



News & Highlights

Space Tourism Moves Closer to Lift Off

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Astronauts are not the only ones who dream of going into space. Since the earliest days of human spaceflight, many other people have also longed to view Earth and the heavens from above the atmosphere.

In 2018, Virgin Galactic, a private—soon to be public [1]—space flight company headed by billionaire Richard Branson, has brought that vision closer to reality than ever before. In December 2018, the company successfully tested its spaceplane, the VSS Unity, reaching an altitude of 51.4 mi (~82.7 km) [2]. In a second test flight on 22 February 2019, it reached an altitude of 55.85 mi (~89.9 km) [3]. The company's ultimate goal is to use the spaceplane to carry six passengers at a time to spend a few weightless minutes in outer space before returning to Earth—all for the price of \$250 000 USD per person [4].

Blue Origin, a company funded by Amazon CEO and billionaire Jeff Bezos, is another private space tourism frontrunner. Blue Origin has been launching test flights of its space capsule New Shepard (named after US astronaut Alan Shepard), most recently in May 2019 when it carried US National Aeronautics and Space Administration (NASA) microgravity experiments, including tests on microchips and three-dimensional (3D) printing [5].

The two private space companies have poured billions of US dollars into their space ventures. Most of the \$1 billion USD that has been invested in Virgin Galactic since its inception in 2004 has been Branson's [6]. Likewise, Bezos has been investing \$1 billion USD of his Amazon stock per year in Blue Origin since the company's founding in 2000 [7].

The suborbital flights of the two companies' intended-for-space-tourism vehicles traverse parabolic arcs that at their height pass through outer space before returning to Earth. To be awarded the title of "astronaut," passengers must sail above the Kármán Line (named for the late aerospace engineer Theodore von Kármán), an altitude 100 km above the Earth's surface. This boundary, defined by the Fédération Aéronautique Internationale (FAI), the world air sports federation that maintains records for both aviation and spaceflight, is recognized by most international and scientific communities and represents the point where the atmosphere is so thin that aerodynamics can no longer influence the craft's flight. In contrast, the US Air Force and NASA place the outer space boundary at 50 mi (80.5 km) above Earth [8].

The Virgin Galactic and Blue Origin projects employ different strategies and have reached different milestones. "It's fascinating to see these two companies take very different approaches," said

Stephen K. Robinson, retired NASA astronaut, professor of mechanical and aerospace engineering, and director of the Center for Human/Robotics/Vehicle Integration and Performance at the University of California, Davis. "It's not obvious which is going to be better for safety and reliability, or economically."

While the Virgin Galactic test flights are still approaching the Kármán Line, they have carried up to three people—two pilots and an aeronautics expert on the February 2019 flight. Blue Origin has sent its New Shepard above the Kármán Line, up to 104.6 km in the May 2019 test flight, but without passengers. Recently, the FAI and the International Astronautical Federation have raised the possibility of lowering the Kármán Line to 80 km, which would allow Virgin Galactic to claim that its spaceplane has reached outer space [8]. At their highest point, the spacecraft enter the mesosphere, a largely unexplored region above the stratosphere and below the thermosphere. While both Virgin Galactic and Blue Origin are focused on realizing space tourism, their spacecraft will also provide opportunities to study this region, which has already started with the experiments carried on the May 2019 New Shepard mission.

The technology for these launch and space vehicles is relatively well developed. The VSS Unity is initially shuttled on the carrier aircraft VMS Eve (Fig. 1), designed by aerospace designer Burt Rutan. The coupled planes take about 1.5 h to reach an altitude of 50 000 ft (~15.25 km). The spaceplane then detaches from its shuttle, and a rocket, powered by thermoplastic polyamide fuel and a nitrous oxide oxidizer [9], ignites and propels the spaceplane upward at Mach 3 for 90 s (Fig. 2). After spending several minutes in space, the craft then begins its 30-minute descent back to Earth. A wing design known as feathering, in which the twin tails of the craft fold upward, stabilizes the craft as it reenters the atmosphere [10].

Blue Origin, in contrast, lofts New Shepard into space on a rocket booster powered by liquid hydrogen/liquid oxygen fuel (Fig. 3). During this lift off, passengers will experience three times the Earth's gravity (3Gs) for 150 s [11]. Detaching from the booster, which is reusable and lands separately, the New Shepard capsule sails through space for several minutes before beginning its descent. Despite being slowed by parachutes, passengers will experience about 5Gs during the return to Earth. This should be manageable if a person is lying horizontal to gravity, said Erik Seedhouse, space flight expert and professor of applied aviation sciences at Embry-Riddle Aeronautical University. The whole flight from launch to return is short, lasting only about 11 min [12]. To



Fig. 1. Virgin Galactic's carrier aircraft VMS Eve shuttles the spaceplane VSS Unity on a test flight. Credit: courtesy of Virgin Galactic (public domain).

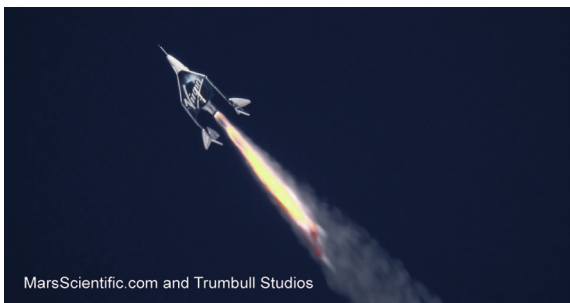


Fig. 2. On 22 February 2019, the VSS Unity, the Virgin Galactic spaceplane developed for space tourism, reached an altitude of 55.85 mi (89.9 km) in a successful test flight with three people on board, including two pilots and an aeronautics expert. Credit: ©MarsScientific.com and Trumbull Studios, courtesy of Virgin Galactic (public domain).



Fig. 3. Blue Origin's New Shepard capsule launches aboard its reusable booster rocket, carrying a payload of nine NASA experiments, on 23 January 2019. Note the large viewing windows on the capsule. Credit: courtesy of Blue Origin (public domain).

provide views for future passengers, the New Shepard's design includes large windows.

The New Shepard can also eject itself from the booster rocket during the initial ascent should an emergency occur [13], a feature

that underscores how risky such space travel remains, despite its popular allure. In fact, during a test flight in 2014, Virgin Galactic's first spaceplane, the VSS Enterprise, suddenly broke apart, killing the co-pilot and seriously injuring the pilot. The results of an investigation blamed the catastrophe, which delayed further test flights by three years, on a combination of pilot error and other factors including inadequate safety procedures [14].

Besides ensuring safety, engineering challenges are also posed by the design of a functional and comfortable cabin for space tourists. "Space is so, so difficult," said Seedhouse. While professional astronauts spend years training, space tourists may only take a few days to prepare for an adventure in which they will be expected to handle G-forces, manage weightlessness, and buckle up on cue before descent, Seedhouse said. Because up to 60% of people will experience motion sickness, taking medication pre-flight will probably be mandatory. Being in a weightless environment presents particular complications that a standard airsickness bag may not be sufficient to handle, Seedhouse said. "Having a ball of vomit coming towards you can ruin your day."

At this point, neither company has set a date for its first space tourist flight. While Blue Origin has not yet priced its adventure, it is accepting reservations on its website. The companies should spend the time to nail down the safety issues, Robinson said. "I think they're both pretty close. It's really difficult work they're doing." The experience gained by these efforts can only be good, he said. "The more people who have flown in space, the better off the human race."

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