# Flight Testing with Heavy Lift Balloons

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**Abstract**

Effective testing of parachute systems for spacecraft returning from low Earth orbit should replicate the relevant environmental conditions under which those parachute systems are deployed following reentry from space. This means testing actual flight parachute systems over the envelope of flight conditions in which they need to perform. This includes the max loading reached at the maximum dynamic pressure, along with demonstrating the dynamic stability of multi-canopy deployments and inflations under both nominal and off-nominal conditions


CST-100 Parachute System Qualification Test

To test the parachute recovery system for their NASA Commercial Crew Development (CCDev) CST-100 Starliner Crew Capsule, Boeing teamed with Near Space Corporation (NSC) of Tillamook, OR for a series of flight tests. These were conducted using full-mass simulator of the capsule as part of the flight certification efforts to demonstrate the parachute systems suitability to carry NASA and commercial astronauts. For Starliner, releases from approximately 40kft, allowed the test vehicle to accelerate to relevant velocities at the same altitudes where the parachute deployment sequence begins during return from orbit.

Lifting a roughly 10-ton test article on a gossamer polyethylene balloon envelope presented a variety of challenges, both in terms of balloon design and flight operations to safely and efficiently launch such a large mass. Lifting this much mass reliably using highly specialized polyethylene balloon film no thicker than 2/1000ths of an inch requires a robust balloon design and fabrication process.

The unique launch technique used by NSC, allows the payload to be connected to a fully inflated balloon system that has been securely anchored to the ground with multiple restraint lines. Once the payload is fully checked and connected, the lines are simultaneously severed by electrically fired pyrotechnic cutters and the payload gently ascends at approximately 1200-1500 ft/min.

Large balloons are always susceptible to surface winds during inflation and launch. To minimize the envelope's exposure to adverse conditions, very careful attention is paid to forecasts, real-time monitoring of launch weather, especially the wind and cloud conditions. NSC dynamically constrains the initial inflated bubble until it is raised vertically over the principal ground anchor at which point helium is rapidly fed into the balloon from multiple large tube trailers, filling the envelop with nearly 12 tons of lift in less than 1 hour. NSC also employs a series of tethers connected from custom ground winches to specially reinforced patches installed on the balloon to control the rotation during inflation and up to launch.

White Sands Missile Range was chosen by Boeing to both conduct these tests and as the primary landing location for operational Starliner flights. To keep the balloon drop tests on the range and the landing site within the desired area, the launch site is moved according to the seasonal winds.