Space Transportation System Stack Assembly

Development of the Space Shuttle began in 1969 and a contract for the construction of the Space Shuttle was awarded in July 1972. The Space Shuttle launch configuration, or Stack Assembly, was comprised of four main components: the Orbiter Vehicle (OV), built by North American Rockwell (later Boeing); three Space Shuttle Main Engines (SSMEs), built by Rockwell (later Boeing); two Solid Rocket Boosters (SRBs), built by Thiokol (later ATK Launch Systems); and an External Tank (ET) built by Martin Marietta (later Lockheed Martin). Of these four components, only the external tank was not reusable.

During prelaunch preparations in the Vehicle Assembly Building (VAB), the SRBs were attached to the Mobile Launch Platform (MLP) at their aft skirts with four trunnion nuts that were severed by explosive charges at liftoff. The ET was then attached to the SRBs at the booster attachment rings and at a point near the SRBs' forward skirt. The Orbiter was then moved to the SRB ET assembly at the ET via attatch points near the propellant and electrical umbilical connections on the Orbiter's aft fuselage and an attachment point behind its nose landing gear door on the forward fuselage. As a result, the SRBs carried the entire weight of the stack and transferred it through their structure to the MLP.

A complete Stack Assembly measured 184.2 feet from the base of the SRBs' aft skirt to the nose of the ET. The depth of the assembly, from the exterior edge of the ET to the tip of the Orbiter's vertical stabilizer, was 78.6 feet and the width of the assembly was 76.06 feet from wing tip to wing tip of the Orbiter.

When the prelaunch activities at the Vehicle Assembly Building were complete, a Crawler Transporter was used to lift the MLP with the Stack Assembly attached and carry it out to launch complex 39 A or B for further launch preparations.

At launch, the two SRBs provided a majority of the thrust required for liftoff. With a combined thrust of 6,600,000 pounds of force, the SRBs contributed approximately 72% of the power through the first launch phase, which ended at SRB separation, about 2 minutes after launch. After separation and at a predetermined altitude, parachutes were deployed to slow the boosters' descent for safe splashdown in the ocean about 141 nautical miles downrange, where they were retrieved, refurbished, and reused for subsequent launches.

The orbital Main Propulsion System consisted of the External Tank, propellant feed and control systems and three SSMEs which produced a combined thrust of 1,181,400 pounds of force at sea level. The liquid hydrogen fuel and liquid oxygen oxidizer were stored in the ET and supplied the SSMEs with propellant from approximately 6 seconds before liftoff until Main Engine Cut Off (MECO) and Jettison, approximately 1 minute and 30 seconds after launch. Under the influence of gravity, the ET would fall towards Earth, eventually disintegrating as it reentered Earth's atmosphere.

After MECO and ET jettison the SSMEs were no longer used. The shuttle used on the Orbital Maneuvering System (OMS) and the Reaction Control System (RCS) during the orbital phases for velocity changes. The OMS was focused in two pods on the aft section of the Orbiter at the base of the vertical stabilizer. The pods also contained the aft RCS. The forward RCS was located just past the nose of the Orbiter. The RCS was used for small velocity adjustments and the two OMS pods were used for large velocity changes.

The Shuttle was designed to transport payloads into low Earth orbit; between 100 and 500 nautical miles, and have nominal mission durations of 4 to 16 days in space. The Orbiter provided accommodation up to seven astronauts, four assisted on the flight deck during the launch while another three were seated in the mid-deck area, although eight astronauts flew on STS-44. After orbital insertion the flight deck, mid deck, additional hardware and software were configured for on-orbit activities.

At the conclusion of orbital operations the payload bay doors were closed, the Orbiter was turned to a tail-first attitude, the OMS engines were fired to reduce the Orbiter's velocity and permit descent; then it was turned back to a nose-first attitude for reentry. During reentry the aft RCS was used to control the roll, pitch and yaw until the atmospheric density was sufficient for the airframe surfaces to become effective. The Orbiter would perform a series of banking maneuvers, using atmospheric drag, to decrease its velocity. Combined with the descent angle and commanded drag these maneuvers reduced the velocity to about 230 mph at main landing gear touchdown.

Spacecraft recovery operations began as soon as the Orbiter stopped rolling, Ground support personnel, wearing protective gear, approached the vehicle with sensors to determine if the area around the Orbiter was safe. After determining the area safe for operations, ground support equipment was attached to the orbiter to begin purging systems, disarming reentry heat and preparing for crew egress. After crew egress the spacecraft was powered down and transported to the Orbiter Processing Facility. If the shuttle landed at sites other than Kennedy Space Center (KSC) the spacecraft was carefully inspected and prepared for landing to the Shuttle Carrier Aircraft and ferried back to KSC for further processing and prelaunch preparations for its next scheduled mission.

This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior, The Space Transportation System recording project was completed during 2011 by the Space Shuttle Program Transition and Retirement Office of the Johnson Space Center (JSC), with the guidance and assistance of Barbara Severance, Integration Manager, JSC, Jennifer Gorman, Federal Preservation Officer, NASA Headquarters and Ralph Allen, Historic Preservation Officer, Marshall Space Flight Center. The field work and measured drawings were prepared under the general direction of Richard O'Connor, Chief, Heritage Documentation Programs, National Park Service. The project was managed by Thomas Benners, HAER Architect and Project Leader. The Space Transportation System Recording Project consisted of five major teams – John Wachtel, Iowa State University, and Joseph Klimpel, Wright Institute of Technology. The documentation is based on high-definition laser scans provided by SmartGeoMetrics, Houston, Texas and documented support provided by NASA's Headquarters, Johnson Space Center and Marshall Space Flight Center. Written historical and descriptive data was provided by Archaeological Consultants Inc., Sarasota, Florida. Large-format photographs were produced by NASA's Imaging Lab at Johnson Space Center with supplemental images provided by Jim Lowe, HAER photographer.
FULL STACK ELEVATIONS
Although liftoff begins at the ignition of the Solid Rocket Boosters (T - 00:00), the Shuttle’s three Main Engines ignite 6.6 seconds prior to this. This gives the SSME’s time to ramp up to 100% thrust, and for the Shuttle’s computers to give the “go for launch” order to the SRB ignition sequence. Once that sequence begins, there is no going back. The Shuttle will lift off the launch pad and begins its ascent. Just after the Shuttle clears the launch tower (T+ 00:07) the vehicle initiates a roll, pitch and yaw sequence. This aligns the Shuttle to the desired orbital plane and allows for clearer communication between the shuttle and Houston.

Around T+00:30 the Shuttle’s Main Engines (followed shortly by the SRB’s) are throttled down to ~65%. This reduces the forces exerted on the craft caused by aerodynamic pressure. The duration of maximum aerodynamic pressure can vary, but thrust resumes to 100% around T+01:30. This is also known as the “thrust bucket” due to its graphed appearance. Solid Rocket Booster separation occurs near T+02:00, using small thrusters to ensure a clean break away from the external tank. The SRB’s will fall toward the Atlantic Ocean, where they are retrieved for re-use. Some missions may call for an Orbital Maneuvering Systems (OMS) assist burn, where excess fuel could be burned off to save weight. The quantity burned and timing could vary according to mission specific conditions.

At ~T+05:30 the Shuttle performs a “roll to heads up” (RTHU) maneuver. This realigns the Shuttle to strengthen communication signals, this time with a satellite above. Prior to STS-87, this maneuver was not necessary because of a ground relay station in Bermuda, which has since closed. Main Engine cutoff occurs at T+08:30, followed by External Tank (ET) separation shortly thereafter. The ET will fall back to earth and separate upon reentry. At this point the OMS burn and RCS systems will nudge the Shuttle into its orbital path.
ORBITER ENTRY + LANDING

POST ATMOSPHERIC INSERTION PROCESS
1) RECONFIGURE TO ON-ORBIT SOFTWARE AND GPC CONFIG.
2) ACTIVATE RADIATORS.
3) OPEN PAYLOAD BAY DOORS.
4) PURGE THE FUEL CELLS.
5) DOFF AND STOW LES, RECONFIGURE COCKPIT FOR ORBIT OPERATIONS.

DE-ORBIT BURN
DIST: 28,865 km (12,966 miles)
ALT.: 282 km (175 miles)
SPEED: 26,498 km/h (16,465 mph)

AT PHASE I BEGIN:
DIST: 7,600 km (4,722 miles)
ALT.: 122 km (76 miles)
SPEED: 25,898 km/h (16,093 mph)

POST INSERTION PROCESS
BEGIN - PHASE I: ENTRY INTERFACE
1A - NOSE INCLINE
1B - BANK MANEUVERS
1C - CONSTANT DRAG PHASE
1D - TRANSITION PHASE

END - PHASE III:
BEGIN - PHASE III:
3A - TRAJECTORY CAPTURE
3B - OUTER GUIDESLOPE (OGS)
3C - PREFLARE + INNER GUIDESLOPE (IGS)
3D - FINAL FLARE
3E - TOUCHDOWN

WHEELS DOWN @ 300 AGL

AT TOUCHDOWN
DIST: 689 km (2,261 ft.) *FROM END OF RUNWAY
ALT.: 0 km (0 miles)
SPEED: 346 km/h (215 mph)

*THIS PAGE IS NOT DRAWN TO SCALE
After the Solid Rocket Boosters (SRB) separated from the stack they began their descent into the ocean. At a predetermined altitude, parachutes were deployed to lessen the impact of splashdown. Two recovery ships, “Freedom Star” and “Liberty Star”, then sailed out to recover and return the SRBs to Kennedy Space Center (KSC) for processing.

After the Main Engine Cut Off sequence the External Tank (ET) is jettisoned on command from the orbiter. The ET descended under the influence of Earth’s gravity and disintegrated as it re-entered the atmosphere. The Michoud Assembly Facility in New Orleans, LA fabricated new ETs for each Shuttle Launch and shipped them by barge to Kennedy Space Center.

While landings primarily occurred at Kennedy Space Center, Edwards Air Force Base in California often served as an alternate landing site. Other contingency sites were also provided in the event the Orbiter must return to Earth in an emergency.

Spacecraft recovery operations began immediately after wheel stop. Systems were secured, crews disembarked, payloads, hazardous components and propulsion elements were removed, inspected and/or refurbished. Afterwards, pre-mate preparations began for the next mission of that Orbiter.