NASA Facts

Space Shuttle: Orbiter Processing

From Landing To Launch

The work of preparing a space shuttle for flight takes place primarily at the Launch Complex 39 Area.

The process actually begins at the end of each flight, with a landing at the center or, after landing at an alternate site, the return of the orbiter atop a shuttle carrier aircraft.

Kennedy's Shuttle Landing Facility is the primary landing site.

There are now three orbiters in the shuttle fleet: Discovery, Atlantis and Endeavour. Challenger was destroyed in an accident in January 1986. Columbia was lost during approach to landing in February 2003.

Each orbiter is processed independently using the same facilities. Inside is a description of an orbiter processing flow; in this case, Discovery.

Shuttle Landing Facility

At the end of its mission, the Space Shuttle Discovery lands at the Shuttle Landing Facility on one of two runway headings – Runway 15 extends from the northwest to the southeast, and Runway 33 extends from the southeast to the northwest – based on wind currents.

After touchdown and wheelstop, the orbiter convoy is deployed to the runway. The convoy consists of about 25 specially designed vehicles or units and a team of about 150 trained personnel, some of whom assist the crew in disembarking

from the orbiter. The others quickly begin the processes necessary to "safe" the orbiter and prepare it for towing to the Orbiter Processing Facility. The team that recovers the orbiter is primarily composed of KSC personnel, whether the landing takes place at KSC, at Edwards Air Force Base in California, or elsewhere.

The first staging position of the convoy after Discovery lands is 1,250 feet from the orbiter. Safety assessment teams dressed in protective attire and breathing apparatus use detectors to obtain vapor level readings around the orbiter. They test for possible explosive or toxic gases such as hydrogen, hydrazine, monomethylhydrazine, nitrogen tetroxide or ammonia.

Once the forward and aft safety assessment teams successfully complete their toxic vapor readings around the orbiter, purge and coolant umbilical access vehicles are moved into position behind the orbiter to gain access to the umbilical areas. Checks for toxic or hazardous gases are completed in the areas of the aft fuselage. If no hydrogen gases are present, convoy operations continue. If hydrogen gases are detected, the crew is evacuated immediately, convoy personnel are cleared from the area and an emergency power-down of the orbiter is conducted.

After carrier plates for the hydrogen and oxygen umbilicals are installed, coolant and purge air begin flowing through the umbilical lines. Purge air provides cool and humidified air conditioning to the payload bay and other cavities to remove any residual explosive or toxic fumes that may be present. The purge of the vehicle normally occurs within 45 to 60 minutes after an orbiter comes to a full stop. Transfer of the air conditioning function to ground services occurs at about the same time, allowing onboard cooling to be shut down.

When it is determined that the area in and around the orbiter is safe, the crew of Discovery prepares to leave the orbiter. The crew hatch access vehicle moves to the hatch side of the orbiter and a "white room" is mated to the orbiter hatch. The hatch is opened and a physician performs a brief preliminary medical examination of the crew members before they leave the vehicle, generally within an hour after landing. Astronauts leave the orbiter more quickly and more comfortably by transferring from the white room directly into the crew transport vehicle, a modified "people mover" similar to those used at airports.

Umbilicals are attached to purge the vehicle of any possible residual explosive or toxic fumes.

In addition to convoy operations on the runway, a KSC engineering test team monitors data from Discovery from a station in one of the Launch Control Center's firing rooms. After the crew has left Discovery and the orbiter ground cooling is established, Johnson Space Center, which controls the vehicle during flight, "hands over" responsibility of the vehicle to Kennedy Space Center. The engineering test team is now able to issue commands to Discovery, configuring specific orbiter systems for the towing to one of three bays of the Orbiter Processing Facility.

The flight crew is replaced aboard Discovery by KSC support personnel who prepare the orbiter for ground tow operations, install switch guards and remove data packages from any onboard experiments.

After a total safety downgrade, vehicle ground personnel make numerous preparations for the towing operation, including installing landing gear lock pins, positioning the towing vehicle in front of the orbiter and connecting the tow bar. Towing normally begins within four hours after landing and is completed within six hours unless removal of time-sensitive experiments is required on the runway.

Orbiter Processing Facility

A tractor tow vehicle pulls Discovery along a two-mile tow-way from the Shuttle Landing Facility to the Orbiter Processing Facility (OPF), a structure similar in design to a sophisticated aircraft hangar, where processing Discovery for another flight begins. The OPF has three separate buildings, or bays, that are each about 197 feet long, 150 feet wide and 95 feet high. Each is equipped with two 30-ton bridge cranes with a hook height of approximately 66 feet. High bays 1 and 2 are adjacent to each other. High bay 3 was constructed north of the Vehicle Assembly Building.

Turnaround processing procedures on Discovery include various post-flight deservicing and maintenance functions, which are carried out in parallel with payload removal and the installation of equipment needed for the next mission.

Before post-flight deservicing can continue beyond initial safing operations, certain vehicle systems must be mechanically secured and access platforms installed.

First, the orbiter is raised off its landing gear and leveled. Workstands are moved into position and preparations begin to allow access to various orbiter compartments. An elaborate system of scaffolding and work platforms provides access to orbiter elements.

Discovery rolls into the Orbiter Processing Facility where it will be processed for another flight.

Inspection and maintenance steps include:

■ Purge Discovery's main engines to remove moisture produced as a by-product of the combustion of liquid oxygen and liquid hydrogen.

■ Open payload bay doors, and install access provisions to support payload operations. Render any hazardous payloads safe during these early OPF operations.

■ Drain fuel cell cryogenic tanks of residual reactants and render them inert using gaseous nitrogen in the oxygen system and gaseous helium in the hydrogen system.

■ Vent high-pressure gases from the environmental control and life support system.

■ Off-load non-storable consumables from Discovery and remove waste products.

■ Drain and remove filters from potable water system, water spray boilers, and the auxiliary power units.

■ Remove engine heat shields and aft access doors. Install main engine gimbal locks and engine covers.

■ Install workstands in the orbiter's rear compartment. Remove three engines for engine standalone checkout.

■ Transfer engines to the Main Engine Processing Facility and service for future flights.

When required, the orbital maneuvering system (OMS)/reaction control system (RCS) pods and forward RCS may be removed and taken to the Hypergol Maintenance Facility in KSC's industrial area for maintenance.

Troubleshooting of problems that may have occurred during launch, flight or re-entry also takes place in the OPF. Orbiter components are removed and repaired or replaced as required. Retesting is often done in parallel with other processing activities.

Visual inspections are made of the orbiter's thermal protection system, selected structural elements, landing gear, and other systems to determine if they sustained any damage during the mission. Any damage to the thermal protection system must be repaired before the next mission. Operations for this system are conducted in parallel with most of the activities in the OPF. There are about 25,000 tiles and thermal blankets on the outside of each orbiter and about 6,000 thermal control blankets on the inside.

During OPF processing, any required vehicle modifications, in addition to routine post-flight deservicing/servicing and checkout, are performed. Planned modifications are typically started as soon as practical after the orbiter returns and are generally completed in parallel with prelaunch servicing whenever possible.

Modifications to orbiters may be performed to meet future mission requirements, resolve an identified deficiency, or enhance vehicle performance. Orbiter upgrades, if they are extensive, may be performed with the vehicle powered down. Many modifications, however, can be completed in parallel with routine servicing.

Modification work is generally completed in the OPF while the orbiter is in a horizontal position. Some upgrades can be carried out in the Vehicle Assembly Building; however, the OPF offers the best access and support equipment for conducting such work.

Except during hazardous operations, routine preflight servicing can begin while deservicing activities are still under way. Routine servicing includes reconfiguring orbiter systems for flight, performing routine maintenance, replacing parts, and installing new mission flight kits and payloads. Consumable fluids and gases are loaded aboard, and the auxiliary power unit lube oil system is serviced.

The final step in OPF orbiter processing is weighing the orbiter and determining its center of gravity. Vehicle performance is affected by both the orbiter's weight and its center of gravity, and flight programming requires accurate measurements.

Finally, all ground support and access equipment is removed, and Discovery is ready to be mated to the external tank and solid rocket boosters in the Vehicle Assembly Building. Time spent in the OPF is typically less than 100 days.

Vehicle Assembly Building

From the OPF, Discovery is rolled over to the Vehicle Assembly Building (VAB). Rollover generally occurs using the 76-wheel orbiter transfer system.

One of the world's largest buildings by volume, the VAB covers eight acres. It is 525 feet tall, 716 feet long, and 518 feet wide. It is divided by a transfer aisle running north and south that connects and transects four high bays. Facing east toward the launch pads are bay 1 and bay 3, used for the vertical assembly of space shuttle vehicles. On the west side of the VAB are bays 2 and 4, used for flight hardware and orbiter storage.

Discovery enters the VAB transfer aisle through the large door at the north end of facility. While in the transfer aisle, the orbiter is raised to a vertical position via 250- and 175-ton cranes. It is then lifted several hundred feet above the VAB floor and slowly lowered beside the waiting external tank and twin solid rocket boosters located in bay 1.

The external tank and boosters already have been stacked atop the mobile launcher platform (MLP). Now Discovery is lowered beside the external tank and mated to the stack. Once Discovery is bolted to the external tank, the erection slings and load beams are removed.

Extendable platforms, modified to fit space shuttle configuration, move in around Discovery to provide access for integration and final testing. Electrical and mechanical verification of the mated interfaces is performed; a shuttle interface test verifies Discovery's interfaces and vehicle-to-ground interfaces are working. Umbilical ordnance devices are installed (but not electrically connected until Discovery is at the pad).

After six days, checkout is complete. Service platforms are retracted, and the VAB doors are opened to permit the tracked crawler-transporter vehicle to move under the MLP and the assembled space shuttle vehicle. The transporter lifts the MLP off its pedestals and onto the crawler-transporter, and the rollout to the launch pad begins. Two crawler-transporters are available for use at KSC.

Rollout

When the space shuttle has completed stacking with its external tank and solid rocket boosters atop the MLP and completed checkout in the VAB, it is ready for rollout to the launch pad.

The journey to the launch pad via the crawler-transporter takes about six hours along the specially built road called the crawlerway. The crawler's maximum speed when unloaded is 2 miles per hour; loaded, it is 1 mph.

The crawlerway is almost as broad as an eight-lane turnpike. Two 40-foot-wide lanes are separated by a 50-foot-wide median strip.

The crawler vehicle moves on eight tracked tread belts, each containing 57 tread belt "shoes." Each shoe is 7.5 feet long, 1.5 feet wide and weighs approximately 2,200 pounds. More than 1,000 shoes (456 per crawler plus spares) were originally provided by Marion Power Shovel Co. when the crawlers were initially built in 1965. New shoes were made by ME Global Manufacturing of Duluth, Minn., and installed in the fall of 2004.

During the rollout, engineers and technicians on the crawler, assisted by ground crews, operate and monitor systems while drivers steer the vehicle toward the pad.

The crawlers have a leveling system designed to keep the top of a space shuttle vehicle vertical within plus or minus 10 minutes of one degree of arc having the dimensions of a basketball. This system also provides the leveling operations required to negotiate the 5-percent ramp leading to the launch pads and to keep the load level when it is raised and lowered on pedestals at the pad and in the VAB.

After the MLP is "hard down" on the launch pad pedestals, the crawler is backed down the ramp and returned to its parking area.

Final Processing at Pad

Both Launch Pads 39A and 39B have permanent structures to complete the processing of a space shuttle for launch: the fixed service structure (FSS) and the rotating service structure (RSS). From these, the final payload processing takes place, if required, before launch.

The FSS provides access to the space shuttle orbiter and to the RSS. Located on the west side of the pad, it is a 40-foot-square, cross-section steel structure that includes the hydrogen vent umbilical and intertank access arm, vehicle service lines (small helium and nitrogen lines and electrical cables), gaseous oxygen vent arm, and orbiter access arm for crew transfer to the orbiter.

The 130-foot-high RSS pivots 120 degrees from an open position to encircle an orbiter for changeout and servicing of the payload at the pad. Orbiter access platforms at five levels provide access to the payload bay with the payload bay doors open. The RSS allows the orbiter's payload bay doors to be open in the environmentally controlled payload changeout room.

An orbiter midbody umbilical unit provides access and services to the midfuselage area. Liquid oxygen and liquid hydrogen for the vehicle's fuel cells and gases such as nitrogen and helium are provided through the umbilical unit.

The RSS also provides access for servicing the OMS pods. Hypergolic fluids are loaded into the pods through these servicing areas. Quick disconnects are used to provide fluid interfaces between the flight hardware and the ground support equipment.

Payload Processing

A wide range of payloads – some to be deployed from the space shuttle, others only to be carried into space in the payload bay and returned at the end of the mission – are delivered to KSC to undergo final processing, checkout and installation aboard an orbiter. Space shuttle payload processing is performed in parallel with vehicle processing so that the fully integrated and tested payloads are ready for installation in the orbiter at the appropriate time to support the launch schedule.

The rotating service structure at left is open to allow Space Shuttle Discovery to roll onto the pad.

In order to obtain the shortest possible space shuttle turnaround flow, KSC performs a simulated orbiter-to-cargo interface verification of the entire payload before it is installed in the orbiter. Payloads may be installed horizontally in the OPF or vertically at the pad in the payload changeout room.

Final Prelaunch Operations

Extravehicular mobility units (astronauts' space suits) and other flight crew equipment are stowed at the pad. Preparations are made to load the propellants for the onboard OMS/RCS pods and forward RCS propellant tanks and storage tanks.

The hypergolic storage area and distribution system provide the propellant for the orbiter's OMS/RCS engines, which use monomethylhydrazine as a fuel and nitrogen tetroxide as an oxidizer. Stored separately because they ignite on contact, they are fed by transfer lines through the FSS to the RSS hypergolic umbilical system. The hypergolic systems also support the orbiter's auxiliary power unit that supports the vehicle's hydraulic systems.

Now begin final preparations for the launch:

- The payload is closed out for flight, with final inspections and testing of the payload.
- The orbiter aft engine compartment is inspected and closed out for flight.
- Electrical connections are made on ordnance devices installed to support solid rocket boosters at liftoff, separation of the boosters from the external tank and separation of the external tank from the orbiter.

Several weeks before launch, the mission crew arrives at KSC for Terminal Countdown Demonstration Test activities. They practice emergency exit from the orbiter via the slidewire basket system. The final activity is a simulated launch countdown with the crew in full suits inside the orbiter.

Launch Countdown

The launch countdown begins at the T-43 hour mark, about three days before launch. Launch control personnel arrive at their stations in the firing room and begin checking out the flight systems and flight software stored in mass memory units. Display systems are also reviewed.

At T-27 hours, a scheduled built-in hold is entered. A test of the vehicle's pyrotechnic initiator controllers is performed. When the countdown resumes, cryogenic reactants are loaded into the orbiter's fuel cell storage tanks.

At T-19 hours, another hold allows demating of the orbiter mid-body umbilical unit. The sound suppression system water tank is filled and orbiter and ground support equipment closeouts resume. After the count is resumed, the three main engines are prepared for main propellant tanking and flight.

At T-11 hours, a third built-in hold gives the launch team a chance to catch up on any unfinished preparations and to troubleshoot any vehicle or ground support equipment problems that may be a constraint to launch. If no problems or delays are encountered at the end of the T-11 hour hold, the countdown continues.

The RSS is rolled back and the orbiter is ready for fuel cell activation and external tank cryogenic propellant loading operations.

The pad is cleared to the perimeter gate for operations to fill the external tank with about 500,000 gallons of cryogenic propellants used by the shuttle's main engines. This is done at the pad approximately eight hours before the scheduled launch.

Liquid oxygen is transferred to the external tank by pumps capable of pumping 1,300 gallons per minute. The liquid vaporizes and is transferred to the external tank using pressure created by the hydrogen itself. Pumps are not needed.

The final hours of the count include crew ingress, crew module and white room closeout, final computer and software configurations, final readiness polls of the launch team, terminal sequencing and, finally, …

LIFTOFF!

After the mission, the shuttle lands and the processing sequence for the next mission begins again to fulfill NASA's vision to complete the International Space Station and prepare to travel to the moon, Mars and beyond.

For more information about space research on the Internet, visit:

http://spaceresearch.nasa.gov

To view photos of any orbiter on the Internet, visit:

http://mediaarchive.ksc.nasa.gov/index.cfm

and select a category.

Discovery lifts off Aug. 10, 2001, on mission STS-105, an assembly flight to the International Space Station.

NASA Facts

Cover Photo: On Oct. 18, 2002, Space Shuttle Atlantis casts a needle-shaped shadow as it descends to the runway at the Shuttle Landing Facility, completing the 4.5-million-mile round trip to the International Space Station on mission STS-112. The mission expanded the size of the station with the addition of the S1 truss segment. This landing was the 60th at KSC in the history of the Space Shuttle Program.

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