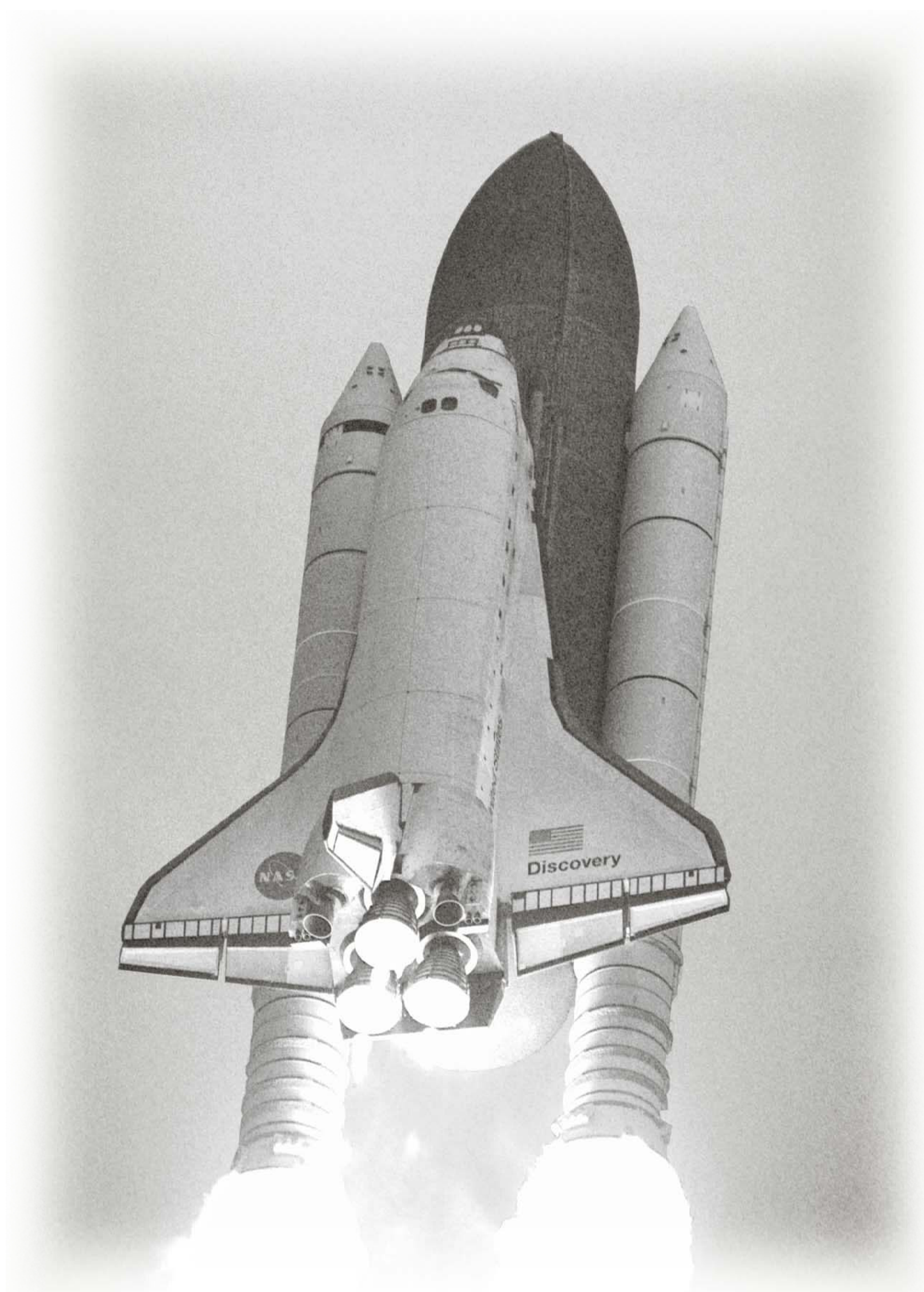
Space Transportation System Stack Assembly



Orbiter Discovery just after launch of STS-96 from Kennedy Space Center, Florida. Image courtesy of NASA Johnson Space Center. Photographer unknown

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 Rocketdyne (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 re-usable.

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 frangible nuts that were severed by explosive charges at liftoff. The ET was then attached to the SRBs at the booster aft attachment rings and at a point near the SRBs forward skirt. The Orbiter was then mated to the SRB/ET assembly at the ET via attach points near the propellant and electrical umbilical connections on the Orbiter's aft fuselage and an attach 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 SRB's 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 78.06 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 SRB's provided the 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 stage, 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 splashdowns in the ocean about 141 nautical miles downrange, where they were retrieved, refurbished and reused for subsequent launches.

The orbiter's Main Propulsion System consisted of the External Tank, propellant delivery 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 jettisoned, approximately 8 minutes, and 30 seconds after launch. Under the influence of gravity, the ET would fall towards Earth, eventually disintegrating as it reentered Earth's atmosphere.

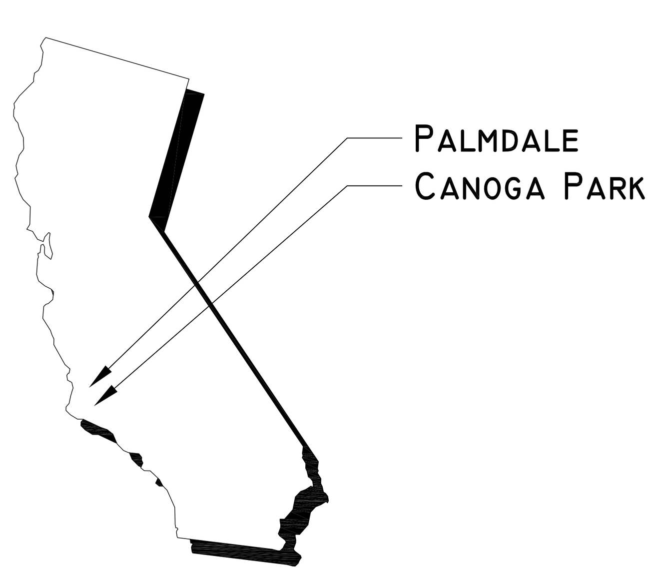
After MECO and ET jettison the SSMEs were no longer used. The shuttle relied on the Orbital Maneuvering System (OMS) and the Reaction Control System (RCS) during the orbital phase for velocity changes. The OMS was located in two pods on the aft section of the Orbiter at the base of the vertical stabilizer. 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 and orientation adjustments and the two OMS engines were used for large velocity changes.

The Shuttle was designed to transport payloads into low Earth orbit, between 100 and 300 nautical miles, and have nominal mission durations of 4 to 16 days in space. The Orbiter provided accommodation to up to seven astronauts, four seated on the flight deck during the launch while another three were seated in the mid-deck area, although eight astronauts flew on STS-84. After orbital insertion the flight deck, mid deck, additional hardware and software were configured for on-orbit activities.

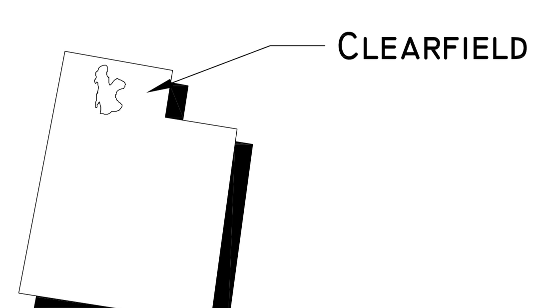
At the conclusion of orbital operations the payload bay doors were closed, the Orbiter was turned to a tail-first attitude, the OMS engines were fired to reduce the Orbiter's velocity and permit deorbit, then it was turned back to a nose-first attitude for reentry. During reentry the aft RCS was used to control the roll, pitch and yaw until the atmospheric density was sufficient for the aero 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 continued 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, dissipating 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 mating to the Shuttle Carrier Aircraft and ferried back to KSC for further processing and prelaunch preparations for its next scheduled mission.

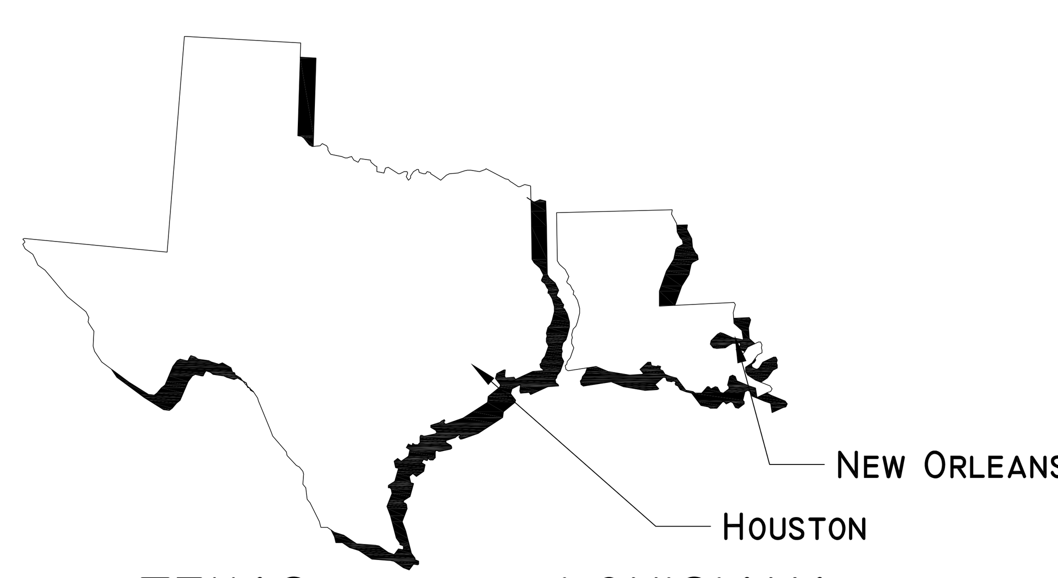
This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. The Space Transportation System recording project was cosponsored 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 Groman, 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 Behrens, HAER Architect and Project Leader. The Space Transportation System Recording Project consisted architectural delineators, John Wachtel, Iowa State and Joseph Klimek, Illinois Institute of Technology. This documentation is based on high-definition laser scans provided by Smart GeoMetrics, Houston, Texas and documentation 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 supplimental images provided by Jet Lowe, HAER photographer.



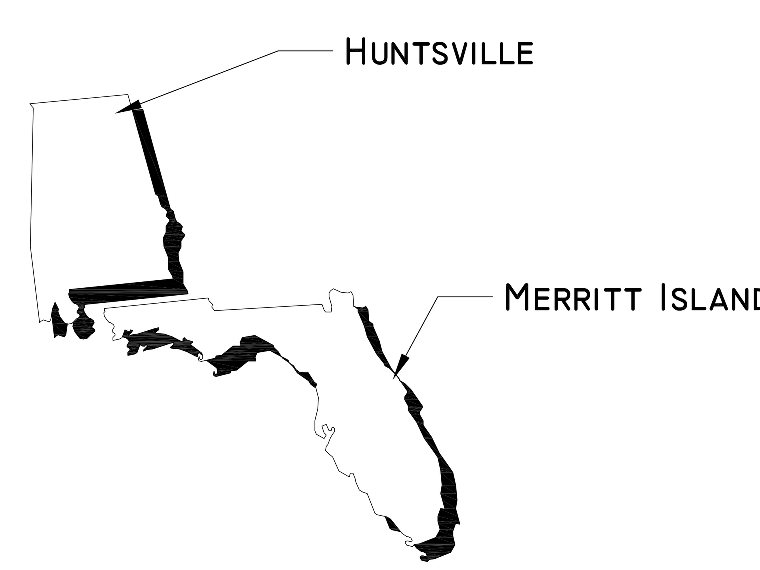
CALIFORNIA



UTAH



TEXAS LOUISIANA



ALABAMA FLORIDA

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TX-116
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TEXAS
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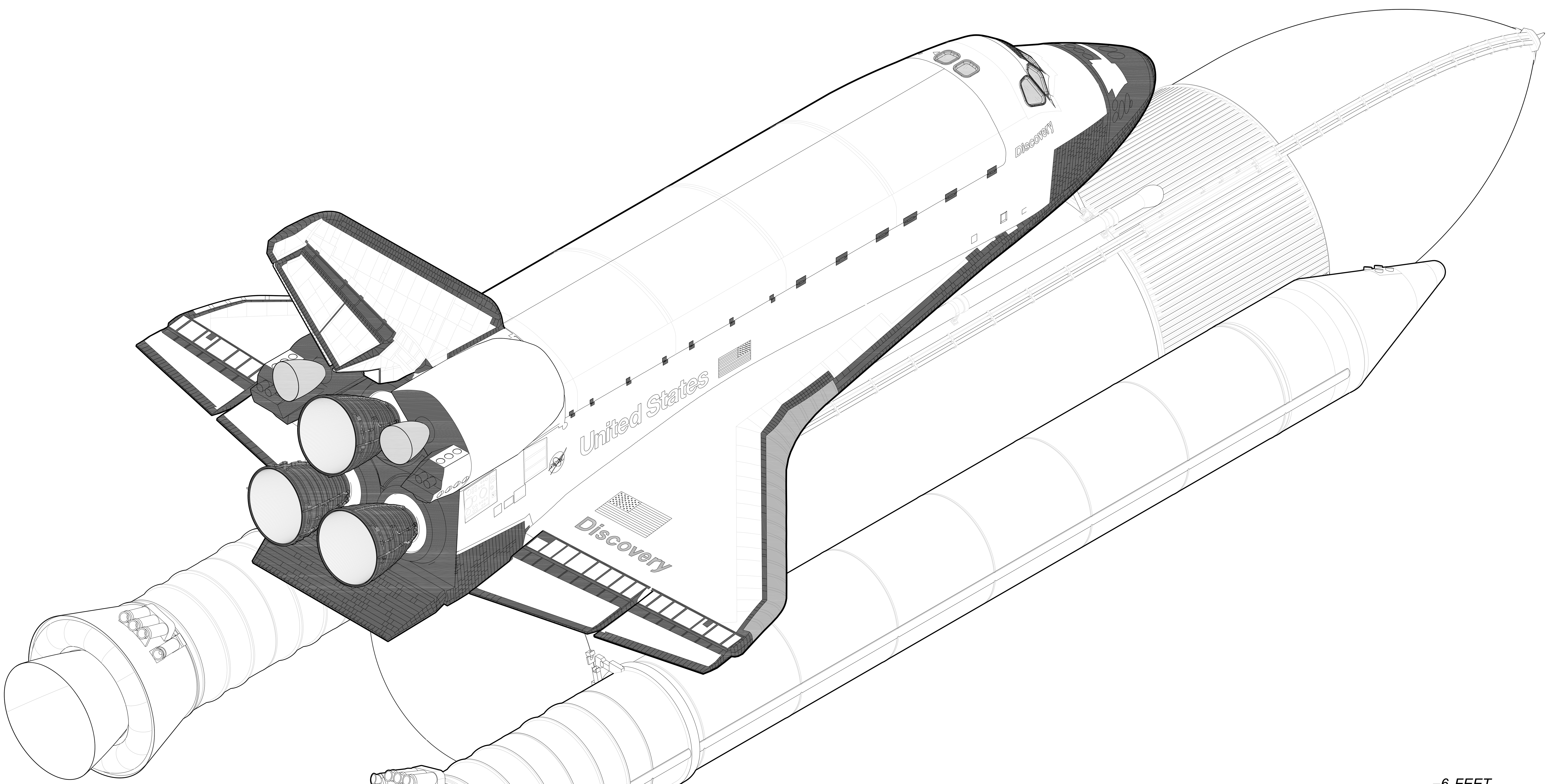
HARRIS COUNTY
HOUSTON
SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
DELINEATED BY: THOMAS M. BEHRENS

FULL STACK ISOMETRIC



SCALE 3/16" = 1'- 0"

6 FEET
2.0 METERS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SPACE TRANSPORTATION SYSTEM, ORBITER DISCOVERY (OV-103)
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TX-116-A

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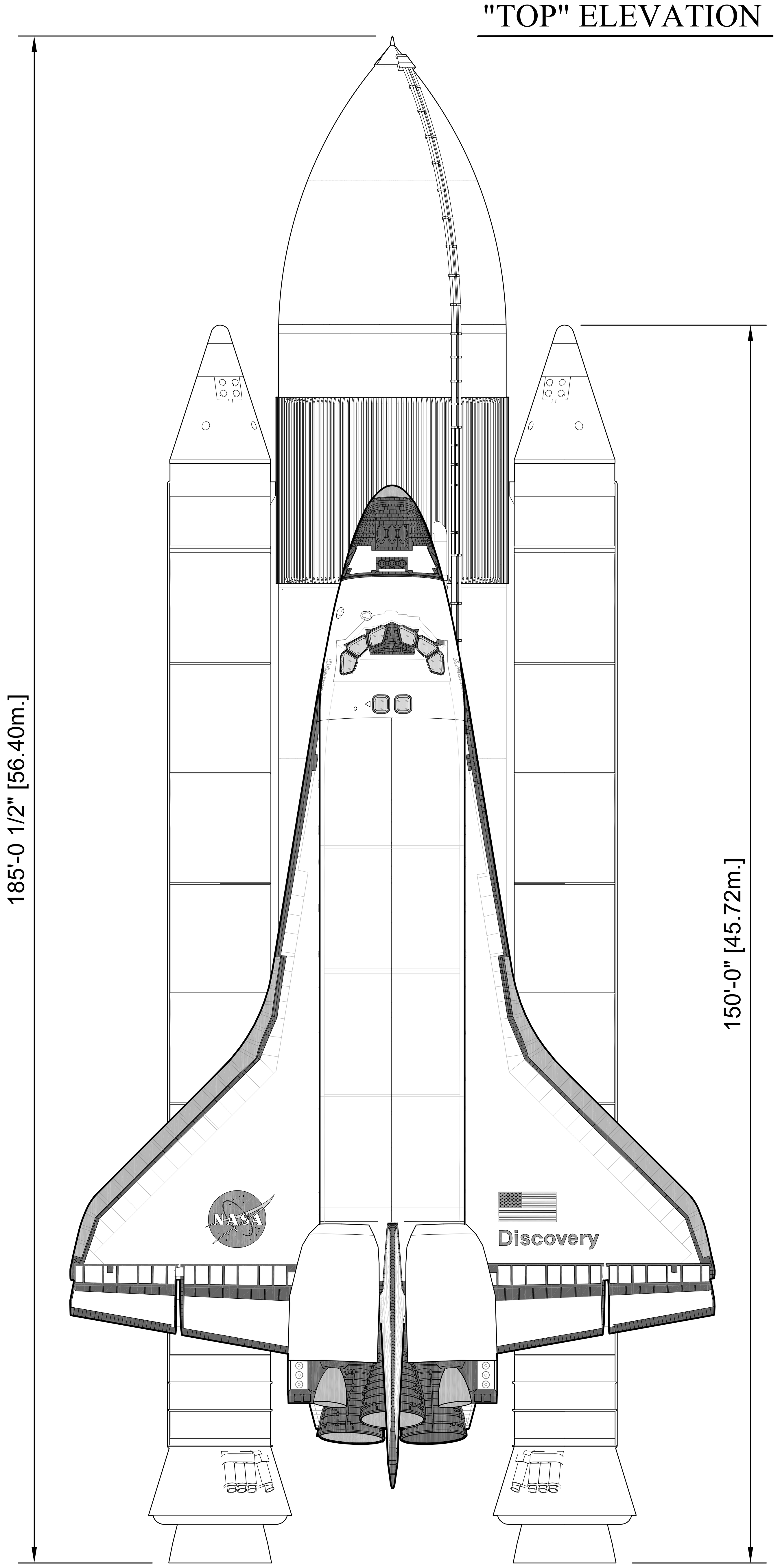
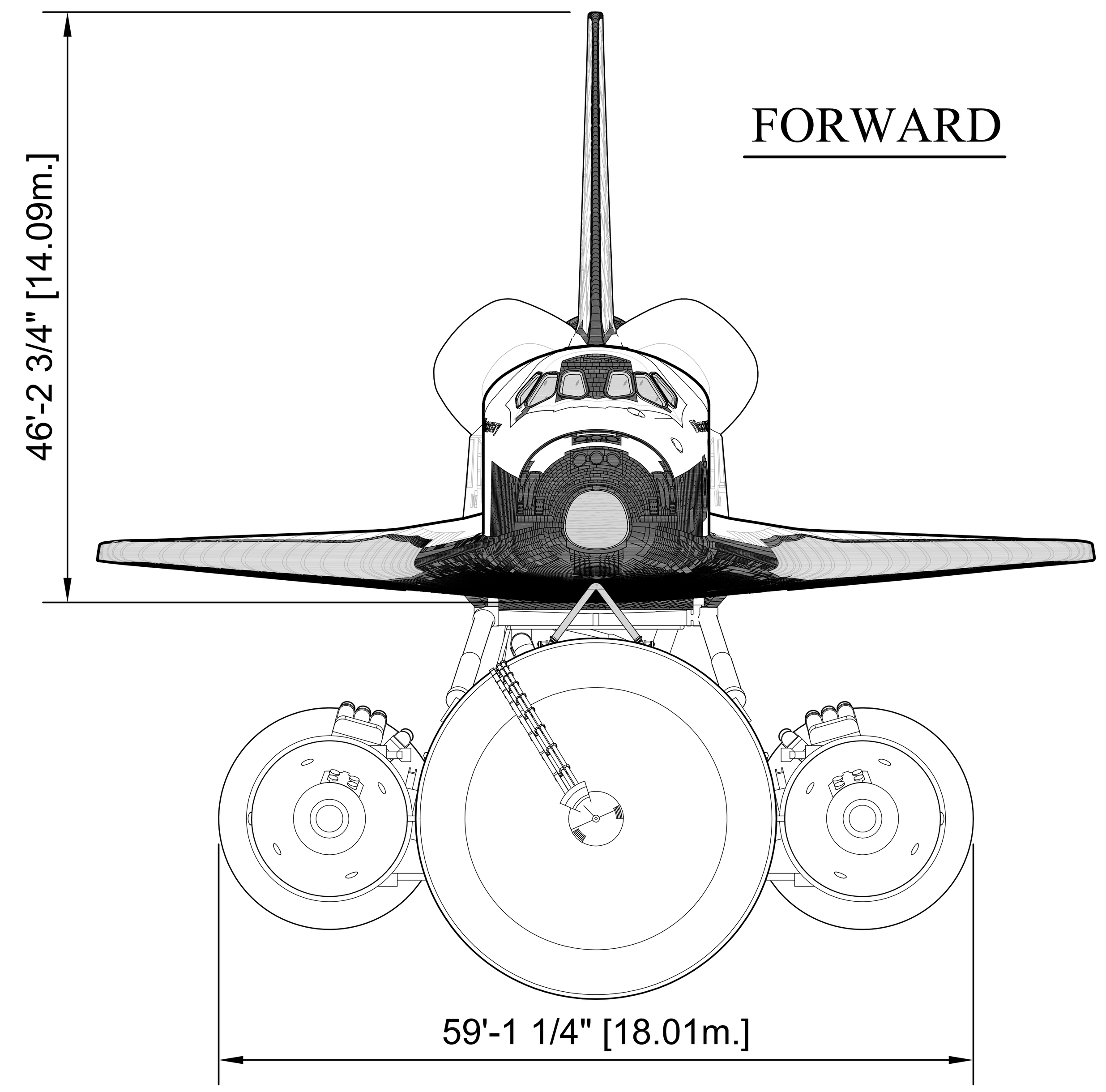
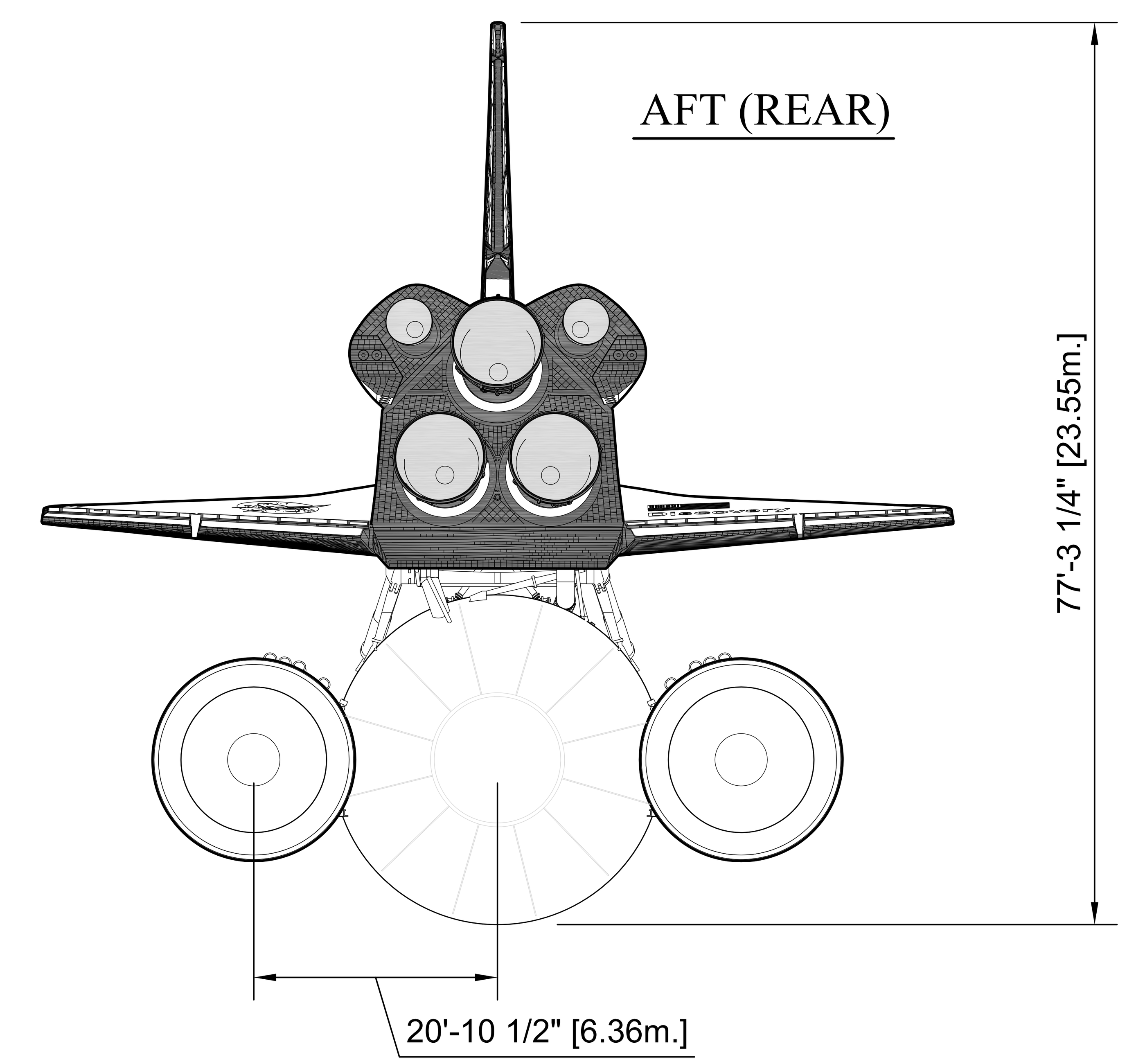
"TOP" ELEVATION



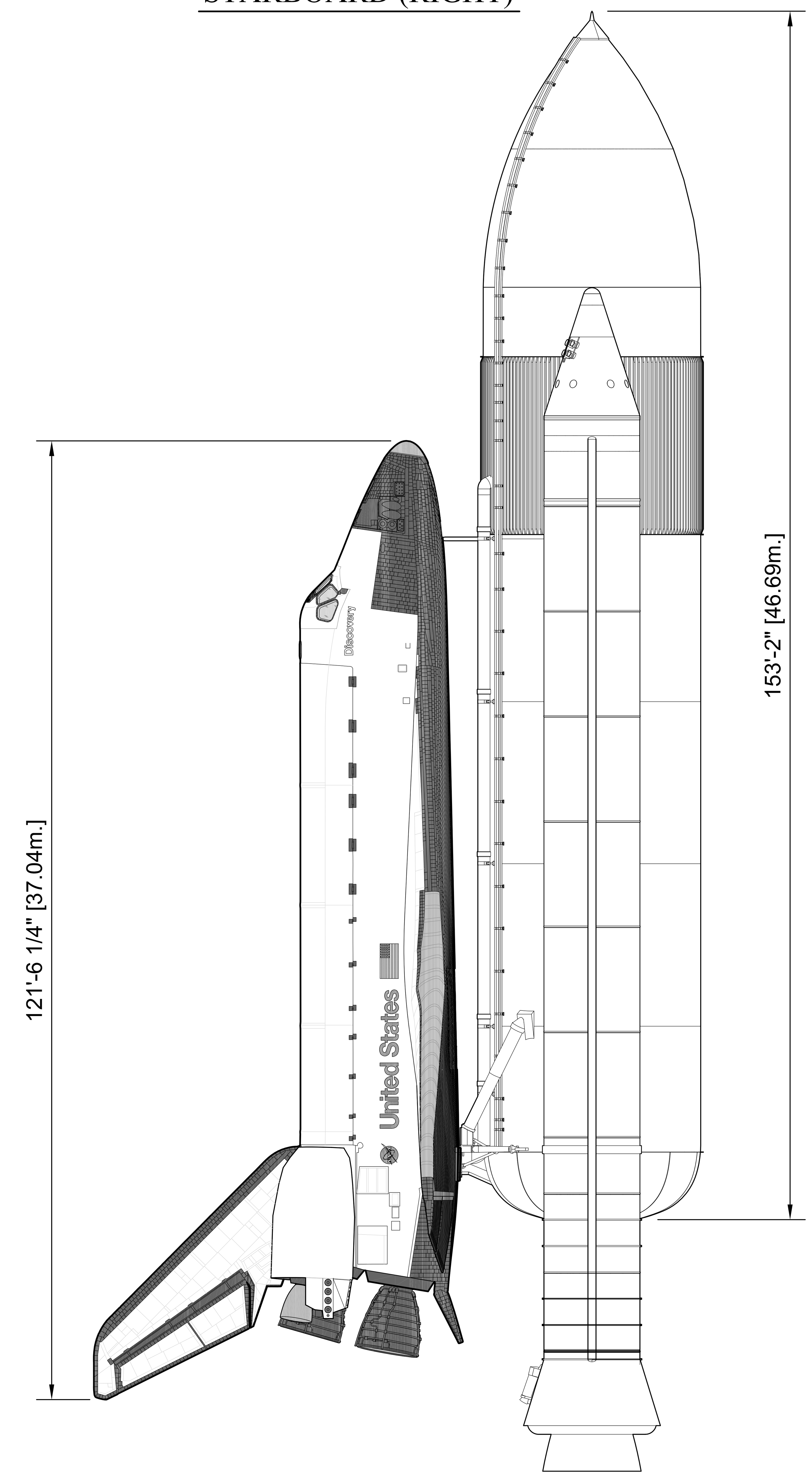
FORWARD



AFT (REAR)



STARBOARD (RIGHT)



SCALE: 3/32" = 1'-0"

0 5 15 30 FEET

0 1 5 10 METERS

FULL STACK ELEVATIONS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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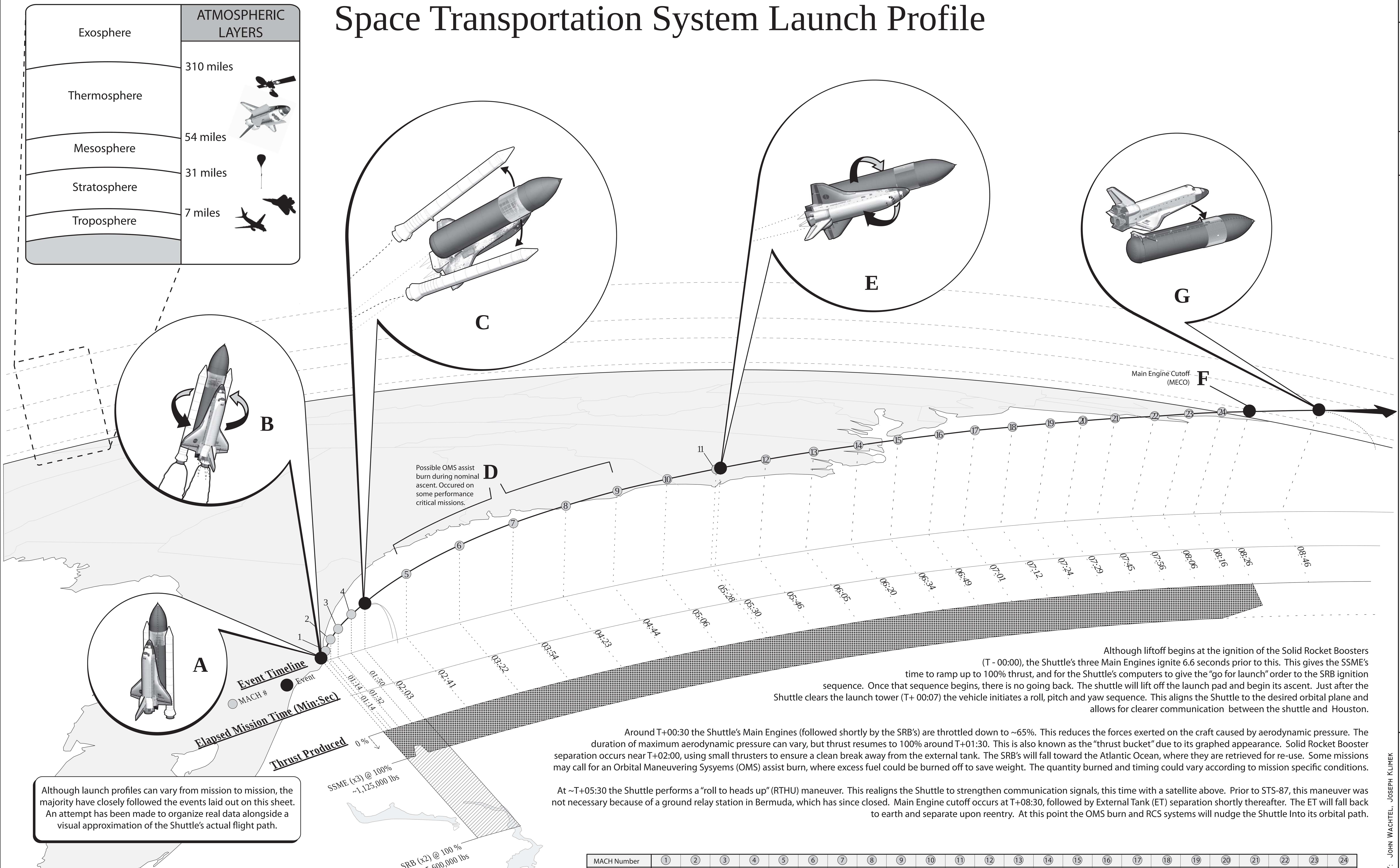
Space Transportation System Launch Profile



Although launch profiles can vary from mission to mission, the majority have closely followed the events laid out on this sheet. An attempt has been made to organize real data alongside a visual approximation of the Shuttle's actual flight path.

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 begin 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 Sysyems (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.

MACH Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Velocity (MPH)	681	1,410	2,067	2,780	3,413	4,102	4,786	5,470	6,158	6,829	7,566	8,231	8,934	9,621	10,265	10,966	11,612	12,302	13,049	13,681	14,345	15,093	15,754	16,386
Altitude (Miles)	3.42	11.08	17.24	24.56	43.52	54.31	60.77	64.71	67.06	68.25	68.72	68.61	68.19	67.59	67.01	66.33	65.69	65.09	64.56	64.23	64.02	63.91	64.01	64.32

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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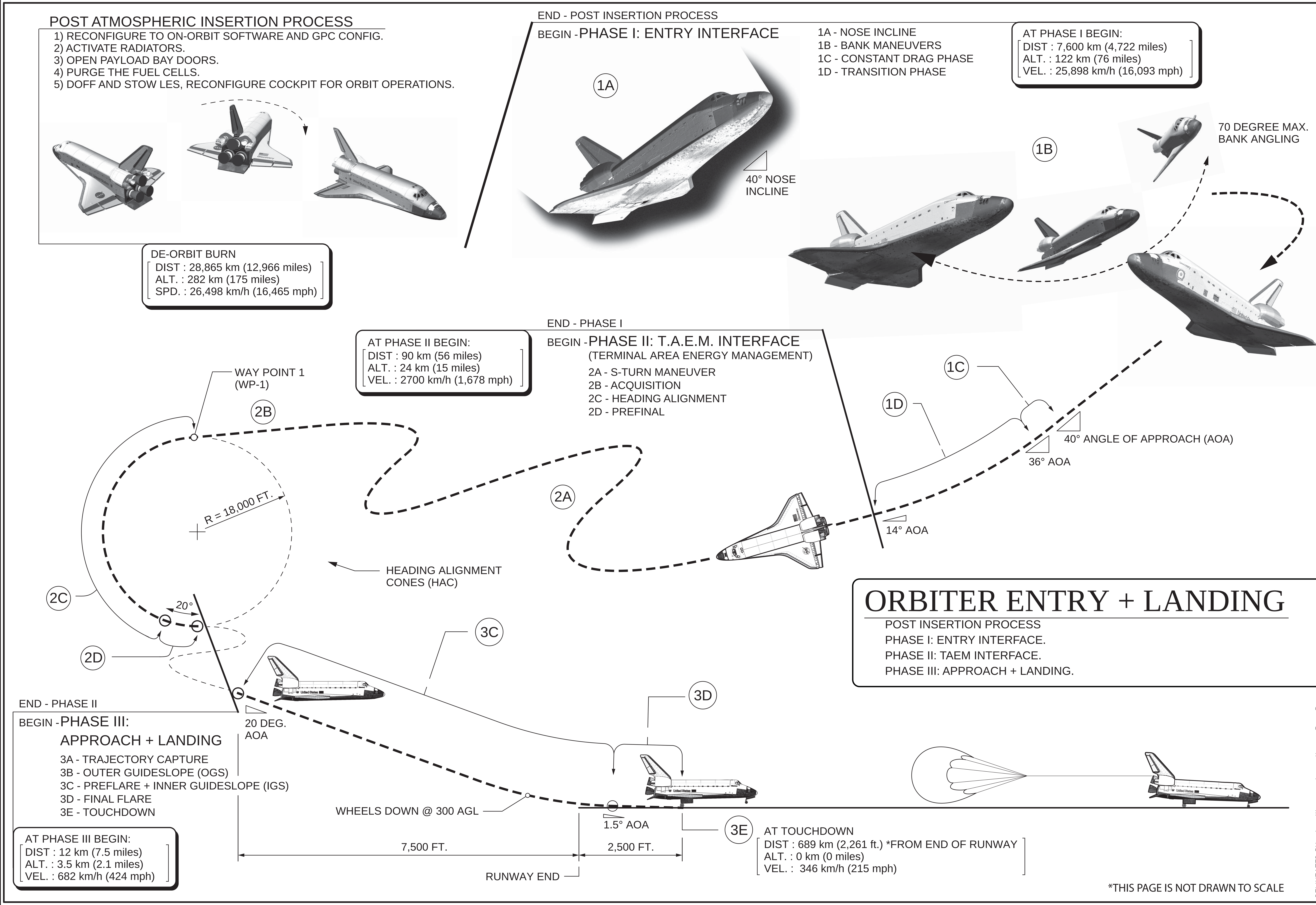

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK, RYAN PIERCE

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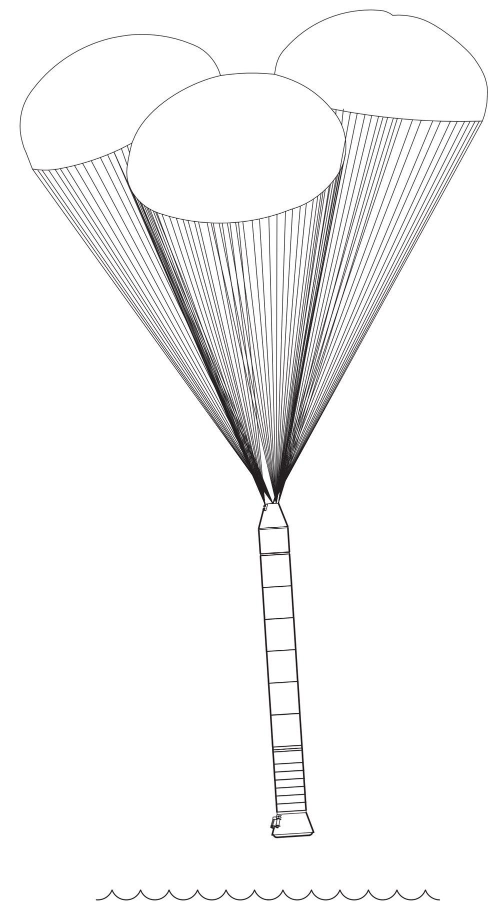
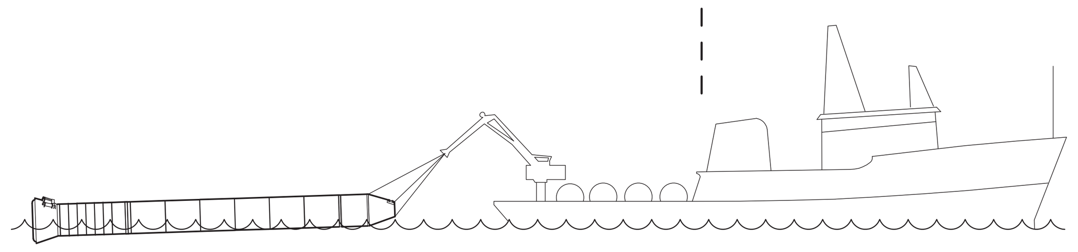
SRB RECOVERY & REFURBISHMENT



After the Solid Rocket Boosters (SRB) separated from the stack they began their decent 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.

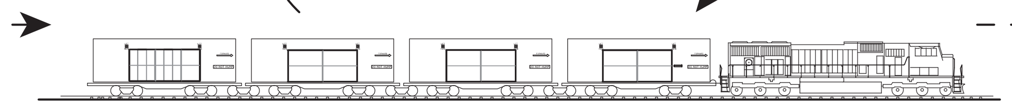


SRB DISASSEMBLY FACILITY

KENNEDY SPACE CENTER (KSC), FL

REFURBISH CENTER

CLEARFIELD & BRIGHAM CITY, UTAH



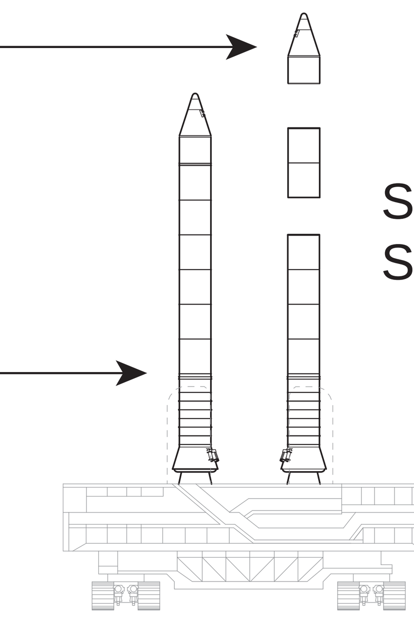
BY RAIL TO UTAH FACILITY

ASSEMBLY REFURBISHMENT FACILITY

KSC, FL

ROTATION PROCESSING AND SURGE FACILITY

KSC, FL

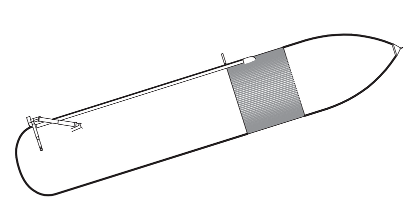


SRB STACKING

VEHICLE ASSEMBLY BUILDING (VAB)

KSC, FL

EXTERNAL TANK DELIVERY



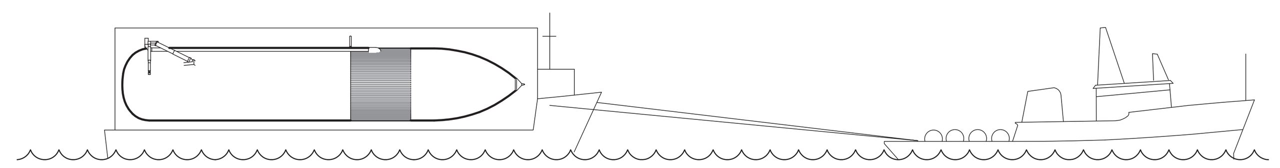
EXTERNAL TANK RE-ENTRY BREAK UP

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.

EXTERNAL TANK MANUFACTURING

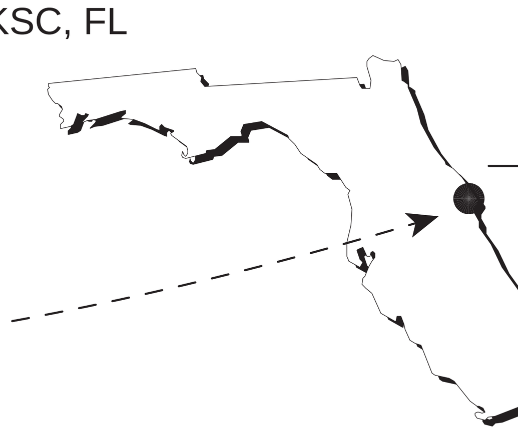
NEW ORLEANS, LA

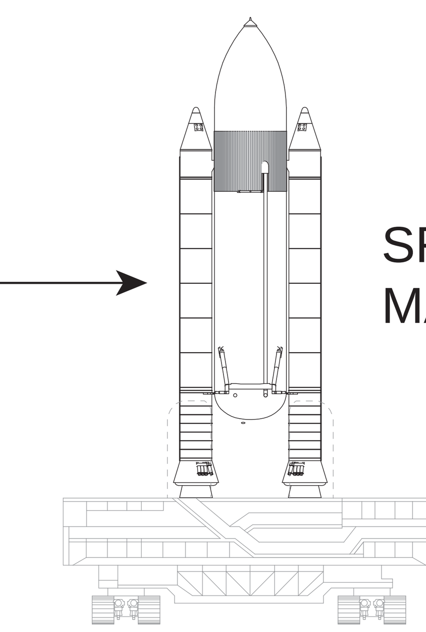
BARGE TRANSPORTATION



VEHICLE ASSEMBLY BUILDING

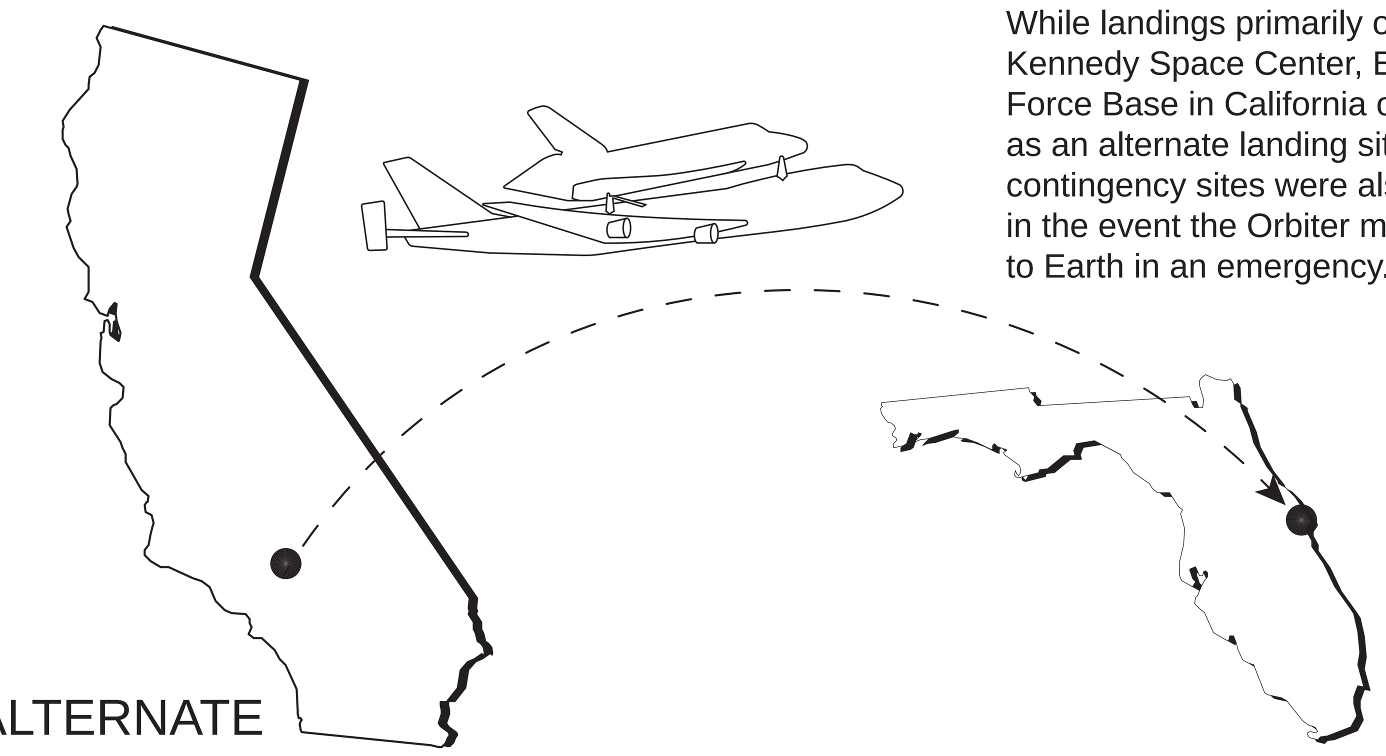
KSC, FL





SRB/ET MATE

SHUTTLE TURNAROUND & TRANSPORT



While landings primarily occured 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.

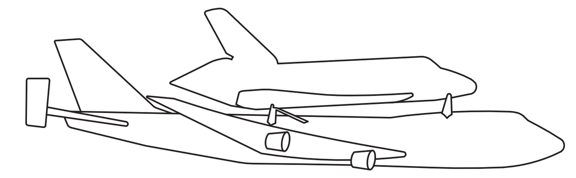
ALTERNATE LANDING SITE

EDWARDS AIR FORCE BASE, CA

ORBITER PROCESSING FACILITY (OPF)

KSC, FL

FROM ALT. LANDING SITE



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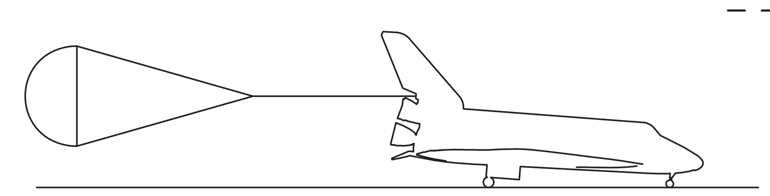


LANDING FROM PREVIOUS MISSION

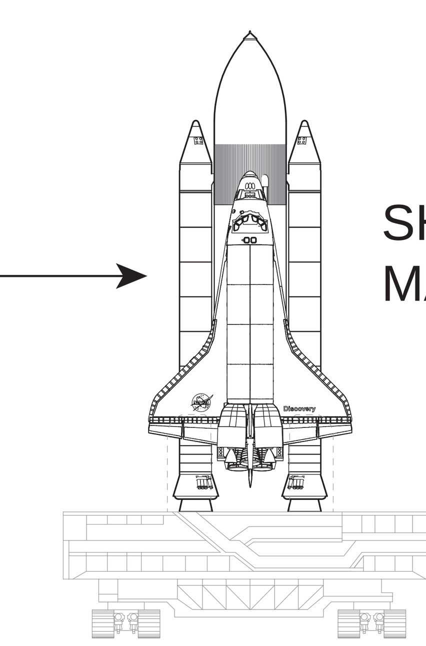
Spacecraft recovery operations began immediately after wheel stop. Systems were secured, crews disembarked, payloads, hazardous components and propulsion elements were removed, inspected and/or refurbished. Afterwards, pre-mate preparations began for the next mission of that Orbiter.

ORBITER PROCESSING FACILITY

KSC, FL

SSME PROCESSING FACILITY

KSC, FL



SHUTTLE MATE

TO LAUNCH PLATFORM FOR LIFT OFF

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK, RYAN RIERCE

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