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Falcon 9's successful return to the launchpad in 2015 proved orbital-class boosters could be reused – and sparked a spaceflight revolution

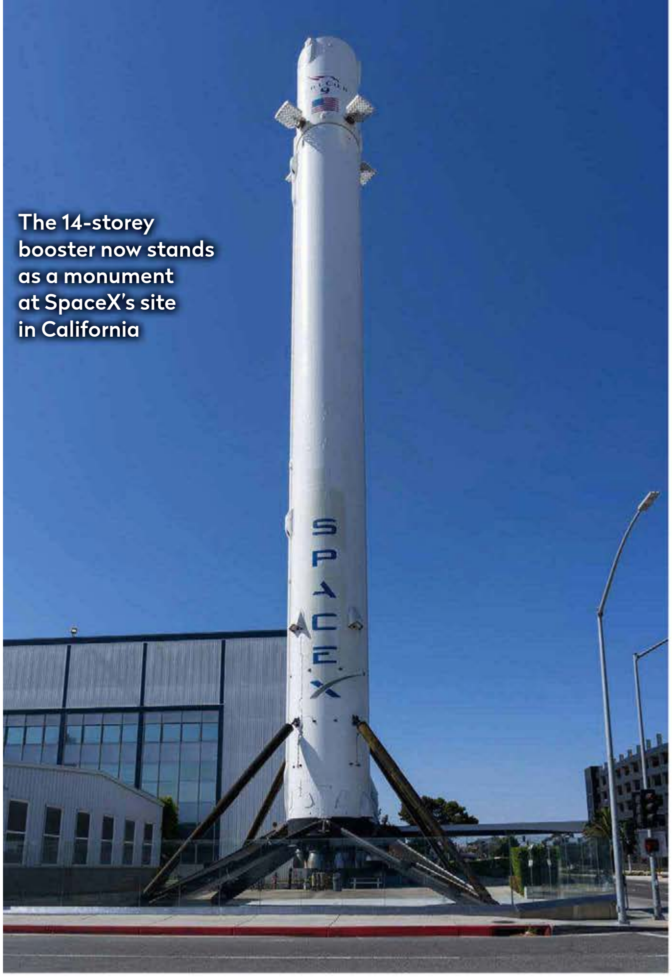
SPACEX

10 years of reusable rockets

Ben Evans charts the rise of multi-flight spacecraft, the tech revolution that's transforming our access to space

On the intersection of Crenshaw Boulevard and Jack Northrop Avenue in Hawthorne, California, stands an unlikely monument – a modern-day obelisk that bears silent witness to a space revolution. Fourteen storeys tall and partially screened by toughened glass, this SpaceX Falcon 9 was the first orbital-class rocket to launch into space and then return to land intact. Ten years ago, it inspired millions. Today, it inspires even more.

Its nine Merlin engines gleam in the California sunlight. Four aluminium grid fins, like great mechanised ears, helped guide this behemoth back from space to alight on a Cape Canaveral landing pad. And four extendable landing legs, spanning 18 metres (60ft) from tip to tip, recall the night ▶



The 14-storey booster now stands as a monument at SpaceX's site in California


▲ Touchdown triumph: the 21 December 2015 flight, from launch (top) and stage separation (middle) to landing back on the pad (bottom) after delivering 11 satellites to low Earth orbit

▶ of 21 December 2015, when it blasted into space, flipped around in mid-flight and roared safely home.

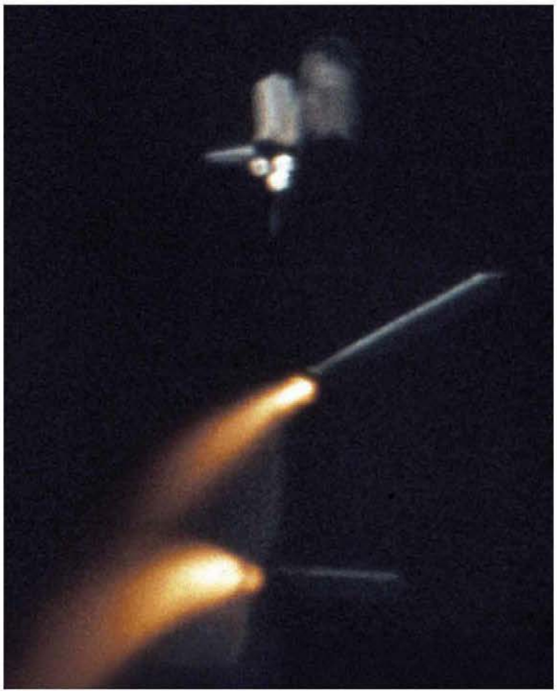
Until that night, 'orbital-class' rockets were discarded after every mission – a lack of reusability that kept the cost of space travel eye-wateringly high. After all, scrapping a brand-new airliner to build a new one after each flight would make air travel prohibitively expensive. But rockets are not airliners. They attain greater energies, reach immense speeds and must withstand tremendous thermal, aerodynamic and structural loads. That demands high levels of reliability and makes them hard to inexpensively reuse.

From Shuttles to SpaceX

Rocket reusability is not new. NASA's partially reusable Space Shuttle flew 135 times between 1981 and 2011. Its fleet of five reusable orbiters – Columbia, Challenger, Discovery, Atlantis and Endeavour – completed multiple missions into low Earth orbit, and its solid-fuelled rocket boosters parachuted into the ocean after each launch and were used again. Only the Shuttle's giant external fuel tank was discarded on each flight.

But the Shuttle's goal to make space access reliable and routine never came to pass, due to its complexity and technical challenges, notably its high-performance main engines and fragile thermal protection tiles. Hopes that individual orbiters would fly 100 times were never realised – even Discovery, the fleet's leader, completed just 39 flights between 1984 and 2011. And the Shuttle never flew more than nine missions in a single year – a far cry from early plans for launches every week.

From the outset, Elon Musk's SpaceX considered rapid rocket reusability as an essential prerequisite


◀ Space Shuttle boosters were jettisoned minutes into a flight and recovered from the ocean for reuse

for a spacefaring species. Musk opted for a 'powered descent' architecture – that is, using restartable, throttleable engines, landing legs, grid fins to furnish precise aerodynamic control and complex computer algorithms to vertically land boosters with pinpoint accuracy on drone ships at sea or on ground-based landing pads.

But the Falcon 9's early drone-ship landings ended dismally. One booster crashed when its grid fins ran out of hydraulic fluid. Another hit the ship at the wrong angle, toppled over and exploded. With grim humour, Musk called it "rapid unscheduled disassembly". A tongue-in-cheek euphemism,

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▲ **Wreckage of a Falcon 9 that exploded on a drone ship in 2016 after one of its landing legs failed to lock**

perhaps, but for SpaceX it was an entirely new design philosophy. Earlier rockets were developed to full maturity before their first launch. But Musk's approach was to iteratively test prototypes to the point of failure, learn lessons quickly and aggressively, make improvements, then fly more, test more and learn more.

"The Falcon has landed"

Late in 2015, SpaceX announced plans to land its first Falcon 9 on solid ground. A disused Cape Canaveral launch facility had been rebuilt to form two giant landing pads and, on 18 December, the Federal Aviation Administration (FAA) granted permission for the landing attempt to go ahead. Local residents were warned that they might hear a loud sonic boom as the returning booster decelerated below the speed of sound, seconds before touchdown. And Cape Canaveral workers received safety notices telling them to take shelter away from windows and doors should the landing go awry.

At 8:29pm EDT on 21 December, the Falcon 9 rose from Cape Canaveral's Space Launch Complex 40 atop a pillar of golden flame, casting an eerie glow over Florida's space coast. Eighty seconds into ascent, it exceeded the speed of sound. And after three minutes, at an altitude of 80km (50 miles), right on the edge of space, the Merlin engines shut down right on time and the rocket's first and second stages parted company.

For its first stage booster, the moment of truth had arrived. Travelling at 4,600km/h (2,900mph), under aerodynamic conditions comparable to balancing a broomstick in the palm of your hand during a fierce storm, the Merlins ignited three times to reverse course back to Florida, flip around and decelerate to a landing speed of 7.2km/h (4.5mph).

Moments before touchdown, the booster's landing legs unfurled, and at 8:38pm it fell gently onto the concrete pad. The last glimmer of flame from its engines flickered for a second or two, then fell dark. "The Falcon has landed," exulted the SpaceX commentator to an online audience of millions.

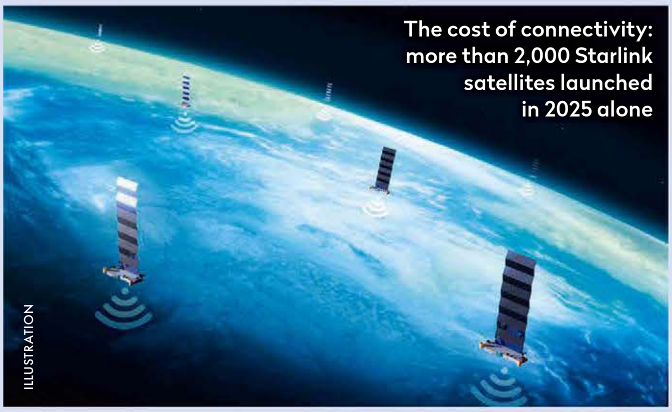
Success was triumphantly accomplished in under 10 minutes. After the flight, the booster was inspected, refuelled and test-fired to see if future ▶

The downside of reusable rockets

Congested skies are the price we pay for easier, cheaper hops into space

At first glance, the benefits of rocket reusability and sustained access to space are self-evident: advancing our path to becoming a spacefaring species. But with a far higher rocket launch rate than ever before, serious concerns have arisen about the wisdom and potential impacts of new and emerging space markets.

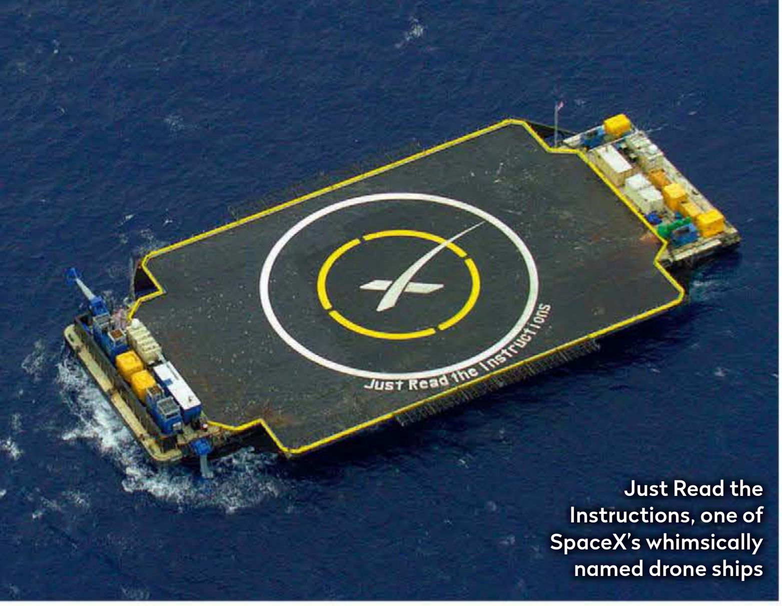
Take 'mega-constellations' of small internet satellites, like SpaceX's Starlink network, launched in batches by the Falcon 9 since 2019. More than 9,700 Starlinks have been put in space – including over 2,000 in 2025 alone. That adds to an already cluttered low Earth orbit environment that has irked the astronomical community with its impact on light pollution.



The cost of connectivity: more than 2,000 Starlink satellites launched in 2025 alone

The risks from worsening space debris are substantial. In 2023, Falcon 9 rockets put 1.2 million kg (2.6 million pounds) of payload into orbit; last year, that figure rose to 1.5 million kg (3.3 million pounds). That poses a significant hazard to other satellites and to human space missions that operate in the low Earth orbit domain. The looming retirement of the International Space Station has a group of private entities – from AxiomSpace and Vast to Blue Origin and Sierra Space – waiting in the wings to assemble large private space stations before 2030, all of which will benefit from the lower costs offered by reusable launch vehicles.

And coupled with Blue Origin's New Shepard having generated over $100 million in space tourism, these lucrative markets will inevitably expand as launch prices fall and demand increases, congesting near-Earth space like never before. A Pandora's box in space has opened and its consequences, good or ill, remain to be seen.



Just Read the Instructions, one of SpaceX's whimsically named drone ships


▲ Recovering the fairing (which protects mission payloads) with a giant net on a moving ship

▶ rockets could also handle multiple launches. But this particular booster had savoured its first – and last – taste of space. Retired from duty, in August 2016 it was trucked from Florida to California, cleaned and then craned upright outside SpaceX's headquarters in Hawthorne.

From rare feat to routine

Ten years on, Falcon 9s have landed safely over 500 times, including 400+ drone-ship landings since 2016. SpaceX typically uses drone ships to recover boosters from heavyweight or high-orbit missions, and landing pads for low-weight, low-orbit flights. But success did not come easily. Thirteen landings failed due to low fuel, incorrect wind-speed data or engine problems – most recently in March 2025. Two boosters landed on the drone ship only to be later lost due to high winds and foul seas during their transit back to port. And in 2018, a booster missed the landing pad and landed in the water.

Improvements over the years, including retractable, self-levelling landing legs for rapid recovery and more durable titanium (rather than aluminium) for grid fins, brought greater reliability. Higher-thrust engines streamlined refurbishment. All this enabled launch rates to soar from six missions in 2015 to missions every two weeks by 2020, to a marathon 134 flights – a mission every two days, on average – last year.

Since 2017, over 50 boosters have flown at least twice. Today, 23 boosters are in active operational service, each capable of 10 flights with minor upgrades and 100 flights with periodic repairs. A booster flew a record 30th time in August 2025. Turnaround times improved, with one booster flying twice in nine days in March 2025. And intervals between missions also improved: from two launches in a month in 2014 to two launches in a day in 2021, to two launches just 65 minutes apart in August 2024.

Unsurprisingly, in terms of flight rate, SpaceX is in a league of its own among launch providers. In 2020,

Reusability by the numbers

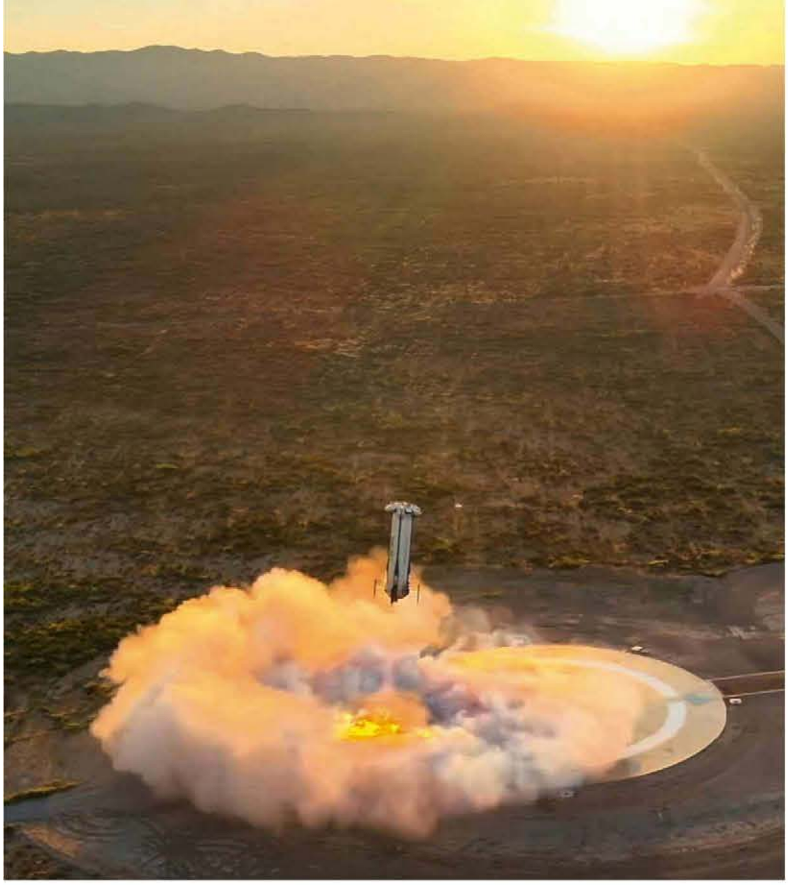
How much money is actually saved by recycling spacecraft?

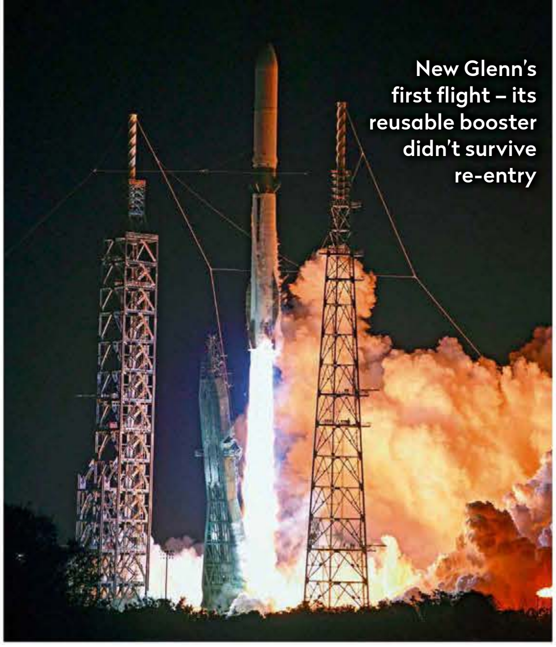
In 2024, SpaceX was responsible for just over half of the world's orbital launches, a market share that's expected to climb above 60 per cent by the end of 2025. And with a cost of $2,750 per kilogram on a reused Falcon 9, this most-flown booster in US history sits head and shoulders above any other launch service provider in the world.

Other rockets struggle to compete with SpaceX's proven reusability and high launch cadence. The now-retired Shuttle averaged $54,400/kg, ULA's Atlas V and Vulcan may reach $9,800/kg and Blue Origin's New Glenn promises launch prices of just $1,500/kg. SpaceX believes its giant Starship vehicle may achieve costs as low as $250–$600/kg when it becomes fully operational.

Since first stages and payload fairings constitute 80 per cent of the expense of a Falcon 9 launch, their recovery and routine reuse crucially keeps costs low. Since 2017, SpaceX has actively recovered first stage boosters, and since 2019 has regularly retrieved and reused fairings. In 2025, a booster flew a record 30th time and a fairing achieved a 33rd flight, helping the Falcon 9 retain its top spot as the most cost-effective launch vehicle in the world.


Return to sender: a Falcon 9 being prepared for reuse at Port Canaveral in Florida





New Glenn's first flight – its reusable booster didn't survive re-entry

Mechanical 'chopstick' arms catch Starship's returning Super Heavy booster

▲ Blue Origin has successfully landed its reusable New Shepard boosters dozens of times

Falcon 9s flew one fifth of all orbital missions. By 2024, that had risen to half. This year, Musk should seize about 60 per cent of the world's launch market.

SpaceX has also reused the Falcon 9's payload fairings since 2019, initially salvaging them with ship-based nets, then since 2021 scooping them directly from the water. In September 2025, one fairing launched a record 33rd time.

Everyone wants in

But SpaceX is not alone in this rocket reusability market. Blue Origin's fully reusable New Shepard suborbital boosters and crew capsules have flown 35 times since 2015, carrying science experiments, postcards and fare-paying human passengers to the edge of space. Its boosters land vertically under their own power, while crew capsules descend by parachute, with turnaround times as short as 59 days.

In 2025, Blue Origin launched its orbital-class New Glenn rocket for the first time; its first stage will be recovered by the company's Jacklyn barge on future missions. Rocket Lab's Neutron booster will also land on a floating platform. China's Tianlong-3, designed for up to 10 flights, will make vertical touchdowns on drone ships or ground pads. And in 2024, a prototype of China's Zhuque-3 rocket climbed to 10km (6.2 miles) before making a controlled vertical landing.

Russia's upcoming Amur rocket will feature grid fins and landing legs for reusability, as will Europe's Miura-5 and Maia boosters, scheduled to come online in 2027. Two years ago, Relativity Space's 3D-printed Terran-R rocket completed a short, low-altitude flight to test control systems, ascending to 10 metres (30ft) before performing a vertical landing.

United Launch Alliance's (ULA) Vulcan booster, first launched in 2024, will feature a reusable engine suite: its entire propulsion system will detach after engine cutoff, then parachute to a water landing for recovery and reuse. ULA anticipates this will cut Vulcan's propulsion system costs by 90 per cent and its first stage costs by 65 per cent.

Rocket Lab's Electron booster – flown 70 times since 2018 – achieved its first controlled re-entry in 2019 and its first parachute-aided splashdown in 2021. One of its Rutherford engines from a May 2022 mission was refurbished and used on another flight in August 2023.

Meanwhile, SpaceX's fully reusable Starship, which has completed 10 test flights since 2023, promises to lift enormous payloads into low Earth orbit, deliver cargo to the Moon and Mars, and potentially carry hundreds of people into space on a single launch. But its genesis has been troubled with fuel leaks, explosions, controllability issues and engine failures.

In October 2025, however, both Starship and its Super Heavy first stage successfully completed a test flight, with both components making a controlled descent. But this may be too little, too late, as NASA has expressed concerns about SpaceX falling behind schedule and, in response, has reopened bidding for its lunar lander contract.

Despite this, there's no doubt that rocket reusability has advanced at breathtaking speed over the last decade and has been far-reaching in its potential. And with other players waiting in the wings to ensure this new era of space exploration is no one-horse race run solely by SpaceX, the coming decade holds great promise as humanity prepares to occupy low Earth orbit and venture to the Moon, Mars and beyond.

Ben Evans is the author of several books on human spaceflight and a science and astronomy writer