Crew Flight Test

STARLINER

REPORTER'S NOTEBOOK

Media Contact List

BOEING:

media@boeing.com, +1 321-360-3602

Starliner Website: boeing.com/starliner

ISS Website: boeing.com/iss

Boeing Media Assets: https://media-portal.boeing.com
(Starliner assets will be available prior to each mission)

@BoeingSpace

@Boeing

@Boeing

(X, formerly known as Twitter)

The Boeing Company

The Boeing Company

The Boeing Company

Boeing

NASA:

Kennedy Space Center Newsroom: +1 321-867-2468

Johnson Space Center Newsroom: +1 281-483-5111

Website: nasa.gov/news/media/info/index.html

Imagery Archive: images.nasa.gov

Table of Contents

SECTION**ONE** Launching a New Space Age

SECTION**TWO** Starliner's Story

SECTION**THREE** The Destination

Cover image: *OFT-2 Starliner approaching the forward port of the International Space Station.*

Launching a New Space Age

Boeing in Space

Boeing is designing and building the future of space exploration. With experience gained from supporting every major U.S. endeavor to space, Boeing is focused on the future and proud to be part of all of NASA's human space exploration efforts. Boeing is developing the CST-100 Starliner spacecraft to ensure NASA and the United States have redundant crew launch capabilities, enabling critical research on the International Space Station (ISS) laboratory and testbed, building heavy-lift propulsion to deep space with the Space Launch System (SLS) rocket, and delivering orbital satellites and deep-space exploratory missions with the United Launch Alliance (ULA) joint venture between Boeing and Lockheed Martin.

Boeing's CST-100 Starliner is a full service system. The program provides all elements needed to transport crew and cargo to and from low-Earth-orbit destinations, including crew training and mission planning; spacecraft and launch vehicle assembly, integration and testing; and crew and cargo recovery. The goal is to provide safe, reliable and sustainable access to space, beginning with missions to the International Space Station and with NASA as the flagship customer. In 2014, Boeing was awarded up to $4.2 billion by NASA to build, test and fly the Starliner. The contract includes six service missions, as well as an uncrewed and a crewed flight test to the ISS.

As NASA's lead industry partner for the International Space Station (ISS), Boeing will continue to support the orbiting laboratory through September 2024 under a $916 million contract extension awarded in July 2020. In 2023, Boeing celebrated its 30-year contract anniversary with NASA for the ISS. The year 2023 also marked the 25th anniversary of the first module launches that formed the core of the ISS. The Boeing-designed and built Unity module was connected perfectly to the Zarya module in space on Dec. 6, 1998, despite having never been in the same hemisphere on Earth. All U.S. segments since have branched off of Unity for what is now an American football field-sized space station. Boeing provided the third set of advanced solar arrays for the ISS in 2023, and was awarded a contract to provide a fourth set, to augment the station's current power system. The new arrays are producing twice as much power as the legacy arrays, and are providing additional power for research hardware and new commercial modules. Sustainable and capable through 2030 and beyond, the ISS continues to support discoveries about humans, the planet, space and more.

In 2020, the Boeing-built NASA Space Launch System (SLS) core stage for the Artemis I lunar mission was completed and delivered to the agency's Stennis Space Center in Mississippi, where it completed a series of verification tests known as Green Run in 2021. That rocket flawlessly launched NASA's Artemis I mission on Nov. 16, 2022. Meanwhile, the core stage for Artemis II, the first mission with astronauts, is complete, while technicians weld the core stage structures for the Artemis III mission that will land the first woman and first person of color on the lunar surface. Boeing also completed a NASA Critical Design Review for the Exploration Upper Stage that will replace the current SLS upper stage on future deep-space missions.

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 m) (Crew Module + Service Module)
Starliner Diameter: 15 ft (4.6 m)

ASCENT ABORT LANDING ZONE CONSIDERATIONS

- 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

LANDING CONSTRAINTS

- Average near-surface (110 ft, 33.5 m) wind speed to not exceed 19 knots (10.3 m/s), 23 knots (11.8 m/s) in a contingency
- Peak near-surface wind speed to not exceed 23 knots (11.9 m/s)
- Temperature to be no lower than 15 degrees Fahrenheit (-9.4 C)
- Cloud ceiling to be no lower than 1,000 ft (305 m) with a visibility of 1 nautical mile (1.9 km)
- No precipitation, lightning or anvil clouds within 21.5 mi (35 km)


Ascent Cover
Forward Heat Shield
Entry Cover
Parachutes
Reusable Crew Module
Landing Airbags
Base Heat Shield
Service Module
RCS and OMAC Thrusters (48)
Launch Abort Engines (4)
Solar Array

FAQ

Q. How many people can fly on Starliner?

A. Starliner is designed to fit a maximum 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 has already flown two uncrewed flight tests. After the crewed flight test, Boeing is on contract with NASA to fly six long-duration crew rotation 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. Starliner is also planned to be used for crew transportation to Blue Origin's upcoming Orbital Reef commercial space station.

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

UNITED LAUNCH ALLIANCE ATLAS V

Propulsion

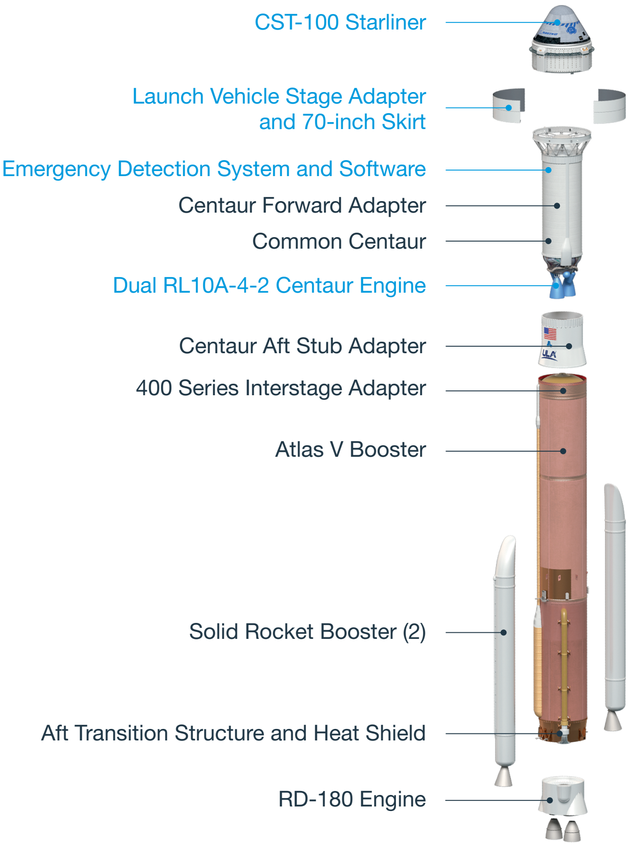
- RD-180 booster engine, 860,000 lbf
- 2 solid rocket boosters, 380,000 lbf each
- Dual RL-10 Centaur engines, 46,000 lbf

Dimensions

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

Launch Weather Constraints

- Wind at the launchpad 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 exceeds plus or minus 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
- Launch prohibition 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
- Launch prohibition 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 plus or minus 2 nautical miles (3.7 km) of the flight path



Legend: ■Heritage ■New Systems

Crew Biographies

Barry “Butch” E. Wilmore

Barry “Butch” E. Wilmore is the Commander of Starliner’s Crew Flight Test (CFT). He was selected as an astronaut by NASA in July 2000. The Tennessee native is a veteran of two spaceflights, STS-129 and Expedition 41/42.

For STS-129, Wilmore was the pilot for the mission that delivered two Express Logistics Carrier racks and about 30,000 pounds of replacement parts to the International Space Station (ISS) to maintain its proper orientation in space.

For Expeditions 41/42, Wilmore launched from the Baikonur Cosmodrome in Kazakhstan and returned to Earth in Kazakhstan. He was a Flight Engineer for Expedition 41 and then Commander for Expedition 42. During his time on the ISS, Wilmore performed three spacewalks to prepare for new international docking adapters and future U.S. commercial crew spacecraft. In addition, he completed a fourth spacewalk to replace a failed voltage regulator.

In total, Wilmore has spent 178 days in space. His launch on an Atlas V / Starliner will be Wilmore’s third rocket and spacecraft combination to orbit.

A retired Navy Captain, he has accumulated more than 8,000 flight hours and 663 carrier landings, all in tactical jet aircraft, and is a graduate of the U.S. Naval Test Pilot School. As a Navy officer and test pilot, Wilmore flew the F/A-18 Hornet and T-45 Goshawk, and was a Flight Test Instructor at the Air Force Test Pilot School at Edwards Air Force Base, California.

He is a graduate of Tennessee Technological University and the University of Tennessee.

Sunita “Suni” L. Williams

Sunita “Suni” L. Williams is the Pilot of Starliner’s Crew Flight Test (CFT). She was selected as an astronaut by NASA in 1998. The Ohio native is a veteran of two space missions, Expeditions 14/15 and 32/33.

For Expedition 14/15, Williams served as an International Space Station Flight Engineer. She launched with the crew of STS-116 and returned with the crew of STS-117. While onboard, she conducted four spacewalks, totaling 29 hours and 17 minutes. She also completed the Boston Marathon on a station treadmill, with an official completion time of 4:23:10. During the run, Williams circled the Earth at least twice, running as fast as 8 mph but flying more than 5 miles per second.

For Expedition 32/33, Williams launched from the Baikonur Cosmodrome in Kazakhstan and returned to Earth in Kazakhstan. She spent four months conducting research and exploration aboard the orbiting laboratory, first as a Flight Engineer for Expedition 32 and then as Commander for Expedition 33. While onboard, Williams performed three spacewalks to replace a component that relays power from the station’s solar arrays to its systems, and to repair an ammonia leak on a station radiator.

Williams, who has spent a 322 total days in space, ranks sixth on the all-time U.S. endurance list, and second all-time for a female astronaut. Her launch on an Atlas V / Starliner will be Williams’ third rocket and spacecraft combination to orbit.

A Navy test pilot and retired Captain, she has logged more than 3,000 flight hours in over 30 different aircraft, including the CH-46 Sea Knight and V-22 Osprey. She also received her designation as a Basic Diving Officer from the Naval Coastal System Command.

Williams is a graduate of the U.S. Naval Academy and the Florida Institute of Technology.

Mike Fincke

E. Michael Fincke, call sign "Spanky," is training as a backup crew member of Starliner's Crew Flight Test (CFT) and has been assigned as Pilot of the Starliner-1 mission. He was selected as an astronaut by NASA in 1996. The Pennsylvania native is a veteran of three spaceflights, Expedition 9 in 2004, Expedition 18 in 2009, and STS-134 in 2011.

For Expedition 9, Fincke served as Science Officer and Flight Engineer during his six-month stay onboard the International Space Station. While there, he performed four spacewalks. For Expedition 18, Fincke served as Commander while he and his crew prepared the station for future six-person crews. For STS-134, he served as Mission Specialist and completed three spacewalks. The mission also delivered the Alpha Magnetic Spectrometer, a cosmic ray particle physics detector, to the space station.

In total, Fincke has logged more than a year on orbit, with nine spacewalks. His launch on an Atlas V / Starliner will be Fincke's third rocket and spacecraft combination to orbit.

An Air Force flight test engineer and retired Colonel, he has logged more than 1,900 flight hours in 30 different aircraft, including the F-15 Eagle. He was the recipient of the U.S. Air Force Test Pilot School Col. Ray Jones Award as the Top Flight Test Engineer/Flight Test Navigator in class 93B.

Fincke is a graduate of the Massachusetts Institute of Technology, Stanford University, El Camino College and the University of Houston-Clear Lake.

Starliner's Story

Development

Boeing and its heritage companies have been a part of every major U.S. human spaceflight program. Continuing to support NASA's human spaceflight efforts is a priority for the company, and providing safe, reliable and sustainable crew transport services to the International Space Station is our next step.

In 2014, NASA chose Boeing as one of two companies to fly the first crews to International Space Station 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.

Exterior of the C3PF at NASA's Kennedy Space Center.

Boeing's program is housed in what had been the space shuttle Orbiter Processing Facility 3 (OPF-3) at NASA's Kennedy Space Center in Florida. 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, California, for the Environmental Qualification Test campaign. It then went into preparations for OFT-2. Spacecraft 3 was the first to fly to space on OFT, and is expected to fly the first crew on CFT.

Land Landing Qualification Test campaign at NASA's Langley Research Center.

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 on orbit and autonomously docks to the space station. Recovery teams practiced the complex task of recovering a vehicle from the desert — which had never been done before with an American orbital crew capsule. Meanwhile, test programs continued to prove Starliner would be able to reliably fly over and over again.

Members of the Starliner team pose in front of the spacecraft.

Taking Flight

ORBITAL FLIGHT TEST

Starliner's first mission to orbit, called Orbital Flight Test (OFT), launched at 6:36 a.m. Eastern time on Dec. 20, 2019, atop a United Launch Alliance Atlas V rocket from Cape Canaveral Space Force Station in Florida. Shortly after separation from the Atlas V rocket, an internal mission timer anomaly caused the Starliner to perform a sequence of maneuvers at the incorrect time and miss its orbital insertion burn. Quick intervention from mission controllers placed the spacecraft in a lower, but stable, orbit. After assessing all possible options, a joint NASA-Boeing team decided to forgo a rendezvous and docking attempt with the International Space Station. Instead, they focused on setting up for an early return landing opportunity while completing as many mission objectives as possible.

Launch of OFT from Cape Canaveral Space Force Station in Florida.

Even though the mission was abbreviated and rendezvous and docking mission objectives were not met, the Starliner demonstrated nominal or better-than-nominal performance during launch, orbital flight, reentry and landing operations. The mission validated many key subsystems, including the launch vehicle, power, propulsion, environmental control and life support, thermal protection, mechanisms, separation events and landing sequence.

During the uncrewed flight test, the spacecraft orbited the Earth 33 times and covered a total distance of 854,367 miles (1.4 million km). Starliner made history at 5:58 a.m. Mountain time on Dec. 22, 2019, with a bull's-eye landing at the U.S. Army's White Sands Missile Range in New Mexico, becoming the first American-made orbital crew capsule to land on U.S. soil.

Boeing worked hand in hand with NASA and an independent review team to complete rigorous post-test flight reviews, including sweeping assessments of Starliner's flight software and improvements to its communications system. The lessons learned from OFT have been shared across the industry for the benefit and safety of everyone in human spaceflight. At no cost to the taxpayer, Boeing decided to fly another uncrewed mission to demonstrate the quality of the Starliner system and evaluate the performance of a second reusable spacecraft.

OFT lands at the White Sands Missile Range in New Mexico.

ORBITAL FLIGHT TEST-2

Starliner began its second Orbital Flight Test (OFT-2) on May 19, 2022, launching atop an Atlas V rocket from Space Launch Complex-41 at Cape Canaveral Space Force Station. Following a successful orbital insertion, the uncrewed spacecraft continued its journey to the International Space Station (ISS). While en route, Starliner conducted a series of far-field demonstration activities, including testing out propulsion and navigation equipment. After flight control teams determined the spacecraft healthy and ready for rendezvous with the ISS, the automated flight control systems began sending the spacecraft to the station.

After about a day on orbit, Starliner began its rendezvous maneuvers, beginning with an inbound flyaround. The spacecraft then conducted its near-field demonstrations, including stop, hold and retreat maneuvers. Once passing those tests, Starliner initiated the final approach, making contact and then docking with the ISS on May 21, 2022. NASA astronauts Bob Hines, Jessica Watkins and Kjell Lindgren, with European Space Agency astronaut Samantha Cristoforetti, assisted in the docking process, opened the hatch, and were the first people to enter a Starliner spacecraft in space.

Starliner spent about four days docked to the ISS, during which astronauts unloaded and loaded cargo and flight control teams conducted various docked and quiescent tests. After the hatch was closed on May 24, 2022, Starliner powered up and undocked from the ISS on May 25, landing later that day at the White Sands Missile Range's White Sands Space Harbor, successfully completing the uncrewed test flight.

CREW FLIGHT TEST

Following the success of Orbital Flight Test (OFT-2), engineers pored over the data collected. As with all test flights, and most spaceflights, Boeing and NASA teams learned about the vehicle and how it behaves on launch, orbit and landing. While the Crew Flight Test (CFT) vehicle was being prepared, engineering teams completed their root cause analysis and corrective actions for the minor anomalies experienced during OFT-2.

CFT Commander Barry "Butch" Wilmore and Pilot Sunita "Suni" Williams, both NASA astronauts, continued their training while their vehicle was readied for launch. On this test flight, they will be the first people to do a number of things: launching in Starliner and on an Atlas V, manually controlling Starliner, testing the crew accommodations in microgravity, and experiencing landing on dry land with Starliner's landing systems.

Starliner docks to the ISS for the first time on OFT-2. (NASA photo)

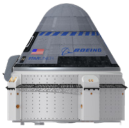
CREWED FLIGHTS

NASA astronauts who have either contributed to the development of Starliner, or trained for flight tests and missions aboard the spacecraft, include Barry “Butch” Wilmore, Mike Fincke, Nicole Mann, Sunita “Suni” Williams, Dr. Jeanette Epps, Eric Boe, Robert “Bob” Behnken, Doug Hurley and Josh Cassada.

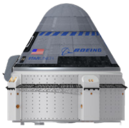
Chris Ferguson, a former NASA astronaut and three-time space shuttle flier, was integral to the development of the Starliner system. As Boeing’s Chief Astronaut and a Flight Crew Representative for the company’s Commercial Crew Program, he focused on ensuring the spacecraft and training systems met the needs of NASA’s astronauts. Prior to that, he was responsible for making sure teammates on the ground were trained and ready to support crewed missions to the International Space Station, from pre-launch to docking and undocking to landing and recovery. Ferguson also trained for the Starliner’s first crewed flight test before transitioning his Commander position to a NASA astronaut in 2020.

STARLINER FLEET

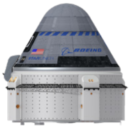
Boeing built three crew modules for flight tests and operational missions. Known originally as Spacecraft 1, 2 and 3, respectively, only Spacecraft 2 and 3 will fly in space. New service modules are built for each flight.



SPACECRAFT 1
Pad Abort Test



SPACECRAFT 2
To be named — Environmental Qualification Testing, OFT-2, Starliner-1



SPACECRAFT 3
Named *Calypso* by NASA astronaut Suni Williams — OFT, CFT, Starliner-2

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.

Rendering of Atlas V Starliner on SLC-41.

ASCENT

01 Atlas V Fueling

02 Hatch Close

03 Cabin Leak Checks

04 Crew Access Arm Retraction

05 Liftoff

06 Maximum Dynamic Pressure (Max Q)

07 Solid Rocket Booster (SRB) Jettison

08 Booster Engine Cutoff (BECO and Separation)

09 Ascent Cover Jettison

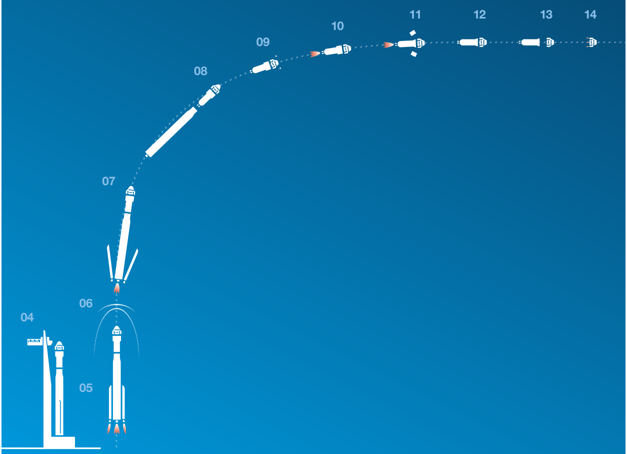
10 Centaur Ignition

11 Aeroskirt Jettison

12 Main Engine Cutoff (MECO)

13 Spacecraft Separation

14 Orbital Insertion



Rendezvous and Docking

Once in a stable orbit on course for the International Space Station (ISS), Starliner begins its rendezvous procedures. Unique to the Crew Flight Test mission, astronauts will test out the manual flight control system on the way to the ISS. 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.

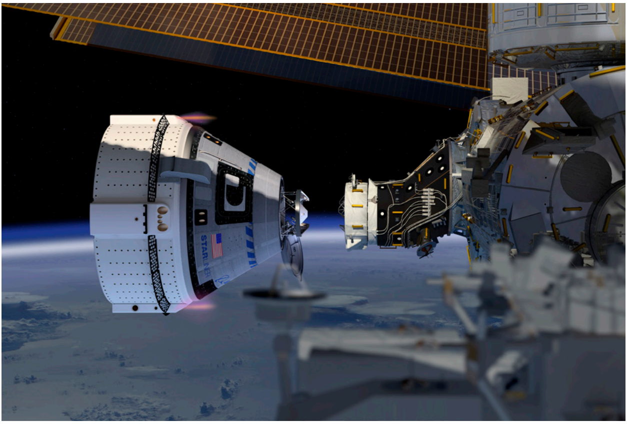


Image Caption
Rendering of Starliner docking to the ISS' Node 2 Forward port.

DOCKING

01 Height Adjustment + Plane Change

02 Height Adjustment + Plane Change

03 Coelliptic + Plane Change

04 Terminal Phase Initiation Burn + Approach Ellipsoid Entry

05 Inbound Flyaround 1

06 Inbound Flyaround 2

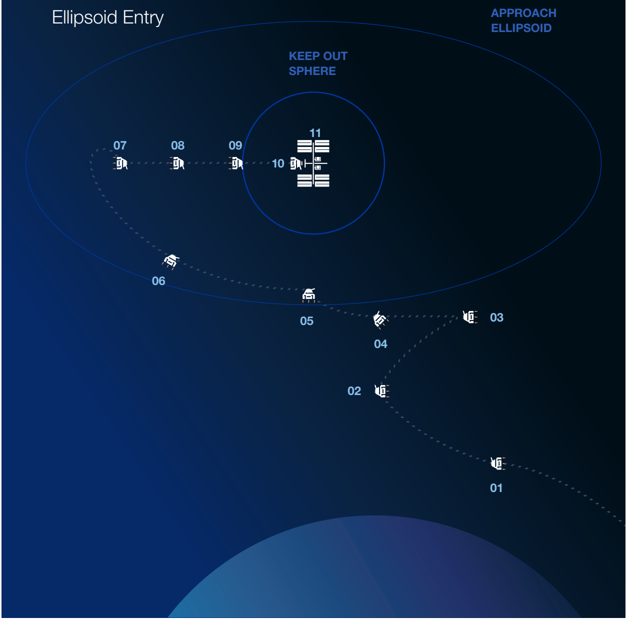
07 Corridor Approach

08 250-Meter Hold + Resume Approach

09 200-Meter Retreat + Keep Out Sphere Entry

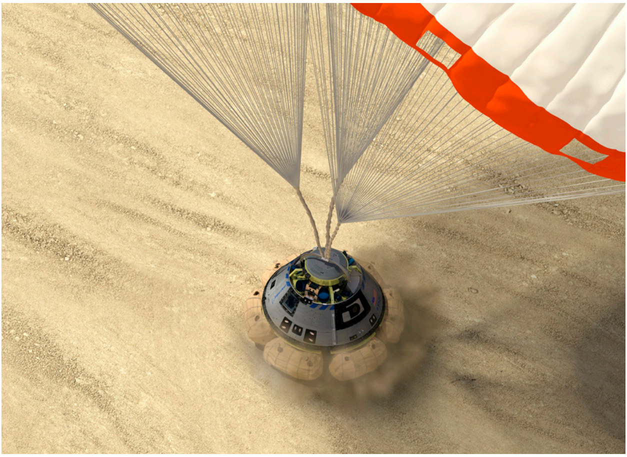
10 10-Meter Hold + Final Approach

11 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. Next, the service module detaches. The crew module begins its descent through the atmosphere, facing reentry heat 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. Around 3,000 feet (0.9 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.



Rendering of Starliner touchdown.

UNDOCKING

01 Undocking

02 Corridor Separation

03 Outbound Flyaround

04 Departure + Entry Cover Close

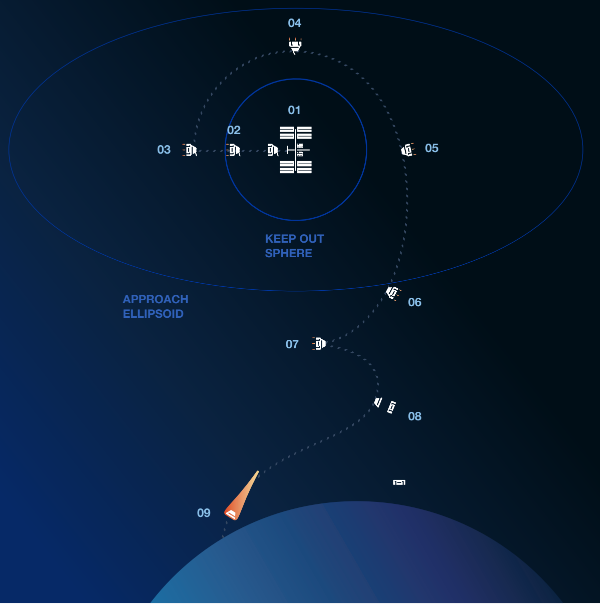
05 Departure Resume + Approach Ellipsoid Exit

06 Coelliptic + Thrust Align

07 Deorbit

08 Service Module Separation

09 Entry Interface



LANDING

01 Forward Heat Shield Jettison

02 Drogue Parachute Deployment

03 Main Parachute Deployment

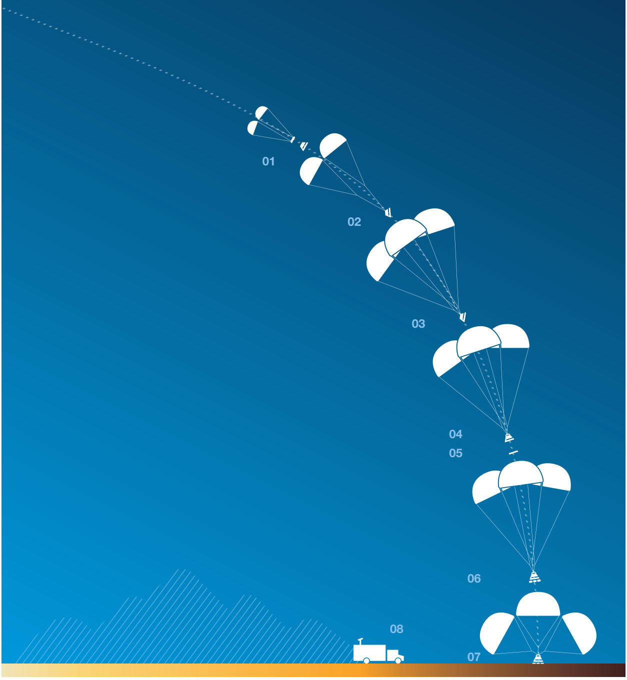
04 Rotation Handle Release

05 Base Heat Shield Jettison

06 Airbag Inflation

07 Landing

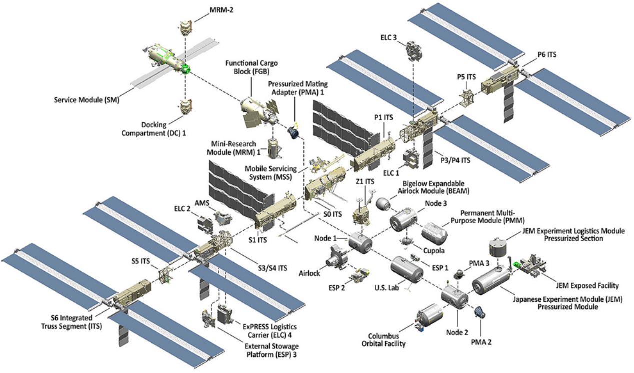
08 Recovery



The Destination

International Space Station

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 (ISS). 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 station prepared the ISS to receive Commercial Crew Program spacecraft, including the Boeing Starliner. A second International Docking Adapter was added in 2019 to provide a second docking port for next-generation spacecraft.

Astronaut Karen Nyberg prepares samples for experimentation aboard the International Space Station. (NASA photo)

Research for Earth and Deep Space

Astronauts on the International Space Station (ISS) work together daily with scientists on Earth to perform about 300-400 experiments every month. The microgravity lab has hosted more than 3,000 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.

Astronaut Ricky Arnold conducts a DNA replication experiment aboard the International Space Station as part of the Boeing-sponsored Genes in Space contest during Expedition 56. (NASA photo)

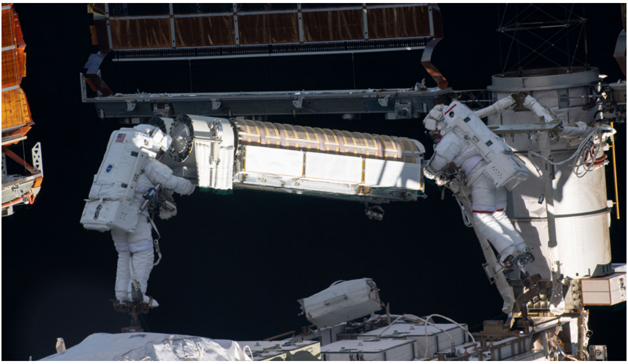
Genes in Space

The Genes in Space competition, founded by Boeing and miniPCR bio, is a science, technology, engineering and math contest that challenges students in grades seven through 12 to design DNA analysis experiments using the International Space Station (ISS) U.S. 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 (ISS) 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 Lab.

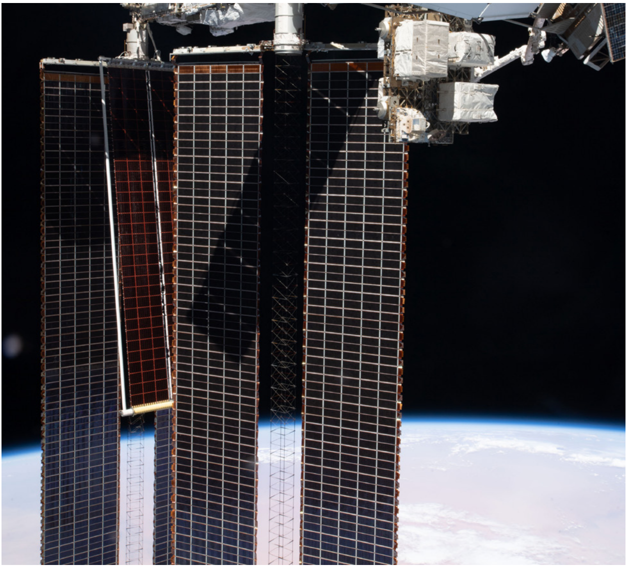
NASA has expanded commercial opportunities on the ISS to help foster a broader market including manufacturing on orbit. Recent additions to the ISS include a commercially owned and operated airlock called Bishop. New modules from private companies are expected to add more to the ISS in the middle of the decade. A NASA directive announced in 2019 is enabling commercial manufacturing and production and allowing both NASA and private astronauts to conduct new commercial activities aboard the orbiting laboratory. The directive also set prices for industry use of U.S. government resources on the space station for commercial and marketing activities.



Astronauts Shane Kimbrough and Thomas Pesquet installing the new ISS Roll-Out Solar Arrays (iROSA). (NASA photo)

Upgrading Station

NASA and partners around the world upgrade International Space Station (ISS) systems frequently to keep it at the cutting edge of its laboratory and workspace capability. One of the most extensive augmentations began with the installation of the first four new Boeing-provided solar arrays designed to boost the power-generating capacity of the station. Although they are half the size of the original arrays, the new ones produce twice as much power and are built to unroll on their own without a heavy motor. The new arrays are mounted over the existing solar "wings" of the ISS, meaning that the old ones can continue producing power. The eight new arrays and the originals will work together to provide the ISS with about a 30 percent power boost. This increased capacity will allow the ISS to continue to meet research goals for years to come and offer proven infrastructure for new, commercially built modules later this decade.



The first two iROSA arrays fully deployed on the International Space Station. (NASA photo)

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES

NOTES