate small satellite space programmes, and help more new space ventures get off the ground'*[61]*."*

In discussions with XCOR's President Andrew Nelson[62], the company also sees satellite demand as a key contributor of revenues for its business. XCOR's Lynx Mark III vehicle can hold a payload (via an externally mounted dorsal pod) up to 650 kg and is large enough to hold a space telescope or a two stage carrier to launch multiple nanosatellites into LEO.

© Citizens in Space

[59] See www.virgingalactic.com/launcherOne/performance-and-specification/ (accessed 22nd July 2014)
[60] See www.spaceflightservices.com/tag/virgin-galactic/ (accessed 1st August 2014)
[61] See www.sstl.co.uk/Blog/July-2012/SST-US-and-Virgin-Galactic-redefine-launch-costs (accessed 16th August 2014)
[62] Interviews, Farnborough Air Show 2014, 15th July 2014

The UK's own Reaction Engines Ltd is developing a fully re-usable, single stage to orbit spaceplane called SKYLON. It will put up to 15 tonnes into LEO. According to the company, the price that operators of SKYLON will pay, will be the cheapest way into orbit - around $10M per launch in the long term[63].

The case for a vertical launch facility in the UK

If a key goal of a UK spaceport is to enable and sustain economic growth of the UK satellite manufacturing industry, then facilitating greater optionality for launch is important, including a vertical launch facility. There will remain a need for vertical launch vehicles - the options mentioned below can offer benefits to satellite manufacturers very similar to spaceplanes in terms of frequency, flexibility and dedicated launch.

Trend towards low cost re-usability and low cost expendable launch systems

New commercial launch providers such as SpaceX, with its Falcon 9 and Falcon Heavy rockets, are developing and demonstrating their vehicle capabilities for application to commercial and government markets. With a strong focus on re-usability of vertical launch vehicles from the outset of their design, SpaceX is currently testing with the intention of landing the first and second stage rocket components with the same accuracy as a helicopter.

In his address to a US Defense Sub-Committee hearing in March 2014, CEO Elon Musk stated that SpaceX could provide national security launch services to the US Department of Defense for around $90M per launch (includes mission assurance overhead on Government missions)[64]. That compares to the average $380M paid for each launch with the current incumbent tasked with national security launches, United Launch Alliance (ULA). SpaceX's published prices for commercial launch are lower; $61.2M and $85M for the Falcon 9 and Falcon Heavy launch vehicles respectively (based on 2016 launch)[65]. In addition, it is estimated that per launch cost of the Ariane 5 is around $137M[66].

More vertical launch firms are focusing on the small satellite market and coming up with low cost rocket designs. Senior management from both Firefly Space Systems and Rocket Lab Ltd have indicated in interviews that orders are building for their services:

> *"Our order book is probably split 50:50 between US firms and international. Our rocket can fit into shipping containers and it was specifically designed with mobility in mind - so if it makes sense to go to the customer at a UK spaceport for example, we will"*[67]*."*

Firefly's target market is likely to be around the 400kg satellite mass category, offering a per launch cost of around $8-9M via its Firefly Alpha vehicle that has been designed with re-usability in mind.

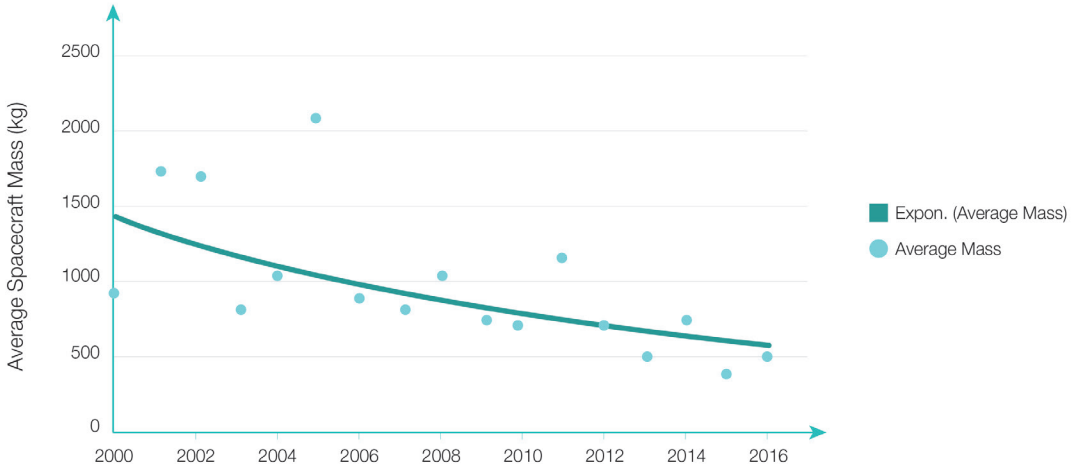
Rocket Lab, an expendable low cost rocket option, is said to have an order book of 30 launches to date, for maximum payloads per launch of 110kg, at a cost of approximately $4.9M[68]. Rocket Lab's CEO Peter Beck has commented on the company's openness to finding a spaceport partner:

> *"If there's a region out there that wants a spaceport, then come and talk to us. It (a spaceport) brings huge economic benefit to the region.*[69]*"*

[63] SKYLON lecture by Mark Hampsell, YouTube, see www.youtube.com/watch?v=8Tjy2tR_bBs (accessed 17th July 2014)
[64] See www.youtube.com/watch?v=O_azyt1Jhl0 (accessed 5th August 2014)
[65] See www.spacex.com/about/capabilities (accessed 18th August 2014)
[66] See www.spacenews.com/article/launch-report/39906former-arianespace-chief-says-spacex-has-advantage-on-cost (accessed 18th August 2014)
[67] Interview, PJ King, COO Firefly Space Systems, July 2014
[68] See www.bloomberg.com/video/five-billionaires-who-don-t-have-a-college-degree-SewP5yAQR9Wje1phwfwiuQ.html (accessed 15th August 2014)
[69] See www.bloomberg.com/video/five-billionaires-who-don-t-have-a-college-degree-SewP5yAQR9Wje1phwfwiuQ.html (accessed 15th August 2014)

Trend towards polar orbits

> *"With the shift towards more commercial small satellites and the launch of satellite constellations, it's likely there will be greater demand for launch into polar orbit*[70]*."*



LEO satellite mass excluding missions to ISS[71]

Missions to low-Earth orbit (LEO) are increasingly dominated by large constellations of small satellites resulting in a downward trend in average mass of spacecraft. Whilst satellite missions to geosynchronous Earth orbit (GEO) are increasing in mass because large launch vehicle capabilities continue to grow, GEO missions are increasingly few in number due to maintained/increased quality and lifetime of these large satellites. With increased use in the future for EO and remote sensing missions, which benefit from a polar orbit, the UK can act as a favourable vertical launch location for such missions.

The CAA technical report has highlighted that a vertical launch site and spaceport would be separate for technical reasons (split sites). Safety of the uninvolved general public is a key concern for all launch operations and, as firms like SpaceX and Firefly Space Systems continue to test and develop multi-stage re-usability of vertical launch vehicles (with precision landing), vertical launch will become safer.

[70] Interview, Christopher Brunskill, Upstream Technologies Lead Satellite Applications Catapult, August 2014
[71] Spaceworks, "*Trends in Average Spacecraft Launch Mass*" June 2014

KEY FINDINGS

- Over 90% of very small satellites (15 kg or less) have been deployed as piggyback payloads on existing launch vehicles. Spaceplanes will offer operational benefits over piggyback launches and reduce logistical costs for UK satellite manufacturers. This may mean spaceplane launches taking share away from larger expendable rockets over time, in the case of small satellites.
- Over the medium to long term, spaceplanes are likely to bring cost advantages to small satellite manufacturers over existing piggyback missions.
- As a result of a spaceplane's high frequency and re-usability, a greater number of smaller satellites could be launched, therefore generating more revenue for a spaceport and satellite launch becoming a key driver of a spaceplane operator's total revenue.
- Dedicated launch also meets the demands of a growing commercial small satellite market, of which the UK is a market leader. The trends toward low cost rocket re-usability and launching small satellites into polar orbits makes a UK vertical launch site an attractive option for vertical launch vehicle providers.

MICROGRAVITY RESEARCH

Microgravity research has mainly been dependent on government and academic budgets but cheaper and faster access to space could, through sub-orbital re-usable vehicles (SRVs), increase interest from commercial players especially from the Biotech and Aerospace sectors.

Microgravity research will be an important customer for SRV providers (assuming a continued level of government and non-profit funding for experiments) and hence another source of revenue for the spaceport. SRVs provide a unique opportunity for the scientific community as they would be able to provide advantages over the following[72]:

Free Fall Towers

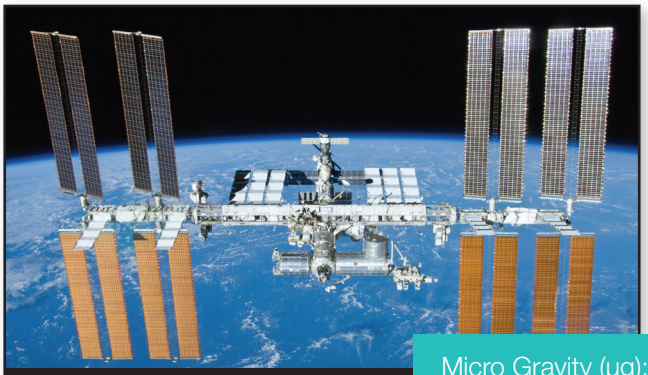
Micro Gravity (µg): $10^{-3..-6}$
Duration: < 5sec
Interaction: Remotely
Waiting Time: ≈ months
Cost/Expt: ≈ £3.9k

Parabolic Flights

Micro Gravity (µg): $10^{-2..-3}$
Duration: ≈ 20-30sec
Interaction: Human
Waiting Time: ≈ months to 1 year
Cost/Expt: ≈ £1M

Sounding Rockets

Micro Gravity (µg): $10^{-4..-5}$
Duration: 5-13mins
Interaction: Remotely
Waiting Time: > 2 years
Cost/Expt: > £317k

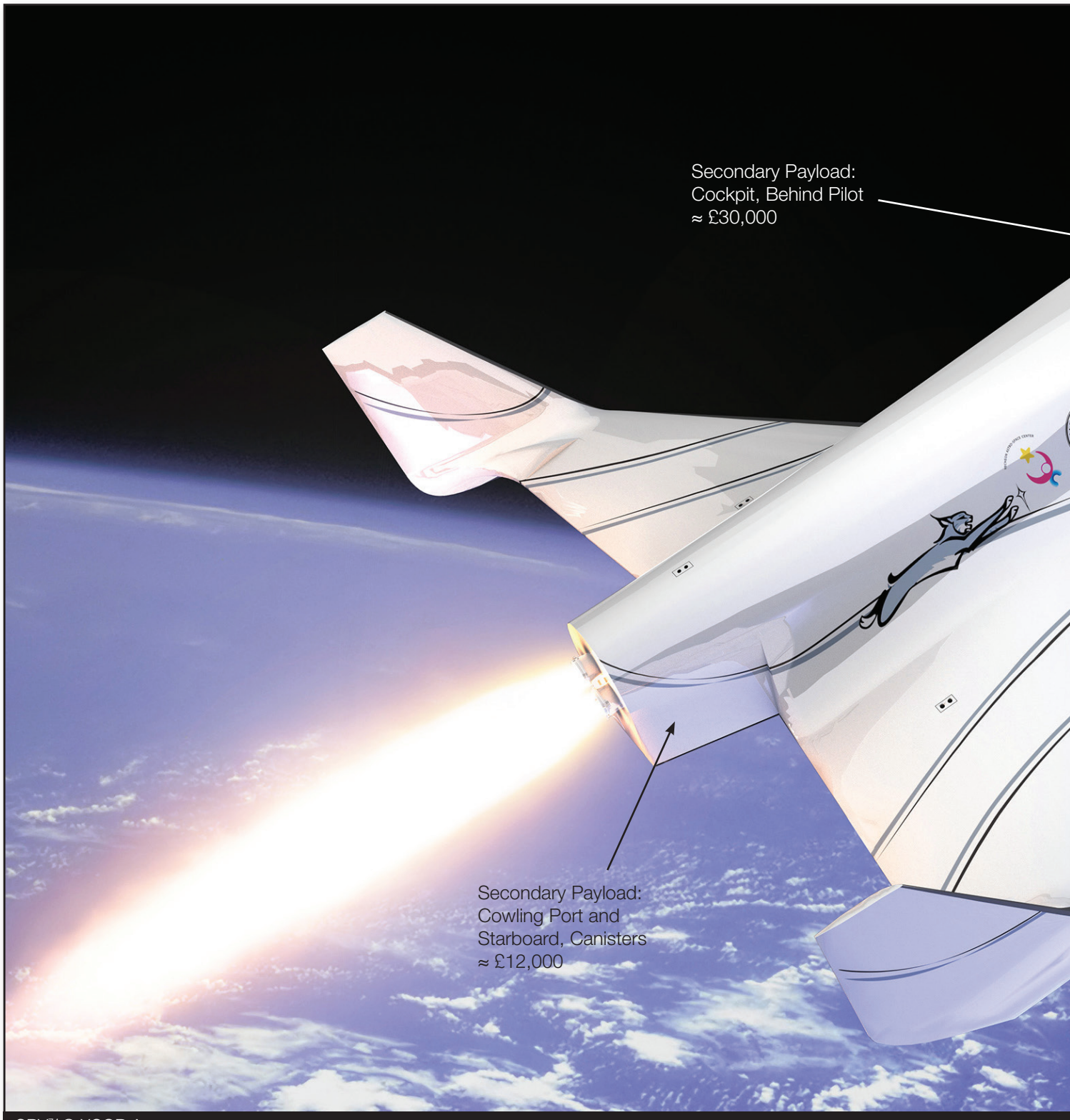


ISS*

Micro Gravity (µg): $10^{-2..-4}$
Duration: As required
Interaction: Human
Waiting Time: > 5 years
Cost/Expt: ≈ £1M-£4M

*Entry of new players such as Nanoracks has substantially reduced the cost of access to the International Space Station (ISS) for long duration microgravity research. Nanoracks has laboratories on the ISS and claims it can send 4x4x4 inch payloads for a period of 30 days at a cost of £18,000 (educational payloads) to £36,000 (commercial payloads)[73]. It also claims that the traditional wait time of more than 5 years is reduced to just 9 months.

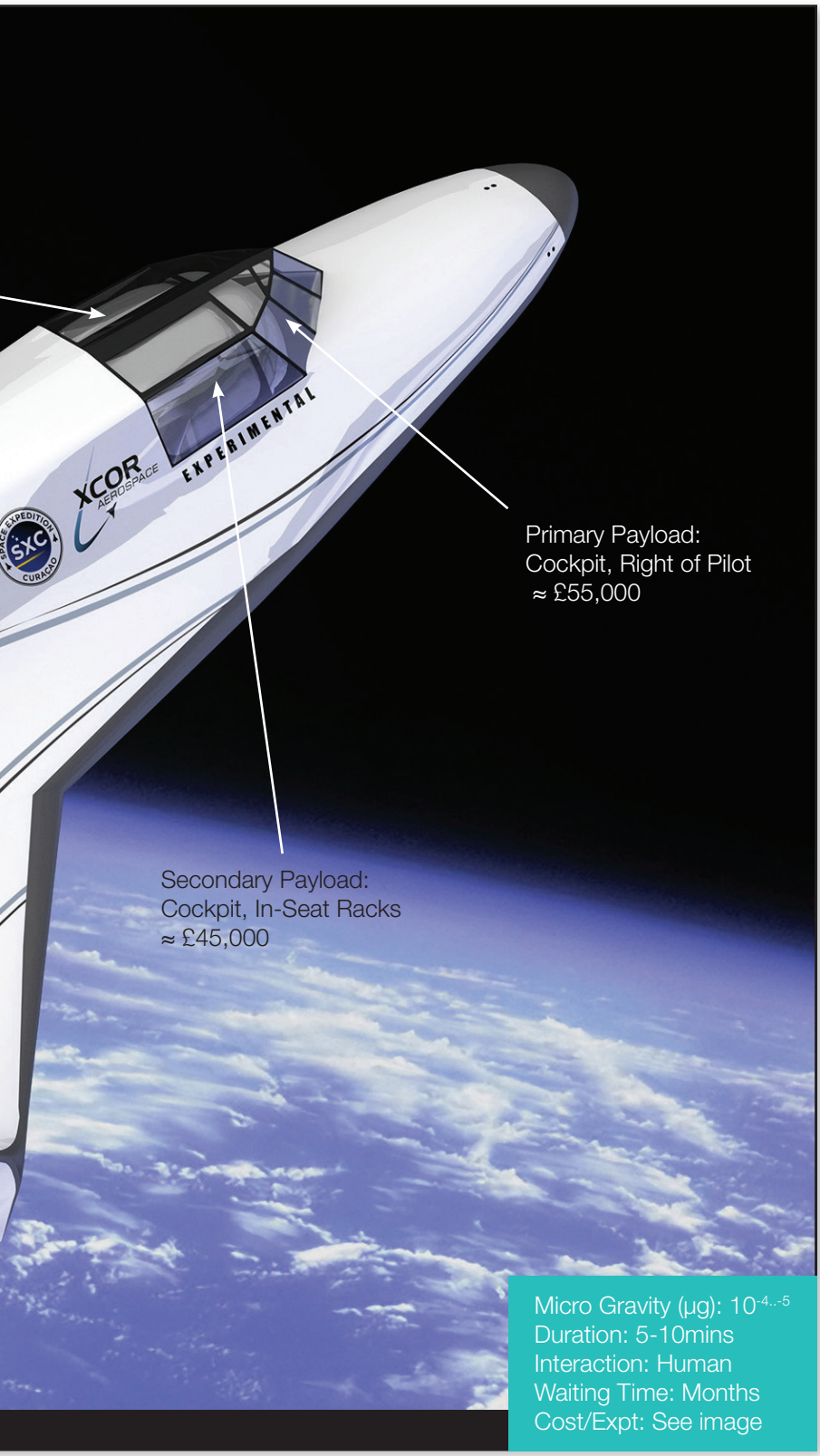
[72] See www.sub-orbital-research.org/wp-content/uploads/2013/11/SRA-and-Lynx-Mission-Eng.pdf (accessed 9th August 2014)
[73] See www.nanoracks.com/resources/faq/ (accessed 15th August 2014)



SRV[74] © XCOR Aerospace

The cost of carrying payloads on Virgin Galactic's SpaceShipTwo is not as well publicised. However the company has stated that for each simple, non-hazardous single payload, the cost is approximately £30,000[75]. Hence costs per payload are, in general, lower than both sounding rockets and parabolic flights.

There is scope for these vehicles to capture some share of the money invested in sounding rockets.



In 2011, the NASA sounding rocket programme was worth £27.26M[76]. This is equivalent to 486 Lynx flights, or even if half the money is spent on building payloads, it amounts to almost 5 flights a week[77]. However, according to some in the scientific community, these vehicles would not be a complete replacement for already existing platforms but rather act as complement to parabolic flights and launches to the ISS[78]. They will therefore act as another medium for conducting experiments.

The selection of Virgin Galactic by NASA for launching some payload experiments involved in NASA's Flight Opportunities Programme, shows there is interest from existing players to change or expand the platforms on which experiments are performed[79]. NASA is promoting three aspects via this programme - research, spaceplane operators as well as spaceports. There is therefore a need to build an ecosystem around this research area which would benefit the spaceport. **A similar ecosystem would need to be created within UK.**

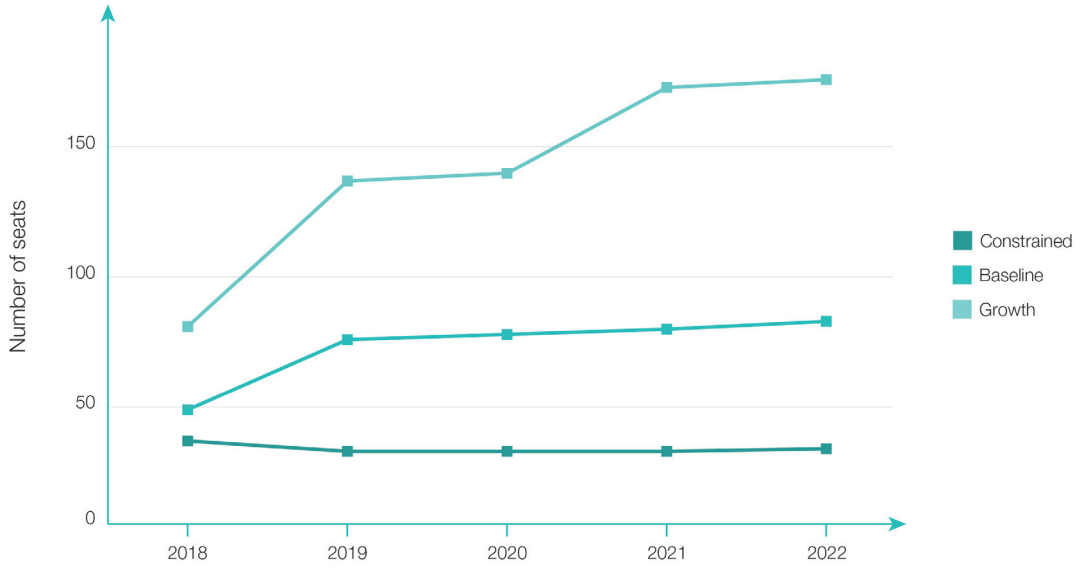
Beyond microgravity, there are other areas of research where SRVs could be used. These include:

- Atmospheric research
- Sub-orbital astronomy
- Longitudinal human research

The funding for all these research areas is dependent on universities, non-profits like the Wellcome Trust, as well as space agencies such as UKSA, ESA, and NASA. Given limited budgets and dependency on government and non-profit financing for research, the uptake in demand due to the introduction of SRVs may be limited. Assuming that the UK spaceport is ready by 2018, the potential global demand that it could capture based on budgets of space agencies, academic institutions

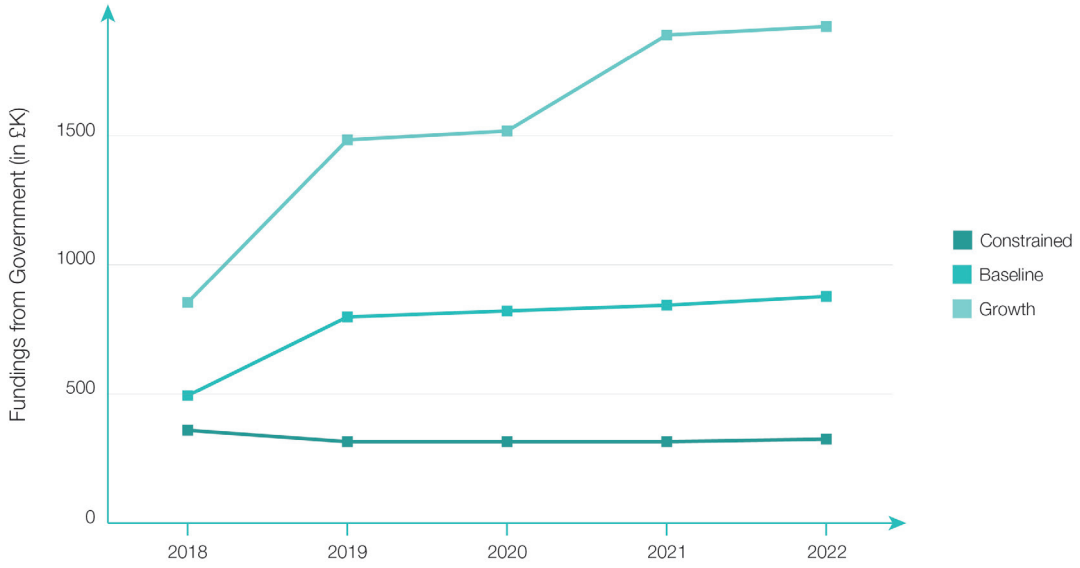
[74] See www.xcor.com/lynxpayloads (accessed 8th August 2014)
[75] Virgin Galactic Payload Users Guide, see www.virgingalactic.com/uploads/VG%20PUG%20WEB004%2020130612.pdf (accessed 19th August 2014)
[76] See www.citizensinspace.org/2012/11/sounding-rockets-and-low-cost-access-to-space (accessed 9th August 2014)
[77] Based on the cost of an XCOR Lynx flight with an engineer (charged at £68,000)
[78] Interview, Pierre-François Migeotte, Phd, Université Libre de Bruxelles, July 2014
[79] See www.nasa.gov/ames/nasa-virgin-galactic-announce-payloads-for-spaceshiptwo-flight/#.U-JKqPldWSo (accessed 9th August 2014)

and non-profits is given below[80]:



N.B. All numbers in seat/cargo equivalent

These are global numbers and since most of the interested organisations would be based in the US, the majority of these flights would take place there. It is assumed most of this demand will be met internally from US spaceports. This would be more than 50-60% of the global demand. Therefore out of the remaining 40%, it is assumed that the UK could potentially capture 15-20%. It is important to note that the below projections are based on majority funding coming from government and allied institutions:



Industry Demand

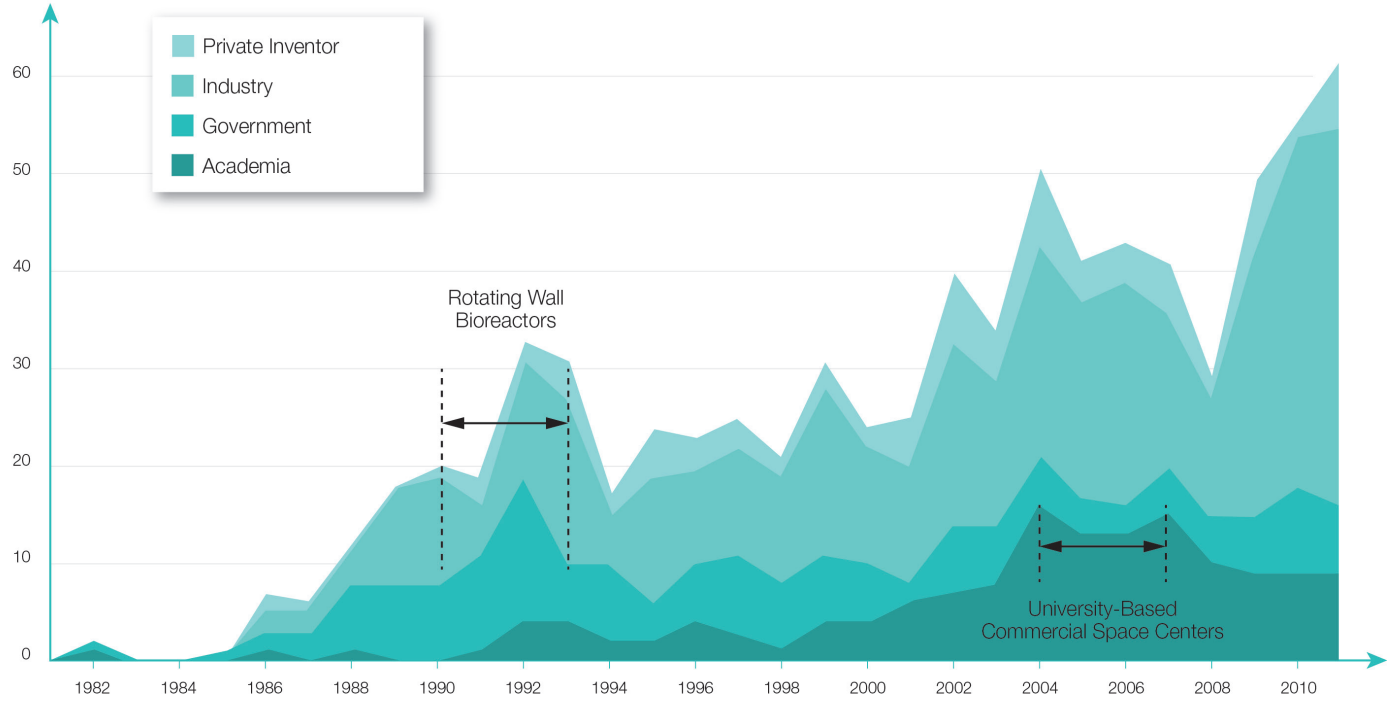
Although the demand from the scientific community could be limited due to the constrained budgets of governments and universities, there is a possibility of commercial players creating market demand for these microgravity experiments. In fact an analysis of patents filed in the US suggests the same. There have been a total of 818 patents filed related to microgravity so far with 587 applications this year[81]. This suggests that industry is getting more involved

[80] Tauri Group, "*Sub-orbital Reusable Vehicles a 10 Year Forecast of Market Demand*", 2012

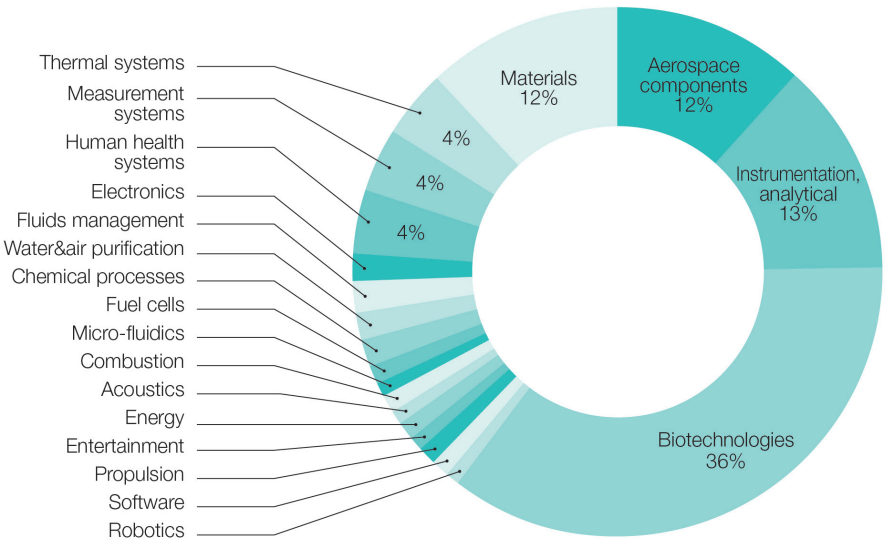
[81] Microgravity related patent history. Mark L. Uharan. See www.iss-casis.org/portals/0/docs/2012%20patent%20history.pdf (accessed 14th August 2014)

in space/microgravity research. A more detailed look at these patents shows that Biotech, Materials, Instrumentation and Aerospace sectors are leading the way:

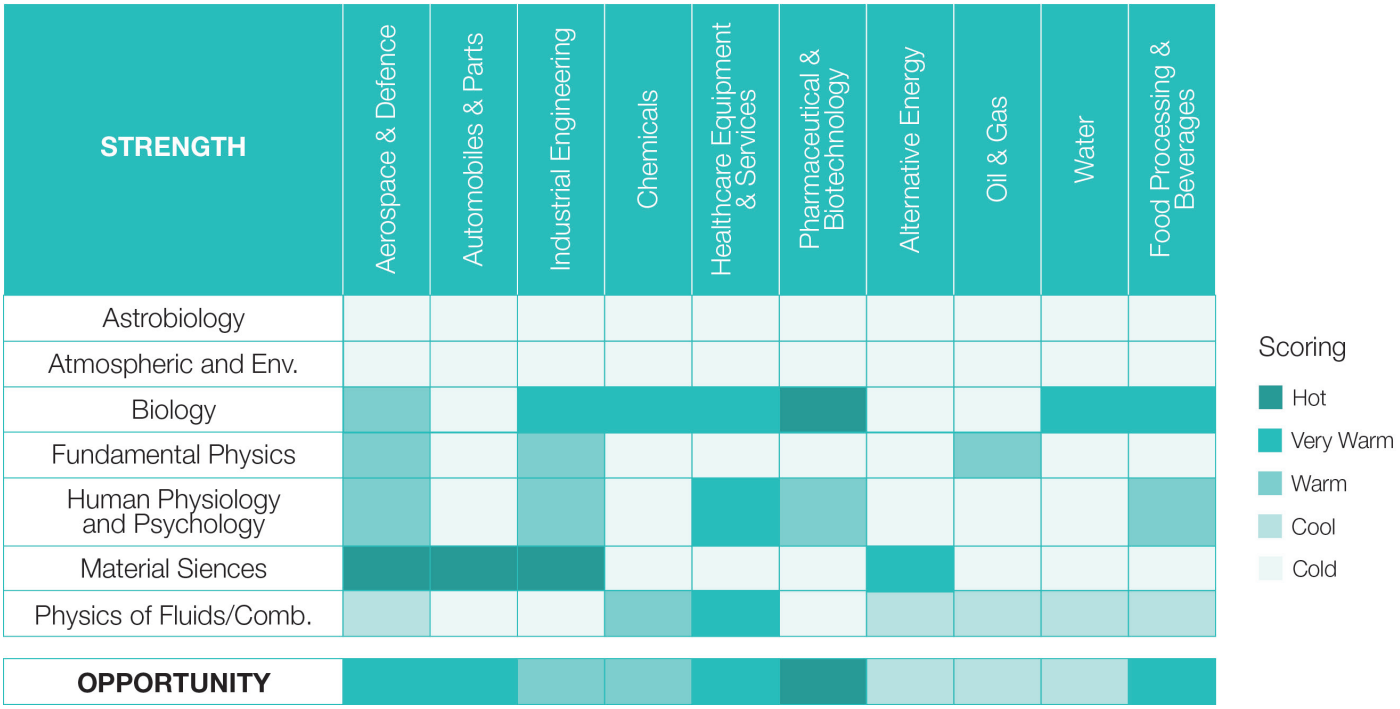
MICROGRAVITY PATENTS FILED



TOP 20 BY CATEGORY



These findings fit in very well with the sectors in the UK where innovation is most likely. The UKSA had pitched some sectors with a high scope of innovation, which would benefit the UK if it were to join ESA's ELIPS[82] programme[83]:



Assessment of UK Participation in the ELIPS-4 Programme

Two important sectors that could benefit the UK directly are Biotech and Aerospace. The UK Biotech and Pharma sector is £18.8B and growing at 17%, and the Aerospace sector is valued at £21.6B and growing at 5-10%[84]. This highlights the potential for microgravity research and its spill-over effects for the UK economy could be very high.

Biotech is an area which is 'red hot' for innovation, it is important to note that most biotech experiments require human interaction and hence would find both sub-orbital and orbital frequent and cheaper flights very attractive. At a later stage for longer exposure to microgravity experiments, the possibility of flights taking place to the ISS from the spaceport would provide an even greater benefit to the industry.

82 European Programme for Life and Physical Sciences in Space
83 Interview, Andrew Kuh, UK Space Agency, July 2014 and Assessment of UK Participation in the ELIPS-4 Programme, Nov 2012
84 Assessment of UK Participation in the ELIPS-4 Programme, Nov 2012

KEY FINDINGS

• The establishment of a spaceport is likely to give fresh impetus to the research sector within UK. This will also encourage universities and schools to be involved in the research, and may have an impact on students pursuing STEM related subjects and careers. It will also help UK industry by providing them the ability to conduct experiments at a cheaper rate, as well as more frequently.
• As the industry becomes more commercialised and private companies offer more opportunities for people to be involved in the space industry, this is likely to increase the level of interest in STEM programmes.
• The UK Government has already shown commitment to this by contributing £12.7M to the ESA ELIPS Programme[85]. Although there have been no UK led experiments selected so far on the ISS, there have been some via drop towers and parabolic flights.
• The space agency/government have an important role to play in building an ecosystem for commercial space exploitation from a research perspective in the UK.
• Analysis also shows that sectors like Aerospace, Defence and Pharmaceuticals are likely to benefit from increased interest in microgravity research by the UK academic community through participation in ELIPS[86]. These benefits are likely to be amplified with better access to research facilities and launch into space.
• It is important to keep in mind that the benefits of microgravity research to the spaceport are likely to come from various sources and are not limited to sub-orbital flights.

[85] See www.physics.open.ac.uk/Astrobiology-Dust/talks/talk3_Kuh_ELIPS.pdf (accessed 8th August 2014)
[86] Assessment of UK Participation in the ELIPS-4 Programme, Nov 2012.

OTHER COMMERCIAL DEMAND

To this point we have outlined the core demand for potential tenants of a spaceport. It is important that the spaceport does not rely solely on these income streams to provide the full potential economic benefit of operating a spaceport. Below are other identified sources of commercial demand that may contribute to a spaceport's income.

© The Wall Street Journal

Zero G Experience Flights

Used for future astronaut training to become accustomed to the micro-gravity environment, and scientific experiments including additive manufacturing (3-D printing)[87], these flights also present an opportunity for enthusiasts to experience zero gravity without leaving the Earth's atmosphere. One of the most well-known operators of such flights is US-based Zero G Corporation (a wholly owned subsidiary of Space Adventures, Ltd.), the first and only approved FAA company to provide commercial weightless flights for the public, using a modified Boeing 727-200F aircraft.

Zero gravity flights are not just for the general public, in fact that was not their original purpose. Key markets have evolved and also include corporate incentive flights, educator and student participants, television and movie production support, and private and government microgravity flights. In a typical flight, up to 15 parabolic flight profiles are flown, enabling microgravity for 20-30 seconds at a time.

The cost of the flight per person is around £3,000 or £97,000 for a fully chartered flight, seating (or floating) 36 passengers. During discussions with a handful of future astronauts as part of this study, it was noted that most of them would recommend these zero gravity flights to friends and family that were visiting the spaceport. For those less enthusiastic about the "vomit comet", there are less adventurous and more cost-effective options to participate[88]:

Non-flyer guest package at £115: Designed for friends and family members who want to join in on the pre and post flight activities. The price includes ZERO-G merchandise and attendance at the pre and post flight orientation and re-gravitation celebration.

Weightless workshop at £70: A 5 hour class where a strong foundation is established in areas like Newton's Laws, microgravity, parabolic flight, sub-orbital and orbital flights, current scientific research in space, effects of space and more. Attendees will then create, design and build a variety of in-flight experiments. Includes refreshments, ZERO-G merchandise, educational resources and experiment design materials. Does not include weightless flight.

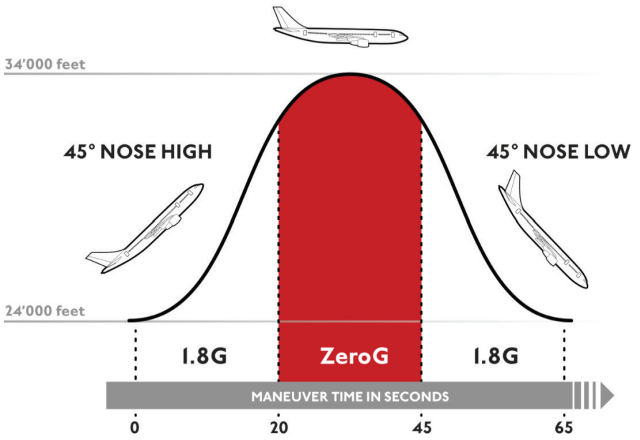
Scientific Research: Zero gravity flights may also provide healthy competition, or complementary services to spaceplane operators. Zero G Corporation publishes its pricing for experiments on its website[89]:

87 See www.madeinspace.us/about-made-in-space (accessed 15th August 2014)
88 See www.gozerog.com/index.cfm?fuseaction=Reservations.welcome (accessed 4th August 2014)
89 See www.gozerog.com/index.cfm?fuseaction=Reservations.welcome&CFID=698634&CFTOKEN=9edc8ca7a7fa0719-E8D174CA-BE4D-80E3-3AD68506BCD819A0 (accessed 10th August 2014)

Service	Price per Seat	Price per Section
Standard	£3,800	£20,500
Customised	-	£150,000
Research Only	£1,500	-

In Europe, too, zero gravity flights are being offered:

© ESA



© Huffington Post

Air Zero G - is a partnership involving Novespace, a CNES subsidiary, and Avico, French airline broker. Spaceport Sweden was selected as a partner and re-seller for some Air Zero G flights[90]. The cost is approximately £4,800 per flight. The company will re-begin flights again in May 2015 as its Airbus A300 aircraft is now retired[91].

Swiss Space Systems (S3) - has announced a new zero gravity service for 2015. The company, based in Switzerland, is to launch what it calls "affordable zero gravity flights" from 15 locations across the world, including Asia, the Middle East, North and Central America[92]. The cheapest way to be weightless is in the "ZeroG Party Zone", which costs approximately £1,600 per passenger, for 40 passengers in the main hold. Pay an additional £4,000 and this entitles you into the "Premium Zone", a section that offers more room for each of a maximum of 28 passengers. The passenger will also receive an exclusive Breitling S3 ZeroG personalised watch, which will also serve as the passenger's boarding pass.

Potential Zero G Demand Forecast – In the last 10 years, there have been 12,000 people that have taken part in Zero G Corporation's experience[93]. At a cost of £3,000 per passenger for a flight, this equates to £3.6M per year in revenue (does not include charter flights for science research). As an approximation, Zero G Corporation is operating about 30 flights per year across 4 locations in the US. Looking at the flight schedule proposed by Swiss Space Systems (S3)[94] they are planning for about 45 flights per year across multiple locations. If the UK could attract approximately 25% of S3's flights, then 10 flights per year equates to £1.2M per year of revenue from experience flights for the operator[95].

[90] See www.spaceportsweden.com/blog/fly-weightless-with-spaceport-sweden-in-europe/#.U9d1b_ldVMk (accessed 29th July 2014)
[91] See www.airzerog.com/en/book-your-flight/practical-information.html (accessed 29th July 2014)
[92] See www.innovation.uk.msn.com/personal/the-space-tourism-zero-gravity-plane (accessed 29th July 2014)
[93] See www.twitter.com/GoZeroG (accessed 29th July 2014)
[94] See www.zerog.s-3.ch/ (accessed 29th July 2014)
[95] £3,000 per pax, 40 pax total = £120,000 revenue per flight, x 10 flights per year = £1.2M

There are also advertising opportunities:

2008: 7Up filmed a TV commercial aboard Zero G to promote their "Free Ticket to Space" sweepstakes for $165k

2011: Justin Bieber filmed a TV commercial for his "Someday" perfume for $165k

2012: Stoli sent a mixologist up with the Zero G Corporation to mix the first ever gravity-free cocktail

2014: Kate Upton Sports Illustrated swimsuit issue 2014 filmed aboard Zero G Corporation jet

Some of this revenue would be paid to the spaceport in the form of landing fees. Using Heathrow Airport's published take-off and landing charges as a benchmark[96], approximately £5,600 would accrue to the spaceport operator per flight, therefore generating £56,000 in revenue from these 10 flights. This figure will be higher if research flights are carried out for microgravity research also. To give an example, if one research flight is flown per month, at a price of around £150,000 (based on the cost for Zero G Corporation's weightless lab charter), there would be an additional £1.8M of revenue from such operations. Again, the spaceport can benefit from take-off and landing fees equal to approximately £67,200 in total.

Commercial Transportation Flights

The ability to connect up, to what some future spaceflight passengers would consider remote locations, with UK hubs like London (Heathrow and Gatwick), Manchester, Edinburgh and Glasgow is an important factor. Supplementing spaceflight operations with landing fees from commercial transportation will add another revenue stream for the spaceport and attract tourists and visitors to the area.

Spaceport Sweden (Kiruna Airport) also has flights to and from Stockholm's main airport. Midland International Airport is tipped to be another spaceport location in the US, but the only one identified to date with commercial aircraft movements. Midland is Texas's 9th busiest airport with US carriers Southwest Airlines, American Eagle and United Express all serving the airport. In 2012 about 500,000 passengers used the airport[97].

There are competing views concerning commercial spaceport operations. One is that operating from the same facility as commercial aircraft will likely impact negatively upon commercial flight operations. That is because of the buffer required (either side of take-off and landing) for safety reasons when a spaceplane is operational, this includes the glide back to Earth of both Virgin Galactic's SpaceShipTwo and XCOR's Lynx spacecraft for example.

> *"It's very hard to separate a gliding spacecraft from a passenger jet[98]."*

Evacuation of passenger terminals may also need to be taken into account if there is an incident at a spaceport that shares commercial flights and spaceplane operators.

On the other hand, Mojave Air and Space Port doesn't shut down the entire airport whilst a Virgin Galactic test flight is going on. It still permits other aircraft movements whilst SpaceShipTwo is waiting to glide back to Earth. Furthermore, it was mentioned:

[96] See www.heathrowairport.com/static/HeathrowAboutUs/Downloads/PDF/Heathrow%20_Airport_Limited_Conditions_of_Use_Draft_Consultation_Proposal_2015.pdf (accessed 14th August 2014)
[97] See www.en.wikipedia.org/wiki/Midland_International_Airport (accessed 29th July 2014)
[98] Interview, Will Whitehorn, ex Virgin Galactic President, July 2014

> *"You don't have to shut down multiple states' airspace to operate a spaceplane test flight*[99]*."*

Mojave Air and Space Port does not have commercial flights but is rather a private aerodrome for general aviation flying, therefore there is no impact on commercial flight services. Sharing a spaceport with general aviation flights may therefore be easier to co-ordinate than with commercial airline operations.

NASA has selected Generation Orbit to provide a CubeSat-class launch via the NASA Launch Services Enabling eXploration and Technology (NEXT) contract[100]. The company operates out of Cecil Airport in Florida which is an ex US Navy base but is now a public joint civil-military airport and spaceport. Generation Orbit's COO believes that given the airport's history and experience with operating military aircraft movements, this is advantageous for the company in terms of the airport being able to co-ordinate multiple forms of traffic better.

> *"The airport operators only have to close the runway to other traffic for 30 minutes when our aircraft is taking off*[101]*."*

This serves to highlight that normal operations do not have to be blocked for many hours to accommodate launch vehicles. In addition, some aerodromes' may have more experience than others of co-ordinating aircraft movements that involve munitions with other commercial and general aviation traffic.

High Altitude Balloons

© NewSpace Journal

Another type of "space" tourism experience is via stratospheric balloons, which are already used as a research tool, especially in regards to atmospheric studies. The idea is to lift a habitable pod carrying participants and crew up to an altitude of more than 32 km. The balloon will be able to spend more than 2 hours above that altitude. It's likely that these near-space systems would launch from a spaceport for similar reasons as spaceplane operators, including utilising clear airspace for launch and landing[102]. The distance between launch and landing sites can be as much as 300 miles[103], which could necessitate a point to point route from one spaceport to another. The US based company World View® Enterprises has confirmed that the FAA determined that its near-space balloon operations fall under the jurisdiction of the Office of Commercial Space Transportation (FAA AST), as is the case for spaceplanes[104].

Even if the participants will not be considered astronauts, this kind of service is an option for those who don't fulfil the fitness requirements to get on-board a SRV and/or are looking for a more luxurious and affordable experience than the adventurous thrill of rocket powered spaceflight. It is open to all ages and medical conditions, effectively widening the market:

[99] Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014
[100] See www.nasa.gov/centers/kennedy/news/releases/2013/release-20130930.html#.U_IAkfldVMk (accessed 18th August 2014)
[101] Interview, AJ Piplica, COO Generation Orbit, July 2014
[102] Interview, Christine Anderson, Executive Director NMSA, Spaceport America, August 2014
[103] See, www.worldviewexperience.com/voyage/#flight-profile (accessed 15th August 2014)
[104] See, www.paragonsdc.com/index.php?action=viewPost&postID=50 (accessed 15th August 2014)

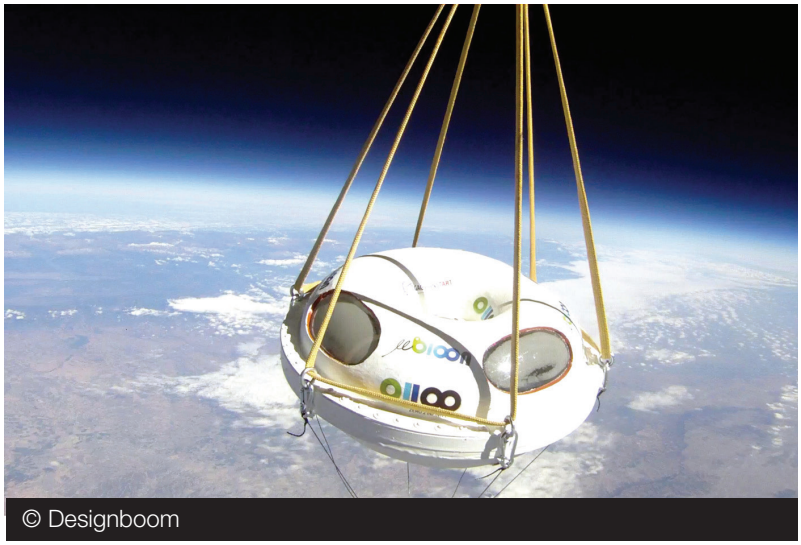
> *"If you can fly on an airliner you can probably fly with us. There are no extra medical requirements, tests or related costs. The nature of the bloon flight, with her gentle trajectory and comfortable cabin conditions guarantees that almost anybody can fly*[105]*."*

It is appealing to passengers seeking a more luxurious ride as the flight profile and services on-board (including bar service) can be tailored to the customer's requirements:

> *"Our flight profile will let you select different levels of gravity. Zero gravity can be very exciting, especially in small doses. And that is why bloon offers it as an option*[106]*."*

A Spanish company called Zero2Infinity will, from 2016, send a pressurised capsule for four passengers and two pilots to the stratosphere. The cabin can be designed to carry a family of four, or separate the cabin for two sets of two people, allowing privacy. Children are allowed but those under the age of 16 must be accompanied by an adult. Therefore this could be a real attraction for family members that are travelling with spaceflight experience customers.

Zero2Infinity highlights that its design is largely for the view of Earth's curvature and a couple of hours of 'black sky time', though on the way back down the capsule separates from the balloon and there's a whole two minutes of weightlessness before a para-foil is deployed and the pod stabilises and slowly sinks back to Earth.



© Designboom

It costs approximately £90,000 per person. The company is currently operational to send scientific and technical payloads to "near-space" as was demonstrated during several test flights conducted in 2012 and 2013. Its aim now is to offer the view from near-space to private passengers[107].

World View® Enterprises is also offering near-space

[105] See www.inbloon.com/en/faq/health-and-safety.php (accessed 14th August 2014)
[106] See www.inbloon.com/en/faq/flight-experience.php (accessed 14th August 2014)
[107] See www.innovation.uk.msn.com/personal/the-space-tourism-zero-gravity-plane (accessed 4th August 2014)

experiences for tourism, research, education and other scientific and commercial pursuits. Tickets for passengers will cost approximately £45,000 and Paragon Space Development Corporation is the vehicle developer. The company describes the balloon ride experience:

> *"The World View spaceflight experience will begin with a gentle ride in the comfort of a luxuriously appointed space-qualified capsule, lifted by a high altitude balloon to 30 km. There, passengers will remain aloft for approximately two hours before gliding back to Earth* [108]*."*

KEY FINDINGS

- Multiple tenants mean fixed costs can be spread across more than just one exclusive operator. In an interview with Stuart Witt at Mojave Air and Space Port, he mentioned that 51% of his facility's revenues now come from commercial space entrepreneurs[109]. There is therefore a significant proportion of revenue being generated by other tenants that are not space businesses.
- If space tourism or satellite launches fail to gain momentum, then the spaceport could plug the revenue gap with other operations that are in demand, including zero g experience flights and high altitude balloon rides. These are less expensive options and their price points are more accessible for those not wishing to pursue a spaceflight experience.
- A spaceport with commercial flight operations will continue to serve the local community and generate landing fees. There is a trade-off associated with this in relation to potential difficulties with co-ordinating spaceplane and commercial aircraft movements.

[108] See www.paragonsdc.com/index.php?action=viewPost&postID=50 (accessed 15th August 2014)
[109] Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014

SPACEPORT UK

3 Spaceport Facilities

This section highlights the core requirements in terms of facilities at a spaceport and examines these in the context of existing military versus commercial/ private aerodromes. It will also identify activities at a spaceport that will attract tourists and visitors and further increase revenue options for a spaceport.

There are two development models for a spaceport:

1) Using an existing aerodrome and readying it for spaceport use
2) Developing a purpose built new facility from the ground up

The UK has short listed existing aerodrome sites so far as per the CAA's technical report. The follow on question from that is whether or not to choose:

A) An existing CAA licensed or private aerodrome with commercial flights and/or general aviation traffic
B) An existing military aerodrome

Commercial/General Aviation Airport
Advantages: existence of core airport facilities including passenger terminals and concessions, maintenance hangars, fuel storage facilities and nearby passenger amenities, including hotels and restaurants. Also connects up a spaceport with other regional and international hubs for visiting tourists and spaceplane customers.

Disadvantages: lack of existing infrastructure such as bunkers and ordnance rooms to be converted into facilities for spaceplanes, including clean rooms for satellite integration. HAZMAT and emergency response capability will need upgrading to deal with risks of handling rocket fuel. Additionally, spaceplanes might limit the commercial flight activity for an active commercial airport given the safety buffers required around take-off and landing.

Military Airport
Advantages: existence of facilities like bunkers, missile silos, ordnance rooms that can be utilised for spaceplane use. Obtaining clearance for dedicated airspace may be easier to achieve than at a commercial airport and existing danger areas can be activated. Furthermore, military air traffic control will have the expertise and experience in terms of handling aircraft with ordnance. If ITAR rules are a significant hurdle in permitting spaceplane operators to function from the UK, then using an existing, secure military aerodrome is likely to go some way to alleviating ITAR constraints.

Disadvantages: Security requirements at a military installation may require substantial pre-screening/ checks of visitors. This can have a detrimental effect on the number of tourists visiting the spaceport if there is a lengthy pre-approval process required to visit. Authorisation may take longer for sub-orbital launch operators also, this has been the case for Swiss Space Systems looking to perform drop tests in Canada from Canadian Forces Base Goose Bay[110]. Therefore a spaceport may need to be cordoned off from the military base, with the runway and other maintenance facilities shared. Some of the basic terminal facilities may need to be converted into passenger friendly facilities, particularly to be up to standard for VIP passengers expecting a top class pre-flight experience. In addition, military aircraft movements are likely to take priority over any spaceplane traffic, thereby reducing the operational flexibility for spaceplane operators.

[110] Interview, Richard Joye, Head of Business Development Swiss Space Systems, August 2014

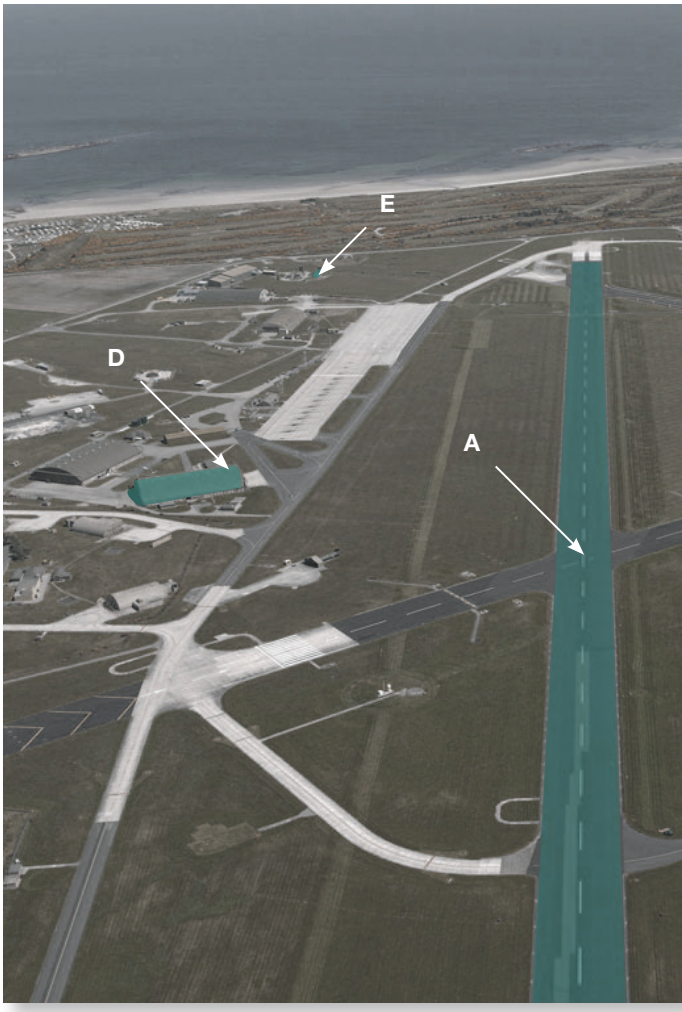
CORE INFRASTRUCTURE REQUIRED

A – Runway extension costs are estimated at around £4M per 100m of runway required, for the purposes of this study. The range communicated by construction companies to the UKSA was £1M-£4M, therefore the most conservative figure in terms of costs was used. This figure was corroborated with a 2005 Futron study done for a commercial spaceport in Florida. Approximate costs for a 3,000m runway were $200M, or £4M per 100m[111].
Runway extension will represent the vast majority of the total cost of development at a spaceport. The same Futron report shows that runway construction can represent as much as 90% of the total cost for a new spaceport site[112]. Therefore an airfield with more than or close to 3,000m will have the benefit of needing less capital for runway extension. All spaceplane operators interviewed will require at least a 3,000m runway. Future proofing for spaceplanes not in service by 2018 would need to be considered – for example Reaction Engine's SKYLON vehicle will require a 5,000m runway – therefore there would be significant extra cost to facilitate this launch vehicle in the UK and a site would need to be chosen that has sufficient land available to extend the runway to such a length once the company nears operations.

B – Hangars and other maintenance facilities are likely to represent the next biggest cost in a spaceport's development. However much of that depends on whether existing facilities are sufficient to house launch vehicles and are up to standard for regular maintenance of the aircraft. In discussions with airfield managers' at some of the shortlisted sites, it was communicated that a basic maintenance hangar could be built for approximately £750k[113]. A more advanced 50,000sq ft hangar facility could be constructed for approximately £5M based on a Futron study into a commercial spaceport in Florida[114].

At Mojave Air and Space Port, most of the hangars and real estate on the spaceport were developed at the tenant's own cost. Stratolaunch Systems built a 100,000 sq ft hangar in 2013 at Mojave and that was completely paid for by Stratolaunch, not the airport. It was the same story for Virgin Galactic. Therefore, assuming only minor refurbishment is required of existing hangar facilities, this cost could be kept to a minimum for the spaceport depending on which operating model it chooses to adopt.

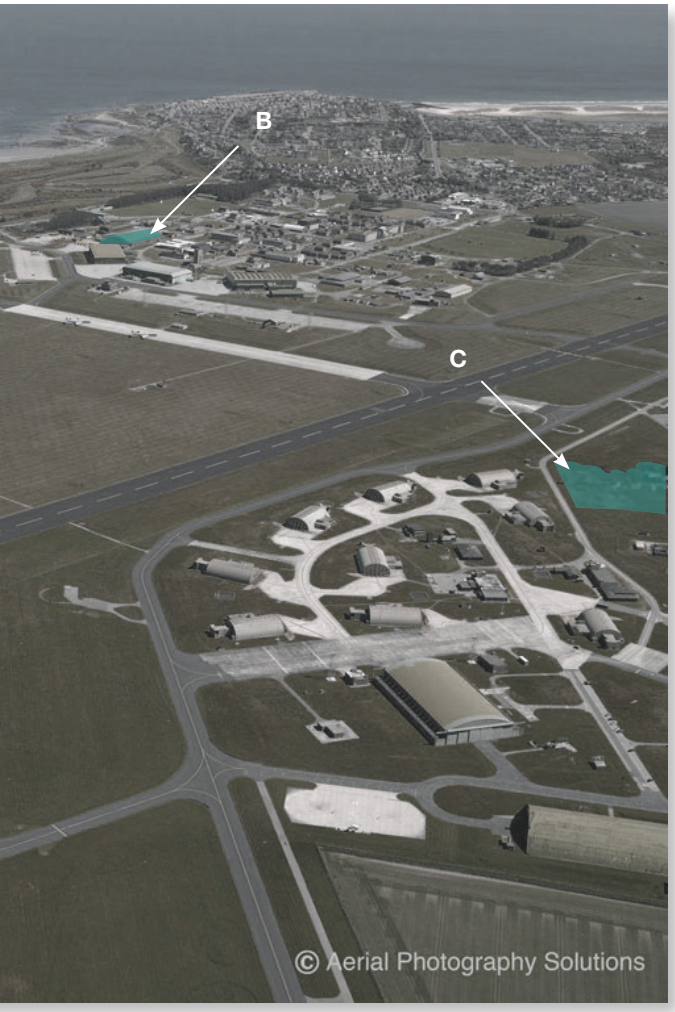
C – Munitions/ordnance bunkers could be used to house satellites in a clean room environment before launch and during the integration phase. Military bases are likely



to have these facilities already and so they could be used for satellites, assuming there is spare capacity. Satellite manufacturers may prefer to use their existing facilities and ship to the spaceport ready for launch, as opposed to perform extensive preparation and construction of the satellite at the spaceport. In that case, basic clean room storage facilities will be sufficient. From brief research, high spec clean rooms can be expensive to construct, potentially as much as £4,000 per sq ft[115]. Clyde Space facilities, for example, include a 2,000sq ft electronics lab and cleanroom.

D – Terminal facilities are an important factor in the overall experience for spaceflight customers. In the discussions with future astronauts, the majority spoke about the excitement of being in a state of the art facility such as Spaceport America. To a large extent, the build-up and preparation for a spaceflight experience should closely resemble the

111-112-114 Futron Corporation, "*Feasibility Study of a Florida Commercial Spaceport*" September, 2005
113 Interview with MACC Development Ltd, Business Manager, 5th August 2014
115 See www.cleanroomtechnology.com/technical/article_page/The_future_of_cleanroom_design/52499 (accessed 10th August 2014)



magnitude of the actual flight:

"*The experience has to be top of the line, the customer wants to feel looked after and be able to celebrate such an experience. The building/terminal facility is a big aspect of that, the Foster designed building at Spaceport America looks futuristic and exciting – would one be as excited about going to a facility that looked like a normal terminal?*[116]"

Therefore it's very likely that some existing aerodromes will need to upgrade their terminals, or welcoming halls, to be in tune with the VIP experience that is human spaceflight. However, spaceport facilities do not have to be as elaborate or expensive as we have seen in some cases in the US. Customers value the wider "location experience" highly and that includes local attractions and the local amenities, not solely a terminal facility.

E – Fuel Storage, HAZMAT and Emergency Response facilities at the spaceport are essential. Operational costs as a result of maintaining fire and rescue services at Spaceport America, for example, are significant. The spaceport is an hour away from local county fire and rescue services so they have had to maintain their own fire equipment and medical facilities on the spaceport. These type of operational costs are important to think about when deciding on where to locate a spaceport:

"If you can synergise and streamline your operations as much as possible, that is very beneficial.[117]"

All the proposed sub-orbital spaceplanes and vertical launch vehicles use rocket-based propulsion at some stage of the flight profile. The following fuels have been identified in the course of evaluating spaceplane operator requirements[118]:

- Hydrocarbon fuel, eg kerosene-based rocket propellant
- Cryogenic propellants, eg liquid oxygen and liquid hydrogen, maintained at very low temperatures
- Solid propellants, eg powdered aluminium-based solid fuel; and
- Hybrid propellants, eg mix of solid propellants with oxidisers such as liquid oxygen.
- Jet Fuel

Spending on HAZMAT will include the training of emergency responders and spaceport personnel certified to handle, load and store rocket fuel. There are significant operational costs to weigh when deciding whether or not to maintain an emergency response for spaceplane operations on site or use local services. It is likely that military bases will have the necessary personnel and emergency procedures already in place given that they would be handling ordnance regularly. Military bases will have trained fire crews on site, therefore offering quick emergency response in relation to military aircraft incidents.

There are different views on the operations management of a spaceport. For example, Mojave Air and Space Port prefers to outsource its non-core operations such as fire and medical emergency services. On the other hand, Spaceport America bears the operational costs of on-site emergency response facilities because it is about one hour away from local emergency services[119].

F (not shown) – Vertical launchpad and towers – As per the CAA review, the greatest commercial benefits would accrue from a site which offers both vertical and horizontal (spaceplane) launch. However these are unlikely to be co-located in the UK:

[116] Interview with future astronaut, Julian Ranger, July 2014
[117] Interview, Christine Anderson, Executive Director NMSA, Spaceport America, August 2014
[118] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.251-252*" July, 2014
[119] Interview, Christine Anderson, Executive Director NMSA, Spaceport America, August 2014

> *"Certainly in the first few years of operation, catering for both horizontal and vertical launch at the same location may not be possible*[120]*."*

If vertical launch operations are planned as part of the later stages of a UK's launch infrastructure, a baseline cost of £7.4M[121] is estimated for the construction of vertical Launchpad and towers[122].

This figure ties in approximately with other reports produced that show a launchpad for a small launcher and resulting infrastructure could be developed for around £10M[123].

[120] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.203*" July, 2014
[121] Pad and tower convertible for multiple vehicles and includes water deluge system
[122] Futron Corporation, "*Feasibility Study of a Florida Commercial Spaceport for Florida Space Authority*", Sept 2005
[123] Consortium of UK companies, "T*owards a UK Launch Infrastructure*", July 2013

SPACEFLIGHT PREPARATION AND TRAINING

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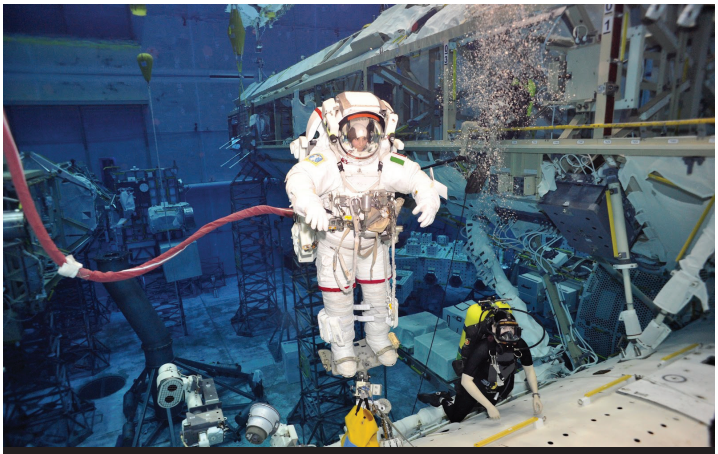

© NASA

Commercial astronaut training serves as another example of how a spaceport could attract other types of commercial space firms, outside of the spaceplane operator category. This type of activity could also attract tourists and space enthusiasts to a spaceport, and offer activities for friends and family of astronauts/tourists not wishing to seek the real spaceflight experience.

Commercial companies offering astronaut training are appearing in the marketplace, including Waypoint 2 Space, located in Houston, Texas. The company runs commercial spaceflight training through its collaboration with NASA centres. Participants can experience every aspect of traditional astronaut training on their way to becoming a Commercial Spaceflight Participant[124].

For around £25,000 for a one week course, participants can go through spaceflight fundamentals training. The company also offers sub-orbital and orbital spaceflight training, however prices are not publicly available for these programmes. Waypoint 2 Space is due to start classes in 2015 and is currently offering the chance to be the first of 300 students[125]. The company's vision is to franchise its offering around the world, not just in proximity to NASA centres.

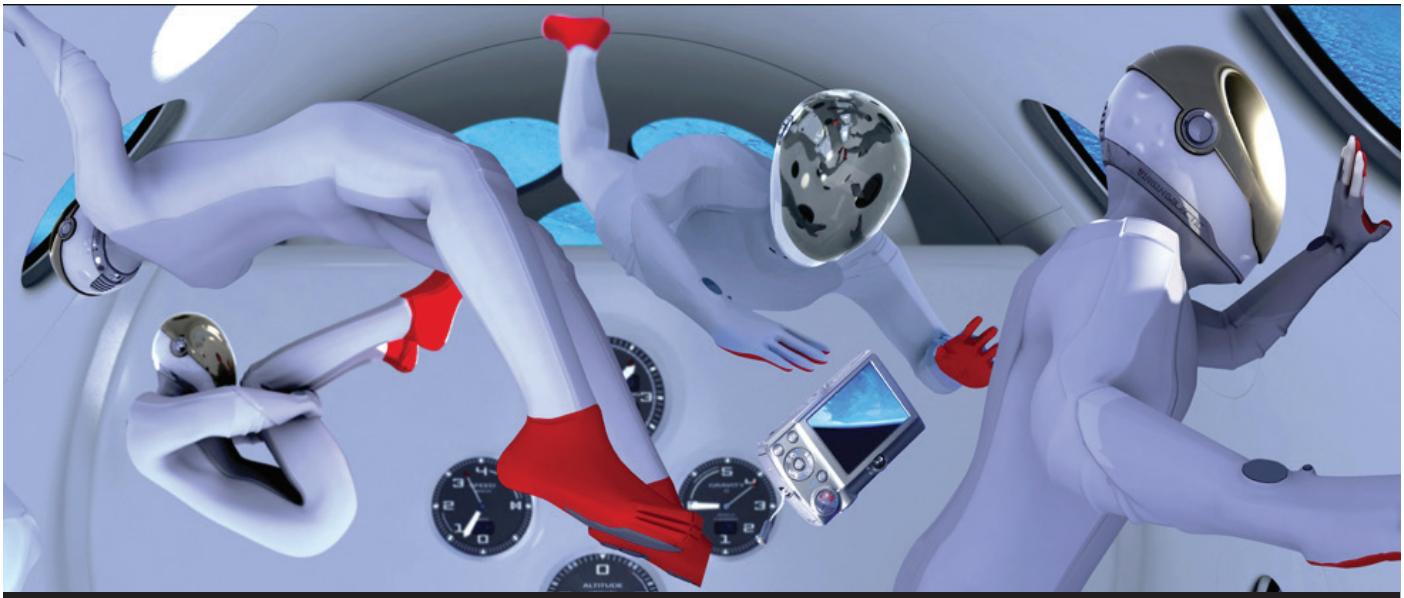
Centrifuge Training

Some Virgin Galactic customers have undergone flight simulation training sessions in the NASTAR Centre, just outside of Philadelphia. The centre's two day Space Flight Training Programme, includes academic classes that train the passengers to deal with the intense G forces experienced in flight, and six flight simulations in NASTAR's STS-400, a centrifuge that provides the same physiological effects of a trip on Virgin's SpaceShipTwo.

The UK's only long-arm centrifuge, and one of only 20 in the world, is located at Farnborough and is operated by QinetiQ, mainly for MOD use. Human centrifuges are large and test the reactions and tolerance of pilots. Whilst a long-arm centrifuge located at a spaceport would assist with streamlining training and medical assessment of spaceplane flight crew, they are expensive. Given the fact that some passengers and crew may prefer to undergo training in close proximity to London (this may be weeks before the actual spaceflight) rather than going to a spaceport, it's unlikely that the UK would need to build an additional centrifuge for training of future astronauts. Consideration could be given to re-locating the centrifuge at a spaceport however, especially if that spaceport was co-located with a military base.

[124] See www.waypoint2space.com/about (accessed 4th August 2014)
[125] See www.waypoint2space.com/ (accessed 4th August 2014)

Spaceflight Simulation



© Virgin Galactic

Having spoken to "future astronauts" (customers of Virgin Galactic), it is known that they will go through a simulation of the flight experience a few days before the actual flight. Virgin Galactic describes the pre-flight experience on its website:

> *"The trip will be intense, exhilarating, and the more that can be simulated beforehand, the better the real thing will be. Learning how to make the most of your time in microgravity and tips on how to be the most comfortable in macrogravity will form an important part of your preparation. Your pre-flight preparation will ensure that you are mentally and physically prepared to savour every second of your spaceflight*[126]*."*

This presents an opportunity for wider commercialisation to the general public and offers them the opportunity to go through these simulation experiences at a much lower cost than actually going into space. Future Virgin Galactic astronauts also highlighted the potential for their family members and guests to pay for a pre-flight experience:

> *"The simulation in pre-flight training is something that could be sold as a package for those not willing to spend the $250k or don't want the risk of going into space*[127]*."*

[126] See www.virgingalactic.com/overview/training (accessed 14th August 2014)
[127] Interview with future astronaut, Julian Ranger, July 2014

TOURS/VISITORS CENTRE

Considering the rich space history of the UK going back to the 1950s, the high integrity satellite manufacturing industry, and newly developed engine and launch vehicle technologies such as those seen at Reaction Engines, it would be fair to say that there is enough compelling content to establish an attractive visitor centre. Ancillary activities like spaceplane simulators could also be used to attract budding test pilots and future astronauts.

Spaceport tours and visitor centres are useful places to showcase the UK's growing space sector to space enthusiasts, tourists and school children alike.

> *"It's imperative that the spaceport gives back to the community and excites kids and encourages them to take up science and maths*[128]*."*

Additionally a visitor centre can serve as a continuous revenue source for the spaceport itself in the longer term as visitors and tourists return to the spaceport in the form of tenants and/or customers of spaceplane operators.

The costs to establish a visitor centre vary widely depending on the availability of an existing building, location, and the content of the exhibits. NASA's Kennedy Space Centre Visitor Complex houses a 90,000sq ft exhibit dedicated to the Shuttle Atlantis. This was reportedly created at a cost of $100M[129], however commercial bank capital went most of the way to funding the exhibit, given the predictable stream of revenue from ticket sales and concessions. For comparison, the Smithsonian National Air & Space Museum in Washington DC attracts over 8 million visitors per year[130].

Spaceport America had plans to build a dedicated visitor centre (capable of attracting 200,000 people a year), and sought funding for around $20M, however those plans are reportedly on hold due difficulties with obtaining favourable financing terms. It's more likely that existing hangar facilities will now be used to house exhibits and facilitate tours of the spaceport by visitors[131]. This will be at substantially lower cost than building a new visitor centre.

Spaceport Sweden is very focused on providing a unique experience to attract visitors to its spaceport and the surrounding area. The spaceport believes as many as 145,000 space tourists will visit the region annually as a result of its activities and offerings[132]. They are also planning to add a Space Visitor and Science Centre[133]. The early concept that emerged includes a unique "Earth and Sky Centre" as a hub for the experience, bringing space exploration to life in the context of planet earth through immersive, interactive and participatory exhibits and programmes. Spaceport Sweden also hopes to build on its launch history by showcasing the Esrange Space Centre - a base for scientific research with high altitude balloons, investigation of the aurora borealis, sounding rocket launches, and satellite tracking.

[128] Interview, Christine Anderson, Executive Director NMSA, Spaceport America, August 2014
[129] See www.spaceflorida.gov/news/2012/09/24/space-florida-secures-financing-for-space-shuttle-atlantis-exhibit (accessed 11th August 2014)
[130] See www.newsdesk.si.edu/about/stats (accessed 23rd August 2014)
[131] See www.parabolicarc.com/2014/03/25/spaceport-americas-incredibly-shrinking-visitors-center-threatens-tourism-plans (accessed 11th August 2014)
[132] See www.parabolicarc.com/2014/02/11/51602/ (Accessed 10th August 2014)
[133] ibid

SPACE CAMPUS

The aerospace sector in the UK is an excellent example of creating a high value ecosystem. There is already a thriving high integrity aerospace industry and there are high-value manufacturing companies throughout the UK in aerospace supply chains. Many tiers of manufacturers revolve around prime contractors such as Airbus, Rolls Royce, and BAE Systems[134]. SSTL is one of the UK's most successful spin-outs from a university campus and therefore there are opportunities for universities/research centres to collaborate with these high value manufacturing firms within the confines of a spaceport.

Spaceport Sweden, for example, has developed a successful space campus. It is focused on research, training, and conferencing. It has a partnership with QinetiQ to develop and deliver a spaceflight preparation programme for future astronauts. Together they run the Flight Psychological Centre that prepares passengers and crew for future space vehicles and their specific acceleration environment. Additionally they offer lectures, practical demonstrations, and one-on-one tuition on space flight experience[135].

Spaceport Sweden holds conferences, PR events, and technical visits to its space campus. These activities are useful for increasing public interest in space and furthering academic interest in space research.

Spaceport America also rents out its facilities to firms looking to hold conferences and seminars. Some companies have even asked the spaceport if they can hold movie shoots at the location. This is another way for a spaceport to diversify its revenue source.

In summary, a space campus can serve multiple purposes that benefit the spaceport, space industry, and space research; creating real value for the wider economy.

KEY FINDINGS

- Selecting an existing site that already has operational synergies, in terms of a number of the core infrastructure requirements for a spaceport, will be beneficial for reducing initial capital investment. Runway costs can represent as much as 90% of the total cost of spaceport site development.
- Consideration should be given to which of the operating models a spaceport will adopt. This will determine the level of capital costs borne out between private investment and the spaceport itself:
  - Renting land and have tenants build/ upgrade
  - Building purpose built facilities and leasing them back
- Other considerations for choosing a spaceport site need to be taken into account - in terms of operating spaceplanes alongside commercial and military traffic.
- The capital investment required to make necessary upgrades to facilities does not have to be on a similar scale as a new facility in order to provide a great customer experience and create a safe and functional spaceport. Upgrading existing facilities will cost much less than an estimated £5M for a new hangar that could serve as a terminal facility also.
- There are a number of other facilities and activities that a spaceport can consider to diversify revenue streams and create interest in the space sector – including spaceflight training and visitor tours.

[134] Interview, Denzil Lawrence, Advanced Manufacturing Research Centre with Boeing (part of the High Value Manufacturing Catapult), August 2014

[135] See www.spaceportsweden.com/blog/spaceport-sweden-signs-strategic-partnering-agreement-with-qinetiq/#.U-s6Ffl5McE (Accessed on 10th August 2014)

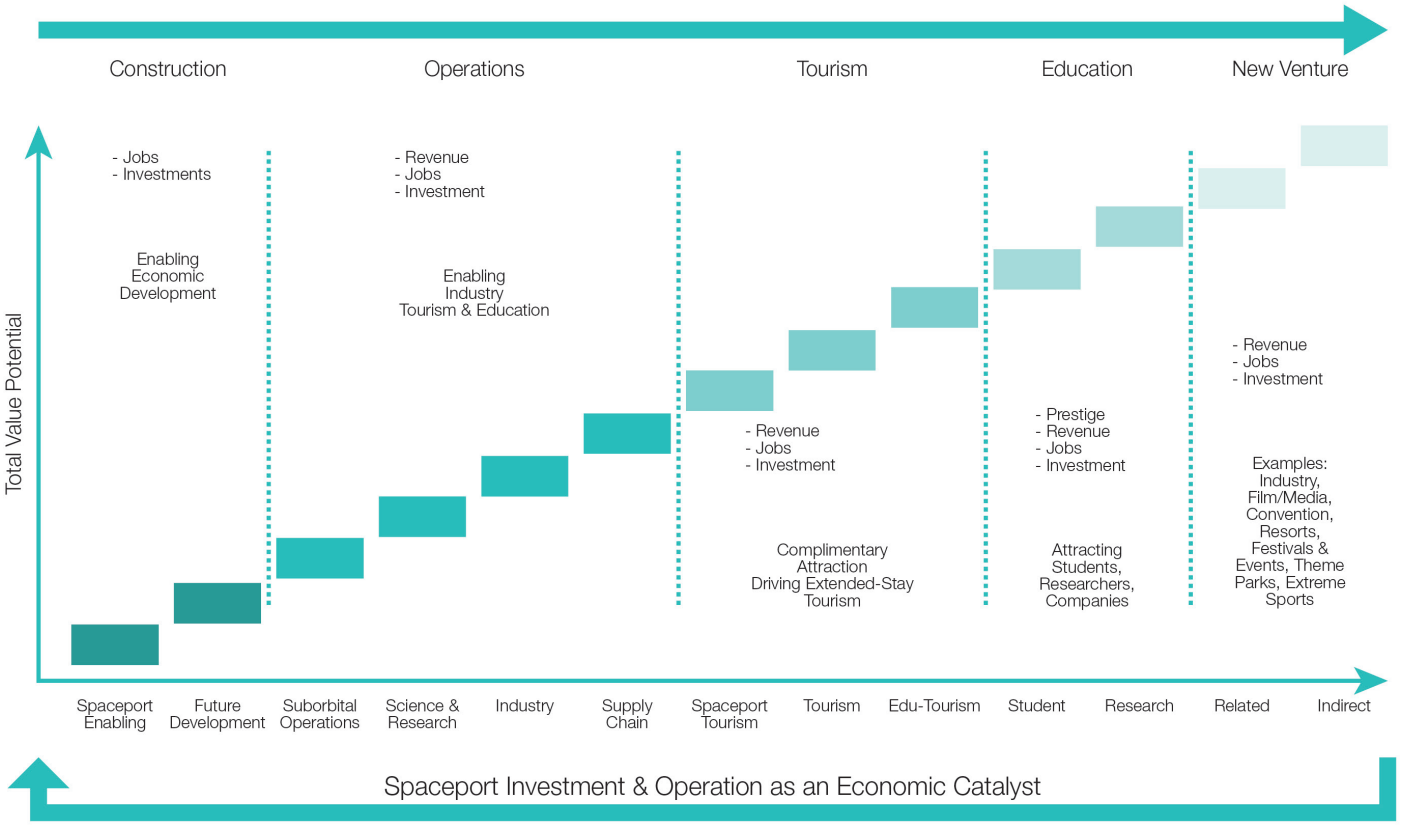
SPACEPORT UK

SPACEPORT UK

4 Wider Economic Impact

In this section the expected economic impact of a UK spaceport is outlined. Whilst the previous sections have looked at the business model for a spaceport, the following highlights how the spaceport can enable a value creation waterfall.

UK SPACEPORT VALUE WATERFALL HAS FAR-REACHING POTENTIAL



This section employs the Regional Input-Output Modelling System from the U.S. Department of Commerce Bureau of Economic Analysis. RIMS II employs a top-level approach to determining regional economic impacts of new projects[136].

The economic impact is calculated in terms of the additional '**Economic Activity**' generated, increase in '**Earnings**' of people already employed and additional '**Employment**' - the number of new jobs created both at the spaceport and in the wider economy.

- **Economic Activity (or output)** is the total additional value of goods and services produced in an economy as a result of the increase in final demand, due to the particular project under consideration. Each additional pound delivered to final demand for a good or service generates a (multiplier x £1) change in output for all of the input industries required to produce the final good or service. Direct, indirect, and induced economic activity is included in the multiplier used.

- **Earnings** are the sum of all wages and salaries (including employee benefits) paid to employees in an economy as a result of the increase in final demand due to the project under consideration. Direct, indirect, and induced employment is included in the multiplier used.

[136] See www.blog.bea.gov/category/regional/rims/ (accessed 21st August 2014)

• **Employment** refers to the total number of additional (full-time equivalent) workers employed to produce goods and services as a result of the increase in final demand due to the project under consideration. The jobs multiplier is in terms of new total jobs generated per million pounds of additional final demand. Direct, indirect, and induced employment is included in the multiplier used.

SUMMARY[137]

The spaceport has the potential to realise a baseline of approximately £225M of cumulative additional economic activity and approximately 1,450 new jobs from sub-orbital space tourism, satellite launch, regional tourism and microgravity research by 2028. Additional earnings are expected to increase by a baseline figure of around £50M. The principal driver of economic impact is the growing sub-orbital space tourism market and the increasing number of small satellite launches. Tourism related baseline additional economic impact is expected to be £20M and new jobs created of approximately 250.

The development of the spaceport is expected to create direct, indirect and induced[138] jobs in various related sectors, and opportunities for employment of engineers, scientists and other highly skilled workers. The expected wider economic and employment impact brought about by spaceport operations is something the government may be interested in re-creating in other industries.

POTENTIAL ECONOMIC IMPACT OF UK SPACEPORT BY 2028 (CUMULATIVE)

		Economic Impact			
Year	**Spaceport Activity Category**	Scenario	Economic Activity	Earnings	Employment
2018	**Spaceport Construction**	Constrained	£23.1M	£5.78M	212
		Baseline	£104.3M	£26.1M	954
		Growth	£185.4M	£46.4M	1697
2028	**Spaceport Operations** (Considers revenues from space tourism and satellite launches)	Constrained	£47.7M	£11.2M	275
		Baseline	£203.7M	£47.9M	1174
		Growth	£383.1M	£90.1M	2208
	Regional Tourism	Constrained	£8.6M	£2.1M	112
		Baseline	£20.1M	£4.9M	262
		Growth	£31.7M	£7.7M	413
	Microgravity research	Constrained	£0.3M	£0.1M	10
		Baseline	£1.2M	£0.4M	12
		Growth	£3.8M	£1.4M	37
	Total (excluding construction)	Constrained	£56.6M	£13.4M	397
		Baseline	£225.0M	£53.2M	1449
		Growth	£418.6M	£99.2M	2659

[137] See Appendix B for explanation of calculations
[138] See Appendix B for further explanation

SITE DEVELOPMENT

The first wave of economic activity is expected to result from some level of construction at the spaceport site. The cost of land, acreage required, and other necessary infrastructure developments will play a significant role in the capital investment requirements.

A number of examples are introduced in order to show the wide range of potential spaceport development costs. They revolve around two models of spaceport development that were highlighted in an interview with Stuart Witt, CEO of Mojave Air and Space Port[139]:

1) Using an existing aerodrome and readying it for spaceport use
2) Developing a purpose built new facility from the ground up

Existing
Former RAF Machrihanish (includes Campbeltown Airport)[140]
This aerodrome is one of the short-listed sites identified for a UK spaceport. It underwent a £100mn upgrade between 1989 and 1994 when it was used as a location by NATO and the RAF (and was an alternate for the Space Shuttle in case it had to land in Europe). The majority of the investment was spent on fuel pipelines connecting storage facilities at Campbeltown harbour to the airfield and on three jet fuel storage installations at the base[141].

New
SpaceX Launch Site, Brownsville, Texas
SpaceX is planning to build a vertical launch site at Boca Chica Beach in the Brownsville area of Texas. This site will be used for the launches of the SpaceX Falcon 9 rocket. The company is planning to invest $80M - $100M in this launch site over the next 10 years[142].

Spaceport America (New Mexico Commercial Spaceport)[143]
Futron estimates New Mexico Commercial Spaceport's development impact and this is given in the table below. Instead of total costs, Futron preferred to display the economic impact of the development activity directly:

Year	Economic Activity
2006	£36M
2007	£195M
2008	£70M

These numbers are for the development of a completely new spaceport facility. Additionally they include investment around the spaceport, for example roads and utilities infrastructure. Therefore the possible economic effect in terms of construction development is anticipated to be significantly lower for an existing aerodrome site in the UK.

New and Existing
Spaceport Florida[144]
Futron's 2005 report estimated the cost of building a new, combined (runway and vertical launch) spaceport, versus a split site at an existing airport. A split site means a pre-existing airport runway, hangars, and other facilities would operate in conjunction with launch pads and other infrastructure built elsewhere.

- Split Site: £6M - £16M
- Combined Site: £110M - £165M

As the proposed sites in the UK are all existing airports, the costs mentioned for split site development are more applicable. The reason for the new, combined site's higher cost is the runway construction.

139 Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014
140 Machrihanish Airbase Community Company, "*Machrihanish Airbase: UK's First Spaceport?*", August 2014
141 Interview with MACC Development Ltd, Business Manager, 5th August 2014
142 See www.spacenewsfeed.com/index.php/news/1675-spacex-to-build-launch-site-at-boca-chica-beach (accessed on 6th August 2014)
143 Futron Corporation, "*New Mexico Commercial Spaceport Economic Impact Study*", December, 2005
144 Futron Corporation, "*Feasibility Study of a Florida Commercial Spaceport for Florida Space Authority*", Sept 2005.

Bottom-up Calculations

It is assumed that construction will take place between 2015 and 2018. As shown in the table below, construction of runway/taxiway, roads, and utilities infrastructure could generate a baseline of approximately £105M of additional economic activity through year three of the build-out phase (assuming construction spending input of around £50M):

Spaceport Activity Category		Input Demand	Economic Activity	Earnings	Employment
Spaceport Construction	Conservative	£11.6M	£23.1M	£5.8M	212
	Baseline	£52.1M	£104.3M	£26.1M	954
	Optimistic	£92.7M	£185.4M	£46.4M	1697

EMPLOYMENT

A spaceport will create both employment from its own operations and its impact on the growth of other businesses surrounding the spaceport and within the supply chain.

Direct Employment
The spaceport will directly provide employment in terms of operational and engineering staff. These employees are assumed to be living in the region where the spaceport is located. Additionally, disposable income of these employees will contribute to the local and regional economy.

It is expected that baseline cumulative direct employment will be around 1,200 by the 10th year after the spaceport is operational:

Year	Spaceport Activity Category	Scenario	Employment
2020	**Spaceport Operations** (includes space tourism and satellite launch)	Constrained	35
		Baseline	153
		Growth	235
2023		Constrained	78
		Baseline	294
		Growth	542
2028		Constrained	162
		Baseline	727
		Growth	1431
Total		Constrained	275
		Baseline	1174
		Growth	2208

It is important to note that the employment numbers above are only due to spaceport operations. The direct and indirect employment created through tourism, R&D and other spaceport activities will be supplementary to these numbers.

Wider Employment Benefits
Having a spaceport will benefit the wider supply chain in terms of employment creation. Due to the high productivity of the space industry, its employment multiplier is also high - estimated to be **3.5** in 2012 [145]. This same UK Space Agency report also shows that the total employment impact of the space industry is estimated to be 101,200 - where 28,900 jobs are directly employed by the space sector and 72,300 jobs are created in the wider supply chain. There are many major contributors in different areas including large scale aerospace companies such as Airbus, BAE Systems, QinetiQ, engine manufacturers such as Rolls-Royce, hybrid engine manufacturers such as Reaction Engines and satellite manufacturers such as SSTL, Avanti and Clyde Space.

[145] UK Space Agency, "*The Size and Health of the UK Space Industry*", October 2012

TOURISM

One of the most important advantages of a spaceport is the increase in tourism in the region, bringing benefits such as:
1) General spending of spaceflight experience participants, their families, and employees of spaceplane operators
2) Spending on specific tourist attractions, depending on what is available in that region
3) Other tourists coming to the region to visit the spaceport and its ancillary facilities

An interesting example of how tourism business has grown around a spaceport is Spaceport Sweden. Visitors to the region can enjoy a wide range of activities such as staying at the renowned ICEHOTEL, visiting the biggest underground iron ore mine in the world, a trip through the Abisko National Park, dog sledging, and skiing at Lapland resorts. The important factor here is that the spaceport is building the wider experience based on the surrounding area's local attractions. There is also the option of partaking in parabolic flights, Northern Lights flights, and spaceflight training. In an interview with a former Virgin Galactic spaceflight experience customer, the importance of the wider experience before and after the actual flight experience was highlighted:

> *"There's a lot to be said for the **location experience**, in other words the local attractions. If I had the choice, I would put a spaceport at Kennedy Space Centre – it has all the history around it of spaceflight* [146]*."*

Similarly for a UK spaceport, depending on the selected region, spaceport visits can be combined with activities and sightseeing in the local area. Sites in Scotland, for example, could take advantage of national parks, golfing packages and whiskey tours. Cornwall attracts many visitors to its beaches, hotels and restaurants during the summer. Wales can offer the picturesque Snowdonia National Park, the Brecon Beacons and much more to its visitors. These are all part of creating a unique local experience that is memorable for both the spaceflight customer and their families. Being able to offer a unique tourism package can increase the number of visitors to the spaceport and the surrounding area significantly[147].

The revenue generated from tourism is used as the input to the model, to predict the increased economic activity and number of new jobs created. Regional tourism is comprised of local spending on tourist attractions, food and accommodation, purchases of spaceflight merchandise and memorabilia by astronauts, and visitors watching launches. These estimates assume a visitor spending £150 per day, for a one week total stay, and that one family member accompanies each astronaut to the spaceport.

CUMULATIVE ECONOMIC ACTIVITY DUE TO REGIONAL TOURISM

Year	Spaceport Activity Category	Scenario	Cumulative Imput demand	Economic Activity	Earnings	Employment
2020	Regional Tourism	Constrained	£0.6M	£1.0M	£0.3M	14
		Baseline	£1.1M	£1.7M	£0.4M	23
		Growth	£1.5M	£2.4M	£0.6M	32
2023		Constrained	£1.4M	£2.3M	£0.6M	30
		Baseline	£2.8M	£4.5M	£1.1M	59
		Growth	£4.1M	£6.8M	£1.6M	88
2028		Constrained	£3.2M	£5.2M	£1.3M	68
		Baseline	£8.4M	£13.9M	£3.4M	181
		Growth	£13.7M	£22.5M	£5.5M	293
	Total	Constrained		£8.6M	£2.1M	112
		Baseline		£20.1M	£4.9M	262
		Growth		£31.7M	£7.7M	413

[146] Interview, PJ King, ex Virgin Galactic future astronaut, August 2014
[147] Spaceport Sweden website, see www.spaceportsweden.com/ (accessed 10th August 2014)

R&D/EDUCATION

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R&D spill-over of the space industry is very high compared to other sectors. As a close example, it's estimated that the aerospace sector creates around **70% R&D spill-over**[148]. Therefore every £100M invested in R&D leads to an increase in GDP of £70M in the longer term. Oxford Economics also estimates the space industry helps to generate £900M per year of GDP in the UK due to the spill-over effects of its R&D. A spaceport in the UK will enable private space companies to increase their activity in the UK. This can also lead to increased R&D spending. The space industry is a very R&D intensive sector with an investment of 4.7% of its GVA (gross value added) into R&D according to 2009 data from Oxford Economics, compared to the UK average of 1.8%[149].

Considering the strong correlation of productivity with R&D spend, an area that can support R&D to this extent will have a positive impact on the capacity of the economy. Additionally, spaceports that are linked to research centres and universities create mutual benefits. Spaceports can provide universities with convenient testing facilities, and thereby help to attract top engineering talent and higher paid research jobs. As an example, Spaceport Sweden collaborates with Lulea University of Technology. The spaceport works with staff and students, studying for the Bachelor programme in Professional Experience Production, to develop innovative and transformative space adventures - contributing to the establishment of space tourism as a new industry in Sweden.
A spaceport and co-located research facilities will create high value employment in various areas of space related technologies and manufacturing. At Mojave Air and Space Port, whilst the spaceport itself employs less than 30 people, 3,000 jobs exist at the site from private companies utilising the facility[150].

The space sector also plays an important role in attracting young people into STEM related subjects.

148 Oxford Economics, "*The Case for Space: The Impact of Space Derived Services and Data*", July 2009
149 ibid
150 Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014

There is a shortage of skilled graduates and space has a special role in using its exciting science and engineering to inspire young people into STEM subjects at school and university. Events such as the impending spaceflight of Major Tim Peake provide great inspiration and opportunities to further interest young people in space and STEM subjects. In an interview with Dale Ketcham of Space Florida, in his experience over the 30 years he has been in the industry, he believes interest in space programmes is one of the main drivers of young students pursuing STEM subjects[151]. Conceivably therefore, as the commercial space sector develops, so too will the interest in STEM subjects from young engineers and entrepreneurs.

KEY FINDINGS

- A UK spaceport has the potential to cumulatively realise a baseline of £225M in additional economic activity and 1,450 new jobs from sub-orbital space tourism, satellite launch, regional tourism and microgravity research by 2028.
- Regional tourism activities boosted by space tourists are expected to create a baseline of £20M in additional economic activity and 250 new jobs
- The impact on wider employment is a very important consideration given the highly skilled nature of the space industry.
- The spaceport could serve to unlock further investment into high value manufacturing and R&D activities, within the industry's supply chain and outside of it.
- A spaceport will create interest in commercial space endeavours, which will in turn serve as a catalyst for greater interest in science and technology amongst younger generations – potentially leading to a larger supply of quality engineers and researchers in the UK.

[151] Interview, Dale Ketcham, Chief of Strategic Alliances, Space Florida, August 2014

SPACEPORT UK

5 Regulatory Environment

This section considers the key regulatory hurdles to address in order to attract tenants and private investment to the spaceport. This includes the timely implementation of a UK regulatory regime for spaceplanes, ITAR and third party liability risk sharing.

> *"The customer base is not going away, but there is some delay in their committing to buying flights, or investors funding projects, until they see regulatory frameworks established. Should the regulatory regime in Europe not be established, or the aviation model is applied fully to the newer space community, then there will be a stagnation of innovation, investment, job growth and the societal impacts this exciting industry may have spawned*[152]*."*

As is the case for many emerging industries, firms and investors will seek areas to operate in that have a stable regulatory and established legal environment. As the CAA report has already highlighted, in the short term a national regulatory framework is needed to meet the goal of attracting spaceplane operators to the UK by 2018. The importance of this recommendation cannot be emphasised enough – in interviews with spaceplane operators, launch vehicle providers and others, there is an urgent need to overcome the key barriers to attracting US operators to the UK, namely:

UK regulatory regime – The UK government has signed a memorandum of understanding (MOU) with the FAA where the FAA will share information on its best practices in developing licensing regulations for space launches and passenger spaceflights. The MOU will serve as a starting point in determining if there is a need for the UK government to issue regulations in the future[153]. However, until there is full clarity around whether more regulations will be required under UK law, it is difficult for operators to plan for expansion of operations to the UK, despite the very positive intentions set out by the Government in committing to a spaceport by 2018.

> *"The legislative framework is essential. You need legislation set in stone or no one will move*[154]*."*

ITAR regulations – spacecraft, including spaceplanes, are subject to US export controls. ITAR is based on a 'presumption of denial' approach with exporters required to prove that their product or service does not pose a significant risk to US national security.

A change to these rules, or exemptions created for the UK, are unlikely based upon a speculative market opportunity – which probably includes human spaceflight.

> *"If the UK could show that ITAR hurdles were overcome, that would be a key barrier jumped over to get us moving internationally*[155]*."*

[152] Andrew Nelson, President XCOR Aerospace, Space Trade Magazine, Issue 9 December 2013
[153] See www.spaceflightnow.com/news/n1407/17ukspaceport/#.U-9tZ_ldVMk (accessed 16th August 2014)
[154] Interview, Will Whitehorn, ex Virgin Galactic President, July 2014
[155] Interview, PJ King, COO Firefly Space Systems, August 2014

The CAA report lays out a set of recommendations to overcome the existing hurdles in attracting US spaceplane operators to the UK, in the short term. The twin-track approach it suggests, to firstly create a national regulatory environment and at the same time spur action within European and other international regulatory bodies to regulate the spaceplane industry, is the right approach to take.

> *"In Europe countries like the UK and Sweden are making great strides quickly to establish a new space regulatory regime that enables the industry's growth and maintains their duties to the public to ensure safety*[156]*."*

However, the speed with which the UK's twin-track approach is pursued, is the critical factor in being ready for operations by 2018. The US Commercial Space Launch Amendments Act of 2004 was designed to accelerate the commercial space industry by setting out a clear framework to promote a permissive regulatory framework of research and development, testing and operating experimental commercial spacecraft and spaceplanes:

> *"Private Industry has begun to develop commercial launch vehicles capable of carrying human beings into space and greater private investment in these efforts will stimulate the Nation's commercial space transportation industry as a whole*[157]*."*

The emphasis of the Amendments Act was on the wider benefits to the space industry of fostering a nascent operation like human spaceflight and creating certainty for operators to enable them to develop competitive technologies and compete.

In the process of creating a regulatory framework for spaceplane operations in the UK, the Government must focus beyond just the near term requirements for wet leases of US spaceplanes in the UK. Taking into consideration the wider opportunity to develop a domestic launch industry that can facilitate much more than just sub-orbital spaceplane operators, is important. In the medium to longer term, the UK can conceivably be the European hub for re-usable launch vehicles (RLVs), orbital and sub-orbital, and thereby set out its intentions to attract an international base of launch providers.

This report strongly agrees with the CAA's recommendation that there is a present need for government to government agreements between the UK and US on how to address the ITAR regulations for spaceplanes initially. This issue was repeatedly raised in interviews with launch vehicle providers as a barrier to entry for US companies considering the opportunity to operate in the UK. There is an opportunity to learn from Sweden who have already had dialogue and raised the issue around ITAR restrictions when the respective leaders of the US and Sweden met in 2013[158].

Work must begin immediately to confirm what changes, if any, are needed to primary legislation and a timeframe drawn up for changes to come into force[159]. This is essential for spaceplane operators in knowing what to expect from the legal environment and to recognise any further requirements they would need to meet to comply with UK regulations. Certainty of the regulatory and legal environment will enable the conditions for private investment to crystallise, in what is a capital intensive industry.

[156] Andrew Nelson, President XCOR Aerospace, Space Trade Magazine, Issue 9 December 2013
[157] See www.faa.gov/about/office_org/headquarters_offices/ast/media/PL108-492.pdf (accessed 9th August 2014)
[158] See www.mynewsdesk.com/se/spaceport/pressreleases/spaceport-sweden-frihandelsfraagan-viktig-foer-svensk-rymdindustri-901081 (accessed 16th August 2014)
[159] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.67*" July, 2014

3rd Party Liability Risk Sharing

The US Commercial Space Launch Act's risk management provision is essential in setting a cap on the liability for US launch operators, including spaceplane providers. The FAA sets a Maximum Probable Loss Limit of $500M and expects licensees to take responsibility for any such 3rd party damages up to that limit in the form of private launch insurance (this includes indemnifying government property)[160].

Damages in excess of the determined maximum probable loss are covered by a launch liability provision administered by the government – this stops the scenario where every time a company launches, they are effectively betting the company's fortune.

> *"The space regulator requires the operator to carry insurance for the 'uninvolved public' to a level commensurate with the risk of probable loss, and the launch proceeds*[161]*."*

This enables innovation and testing of new technology to flourish and reduces the risk to incumbent and emerging firms alike. The US has extended this provision multiple times, in part because of the relatively low risk in it ever being needed, but more likely because of the importance placed on it by the space industry in the US to ensure financially viable operations.

The CAA report mentions that the UK Government was in the process of stating its intention to cap unlimited liability at €60mn for the majority of missions in relation to 'space objects' under the Outer Space Act 1986. This is further clarified as 'missions employing established launchers, satellite platforms and operational profiles' - there may be some doubt as to whether spaceplane operators are included in this definition.

Following a similar approach to liability of the operator as is the case in the US will help to promote research and development, testing and operations of sub-orbital and orbital flight in the UK.

The CAA must also work with spaceplane operators and other agencies to define how the concept of informed consent, for participants on sub-orbital spaceplanes, may apply to spaceplane operators under UK law. There was some doubt, from discussions with insurance experts, as to how this would affect insurance rates if there is uncertainty around whether or not this concept can be enforced in UK courts. If informed consent cannot be enforced, this may deter spaceplane operators from operating in the UK if they are open to undue liability claims. Spaceport America makes this a prominent point in its Business Plan:

> *"If New Mexico fails to limit exposure to operators and their supply chain via an updated, more robust Space Flight Informed Consent Act, which allows spaceflight participants the right to hold harmless the companies in the event of an accident (caused by other than gross negligence or mal-intent), the state will not be seen as competitive with other space states, such as Florida, Texas and Virginia*[163]*."*

[160] Satellite Industry Association, Commercial Space Hearing, Senate Subcommittee, Nov 2013, see www.youtube.com/watch?v=uWtBundJ6_A (accessed 7th August 2014)
[161] Andrew Nelson, President XCOR Aerospace, Space Trade Magazine, Issue 9 December 2013
[162] Satellite Industry Association, Commercial Space Hearing, Senate Subcommittee, Nov 2013, see www.youtube.com/watch?v=uWtBundJ6_A (accessed 7th August 2014)
[163] New Mexico Spaceport Authority, Strategic Business Plan 2013-2018, Jan 2013

KEY FINDINGS

"*It was the Commercial Space Launch Amendments Act of 2004 that enabled the commercialisation of the space industry in the US*[164]."

- Clarifying and implementing a clear and stable regulatory framework, as soon as reasonably possible, will give companies and individuals the permission to take calculated risks with their capital and resources in the UK.
- The Mojave Air and Space Port in the US, for example, has been successful up until now in attracting multiple launch companies to test rocket motors and spaceplanes because of the permission given to those firms to operate within a well understood regulatory environment, in addition to convenient clear airspace.
- ITAR is the single biggest barrier to operations outside of the US and spaceplane operators are pessimistic about exemptions happening any time soon without high level government to government dialogue. Operating spaceplanes from military aerodromes may go some way to mitigating concerns and securing ITAR exemptions.

[164] Interview, Will Whitehorn, ex Virgin Galactic President, July 2014

SPACEPORT UK

SPACEPORT UK

6 Risks

This section identifies some of the main risks around spaceplane operations and developing a spaceport.

ACCIDENTS

This is likely to be the biggest risk facing spaceplane operators. As the CAA's technical report has highlighted, spaceplanes are likely to be classed as experimental aircraft and regulating for a safe operation of this emerging industry is a complex and difficult process. A catastrophic or fatal accident to occur in the early stages of human spaceflight would clearly have an impact on future demand from space tourists.

This risk can be mitigated with a safety regulation framework that the CAA has highlighted in its technical report, and a better understanding of the operations of spaceplanes. The slight benefit of being ready for spaceplane operations in 2018 is that commercial flights carrying spaceflight participants will likely already have taken place, providing further flight performance information and building up some basic history of safe flight. Spaceplane operators have a firm commitment to creating safe operations and are not in a race against time.

"We're not driven by deadlines, we'll need to respond to little things that might come up in the test flight programme, but we have an achievable path toward the start of operations [165]*."*

Needless to say that an accident could also increase insurance rates. This may impact on the commercial viability for the spaceplane operator if rates increase significantly following an accident.

SINGLE OPERATOR

The need for multiple tenants and not just relying on one operator is important for a UK spaceport. Compare and contrast Mojave Air and Space Port which has 165 contracts[166] with various firms (not just space related) and has been in business for many years, with that of Spaceport America which is now diversifying its tenant base as it waits for commercial spaceflight operations to begin with Virgin Galactic.

Spaceplane operators themselves understand that co-existing with competitors is more sustainable for a spaceport, as the spaceport is able to spread operational costs across a number of tenants. Mojave Air and Space Port has railroad, wind farm and aerospace businesses co-located on the airfield, and this diversifies the revenue stream available to the spaceport operator[167].

This report firmly recommends that a UK spaceport not offer exclusive use to a spaceplane operator.

[165] See www.abqjournal.com/432663/news/virgin-galactic-preparing-for-an-economic-takeoff.html (accessed 19th August 2014)

[166-167] Interview with Stuart Witt, CEO, Mojave Air and Space Port, August 2014

LOCAL OPPOSITION

Having spoken to some of the short-listed sites, management believes the local communities around the aerodromes would be supportive of spaceport operations. There is genuine interest in commercial spaceplanes and commercial manned human spaceflight.

Potential spaceport locations are identified because of the low population density around the aerodrome. Therefore there will be a relatively low number of residents affected by spaceplane noise and some designs take-off and land like a conventional jet airplane, with rocket launch taking place at much higher altitudes. However, if a spaceport does go through a period of site development for a long period of time, this can affect the local community in a negative way because of traffic congestion from supply vehicles for example.

Local opposition is likely to be limited given the wider economic activity that a spaceport can generate, which can benefit the local community and create job opportunities in the supply chain that may not have been present before. Councillor John Cowe of Moray Council, which has RAF Lossiemouth and RAF Kinloss within its remit, recently mentioned that:

> *"The advent of a spaceport would be a fantastic business opportunity for Moray-Speyside as a region…….everyone in Moray will be working tremendously hard to persuade the government to locate the spaceport here if possible* [168]*."*

Local opposition could come from environmentalists that are worried about the future usage of a spaceport, including vertical launch with rockets, or an extended runway taking up more land. Increased aircraft noise and traffic may also be elements that local people highlight in their opposition to the operation of a spaceport.

The Government has already noted that it will ensure the views of local people are taken into account and will seek their buy-in to any proposed location that may be identified, before decisions are taken to proceed with a UK spaceport[169].

[168] See www.moray.gov.uk/moray_news/news_94431.html (accessed 10th August 2014)
[169] See www.gov.uk/government/uploads/system/uploads/attachment_data/file/330484/spaceport-consultation.pdf (accessed 10th August 2014)

SPACEPORT UK

SPACEPORT UK

7 Financing

This section discusses the current competitive spaceport environment in the US and how government incentives are used to attract tenants to spaceports. It identifies a number of potential local, regional and European government sources of finance to develop a spaceport. It also gives a brief overview of the space insurance market for spaceplane operations.

EXISTING SCENARIO

Some spaceports in the US are funded almost entirely by State resources. This is because these facilities are completely new and/or purpose built for tenants, where local state resources are used for initial capital investment. For example total funding for Spaceport America was $209M:

Approximately $25M from the State of New Mexico general fund appropriations and capital outlay. Another $108M from the State of New Mexico severance tax bond proceeds, and a further $76M from local gross receipts tax bond proceeds[170].

Injection of Incentives

More States in the US are implementing favourable incentives to attract space related companies to operate in their State and use their chosen spaceport for operations. Stuart Witt of Mojave Air and Space Port has repeatedly called for the State of California to create the right incentives to maintain the jobs and innovation that are present at his spaceport[171]. However he also believes that:

> *"Incentives are a race to the bottom*[172]*."*

States including Virginia, Texas, Maryland, Florida, New Mexico and Colorado are all establishing aggressive, favourable tax incentives to attract space related companies to their States[173].

In 2012, the Midland Development Corporation and Midland City Council agreed on a $10M economic development agreement with XCOR Aerospace. XCOR will re-locate its R&D facilities to Midland Airport, which has applied to the FAA for spaceport status. The $10M incentive will go toward improvements and lease payments for hangar space, as well as toward performance incentives[174]. Spacesuit manufacturer Orbital Outfitters was also attracted to Midland in part because of the $3.2M altitude chamber that was constructed by the Midland Development Corporation, and then leased back to Orbital. There was also a $2.2M incentive granted to Orbital for it to construct its HQ in the city[175]. Just recently, according to the Reuters News agency, the greater Brownsville area of Texas is funnelling approximately $15.3M into a launch facility dedicated for SpaceX. $13M of that will be used to develop the necessary infrastructure. This is estimated to create 300 new jobs and bring around $80M in capital investment into the region[176].

Therefore there is an ever increasing race to attract commercial space companies and the jobs that are being created by these firms. Given the global nature of the space industry, the UK must similarly compete in an increasingly competitive environment. Public investment and incentives can play a role in attracting firms to operate in the UK.

However, Stuart Witt of Mojave Air and Space Port would argue that his spaceport continues to be successful in being self-funded from its multiple tenant contracts and diversification of revenue sources. Public money does not have to fund up front capital

[170] See www.spaceportamerica.com/about-us/faq/what-is-the-budget-for-spaceport-america/ (accessed 31st July 2014)
[171] See www.spaceports.blogspot.co.uk/2012/02/mojave-air-and-space-port-asks-for.html (accessed 2nd August 2014)
[172] Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014
[173] See www.texasspacealliance.org/our-agenda/zgzt (accessed 2nd August 2014)
[174] See www.mrt.com/top_stories/article_b3521e94-c9d6-11e1-b5f0-0019bb2963f4.html (accessed 2nd August 2014)
[175] See www.parabolicarc.com/2014/01/27/orbital-outfitters-moving-midland (accessed 16th August 2014)
[176] See www.reuters.com/article/2014/08/04/us-space-spacex-texas-idUSKBN0G421L20140804 (accessed 5th August 2014)

investment – in the case of Mojave Air and Space Port, tenants would find the capital themselves to develop facilities but crucially the spaceport would provide "permission" to operate under a certain regulatory environment[177].

The UK

A similar level of local government funding to that seen in the case of Spaceport America is unlikely to be a model that the UK Government will follow, however. While spaceplane operators would receive the direct benefit of access to a spaceport, initial assessment indicates sizeable potential returns to the UK economy, as well as large spill-overs in the medium to long term, within the industry supply chain and beyond[178].

As has been highlighted above in this report, the phased approach to a spaceport development is likely to reduce the need for significant upfront capital investment. In interviews with management from some of the proposed sites, there was a recurring argument that local government funding would be needed to pay for necessary runway upgrade costs, and improvements to existing facilities that are necessary for spaceplane operations - in other words the core infrastructure requirements at a spaceport. However, with a relatively well equipped existing aerodrome, this cost does not have to be excessive.

> *"Businesses coming into the area can access regional development funding. Upgrades for spaceport purposes would need to come from the Enterprise Authority or some other government source* [179]*."*

Any further development beyond essential requirements would more than likely need to be met with private funding including in relation to:

- Tours/visitor centre
- Spaceflight training
- Other near-space activities at a spaceport
- Private R&D facilities

The current Government's aviation policy framework, published in March 2013, is the statement of the Government's policy on aviation. It replaces to a large extent the policy set out by the previous Government. The framework recognised "the very important role airports across the UK play in providing domestic and international connections and the vital contribution they can make to the growth of regional economies" as focal points for business development and employment[180].

As this report has already highlighted, a spaceport will play a role in contributing to the growth of a local and regional economy. Determining how best to fund that opportunity will require close dialogue between Government and the proposed site for a spaceport. Some of the options for financing an initial phase of development are considered in the following.

[177] Interview, Stuart Witt, CEO Mojave Air and Space Port, August 2014
[178] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.42*" July, 2014
[179] Interview, MACC Development Ltd, Business Manager, August 2014
[180] See www.parliament.uk/briefing-papers/sn00323.pdf (accessed 3rd August 2014)

POTENTIAL FUNDING SOURCES

Given that 6 of the 8 shortlisted spaceport sites are in Scotland, this section will look at potential options for Scotland first.

Scotland
Apart from the Ministry of Defence aerodromes on the shortlist, the other potential sites in Scotland are owned by the Scottish Government. Glasgow Prestwick Airport was sold last year to TS Prestwick Holdco Limited, an entity wholly owned by the Scottish government[181]. In addition, both Stornoway and Campbeltown are operated by Highlands and Islands Airport Ltd (HIAL), which itself is a private limited company owned by Scottish Ministers. HIAL receives operating subsidies from the Scottish Government and is sponsored by the Transport Scotland - Aviation, Maritime, Freight and Canals Directorate[182]. In the year ended March 2013, HIAL received funding from the Scottish Government of approximately £22.2M, compared to £26.8M in 2012[183].

Glasgow Prestwick Airport's latest accounts state that it is only a going concern if its owner, the Scottish Government, is willing to continue funding deficits as a result of losses from its operations and write-downs. The airport states that such an undertaking has been made by Transport Scotland[184]. The Scottish Government recently outlined a long-term plan for the facility and revealed £7M in Government funding would be invested, with £5.5M already provided since the airport was acquired in November 2013. The Government in Scotland has made it clear that its ownership of Prestwick is a long-term investment, but a return to the private sector remains the end objective[185].

Therefore the Scottish Government has a role to play in capital requirements needed to fund the development of a spaceport at these locations. This is most likely to be used for meeting the core infrastructure requirements at a spaceport including:

- Runway extension and upgrade
- Hangar and terminal construction and/or upgrades
- HAZMAT and emergency response readiness

It is not possible at the moment for investment to come from profits generated through ongoing operations, because in the case of the three Scottish Government owned sites, none are making a profit. In discussions with one of the proposed sites in Scotland, its management anticipates that the local Enterprise Authority would need to put capital upfront for spaceport development requirements. It was also highlighted that a spaceport could be a candidate for regional development funding as it may fall into a high value industry with the potential to create jobs and innovation in the area.

European Structural and Investment Funds (ESIF)
The next ESIF programme (2014-2020) could be a source of funding for a spaceport in Scotland, assuming a number of criteria were met to show the economic value and return on investment from such an operation. In its latest report of the aforementioned European funds, the Scottish Government highlights that European Funds have played an important role in supporting reform and recovery in the Scottish economy. The programme just ended in 2013 has delivered £700M of European Structural Funds into innovation, low carbon, sustainable transport, tourism infrastructure, business support, skills and community development[186].

In the report, the European Regional Development Fund (ERDF), one of the EU's structural funds, is suggested as an ESIF funding source for sustainable transport investment. In the Highlands and Islands Operational Programme for European Regional Development Funds, it also mentions the essential funds provided for transportation within the region[187].

181 See www.uk.finance.yahoo.com/news/infratil-sells-glasgow-prestwick-airport-195200199.html (accessed 3rd August 2014)
182 See www.ripassetseu.s3.amazonaws.com/www.hial.co.uk/_files/documents/oct_13/hia__1381234814_2012-13_-_HIAL_Group_signed_An.pdf (accessed 3rd August 2014)
183 ibid
184 See www.heraldscotland.com/news/transport/prestwick-airport-reveals-spiralling-losses.23613366 (accessed 3rd August 2014)
185 See www.news.stv.tv/west-central/279595-prestwick-airport-to-receive-7m-in-scottish-government-investment/ (accessed 3rd August 2014)
186 See www.www.scotland.gov.uk/Resource/0044/00440399.pdf (accessed 3rd August 2014)
187 See www.cornwalldevelopmentcompany.co.uk/assets/file/July%202014%20Press%20Releases/13%2007%2014%20Newquay%20Cornwall%20Airport%20shortlisted%20for%20UKs%20first%20space%20port%20nationaltrade.pdf (accessed 7th August 2014)

England and Wales

England and Wales also benefit from ESIF allocations and again could use this as a funding source for a spaceport. For example, the Newquay Cornwall Airport Infrastructure and Business Development Project has been financed by the European Union with £2M from the European Regional Development Fund Convergence Programme (2007 to 2013)[188].

Local enterprise partnerships (LEPs) in England are partnerships between local authorities and businesses. LEPs can apply for Local Enterprise Zones (LEZs), of which 24 have been awarded so far. These zones can take advantage of tax incentives and simplified local planning regulations. Newquay Aerohub, for example, is a LEZ. In January 2013 the Welsh Government included Llanbedr airfield in the Snowdonia Enterprise Zone. The LEP can seek freedoms and influence over resources from Government; and a share of the new Local Growth Fund to target their identified growth priorities[189]. The allocation of Local Growth Fund resources will be one element of the Growth Deal for each LEP. The Local Growth Fund was committed to be at least £2B a year from 2015 to 2016. In 2015 to 2016, £1.1B of the Fund was already committed (principally to local transport projects)[190].

It is clear from the discussions with potential spaceport sites that initial investment is expected to be sourced from central or local government funding. Government support is important in promoting the right conditions for further development at the spaceport, however the spaceport must also be able to cover any debt repayment requirements through steady streams of revenue, including from services outside of normal spaceplane operations.

[188] See www.cornwalldevelopmentcompany.co.uk/assets/file/July%202014%20Press%20Releases/13%2007%2014%20Newquay%20Cornwall%20Airport%20shortlisted%20for%20UKs%20first%20space%20port%20nationaltrade.pdf (accessed 7th August 2014)

[189] HM Government, "*Growth Deals, Initial Guidance for Local Enterprise Partnerships*" July 2013, see www.gov.uk/government/uploads/system/uploads/attachment_data/file/224776/13-1056-growth-deals-initial-guidance-for-local-enterprise-partnerships.pdf (accessed 3rd August 2014)

[190] See www.gov.uk/government/news/growth-deals-firing-up-local-economies (accessed 29th July 2014)

OTHER SOURCE OF FUNDS

Private Investment: As has been highlighted in the Regulation section, once a clear and stable regulatory framework is in place, it is likely to accelerate private investment in a spaceport and space-related businesses using the spaceport. It's highly unlikely that a spaceport could be established in the UK without some firm commitment of government assistance for core infrastructural requirements. However the measures outlined in this report, in terms of the potential diversification of commercial activities at a spaceport, will lead the spaceport onto a path of sustainable funding from its own operations. Private funds could be used to secure:

- A visitor centre
- R&D facilities
- Bespoke hangar space and maintenance
- Shops and restaurants within terminal facilities
- Conference centre for events

Bank funding is also an option, probably dependent on government guarantees to cover interest payments in the initial years of operation of a spaceport. An example of funding coming into the UK's airports includes one of China's largest banks, ICBC, agreeing to invest in a new business district to be developed at Manchester Airport (reportedly £650M), boosting the airport's role as an aviation hub[191]. In 2012 Space Florida, Florida's aerospace development organisation, agreed a $62.5M credit facility with Bank of America to support the construction of the Space Shuttle Atlantis Exhibit at Kennedy Space Centre Visitor Complex.

The financing agreement allocates a percentage of the revenues earned from Visitor Complex concessions to provide debt service on the loan[192]. Bank of America felt that the ticket sales were a reliable enough revenue stream for the visitor complex due to the popularity of such an experience for the visitor. The UK doesn't have the same history as Florida does in terms of spaceflight, but this serves as an example for how private funding can be allocated to space projects.

Local Authority funding: Local authorities fund their activities from 3 main sources:
- Grants from central government
- Council tax
- Other locally generated fees and charges for services

Central government funding for local councils is announced each year in the annual local government finance settlement. The Local Services Support Grant enables local councils to decide how most of their grants from central government should be spent in their area[193]. Some of that support grant could be used for spaceport development by a local council.

Resources from revolving funds such as Growing Places Fund - The Department for Communities and Local Government (DCLG) and the Department for Transport (DfT) jointly administer the Growing Places Fund, with funding allocations issued by DCLG. The two Government Departments expect the £500M investment to enable the creation of Local Enterprise Partnership led local infrastructure funds across England. These will provide the up-front funding needed to get development underway, and give local areas the flexibility to recycle funding for other projects as developments are completed[194].

191 See www.uk.finance.yahoo.com/news/chinas-icbc-bank-invest-uk-101849618.html (accessed 3rd August 2014)
192 See www.spaceflorida.gov/news/2012/09/24/space-florida-secures-financing-for-space-shuttle-atlantis-exhibit (accessed 7th August 2014)
193 See www.gov.uk/government/policies/giving-local-authorities-more-control-over-how-they-spend-public-money-in-their-area--2 (accessed 3rd August 2014)
194 See www.gov.uk/government/uploads/system/uploads/attachment_data/file/7521/2024617.pdf (accessed 3rd August 2014)

INSURANCE

It is likely that a spaceport would insure itself along the same lines as a commercial airport, unless there are additional facilities that warrant a re-evaluation of risk by the insurer, which is a possibility. Therefore insurance rates, or the cost of the premium to the insured party, are likely to be similar for spaceports as for airports.

Spaceplane Insurance: Given the fact that this is a new activity and still in testing, the space insurance market is very cautious about how to price the risk of such an operation. Current rates for spaceflight experience are high because only test flights have taken place. Rates would need to come down from approximately 1% per flight to make spaceflight experience a viable business[195].

If rates are charged on a per flight basis, which is the case for vertical launches, assuming a value of the spaceplane asset of $100M, a 1% rate would equate to a premium paid by the spaceplane operator on each flight of $1M. If, in the case of Virgin Galactic's offering, 6 passengers paying $250,000 each are on the flight, the insurance cost is therefore two thirds of the revenue generated from each flight. Add on top the operational costs of the flight, and it might make the operation economically unviable for the spaceplane operator.

Inherently it will be difficult for the insurance market to lower rates until there are multiple flights and operations become more predictable as is the case with commercial aviation, where typical rates are around 0.35% per annum (with no cap on the number of flights). These aviation rates are much lower due to the safety track record of commercial aviation and technological safety improvements being made.

Insurance Premium Tax: Secondary legislation will shortly be introduced to exempt Insurance Premium Tax (IPT) from having to be paid for satellite risks in the Space Insurance class. It is not clear whether this exemption would extend to spaceplane insurance also. Space IPT in the UK is currently charged at a rate of 6% of the premium paid and is levied on UK-based satellite operators for their satellite and launch risks. Compare this to countries that do not impose this tax and nations like Germany which currently charge satellite IPT at a rate of 19%[196].

Passenger Liability: This is another hurdle for the spaceplane operators to overcome. If the spaceflight participant signs a waiver (based on the principle of informed consent), it is not yet determined whether this waiver is enforceable by law in the UK. Therefore the operator may not be fully excluded from liability relating to injury during a spaceflight. As the CAA report points out however, informed consent does not absolve the operator of liability claims brought by spaceplane flight crew or participants in the event of death or serious injury following a spaceplane accident or serious incident[197].

[195] Discussions with space insurance industry representatives
[196] See www.seradata.com/SSI/2014/03/chancellor-of-exchequer-to-remove-insurance-premium-tax-from-space-risks/ (accessed 3rd August 2014)
[197] CAA, "*UK Government Review of commercial spaceplane certification and operations, Technical Report. CAP 1189, p.70*" July, 2014

KEY FINDINGS

• The UK will play in an increasingly competitive global incentive regime to attract companies to a spaceport. However, incentives can be a "*race to the bottom*" and establishing a spaceport with viable streams of revenue, outside of spaceplane operations, will be very important to attract private sources of debt funding.
• Government funding will be required to develop an operational spaceport by 2018, in particular for runway extension requirements. If a runway was to be extended by 500m for example[198], funding required would be £20M. A spaceport could justify European funding given the likely secondary economic impact it will have on the local and regional economy.
• Space insurance market rates will likely come down over time once a better understanding of the risks are obtained. A similar scenario has been observed in the airline insurance market. Some operators may be able to secure lower rates than others.

[198] Based on a cost of £4M per 100m. Range communicated by construction companies to the UKSA was £1M-£4M, therefore the most conservative figure is used.

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Appendices

APPENDIX A

Commercial Human Spaceflight Demand Model:

Year	Total HNWIs Excluding NA (in M)	HNWIs Investable Asset>$2.5M	Interested in Space Travel (in M) (25%)	Willing to Pay (in 000) (10%)	Having Spent >$50k on Leisure Earlier (6%)	Those who Can Buy the Ticket (50%)
2018	20.2	11	2.8	275	16500	8250
2019	21.1	11	2.9	286	17160	8580
2020	21.9	12	3.0	297	17846	8923
2021	22.8	12	3.1	309	18560	9280
2022	23.7	13	3.2	322	19303	9651
2023	24.6	13	3.3	335	20075	10037
2024	25.6	14	3.5	348	20878	10439
2025	26.6	14	3.6	362	21713	10856
2026	27.7	15	3.8	376	22581	11291
2027	28.8	16	3.9	391	23485	11742
2028	30	16	4.1	407	24424	12212

TICKET PRICE PROJECTIONS (IN $000)

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Price (in $000)	250	238	226	214	204	193	174	157	141	127	114

Assumptions:

- Year 1 taken as 2018, the expected start date for a UK Spaceport
- Timeframe is 2018-2028
- High Net Worth Individuals (HNWIs) are those with investable assets > $1M
- Average growth rate of HNWIs taken as 4% until 2030[199]
- Starting ticket price for spaceflight experience taken as $250k
- Projected ticket price to range from $250k - $100k within next 10 years
- US citizens/residents will undertake spaceflight only within the US
- Revenues not adjusted for inflation
- All prices used are constant prices
- The results of survey respondents by Futron and Tauri are applicable to a subset of HNWIs that are non-US citizens/residents

[199] IPSOS/Astrium, "*Demand Analysis of Sub-Orbital Space Tourism*", 2012

Methodology:

- HNWI figures from Capgemini Global Wealth Report for 2014[200]
- Project average growth of HNWIs over the next 15 years (4%)
- Take HNWIs with investable assets > $2.5M (as ticket price is $250k, and HNWIs willing to spend ~8% of their wealth on Sports & Leisure category)
- Filter down to those HNWIs interested in space travel[201] (25%)
- Filter further to those HNWIs interested in undertaking space travel AND willing to pay ticket price[202] (10%)
- Filter to those HNWIs of this group who actually spent >$50k on a single leisure activity (6%)
- This is then the HNWI group most likely to consider purchasing a spaceflight experience in the next 10 years and are not US citizens/residents (therefore may be more likely to choose a spaceport in the UK)
- Projected share of a UK spaceport in this market, can range from 25%-50%
- Perform sensitivity analysis with these different variables to calculate revenues of a UK Spaceport from human spaceflight operations over the next 10 years

Propensity to Buy

The key factors in willingness to buy a ticket for a sub-orbital flight are:

- Ticket Price: This is a major determinant of the decision to undertake a space flight. Another aspect is the willingness to pay for such a one-time expense.
- Safety: of spaceflight is a concern and any negative PR may affect the propensity to purchase a ticket.
- Medical requirements: Some basic level of fitness is required for sub-orbital flight and therefore may exclude some interested HNWIs.

[200] Capgemini World Wealth Report, see www.worldwealthreport.com (accessed 5th August 2014)
[201] Futron/Zogby, "*Space Tourism Market Study*", 2006
[202] ibid

APPENDIX B

Secondary Economic Impact Methodology

RIMS II Economic Impact Model: The economic impact calculations have been done as per the Regional Input-Output Modelling System II (RIMS II) developed by the U.S. Department of Commerce's Bureau of Economic Analysis[203]. Revenue and demand is fed as an input from the demand projections to calculate the additional economic activity, extra workers' earnings and new employment.

Direct, Indirect and Induced: Total economic impact includes not only direct and indirect effects, but also induced. The direct effect of spaceport activities will consist, for instance, of the number of direct jobs it creates, and the indirect effects could consist of jobs created in supplier industries. An induced effect includes the impact of spending by the people employed directly or indirectly because of the spaceport[204].

Economic Multipliers: The multipliers used are specific to Scotland which has 6 out of the 8 short-listed spaceport locations. These are taken from "*Type II, output, income, employment and GVA multipliers for Scotland 1998-2011 (SIC 2007 basis)*"[205]. The industry multipliers used are 'Construction', 'Air Transport', 'Travel and Related Services', 'Accommodation', 'Food and Beverage Services' and 'Research and Development'.

AS PER TYPE II, OUTPUT, INCOME, EMPLOYMENT AND GVA MULTIPLIERS FOR SCOTLAND 1998-2011 (SIC 2007 BASIS)

		Multipliers		
Spaceport Activity Category	Industry Sector Description	Economic Activity	Earnings	Employment
Spaceport Construction	Construction	2.0	0.5	18.3
Spaceport Operations (Suborbital Space Tourism & Satellite Launch)	Air Transport	1.7	0.4	9.8
Regional Tourism, Hotels and Restaurants	Travel and Related Services, Accomodation, Food and Beverage Services	1.6	0.4	21.5
Microgravity Research	Research and Development, Air Transport	1.8	0.6	17.7

The model forecasts figures over a period of 10 years from 2018 to 2028 and has demand inputs which have been assessed based on optimistic, baseline and pessimistic scenarios as per demand forecasts and projections. Economic impacts are measured in terms of economic activity (revenues or output), earnings and jobs, as defined below. Cumulative impacts were calculated for construction of the spaceport over a period of three years (2015-2018) and five and 10 year impacts were calculated for operations of the spaceport (2023 and 2028).

The following definitions of terms are useful in understanding the economic impact methodology[206]:

- **Economic activity (or output)** is the total additional value of goods and services produced in an economy as a result of the increase in final demand due to the particular project under consideration. Each additional pound delivered to final demand for a good or service generates a (multiplier x £1) change in output for all of the input industries required to produce the final good or service. Direct, indirect,

[203] Regional Input-Output Modelling System II (RIMS II). See www.bea.gov/regional/rims/rimsii/ (Accessed 1st August 2014).
[204] See www.ehow.com/info_7946230_economics-induced-effects.html (accessed 21st August 2014)
[205] UK Standard Industrial Classification 2007 (SIC 2007 Basis). "*Type II, output, income, employment, and GVA multipliers*". Scotland 1998-2011. See www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html (Accessed 1st August 2014)
[206] Futron, "*Feasibility Study of a Florida Commercial Spaceport for Florida Space Authority*", Sept 2005

and induced economic activity is included in the multiplier used.

• **Earnings** are the sum of all wages and salaries (including employee benefits) paid to employees in an economy as a result of the increase in final demand due to the project under consideration. Each additional dollar delivered to final demand for a good or service generates a (multiplier x £1) change in earnings for all employees of the input industries required to produce the final good or service. Direct, indirect, and induced earnings are included in the multiplier used.

• **Employment** refer to the total number of additional (full-time equivalent) workers employed to produce goods and services as a result of the increase in final demand due to the project under consideration. The jobs multiplier is in terms of new total jobs generated per million pounds of additional final demand. Direct, indirect, and induced employment is included in the multiplier used.

RIMS II employs a top-level approach to determining regional economic impacts of new projects. "Bottom-up" surveys conducted by the Department of Commerce have demonstrated that the RIMS II model can overestimate impacts by as much as 10%[207].

[207] Department of Commerce, Bureau of Industry and Security, see www.bxa.doc.gov/DefenseIndustrialBasePrograms/OSIES/DefMarketResearchRpts/TSVReportAppendix.htm (accessed 10th August 2014)

ACKNOWLEDGMENTS AND CONTACT INFORMATION

This report was commissioned by the Satellite Applications Catapult and forms part of the report authors' MBA programme at the Saïd Business School, University of Oxford.

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The Report Team would like to thank the following organisations that contributed to this study through primary research assistance, interviews and informal discussions:

Virgin Galactic
XCOR Aerospace
Reaction Engines Limited
Generation Orbit
Swiss Space Systems (S3)
Hypermach Aerospace Ltd

Mojave Air and Space Port
Spaceport America
Space Florida
Spaceport Sweden

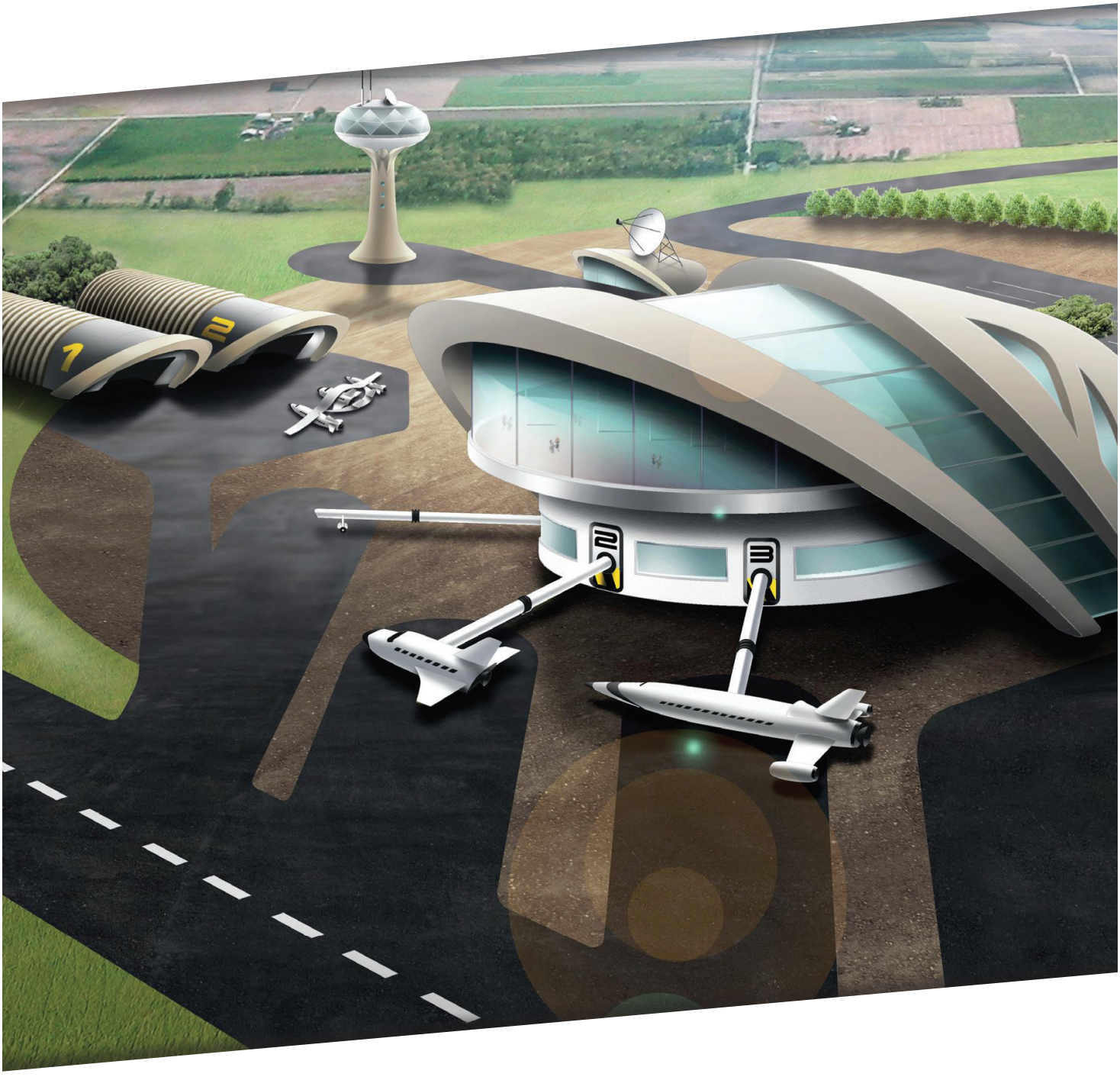
Firefly Space Systems
Rocket Lab Ltd.

Surrey Satellite Technology Ltd
Clyde Space

UK Space Agency
Civil Aviation Authority
Department for Transport
High Value Manufacturing Catapult

Newquay Cornwall Airport
Machrihanish Airbase Community Company

Pembroke Managing Agency
London Economics



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