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SECTION 1
LAUNCHING A NEW SPACE AGE

BOEING IN SPACE

Boeing’s space portfolio covers a broad spectrum of innovative platforms and capabilities. We’re designing and building the future of safe, assured space exploration and commercial access, even as we lead the digital transition of the satellite industry for both government and commercial customers around the globe.

With experience gained from supporting every major U.S. endeavor to escape Earth’s gravity, Boeing is focused on the future and proud to be part of all NASA’s efforts from low Earth orbit to the moon, Mars and beyond. We are committed to the National Space Council’s vision for continued American leadership in space.

Boeing is enabling critical research on the International Space Station (ISS) that benefits the future space economy, deep-space exploration and life on Earth; returning crew launch capabilities to U.S. soil with the CST-100 Starliner spacecraft that will launch to the ISS in 2019; building heavy-lift, human-rated propulsion to deep space with the Space Launch System (SLS) rocket that will launch missions to the Gateway cislunar outpost, the moon’s surface, and Mars; and ensuring successful delivery to Earth’s orbit with the United Launch Alliance (ULA) joint venture between Boeing and Lockheed Martin. The Boeing Phantom Works organization’s Phantom Express experimental spaceplane for the Defense Advanced Research Projects Agency (DARPA) will result in rapid, low-cost access to space.
STARLINER FACTS

Propulsion

Crew Module:
- 12 Reaction Control System (RCS) thrusters, 100 pound-force (lbf) each

Service Module:
- 28 RCS thrusters, 85 lbf each
- 20 Orbital Maneuvering and Attitude Control (OMAC) thrusters, 1,500 lbf each
- 4 Launch Abort Engines, 40,000 lbf each

Dimensions

Starliner Height: 16.5 ft (5.03 m) (Crew Module + Service Module)
Starliner Diameter: 15 ft (4.56 m)

Ascent Abort Landing Zone Considerations

- Active only on crew flights
- Wave height below 4 meters (13.1 ft)
- Surface wind below 27 knots (13.9 m/s)
- No thunderstorms within abort landing area
- No lightning within abort landing area
FAQ

Q. How many people can fly on Starliner?
A. Starliner is designed to fit a max crew of seven, but NASA missions will carry a crew of four to five.

Q. Is Starliner reusable?
A. The crew modules are designed to fly up to 10 missions. Service modules are made for each mission.

Q. How many missions will Starliner fly?
A. Boeing is currently on contract for two test flights and six missions to the International Space Station. Future Starliner missions depend on NASA’s needs for station crews and commercial demand.

Q. Are you planning to fly private astronauts?
A. Yes. We are selling the extra fifth seat on NASA missions. Potential customers include commercial and government-sponsored astronauts and even private citizens flying as tourists.

Q. How long does it take to get to the space station?
A. Most flights on operational missions will be about six to 12 hours from launch to docking, but times will vary on specific missions depending on launch and rendezvous requirements.

Q. Can Starliner fly only on an Atlas V?
A. Starliner is designed to be launch vehicle agnostic and is compatible with various current and future launch vehicles in the Atlas V’s class.

Q. Where will Starliner land?
A. We have identified five landing sites in the western United States. There are two on the White Sands Missile Range in New Mexico, one on the Dugway Proving Ground in Utah, one on the Willcox Playa in Arizona and one on Edwards Air Force Base in California.
THE ROCKET
UNIFIED LAUNCH ALLIANCE ATLAS V

Propulsion
- RD-180 booster engine, 860,000 lbf
- 2 solid rocket boosters, 380,000 lbf each
- Dual RL-10 Centaur engines, 46,000 lbf

Dimensions
- Atlas V Starliner total height: 171 ft (52m)

Launch Weather Constraints
- Wind at the launch pad exceeds 61 kilometers per hour; 38 miles per hour (33 kn)
- Upper-level conditions containing wind shear that could lead to control problems for the launch vehicle
- Cloud layer greater than 1,400 meters (4,500 ft) thick that extends into freezing temperatures
- Cumulus clouds with tops that extend into freezing temperatures within 5 to 10 miles (8.0 to 16.1 km)
- 19 kilometers (10 nmi) of the edge of a thunderstorm that is producing lightning, for 30 minutes after the last lightning is observed.
- Field mill instrument readings within 9.3 kilometers (5 nmi) of the launch pad or the flight path exceed +/- 1,500 volts per meter, for 15 minutes after they occur
- Thunderstorm anvil is within 19 kilometers (10 nmi) of the flight path
- Thunderstorm debris cloud is within 5.6 kilometers (3 nmi) or fly through a debris cloud for three hours
- Do not launch through disturbed weather that has clouds that extend into freezing temperatures and contain moderate or greater precipitation, or launch within 9.3 kilometers (5 nmi) of disturbed weather adjacent to the flight path
- Do not launch through cumulus clouds formed as the result of or directly attached to a smoke plume
- Starliner unique precipitation restriction, No-Go if precipitation is within +/- 2 nautical miles of the flight path
SECTION 2
STARLINER’S STORY

Boeing and its heritage companies have been a part of every U.S. human spaceflight program. Continuing to support NASA’s human spaceflight efforts are a priority for the company, and leading the nation’s return to human spaceflight in support of the International Space Station is our next step.

In 2014, NASA chose Boeing as one of two companies that will fly the first crews to ISS as a part of NASA’s Commercial Crew Program. While the company has a long history of spacecraft development and manufacturing, Starliner is the first time Boeing has been tasked with operating the entire mission, from astronaut training to launch, on-orbit operations, landing, recovery and refurbishment.

Boeing’s program is housed in what had been the space shuttle Orbiter Processing Facility 3 at NASA’s Kennedy Space Center. Now known as the Commercial Crew and Cargo Processing Facility (C3PF), the renovated building is a full-fledged spacecraft factory where Boeing assembles and processes Starliner’s crew and service modules.
The first pieces of hardware to roll out of the C3PF were mainly for test purposes, but a secondary goal was to refine manufacturing techniques. Meanwhile, Boeing teams across the country launched into component testing and manufacturing, and suppliers spread across 38 states began manufacturing flight hardware.

Once the first test articles had rolled out, attention turned toward the flight test hardware. Spacecraft 1 was used for testing the launch abort system during the program’s Pad Abort Test in New Mexico. Spacecraft 2 went to Boeing’s facility in El Segundo, Calif., for the Environmental Qualification Test campaign. It’s now being prepared to fly the first people on Starliner’s Crew Flight Test. Spacecraft 3 will be the first Starliner launched to space, slated for the uncrewed Orbital Flight Test, and will then be turned around for the first operational mission for NASA.

While Starliner manufacturing continued in Florida, integrated test campaigns and operational training ramped up around the country. Mission control teams in Houston worked with the software team to develop and refine how Starliner flies in orbit and autonomously docks to the space station. Recovery teams practiced the complex task of recovering a vehicle from the desert – which has never been done before with an American orbital crew capsule. Meanwhile, test programs continued to prove Starliner would not be able to fly just one mission safely; it would be able to reliably fly over and over again.
Boeing astronaut Chris Ferguson and his two NASA crewmates, Mike Fincke and Nicole Mann, will be the first people to fly in Starliner, while NASA astronauts Suni Williams and Josh Cassada are training for Starliner’s first operational mission.
MISSION PROFILE

Launch and Ascent

The ascent phase of the mission starts at T-0 after ignition of the Atlas V’s RD-180 main engine and two solid rocket boosters. As the Atlas V continues to climb, it works its way through each launch milestone, including Max Q, solid booster jettison, booster stage separation and Centaur ignition. Just before 15 minutes after liftoff, the Centaur upper stage separates from Starliner, sending the capsule on its way to the space station. But the ascent profile isn’t complete until about 31 minutes after launch, when Starliner fires four of its orbital maneuvering and attitude control thrusters to conduct the orbital insertion maneuver.
Rendezvous and Docking

Once in a stable orbit on course for the International Space Station, Starliner begins its rendezvous procedures. Unique to the Orbital Flight Test mission, Starliner will conduct a series of demonstration burns a few hours after launch to prove the spacecraft can maneuver itself safely in space. As Starliner closes on the station, the vehicle’s star tracker cameras will first see the orbiting lab as a distant, but bright, point of light moving in front of a background of fixed stars. Over the next few hours, Starliner will slowly move itself closer to the station and then pause before entering the 200-meter “keep out sphere” until station flight controllers clear it to enter. Starliner then begins the docking process, pausing once more 10 meters away from a Boeing-built International Docking Adapter and then continuing to final approach and docking.
Undocking, Reentry and Landing

Once Starliner is ready and cleared to leave the International Space Station, the undocking process begins and the spacecraft slowly backs away from the station. After a flyaround maneuver, Starliner positions itself for the deorbit burn. A short time later, when Starliner is in the right position over the Pacific Ocean, the service module conducts the deorbit burn, slowing down Starliner from orbital speeds, and then the service module detaches. The crew module begins its descent through the atmosphere, facing reentry heating of 3,000 degrees Fahrenheit (1,650 degrees Celsius). The parachute sequence begins around 30,000 feet (9 km) above the ground, when Starliner jettisons the forward heat shield that protects the parachutes during reentry. Two drogue parachutes begin slowing Starliner down, then detach. The three main parachutes are then deployed and inflated, and about 3,000 feet (.9 km) off the ground, the airbags inflate. On touchdown, those airbags absorb the initial forces of landing, cushioning the crew for a soft, safe return to Earth.
The International Space Station (ISS) is a permanently crewed, orbiting laboratory that enables scientific research supporting innovation on Earth and future deep space exploration. From design to launch, 15 countries collaborated to assemble the world’s only permanently crewed orbital facility, which can house a crew of six and dozens of experiments across an array of disciplines. The ISS represents a global effort to expand our knowledge while providing a technological test bed to extend our reach throughout the solar system. By far the largest spacecraft ever built, the ISS has been inhabited continuously since Nov. 1, 2000.

NASA is the principal customer for the International Space Station. The space agencies of the United States, Russia, Canada, Japan, and Europe operate the ISS. Boeing was the prime contractor for ISS construction, and continues to support processing of the laboratory experiment racks to facilitate experiments, as well as regular capability enhancements. Some of these include a new communications system for visiting spacecraft, lithium-ion batteries to collect power from the solar arrays, and a new NASA docking system. In 2016, the installation of the International Docking Adapter onto the ISS prepared the ISS to receive Commercial Crew spacecraft, including Boeing’s Starliner. A second International Docking Adapter was added in 2019 to provide a second docking port for next-generation spacecraft.
Research for Earth and Deep Space

Astronauts on ISS work together daily with scientists on Earth to perform about 250 experiments every month. The microgravity lab has hosted more than 1,500 experiments involving scientists from more than 65 countries. This research is benefiting scientific knowledge across a broad spectrum of disciplines, from physiology and medicine to robotics and astrophysics. In addition, the ISS is the only facility that allows researchers to investigate the physiological and psychological effects of long-duration spaceflight in preparation for future missions to the moon and Mars.

Genes in Space

The Boeing-sponsored Genes in Space competition is a science, technology, engineering and math contest that challenges students in grades seven through 12 to design DNA analysis experiments using the ISS National Laboratory. The competition’s other partners are miniPCR and New England Biolabs Inc. Genes In Space winners give a presentation on their research, and are invited to watch their experiments launch on ISS resupply missions. They have published scientific studies based on their results and are contributing to the knowledge base researchers are using to develop deep-space exploration mission profiles and system requirements.
Increasing Commercial Opportunities

The unique opportunities offered by the International Space Station are being made increasingly more available to commercial, private and other organizations. More than 50 companies already conduct commercial research and development via the ISS U.S. National Laboratory. In addition, NASA has worked with 10 different companies to install more than 14 commercial facilities on the station that support research and development projects for NASA and the ISS National Laboratory.

This effort is intended to broaden the scope of commercial activity on the space station beyond the ISS National Laboratory mandate, which is limited to research and development. A NASA directive announced in 2019 will enable commercial manufacturing and production and allow both NASA and private astronauts to conduct new commercial activities aboard the orbiting laboratory. The directive also sets prices for industry use of U.S. government resources on the space station for commercial and marketing activities.