

Virgin Galactic Holdings, Inc. (SPCE) *Putting the Zero in Zero-G*

We are short shares of Virgin Galactic Holdings, Inc., often [described](#) as the only publicly traded space-tourism company. After going public in October 2019 by way of a merger with a “blank check” company, Virgin Galactic has seen its share price and trading volume soar. It’s become a retail darling, with day traders captivated by images of billionaires donning space suits, blasting off from launchpads, and looking down on the [blue marble](#) of Earth.

But Virgin Galactic’s \$250,000+ commercial “spaceflights” – if they ever actually happen, after some 17 years of delays and disasters – will offer only the palest imitations of these experiences. In lieu of pressurized space suits with helmets – unnecessary since so little time will be spent in the upper atmosphere – the company commissioned Under Armour to provide [“high-tech pajamas.”](#) In lieu of vertical takeoff, Virgin’s “spaceship” must cling to the underside of a specialized airplane for the first 45,000 feet up, because its rocket motor is too weak to push through the lower atmosphere on its own. In lieu of the blue-marble vista and life in zero-g, Virgin’s so-called astronauts will at best be able to catch a glimpse of the curvature of Earth and a few minutes of weightlessness before plunging back to ground.

This isn’t “tourism,” let alone Virgin’s more grandiose term, “exploration”; it’s closer to a souped-up roller coaster, like the “Drop of Doom” ride at Six Flags. It isn’t even really “space.” The traditional international definition of “space” (known as the Kármán line), which [Virgin Galactic itself](#) once targeted, puts the boundary at an altitude of 100 km, which the company’s technology [can’t reach](#). Indeed, Jeff Bezos, whose Blue Origin is also working on suborbital flights, [noted this Virgin weakness](#) in a 2019 interview, adding that Blue Origin’s “mission” has always been “to fly above the Kármán line, because we didn’t want there to be any asterisks next to your name about whether you’re an astronaut or not.” Veteran astronaut [Chris Hadfield](#) put it even more bluntly back in 2013, calling Virgin Galactic’s planned offering “not much of a space flight...They’re just going to go up and fall back down again...[W]hether that’ll be enough for the quarter-million-dollar price tag? I don’t know.” With Blue Origin’s superior experiences likely to beat out Virgin’s in the near term, and SpaceX’s multi-day excursions – going into Earth’s orbit and staying there for several days rather than several minutes – winning out in the longer term, Virgin’s moment in the sun may be over soon after its first real flights finally lift off.

Hadfield also presciently warned, “Eventually they’ll crash one” – and was proven right just twelve months later by a [fatal catastrophe](#). Tests of Virgin’s systems have already killed four people, and since the company is “not building new technologies but just copying very old ones,” as one industry veteran [complained](#), the company’s crude aerospace technology will likely lead to more deaths. How quickly will spaceflights screech to a halt as fatalities pile up? Dangerous and unappealing, Virgin Galactic’s sole product – whose official commercial launch has been delayed so many times it’s a running joke – cannot justify the company’s \$8 billion valuation. “Virgin” or not, this business is screwed.

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Table of Contents

COMPANY BACKGROUND	3
NOT SPACE, NOT TOURISM, NOT WORTH IT	6
Real Competition Is Imminent	12
UNSAFE AT ANY SPEED	14
CONCLUSION	18
FULL LEGAL DISCLAIMER	19

Company Background

Virgin Galactic: Capitalization and Financial Results					
Capitalization		Financial results (\$mm)			
			2018	2019	2020
Share price (\$)	\$31.02	Revenue	\$ 3	\$ 4	\$ 0
Fully diluted shares (mm):		Net income	(138)	(211)	(273)
Shares outstanding	237.3				
Impact of warrants/options/RSUs	12.2	FCF*	\$ (157)	\$ (223)	\$ (250)
Total	249.5				
Fully diluted market cap (\$mm)	\$ 7,740				

Source: company filings, Capital IQ, Kerrisdale analysis
Note: dilutive impact estimated using treasury method, incorporating private-placement warrants and options/RSUs under the 2019 Plan.
** FCF = free cash flow, defined as operating cash flow less capital expenditures.*

Despite never having flown a single paying customer, Virgin Galactic has a history that stretches back decades. It was born out of the X Prize, an effort initiated in 1996 by the entrepreneur Peter Diamandis to stimulate the development of private-sector spaceflight by offering \$10 million to the first non-governmental organization to launch a manned vehicle into space. “Space,” for the purposes of the prize, began at 100 km (about 62 mi) above the earth’s surface – a boundary known as the Kármán line (named after Theodore von Kármán, a Hungarian-American scientist). Burt Rutan, a maverick aerospace engineer, came up with an unusual design that was optimized to win the prize at minimal cost: a specialized plane would carry a craft called SpaceShipOne up into the air and drop it; SpaceShipOne would then ignite its rocket motor, shoot almost vertically up toward the Kármán line – and very soon plummet right back down to earth. A complex mechanism on SpaceShipOne’s tail, referred to as the “feather” and reminiscent of a badminton shuttlecock, would slow the descent.

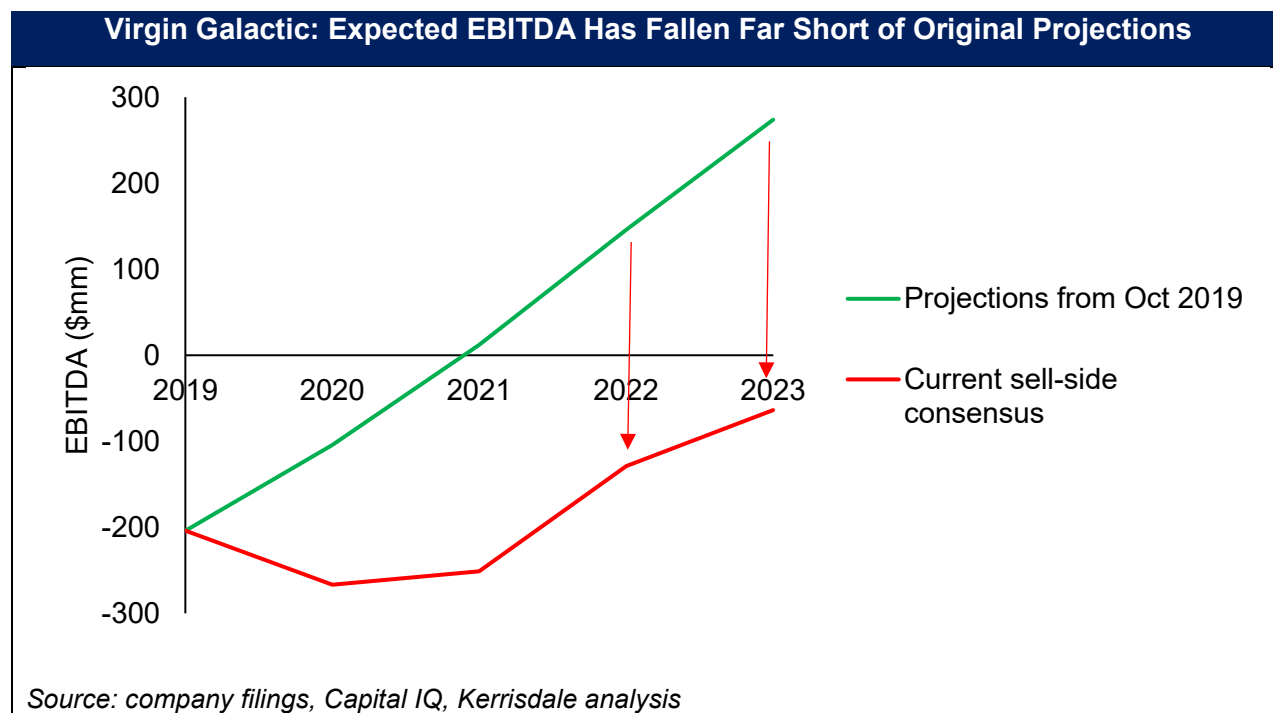
This design lacked anything close to the power to get into or out of orbit, but, after years of struggle to make it work, it was just barely good enough to, in the words of [one reporter](#), “briefly slap the rim of space”; thus SpaceShipOne won the X Prize in 2004. It was around then that Sir Richard Branson, the flamboyant British business mogul best known for his Virgin Atlantic airline, entered the story. Branson’s vision was to license and scale up Rutan’s SpaceShipOne technology and use it as the basis for the world’s first “spaceline,” “[offering commercial flights to space by 2007-8](#)” for a few hundred thousand dollars per passenger.

But 2007 came and went, marked by an on-the-ground nitrous-oxide explosion that killed three people working on Virgin’s craft – but no commercial flights. Years passed, with new technical difficulties always cropping up to impede the company’s progress, including another fatal accident in 2014 that destroyed the first iteration of SpaceShipTwo. Branson’s endlessly repeated false predictions that commercial service was just around the corner became

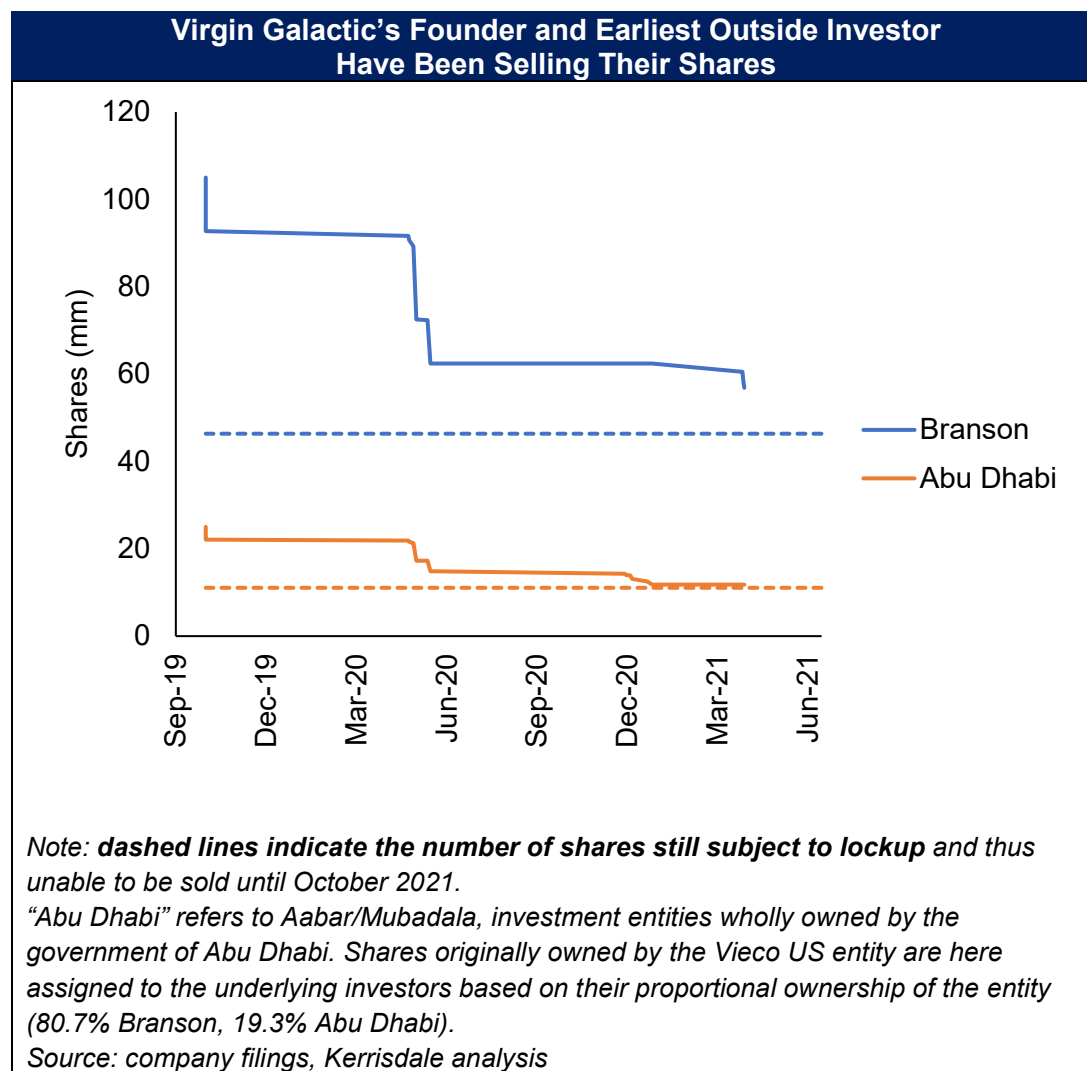
notorious; in his own words, [speaking to a journalist in 2018](#), “It would be embarrassing if someone went back over the last thirteen years and wrote down all my quotes about when I thought we would be in space.”

All of those years of failure didn’t come cheap – from 2017 to 2020 alone, the company burnt more than \$700 million of cash – so Branson periodically sought to shore up Virgin Galactic (and his other, less sexy space-related effort, the satellite-launch business Virgin Orbit) with infusions of outside money. In 2009 Abu Dhabi [invested](#) \$280 million for a minority stake in these businesses, and in [late 2017](#) Branson signed a memorandum of understanding for \$1 billion from Saudi Arabia – but the deal [fell apart](#) the following year in the wake of the assassination of Jamal Khashoggi. Help arrived from an unexpected quarter: a SPAC called Social Capital Hedosophia, created by two tech investors with no experience in aerospace. Within three months of hearing from a financial advisor about Virgin Galactic’s funding needs, Social Capital Hedosophia had already sent the company a letter of intent to invest in it and take it public. In October 2019, the process was complete, and Virgin Galactic, now trading on the New York Stock Exchange, [projected](#) “a June 2020 commencement of commercial operations,” with Branson himself as the long-awaited first passenger.

Of course, June 2020 came and went; commercial operations did not commence. At the time of its deal with Social Capital Hedosophia, Virgin Galactic projected that its EBITDA would reach \$146 million in 2022; today, however, the consensus EBITDA estimate for 2022 (via Capital IQ) is **negative** \$129 million – a staggering \$274 million shy of the original target. But, carrying on in Branson’s tradition of delusionally optimistic messaging, the company insists it’s still on track.



Interestingly, Social Capital Hedosophia initially sought to merge with both Virgin Galactic and Virgin Orbit, but, according to the subsequent [proxy statement](#), “Mr. Branson conveyed a preference on behalf of Virgin management for a potential business combination transaction involving...the ‘Virgin Galactic’ business only” – retaining the more practical, less speculative Orbit business but relinquishing control over the 15-year-old suborbital “space tourism” boondoggle. In fact, as part of the initial SPAC transaction, Branson and Abu Dhabi didn’t just issue *new* shares in Virgin Galactic; they sold 12% of their preexisting stake at just \$10 per share. Though they’re prohibited until October from selling more than half of their remaining shares, these original investors have made good progress in liquidating what they can, selling shares in the open market last May and June (with respect to both Branson and Abu Dhabi) and continuing to sell in December and January (with respect to Abu Dhabi) and April (with respect to Branson). All in, relative to their pre-SPAC position, Branson and Abu Dhabi have reduced their combined holdings by 47% at a weighted-average sale price of \$15.16 per share – 51% below the current price.



Branson and Abu Dhabi are not alone in selling Virgin Galactic shares at prices much lower than the current trading level. Chamath Palihapitiya, the co-founder of the Social Capital Hedosophia SPAC and chairman of Virgin Galactic, has economic exposure to Virgin Galactic shares and warrants via the SPAC sponsor entity over which he shares control with his business partner Ian Osborne. In addition, as part of the SPAC transaction, Palihapitiya purchased 10 million shares directly from the original owners (Branson and Abu Dhabi) at a price of \$10 per share. On December 14th and 15th, Palihapitiya sold 3.8 million of these shares – “to help manage my liquidity,” he [tweeted](#) – at a weighted-average price of \$25.74, 18% below the current level.

Even Virgin Galactic itself has hit the bid, raising money in August 2020 by selling shares at an effective price, net of offering costs, of \$18.60 per share – 40% below the current level. Thus all the parties most intimately familiar with Virgin Galactic – its founder, its earliest external investor, its chairman, and the company itself – have been willing sellers even at what now look like “low” prices, taking advantage of the enthusiasm of less informed outsiders.

Not Space, Not Tourism, Not Worth It

[Canadian astronaut Chris] Hadfield...said sign-ups for Virgin Galactic, such as Paris Hilton, might be disappointed if they expect an experience on the lines of the space blockbuster Gravity.

He said: “I’m all for the idea. I commend [Branson] for it. But it’s not much of a space flight. I’m not sure she knows what she’s paying for. She may think she’s going to...see the universe and stars whipping by. None of that’s happening. They’re just going to go up and fall back down again.

“They’ll get a few minutes of weightlessness, and they’ll see the black of the universe. And they’ll see the curve of the Earth and the horizon, because they’ll be above the air. But whether that’ll be enough for the quarter-million-dollar price tag? I don’t know.”

Hadfield added: “Eventually they’ll crash one. Because it’s hard. They’re discovering how hard.”¹

—[The Guardian, October 25, 2013](#)

The VG business case also never really made sense to me. I think the people that bought a VG ride are not really cognizant of the shortness and violence of the ride they have purchased. ... I’m a space fanatic, I could afford a VG ticket if I really wanted to... I have zero interest. I just don’t see the market for 3 min of terror followed by 3 min of floating followed by 3 min of terror.

—engineer and rocket designer Paul Breed on Twitter, December [12](#) & [13](#), 2020

¹ Notwithstanding these comments, Hadfield recently joined Virgin Galactic’s [“Space Advisory Board.”](#)

What are Virgin Galactic shareholders so enthusiastic about? In a word, space. The success and high profile of “new space” trailblazers, especially Elon Musk’s SpaceX, has reignited global interest in the final frontier, but, since SpaceX is privately held, public-market investors have cast about for alternative ways to bet on space and seized on Virgin Galactic as their best option. (The cute ticker “SPCE” doesn’t hurt either; we wonder how many Virgin Galactic shareholders at any given time believe they’re actually SpaceX shareholders.)

In our view, this is a case of mistaken identity. For all of Virgin Galactic’s efforts to pitch itself as the future of space travel or space tourism, it bears little resemblance to what people imagine when they hear those phrases. Analogies can help – others have characterized the company’s planned offering as [“a high-altitude bungee jump”](#) or [“simply a roller coaster for rich people”](#) – but, to dispel some of the misunderstandings, we believe it’s worth going over the expected Virgin Galactic experience in detail, with a critical eye. It’s worth remembering, though, *that all of this is still completely hypothetical*: the company’s current-generation vehicle, SpaceShipTwo, has only reached what the company regards as “space” – ~80 km up, still 20 km short of the Kármán line – on two occasions. The first, in December 2018, included two test pilots and no passengers; the second, in February 2019, included two pilots and the first ever passenger, Virgin’s “chief astronaut instructor” Beth Moses, an aerospace veteran who had previously been through [more than 400 zero-g parabolic flights](#) in conventional airplanes. No unaffiliated passengers, let alone anyone not used to extreme and dangerous flying, have ever flown on SpaceShipTwo. The scenario that follows also assumes that *everything goes according to plan* – a bold assumption to make for a company with Virgin Galactic’s history of error, delay, and disaster.

The Virgin Galactic amusement ride will begin at Spaceport America in New Mexico, a \$250-million taxpayer-funded white elephant whose scandalous history could be the subject of its own report. (When the construction of the spaceport was announced in 2005, Branson [said](#) that Virgin Galactic would use it to “send 50,000 customers to space in the first ten years of operation.” So far, the actual number has been zero.) Passengers will initially have to travel to the middle of a desert in New Mexico; the nearest town, called Truth or Consequences (population: ~6,000), is 20 miles away. Once there, the customer will spend three full days on pre-flight training “to prepare...to safely experience the spaceflight, particularly the key attributes of the unique sensation of weightlessness and the feeling of dramatic acceleration upon launch” (source: [October 2019 prospectus](#)). This sounds benign enough, but Beth Moses gave a journalist [a more vivid sense](#) of what this training might entail (emphasis added):

Occasionally, she said, “passengers may get some grayout,” a loss of color perception, which is the mildest form of g-induced stress. “And we may, once in a blue moon, have someone who’s on the edge of having more than grayout”—ranging from tunnel vision to brief “G-LOC,” or loss of consciousness. But, she added, **“we’re going to show them how to keep some blood in the back of their eyeballs.”**

(The risk of G-LOC is especially acute for Virgin Galactic's pilots, who will experience more intense g forces than passengers; since there is no autopilot system, pilots need to remain fully alert for anyone to make it back alive.)

On the fourth day at the spaceport, it will finally be time to launch. First, WhiteKnightTwo, a customized twin-fuselage airplane, will take off, with SpaceShipTwo “attached like a marsupial to [its] belly,” in the memorable [phrase](#) of journalist Nicholas Schmidle. During Virgin Galactic's first successful “space” mission in [December 2018](#), this phase lasted 49 minutes, during which a hypothetical customer would simply be sitting and waiting, carried aloft by the larger craft. Then, WhiteKnightTwo will drop SpaceShipTwo. For a few hair-raising seconds, the craft will simply plummet, but, if all goes according to plan, the SpaceShipTwo pilots will then successfully activate the rocket motor, which will burn ferociously for 60 seconds, then shut off. The craft will then coast to its apogee (well below the Kármán line), providing what Virgin calls “several minutes of weightlessness” (likely three to four) before falling back down toward the spaceport runway. With the rocket motor spent and no other major energy source available, this descent will be purely an unpowered glide; if the pilots somehow miss the runway, there will be no straightforward way to circle back and avoid an ugly crash landing. Incredibly, to reduce the craft's weight, SpaceShipTwo doesn't even land with a traditional front wheel; it has a *piece of wood* that serves as a skid. One [observer](#) of a SpaceShipTwo test-flight landing in 2013 even noted that “[t]he weather was perfect and the wind was blowing out of the east, which meant that when the spaceship slid to a stop on its landing gear and wooden nose skid, **the handful of spectators got a whiff of burnt wood**” (emphasis added). Though it might be a clever engineering workaround, the substitution of a wooden skid for a normal wheel highlights just how rickety – how just barely functional – SpaceShipTwo is.

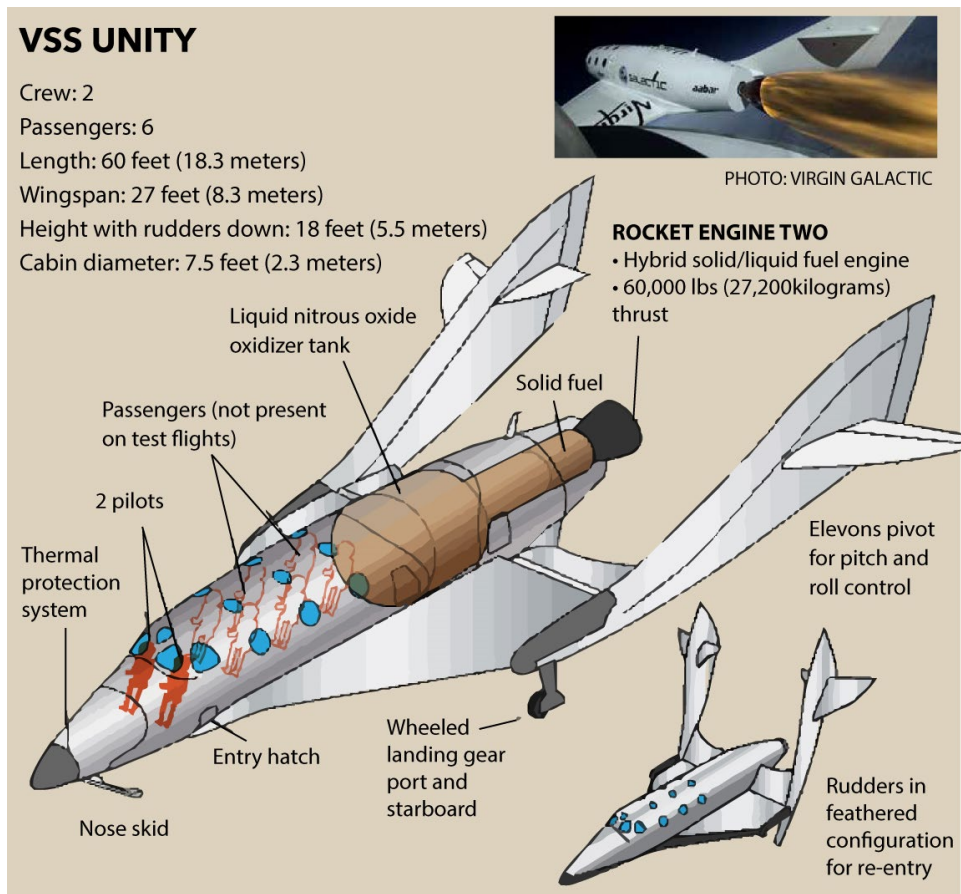
How long will passengers spend with SpaceShipTwo doing more than just being lugged up by WhiteKnightTwo? Roughly 15 minutes, including one minute of rocket fire followed by “several” minutes of weightlessness. From beginning to end – from the takeoff of WhiteKnightTwo to the landing of SpaceShipTwo – the entire process will last about an hour.² And that's it. A seven-hour flight to El Paso (if leaving from New York), a two-hour drive into the middle of nowhere, three days of classes (including Keeping Some Blood in the Back of Your Eyeballs 101), all for 15 minutes in a rocket-powered parabolic arc, a small portion of which might, by one controversial and nonstandard definition, impinge upon “space.” That'll be \$300,000, please. Is this “tourism”? Usually, a tourist gets to spend meaningful time in a new place, not come and go in a matter of minutes.

² Virgin Galactic's [October 2019 prospectus](#) claims that SpaceShipTwo “has a flight duration, measured from the takeoff of our carrier aircraft to the landing of SpaceShipTwo, of **up to approximately** 90 minutes.” However, during the December 2018 [test flight](#), WhiteKnightTwo takeoff was at 10:10 a.m. EST; SpaceShipTwo drop, 10:59 a.m.; and SpaceShipTwo landing, 11:14 a.m., for total real-world flight duration of 64 minutes, with 49 minutes of WhiteKnightTwo acting as carrier and 15 minutes of SpaceShipTwo independent flight. During another test flight in 2018 (albeit one with a shorter rocket burn), SpaceShipTwo's independent flight time was only 13 minutes (source: [New Yorker](#)).

And how much fun is it to be in this version of “space” anyway? Again, the only people who have actually been through a version of this experience so far are seasoned test pilots and aeronautical adventurers who can swap personal stories about run-ins with g-induced loss of consciousness. One problem for more ordinary people – besides the fear induced by the noise and intense acceleration – will be motion sickness, which could easily ruin their few minutes of weightlessness. An astrobiologist with an M.D. discussed some of the problems [back in 2012](#):

Although symptoms of space motion sickness typically don’t appear during the first 30 seconds of weightlessness, astronauts often feel them in the first few minutes after reaching space, which makes it a concern for suborbital tourists. Anti-motion sickness drugs might not be enough. Astronauts typically try to minimize head movements and stay still during their first moments in space. Tourists may want to plan their moves carefully, or just accept that once-in-a-lifetime acrobatics are worth a little vomiting.

Even if none of the passengers ends up vomiting in zero g, it seems unlikely they’ll be able to do much besides look out the windows; the cabin just isn’t that large. A [2014 Space.com infographic](#) gives a sense of the scale. With four to six inexperienced passengers crammed inside a cabin only 7.5 feet in diameter, sandwiched between the cockpit and the rocket motor, will there really be a lot of time or space for somersaults or any other “acrobatics”?



Source: [Space.com](#)

Tellingly, in recounting her experience as the first passenger aboard SpaceShipTwo, Beth Moses [wrote](#) that “[t]he cabin felt just the right size, I was never out of reach for something to touch to help me move around.” To our jaded ears, this sounds a bit like a real-estate agent describing a tiny apartment as “cozy.” Indeed, one [photo](#) from her trip, showing her floating up into the cockpit area (which is not walled off from the rest of the cabin), is enough to induce claustrophobia. Is Virgin Galactic really going to stuff three to five additional people in there? What if they all head toward the cockpit at the same time?



Source: Virgin Galactic via [Parabolic Arc](#)

Of course, risk-loving people with money to burn do exist, but how many of them would sign up for this experience if they understood what it would really be like – not just expensive and dangerous but often unpleasant, with only a brief window of exhilaration possibly marred by floating vomit? Surely this isn't the best bang for one's thrill-seeking buck.

Indeed, it's already been possible for many years to obtain the experience of weightlessness much more cheaply and safely: by booking a flight with the Zero Gravity Corporation, whose modified Boeing 727, flown in parabolic arcs that simulate the zero g of spaceflight, is affectionately known as the “vomit comet.” Paul Breed, the rocket designer quoted above, has explicitly [pointed out](#) that, relative to the Virgin Galactic experience, “[y]ou get more cumulative zero G time on a vomit comet for 1% of the price” – just [\\$6,700](#) for a flight in Long Beach, California. Though it never reaches extremely high altitudes, the Boeing 727 is spacious enough to allow for plenty of hi jinks that would likely be infeasible on SpaceShipTwo:



Source: [Zero Gravity Corporation](#)

But is the world beating a path to Zero-G's door? Is the demand for weightless adventure large enough to make this enterprise worth billions? Not really. In a 2016 [article](#) about Zero-G, the company's president said that it "operates between 70 and 80 flights a year, each with about 25 passengers"; at \$5,000-7,000 per passenger, that implies annual revenue of ~\$10 million – likely an overestimate, according to our discussion with a former employee, who pointed out that many flights operate well below capacity and many seats are given away for free to celebrities and influencers to promote the brand. In fact, though Zero-G recently [received](#) an infusion of cash from a private-equity firm, as [recently](#) as 2019 its "financial distress was so extreme that the company could not make payroll."

Virgin Galactic does, of course, promise more than just the experience of weightlessness – but does it promise enough to justify an astronomical ticket price? If Zero-G is a modest niche business, is Virgin Galactic really worth \$8 billion? This question will only become harder to answer as more direct competitors begin to breathe down Virgin's neck.

Real Competition Is Imminent

In April, 2015, after Blue Origin completed a successful test of New Shepard, its space-tourism rocket, [Virgin Galactic President Mike] Moses said to me, “I see that and go, ‘Crap!’ Because I look at their timeline and see that they have a good shot at beating us.”

—Nicholas Schmidle in [The New Yorker](#), August 2018

In February, Jeff Bezos [announced](#) that he was stepping down as CEO of Amazon to focus on other projects, including Blue Origin, his spaceflight company, which he has been personally funding by selling a billion dollars’ worth of Amazon stock every year [since 2017](#) and which he has [called](#) “the most important work I’m doing.” Previously known for being quiet, even secretive, and moving forward at a slow pace, Blue Origin has recently begun to raise its profile – a very bad omen for Virgin Galactic.

Blue Origin’s long-term aspiration is to enable millions of people to work and live in space; to that end, its large, reusable New Glenn rocket is designed to put heavy loads into orbit. But Blue Origin has also been testing a smaller “suborbital tourism vehicle” known as New Shepard, “[t]he strategic objective” of which, in Bezos’s [words](#), “is to practice...[A] lot of the subcomponents of New Shepard actually get directly reused on the second stage of New Glenn.” Thus, unlike Virgin Galactic’s system, which was designed from the start to just barely “slap the rim of space” and nothing more, New Shepard – though also intended to simply shoot up toward the Kármán line and then fall back down – was designed as a stepping stone to the much more difficult project of full-scale orbital spaceflight, with its vastly higher speeds and altitudes. Thus, for instance, while Virgin Galactic’s SpaceShipTwo uses a bespoke rubber-and-nitrous-oxide hybrid rocket motor that eschews the difficulties of cryogenically stored propellants but can’t scale up to orbital capability, New Shepard uses the old, proven standbys: liquid hydrogen and liquid oxygen. While Virgin Galactic minimizes the power required for its rocket by using a carrier aircraft to haul it up the first 45,000 feet, New Shepard has the power to simply take off vertically from the ground. And while Virgin Galactic requires highly skilled human pilots to manually control two complex, one-of-a-kind vehicles, New Shepard is fully automated and requires no human pilots at all. In sum, Virgin Galactic has taken many shortcuts; Blue Origin hasn’t.

Additional design details only stack the deck further in Blue Origin’s favor. For customers who mainly care about the view, the individual windows on the New Shepard capsule are 5 to 9 times larger than those on SpaceShipTwo. For those more concerned with comfort, New Shepard’s parachute-slowed descent, coupled with a retro thrust system designed to further soften the landing, appears gentler than SpaceShipTwo’s runway landing on a scorched wooden skid. And for those who prioritize style, New Shepard just looks and feels like a classic spacecraft from the good old days.

In April, Blue Origin [completed](#) its 15th successful unmanned test launch of New Shepard, easily going beyond the Kármán line. Now the company is [auctioning off](#) a single seat on its

next test flight (the first to include a human crew), scheduled for July 20th, with proceeds to go to its nonprofit foundation, Club for the Future. Though not yet representing full “commercialization,” Blue Origin’s smooth and rapid recent progress has clearly put it in the lead.

For years, Virgin Galactic has known that Blue Origin was working toward a competitive suborbital “tourism” offering, but it had a large enough head start, and Blue Origin appeared to be moving so slowly, that it was always just an abstract threat. Between the accelerating pace of Blue Origin’s test flights, the prospect of a near-term launch with real, live humans on it, and the shift in Jeff Bezos’s personal focus, the Blue Origin threat has rapidly gone from abstract to concrete. Bezos is, of course, no stranger to cutthroat competition; what are the odds that he not only outdoes Virgin Galactic on flight capabilities but also undercuts it on price?

Bezos already fired a shot across the bow in a [2019 interview](#) with the Space News writer Jeff Foust, drawing attention to Virgin Galactic’s technical weakness:

Foust: Do you think about New Shepard in sort of the competitive landscape? There’s Virgin Galactic, there’s SpaceShipTwo. ... Do you think about how that’s going to shake out?

Bezos: Yes, I do. One of the issues that Virgin Galactic will have to address, eventually, is that they are not flying above the Kármán line. Not yet. The vehicle isn’t quite capable. So for most of the world, the edge of space is defined as 100 kilometers [62 miles]. In the US it’s different [80 kilometers or 50 miles]. But I think that one of the things that they will have to figure out is how to get above the Kármán line. We fly to 106 kilometers [66 miles]. We’ve always had as our mission that we wanted to fly above the Kármán line, because we didn’t want there to be any asterisks next to your name about whether you’re an astronaut. And so that’s something they’re going to have to address, in my opinion.

Foust: So with you flying New Shepard, you’ll definitely be above that 100 kilometers, no asterisk?

Bezos: Absolutely.

Virgin Galactic supporters can complain all they want about the arbitrariness of a single boundary line for “space”; the fact remains that SpaceShipTwo has failed to achieve the same technical feats that allowed its predecessor to claim the X Prize 17 years ago, and competitors will not be shy about pointing out that abysmal lack of progress.

On a longer time scale, Virgin Galactic will face an even more challenging form of competition: true *orbital* space tourism. Already the wheels are in motion: as veteran space journalist Doug Messier put it in a recent headline, “[Private Space Missions Multiplying Like Rabbits](#).” SpaceX’s Crew Dragon vehicle, which proved its worth last year by carrying NASA astronauts to and from

the International Space Station, is now expected to take four private citizens into orbit for two to four days by the end of this year; meanwhile, another private group plans to take Crew Dragon to the ISS for an eight-day stay early next year. Further down the road, a Japanese billionaire aims to take SpaceX's planned Starship spacecraft on a six-day voyage flying around the moon. Though deadlines for these missions have a way of slipping, it's becoming harder to deny that genuine space tourism – going into earth orbit (or beyond) using high-powered rockets and staying there for extended periods of time rather than just a few minutes – is becoming a reality. Of course, such trips will be extremely expensive at first, with members of one group [reportedly](#) paying \$55 million each. But costs will inevitably fall. (Elon Musk has [offered](#) a back-of-the-envelope estimate of Starship's long-run marginal cost per flight: \$2 million. If it can carry [100 passengers](#), then the cost per passenger will be just \$20,000.) An astute [commenter](#) on the tech news site Ars Technica framed the issue well:

I feel like suborbital tourism as a concept at this price point is going to miss its window of opportunity very soon. 15 years ago this was an exciting concept and there would have been a lot of people who would have saved for this as an aspirational once-in-a-lifetime opportunity.

Now, with the cost of orbital flight dropping so quickly, there's the prospect of orbital tourism at a similar price within a decade. If you only have the means to purchase one of these experiences in a lifetime, I'm sure most people will hold out for an orbital opportunity.

In the long run, then, Virgin Galactic will be squeezed from both sides: Blue Origin's New Shepard will outcompete it among suborbital thrill-seekers, while SpaceX and perhaps eventually Blue Origin's New Glenn will outcompete it among real space enthusiasts. It's hard to make a lot of money when you're up against the passion projects of the world's two richest men.

Unsafe at Any Speed

...Geoff Daly [a British rocket engineer] wrote to the Federal Aviation Administration describing 'the considerable concern' expressed by the 'rocket motor/engine arena worldwide'. After describing 'a very serious situation' caused by Virgin's use of nitrous oxide in a hybrid, Daly concluded, 'This is another accident waiting to happen.' Among those concerned, he added, was the 'gentleman [who] had Glenn May die in his arms'. He was referring to the fatal accident in 2007 witnessed by a Scaled consultant. 'I still want to know', the eyewitness had emailed Daly, referring to May's death, 'if every one of those 500 prepaid passengers know about the fatal accident that left my friend dead with a blown open chest and exposed beating heart in the last seconds of his life?'

—Tom Bower, *Branson: Behind the Mask* (2014)

*“The structural integrity of the entire stabilizer was compromised” [after a 2019 test flight], Todd Ericson, a test pilot who also served as a vice president for safety and test, said, according to a soon-to-be-published book. **“I don’t know how we didn’t lose the vehicle and kill three people.” ... “This should have been a Come-to-Jesus Moment, not the kind of thing you brush under the rug,”** Ericson said, according to the book.*

—[Washington Post, February 1, 2021](#)

Virgin Galactic’s technology would not merit the company’s \$8 billion valuation even if it always worked as intended. But the tragic reality is that it often doesn’t. The development of SpaceShipOne and SpaceShipTwo has so far killed four people, seriously injured four more, and led to numerous harrowing close calls – many of which only became public knowledge years later, since Virgin Galactic didn’t disclose them. While the company contends that these incidents are just the growing pains of a new technology, it’s debatable just how “new” it is. According to a biography of Richard Branson, Tommaso Sgobba, the former president of the International Association for the Advancement of Space Safety, “disliked Branson’s boastful description of Virgin Galactic as a trailblazer. ‘He’s not building new technologies but just copying very old ones...No new principles of physics are involved. SpaceShipTwo is getting no higher than the high-altitude planes developed after 1945.’”³ Indeed, the craft most similar to SpaceShipTwo is the [X-15](#), a hypersonic, rocket-powered plane developed by the US government in the 1960s. The X-15 flew 13 flights that reached what Virgin Galactic would call “space” (an altitude of 80 km/50 mi); “[t]hat’s the basis of our models,” Virgin Galactic’s president told a [journalist](#). But the X-15 is also a sobering precedent: [one](#) of those 13 suborbital flights ended in death and destruction when the pilot lost control of the craft’s descent and entered into a high-g spin that killed him and broke apart the plane. Soon after, the X-15 was retired.

Below we summarize the poor safety track record of Virgin Galactic’s technology. At times, the company has tried to shift the blame onto partners and contractors, but the key point isn’t who did what; it’s that the fundamental design itself, which traces back to SpaceShipOne and the X Prize, is flawed and dangerous, wholly incompatible with routine use by inexperienced civilians.

- December 2003: in [its first powered test flight](#), “SpaceShipOne sustained what Scaled Composites called minor damage at the end of the flight when its left landing gear retracted at touchdown at Mojave airport, causing the aircraft to veer to the left and leave the runway.”
- [June 2004](#): “a control needed to steer SpaceShipOne...malfunctioned. The problem caused [the pilot] to veer more than 20 miles outside the flight’s planned re-entry zone. ... The pilot [also] said that immediately after he fired his engines, SpaceShipOne rolled 90 degrees to the left. When [he] tried to correct the uncommanded movement, the ship then rolled 90 degrees to the right.”
- [September 2004](#): “During the motor burn the spacecraft began to roll uncontrollably.”

³ Tom Bower, *Branson: Behind the Mask*.

- July 2007: while engineers were conducting an on-the-ground, “cold flow” test of SpaceShipTwo’s motor by sending nitrous oxide through it – a test that did *not* involve any ignition or other fuel – the nitrous-oxide tank exploded, [killing three people and seriously injuring three others with shrapnel wounds](#).
 - Nitrous oxide, though considered safe in small quantities, can, under the proper conditions, spontaneously and explosively decompose into nitrogen and oxygen. A 2017 [report](#) from the U.S. Chemical Safety and Hazard Investigation Board noted that “[s]ince 1973, the nitrous oxide industry has averaged one major explosion about every seven years” – but “since 2001 **these explosions have occurred more frequently** with an average of one explosion every four years during this timeframe” (emphasis added), often caused simply by a transfer pump that happens to generate too much heat. A 2007 op ed in Space News was headlined “[Dangers of Nitrous Oxide No Surprise](#),” yet Virgin Galactic’s technology continues to use the substance as its oxidizer.
- [September 2011](#): “A malfunction during the most recent test flight of the private spacecraft SpaceShipTwo sent the vehicle hurtling out of control until its crew could stabilize the craft for a safe landing. ... According to one observer of the craft’s rapid descent, ‘It dropped like a rock and went straight down.’”
- May 2013: Virgin Galactic’s partner Scaled Composites “was testing a hybrid motor...Seemingly unexpectedly, the engine exploded, sending the nozzle and casing beyond the perimeter fence. The devastation resembled the scene in 2007, except this time there were no casualties” (source: Bower, *Branson: Behind the Mask*). The “explosion [all but obliterated](#) the test stand.”
- September 2014: during a powered test flight, [VSS Enterprise](#), the first iteration of the SpaceShipTwo design, broke apart seconds after firing its rocket, killing its co-pilot and seriously injuring its pilot, who miraculously [survived](#) a 10-mile parachute-slowed fall but broke his arm and collarbone and endured severe damage to his eyes. The proximate cause of the crash was the co-pilot’s premature activation of the feather mechanism, but the [Wall Street Journal](#) reported that, according to a former government official, “Nagging vibrations were ‘very distressing to pilots because they simply couldn’t read their instruments,’” though Virgin Galactic has denied this claim. A government [investigation](#) found that “pilots were unfamiliar with the vibration and loads to be expected during powered flight.”
- [2016](#): on the morning of a test flight, “a crewman announced bad news: an hour earlier, he’d been inspecting the spaceship with a flashlight, and noticed a one-inch hairline crack along the spine of the vehicle, near the spot where it attached to WhiteKnightTwo.” Virgin Galactic decided to proceed with the flight anyway; fortunately, it was without incident.
- [2017](#): “A technician accidentally damaged the bonding on SpaceShipTwo’s body with a blast of compressed air that he’d applied to remove drill shavings; repairs took weeks. Then the engineers discovered a problem with the horizontal stabilizers, or h-stabs, which are attached to the tail booms and control pitch and roll at supersonic speeds. One day, during ground tests, the h-stabs suddenly stopped working. It took months to solve the problem.”

- [April 2018](#): during a powered test flight, the pilot “suddenly felt the wings tipping, as if the spaceship were about to roll upside down. ... The spaceship was slipping beyond his control. ... SpaceShipTwo had somehow rolled over without his noticing. ‘Oh, shit,’ Stucky [the pilot] said. ‘The gyros are messed up.’ For unknown reasons, they indicated that the spaceship was right side up.” Fortunately, the pilots managed to recover. “As it turned out, there had been a glitch in the gyros’ software; **the manufacturer had issued a patch, but hadn’t indicated that it fixed a major problem, so Virgin Galactic hadn’t installed it**” (emphasis added).
- February 2019: after a powered test flight, “company officials [discovered](#) that a seal running along a stabilizer on the wing...had come undone – a potentially serious safety hazard...[T]he ‘seal had disbanded on the way up’...ultimately leaving a ‘wide gap running along the trailing edge of the right h-stab’...When Mike Moses, Virgin Galactic’s president, missions and safety, saw the gap, ‘he felt his stomach drop’...Virgin Galactic ‘tried to keep the h-stab problem quiet, worried that it might spook customers.’
 - According to a journalist who was embedded at Virgin Galactic for four years, the company’s vice president of safety “concluded that members of the maintenance team were ‘pencil whipping’ inspections – signing for inspections that were not conducted properly.” The inspectors not only failed to notice the structural flaw in the h-stab **“but also missed a bag of screws taped to the inside of the h-stab.”** The vice president recommended firing the head of maintenance but was rebuffed. He threatened to resign but was moved to a different position until he left the company in October 2020.
 - Additional [coverage](#) of this recently revealed incident by the space news site Parabolic Arc provided more details from anonymous sources, who noted that, after this flight, SpaceShipTwo was “[w]ay too damaged to fly again. Whole structure ruptured...[C]lose call...**Other serious structure problems now appearing, including composite structure coming apart. Adding bolts to try to hold things together...Mothership has problems too. Launch pylon is falling apart. [SpaceShipTwo] is way too heavy. Way heavier than mothership was designed for**” (emphasis added).
 - While Virgin Galactic told the *Washington Post* that “the company immediately notified board members **and shareholders** as well as the FAA,” this incident was, as far as we know, never mentioned to *public* shareholders during or after the SPAC process.
- December 2020: a powered test flight was cut short when, after one second of rocket burn, “the onboard computer which monitors the propulsion system lost connection, triggering a fail-safe scenario that intentionally halted ignition of the rocket motor,” according to [Virgin Galactic](#). Fortunately, the pilots again managed a successful emergency landing.

Several important themes emerge from this history of appalling incidents. First, Virgin Galactic’s materials do not appear to be robust enough for frequent use. As the company-embedded journalist [noted](#), “Building the spaceship’s frame was labor-intensive: you had to bind together sheets of honeycombed carbon by applying resin, cut the sheets into shapes with laser-guided

precision, and bake each piece in a Celotex oven.” One company official even boasted that “you can literally tape and glue parts on and off.” But over the years this highly manual, labor-intensive “tape and glue” approach has left WhiteKnightTwo and SpaceShipTwo in poor condition, even when only flying a handful of test flights per year. What would regular commercial service do to them?

Second, many close calls in the history of Virgin Galactic’s technology were narrowly avoided by the company’s skillful and courageous pilots, who compensated for a wide range of technical difficulties. But there are only so many exceptional test pilots in the world. For Virgin Galactic to be a viable, large-scale business in the long run, it can’t just rely on extraordinary individuals – but in the hands of run-of-the-mill pilots, its vehicles would become even more dangerous.

Finally, we see no trend toward improving safety over time. With each terrifying failure or near-miss, the story is always that the company has learned its lesson and can move forward once again. But new problems, like the heads of the hydra, keep coming: a tendency to roll uncontrollably, the explosive power of nitrous oxide, the danger of intense vibrations leading to pilot error, cracks and gaps in key parts, perfunctory safety inspections, computer malfunctions. What next? And do those who have expressed interest in Virgin Galactic’s flights truly realize what they’ve signed up for? We doubt it. Indeed, we agree with the industry observer who wrote the [following](#) last year:

Unless I missed something, space tourism is being marketed as the equivalent of getting on a corporate jet for, pardon the pun, an out of this world experience. It is supposed to be easy, luxurious, and safe. The people who will be able to afford space tourism are not members of the “die-hard” crowd. The industry, which actually is about high cost joy riding, may possibly be able to survive a single crash. Any more than that will destroy the market.

Conclusion

We believe that the current wave of market enthusiasm for Virgin Galactic depends on an ignorance of its long and often ugly history, as well as a misunderstanding of its core technology. The original sin goes back to SpaceShipOne, which was jury-rigged to just barely win the X Prize, with no potential for further scaling up to true orbital spaceflight. In the long run, this approach is a dead end – too expensive, unappealing, and uncompetitive to garner sizable revenues – a fact only masked, temporarily, by canny marketing. Even if the company, after nearly two decades of fits and starts, finally does manage to initiate commercial service, it will wind up in the ash heap of history – hopefully without killing or maiming any more people along the way.

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