

Touring the universe

Space is the stuff of dreams – Anyone in the world can look up at night, and there it is, always present, and always out of reach. The distance between human kind and space is shrinking, however, as space tourism edges ever-nearer reality.

Back in the 20th Century, tourism of any kind was extremely limited. For most families, tourism described that one week a year where entire families would decamp to relatives living somewhere else in the country, or a week in a B&B by the seaside or camping in a rickety old tent in Cornwall. As time has passed, tourism has changed; air travel costs have plummeted, making individuals and families much more likely to be jetting off to destinations abroad. Multiple foreign holidays a year are not unusual anymore, to cost-effective destinations in France, Spain, Turkey, etc., where money stretches further, and the change of pace can uplift spirits.

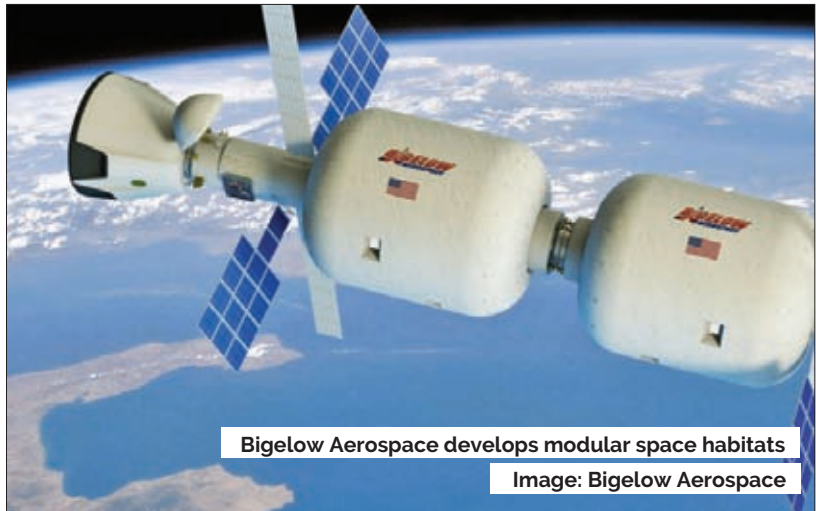
Space tourism, however, has remained largely out of reach, much to the dismay of science fiction fans everywhere. The different types of space tourism – orbital, suborbital, lunar and Martian – have captured the imagination of many. While we're not quite there yet, work continues on the development of space tourism programmes, and soon we may see the beginning of a (not entirely) new industry.

Space tourism in the 2000s

Space tourism is not a new endeavour by any means. It's actually already been demonstrated, albeit on a very small scale, some years ago.

Space Adventures, founded in 1998 by Eric C Anderson, has already sent seven non-government astronauts into space on eight successful missions (one astronaut flew two missions). During 2001-2009, these tourists (see below) were flown to the International Space Station (ISS) on board Russian Soyuz spacecraft. Several made deals with third parties to perform research while on board the ISS. The flights cost a reported US\$20-40 million apiece.

- Dennis Tito: The American businessman was the world's first private space tourist was launched to the ISS in April 2001 as Space Adventures' first client.
- Mark Shuttleworth: Launched in 2002, Shuttleworth spent 10 days in space, and dedicated his flight to educating South African youth and conducting scientific research.
- Gregory Olsen: Another private astronaut who studied the human body's response to the microgravity environment, Olsen was launched in 2005 and maintained contact with high school



Bigelow Aerospace develops modular space habitats

Image: Bigelow Aerospace

students in New York and New Jersey while on board the ISS.

- Anousheh Ansari: Launched in 2006, Ansari was the first female space tourist. Spending eight days on board the ISS, she conducted four experiments with the European Space Agency (ESA), including studying mechanisms behind anaemia.
- Charles Simonyi: Space Adventures' first repeat customer, Simonyi was launched in 2007 and 2009 to advance civilian spaceflight activities.
- Richard Garriott: Launched in 2008, Garriott demonstrated the opportunities for commercial potential in private space exploration during his stay on board the ISS.
- Guy Laliberté: As the first Canadian space tourist, in 2009 Laliberté conducted the first ever artistic and social event from space on board the ISS.

The Space Adventures programme was halted in 2010 when the ISS crew size increased. The launch vehicle seats were therefore reserved for space station crew, rather than becoming available for private sale.

A luxury market

In previous decades, travelling by plane was the preserve of wealthy individuals or important business travellers. Travelling by plane back then was a real feather in the cap for importance. Over the years, flight costs have plummeted – it's now possible to fly between some European destinations for as little as £20 – and uptake has boomed. There are now more air passengers than ever before, and all the prestige of air travel is gone.

With the advent of space tourism, we'll be seeing a new luxury tourism market, one which can only be enjoyed by the one percent (at least at first). According to ReportsnReports, the global space tourism market is expected to grow at a CAGR of 14.34 percent during 2017-2021, presumably starting from a baseline of zero. The addressable market is extremely slim, with more than 99 percent of future space tourists having a net worth greater than US\$5 million. This makes sense when you consider the huge costs expected for private

spaceflight activities; ReportsnReports notes that 'these people are motivated to try out activities that have not been experienced by the common man.' Charming, I'm sure. One key trend to emerge from the upcoming space tourism industry is the inspiration of a new generation of highly-skilled engineers. When the sky is no longer the limit, we can expect to see a boom in rocket scientists.

Although the space tourism market remains in its infancy, there are a surprising number of companies investing heavily. Well-known household names like SpaceX and Virgin Galactic are joined by newcomers and start-ups as the race for commercial spaceflight is on...

Space Adventures moves on from 2000s

Space Adventures is the only entity that has already demonstrated a successful commercial spaceflight programme back in the 2000s. The company wants as many people as possible to experience what is 'like to live in space, orbit the Earth, or travel beyond it. In the next ten years, Space Adventures plans to enable customers to choose between multiple space tourism options, including a variety of vehicles and destinations.

Today, Space Adventures is offering a variety of programmes, including orbital spaceflight missions to the ISS, zero gravity flights, cosmonaut training programmes, spaceflight qualification programmes, circumlunar missions around the Moon, and is taking reservations for future suborbital spacecraft. The company has been notably quiet regarding recent activities, with no updates on bookings or further programme development.

However, in August 2018, Space Adventures was selected by NASA as one of 13 companies to study the future of commercial human spaceflight in low Earth orbit (LEO). The study will inform NASA's strategy for enabling the commercialization of human spaceflight in LEO, and NASA's long-term requirements for the ISS. Space Adventures was due to submit recommendations to NASA on how to quantify the LEO market opportunity, evaluate technical concepts for low-cost habitation, and describe a viable and sustainable business case in LEO, in December 2018.

"We are excited to work with NASA and to have the opportunity to provide input into the future of commercial activities in LEO and thoughtful suggestions on what the agency can do to assist in the development of the marketplace," said Tom Shelley, President of Space Adventures. "When commercial crew vehicles are providing regular access to LEO we will see a great future for space tourism; and we are excited to partner with Made in Space to further understand the in-space manufacturing and the materials processing marketplace."

Roscosmos starts up own space tourism programme

Roscosmos has historically worked with Space Adventures to launch space tourists to the ISS, but it has also recent begun to work on its own independent programme. Now, the agency is developing its own luxury space hotel module for installation on the ISS, in partnership with space station contractor RKK Energia.

Although the full plans have yet to be released, the hotel module will feature four bedrooms, hygiene and medical facilities, and a lounge. According to recent



reports, prices are expected to range from US\$20-60 million for durations of one to four weeks, with a spacewalk accompanied by a professional cosmonaut available for an additional US\$20 million.

Roscosmos plans to launch its space hotel by 2022.

KosmoKurs plans for suborbital space complex

Russia's KosmoKurs is another recent private start-up company exploring space tourism activities. The company announced its plans in 2016, featuring a reusable suborbital space complex (MSCC) consisting of a reusable suborbital rocket (MSRN) and reusable suborbital spacecraft (MSCA).

According to reports, the short-duration missions of around 15 minutes will require a three-day training programme. Passengers will experience 5-6 minutes of weightlessness at 180-220km above the Earth, during which they can freely move inside the 30m³ cabin. The entire package will cost around US\$200,000-250,000 per person. Commercial flights are expected to begin in 2025, although the company faces years of testing first.

Virgin Galactic moves ahead with suborbital spaceflight

Part of Richard Branson's Virgin Group, Virgin Galactic, alongside its sister companies The Spaceship Company and Virgin Orbit, is developing a new generation of reusable space vehicles to open space to everyone. The company's mission is to be the 'Spaceline for Earth.' Virgin Galactic plans to run a regular schedule of spaceflight for private individuals from its operational hub at New Mexico's Spaceport America, the world's first purpose-built commercial spaceport.

Virgin Galactic's spaceflight model consists of a reusable launch system featuring a carrier aircraft, WhiteKnightTwo, and a suborbital spacecraft, SpaceShipTwo. The carrier aircraft climbs to an altitude of around 16km above the Earth, where SpaceShipTwo is released. The spacecraft will be projected to a height of 110km, exceeding the defined boundary of space (100km), reaching a top speed of 2,485mph, and creating a weightless experience for passengers.

Following a shaky start with the inflight loss of SpaceShipTwo VSS Enterprise, Virgin Galactic's first spaceflight vehicle, the future looks promising for the

SpaceShipTwo VSS Unity, which has completed a number of successful test flights since 2014. In May 2018, the VSS Unity achieved its second supersonic rocket powered test flight. The rocket motor burned for the planned 31 seconds and propelled VSS Unity to a speed of Mach 1.9 and an altitude of 114,500ft. The flight advanced Virgin Galactic's understanding of the spaceship's supersonic handling characteristics and control system performance, with vehicle parameters closer to the ultimate commercial configuration. After the flight, VSS Unity's unique re-entry feathering system was deployed for the initial descent.

Meanwhile, December 2018 saw the successful launch of SpaceShipTwo to the 'edge of space' - at 51.4 miles above the Earth - and back again. The ride, which transported two pilots, four NASA payloads and a mannequin, was considered a great success, and the first manned spaceflight launched from US soil since 2011.

In other news, in July 2018, Virgin Galactic signed a framework agreement with Sitael and Altec to bring Virgin Galactic spaceflights to Italy. The agreement envisions a dedicated space vehicle system, built by The Spaceship Company, being positioned at the Grottaglie Spaceport, which will integrate significant technological and industrial contribution from Sitael and the Italian aerospace industry, pending regulatory approvals. The spacecraft will be utilized by customers like the Italian Space Agency as a platform for high-frequency space research, as well as private individuals to experience space.

"From the Renaissance to modern space science, Italy has always been a natural home to great investors and breakthrough ideas which have shaped the human experience," said Sir Richard Branson, Virgin Group founder. "I believe Italy's vision which has led to this collaboration with our Virgin space companies, will provide a real impetus as we strive to open space for the benefit of life on Earth. This partnership could see Virgin Galactic launch the first person in history into space from Italian soil - and in fact from any European territory. Together, we will help to expand opportunities for science, industry and the millions of people who dream of experiencing space for themselves."

Bigelow Aerospace develops modular space habitats

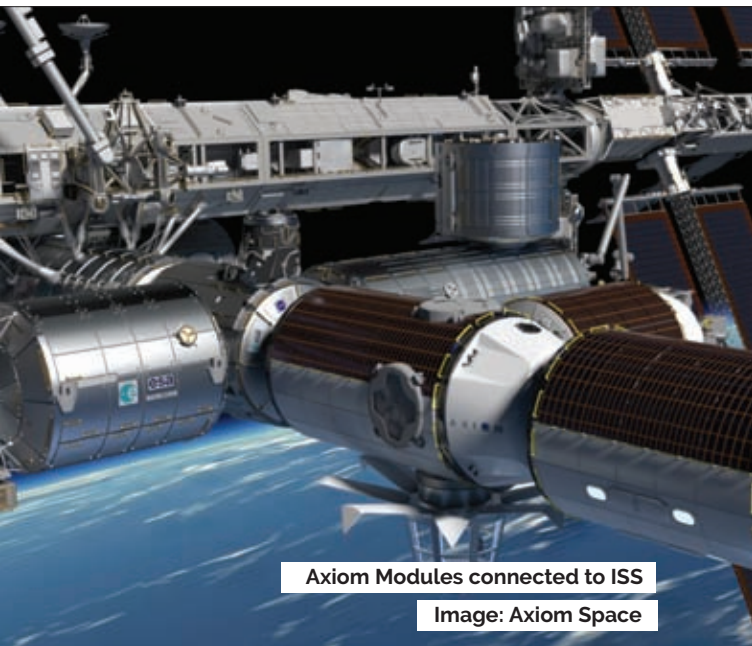
Bigelow Aerospace is a serious contender in the space tourism sector in its own right. Founded in 1998, Bigelow Aerospace develops and manufactures expandable space station modules, and is the only company commercializing NASA expandable module technologies. Bigelow aims to create a modular set of space habitats for creating standalone or expanding existing space stations. The inflatable modules are expected to be more durable than rigid modules due to the use of Vectran, a material twice as strong as Kevlar, and because the flexible walls are theoretically more likely to withstand micrometeoroid impacts better than rigid walls.

Under the Genesis programme, Bigelow has demonstrated the viability of expandable habitat technology in space. Genesis I, Bigelow's first operational spacecraft, was launched into orbit in 2006, while Genesis II was launched in 2007; both remain in orbit today and observations are ongoing. Meanwhile, in 2012, NASA signed a US\$17.8 million contract with Bigelow to



Blue Origin's orbital rocket New Glenn

Image: Blue Origin



Axiom Modules connected to ISS

Image: Axiom Space

develop the Bigelow Expandable Activity Module (BEAM), which was attached to the ISS in 2016, where it remains today.

Bigelow is currently developing the B330 standalone commercial space station for operation in low Earth orbit (LEO), cislunar space and beyond. A single B330 is comparable to one third of the current pressurized volume of the entire International Space Station. Bigelow Aerospace is developing two B330 commercial space station habitats that will be ready for launch any time after 2020. Indeed, at the end of 2017, Bigelow and United Launch Alliance (ULA) announced plans to launch a B330 module on ULA's Vulcan launch vehicle, placing it into low lunar orbit (LLO) by the end of 2022 to serve as a lunar depot.

The B330 will launch to LEO on a Vulcan 562 configuration rocket, the only commercial launch vehicle in development today with sufficient performance and a large enough payload fairing to carry the habitat. Once in orbit, Bigelow will outfit the habitat and demonstrate it is working properly. Once fully-operational, ULA's industry-unique distributed lift capability will be used to send the B330 to lunar orbit. Distributed lift will also utilize two more Vulcan ACES launches, each carrying 35 tons of cryogenic propellant to LEO. In LEO, all the cryogenic propellant will be transferred to one of the Advanced Cryogenic Evolved Stage (ACES). The now full ACES would then rendezvous with the B330 and perform multiple manoeuvres to deliver the B330 to its final position in LLO.

SpaceX sets sights on commercial spaceflight

Elon Musk has been very vocal in his plans for SpaceX to enter the commercial spaceflight sector by bringing humans to Mars. Development work towards this goal could be considered as starting in 2012 with the design of the Raptor rocket engine, which will propel all versions of the BFR launch vehicle.

Since one of SpaceX's key ethos is to make space travel affordable, the company's long-term plans envisage a re-usable launch vehicle capable of lifting 150 tonnes into space. The system will be powered by the Raptor bipropellant liquid rocket engines for both

stages, using densified liquid methane fuel and liquid oxygen oxidizer. The engine is expected to be test fired for the first time in 2020.

SpaceX aims to send its first cargo mission to Mars in 2022. The objectives for this first mission will be to confirm water resources and identify potential hazards in establishing initial power, mining, and life support infrastructure. A second mission carrying a crew is planned for 2024, with primary objectives of building a propellant depot preparing for future crew flights. The spacecraft used for transportation from Earth will also be utilized for the first Mars base.

Landing the first humans on Mars is one of the great races underway today. Recently, Boeing's CEO Dennis Muilenburg made the news when he claimed that the SLS rocket the company is developing for NASA would bring humans to Mars ahead of SpaceX. Boeing is currently developing the world's biggest rocket for NASA, complete with 9.2 million pounds of thrust, and measuring 38 stories tall. The first test firing is scheduled for 2019.

Indeed, when CNBC host Jim Cramer asked whether Boeing or SpaceX would get a man to Mars first, Muilenburg reportedly responded: "Eventually we're going to go to Mars, and I firmly believe the first person that sets foot on Mars will get there on a Boeing rocket."

SpaceX CEO Elon Musk responded concisely on Twitter: "Do it."

Blue Origin readies for suborbital space tourism

Not quite a household name yet (but surely it will be soon), Blue Origin is Amazon Founder Jeff Bezos' answer to developing technologies to enable private human access to space, dramatically lowering costs and increasing reliability.

The company has developed several launch vehicles with an ultimate focus on providing access to both suborbital and orbital space. The suborbital New Shepard spacecraft has performed several successful test and commercial satellite launches, including the launch of its pressurized Crew Capsule. Both launcher and capsule have been successfully re-landed after launch, making them suitable for reuse.

The Crew Capsule, which includes six large observation windows, is expected to be launched with crew on board in the near future, after which tickets for suborbital space tourism will be made available for sale. Passengers will experience weightlessness for about four minutes of the eight-minute flight, and be propelled to a height of 307,000ft after separation from the launch vehicle.

Blue Origin is also working on the development of the New Glenn vehicle, which has a reusable first stage. The orbital launch vehicle will be utilized for satellite launches but is also the company's answer to commercial spaceflight. The first test flights are expected to commence in 2020, although recent reports state this may be pushed back.

Axiom Space prepares for world's first commercial space station

American start-up company Axiom Space was established in 2015 with plans to develop and manufacture the world's first commercial space station. The company's vision is to make living and working in space commonplace as a means to sustained deep

space exploration and to improve the quality of life on earth.

"It is an honour to continue the work that NASA and its partners have begun, to bring awareness to the profound benefits of human space exploration and to involve more countries and private citizens in these endeavours," said Axiom Space CEO and President Michael Suffredini, who managed NASA's ISS program for a decade.

The company plans to link a module with the ISS in 2019; upon the retirement of the ISS in 2028, the Axiom module will be joined by additional elements that will function as the Axiom International Commercial Space Station. As such, Axiom will conduct astronaut training for commercial astronauts, host government and commercial partners, as well as space tourists.

For space tourists, an eight-day stay on the space station will cost US\$55 million, following 15 weeks of training prior to the flight. Passengers will have access to high speed WiFi, video screens, and a glass-walled cupola, reportedly the largest window observatory ever constructed for the space environment.

Orion Span plans Aurora Space Station

Orion Span is one of the latest space tourism start-up companies, having announced plans to build a private space station in LEO in March 2018. The Aurora Space Station will have a six-person capacity, two crew and four tourists, and will be designed, built and tested in Houston, Texas.

"We developed Aurora Station to provide a turnkey destination in space. Upon launch, Aurora Station goes into service immediately, bringing travellers into space quicker and at a lower price point than ever seen before, while still providing an unforgettable experience," said Frank Bunker, CEO and Founder of Orion Span. "Orion Span has additionally taken what was historically a 24-month training regimen to prepare travellers to visit a

space station and streamlined it to three months, at a fraction of the cost. Our goal is to make space accessible to all, by continuing to drive greater value at lower cost."

Space tourists will experience the zero-gravity environment, be able to float freely throughout the habitat, and take part in research experiments such as growing food while in orbit.

A virtual reality holodeck will be available, and customers will be able to stay in touch with loved ones on Earth via high-speed wireless Internet access. The Aurora Space Station will orbit the Earth every 90 minutes, allowing guests to view around 16 sunrises and sunsets every 24 hours.

Orion Span has shortened the traditional 24-month astronaut certification down to three months, with the first phase being completed online. The next stage will be completed in person in Houston, and the final step will be finished onboard the space station.

Reports state that the Aurora Space Station will be launched in 2021 and will be accepting its first guests in 2022. A 12-day stay will reportedly cost US\$9.5 million, and a place can be secured with a US\$80,000 deposit. Within the first 72 hours of announcing the space station, four months of reservations were sold out.

Orion Span made an interesting announcement in June 2018, when it was revealed that the company is now accepting cryptocurrency payments for future reservations. Payments in Bitcoin, Ethereum, Bitcoin Cash and Litecoin will be accepted.

"To better reflect the global nature of Aurora Station, we're putting together these two worldwide resources - space and cryptocurrency - to further serve and improve access for our global clientele. This is part of our continuing mission: to make it easier than ever before to travel to and stay in space," said Bunker. "As a forward-thinking company, we're proud to once again be pioneering the leading edge of the space industry by streamlining the technology involved in getting there." ■

