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Cosmic Explorers: Reusable Rockets

The Launch Revolution

Aira Astralis

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Introduction

A reusable launch vehicle has parts that can be recovered and reflown, while carrying payloads from the surface to outer space. Rocket stages are the most common launch vehicle parts aimed for reuse. Smaller parts such as fairings, boosters or rocket engines can also be reused, though reusable spacecraft may be launched on top of an expendable launch vehicle.

Reusable launch vehicles do not need to make these parts for each launch, therefore reducing its launch cost significantly.

However, these benefits can be diminished by the cost of recovery and refurbishment. Reusable launch vehicles may contain additional avionics and propellant, making them heavier than their expendable counterparts. Reused parts may need to enter the atmosphere and navigate through it, so they are often equipped with heat shields, grid fins, and other flight control surfaces.

By modifying their shape, spaceplanes can leverage aviation mechanics to aid in its recovery, such as gliding or lift.

In the atmosphere, parachutes or retrorockets may also be needed to slow it down further. Reusable parts may also need specialized recovery facilities such as runways or autonomous spaceport drone ships. Some concepts rely on ground infrastructures such as mass drivers to accelerate the launch vehicle beforehand. Since at least in the early 20th century, single-stage-to-orbit reusable launch vehicles have existed in science fiction.

In the 1970s, the first reusable launch vehicle, the Space Shuttle, was developed.

However, in the 1990s, due to the program's failure to meet expectations, reusable launch vehicles were reduced to prototype testing. The growth of private spaceflight companies in the 2010s lead to a resurgence of their development, such as in SpaceShipOne, New Shepard, New Glenn, Electron, Falcon 9, and Falcon Heavy. At the same time, the US Boeing X-37 and Chinese CSSHQ military spaceplanes began deploying small satellites.

Many launch vehicles are now expected to debut with reusability in the 2020s, such as the US Starship, Neutron, Terran R, Stoke Space Nova, and Eclipse, the Chinese Long March 10 and 12, Tianlong-3, LandSpace Zhuque-3, and the European Maia and Miura 5. The impact of reusability in launch vehicles has been momentous for the spaceflight industry.

Single or main stages, as well as fly-back boosters can employ a horizontal landing system.

As of August 2026, VTVL first-stage recovery of orbital rockets has been achieved by the following:

SpaceX - Falcon 9 and Falcon Heavy

China Aerospace Science and Technology Corporation - Long March 10B

There is also the concept of a launch vehicle with an inflatable, reusable first stage.

Chapter 01: The Discovery of Reusable Rockets

In 2024, the Cape Canaveral Space Force Station initiated a 50-year forward looking plan for the Cape that involved major infrastructure upgrades

(including to Port Canaveral) to support a higher anticipated launch cadence and landing sites for the new generation of vehicles. Several companies are currently developing fully reusable launch vehicles as of January 2026. Each of them is working on a two-stage-to-orbit system.

SpaceX is testing Starship, which has been in development since 2016 and has made an initial test flight in April 2023 and a total of 12 flights as of May 2026. Stoke Space's Nova vehicle is also planned to be reusable. As of June 2026, SpaceX's launch vehicle Starship has made significant progress towards full reuse of the entire launch vehicle, both first and second stages.

The Super Heavy boosters have demonstrated capability to return to the launch site where they are caught by a "chopstick system" on the launch tower where they can then be reused. The Starship upper stage has completed six controlled splashdowns in the ocean but has not yet been recovered or reused.

Partial reusable launch systems, in the form of multiple stage to orbit systems have been so far the only reusable configurations in use.

The historic Space Shuttle reused its Solid Rocket Boosters, its RS-25 engines and the Space Shuttle orbiter that acted as an orbital insertion stage, but it did not reuse the External Tank that fed the RS-25 engines. This is an example of a reusable launch system which reuses specific components of rockets. ULA's Vulcan Centaur was originally designed to reuse the first stage engines, while the tank is expended.

The engines would splashdown on an inflatable aeroshell, then be recovered.

On 23 February 2024, one of the nine Merlin engines powering a Falcon 9 launched for the 22nd time, making it the most reused liquid fuel engine used in an operational manner, having already surpassed Space Shuttle Main Engine number 2019's record of 19 flights. As of 2026, Falcon 9, Falcon Heavy and New Glenn are the only orbital rockets to reuse their boosters, although multiple other systems are in development.

All aircraft-launched rockets reuse the aircraft.

Other than that, a range of non-rocket liftoff systems have been proposed and explored over time as reusable systems for liftoff, from balloons to space

elevators. Existing examples are systems which employ winged horizontal jet-engine powered liftoff. Such aircraft can air launch expendable rockets and can because of that be considered partially reusable systems if the aircraft is thought of as the first stage of the launch vehicle.

An example of this configuration is the Orbital Sciences Pegasus.

For suborbital flight the SpaceShipTwo uses for liftoff a carrier plane, its mothership the Scaled Composites White Knight Two. Rocket Lab is working on Neutron, and the European Space Agency is working on Themis. Both vehicles are planned to recover the first stage. So far, most launch systems achieve orbital insertion with at least partially expended multistaged rockets, particularly with the second and third stages.

Only the Space Shuttle has achieved a reuse of the orbital insertion stage, by using the engines and fuel tank of its orbiter.

The Buran spaceplane and Starship spacecraft are two other reusable spacecraft that were designed to be able to act as orbital insertion stages and have been produced, however the former only made one uncrewed test flight before the project was cancelled, and the latter is not yet operational, having completed eleven suborbital test flights, as of November 2025, which achieved all of its mission objectives at the fourth flight.

Launch systems can be combined with reusable spaceplanes or capsules.

The Space Shuttle orbiter, SpaceShipTwo, Dawn Mk-II Aurora, and the under-development Indian RLV-TD are examples for a reusable space vehicle (a spaceplane) as well as a part of its launch system. Contemporary reusable orbital vehicles include the X-37, Dragon 2, and the upcoming Dream Chaser, Indian RLV-TD and the upcoming European Space Rider (successor to the IXV).

As with launch vehicles, all pure spacecraft during the early decades of human capacity to achieve spaceflight were designed to be single-use items.

This was true both for satellites and space probes intended to be left in space for a long time, as well as any object designed to return to Earth such as human-carrying space capsules or the sample return canisters of space matter collection missions like Stardust (1999-2006) or Hayabusa (2005-2010).

Exceptions to the general rule for space vehicles were the US Gemini SC-2, the Soviet Union spacecraft Vozvraschaemyi Apparat (VA), the US Space Shuttle orbiter (mid-1970s-2011, with 135 flights between 1981 and 2011) and the Soviet Buran (1980-1988, with just one uncrewed test flight in 1988). Both of these spaceships were also an integral part of the launch system (providing launch acceleration) as well as operating as medium-duration spaceships in

space.

This began to change in the mid-2010s.

The shape of this structure will be supported by excess internal pressure (using light gases).

During ascent the two outer spaceplanes, which formed the first stage, would detach and glide back individually to earth.

In 2017, the German Aerospace Center (DLR) started working on the Reusable Flight Experiment (ReFEx) aiming to demonstrate a winged fly-back rocket booster. As of 2024, its launch was planned for late 2026 atop a Brazilian VSB-30 sounding rocket from the Koonibba Test Range in Australia. In 2018, China was researching possible reusability for the Long March 8 system. This had been later abandoned.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.