UK Government review of commercial spaceplane certification and operations

Summary and conclusions

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Civil Aviation Authority

UK SPACE AGENCY

Department for Business Innovation & Skills

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Foreword

In August 2012, the Government tasked the Civil Aviation Authority under section 16 of the Civil Aviation Act 1982 to undertake a detailed review to better understand the operational requirements of the commercial spaceplane industry. I am pleased to present the summary and core recommendations of this Review. This report is the culmination of some 18 months of work undertaken by the Civil Aviation Authority and the UK Space Agency, and is published alongside a full technical report, providing more detailed analysis and evidence to support the recommendations made.

Our mandate was to inform Government, the aerospace and space industry, and other key stakeholders, about how the UK could accommodate and support future commercial space operations in the UK and pave the way for the appropriate regulatory frameworks that would allow this to happen. From the very start of the Review, it was clear that there is a genuine appetite to begin spaceplane operations in the UK by 2018 – or, in the case of some operators who are confident their technology may be operationally ready sooner, potentially even earlier. This report does not seek to verify their readiness but ensure that uncertainty over regulatory oversight is not an impediment.

These developments present an exciting opportunity for the UK on many levels, from the economic gains that would come from being a global leader in the commercial space sector, to the boost to scientific research. Let us not forget just how inspiring it will be for future generations to see spaceplanes taking off from the UK.

As this summary report explains, there are considerable challenges which must be addressed before any such operations can take place in the UK. None of these challenges are insurmountable; indeed, the Review provides practical recommendations for addressing each of them. In line with the original mandate, these happen on twin tracks: the first focuses on how the UK can accommodate these initial spaceplane operations as safely as possible, and the second paves the way for the regulatory framework we believe will be needed for the future.

Work should commence to develop the regulatory framework immediately so that it can facilitate and guide future spaceplane operations in the UK and help to shape any future European regulatory development. Regulatory clarity for the medium and longer term is essential if the UK is to build a world-leading spaceplane industry.

During their research, the members of the Civil Aviation Authority-led Review team have gained an unprecedented level of insight into spaceplanes and their operation. They have engaged closely with the organisations developing spaceplanes, as well as with those responsible for supporting and regulating them, including the US Federal Aviation Administration Office of Commercial Space Transportation; the US National Aeronautics and Space Administration; and the European Aviation Safety Agency. They have benefited extensively from the input of officials from the Department for Transport; the Department for Business, Innovation and Skills; and the UK Space Agency; the Ministry of Defence as observers; and a range of experts in topics such as aviation law, space law and insurance.

All of this has helped to shape the recommendations that are in this report, and we are grateful for their input. The many people with whom the Review team has worked share our enthusiasm for and commitment to the goal of enabling spaceplane operations from the UK. Early ministerial acceptance of recommendations will allow such operations to commence, in as safe an environment as possible.

Andrew Haines
Chief Executive, Civil Aviation Authority

Executive summary

Spaceplanes are widely acknowledged as the most likely means of enabling commercial spaceflight experience or, as it is widely known, 'space tourism' – in the near future. They also have the potential to transform the costs and flexibility of satellite launches, and the delivery of cargo and scientific payloads. Several operators have indicated that their spaceplanes will be ready to commence operations within the next five to ten years; several have also indicated their desire to operate from the UK.

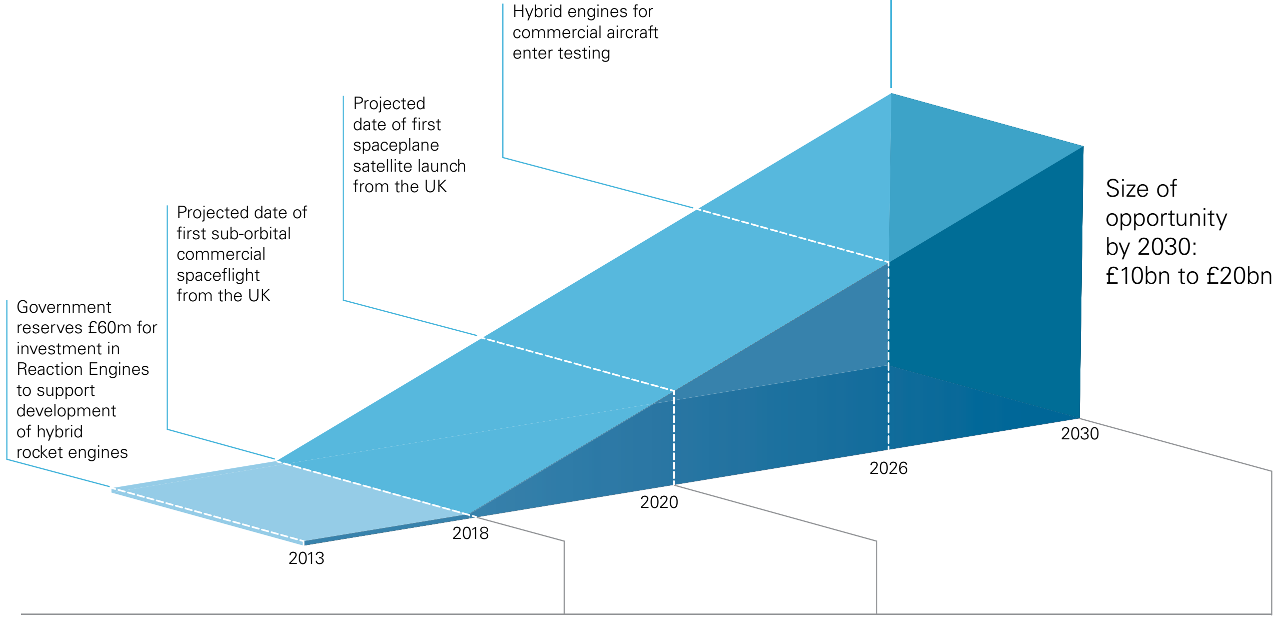
In 2012, the Civil Aviation Authority (CAA) was tasked by Government to undertake a detailed review of what would be required – from an operational and regulatory perspective – to enable spaceplanes to operate from the UK within the timescales that operators have proposed. The Review has identified a wide range of potential obstacles that would inhibit this, but also recommended ways to overcome these obstacles. Some of the most significant of these are:

- Current legislation does not fully address spaceplanes. It is the view of Department for Transport (DfT) and CAA legal experts that spaceplanes are aircraft, and hence the existing body of civil aviation safety regulation would apply to spaceplanes. But at this stage of their development, commercial spaceplanes cannot comply with many of these regulations. So to enable spaceplane operations to start from the UK in the short term, we have recommended that sub-orbital spaceplanes are classified as 'experimental aircraft' under the European Aviation Safety Agency (EASA) Basic Regulation. This effectively takes them out of core civil aviation safety regulation, and allows us to regulate them at a national level.

- Experimental aircraft are not typically allowed to conduct public transport operations – such as carrying paying participants for spaceflight experience. Given that this is the key goal of initial operations, we believe regulation could be possible under the Civil Aviation Act 1982 to issue exemptions and attach special conditions to the articles of the Air Navigation Order (ANO). However, spaceplane flight crew and participants will have to be informed of the inherent risks before flight, and acknowledge receipt of this information in writing: this is known as giving informed consent. In doing so, these paying participants will also acknowledge and accept that they will not benefit from the normal safeguards expected of public transport. In the US, they are therefore not considered passengers in the traditional sense, and the CAA considers the UK should take a similar approach – starting with the nomenclature.
- While these steps would make it possible in legal and regulatory terms for commercial spaceplane operations to take place from the UK, there remains a clear risk. Spaceplanes cannot currently achieve the same safety standards as commercial aviation, and may never be able to. Before allowing spaceplanes to operate from the UK, the Government must accept that these operations carry a higher degree of risk than most routine aviation activities.
- If this risk is accepted then protecting the uninvolved general public should be our highest safety priority. Our further recommendations in this Review focus on the creation of a permissive regulatory framework for spaceplane operations. To allow operations to take place by 2018, this should be established and functioning at least one year in advance of planned operations – so work to develop it must commence immediately. This would allow operators sufficient time to understand and address the regulatory requirements, several of which build on the US regulatory framework for spaceplane launches, which also places the protection of the uninvolved general public as its highest safety priority. It would also ensure the UK is ready to allow operations before 2018, should any operators be ready earlier. The Review details some of the key elements of the proposed regulatory framework, including the adoption of a safety management system for spaceplane airworthiness and the need for operations to take place within segregated airspace.

- One of the most important factors in protecting the uninvolved general public is the choice of a launch site for spaceplanes – a spaceport. The Review details the different operational, safety, environmental and economic criteria involved in selecting a suitable launch site, and recommends that operations should commence from an existing operational aerodrome, in an area of low population density such as near the coast. It provides a shortlist of aerodromes that meet these criteria.
- If accepted and if work were to begin immediately, the Review recommendations would make it possible for spaceplane operations to commence from the UK by 2018 or earlier, while providing the best possible level of safety assurance that can be achieved. They would also help build a transparent regulatory framework for future spaceplane operations – essential if the UK is to be a leading player in the global space industry. As Figure 1 below shows, the potential prize is considerable.

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



	2014–2016 ENABLING INITIAL LAUNCHES	2016–2020 BUILDING CONFIDENCE	2020–2030 REGULATING A MATURING INDUSTRY
OPERATIONS	Spaceplanes classed as 'experimental'; passengers permitted by ANO exemption Agreement to allow initial operations under wet lease type arrangement FAA AST and UK standards Detailed development of ANO exemptions and special conditions	Single regulator (competent authority) appointed for all spaceflight operations	Experimental classification phased out
AIRWORTHINESS	Principles of safety management framework for spaceplane airworthiness agreed	Start development of pan-European spaceplane regulation and certification	Publication of certification codes for spaceplanes All spaceplanes launched from the UK meet certification codes
AIRSPACE	Airspace Change Proposal (ACP) developed Discussions with MOD and NATS re use of military managed segregated airspace	Spaceplane ops within segregated airspace Further ACPs as required	
SPACEPORTS	Process for selection of spaceport determined Location for UK spaceport selected	UK spaceport fully operational Vertical launch site identified on the north coast of Scotland	Spaceplane operations from other suitable sites in the UK
FLIGHT CREW	Validation of the FAA AST process around flight crew Investment in training facilities for spaceflight crew	With FAA AST and EASA, develop standards for spaceflight crew Spaceflight crew training begins in UK	Most UK spaceflights use UK-trained crew Long-arm centrifuge opens in UK
MEDICAL	Medical requirements for spaceplane flight crew are developed	Assessments undertaken by suitably trained examiners	UK at the forefront of space medicine

Figure 1: The value of spaceplanes to the UK and how we can help secure it

SECTION 1

Context of this Review

The prospect of commercial space travel is now becoming reality. According to its current plans, late in 2014, Virgin Galactic anticipates taking the first paying participants on a sub-orbital spaceflight experience, launching from the US.

Within just a couple of years, others are set to follow. XCOR Aerospace intends to start commercial operations from the US in 2016 and several further businesses anticipate being technically able to offer spaceflight experience – or, as it is widely known, 'space tourism' – within the next decade. Others plan to use spaceplane technology to transform the cost of satellite launches and of carrying cargo into space.

The UK: European centre for space tourism?

Clearly, this is an exciting prospect – and it is one of which the UK Government has long been aware. In its Plan for Growth (2011)1, the UK Government identified the space industry as one of eight key sectors covered by the Growth Review, and stated that it 'wants the UK to be the European centre for space tourism'.

The only successful UK-led space launch was that of the Prospero satellite, which took place in Australia in 1971. While there are UK-based businesses that are developing space technology, and many UK scientists and engineers who are extensively involved in designs, no spacecraft of any description has yet been launched from the UK.

The UK is far from being alone in this. The overwhelming majority of space launches have taken place from the US, Russia or China. There is, as yet, only one operating spaceport in Europe – Spaceport Sweden, located inside the Arctic Circle. It is, however, currently only used for sounding rockets. Launches have also taken place from French Guiana, a French overseas department, which is thus deemed by some to be a European spaceport.

1 HM Government (2011) The Plan for Growth, London, HM Government, www.gov.uk/government/uploads/system/uploads/attachment_data/file/31584/2011budget_growth.pdf (accessed 23 February 2014)

Understanding the opportunity

However, given that spaceplane operators have expressed a strong interest in launching from the UK by 2018 or earlier, there is a clear opportunity for the UK to become the European centre for space operations – something that could offer a wide range of benefits commercially and scientifically.

If spaceflights could launch from the UK, then it would be the logical location for operators to base themselves; a range of related industries would also stand to gain, from manufacturing to services and beyond. As the Plan for Growth underlines, space is a research and development-intensive sector, so there could also be a considerable knock-on effect across UK science and innovation.

Practical challenges

While the long-term potential is thus clear, there are significant practical challenges that need to be overcome if we are to realise it. No location has yet been firmly identified for space launches; the necessary infrastructure for spaceplane operations does not yet exist (although the infrastructure in place for aviation can provide the basis). Spaceplane technology is still comparatively in its infancy and, compared with conventional aviation activities, is largely unproven. Airspace over the UK is both complex and busy every day with essential commercial travel and recreational aviation, as well as military operations. How can spaceplanes fit within this?

These issues have already been acknowledged. The Plan for Growth recognised the need 'to define regulations for novel space vehicles that offer low cost access to space' and the UK Space Agency has stated its intention to 'work with the Civil Aviation Authority and the European Aviation Safety Agency to ensure the right regulatory framework is in place to facilitate UK launch capabilities and space tourism'[2]. The CAA's own Future Airspace Strategy[3] highlighted the importance of addressing the regulatory requirements to enable sub-orbital flight in the UK.

With spaceplane technology almost ready for commercial operation, and demand building, the time is now right to address these practical challenges.

The Review mandate

In expectation of the advent of commercial space operations, in August 2012 the DfT requested, under section 16(1) of the Civil Aviation Act 1982,[4] that the CAA undertake a detailed review to better understand the operational requirements of the commercial spaceplane and spaceport industry. The findings of this Review

2 UK Space Agency (2011) UK Space Agency Strategy 2011–2015: Consultation document, Swindon, UK Space Agency, www.bis.gov.uk/assets/ukspaceagency/docs/strategy/11-834-uk-space-agency-strategy-2011-2015-consultation.pdf (accessed 3 March 2014)

3 Civil Aviation Authority (2011) Future Airspace Strategy for the United Kingdom 2011 to 2030, London, CAA, www.caa.co.uk/docs/2065/20110630FAS.pdf (accessed 23 February 2014)

4 Section 16 (1) of the Civil Aviation Act 1982 states: '...it shall be the duty of the CAA to provide such assistance and advice as the Secretary of State may require it to provide for him or any other person in connection with any of the Secretary of State's functions relating to civil aviation.' www.legislation.gov.uk/ukpga/1982/16/section/16 (accessed 7 March 2014)

should inform the aerospace and space industry and other key stakeholders about how the UK could accommodate and support future spaceplane operations, and pave the way for an appropriate regulatory framework that would allow this to happen.

The Review was specifically tasked to provide:

- a description and analysis of actual or anticipated key spaceplane operations and their requirements;
- an assessment of the potential for the growth of the spaceplane industry beyond sub-orbital space tourism and satellite launches;
- an analysis of the applicability of the procedures and requirements utilised by the US Federal Aviation Administration Office of Commercial Space Transportation (FAA AST) to the UK;
- recommendations for the appropriate regulatory framework for commercial spaceplane operations in the UK. This will include:
    - spaceplane airworthiness;
    - airspace requirements;
    - Air Traffic Management;
    - flight operations;
    - flight crew licensing; and
    - flight crew and participant medical requirements;
- an analysis and recommendations regarding the appropriate regulatory requirements for spaceport operations;
- recommendations as to the most suitable locations for a spaceport in the UK;
- consideration of the likely environmental impacts peculiar to spaceplane and spaceport operations; and
- an assessment of the value to the UK of commercial spaceplanes and related technologies.

To deliver this, the Review team has undertaken a wide range of research over the last 18 months. We have engaged extensively with industry and regulators in the UK, in the US and across Europe. We have examined the publicly available information about proposed spaceplane technologies and visited development and launch sites.

We have also reviewed the existing legal and regulatory frameworks in different countries and for different types of flight to consider their applicability to the UK.

Vertical launch vehicles

Vertical launch vehicles are not the prime focus of this Review. However, as they are the main current method of launching satellites, which is by far the most mature commercial space operation, they merit some consideration.

The expectation is that reusable spaceplanes will be able to offer satellite launch at a lower cost than vertical launch vehicles. However, there are limits to the size of satellites that spaceplanes can carry and the distance they can travel. Therefore, even though satellite technology is rapidly advancing and nanosatellites (satellites weighing between 1 kilogram and 10 kilograms) now have the ability to perform tasks that previously required microsatellites, there will remain a need for vertical launch vehicles. We have, therefore, considered the potential for a vertical launch site in the UK as part of the wider Review.

Output of the Review

The formal output of the Review consists of two documents: a technical report containing detailed findings and recommendations, and this summary report including high-level recommendations. The two are being published simultaneously.

SECTION 2

Spaceplanes today and tomorrow

Spaceplanes are winged vehicles that act as an aircraft while in the atmosphere and as a spacecraft while in space. They are widely seen as the most feasible method, at least with current technology, of enabling commercial space operations such as spaceflight experience. They also have the potential to transform the costs and flexibility of satellite launches, and the delivery of cargo and scientific payloads.

In the longer term, it is possible that spaceplanes will enable intercontinental travel at very high speeds. There have been suggestions that by travelling on a sub-orbital trajectory, journey times from the UK to Australia could be cut from the current duration of around 20 hours to as little as two hours.

Such possibilities are still theoretical – and are likely to remain so for some years. Even if such spaceplanes are successfully developed, they are not likely in the foreseeable future to be realistic or cost-effective alternatives for mass market travel.

Like all earlier spacecraft, spaceplanes use a rocket engine as their primary source of power. Rocket engines generally rely on fuel and oxidiser that is carried within the vehicle; this is different from jet engines used in most conventional aircraft, which are air-breathing. Rocket engines are required not only for the additional power and thrust they offer, but also because spaceplanes must operate at a much higher altitude, where the air is thinner.

Unlike many earlier spacecraft, spaceplanes are designed to be reused rather than just for a single mission. Some are expected to reach orbit, others will fly at a sub-orbital level. The most well-known spaceplane is the Space Shuttle.

There are a number of spaceplane designs currently being tested; some have begun test flights and are nearing operational readiness. The following section provides a brief overview of the operators we believe to be leading the way and who have indicated some intention to operate from the UK (listed in alphabetical order).

Airbus Defence and Space

Airbus Defence and Space (formerly EADS Astrium) is developing a spaceplane about the size of a business jet for spaceflight experience. It will be powered by two turbofan engines for normal flight and a rocket engine for the sub-orbital trajectory, and will take off and land conventionally from a runway using its jet engines. The entire flight will last approximately one hour. No in-service date has yet been set. Assuming relevant funding is available for further development effort, commercial operations would start by the beginning of the next decade.

Figure 2: Airbus Defence and Space spaceplane (Image: Airbus Defence and Space)

Bristol Spaceplanes

Bristol Spaceplanes, based in the UK, was founded in 1991. It has developed plans for Spacecab, which is aimed at being the first orbital spaceplane. Spacecab is an update of the European Aerospace Transporter project of the 1960s. Spacecab is designed to carry six astronauts to a space station or launch a 750 kg satellite.

As a lead-in to Spacecab, the company has plans for the Ascender sub-orbital spaceplane. Ascender would carry one paying participant and one crew member. It would take off from an ordinary airfield and climb to 26,000 feet (8 kilometres) at subsonic speed, before starting the rocket engine. It would then accelerate to a speed of around Mach 3 on a near-vertical climb and then follow an unpowered trajectory to reach a height of 330,000 feet (100 kilometres).

Bristol Spaceplanes has received some UK government funding, as well as contracts from the European Space Agency, to support feasibility studies into its spaceplane designs. It has also run successful tests of its engines in the Mojave Desert.

Figure 3: Ascender (Image: Bristol Spaceplanes)

Orbital Sciences Corporation

US-based Orbital Sciences Corporation was behind the world's first privately developed space launch vehicle. It made its maiden voyage in 1990 and has since conducted 42 missions, including launches from the Canary Islands, to insert satellites into Low Earth Orbit (LEO). It uses a carrier aircraft and a winged multi-stage solid fuel rocket known as Pegasus. As far as we are aware, it has not yet expressed an interest in operating from the UK.

Figure 4: Launching Pegasus (Image: Orbital Sciences Corporation)

Reaction Engines

UK-based company Reaction Engines is developing a fully reusable, single-stage to orbit, unmanned spaceplane called SKYLON. It will use a pioneering engine design known as SABRE (Synergetic Air-Breathing Rocket Engine) that will enable it to reach five times the speed of sound (Mach 5) in air-breathing mode and then accelerate to Mach 25 (18,000 miles per hour) for orbital insertion. It will take off from a runway and transition from air-breathing to rocket propulsion at an altitude of 80,000 feet (26 kilometres).

Proposed initial uses for SKYLON are to launch satellites and carry cargo to the International Space Station (ISS). However, it may also be able to carry spaceflight experience participants, or transport astronauts to the ISS, in a specially designed pod within the existing cargo bay. It is anticipated that after testing, which should commence in 2020, SKYLON would become operational in 2022.

Figure 5: SKYLON (Image: Reaction Engines)

Stratolaunch Systems

Stratolaunch Systems is a relatively new company based in the US. According to information on the company website[5], it is developing a very large spaceplane that is designed to launch satellites weighing over 6,800 kilograms into LEO. It will also be able to launch smaller payloads into Geostationary Earth Orbit.

It plans to use a twin-fuselage aircraft, powered by six engines (the same as are used in the Boeing 747). The Air Launch Vehicle booster rocket will be developed by Orbital Sciences Corporation. The aircraft is expected to start flight testing in 2016 and the first launch is expected in 2018.

Figure 6: The Stratolaunch Systems spaceplane (Image: Stratolaunch Systems)

5 See http://stratolaunch.com/presskit/Stratolaunch_PressKitFull_May2013.pdf (accessed 10 June 2014)

Swiss Space Systems (S3)

Swiss Space Systems (S3) plans to offer a means of launching small satellites – weighing up to 250 kilograms – into orbit, using a spaceplane. The first satellite launches are planned for 2018.

It will launch its spaceplane from a carrier aircraft at high altitude. It plans to use a slightly modified Airbus A300; its spaceplane, the unmanned Sub-Orbital Aircraft Reusable (SOAR) vehicle, will then be released and will use rocket-powered engines to reach sub-orbital levels. Both the carrier aircraft and SOAR use standard fuels and are reusable, key to achieving the company's aim of making make the launch system highly efficient, secure and affordable. S3 is also considering spaceflight experience and intercontinental very high speed transport as future uses for SOAR in the course of the next decade.

Figure 7: SOAR on board an Airbus A300 (Image: Swiss Space Systems)

Virgin Galactic

Figure 8: WhiteKnightTwo (Image: Virgin Galactic)

As recently as February 2014, the founder of Virgin Galactic, Richard Branson, reaffirmed his confidence that his company anticipates being able to start commercial operations in the US by the end of 2014[6] after completion of the flight test programme and approval by the FAA AST. These will involve a spaceflight experience for up to six participants as well as two crew. The company has been accepting deposits for several years and more than 700 'future astronauts' have signed up. At the time of writing, the price for the flight experience including training is US$250,000 each[7].

Virgin Galactic uses a specially designed carrier aircraft known as WhiteKnightTwo to carry a rocket-powered spaceplane (SpaceShipTwo) to approximately 50,000 feet (15 kilometres). The spaceplane is then released to begin its rocket-powered ascent to over 327,000 feet (100 kilometres) above the Earth's surface. The carrier aircraft returns to land conventionally; after re-entering the atmosphere using a tail feathering system to control speed and angle of descent the spaceplane glides back to land on the same runway from which it departed. To date, it has performed several successful supersonic test flights.

6 See, for instance, 'Richard Branson insists he will be aboard first Virgin Galactic space flight', *Guardian*, 21 February 2014, www.theguardian.com/science/2014/feb/21/richard-branson-first-virgin-galactic-space-flight (accessed 3 March 2014)

7 www.virgingalactic.com/booking/ (accessed 3 March 2014)

As well as offering spaceflight experience, it is intended that SpaceShipTwo will carry scientific payloads which will benefit from approximately five minutes in a microgravity environment. Virgin Galactic also plans to use WhiteKnightTwo to deploy small satellites into orbit with a reusable launch vehicle, LauncherOne, currently in development. The company is currently carrying out test flights from its base at Mojave Air and Space Port in California and plans to undertake its first commercial flights from Spaceport America in New Mexico. It has expressed an interest, subject to US regulatory approvals, in conducting operations outside the US, and the UK is a potential location.

XCOR Aerospace

Another Mojave-based company, XCOR Aerospace, is also taking bookings for spaceflight experience on its Lynx spaceplanes. These are two-seat vehicles: one seat is for the pilot; the other can be used by a paying participant. It proposes to offer half-hour sub-orbital flights to 330,000 feet (100 kilometres), and plans to commence commercial operations in the US in 2016.

Lynx is much smaller than the Virgin Galactic spaceplane and has been designed to take off horizontally from a runway before ascending to space. To do so, it will use rocket engines as its propulsion system from take-off: a significant difference from some other spaceplane designs.

From space, the Lynx spaceplane will return as a glider to land horizontally on the same runway as departure. The company has also published early-stage designs for future spaceplanes, including Lynx III, which will be able to launch multiple nanosatellites into LEO.

Figure 9: XCOR Lynx (Image: XCOR Aerospace)

Conclusions

This brief overview of current and emerging spaceplane technology demonstrates that:

- there are very few spaceplanes that are currently ready for commercial use, though this is expected to change over the next five years;
- in the short term, spaceplanes are most likely to be used for spaceflight experience, scientific experiments and satellite launches. Further uses are some way into the future; and
- there are some significant differences in spaceplane designs, but the majority fall into one of two categories: they are either launched at altitude from a carrier aircraft or take off from a runway. All return to land on a runway.

These facts have several implications from a regulatory and infrastructure perspective – as well as a commercial one. These are explored in the following sections.

SECTION 3

The opportunity for the UK

The main uses for spaceplanes in the immediate term are likely to be spaceflight experience, scientific experiments and satellite launches. In the longer term, other markets are expected to develop. However, it is clear that the pivotal factor in realising many of these benefits is having an operational UK base or spaceport.

Benefits of a UK spaceport

Having a spaceport would make the UK a highly attractive location in Europe for spaceplane operators, as well as for manufacturing and related services. There could also be direct technology spillovers, with a spaceport acting as a hub for high-technology firms. In the longer term, there would be opportunities in the supply chain for advanced manufacturing.

Some of these gains may be partly realised without the existence of a UK launch capability, for example, through the export of newly developed technology to other space-faring nations; however, they would be significantly diminished. Therefore, even though a spaceport would have little productive value in isolation – especially in the short term, when the volume of flights is likely to be small – it would be the catalyst for the accelerated growth of the UK space industry.

It is also expected to offer some opportunities for the construction industry, even if – as we recommend in Section 8 of this Summary report – a spaceport is based at an existing aerodrome. Additional construction would be required on site and there may also be a need for infrastructure improvements. Experience in the US indicates that those paying for a spaceflight experience will expect a high-quality product at the spaceport as well as on the flight itself.

Other industries that might benefit include tourism, education and various professional services such as space finance, legal services and insurance. The UK would develop expertise in each of these areas which could then be 'exported' as other countries develop their own space operations.

Market analysis: spaceflight experience

Spaceflight experience is expected to be the first market for commercial spaceplane operations. As shown above, spaceplanes are nearing operational readiness, and despite the lowest published price of US$95,000 for a flight experience (with XCOR Aerospace), hundreds of customers worldwide have signed up.

Market research undertaken by Surrey Satellite Technology Limited (SSTL)[8] indicates that UK demand for such flights would start at around 120 paying participants per year, increasing to 150 per year by year three. A rough calculation based on the proportion of capacity of the two businesses that are most likely to be able to offer spaceflight experience in the next few years (Virgin Galactic and XCOR Aerospace) and their corresponding prices would indicate annual revenue from spaceflight experience of approximately US$19 million in year one and US$24 million by year three. In the medium term, it is expected that the number of spaceflights will increase in line with demand, up to perhaps 400+ participants in year 10, offering annual revenues of US$65 million.

Clearly, the revenue would predominantly go to these main operators, which are both US based. However, there are significant maintenance and support costs related to spaceflight operations, which, if flight volumes develop in line with projections, could provide a valuable opportunity for the UK.

These projected revenue figures are dependent on a number of factors, such as the ability to reduce prices, the presence of appropriate weather conditions, supply sufficiently meeting demand and the possibility that the market for spaceflight experience could be a short-term bubble, with demand declining relatively quickly. However, if take-up is as predicted, then in only a few years time, annual revenues from spaceflight experience alone would outstrip the estimated capital costs of developing an operational spaceport at an existing aerodrome.

8 Surrey Satellite Technology Limited (2013) 'Sub-Orbital Reusable Vehicles Market Analysis' unpublished study

Market analysis: satellite launches

There are currently more than 1,000 satellites in orbit around the Earth, and a significant number are launched each year. In 2012, 81 satellites were launched, a slight decrease from 90 in 2011; however, the total launch revenues increased by 35 per cent year-on-year, reflecting the fact that 2012 saw a greater proportion of larger, more expensive satellites.

There is therefore a healthy and growing market for space access that is currently met with expendable, vertically launched rockets. Because spaceplanes are reusable, they will be able to meet some of this market demand at a comparatively low cost. The average price of a rocket launch varies between US$10 million and US$150 million; Virgin Galactic has indicated its launch costs would be lower than US$10 million, the bottom end of the current estimated price bracket. However, with its initial spaceplane designs it would not be able to carry larger payloads or satellites into Medium and High Earth Orbit.

Approximately 35 per cent of global satellite launches are funded from and take place in the US; it is essentially self-sufficient, so even if the UK market matured, it would be unlikely to capture much of the US demand. However, a large proportion of launch orders are derived from European demand. In 2012, 11 of the 25 recorded orders were from Europe[9]. The only operational launch capability within Europe at the time of writing is in Sweden, and to date it has only been used for sounding rockets and scientific balloons. This suggests that a UK launch capacity would have a good chance of gaining some of these orders due to geographical proximity and lower costs – though it is important to be clear that, due to its northerly latitude, the UK is only suitable for launching satellites into polar orbit (as opposed to equatorial orbit).

The exact demand is hard to predict, and in the short term it may amount to only one or two launches per year; however, this would be expected to increase as spaceplane technology evolves.

9 The Tauri Group (2013) The State of the Satellite Industry Report, Washington DC, Satellite Industry Association, www.sia.org/wp-content/uploads/2013/06/2013_SSIR_Final.pdf (accessed 3 March 2014)

The case for investing

Constructing a spaceport will require significant capital investment; however, exact costs cannot be confirmed at this stage. They will depend upon the location chosen and its existing facilities: some aspects may be usable as is, others may need improvement. In addition, there would be a requirement for broader industrial and academic activities associated with the development of this type of infrastructure. Further investigation would be required to identify how best to fund the construction.

While recognising the inherent risks in a project of this scale, and the uncertainties around market development, our initial assessment indicates sizeable potential returns to the UK economy, as well as large spillovers in the medium to long term, as Figure 10 below shows. These would not be captured by the investing firms but would instead radiate out through the UK economy. As well as private investment, there would also be opportunities to explore what investment could be made by local government and/or devolved administrations in the region where a spaceport could be located.

However, if Government wants the UK to become the European centre for the space industry, it is likely that central funding for a spaceport would be needed.

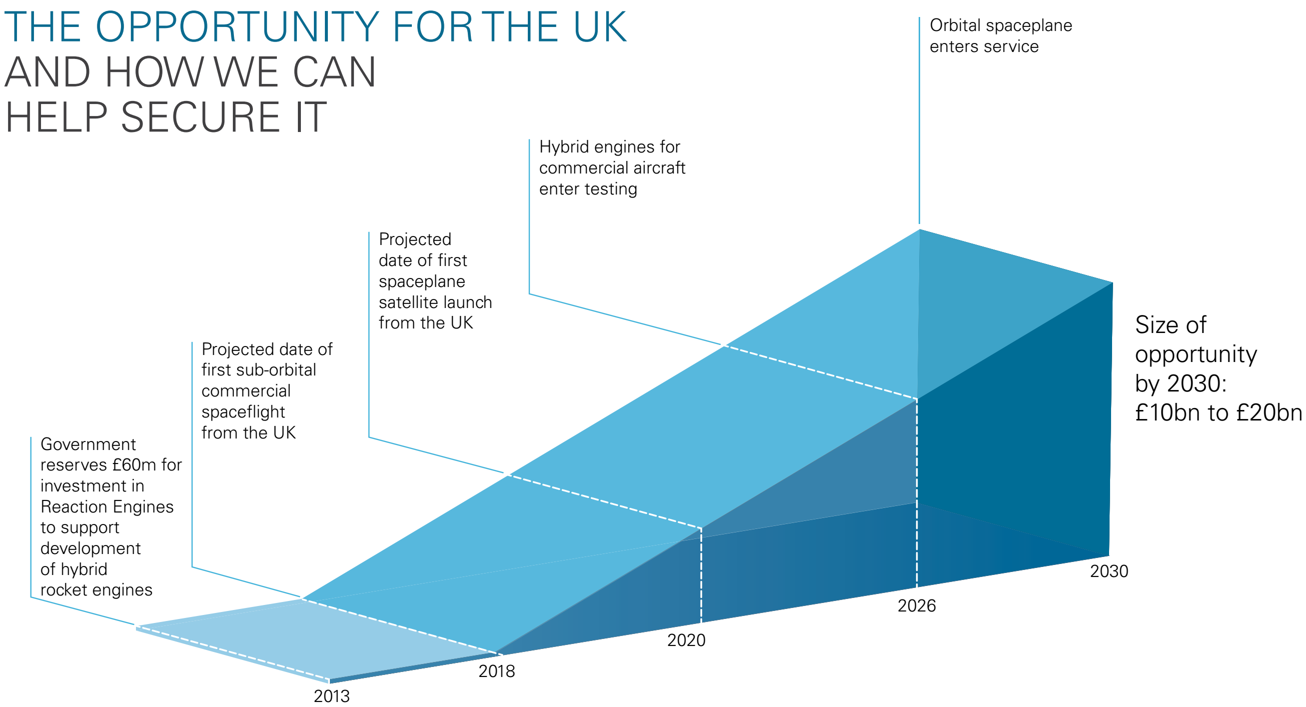


Figure 10: Projected growth over time of UK space operations

Additional central government involvement

As well as funding challenges, there is a further significant issue that needs to be addressed if we are to secure the full benefits of allowing spaceplane operations in the UK. This involves US export controls.

Sub-orbital and orbital spacecraft are on the US Munitions List (USML) and are subject, therefore, to the US International Traffic in Arms Regulations (ITAR). Within ITAR, it is specified that any information and material concerning items on the USML may only be shared with US persons, unless authorisation is received from the US Department of State or a special exemption is issued.

While an established process exists for obtaining such authorisation, this limits discussions and information exchange between companies such as XCOR Aerospace and Virgin Galactic with countries outside the US. For example, it restricts what data can be shared for safety analysis to support regulation; it also means that it is likely that initial commercial operations outside the US would have to be conducted under a ‘wet lease’ type arrangement, ie the US operator would be responsible for the entire operation, including the aircraft, its flight crew and its maintenance staff. Clearly, this limits the potential for UK businesses to supply the operator, and restricts knowledge sharing.

Finding a way forward on this issue will be essential to enable short-term UK commercial sub-orbital or orbital operations and to deliver long-term commercial benefits. The commercial space industry in the US is keen to address this and would welcome UK support.

1	**The UK Government should enter into early discussions with the US Government and the US sub-orbital industry to obtain appropriate export licences to commence operations in the UK.**

It should be clearly articulated in any discussion that it is not the intention to remove any products from control; instead, the aim is simply to facilitate exports of spaceplanes and essential related information from the US to the UK on a case-by-case basis, to enable spaceplane operations to take place in the UK. This would only be done where there is minimal risk to US national security interests. This is in line with the 2011 rule change to ITAR (section 126.18), which provides an exemption for UK end users and consignee companies only, subject to satisfying screening and record-keeping requirements.

SECTION 4

Overarching regulatory and operational challenges

The Review was tasked with providing recommendations for the appropriate regulatory framework for commercial spaceplane operations in the UK, covering six specific areas. However, there are some overarching issues and challenges that apply across all areas and fundamentally guide the specific recommendations made in each.

Legal framework

Current legislation does not fully address spaceplanes. International space law is based on five UN treaties[10] which do not refer to spaceplanes; neither does the UK Outer Space Act 1986,[11] which was introduced to manage UK obligations under the UN treaties. There is also no internationally established boundary for where outer space begins (nor is there likely to be one in the foreseeable future), and at present there is no worldwide consensus on what regulatory framework should be used for sub-orbital operations – and in particular for spaceflight experience.

10 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the 'Outer Space Treaty'); Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (the 'Rescue Agreement'); Convention on International Liability for Damage Caused by Space Objects (the 'Liability Convention'); Convention on Registration of Objects Launched into Outer Space (the 'Registration Convention'); and Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the 'Moon Agreement'). Full details are available at www.unoosa.org/oosa/en/SpaceLaw/treaties.html (accessed 3 March 2014)

11 Overview at www.bis.gov.uk/ukspaceagency/what-we-do/space-and-the-growth-agenda/uk-capabilities-for-overseas-markets/the-outer-space-act-1986 (accessed 3 March 2014). Full text at www.legislation.gov.uk/ukpga/1986/38/contents (accessed 12 June 14)

This has a number of consequences. DfT and CAA lawyers are of the initial opinion that:

- because they meet the International Civil Aviation Organization (ICAO) definition of 'aircraft'[12] ('any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the Earth's surface'), spaceplanes are aircraft; and
- the carriage of paying participants for spaceflight experience would be deemed to be public transport.

It has therefore been determined that the existing body of civil aviation safety regulation would apply to spaceplanes. Within the EU, this means those set by EASA which cover certification, continuing airworthiness and operations. But at this stage of their development, commercial spaceplanes cannot comply with these regulations: technology will need to be developed and mature before it can comply with the norms of commercial aviation.

An alternative would be to adapt the rules and develop an alternative framework for spaceplane regulation. However, here too there are problems: legislation would take some years to develop, meaning that it is unlikely that new legislation could be in place within the desired timescales to allow commercial space operations from the UK in the short term. Having engaged closely with EASA, we understand that it would be unlikely to commence any rulemaking before 2016, so rules would not be in place by 2018.

However, there is an alternative option. Under Annex II of the EASA Basic Regulation, some categories of aircraft are excluded and remain subject to national regulation. These include 'aircraft specifically designed or modified for research, experimental or scientific purposes, and likely to be produced in very limited numbers'.[13] We recommend that we use this exclusion to allow initial spaceplane operations to take place in the UK, designating spaceplanes as 'experimental' aircraft for the short term.

12 See https://easa.europa.eu/agency-measures/docs/opinions/2011/04/Annexes%20to%20Regulation.pdf (accessed 3 March 2014)

13 See www.easa.europa.eu/certification/docs/policy-statements/E.Y013-01_%20UAS_%20Policy.pdf (accessed 3 March 2014)

2	**To enable spaceplane operations to start from the UK in the short term, we recommend that sub-orbital spaceplanes are classified as 'experimental aircraft' and treated as Annex II aircraft under the EASA Basic Regulation. This will allow regulation of sub-orbital spaceplanes to be managed at a national level.**

This is a view endorsed by DfT legal advisers.

Regulating experimental aircraft

Designating spaceplanes as 'experimental aircraft' allows them to be regulated at a national level. They then fall within the responsibility of the CAA, as national aviation safety regulator.

However, experimental aircraft are not typically allowed to conduct public transport operations – such as the carriage of paying participants for spaceflight experience. Clearly this would be inappropriate for the type of operations envisaged.

Using powers granted under section 60 of the Civil Aviation Act 1982,[14] the CAA can issue exemptions against articles of the ANO and also attach special conditions. While further consideration will need to be given to whether Annex II can be applied in this way once paying participants are involved, these exemptions and special conditions could offer a means of allowing the carriage of fare-paying participants and cargo on sub-orbital spaceplanes in the short term, subject to further legal analysis.

3	**To allow the carriage of paying participants and cargo on sub-orbital spaceplanes while they are classified as experimental aircraft, the CAA should use its powers granted under the Civil Aviation Act 1982 to issue exemptions and attach special conditions to the articles of the ANO.**

14 See section 60 of the Civil Aviation Act 1982, www.legislation.gov.uk/ukpga/1982/16/part/III/crossheading/general (accessed 7 March 2014)

Who should regulation protect?

Over the past 100 years, commercial aviation has evolved to the extent that, for public transport, modern aeroplanes achieve a catastrophic failure rate better than 1 x 10^{-7}. Put in simpler terms, that means catastrophic failure – ie incidents where there is a substantial risk of loss of life – takes place in less than 1 in every 10 million hours of flight. For aeroplanes to be allowed to offer public transport, they must be able to meet these safety and performance standards. For general aviation, the standards are typically between 1 in 10,000 and 1 in 100,000: less stringent than for public transport, but still deemed an acceptable level of safety given the nature of the activity.

During our research visit to the US, the Review team was informed by NASA that it considered a target level of safety of 1 in 1,000 was achievable for orbital operations and 1 in 10,000 for sub-orbital operations.

The FAA AST has made clear that it accepts spaceflight is a high-risk activity; hence its regulatory approach is to focus on the protection of the uninvolved general public (also known as third parties). This differs from normal commercial aviation, where the focus is on protection of passengers and crew and works on the basis that if the risks to passengers and crew are minimised, then the public is inherently protected too.

We believe that the UK's regulatory framework for spaceplanes should ultimately follow the same principles as commercial aviation regulation. However, it is clear that commercial spaceplanes cannot currently achieve the same safety standards as commercial aviation, and may never be able to. If we are to allow spaceplane operations to take place in the short term – which is key to maximising their commercial benefits – then the Government needs to understand and accept this risk. If this is accepted, then protecting the uninvolved general public, rather than participants and crew, becomes our underlying priority.

4	**In order to allow spaceplane operations from the UK by 2018 or earlier, the Government must accept that spaceplane operations carry a higher degree of risk than most normal aviation activities and that protecting the uninvolved general public should be its highest safety priority.**

The regulatory framework we recommend over the following pages reflects this priority. While in no way underestimating the potential risks inherent in spaceplane operations, we believe it is a permissive framework that seeks to make spaceplane operations possible on a legal basis and one which, given the expected low volume of flights in the short term, provides as high a degree of safety for the public as we believe can be achieved given the current unproven nature of spaceplane technologies. To allow operators sufficient time to understand and address the regulatory requirements, the framework needs to be published well in advance of the start of operations.

5 **In order for sub-orbital spaceplane operations to take place from the UK by 2018 or earlier, a permissive regulatory framework needs to be established and be functioning at least one year in advance of planned operations.**

In the longer term, the aim of regulation of commercial spaceplane operations will be to provide the best possible level of safety assurance that can be achieved by establishing rules and guidance material which promote a culture of safety management, safe spaceplane design and manufacture, together with safe operation – as the regulatory framework for commercial aviation does.

The challenge will be to arrive at a suitable regulatory framework for each type of spaceplane operation which is risk-based and will encourage an acceptable level of safety without being so burdensome that it stifles the development of this new industry. It should be compatible with existing spaceplane operations and be flexible enough to allow for future regulatory development in the EU, as and when that takes place.

SECTION 5

Flight operations

Flight operations cover the overall regulatory framework under which spaceplane operations can take place from the UK. As set out above, our aim is to provide a permissive regulatory framework that allows spaceplane operations to take place, while adhering to our underlying priority of protecting the uninvolved general public.

In the future, regulatory frameworks for commercial space operations are likely to be required for a range of different types of operation. To help the industry develop designs that will meet safety goals and targets, work should begin as soon as possible to develop outline frameworks for air-launched orbital, single-stage to orbit, intercontinental very high speed transport, and vertical launch operations.

However, for now our focus is on the framework for sub-orbital spaceplane operations, which necessarily includes a regulatory framework for spaceports.

There are two broad regulatory models that already exist: the global aviation model as developed by ICAO, and the US model for commercial space operations.

Given that the designs of the spaceplanes that are most likely to launch from the UK by 2018 or earlier have been developed in line with the US model, any regulation we propose should be compatible with this model.

The FAA AST regulatory framework

In the US, space regulation is the responsibility of the FAA AST, under the Commercial Space Launch Act 1984 (CSLA). The FAA AST issues licences and permits for commercial launches of orbital rockets and sub-orbital rockets – including spaceplanes. The first US-licensed launch was a sub-orbital launch of a Starfire vehicle on 29 March 1989. Since then, the FAA AST has licensed more than 220 launches, all conducted without any fatalities, serious injuries or property damage to the uninvolved general public. It is important to highlight, however, that very few of these launches have been for spaceplanes.

The following is a brief summary of how the FAA AST framework operates.

For a commercial space launch, two licences are required: one for the vehicle or the operator, and a separate one for the launch site (ie spaceport). Vehicle or operator licences are granted based on acceptance of a detailed written application. Operators have to provide information about payload, environmental impact and, crucially, safety – giving comprehensive details of the launch schedule and trajectory, as well as the systems being used. There is a mandatory consultation period before applying for a launch vehicle or operator licence, during which the applicant must familiarise the FAA AST with its proposal. The overall process can take a significant amount of time: the FAA AST has a maximum of 180 days to review each formal licence application.

It takes longer still to obtain a licence for the launch site: for example, an environmental impact assessment for a launch site can take up to two years to complete. Understandably, operators in the US will opt to launch from a site that has already been licensed (eg for test flights). However, no such sites exist yet in the UK. Therefore, given the timescales involved in gaining a launch site licence, to enable spaceplane operations to take place from the UK by 2018 or earlier, it is essential that the licence application process begins as soon as possible.

Once an operator has been granted a licence for a specific type of flight using a specific type of reusable vehicle (such as a spaceplane), it may be easier for that operator to gain licences for future launches with slightly different payloads or trajectories. Alternatively, by gaining an operator licence, the operator can conduct multiple launches or re-entries of the same or similar type, from the same site. Operator licences remain in effect for two to five years from the date of issue.

However, one essential task for every flight involving paying spaceflight participants is that each participant must sign as giving ‘informed consent’. Under section 50905 of the 2004 Amendment to the CSLA, a holder of a launch licence or permit must inform any crew and spaceflight participants that the US Federal Government has not certified the launch vehicle as safe. A reusable launch vehicle operator must inform a spaceflight participant in writing about the risks of launch and re-entry, and the safety record of the vehicle type.

Can the UK use the FAA AST framework?

As stated earlier, the EU has not yet exercised competence in regulating spaceplane operations, so competence can default to national authorities. As a result, the UK could:

- regulate spaceplanes under national law; and
- choose to adopt the FAA AST regulatory framework for all commercial spaceplane activities.

However, this may require changes to UK primary legislation, possibly including the adoption of the US definition of a sub-orbital spaceplane into UK law, a process that would take considerable time. Responsibility for administering the regulatory framework would have to be defined, and potentially a separate organisation, similar to the FAA AST, might need to be established. The framework would help to ensure the safety of the uninvolved general public, would have the added benefit that it would apply to all the operations within the scope of the Review (including expendable vertical launch vehicles) and could be adjusted to include the liability requirements of the UK Outer Space Act 1986.

Given that the EU may start the development of spaceplane legislation within the next few years and that such legislation is likely to be based on international aviation law and be included in the EASA Basic Regulation, we believe that the best answer for the UK is not to adopt the FAA AST framework in the long term but instead to remain in step with future EU developments.

This returns us to the short-term approach of treating spaceplanes as experimental aircraft under Annex II of the EASA Basic Regulation, allowing initial launches to take place using a wet lease type arrangement under FAA AST licences, and using special conditions attached to the ANO for the regulation of sub-orbital spaceplanes. These conditions, along with those required to gain an FAA AST launch licence, will help mitigate the risks to the uninvolved general public and, where possible, identify and mitigate the risks to spaceplane flight crew and participants. These special conditions should be based on industry best practice, from aviation regulation and from suitable space safety regulation where available. The required ANO exemptions and special conditions will need to be published before sub-orbital spaceplane operations can take place.

6	**To further develop the regulatory framework, and help mitigate the risks to the uninvolved general public and spaceplane flight crew and participants, the Government should task the CAA with the detailed assessment of risks, and development of appropriate exemptions and special conditions to the ANO for sub-orbital spaceplanes.**

As experience is gained in spaceplane operations, the exemptions and special conditions should be reviewed and adjusted as necessary. These will apply equally to any unmanned spaceplane operations.

Sub-orbital spaceplanes are not designed and built to any internationally recognised safety standards, therefore spaceplane flight crew and participants will have to be informed of the inherent risks, including to their health, and its known safety record before flight. Crew and participants will have to acknowledge receipt of this information in writing; this is known as informed consent. Informed consent does not absolve the operator from liability claims brought by spaceplane flight crew or participants or their families in the event of death or serious injury following a spaceplane accident or serious incident.

7	**The Government should adopt the principle of informed consent to permit the carriage of participants and cargo on sub-orbital spaceplanes.**

Orbital operations

Orbital operations are not expected during the initial stages of spaceplane operations from the UK. However, it is important that we consider the challenges involved as soon as possible – in particular, the fact that at the moment as many as three different regulatory frameworks may apply to them.

- Conventional carrier aircraft will be regulated under aviation law.
- The Outer Space Act will apply as the orbital vehicle will have to be registered as a 'space object' and licensed by the UK Space Agency.
- A new regulatory framework would be needed for orbital insertion and re-entry.

Currently there is no safety regulation of orbital launch systems in the UK and, if the market develops as projected, the ideal solution ultimately will be to establish a regulatory framework to address all the regulatory requirements under a single competent authority. The competent authority could be the CAA, the UK Space Agency or a new, separate organisation. However, the creation of a new organisation would probably only be justified if regular orbital launch operations were taking place.

8	**To ensure the safety of the uninvolved general public, and provide a single, clear regulatory framework for spaceplane and spaceflight operators, the Government should appoint a single competent authority for the safety regulation of all spaceflight operations.**

SECTION 6

Spaceplane airworthiness

A key contributor to safety is ensuring that, whenever a spaceplane is flown, it is 'airworthy' – in other words, it has been designed, manufactured and maintained to be fit for its intended purpose. In commercial aviation, airworthiness assurance requires that the vehicle and those working on it meet specific standards, based on the lessons learned over many years of securing airworthy operations. As spaceplane operations develop, we would aim to adopt a similar approach.

However, spaceplane operations are still in their infancy, and the standards of airworthiness for commercial aviation are not fully compatible with spaceplane technology. An alternative approach is needed: we recommend that it be based on direct systematic management of the safety of the spaceplane by those who operate it.

Airworthiness of initial spaceplane operations

To secure safe initial UK operations, we have recommended that sub-orbital spaceplanes are classified as 'experimental aircraft' regulated at a national level through suitable amendments to the UK ANO.

Such amendments would provide an approach to airworthiness aimed at securing the safety of the general public, while also providing an acceptable level of safety for spaceplane occupants.

To secure these airworthiness standards, we would propose to:

- give due recognition to safety evidence verified within the FAA AST system;
- permit suitably capable operators to include the management of spaceplane design, production and maintenance risks as an integral part of an approved safety management system; and
- provide, in due course, a spaceplane certification and continuing airworthiness system aligned to that in use for international commercial aircraft operations.

The FAA AST system

In the short term, a number of UK sub-orbital operations are likely to use spaceplanes that have been designed and manufactured in the US which, due to ITAR constraints, will operate under a wet lease type arrangement and require an FAA AST launch licence obtained via the process outlined in Section 5 of this Summary.

Given that the FAA AST licensing system includes assessments of safety standards and operating procedures, the UK should develop a methodology that gives due recognition to FAA AST verification of these assessments. This methodology will need to be based on a clear understanding of the FAA AST process and, specifically, the extent to which spaceplane flight crew, participants and the uninvolved general public are protected from an accident or serious incident occurring, as well as the mitigation of the effects of a vehicle failure or break-up.

9 **In order to obtain a better understanding of the FAA AST licensing process and the safety performance of any US sub-orbital spaceplanes that are likely to operate in the UK, the DfT should agree a Memorandum of Understanding with the FAA AST.**

10 **Work should be commissioned to develop, within the airworthiness assessment approach, a methodology for giving due recognition to FAA AST licensing system assessments.**

Safety management system approach

Given the small number of operators, constructors and spaceplanes involved in initial UK operations, and the arrangements for participation in such operations, we believe that it would be appropriate to adopt an alternative airworthiness assurance process to that employed for commercial mass transport aircraft. This would centre on a formal and systematic safety assurance approach that particularly recognises the high degree of involvement of the operator in the spaceplane design and build process.

In cases where an operator commissions a bespoke spaceplane design and remains intimately engaged throughout the design and manufacturing process of each individual unit, it would seem possible that the operator can develop the knowledge and have access to the data that are necessary to competently assess the risks to its operation. The operator should, therefore, be capable of managing such risks within a formalised safety management systems (SMS) approach, and should be afforded the opportunity to do so as an alternative path to the current commercial aviation airworthiness assurance process. This approach is considered appropriate for the airworthiness oversight and approval of spaceplanes produced in small numbers. It also reflects the fact that, from a commercial perspective, spaceplane operators will necessarily take every possible step to operate safely: put simply, it is entirely in their interests to do so.

This approach lends itself to the situation that exists, for example, between the spaceplane operator, Virgin Galactic, and its spaceplane design and production organisations, Scaled Composites and The Spaceship Company. Because Virgin Galactic's aircraft are essentially being designed and manufactured in small numbers for its sole use, a holistic SMS covering the initial and continuing airworthiness, could be established by the operator. Virgin Galactic has been working very closely with Scaled Composites and is well placed to gain access to the necessary compliance information that any regulator would normally require as part of conventional certification. It would be the responsibility of the operator to use that information to manage airworthiness and demonstrate the required level of safety to the CAA.

However, it is important to underline here that this approach would only work for US operators if they are permitted, under ITAR, to give the CAA sufficient information about their safety management systems, including spaceplane design and manufacturing and maintenance processes. This requires that ITAR controls are addressed.

11	**In the short term, spaceplanes currently under development should be regulated in the UK in accordance with an overall safety management system framework, to be specified by the CAA and managed by the operator.**

We believe that such an approach would be cost-effective, while not being overly burdensome for spaceplane operators, as it is firmly based within the current civil aviation safety system.

12	**Spaceplanes currently under development should be required (and seen to be required) to achieve the highest level of safety that is reasonably practical.**

That would mean following industry best practices, working to the current requirements as far as possible, and manufacturing and maintaining spaceplanes to a high standard. This applies to both manned and unmanned spaceplanes.

Assuring airworthiness in a maturing spaceplane industry: aligning with the commercial aircraft certification approach

Many technologies employed in spaceplane designs are used conventionally in civil aviation, such as composite structures, advanced alloys, electrically signalled aerodynamic flying controls and electronic instrument displays. However, there are some spaceplane technologies – notably rocket-based propulsion systems and reaction control systems – which, due to their current levels of reliability and failure modes, do not lend themselves to being assessed and approved according to current civil aviation regulatory practice.

The commercial aircraft certification standards for engines require, for example, that an engine failure must not directly cause the loss of the aircraft. This drives the design not only of the propulsion system in terms of reliability, containment of engine debris, etc, but also the design of the aircraft itself: its fuel systems, flight deck controls and the aerodynamic handling qualities that ensure continued controllability of the aircraft.

As the spaceplane industry matures, it should be possible to develop certification codes and technical requirements for objective airworthiness regulations. Discussions with European spaceplane manufacturers have indicated a preference for certification to be developed and EASA supports this view. Given the vast range of technologies involved, codes should be modular so that parts of the code could be selected or deselected according to their relevance to a particular project. This would offer a level of transparency but also flexibility.

13 **The UK should further engage with the EU to start the development of EU spaceplane regulations and certification. Once such regulations are mature, it is anticipated that they will replace the UK regulatory framework.**

SECTION 7

Airspace requirements

Every spaceplane that launches from the UK will fly through UK airspace – one of the busiest areas of airspace in the world. It is essential, therefore, that clear rules are in place from the outset to ensure that existing air traffic can continue to operate safely while spaceplane operations take place.

UK airspace is busy and complex: in 2013, almost 2.2 million flights and 220 million passengers transited through UK airspace.[15] The effective management of UK airspace is fundamental to allowing this much traffic to pass through safely: the CAA has a statutory duty[16] around this. Some airspace is controlled and some is uncontrolled, depending on the nature of the operation conducted within it. ICAO airspace classifications are applied and regulated by the CAA in line with EU requirements.

The main aim of Airspace Management is to achieve the most efficient use of the airspace based on actual need. As discussed earlier, the number of spaceplane operations – at least in the next few years – will be very low; however, due to the nature of the operations, to manage them safely in line with our underlying priority of minimising the risk to the uninvolved general public, they are likely to require a significant volume of airspace.

15 Official National Air Traffic Services (NATS) figures as cited in 'NATS sees increase in air traffic in 2013', news release, 17 January 2014, www.nats.aero/news/nats-sees-increase-air-traffic-2013/ (accessed 4 March 2014)

16 UK Transport Act 2000, section 70(1)

The case for segregation

Spaceplane operations will be difficult to integrate through normal Air Traffic Management means. The Rules of the Air[17] govern the flight of all aircraft in the UK;[18] these are, in the simplest sense, a highway code for the sky. They set certain standards that flight crew are expected to follow – such as being able to change trajectory to avoid other aircraft. It is clear that for some spaceplanes, once take-off or launch commences, this will not be possible as the spaceplane is committed to a planned trajectory. Recovery of non-powered spaceplanes from high altitude will also require careful integration with existing airspace activity.

While some spaceplanes may be able to comply with the Rules, there is still sufficient uncertainty about safety that it seems prudent initially to keep spaceplane launches separate from normal aviation as far as possible. There is already a standard procedure for creating areas of segregated airspace for different types of air traffic, including certain military operations and – currently – unmanned vehicles. This should be used in the short term as the basis for spaceplane operations.

14 **In the short term, spaceplane launches and recovery of unpowered vehicles should take place only within areas of segregated airspace.**

This approach is in line with that taken in the US, where extensive tracts of military segregated airspace are used for the launch and recovery of spaceplane test flights. In the US, all spaceplane and vertical launch operations to date have utilised segregated airspace; all licensed US spaceports have significant, existing, restricted military airspace within which much of the activity can occur. This limits their interaction with other air traffic.

17 Civil Aviation Authority (2010) CAP 393 Air Navigation: Rules of the Air Regulations, section 2, page 5

18 The Rules of the Air will be replaced by the Standardised European Rules of the Air, which will be adopted in the UK with effect from 4 December 2014.

How segregation can be achieved

In the UK, such segregated airspace would be far harder to achieve than in the US. We simply do not have large expanses of under-used airspace: even in the relatively less congested north of Scotland, the upper air routes can be busy with traffic transiting to and from the North Atlantic airspace. There are areas of segregated airspace, but these are currently designated for military use ('Danger Areas'). One potential option would be to work with the Ministry of Defence (MOD) to put in place an airspace-sharing agreement for the use of these Danger Areas for spaceplane launches. Clearly, this would depend on the respective levels of demand on the airspace; no formal discussions have begun around this.

Currently, none of the aerodromes that meet the criteria for initial spaceplane operations (see Section 8, Spaceports) have segregated airspace around them. To enable spaceplane operations, we would therefore need to create one or more areas of segregated airspace, perhaps to connect to an existing segregated airspace structure.

There are two fundamental options for creating segregated areas of airspace for spaceplane operations:

- The creation of a bespoke area of segregated airspace around the aerodrome selected for initial spaceplane operations. To do this, an airspace change proposal would be required, which could take up to two years to complete.
- The creation of a Temporary Danger Area for the purpose. There is an established fast-track process for this, but it is designed to be used only in extreme situations, such as those relating to national security.

While the latter approach could be used for a one-off spaceplane operation, it would not be appropriate for regular or ongoing operations. Therefore, a full airspace change proposal should be initiated as soon as possible.

15 **An airspace change proposal should be initiated as soon as an aerodrome is selected for spaceplane operations. To enable spaceplane operations to take place in the UK before 2018, this would need to happen within the next few months.**

16 **Depending on the chosen location(s) of a spaceport to support spaceplane operations, the CAA should undertake initial discussions with the MOD and NATS to scope the options for using existing military-managed segregated airspace for spaceplane operations in the medium term, with a view to ensuring the establishment of effective governance and oversight arrangements.**

Managing segregated airspace

Once a segregated area is designated, the process for the flexible use of the airspace is well established. The Airspace Management Cell UK collects and analyses all airspace requests and, in consultation with the Military Airspace Booking and Coordination Cell, develops an Airspace Use Plan, which it shares with all airspace users. This is updated on a daily basis, so requests for temporary segregation of airspace to allow spaceplane operations would be included within it. Again, this is in line with US practice, where Temporary Flight Restrictions – an equivalent of the UK's segregated Special Use Airspace – are employed to segregate the airspace on the day of operation, and promulgated in advance.

One of the key principles of airspace segregation is that airspace users should be excluded from the segregated areas for the shortest time possible – so minimising disruption. What is unclear at this stage is how much time would be needed for spaceplane launch and recovery and how flexible this needs to be. We understand that spaceflights are likely to be weather-dependent, both for technical and commercial reasons. Therefore an element of flexibility would be required. It is also uncertain how large an area should be segregated; this will depend on the type of spaceplane being used, its flight profile and any pre-planned failure modes. As a result, airspace requirements for spaceplane operations will – in the near term – be designed on a case-by-case basis.

This process will be sufficient to provide the basis for the dynamic management of airspace segregation for spaceplane operations, but a review of operational procedures will be needed to ensure that they are fit for purpose. In the short term, the impact of airspace segregation on other airspace users is likely to be small as the numbers of expected spaceplane flights will be relatively low. The level of impact on other airspace users will increase as spaceplane technology matures and flight volumes increase.

17	**Airspace Management notification procedures should be reviewed in full at a time appropriate to the development of the initial anticipated spaceplane operations from the UK.**

SECTION 8

Spaceports

As our analysis of the opportunity for the UK makes clear, the pivotal factor in realising many of the economic and scientific benefits associated with spaceplane operations is the availability of a UK launch site: a spaceport. This section sets out the factors involved in deciding where a UK spaceport could be located, and provides a list of locations from which commercial space operations could feasibly take place in the short term.

Identifying suitable locations for a spaceport is a complex balancing act. There are:

- **essential operating criteria:** based on available information about current spaceplane designs, a spaceport will need to be a large site and have a runway that is at least 3,000 metres (9,800 feet) long. For single-stage to orbit operations, such as SKYLON, a substantially longer runway will be required – potentially of around 5,000 metres (16,500 feet);
- **safety factors:** given our underlying priority of protecting the uninvolved general public, and the level of risk involved in spaceplane operations, the ideal location will be away from densely populated areas. It will also need the protection of segregated airspace;
- **meteorological considerations:** we know that strong crosswinds are likely to restrict initial spaceplane operations and that spaceplanes are likely to need to operate clear of cloud. There are also commercial issues involved here: being able to see the Earth from space is a key attraction of spaceflight experience, so if cloud cover restricts that, the experience may not live up to expectations;
- **environmental concerns:** there is a range of legislation for noise, air quality and use of hazardous materials that apply to aerodromes. These need to be considered with regard to the suitability of a site for spaceplane operations; and

- **economic issues:** a spaceport will need good transport links. Visitors (including spaceflight experience participants) must be able to get there with relative ease, but so must staff. Component parts may need to be brought to the site by sea. This must be balanced, therefore, with the safety requirement to have a remote location.

These factors would apply to the selection of suitable locations for a spaceport in any situation. However, there is a further critical factor in our work: the desire to enable sub-orbital spaceplane operations to commence before 2018. To meet this demand, it is likely that an interim spaceport solution would need to be found: we would not expect to be able to build a new aerodrome in such a timescale as, even if construction could be accelerated, the planning and approval process necessarily takes a long time. Therefore, we believe that a purpose-built spaceport is not a realistic option in the short term.

18 **Sub-orbital operations should commence, either on a permanent or a temporary basis, from one (or more) of the following:**

- **an existing EASA-certificated aerodrome;**
- **an existing UK CAA-licensed aerodrome; and/or**
- **an existing UK military aerodrome, subject to approval from the MOD.**

19 **In order to make maximum use of existing infrastructure, the location should still be active but at a low level of aircraft movements. It should have existing and appropriate ground infrastructure/facilities and Air Traffic Control.**

Feasible sites in the UK

We have reviewed all civil and military aerodromes within the UK to identify those that meet these fundamental criteria of runway length, local airspace complexity and population density. Firstly, we looked for aerodromes that already have a runway of sufficient length for spaceplane operations, or where the runway could be extended. There are 46 of these. Some, however, are not currently operational and were ruled out.

We then looked at the civilian aerodromes and their aircraft movement rates which ruled out many of the 46; for example, the two UK aerodromes with the longest runways are Heathrow and Gatwick. Segregating airspace and spaceplane operations on the ground at these and a number of other civil aerodromes would be wholly impractical.

Our analysis left 26 potential sites where the runway is long enough, or could be extended, and where airspace could potentially be segregated to allow spaceplane operations. Of the 26, several are in or near to areas of relatively high population. Eighteen are military aerodromes, hence could only be used with the agreement of the MOD: although the MOD has been observing the Review, and has indicated that it is supportive of the initiative, no formal agreement has yet been sought for the use of military aerodromes for spaceplane operations, and how they might be integrated with the military operations. Significant further study would be required, based on assumptions about spaceplane operations, to assess the viability of using a currently active military base while minimising any impact on its operations. This further study may result in some military aerodromes being removed from the list.

20	**To allow sub-orbital operations in the near future, possible locations should be selected from the identified list and further investigations carried out as to their viability. Government will need to agree a process for how sites would be selected.**

As set out earlier, it is anticipated that initial spaceplane operations in the UK may take place under a wet lease type arrangement. This means that the FAA AST will require operators to meet certain safety criteria, and in particular carry out an expected casualty analysis. The result of this analysis needs to demonstrate that operations are safer than the minimum standards stated by the FAA AST; to date, this has resulted in the FAA AST licensing operations only in areas of very low population density such as desert or coastal locations. This would imply that an initial UK spaceport would best be established at a coastal location.

21	**In order to ensure the safety of the uninvolved general public and to enable initial operations under a wet lease type arrangement to take place in line with FAA AST launch site licensing requirements, the Review strongly recommends that a UK spaceport should be established at a coastal location.**

This initial assumption again reduces the list of potential sites from which sub-orbital operations could occur to eight, as can be seen on the map in figure 11 below.

Of these eight:

- one, Campbeltown Airport, has a runway potentially over 3,000 metres long;
- four – Glasgow Prestwick Airport, Newquay Cornwall, RAF Leuchars and RAF Lossiemouth – have a runway between 2,500 metres and 3,000 metres long, so would require a runway extension to allow spaceplane operations; and
- the other three, indicated by triangles, have a runway between 2,200 metres and 2,500 metres long. Each would, therefore, need a significant runway extension that would considerable investment. One of these, Llanbedr, is unlicensed at the time of writing, so – if recommendation 17 above was followed – it would also need to reapply for a CAA licence or EASA certification, so that appropriate aerodrome safety regulation could be provided.

Runway extension and aerodrome expansion would need to be carried out through the normal development and planning procedures and according to the timescales related to those procedures. Consideration will also have to be given to the indirect costs of disruption to normal operations during any runway extension engineering works, which could take several months to complete.

In the future, with a better understanding of sub-orbital spaceplane safety performance and the possibility of the developments of suitable certification codes, it may be possible to relax this coastal location requirement.

However, a coastal location also helps to meet some of the environmental issues discussed below. It should be noted that whilst possible locations have been identified, no detailed discussions have taken place with existing civil or military aerodrome or site operators to ascertain their appetite for sub-orbital operations.

Figure 11: Locations of UK coastal civil and military aerodromes that could potentially host sub-orbital operations

Meteorological factors

Having identified sites that meet the key criteria around runway length and airspace complexity, the selection of the right location for a UK spaceport will involve a more detailed review of the meteorological factors. Key issues include hours of sunshine (as an indicator of cloud cover), wind speed and rainfall.

There will be different requirements in the acceptable meteorological criteria for each commercial space operation and their respective spaceplanes. These criteria will differ with respect to cloud cover, wind speed, precipitation and temperatures.

Early indicators, which need to be confirmed, suggest that initial spaceplane operations will have limiting crosswind requirements. Runway orientation will be an important factor: a runway oriented into the prevailing wind (typically from the south west in the UK) will allow more opportunities to operate. In addition to low-level wind speeds, upper-air wind speeds are important when planning the flight profile.

Given that the first entrants to the sub-orbital market are expecting to offer the 'view from space' as an integral element of the spaceflight experience, they will also require weather conditions appropriate to providing that view. Sub-orbital flights with a scientific payload may have less restrictive weather criteria.

In general, for sub-orbital flights that are limited by cloud cover and wind speeds, locations in Scotland are likely to offer fewer hours of potential flight operations than locations further south in the UK. This is because, generally, hours of sunshine are fewer (cloud cover is greater), rainfall is higher and wind speeds are greater. The more challenging meteorological environment in these locations is, therefore, very likely to impact on the economic potential and viability of operations in these locations. Once sub-orbital spaceplane operators have confirmed their meteorological operating criteria, further in-depth investigation of these eight aerodromes can take place: the meteorological requirements for spaceplane operations may reduce the number of potential sites further.

Vertical launch sites

The greatest potential economic returns for a UK spaceport would come from a location that could support both horizontal launches (ie spaceplanes taking off from a runway) and vertical launches, which would allow satellites to be inserted into polar orbit. However, there are additional criteria that affect vertical launch sites – for operational, safety and environmental reasons. A number of reviews have identified that the only suitable location in the UK for vertical launch is on the north coast of Scotland. This would require a new vertical launch spaceport to be built – so would not meet our goal of enabling spaceplane operations in the short term.

22	**A separate vertical launch site should be identified, which due to the restricted operational criteria for vertical launch to orbit, should be on the north coast of Scotland.**

Spaceport regulation and safe operations

Given that the earliest sub-orbital operations in the UK are likely to take place from an existing aviation facility, it may not be necessary to define or designate this facility as a spaceport but rather as an aerodrome at which sub-orbital operations can take place. This will mean it is covered by existing safety management requirements for aerodromes, derived from ICAO, EASA and the CAA. These requirements are well developed and are central to the excellent safety record of UK aerodromes.

Any additional commercial spaceflight activity can be viewed as an 'add-on' to routine aerodrome operations with a specific 'safety case' for that activity. The basic framework of the EASA certification or CAA licensing regime should be used, together with an additional process for sub-orbital operations, as this will need to be a unique and bespoke procedure related to the specific location. Further detailed analysis of the health and safety risks will be needed as part of the investigation into potential sites; this will be conducted by the Health and Safety Executive, with which the CAA already has established working arrangements.

Whichever region and specific location is chosen, the underlying safety requirement will be protecting the uninvolved general public through setting clear ground blast zones, the segregation of airspace, meeting any drop zone requirements and mitigating down-range abnormal occurrences. Full contingency plans involving local health and emergency services would need to be put in place to deal with major incidents, but this is comparable with major commercial operations at a licensed aerodrome.

23 **Local authorities should establish contingency plans for major incidents in advance of the commencement of spaceplane operations from a spaceport.**

Environmental regulation

International aviation environmental regulation exists for aircraft, aerodromes and airspace, covering issues such as noise, air quality (including carbon emissions) and the storage of hazardous materials. Accepting that in the UK spaceplanes will be considered as aircraft, aviation environmental regulations will also apply to spaceplane operations.

Given the initial low volume of flights expected, and the fact that they will be sub-orbital, spaceplanes should be able to operate from existing aerodromes within the environmental standards expected. Optimised flight procedures and flight paths should be used to effectively mitigate the noise impacts associated with the carrier aircraft, while operations for rocket-powered spaceplanes will need to be restricted in terms of time of day and total number of flights.

Even with these restrictions, environmental issues around spaceplanes will be of significant public concern – in terms not only of noise, but also air quality and the impact on the local area. To address these concerns, a full environmental impact assessment should be undertaken for each spaceplane type at each launch location. This is in line with FAA AST requirements, and would ensure that all appropriate mitigation can be put in place. Because environmental impact assessments can take some time to complete, it is important that any such assessment begins immediately an operator confirms its intention to launch from a given site.

24 **A full environmental impact assessment should be undertaken for each spaceplane type at each launch location.**

SECTION 9

Flight crew licensing

Clearly, any commercial space operations will require fully trained pilots – including trained remote pilots for unmanned operations. However, with no existing commercial standards for spaceplane pilot training, we need to establish the most effective ways to achieve our short and longer-term goals.

To date, most astronauts and cosmonauts have been selected from military aircrew – hence they are already highly trained and physically fit. They have undergone specific training for their mission and role, giving them in-depth knowledge of their spacecraft. Though full details of such training are difficult to obtain, it is clear that it has been a lengthy process, taking up to four years from selection through to onboard training.

Given the goal of enabling spaceplane operations to commence by 2018 or earlier and the fact that no UK spaceflight training programme currently exists, it is at best unlikely that any UK-trained spaceplane pilots would be available for these initial operations.

A short-term solution: validating FAA AST processes

In the immediate term, this is not a problem. It is highly likely that initial operations will take place under a wet lease type arrangement: the spaceplane and its crew will be from the US and will have to meet FAA AST requirements. One of these, CFR (Code of Federal Regulations) 460, places a responsibility on operators to ensure that all members of the flight crew:

- have appropriate experience;
- are appropriately trained for their craft; and
- have demonstrated an ability to withstand the stresses of spaceflight, which may include high acceleration and deceleration, microgravity, and vibration, and any abort or emergency procedures in sufficient condition to safely carry out their duties so that the vehicle will not harm the public.

The simplest way forward to allow these initial operations would be to validate the FAA AST process. The validation could be in accordance with Annex III to the Aircrew Regulation, which requires the pilot to hold a valid ICAO-compliant licence and suitable medical certification and to have successfully completed a skill test on the appropriate aircraft or in a synthetic training device.

25 **To allow spaceplane operations in the short term, the Government should agree to the CAA validating the FAA AST process around flight crew licensing.**

Longer term: building a UK licensing model

A short-term validation of FAA AST crew licensing offers an interim solution; however, if the UK is to become a lead player in the space sector, we will need our own cadre of spaceplane flight crew, and our own training and qualification systems. The foundations for these are likely to be established flight crew training programmes and qualifications, but additional elements will be needed.

This is exactly the process that has begun in the US, where a number of training organisations have built on their conventional flight training programmes to offer training in the additional skills necessary to maintain safety of the vehicle and the participants during spaceflight. These programmes have been approved by the FAA AST.

The UK should follow a similar pattern, using established flight crew training programmes and encouraging commercial organisations to construct training programmes for flight crew of spaceplanes, while establishing performance-based rules and regulations for such operations. The exact requirements of this additional training will need to be established.

26 **As soon as possible, the competent authority for spaceplane and spaceflight regulation should work with the FAA AST and EASA to develop standards and levels of competence for sub-orbital and orbital spaceflight crew, as well as for instructors and examiners. These should be followed by suitable training and guidance materials.**

The UK has a mature and sophisticated flight training industry, which is also equipped to cope with change and new requirements: for example, it is currently adapting to the new EU Aircrew Regulation. This transition is having a profound effect on the courses available and technology being used to train student pilots.

Licensing for pilots of unmanned aircraft

Several of the current industry proposals are for unmanned spaceplanes. As the 'piloting' function is essentially the same for both manned and unmanned aviation – 'managing' an aircraft's flight through the air in line with airspace rules – there is clearly a need for equivalence with regard to any interactions with manned aviation. This does not mean that all of the traditional pilot skills will be required in an unmanned aircraft; however, a remote pilot of an unmanned spaceplane will still be expected to possess the equivalent aviation skills needed to manage the flight safely, including the appropriate reactions to system failures or emergencies.

In general, therefore, the overall requirements (knowledge of flight procedures, airspace, Air Traffic Control procedures, aircraft 'captaincy', etc) will be the same for an unmanned spaceplane as they are for a manned one. Added to this, there will be the requirement for knowledge of any 'unmanned aircraft specific' subjects (such as the ability to manage a C2 communications link).

The current intention internationally is that a new licence will be developed, known as the Remote Pilot's Licence, which will act as the unmanned aircraft equivalent to the current pilot licensing regimes.

SECTION 10

Flight crew and participant medical requirements

Aviation and space medicine expertise is essential for all aspects of human spaceflight participation – not only for the assessment of medical fitness of crew and participants. In fact, some of the most important roles of space medicine experts will be in the operational aspects, including involvement in design of the spaceplane to incorporate life support systems.

Flight crew

The fitness and performance of commercial flight crew clearly has to be assured. The process for this is relatively straightforward: flight crew would need to be assessed against agreed standards.

In the short term, it is likely that the majority of spaceplane pilots will have experience either as astronauts or as pilots in military service. Medical selection requirements for both are stringent; furthermore, astronaut fitness standards are set by international consensus. In conjunction with current aviation medical requirements, these can form the basis for medical standards for spaceplane crew.

27	**The Government should ensure that medical requirements for spaceplane crew are developed at least a year before spaceplane operations commence in the UK, by international experts experienced in both aviation and space medicine, and that aeromedical examiners are trained to undertake the required medical assessments.**

The UK has an established network of aeromedical examiners and aeromedical centres. With minimal additional training (possibly a one-week training course), these practitioners could undertake medical assessments of spaceplane flight crew.

Initially, it may be appropriate to assess each pilot pre-flight. Our knowledge of space medicine is still relatively small; in particular, there has been no experience of frequent sub-orbital missions, so it remains to be determined whether these have any unforeseen effect on pilot health or performance. Therefore, crew health should be monitored on a regular basis, to ensure that any effects of frequent exposure to this new environment are detected early.

Preparing for the effects of high G flight

Drawing on the experience of the UK military in training fast jet pilots, one essential element will be ensuring that spaceplane flight crew – and potentially participants – are prepared for the effects of high acceleration and deceleration forces (high G).

28 **All flight crew must be suitably trained in the effects of high acceleration and deceleration forces.**

The effects of high G can impair even highly trained fast jet pilots. The only ground-based training for high G in the UK is a long-arm centrifuge located at Farnborough, which is used mainly by the military.

Given the goal of building a UK spaceplane operation capability, we believe it is important that appropriate training facilities are in place and recommend, therefore, that a modern long-arm centrifuge facility be established in the UK. These same facilities could also be used on a commercial basis to provide spaceflight participants with experience of high G flight. It would be up to individual spaceplane operators, and potentially even individual participants, whether to make this a pre-spaceflight requirement.

29 **The Government should explore with industry how sufficient and appropriate facilities can be made available to support the pre-spaceflight training of spaceplane flight crew in the long term – and in particular ensure that a modern long-arm centrifuge is available and accessible in the UK.**

Medical assessments for participants

Space travel to date has been restricted to highly trained, physically fit astronauts and cosmonauts. Unscreened individuals with chronic medical conditions, or conditions that could deteriorate rapidly, have not yet travelled into space, so potential problems or adverse effects are currently largely theoretical.

However, it is clear that spaceplane flights will expose both participants and flight crew to hazards at levels not usually encountered in commercial air transport, such as reduced ambient pressure, a reduced oxygen level, high G, microgravity, high noise levels, increased radiation exposure, vibration and thermal extremes. Operators will want to consider the potential effect of these on each individual; risks to participant health need to be considered in advance of flight, with mitigations put in place where appropriate. The availability of back-up life support systems and equipment, and training in their use and in emergency procedures will be essential.

There is no UK or European regulation governing medical requirements for passengers in commercial air operations, but most individual operators have a medical advisory service for passengers with medical conditions and will determine whether they consider these passengers fit to travel. Spaceplane operators are likely to take a similar approach for their paying participants.

Overall, operators are likely to rely on participants giving specific, written, informed consent to their carriage on board a spaceplane and accepting the inherent risks. This is the intended practice in the US and is a reasonable approach for the carriage of participants on UK spaceplanes.

There are therefore important opportunities for aviation and space medicine knowledge to be applied in the design stage of spaceplane development. In particular the design of life support systems, both built in and 'carry on', is crucial for the safety of any manned operation. Other aspects, for example impact protection, seat design and crash resistance, will need to be considered. The UK has considerable knowledge and expertise in the design, development and testing of aviation systems, particularly life support systems and equipment. This could provide a valuable asset in spaceplane development and be one of the spillover commercial benefits of spaceplane operations in the UK.

Learning from the first flights

The more spaceplane flights that are made, the more we will learn about the medical effects of spaceplane travel. Guidelines can then be reviewed and, where necessary, amended. It will be important to ensure that there is collaboration among the medical advisers to the different companies involved so that there can be mutual exchange of medical findings. The information gathered can then also be used to develop appropriate guidelines for other types of spaceplane travel, such as intercontinental flights. It can also be used to help build our overall knowledge of space medicine.

30 **The competent authority should ensure that medical assessment guidelines are reviewed once information has been gained from operational experience.**

Recommendations at a glance

1. The UK Government should enter into early discussions with the US Government and the US sub-orbital industry to obtain appropriate export licences to commence operations in the UK.

2. To enable spaceplane operations to start from the UK in the short term, we recommend that sub-orbital spaceplanes are classified as 'experimental aircraft' and treated as Annex II aircraft under the EASA Basic Regulation. This will allow regulation of sub-orbital spaceplanes to be managed at a national level.

3. To allow the carriage of paying participants and cargo on sub-orbital spaceplanes while they are classified as experimental aircraft, the CAA should use its powers granted under the Civil Aviation Act 1982 to issue exemptions and attach special conditions to the articles of the ANO.

4. In order to allow spaceplane operations from the UK by 2018 or earlier, the Government must accept that spaceplane operations carry a higher degree of risk than most normal aviation activities and that protecting the uninvolved general public should be its highest safety priority.

5. In order for sub-orbital spaceplane operations to take place from the UK by 2018 or earlier, a permissive regulatory framework needs to be established and be functioning at least one year in advance of planned operations.

6. To further develop the regulatory framework, and help mitigate the risks to the uninvolved general public and spaceplane flight crew and participants, the Government should task the CAA with the detailed assessment of risks, and development of appropriate exemptions and special conditions to the ANO for sub-orbital spaceplanes.

7. The Government should adopt the principle of informed consent to permit the carriage of participants and cargo on sub-orbital spaceplanes.

8. To ensure the safety of the uninvolved general public, and provide a single, clear regulatory framework for spaceplane and spaceflight operators, the Government should appoint a single competent authority for the safety regulation of all spaceflight operations.

9. In order to obtain a better understanding of the FAA AST licensing process and the safety performance of any US sub-orbital spaceplanes that are likely to operate in the UK, the DfT should agree a Memorandum of Understanding with the FAA AST.

10. Work should be commissioned to develop, within the airworthiness assessment approach, a methodology for giving due recognition to FAA AST licensing system assessments.

11. In the short term, spaceplanes currently under development should be regulated in the UK in accordance with an overall safety management system framework, to be specified by the CAA and managed by the operator.

12. Spaceplanes currently under development should be required (and seen to be required) to achieve the highest level of safety that is reasonably practical.

13. The UK should further engage with the European Commission and EASA to start the development of pan-European spaceplane regulations and certification. Once such regulations are mature, it is anticipated that they will replace the UK regulatory framework.

14. In the short term, spaceplane launches and recovery of unpowered vehicles should take place only within areas of segregated airspace.

15. An airspace change proposal should be initiated as soon as an aerodrome is selected for spaceplane operations. To enable spaceplane operations to take place from the UK before 2018, this would need to happen within the next few months.

16. Depending on the chosen location(s) for spaceplane operations of a spaceport, the CAA should undertake initial discussions with the MOD and National Air Traffic Services (NATS) to scope the options for using existing military-managed segregated airspace for spaceplane operations in the medium term, with a view to ensuring the establishment of effective governance and oversight arrangements.

17. Airspace Management notification procedures should be reviewed in full at a time appropriate to the development of the initial anticipated spaceplane operations from the UK.

18. Sub-orbital operations should commence, either on a permanent or a temporary basis, from one (or more) of the following:

    - an existing EASA-certificated aerodrome;
    - an existing UK CAA-licensed aerodrome; and/or
    - an existing UK military aerodrome, subject to approval from the MOD.

19. In order to make maximum use of existing infrastructure, the location should still be active but at a low level of aircraft movements. It should have existing and appropriate ground infrastructure/facilities and Air Traffic Control.

20. To allow sub-orbital operations in the near future, possible locations should be selected from the identified list and further investigations carried out as to their viability. Government will need to agree a process for how sites would be selected.

21. In order to ensure the safety of the uninvolved general public and to enable initial operations under a wet lease type arrangement to take place in line with FAA AST launch site licensing requirements, the Review strongly recommends that a UK spaceport should be established at a coastal location.

22. A separate vertical launch site should be identified, which due to the restricted operational criteria for vertical launch to orbit, should be on the north coast of Scotland.

23. Local authorities should establish contingency plans for major incidents in advance of the commencement of spaceplane operations from a spaceport.

24. A full environmental impact assessment should be undertaken for each spaceplane type at each launch location.

25. To allow spaceplane operations in the short term, the Government should agree to the CAA validating the FAA AST process around flight crew licensing.

26. As soon as possible, the competent authority for spaceplane and spaceflight regulation should work with the FAA AST and EASA to develop standards and levels of competence for sub-orbital and orbital spaceflight crew, as well as for instructors and examiners. These should be followed by suitable training and guidance materials.

27. The Government should ensure that medical requirements for spaceplane crew are developed at least a year before spaceplane operations commence in the UK, by international experts experienced in both aviation and space medicine, and that aeromedical examiners are trained to undertake the required medical assessments.

28. All flight crew must be suitably trained in the effects of high acceleration and deceleration forces.

29. The Government should explore with industry how sufficient and appropriate facilities can be made available to support the pre-spaceflight training of spaceplane flight crew in the long term – and in particular ensure that a modern long-arm centrifuge is available and accessible in the UK.

30. The competent authority should ensure that medical assessment guidelines are reviewed once information has been gained from operational experience.

Glossary

Aerodrome	A defined area intended to be used either wholly or in part for aircraft to take off from or land at. Used in preference to airport or airfield, etc, as these latter terms are associated with having met certain regulatory requirements.
Air Navigation Order (ANO)	Overarching regulation for air navigation in the UK, in line with the Chicago Convention on International Civil Aviation.
Civil Aviation Authority (CAA)	The UK's specialist aviation regulator.
Competent authority	Any person or organisation that has the legally delegated or invested authority, capacity or power to perform a designated function. For example, the CAA is the competent authority in the UK for aviation regulation.
Danger Area	An area of segregated airspace within which activities that are potentially dangerous to the flight of aircraft may take place, at specified times.
European Aviation Safety Agency (EASA)	An EU agency, which regulates civil aviation across Europe – supporting a single European market in the aviation industry.
Experimental	Under Annex II of the EASA Basic Regulation, some categories of aircraft are excluded and remain subject to national regulation. These include 'aircraft specifically designed or modified for research, experimental or scientific purposes'. To allow initial spaceplane operations to be regulated at the national level, we have recommended that spaceplanes are classified initially as experimental aircraft.
FAA AST	The US Federal Aviation Administration Office of Commercial Space Transportation – the organisation responsible for regulating commercial space launches in the US.
High Earth Orbit (HEO)	An orbital path around the Earth that takes place entirely above 35,786 kilometres.

Horizontal launch	Taking off from a runway like an aircraft.
Informed consent	Before taking part in a spaceflight, spaceplane flight crew and participants will have to be informed of the inherent risks, including to their health, and of the spaceplane's known safety record. They will then sign to say they have received this information in writing; this is known as giving informed consent.
International Civil Aviation Organization (ICAO)	A UN specialised agency, which works with all signatory states to the Chicago Convention and global industry and aviation organisations to develop international Standards and Recommended Practices for aviation.
ITAR	US International Traffic in Arms Regulations, designed to restrict the sharing of any information and material concerning items on the US Munitions List with anyone outside the US.
Launch licence	The FAA AST issues licences and permits for commercial launches of orbital rockets and sub-orbital rockets. Licences are granted based on acceptance of a detailed written application.
Low Earth Orbit (LEO)	An orbital path around the Earth at an altitude between 160 kilometres and 2,000 kilometres. Most remote sensing satellites and many weather satellites are in LEO.
Microsatellite	A satellite weighing between 10 kilograms and 100 kilograms.
Nanosatellite	A satellite weighing between 1 kilogram and 10 kilograms.
Orbital	An orbit is the curved path of an object around a point in space – such as a planet. An orbital flight around Earth would therefore complete a full path around Earth.
Participant	In this Review, a participant is anyone other than flight crew who participates in spaceflight. This could be a paying participant.
Spaceplane	A winged vehicle that acts as an aircraft while in the atmosphere and as a spacecraft while in space.
Spaceport	A launch site for space operations.
Sub-orbital	A sub-orbital spaceflight reaches space, but does not complete an 'orbit' of the Earth.

Unmanned An aircraft, or spaceplane, that has no onboard flight crew and is remotely piloted from another location.

Vertical launch Taking off from a vertical launch pad, like a space rocket.

Wet lease In aviation, an arrangement in which an operator leases an aircraft together with its flight crew and its maintenance staff to another operator. Within this Review, wet lease type arrangement refers specifically to an arrangement which would allow a US spaceplane operator to conduct operations from the UK (or any other country outside the US); the spaceplane would have to be wholly crewed and maintained by the operator's staff. This would ensure that the operation was in compliance with ITAR. This cannot be a true wet lease because wet leasing can only be conducted if the aircraft system has an Air Operator's Certificate, and initial spaceplane operations are not expected to have an AOC.