

UK Government review of commercial spaceplane certification and operations

Summary and conclusions

July 2014

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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

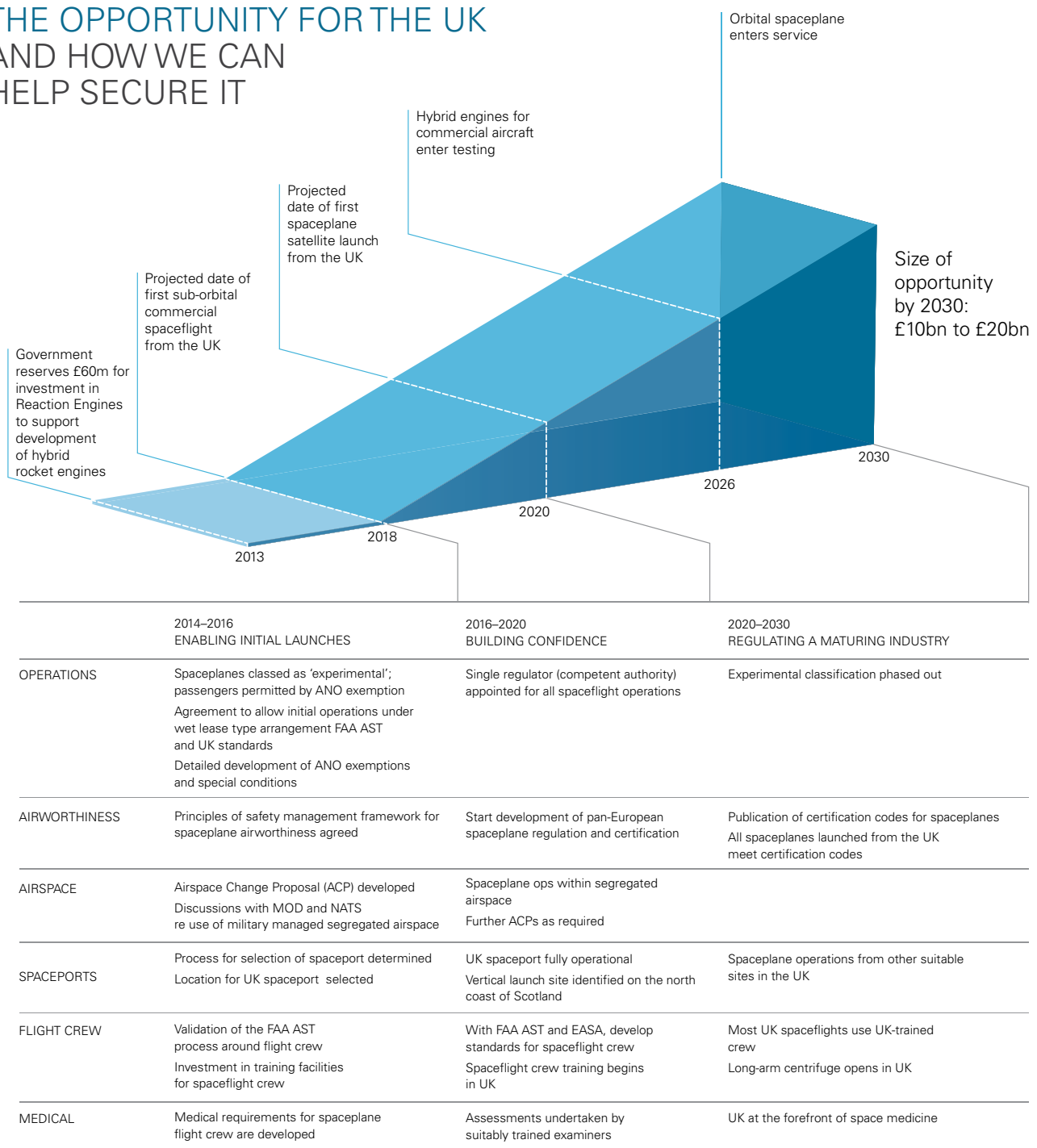


Figure 1: The value of spaceplanes to the UK and how we can help secure it

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 Strategy³ 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.

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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).

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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 website⁵, 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 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 2014⁶ 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 each⁷.

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)