12 Spaceplanes, Space Tourism and Private Space Habitats

Introduction

Spaceplanes carrying celebrities, sports figures, movie stars and royalty will soon be the rage for the next few years – barring a serious accident. Sir Richard Branson has done well to book not only millionaires but media idols to promote his space adventures business known as Virgin Galactic. His VSS Unity spaceplane is now set to carry would-be citizen astronauts up 120 kilometers into space. Jeff Bezos, with his increasingly successful Blue Origin suborbital flights will apparently soon follow suit. In what is not always friendly rivalry with Musk and Branson, Bezos's company will also be booking big names to capture headlines and promote his suborbital launch service as well.

At the start, both Branson's and Bezos's companies will provide customers with about four minutes of weightlessness and a chance to see the big blue marble we call Earth in the dark sky of outer space during a several-hours-long flight.

Robert Bigelow, whose fortune is based on the Budget Suites hotel chain, heads Bigelow Aerospace, and his goal is commercial space habitats. His innovative company is pursuing the operation of inflatable space habitats for those willing to pay for a true trip to space and a longer stay. The key question is whether the space tourism business, which now finally seems to be on the point of blossoming into paying services, represents an economic bonanza or simply headline hype?

Space tourism services are perhaps just a small part of the overall Space 2.0 enterprise, but nevertheless they can play a key role. That role is to keep NewSpace companies in the news and firing the imagination of a global public that has perhaps grown weary of space agency accomplishments that seem to come at tremendous expense.

As we have seen in earlier chapters, the space industry is currently closing in on becoming a $400-billion enterprise and seems headed toward becoming a trillion-dollar business in the decade ahead. But it is things like Elon Musk's boldness in launching his Tesla into orbit, or Richard Branson launching A-list celebs into orbit, that captures newspaper ink or global television news. The truth is

J. N. Pelton, *Space 2.0*, Astronautical Engineering,
https://doi.org/10.1007/978-3-030-15281-9_12

that actual space tourism businesses, according to detailed market studies, are not expected be a large percentage of the Space 2.0 total market. The leaders of the space tourism industry themselves are changing their business models to capture additional revenue streams.

Certainly Richard Branson and Virgin Galactic have altered their business plans to develop a small satellite launcher, called Launcher One. This vehicle is clearly designed to augment revenues. The contract to use Launcher One for several dozen OneWeb satellites now represents a significant portion of the projected future revenues of Virgin Galactic.

Robert Bigelow, of Bigelow Aerospace, has indicated that his space habitats will also be available for low-g experiments. Jeff Bezos's Blue Origin is intent on developing full launch capacity to provide commercial launch services that go well beyond space tourism services. Swiss Space Systems (S-3), now bankrupt, was developing a spaceplane capability, but also announced detailed plans about how it intended to use its spaceplane not only for suborbital flights but also as an intermediate lift stage that would allow a final stage launcher to lift small satellites to orbit. Indeed Virgin Galactic has implemented a similar strategy by developing its Launcher One small satellite launcher to supplement revenues from its suborbital flights for its space adventures.

This chapter thus not only explores the development of the space tourism industry to date, but also examines where new space enterprises in this sector of the Space 2.0 industry is now headed. Are these various efforts to develop spaceplanes and private space habitats aimed well beyond just the space tourism market? Are they spearheading a number of new ventures that ultimately will open up major new markets? Do these new markets include such new enterprises as hypersonic transportation systems and other space transport systems? Are carrier vehicles and spaceplanes just the first step towards innovative new ways to launch spacecraft into orbit? Is Sierra Nevada's Dreamchaser spaceplane just as key to the future as Branson's SpaceShipTwo? And finally, has the importance of Bigelow Aerospace Genesis 1 and 2 in orbit more to do with new and more cost-effective ways to carry out micro-gravity experimentation than to do with space tourism?

The answers to these questions are still far from clear. It may turn out in the strange and wonderful world of Space 2.0 that the final answer might be all of above. The interesting thing is that some very clever space entrepreneurs are keeping as many options open as possible. Space billionaires Elon Musk, Richard Branson, Jeff Bezos, Robert Bigelow, Paul Allen and others are doing more than developing a future path to more exciting and cost-effective space tourism. No, they are about much more. They are truly opening the door to a wide range of new Space 2.0 business opportunities as well.

The XPRIZE and Efforts to Build Spaceplanes to Carry Citizen-Astronauts into Space

The person who was one of the first to recognize the serious potential of what we now call NewSpace or Space 2.0 was the author's friend and colleague Peter Diamandis. When we worked to set up the International Space University (ISU) in the mid-1980s, some 30 years ago, it was Peter who conceived of the iconic poster that showed a university in space. This remarkable artwork fired the imagination of the first hundred students to attend the sessions at MIT. It was Peter who conceived of the $10 million XPRIZE to fuel the competition to create the world's first privately funded development of a spaceplane.

At the time the set objectives seemed impossible to achieve. The goal was for a pilot and crew member to fly a spaceplane up above 100 km and then descend to land safely. Then, they had to do it all over again within an 8-day period.

It was a challenging feat indeed. The objective at the time seemed to be so unlikely at the time that an insurance company provided the Ansari family a $10-million policy against this happening. It turns out that the Ansari family, who underwrote the prize in this manner for a $1 million outlay, were shrewder than the hapless insurance company. The insurers had to pay out when Microsoft co-founder Paul Allen and aerospace designer Burt Rutan designed SpaceShipOne and the carrier plane White Knight that twice achieved this incredible feat. When pilot Mike Melvill successfully landed in the Mojave Desert for the second time on October 4, 2004, an impromptu sign was hoisted aloft that read: "SpaceShipOne-Government Zero." [1] This bold initiative that combined the wealth and moxie of computer entrepreneur Paul Allen and the unconventional aerospace design of Burt Rutan signaled a new day in the commercial space industry.

The NewSpace initiatives that followed frequently combined the inventive genius of Silicon Valley and the thinking of traditional aerospace industries. The next major initiative of Peter Diamandis is indicative of the new Silicon Valley focus that is seen over and over again in Space 2.0 enterprises. Peter worked with A. I. guru Ray Kurzweil, who gave us SIRI, and Pete Worden, then director of NASA Ames and now head of the amazing Breakthrough Starshot initiative, to start the Singularity University. This counterpart to the International Space University is seeking to train young entrepreneurs to start new ventures – often Space 2.0 start-ups – to make a positive impact on the lives of over a million people. The SU venture in Mountain View, California, on the grounds of NASA Ames and in the heart of Silicon Valley, is striving to bring new thought and innovation to the world by training young entrepreneurs from all over.

New Models of How to Get to Space

Based on the successful test flights of the SpaceShipTwo VSS Unity spaceplane in July 2018, it is expected that actual commercial flights to bring the first 500 citizen-astronauts on suborbital flights to outer space will be the featured Space 2.0 accomplishment of the next few years (Fig. 12.1) [2].

As of July 2018, the Virgin Spaceplane System (VSS) Unity had flown for the first time successfully into the stratosphere. This successful test and fault free landing at the Mojave Desert spaceport facilities was yet another indication of a successful recovery from the disastrous Halloween crash of the

Fig. 12.1 Landing of SpaceShipOne, which that claimed the $10 million Ansari XPRIZE. (Graphic courtesy of Virgin Galactic.)

Fig. 12.2 Free flight of the VSS Unity spaceplane into the stratosphere after separation from carrier plane Eve. (Graphic courtesy of Virgin Galactic.)

earlier version of SpaceShipTwo that occurred in October 2014 [3].

Currently there are still some 640 would-be citizen-astronauts who have signed up at either $200,000 or $250,000 for a short ride into space on SpaceShipTwo. And Jeff Bezos's test of his vehicle with its vertical takeoff and capsule landing design is not far behind (Fig. 12.2).

SpaceShipTwo takes off horizontally while hoisted on a carrier aircraft and also lands like a conventional aircraft on a runway. Jeff Bezos's Blue Origin Company is very much taking the opposite approach to carry citizen-astronauts into space. His New Shepard vehicle takes off vertically from a launch gantry and then the passengers and crew come back floating down inside of a capsule

Fig. 12.3 The New Shepard vehicle with return capsule during a July 2018 test flight. (Graphic courtesy of Blue Origin.)

Table 12.1 Comparison of energy required for different types of vehicles.

Comparing airplanes, jets, and spaceplanes to rockets to orbit				
Comparison	**Airplane**	**Jet**	**Spaceplane**	**Rocket to LEO orbit**
Velocity (m/s)	**250**	**500**	**1600**	**7800**
Height (km)	**Up to 10**	**Up to 20**	**Up to 120**	**200+**
Specific energy (Joules/kg)	**0.13**	**0.7**	**14.5**	**324**

on a parachute. The New Shepard design is heavily focused on providing crew and passengers an escape option at every phase of the operation to maximize safety (Fig. 12.3).

Blue Origin has aspirations that go well beyond providing rides to space tourists on suborbital flights. Its New Glenn vehicle is intended to be able to fly into space. But certainly they are difficult transitions to make the climb from jet plane to suborbital spaceplane to launch vehicle capable of delivering spacecraft to orbit. The following chart shows how challenging such transitions are in terms of the energy required that (expressed in Joules/kg) goes up exponentially rather than linearly (Table 12.1) [4].

Virgin Galactic and Blue Origin are not alone in their efforts to create commercial capabilities either to provide suborbital spaceplanes or launch satellites to orbit. As previously noted, Boeing and SpaceX are also seeking to provide commercial launches to the International Space Station (ISS) for NASA under commercial crew contracts, and Sierra Nevada continues with the development of their Dreamchaser spaceplane, which can be launched to orbit via vehicles such as the Atlas V and then bring cargo and potentially crew back from low Earth orbit (LEO).

And this is just U. S.-related commercial programs. ESA is working with industry in Europe to develop spaceplanes and commercial launch capabilities. There have been various initiatives with Airbus Defence and Space, Bristol Space Planes and other contractors to develop spaceplanes under the Future European Space Transportation Investigations program and its follow on, the so-called PRIDE program [5].

Efforts now include those of Reaction Engines to develop the Sabre engine and the Skylon vehicle to prove the viability of a ramjet engine propulsion system working in tandem with a rocket engine to allow an efficient and reusable single-stage-to-orbit vehicle. This is a hybrid rocket system and ramjet spaceplane that developer Alan Bond has said will revolutionize the space launcher industry [6].

Indeed there are active research programs to develop spaceplane technologies and systems in Japan, India, China and Russia at various stages of capability. Most of these, however, are at the governmental level rather than as privately funded capital ventures.

Many of the initiatives to develop spaceplanes started off with the XPRIZE competition, and this gave rise to an incredible diversity of concepts as to how these systems would take off and

Table 12.2 New approaches to space inspired by the XPRIZE competition. (Prepared by the author and derived from a chart created for the International Space University.)

Efforts to create new commercial systems for space tourism in the past 15 years	
Various approaches for accessing space	**Companies using this particular approach**
Lighter than air ascender vehicles and ion engines with high altitude lift systems providing access to LEO	JP aerospace
High altitude experience from stratospheric dirigible ascent	World view, zero-to-infinity
Balloon-launched rockets with capsule return to ocean by parachute	Planetspace
Launch space plane to orbit on conventional launcher and horizontal landing	Sierra Nevada Dreamchaser
Vertical takeoff and vertical landing	Armadillo aerospace, blue origin, Lockheed Martin, Masten space plus new SpaceX grasshopper project
Vertical takeoff and horizontal landing (spaceport)	Aera space Tours, Planetspace, SpaceDev., SpaceX, Sub-Orbital Corp, t/Space, TGV rocket, Wickman spacecraft & propulsion
Vertical takeoff and horizontal landing (from ocean site)	Advent launch site
Horizontal takeoff and horizontal landing	Andrews, scaled composites, the spaceship corporation, virgin galactic, XCOR
Tow launch and horizontal landing	Kelly Space & Technology, Inc.
Vertical launch to LEO from spaceport	Alliant ATK (now orbital ATK), Inter Orbital Technologies, SpaceHab, UP aerospace
Launch to LEO from carrier jet drop	Triton systems, Stratolauncher, launcher one

land. Table 12.2 provides a summary of just the U. S. XPRIZE-inspired initiatives to develop a better and more cost-effective approach to creating a spaceplane business. Some might suggest that this was an incredibly inefficient process. But such a competitive thought process, largely inspired by the XPRIZE competition, has weeded out weaker ideas and business practices and has left the strongest technical approaches now moving ahead [7].

Today there are still many ideas moving ahead, although a majority of the XPRIZE initiatives have now folded. The net result is that there is more coherence and focus on the approaches defined by Virgin Galactic and Blue Origin in terms of space tourism flights, although one could also say that the stratospheric flights by dirigibles, as being pursued by World View and Zero-to-Infinity, were also originally inspired by the XPRIZE competition.

Private Habitats in Space

Robert Bigelow, who created the Budget Suites of America string of hotels, has always had a desire to be more than just another Las Vegas-based hotelier. His reputation among the hotel and casino owners of Las Vegas is that he was a loner, and when he founded his aerospace company in 1998, it was clear he was not just your usual hotel magnate and entrepreneur.

Bigelow went on to purchase the license from NASA to develop inflatable space habitats that had been originally created by SpaceHab under U. S. government funding. He has launched two Genesis space habitats that are now fully deployed in space, with cameras streaming down video from their low Earth orbit. His next step was to design a much large inflatable habitat called BEAM. This stands for Bigelow Expandable Activity Module. Under contract with NASA he has deployed a prototype on the ISS to create expanded living and experimental space for ISS crew members. Although there was an initial problem with this unit, it has now successfully deployed. See the BEAM prototype as deployed on the ISS; it's the ovoid structure at the upper middle of Fig. 12.4 [8]. This BEAM structure could be made much larger.

Bigelow has ambitious plans that go well beyond the BEAM experiment on board the ISS. He feels he has the key parts of the design of the habitat with a viable life-support system and a solar array power system well in hand. The key missing element was a reliable and cost-effective transportation system to and from a private space station. In this respect he is seeking a U. S. developer of a rocket launcher system that could ferry experiments and space tourists for a stay on his private space habitat.

How could he find a reliable way of transporting humans to and from low Earth orbit (LEO)? In 2004 Bigelow launched his own competition and promised the winner a $50-million payout. This competition he dubbed America's Space Prize, but its conditions of performance and commitment to provide private ferrying services to Bigelow made it a very long shot that there would be any viable competitors. In early 2010, over five years later, the prize offer expired without a winner.

In fact, in August 2009, Bigelow Aerospace essentially abandoned the competition initiative by announcing an effort to develop the so-called Orion

Fig. 12.4 BEAM Inflatable barrel-like structure as deployed on the Tranquility node of the ISS. (Graphic courtesy of NASA.)

Fig. 12.5 Private space station concept for Bigelow private space habitat. (Graphic courtesy of Bigelow Aerospace.)

Lite spacecraft. The idea was to use the Orion Lite capsule in tandem with either an Atlas 5 or Falcon 9 launch system. This system would be able to carry a 'pilot' and up to six passengers [9].

Bigelow has provided a mockup of his plans for a module-like space station as shown in Fig. 12.5. He has announced fees for not only space tourist visits to his private space station but also for in-orbit low-g experiments. There have also been early indications that governments and various pharmaceutical, chemical and biological industries are likely to sign up for these types of in-orbit activity.

Nor is Bigelow Aerospace the only entity that has contemplated creating private space habitats or space hotels. German aerospace engineers such as Krafft Ehricke considered the technical aspects of such a design, and von Braun worked with Walt Disney on such a concept. Stanley Kubrick and Arthur C. Clarke created a vivid image of what a Hilton hotel in space might be like in *2001: A Space Odyssey*. More recently, the Spanish space hotel company Galactic Suites announced its plans for a space hotel in 2007 with fanfare but no actual follow through to date [10]. The Russian company Orbital Technologies indicated plans for an in-orbit habitat in 2011, while a Japanese construction company indicated plans for building a lunar colony [11]. But to date such initiatives have been largely talk. Only Bigelow Aerospace has actually tested what seems to be viable technology in space to date.

Commercial Hypersonic Transportation

The skeptics of space tourism or space adventures have discounted the basic business plan of those seeking to simply fly people on suborbital flights so that they can experience weightlessness and see the Big Blue Marble against a black sky black drop. Those that discount this type of space tourism business plan suggest that there are a limited number of people who are willing to pay big bucks for such an experience and that once accomplished the repeat market would be quite small. The entrepreneurs who have looked into the future of spaceplanes or hypersonic planes have looked beyond space tourism. These Space 2.0 entrepreneurs have consistently suggested that the truly sustainable future business would not be flights to nowhere – i.e., suborbital parabolic flights that take off and land at the same point. They see the true potential as being hypersonic transport that could connect London to Sydney or New York to Tokyo in only a few hours.

These hypersonic flights for business tycoons and wealthy jetsetters would take off from airports and fly up to 50,000 ft at subsonic speeds. Then they would use rocket propulsion to reach speeds of Mach 3 to Mach 6 to reach an apogee of perhaps 80 kilometers and then descend and slow to subsonic speeds before landing half way around the world. New technology is being developed by NASA and others, such as an extendible needlelike nose system that would extend from the front of the spaceplane to avoid the generation of a huge sonic boom in the landing process. This type of extension system from the spaceplane's nose would create a thousand lower-level 'micro-booms' that would replace a thunderous clap of noise prior to landing.

Currently there is a dual path of development. One type of development is for supersonic aircraft that might fly at speeds such as Mach 2 or Mach 3. Then there are various spaceplane models that might fly at velocities on the order of Mach 5 or Mach 6.

There are quite a few questions that must be answered before true hypersonic services can seriously be started. Prime among these are the following:

- Is there a solid business case for hypersonic flights for truly long-distance flights of over 12,000 kilometers (7500 miles)?

- Are the considerations of speed, safety and cost sufficient to drive the development of spaceplanes (i.e., with speeds up to Mach 6) over the development of more conventional supersonic jets (i.e., with speeds of only Mach 2 or 3)?
- Which of the various technologies that are now available are the best ones going forward? The Japanese have made serious progress with H_2–0_2 hypersonic transport systems. Reaction Engines ramjet technology uses air from the atmosphere and makes it more efficient in that oxidizers do not have to be used in suborbital flights. Some of the spaceplanes to be used by Virgin Galactic use metallic fuels that spew particulates into the stratosphere. Performance, safety, reliability, cost and environmental impact are currently at odds with one another.
- Are there serious environmental concerns that apply to any of these types of vehicles in terms of their longer term operation in the stratosphere? Is the likely level of air pollution and particulates that would occur from flights through the upper reaches of the vulnerable stratosphere entirely too large if operated over multiple years? Would such hypersonic flights with apogees in the 80- to 100-kilometer range turn out to be too destructive to this fragile part of the atmosphere? Would systems such as Hyperloop or Maglev trains, especially if they are designed to use vacuum tunnels, turn out to be a better answer in terms of speed, safety and even longer-term cost?
- Can sufficient space traffic management systems be created to allow the safe operation of hypersonic craft through the protozone region of the stratosphere? What types of technology need to be developed and implemented in order to operate such hypersonic transportation systems in a safe and reliable manner?

Figure 12.6 shows the Skylon single-stage-to-orbit scramjet vehicle by Reaction Engines, the Japanese Hypersonic vehicle and SpaceShipTwo. Each of these vehicles have advantages and disadvantages that could advance the idea of hypersonic travel or even more cost effective travel to orbit. The future of hypersonic and space travel will be facing key challenges in the years ahead, and we are still lacking a

Fig. 12.6 *From left to right:* The Skylon Scramjet, Japan's Hypersonic, and SpaceShipTwo.

clear set of criteria for judging what is the best way forward.

Conclusions

There has been enormous progress made in the development of spaceplane and hypersonic transportation systems in the past decade. The 2020s will be a critical time for deciding what is the best path forward for the development of new transport systems for air and space. Never before have there been quite so many options that might be used to launch spacecraft into orbit, perform suborbital flights, and provide new options for hypersonic flight.

In 2004, when Burt Rutan, Paul Allen and Mike Melvill teamed up to win the $10 million Ansari XPRIZE, the next step forward into the world of space tourism and forthcoming public rides into space seemed clear cut and inviting. The prospect of hundreds of new citizen-astronauts was seemingly on the doorstep of that new tomorrow. The pathway was more difficult than it was thought at that time. A fatal Halloween accident in 2014 proved a serious step backward in the development of SpaceShipTwo. Sir Richard Branson, who had said that the spaceplane suborbital flights would carry him and his family on the first commercial flights, wisely deferred the development until tests proved his new vehicles to be truly safe. The development of commercial flights for citizen-astronauts since 2004 has been a story of one step forward, two steps back, and then one step forward again.

This chapter, however, tries to put developments since 2001 in perspective – going back to when the XPRIZE was established. In the last two decades there has been a broader rise in commercial space, or Space 2.0. We have seen the cross-fertilization of the aerospace industry and cyber-industry in new and innovative ways. This innovation has seen the rise of small satellites, new launch systems, large-scale satellite constellations, new applications in the protozone, on-orbit servicing, new manufacturing techniques and key new technologies in Earth station systems. The enthusiasm for space tourism and the media attention that has been heaped on celebrities going into space has helped the overall broad revolution in the space industry. This is not to dismiss the spaceplane initiatives to give rides to the stratosphere for high-rolling celebs or efforts to create private space habitats, but it is to say that the changes across the broad spectrum of the space industry must be considered as a whole.

References

1. Haines, L.: SpaceShipOne Claims X-Prize: Triumph for Private Space Vehicle. The Register, London (2004). https://www.theregister.co.uk/2004/10/04/spaceshipone_claims_x_prize/
2. Foust, J.: Second SpaceShipTwo Performs First Powered Test Flight. Space News, Alexandria (2018). https://spacenews.com/second-spaceshiptwo-performs-first-powered-test-flight/
3. Weitering, H.: Virgin Galactic's VSS unity space plane aces test flight, reaching mesosphere for the 1st time. Space.com (2018). https://www.space.com/41295-virgin-galactic-reaches-mesosphere-epic-test.html?utm_source=sdc-newsletter&utm_medium=email&utm_campaign=20180728-sdc
4. Pelton, J.N., Marshall, P.: Launching into Commercial Space. AIAA, Reston (2016)
5. The ESA-initiated future European space transportation investigations program. Accessed 29 July 2018. https://www.

researchgate.net/publication/301195167_The_ESA-initiated_Future_European_Space_Transportation_Investigations_Program_1994-1998
6. Merrill, J.: Alan Bond: the British engineer says he will revolutionise space travel – and he's building the rocket to do it. (2014). https://www.independent.co.uk/news/people/alan-bond-the-british-engineer-says-he-will-revolutionise-space-travel-and-hes-building-the-rocket-9587165.html
7. Op Cit, Pelton and Marshall, Chapter 6
8. Inflatable BEAM structure. NASA. Accessed 30 July 2018. https://www.nasa.gov/mission_pages/station/research/experiments/BEAM1.jpg
9. Wall, M.: Private space habitat to launch in 2020 under commercial spaceflight deal. Space.com (2016)
10. Gordon, S.: Space hotel to open to tourists. Daily Mail (2009). http://www.dailymail.co.uk/travel/article-1224629/Galactic-Suite-Space-Resort-hotel-2012-First-space-hotel-open-tourists.html
11. Boyle, R.: Luxury getaways of the future: visit orbital technologies' space hotel. Pop. Sci. (2011). https://www.popsci.com/technology/article/2011-08/luxury-getaways-future-visit-orbital-technologies-space-hotel