high hopes

Is Elon Musk's Starship Doomed?

The future of SpaceX keeps blowing up, and no one knows if he can fix it.

By Jeff Wise, a science journalist and private pilot.

On a bright spring morning in 2023, SpaceX's first fully assembled Starship launch vehicle stood at its launchpad in Boca Chica, Texas, ready for its debut. Gleaming in the sun, the most powerful rocket ever built stretched as high as an office tower. It was beautiful not just for the boldness and elegance of its design, but for what it represented: the next chapter in humanity's voyage into space. Able to boost more than 100 tons into orbit, it meant that huge swarms of satellites would soon bring cheap data to the whole planet. With greater engine thrust than the Apollo program's Saturn V and reusable, it would carry astronauts back to the moon and then on to Mars.

A crowd of space enthusiasts had gathered to experience the moment, chanting along with the countdown clock, then cheering as the mighty engines let loose a wall of flame.

Then, four minutes after takeoff, the unmanned rocket blew up. The eruption of white smoke was met not with stunned silence, but whoops and cheers like you might hear at a fireworks finale. "This was a development test; this was the first test flight of Starship," explained one of the live-broadcast presenters. "And the goal was to gather the data, as we said, clear the pad, and get ready to go again."

Mission accomplished.

"Fail fast and fail often" is the Silicon Valley mantra. Make a lot of mistakes quickly so you can learn and leapfrog the competition. By that metric, the Starships have performed swimmingly over the past two years. No. 2 managed to separate from the booster, then blew up. No. 3 disintegrated on reentry. Nos. 4, 5, and 6 made it to space and splashed down in the ocean, but No. 7 exploded 11 minutes after liftoff. No. 8 spun out of control. No. 9 suffered a fuel leak and disintegrated on reentry. No. 10 exploded on the launchpad.

You don't hear as much cheering anymore.

"Having a rocket ascend a few hundred meters and blow up is not a success to me," says Dallas Kasaboski, an analyst who covers the space industry for the research firm Analysys Mason.

No one doubts that rocket tests mean failures, but the question for Starship is this: Is it just having extended teething pains, or are its failures a symptom of a fundamentally unworkable design that will never be fixed?

It's a question upon which a great deal is riding — not just for SpaceX but for the space industry as a whole, which until recently has assumed that Starship would succeed exactly as Elon Musk had promised. Plans have been laid, money has been raised, and hardware has been built for a future that seemed certain to lie just around the corner. But now, maybe the launch vehicle everyone was counting on isn't going to come. For now, no one really knows.

If we were talking about any company other than SpaceX, there wouldn't even be a debate. No one else who spent more than a billion dollars blowing up rocket after rocket would be viewed as anything other than an epic failure.

SpaceX is different. Along with incredibly deep pockets, the company has an almost mythical reputation in the space-launch industry. The first rocket it ever launched, a Falcon 1, blew up 33 seconds after takeoff. The second suffered a malfunction and failed to reach orbit. But the third one succeeded, and from then on, SpaceX built and launched more and honed and improved its designs with each iteration, ultimately launching hundreds of times at low cost and with a remarkably low failure rate. It also achieved exciting breakthroughs, like building a first stage for the Falcon 9 rocket that returns to its launchpad and lands vertically for use later, thereby further cutting costs.

"SpaceX is a company that went from nobody believed in, almost bankrupt, to dominating the market. They're launching 50 percent of everything that goes into orbit," says Kasaboski. It's a transformation that has lent the company an almost mystical aura of invincibility. "People have a great amount of faith in SpaceX."

Musk's vision was for SpaceX to do for orbital launch what Henry Ford did for cars — achieve economies of scale through mass production, which then leads to such low costs that customers can buy the product in the quantities needed for mass production. Except there wasn't a consumer. Musk solved this chicken-and-egg problem by creating his own biggest customer, Starlink, a communications company that requires a huge fleet of satellites and hence provides a business case for SpaceX's cheap mass-produced rockets. "The metaphor that I always use is *Wallace and Gromit*, the Claymation dog, where he's on a model train and he's laying the tracks in front of the train as it's rolling," Kasaboski says. Today, Starlink has more than 4 million customers and $8 billion in revenue.

Against the odds, SpaceX had built two successful businesses in two industries where profit margins historically had been thin and failure was common. But Musk had still bigger ambitions. For one thing, he wanted to help humanity find a second home on Mars. Closer to home, he wanted to build out a massive constellation of Starlink satellites, some 42,000 orbiting Earth at a time, with a collective data capacity so large that it could carry a significant share of global-communication bandwidth. To do both of those things, he needed an even bigger rocket that launched bigger satellites capable of transmitting more data.

After numerous design iterations, the machine that reached the launchpad in 2023 was an enormous reusable two-stage rocket that not only dwarfed Falcon 9 in scale but was more ambitious. The first stage, called Super Heavy, stands 233 feet tall and boosts the second stage, dubbed Starship, to 5,370 mph and then returns to land vertically at the launchpad. Unlike the second stage of the Falcon, which burns up on reentry, Starship is designed to be fully reusable, reducing launch costs even further. After accelerating to an orbital velocity of 17,500 mph, Starship is meant to either refuel and journey to the moon or Mars or to release its cargo and return to Earth. It does this by firing its rockets to slow down, then turns sideways as it reenters the atmosphere so that the drag slows it down further. Two pairs of fins allow it to steer toward a landing pad, where it uses rockets to achieve a soft touchdown.

Musk has predicted that this new configuration could bring down launch costs to much lower than the Falcon 9's. In 2022, he said that eventually, the cost of each Starship launch could be as little as $1 million — meaning it would cost just $10 to put a kilogram into orbit, a thousandth of the current price. That dramatically lower cost, together with a giant payload compartment that stretches 26 feet across, allowed potential customers to envisage all sorts of missions that wouldn't be possible otherwise.

Artemis, NASA's program to return astronauts to the moon, will use Starship to shuttle crew members between lunar orbit and the surface. "A lot of the moon infrastructure conversation that's happening right now still depends on the success of Starship," says space architect Phnam Bagley.

On the commercial side, there's Vast, a company funded by cryptocurrency billionaire Jed McCaleb to build space stations for tourism and scientific research. Haven-2, which it plans to start launching in 2028, will consist of individual modules so large that they can only be delivered to orbit by Starship. "If Starship never works out, that company goes bust," Bagley points out.

Perhaps the most important customer is Starlink. Its satellites are designed to operate at an altitude where a tiny amount of atmosphere causes their orbits to degrade over time, limiting their life span to about five years. Building and maintaining a constellation of 42,000 would mean replacing more than 8,000 a year. That would require about two launches per week of the Starship, the only vehicle able to carry Starlink's next-generation satellite. "Their plans cannot move forward without Starship," Kasaboski says.

Within the space industry, it's come to be expected that if SpaceX sets out to do something, it will do it. But this challenge of getting Starship to work may be more daunting than many realize.

Reusing both parts of a rocket, instead of just one, sounds like a modestly more ambitious undertaking — if you can do it once, why not twice? — but in fact, it's exponentially harder, since the amount of energy to be dissipated while returning to Earth goes up not as a linear function of velocity but its square. The energy gets turned into heat, which sends the temperature of the Starship soaring into the thousands of degrees, such that it glows white-hot. To reduce the effects of this heat, the rocket's exterior is coated in thermal tiles. But these are heavy. So is the internal bracing required to hold the ship together during the turbulence of reentry.

All that weight has to be subtracted from the payload that is sent up during launch. So there's a very strong incentive to use as little of it as possible. The trick is in calculating how much you can reduce that weight without risking catastrophic failure.

For critics, like Substack writer Will Lockett, the fact that Starship has failed so many times in a row is proof that the concept is fundamentally unworkable. "SpaceX is having to make the rockets too light, resulting in them being fragile, meaning that just the vibrations from operation with a fraction of its expected payload would be enough to destroy the rocket," he wrote in one typically acerbic post.

Many industry insiders feel that, given Starship's enormous planned lift capacity, SpaceX engineers have plenty of wiggle room to add weight to the craft's structure. But doing so will increase the cost of launching each kilogram into orbit, which in turn undermines the craft's economic viability. "The question is not, 'Can you build an upper stage that is reusable with high-performance rocket engines?'" space-launch engineer Charlie Garcia says. "The question is, 'Can you do it cost-effectively, and can you do it with quick reusability turnaround?'"

This problem has arisen before. After the wild success of the moon landings, NASA commissioned the Space Shuttle, a reusable launch system that would make reaching orbit so cheap, safe, and easy that it would serve all of the agency's needs without any backup. "I remember reading a book in the 1970s about how the space shuttle would be flying every two weeks and cost low hundreds of dollars per pound to orbit," says Grant Anderson, co-founder of the space-systems-maker Paragon Space Development Corporation, which helped launch SpaceX in 2002. "It never did that, obviously."

The Space Shuttle worked, but not at the price and tempo that was originally billed. And then, fatally, it blew up: once on launch with *Challenger* and then two decades later on reentry. The project was canceled. Having put all of its eggs in one basket with a design that in retrospect had been deeply flawed all along, NASA was left with no human-rated launch ability for a decade until SpaceX came to the rescue with the Falcon. By pinning all its ambitions on Starship, Musk might be repeating NASA's own mistake.

When would we know if Starship is toast? One major red flag is persistent failures. “If you have a failure at the same stage twice for the same reason, and they can’t solve the problem, that’s an indication that there’s a design flaw that’s more than just an ‘Oops!’” says Anderson.

Starship’s next test will come in early August. Even SpaceX’s super-confident cadre of engineers will likely watch with a lump in their throats. There are so many fireballs a reputation can take.

“I haven’t heard one person in the space industry tell me that Starship is doomed,” Bagley says. “Not yet.”