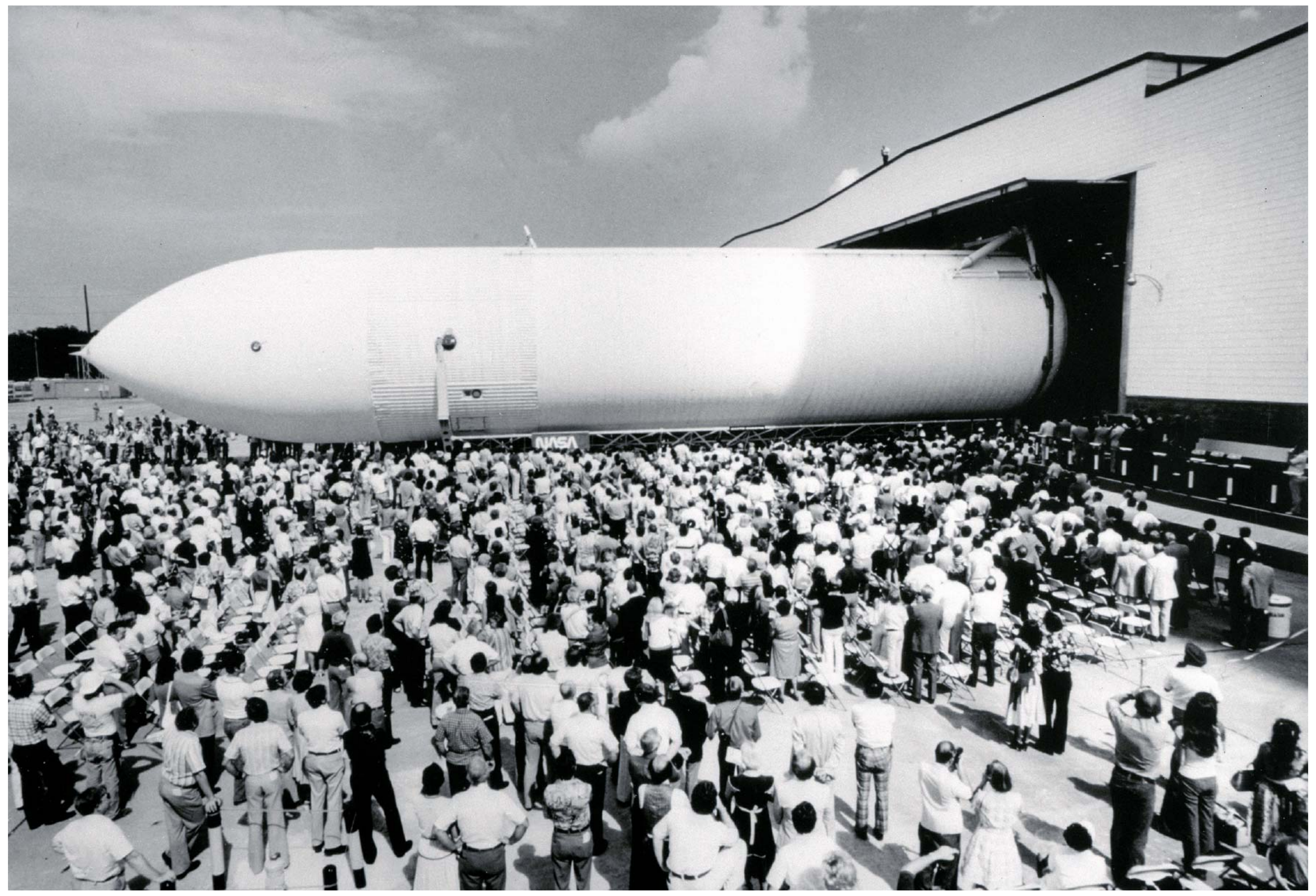
Space Transportation System External Tank



The first External Tank rolling out of the Michoud Assembly Facility on September 9, 1977. Image courtesy of NASA Marshall Space Flight Center. Photographer unknown.

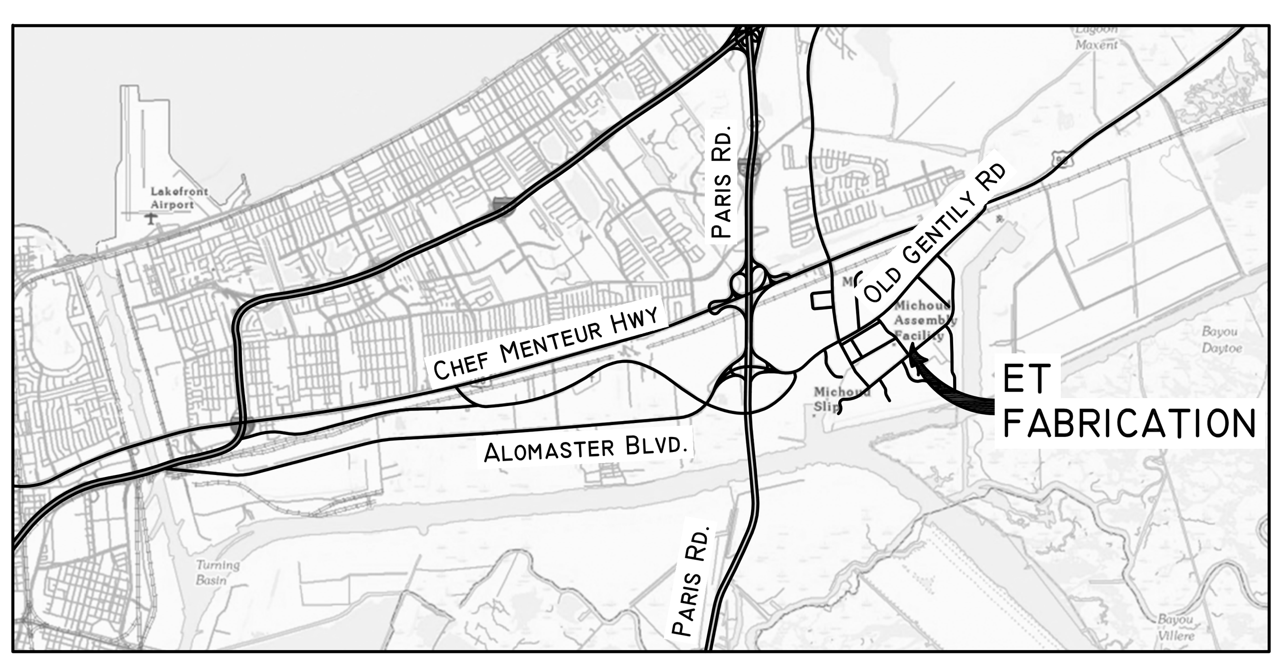
The External Tank (ET) was the largest and heaviest component of the stack assembly at approximately 154 feet long, 28 feet in diameter and over 1.5 million pounds when loaded with propellants. The ET was comprised of three distinct major elements, the forward or top liquid oxygen tank, an unpressurized inter-tank that housed the electronic components and an aft or bottom liquid hydrogen tank. Both liquid oxygen and liquid hydrogen are cryogenic fuels, oxygen becomes a liquid at minus 296 degrees Fahrenheit and hydrogen liquefies at minus 423 degrees Fahrenheit. The familiar orange color of the ET is from the spray-on polyurethane foam insulation used to keep the propellants at an optimum cryogenic temperatures and also protect the tanks from high temperatures during ascent. The foam also was also designed to withstand a potential 180 days exposure to the harsh marine climate at the launch pad with temperatures that could reach 115 degrees Fahrenheit and 100 percent humidity, with sand, salt, heavy rain and intense solar radiation.

The hydrogen tank, which was the bigger of the two tanks could hold a maximum of about 230,000 pounds of hydrogen, or about 390,000 gallons. The smaller oxygen tank, located at the top of the ET, could hold a maximum of about 1,375,000 pounds of oxygen or 145,000 gallons During powered flight the ET provided approximately 47,000 gallons per minute of hydrogen and approximately 18,000 gallons per minute of oxygen to all three Space Shuttle Main Engines (SSME) with a 6-to-1 mixture ratio, by weight, of liquid oxygen to liquid hydrogen.

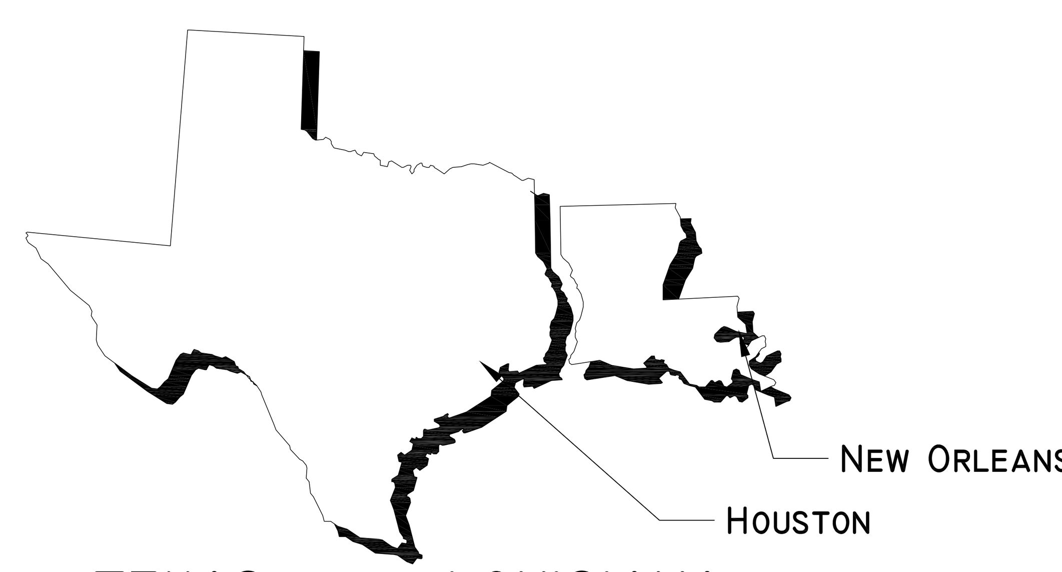
In addition to containing and delivering cryogenic propellants to the Space Shuttle Main Engines the ET also served as the structural support for the attachment of the Orbiter and Solid Rocket Boosters. While the STS stack assembly is sitting on the Mobile Launch Platform (MLP) the ET transfers the weight of the Orbiter and itself to the Solid Rocket Boosters (SRBs) which are attached to the MLP. At launch and ascent the ET absorbs the thrust loads produced by the SSMEs and the SRBs. Despite its size and structural requirements the aluminum alloy skin of the ET is only one eighth of an inch thick in most areas. As with all of the other components of the STS stack assembly, the ET has undergone improvements during the STS operational lifespan. Most notably, was two weight-saving redesigns that made the ETs lighter and stronger. The original version of the ET weighed 76,000 pounds empty. The first redesign, flown on STS-6, was the Lightweight ET which dropped 10,000 pounds from the original ETs. The second redesign, flown on STS-91, was the Super Lightweight ET that dropped an additional 7,500 pounds from the Lightweight tank resulting in a weight of 58,500 pounds.

The ET is the only part of the stack assembly that is not reused. At approximately 8 minutes and 30 seconds after launch the propellant has been consumed and the SSMEs are shut down. The ET is no longer needed and is jettisoned from the Orbiter. The effects of gravity pull the ET back into the Earth's atmosphere where heat and friction cause it to break up over a remote part of the Pacific Ocean.

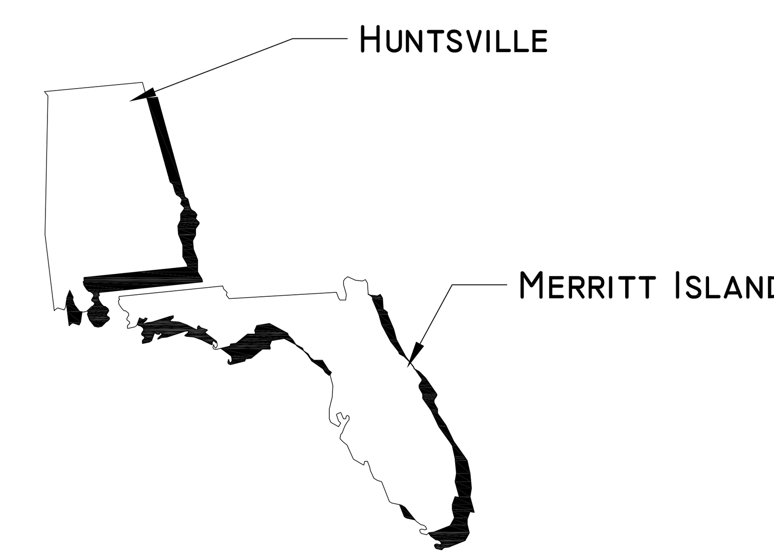
This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. 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.



VICINITY MAP NEW ORLEANS, LA



TEXAS LOUISIANA



ALABAMA FLORIDA

DELINEATED BY: THOMAS M. BEHRENS

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

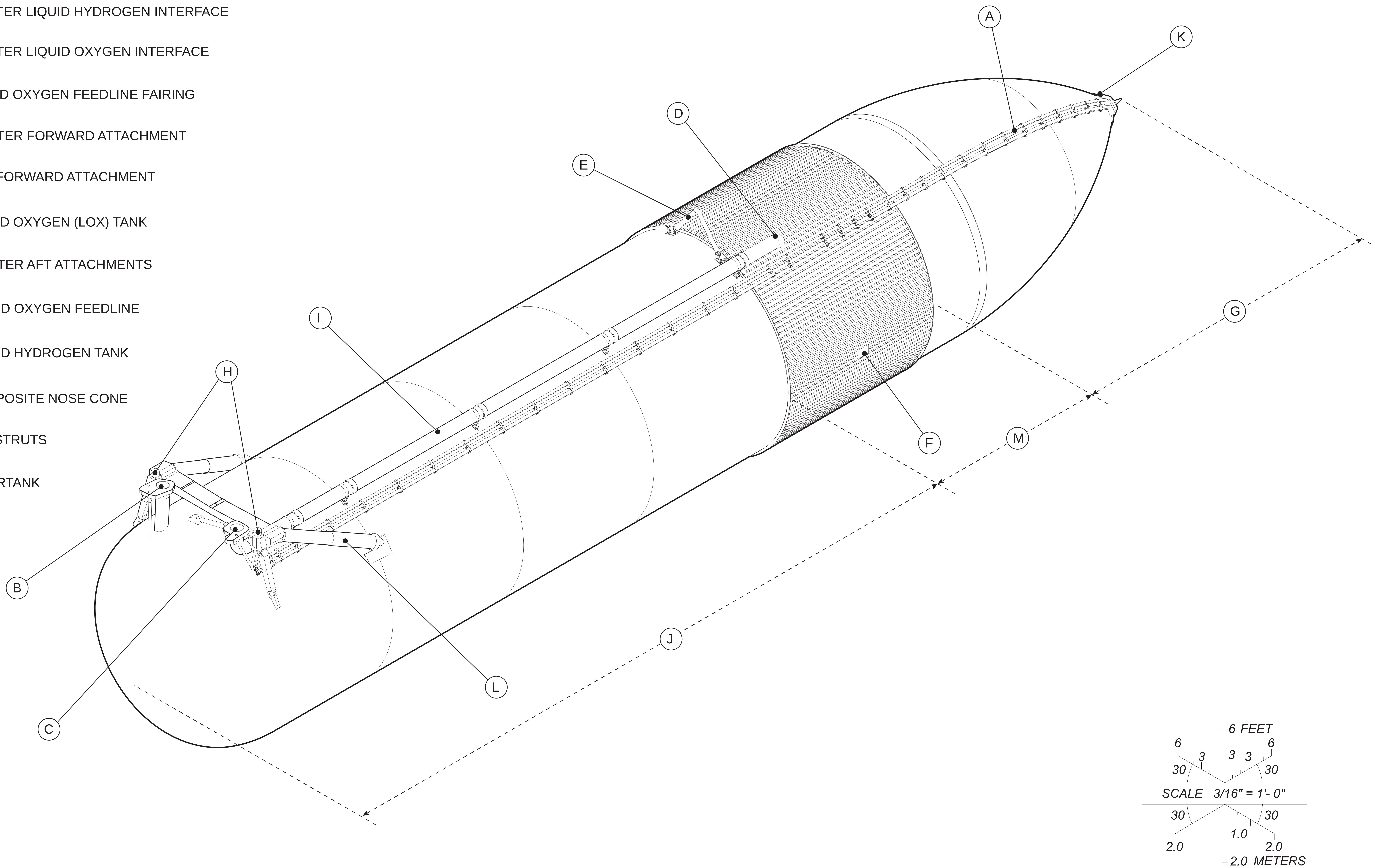
SPACE TRANSPORTATION SYSTEM, EXTERNAL TANK
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

SHEET 1 OF 3

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-J

LIBRARY OF CONGRESS INDEX NUMBER

Ⓐ CABLE TRAY, FAIRINGS AND PRESSURIZATION LINES
Ⓑ ORBITER LIQUID HYDROGEN INTERFACE
Ⓒ ORBITER LIQUID OXYGEN INTERFACE
Ⓓ LIQUID OXYGEN FEEDLINE FAIRING
Ⓔ ORBITER FORWARD ATTACHMENT
Ⓕ SRB FORWARD ATTACHMENT
Ⓖ LIQUID OXYGEN (LOX) TANK
Ⓗ ORBITER AFT ATTACHMENTS
Ⓘ LIQUID OXYGEN FEEDLINE
Ⓙ LIQUID HYDROGEN TANK
Ⓚ COMPOSITE NOSE CONE
Ⓛ AFT STRUTS
Ⓜ INTERTANK



EXTERNAL TANK ISOMETRIC

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

HOUSTON

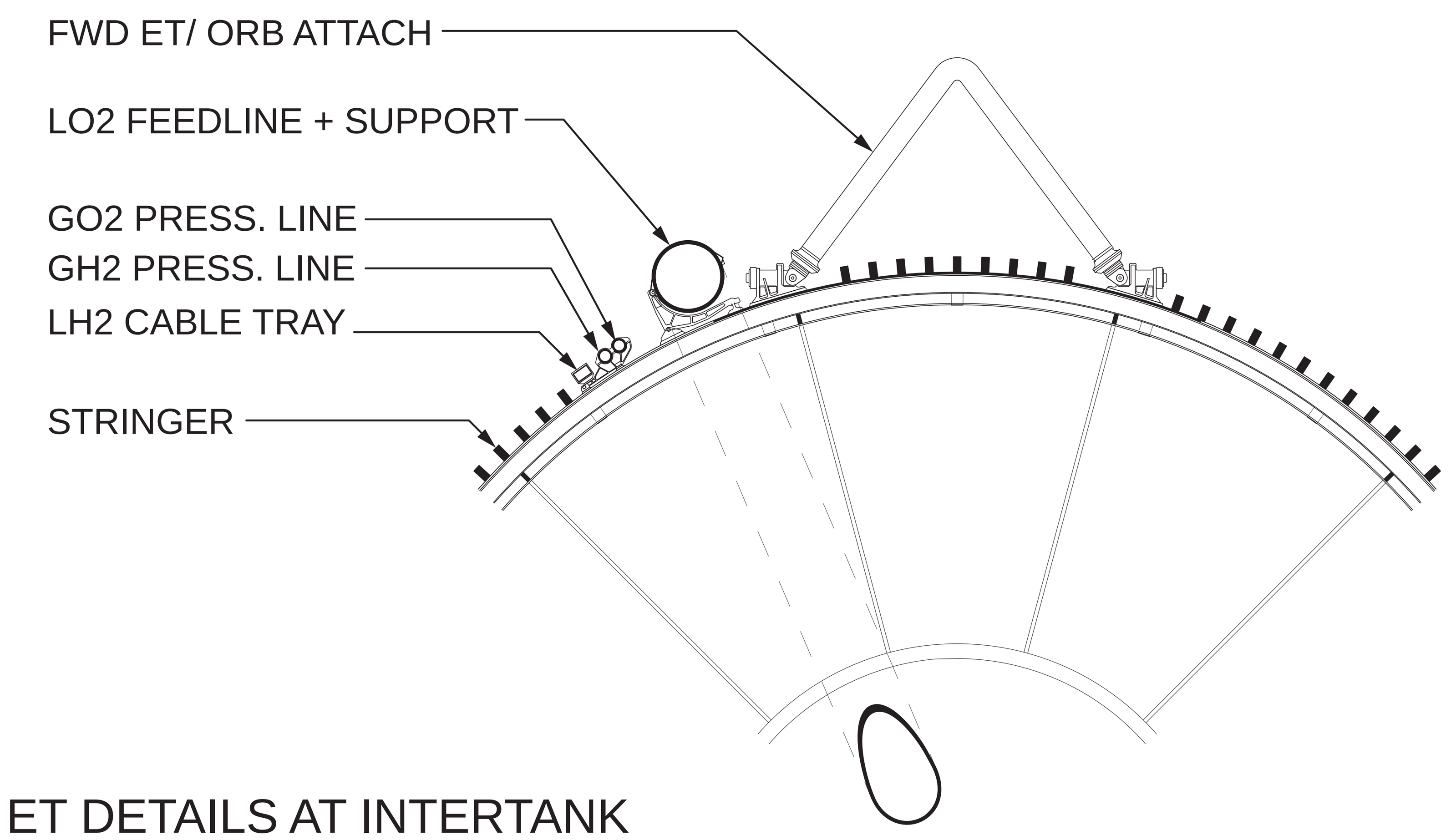
SPACE TRANSPORTATION SYSTEM, EXTERNAL TANK
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY

TEXAS

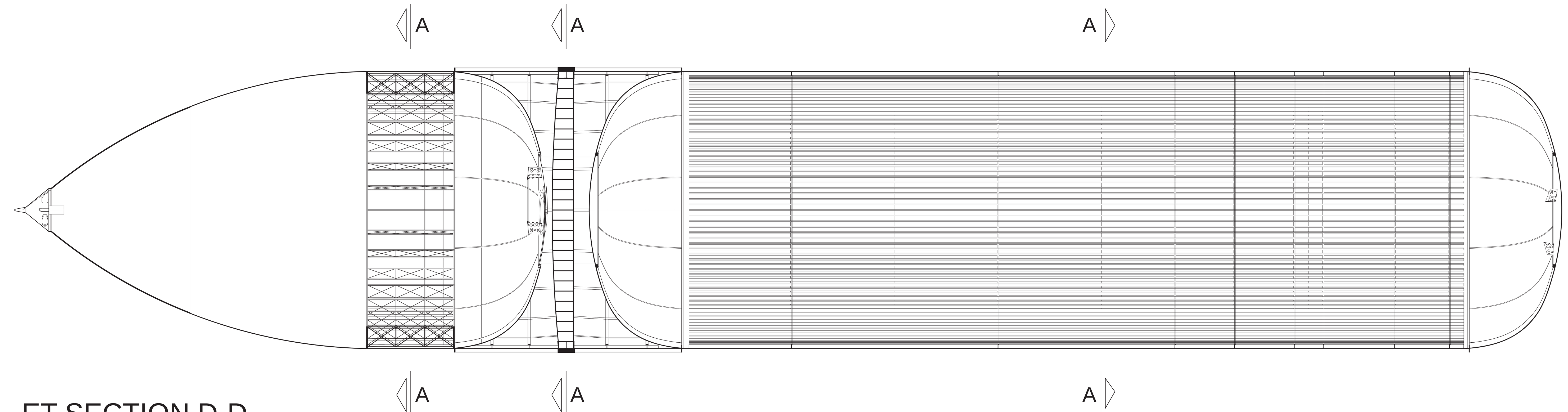
SHEET 2 OF 3

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-J

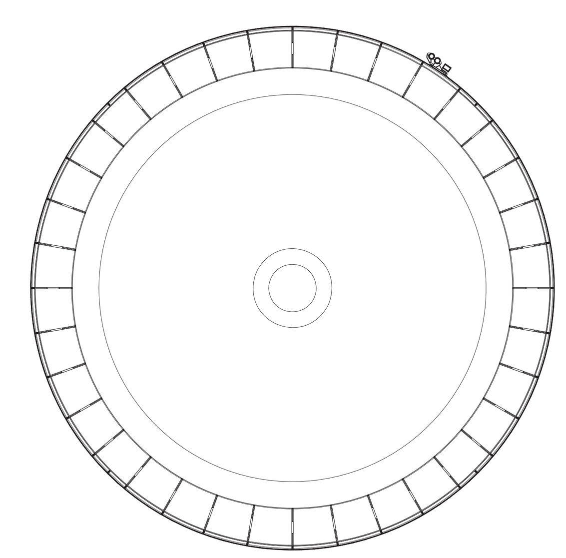
LIBRARY OF CONGRESS INDEX NUMBER



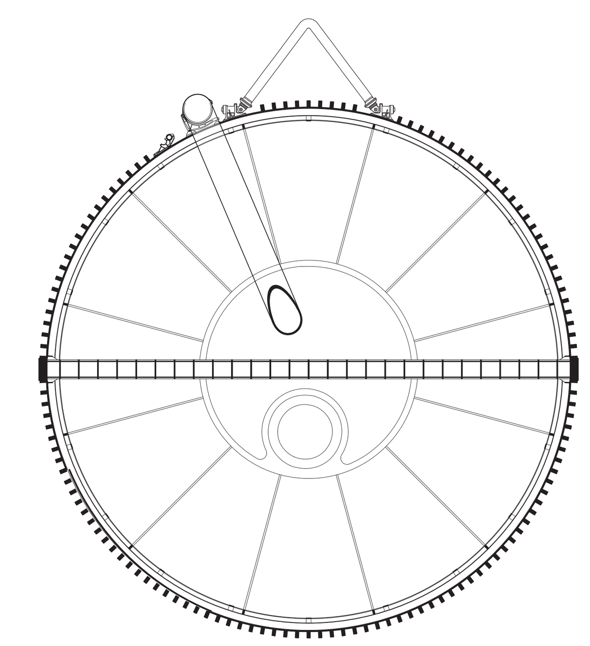
ET DETAILS AT INTERTANK
SCALE: 1" = 3'-0"



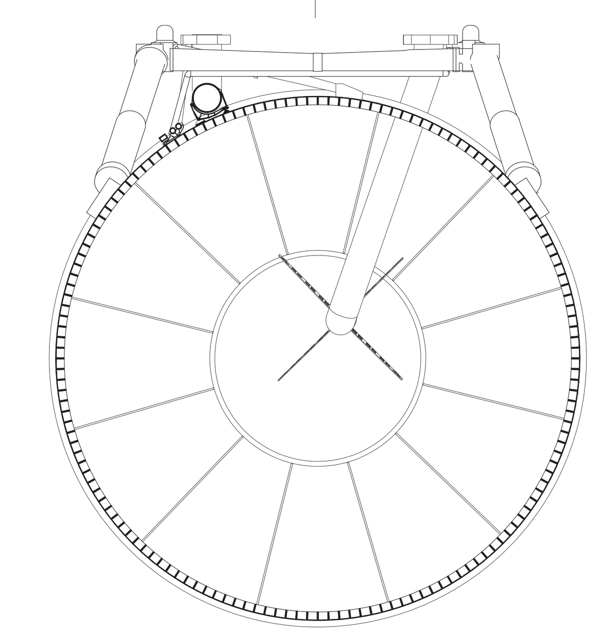
ET SECTION D-D
SCALE: 1/8" = 1'-0"



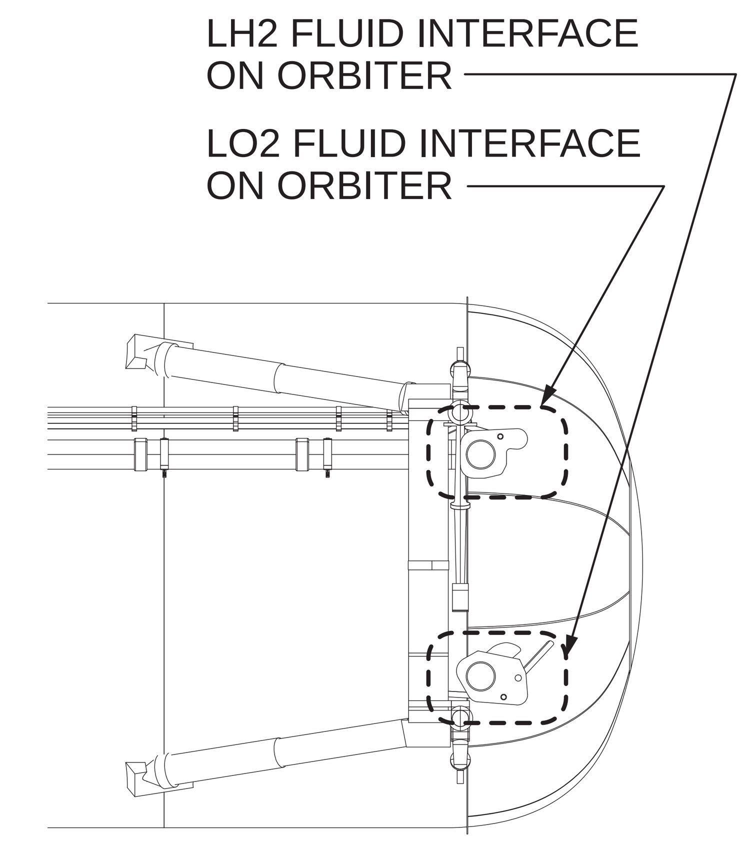
LO2 TANK SECTION
SCALE: 1/8" = 1'-0"



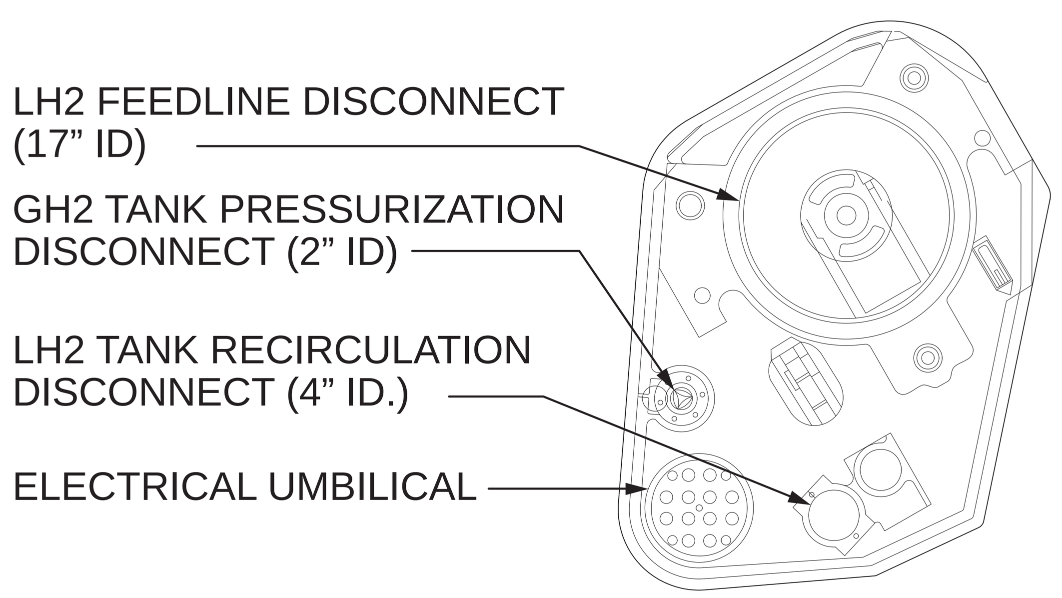
INTERTANK TANK SECTION
SCALE: 1/8" = 1'-0"



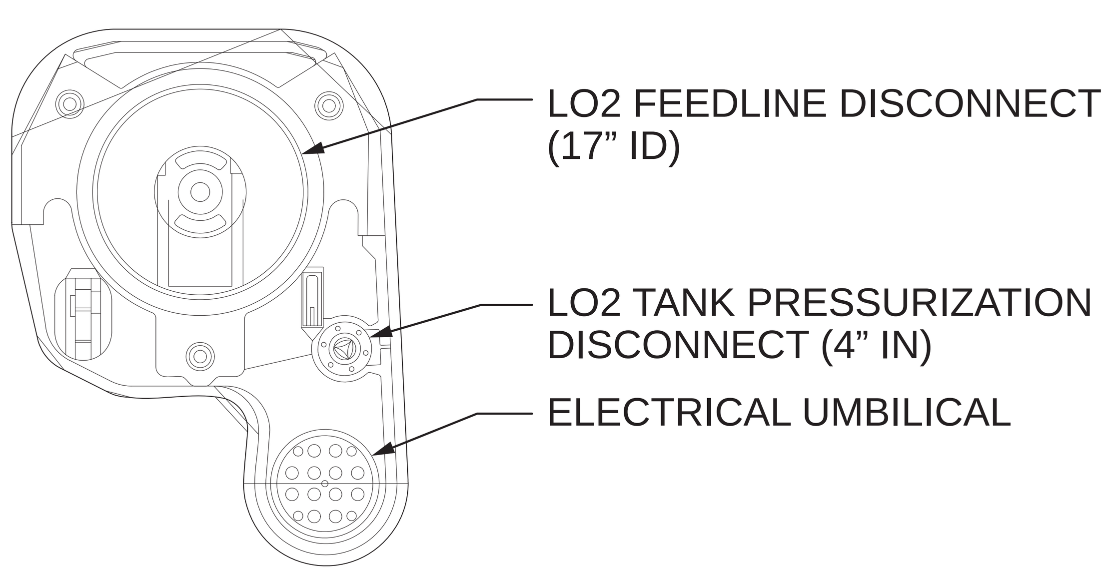
LH2 TANK SECTION
SCALE: 1/8" = 1'-0"



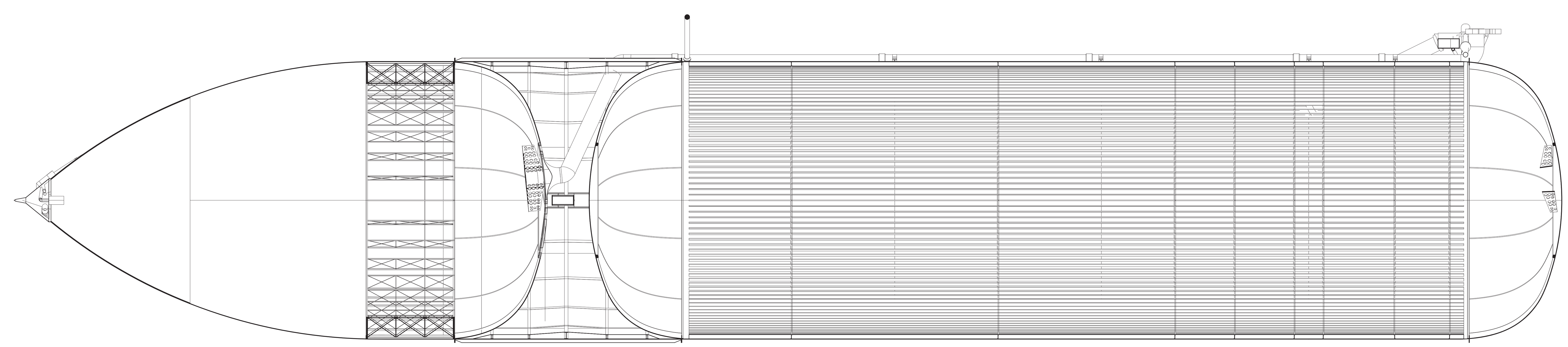
OV CONNECTION @ AFT
SCALE: 1/8" = 1'-0"



ORBITER/ ET LH2 FLUID INTERFACE
SCALE: 1" = 1'-0"



ORBITER/ ET LO2 FLUID INTERFACE
SCALE: 1" = 1'-0"



ET SECTION E-E
SCALE: 1/8" = 1'-0"

0 5 10 20 FEET
0 1 2 4 METERS
SCALE: 1/8" = 1'-0"

EXTERNAL TANK DETAILS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

SPACE TRANSPORTATION SYSTEM, EXTERNAL TANK
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY
HOUSTON
TEXAS

SHEET 3 OF 3

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-J

Space Transportation System Orbiter Discovery (OV-103)

1981 — STS-1 [First Flight, Columbia]
1982
1983 — STS-14 (41-D)
1984 — STS-19 (51-A), STS-20 (51-C)
1985 — STS-23 (51-D), STS-25 (51-G), STS-27 (51-I)
1986 — STS-33 (51-L) [Challenger Tragedy]
1987
1988 — Return To Flight-1
1989 — STS-26R, STS-29R
1990 — STS-33R, STS-31R
1991 — STS-41, STS-39
1992 — STS-48, STS-42, J-1 (Uprgrade Downtime)
1993 — STS-53, STS-56, STS-51
1994 — STS-60
1995 — STS-64, STS-63, STS-70
1996 — J-2 (Uprgrade Downtime)
1997 — STS-82, STS-85
1998 — STS-91
1999 — STS-95, STS-96
2000 — STS-103
2001 — STS-92, STS-102, STS-105
2002
2003 — STS-107 [Columbia Tragedy]
2004 — J-3 (Uprgrade Downtime)
2005 — Return To Flight-2, STS-114
2006
2007 — STS-121, STS-116
2008 — STS-120, STS-124
2009 — STS-119, STS-128
2010 — STS-131
2011 — STS-133, STS-135 [Final Flight, Atlantis]
2012

Discovery (OV-103), NASA's third Orbiter to join the fleet, was named after one of the two ships that were used by British explorer James Cook in the 1770s. It was the first Orbiter built solely for operations and not for testing and benefited from the knowledge gained from the construction, assembly and testing of the Orbiters Enterprise, Columbia and Challenger. When it was completed, Discovery was almost 7,000 pounds lighter than Columbia

Discovery arrived at the Kennedy Space Center in Florida on November 9, 1983. After checkout, testing and processing, it was launched on Aug. 30, 1984, for its first mission, 41-D, to deploy three communications satellites. Since its inaugural flight Discovery has completed 39 missions, more flights than any other orbiter in NASA's fleet, carried 252 crew members, spent 365 days in space and travelled over 148,000,000 miles.

Just like all of the orbiters, it has undergone some major modifications and upgrades over the years. Most of the improvements were made during periods when the Orbiters were out of flight rotation for their Orbiter Maintenance Down Periods or their Orbiter Major Modifications which lasted from a few months to over a year. Additional improvements were made during both Return to Flight work flows. A sample of the changes included improvements in steering and braking, the addition of the drag chute system, weight-saving modifications to the Thermal Protection System, installation of the Multifunction Electronic Display Subsystem in the flight-deck cockpit and the installation of an external airlock and docking system to facilitate docking with the International Space Station.

Discovery has the distinction of being chosen as the Return to Flight Orbiter twice. The first was for STS-26 in 1988, and the second when it carried the STS-114 crew on NASA's Return to Flight mission to the International Space Station (ISS) in July 2005. Other missions of note were STS-31R, the deployment of the Hubble Space Telescope (HST), STS-63, first female shuttle pilot and the first rendezvous and fly around by the shuttle of the space station Mir, STS-82 the second servicing of HST and highest altitude known for a shuttle flight at 360 statute miles, STS-95, the return of astronaut John Glenn to orbit as the oldest human to fly in space, STS-96, the first docking to the ISS and STS-103 the third HST servicing mission.

Discovery touched down for the final time at Kennedy Space Center at 11:57 am EDT, concluding STS 133, a mission to the International Space Station. Discovery was ferried atop the Shuttle Carrier Aircraft to the Smithsonian Institution's Air and Space Museum's Udvar-Hazy annex in Chantilly, Virginia where it is now on permanent display.

Orbiter Discovery on orbit during STS-131. The Leonardo Multi-Purpose Logistic Module for the International Space Station is in its payload bay. Image courtesy of NASA Johnson Space Center. Photographer unknown

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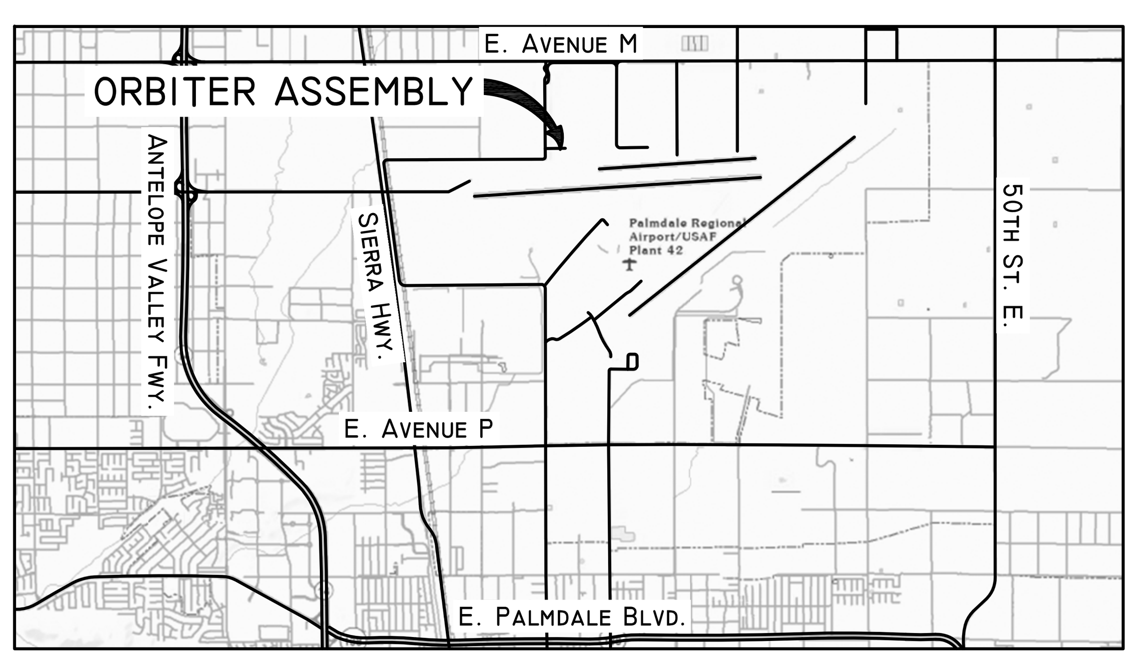
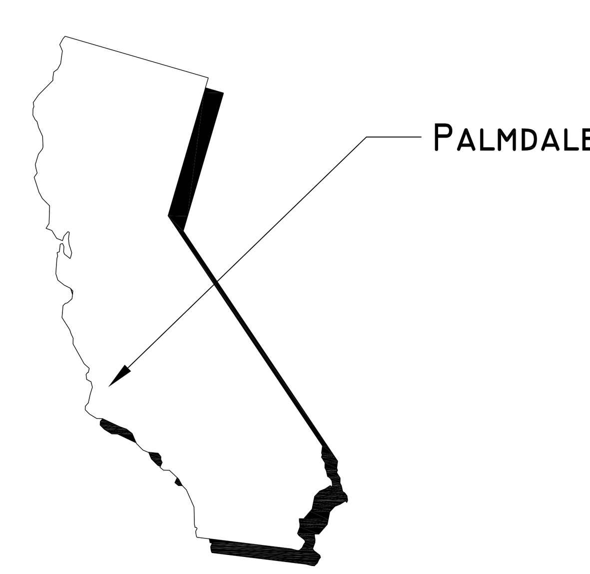
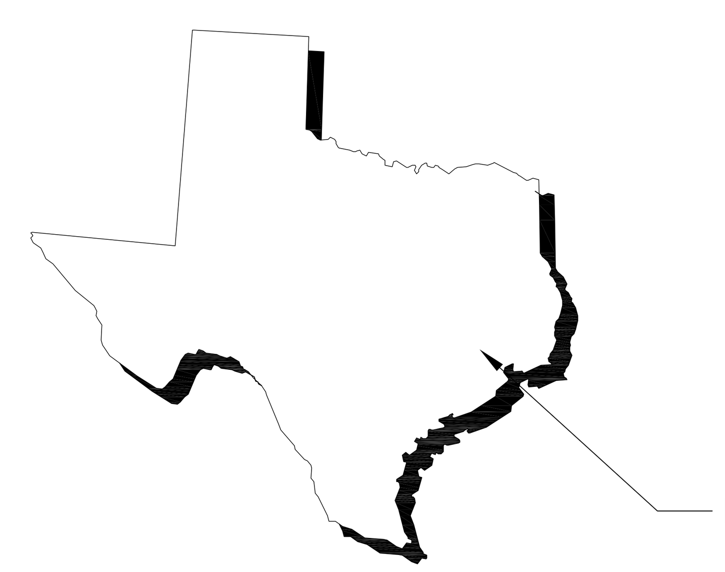


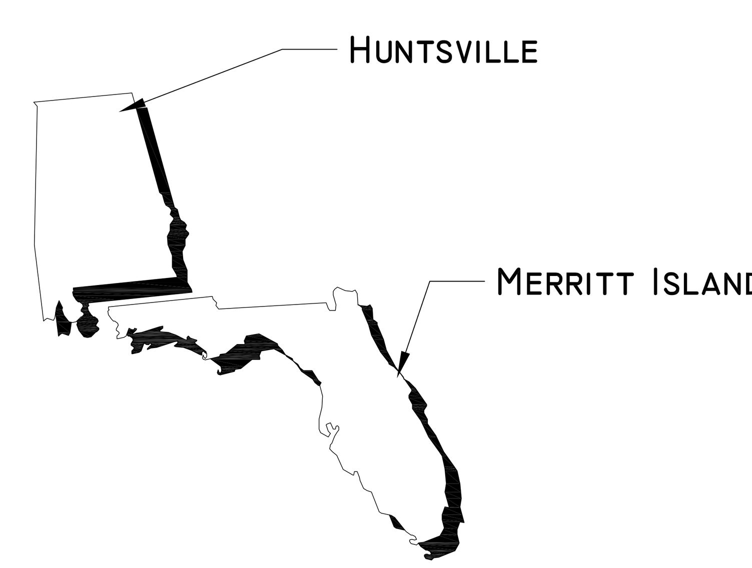
Vicinity Map Palmdale, CA



California



Texas



Alabama Florida

Delineated by: Thomas M. Behrens

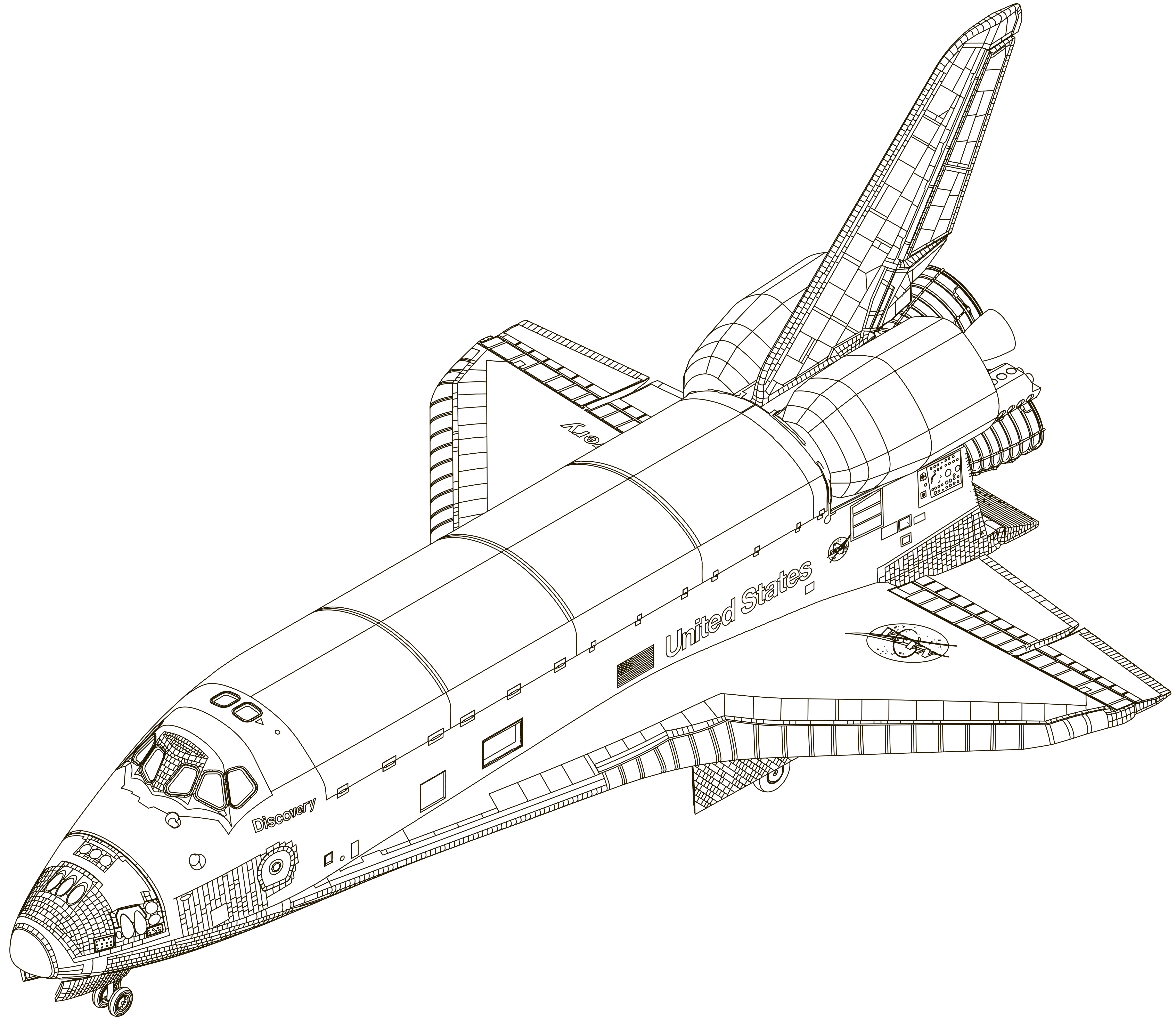
Space Transportation System Recording Project
National Park Service
United States Department of the Interior

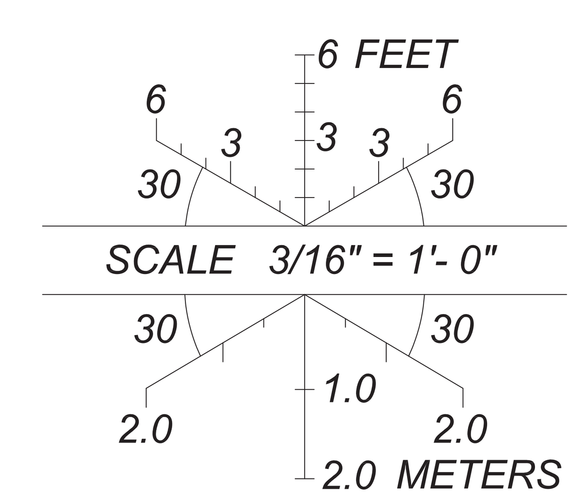
Space Transportation System, Orbiter Discovery (OV-103)
Johnson Space Center, 2101 NASA Parkway
Houston Harris County Texas

Sheet 01 of 15

Historic American Engineering Record
TX-116-A

Library of Congress Index Number





FRONT PORT ISOMETRIC

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)
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

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HISTORIC AMERICAN ENGINEERING RECORD
TX-116-A

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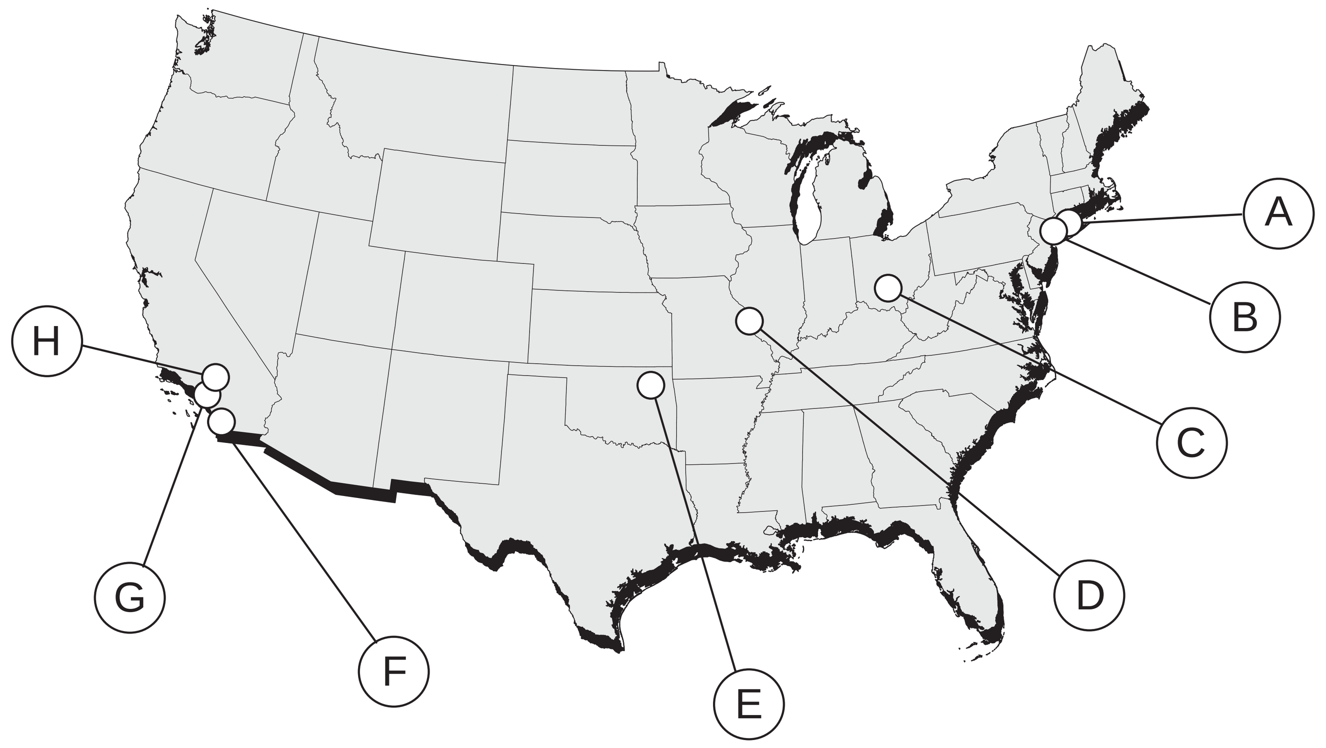


(A) FAIRCHILD REPUBLIC
FARMINGDALE, NY
- VERTICAL TAIL

(B) GRUMMAN
BETHPAGE, NY
- WINGS

(C) NORTH AMERICAN ROCKWELL
COLUMBUS, OH
- BODY FLAP

(D) MCDONNELL DOUGLAS
ST. LOUIS, MO
- OMS PODS

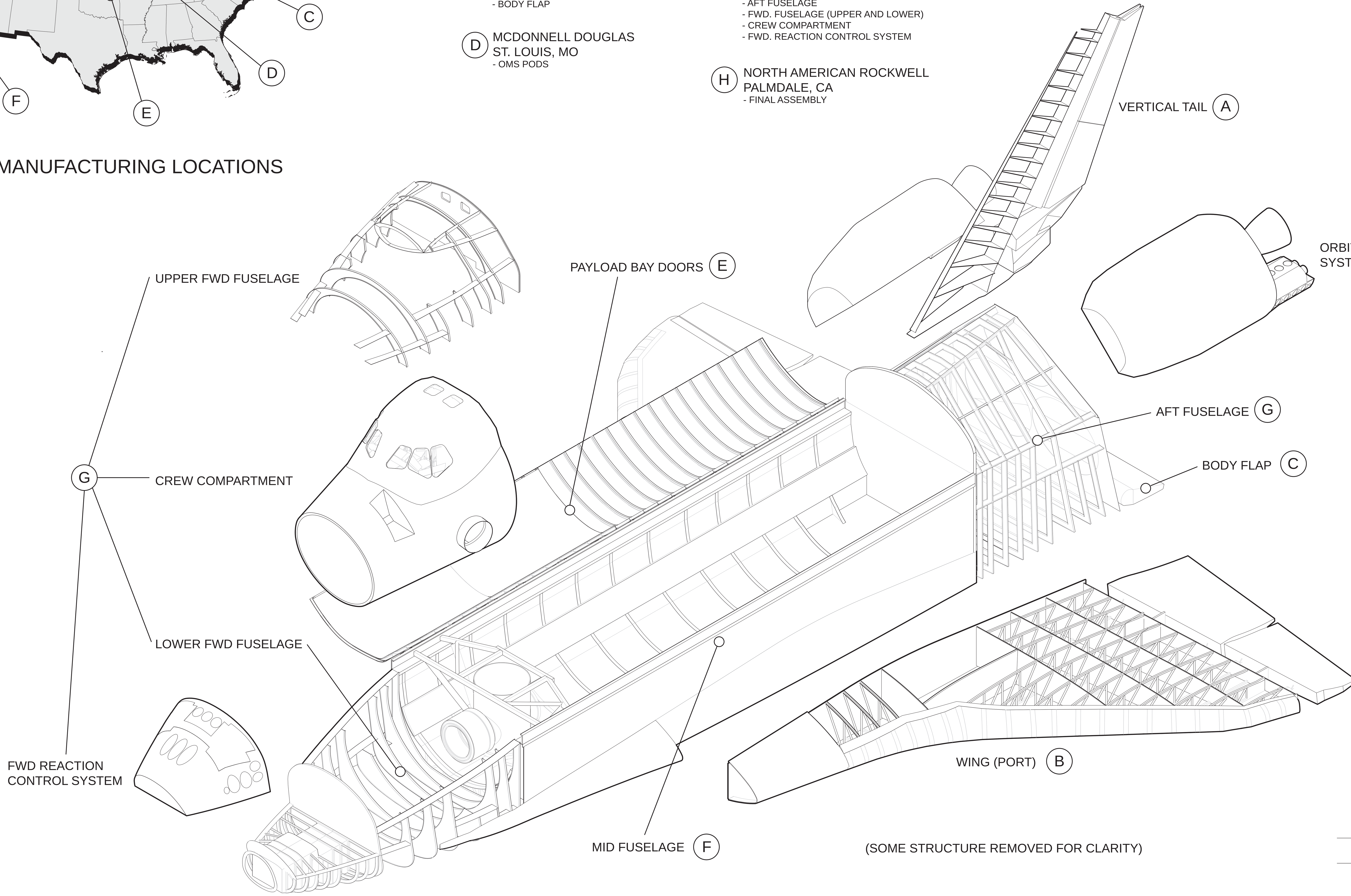
(E) NORTH AMERICAN ROCKWELL
TULSA, OK
- ORBITER PAYLOAD BAY DOORS

(F) GENERAL DYNAMICS
SAN DIEGO, CA
- ORBITER MID FUSELAGE

(G) NORTH AMERICAN ROCKWELL
DOWNEY, CA
- AFT FUSELAGE
- FWD. FUSELAGE (UPPER AND LOWER)
- CREW COMPARTMENT
- FWD. REACTION CONTROL SYSTEM

(H) NORTH AMERICAN ROCKWELL
PALMDALE, CA
- FINAL ASSEMBLY

MAJOR MANUFACTURING LOCATIONS



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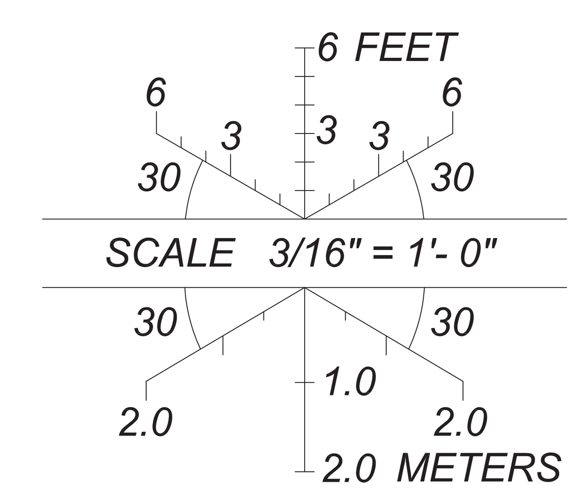

COMPONENT ISOMETRIC

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
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SPACE TRANSPORTATION SYSTEM, ORBITER DISCOVERY (OV-103)
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

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HISTORIC AMERICAN ENGINEERING RECORD
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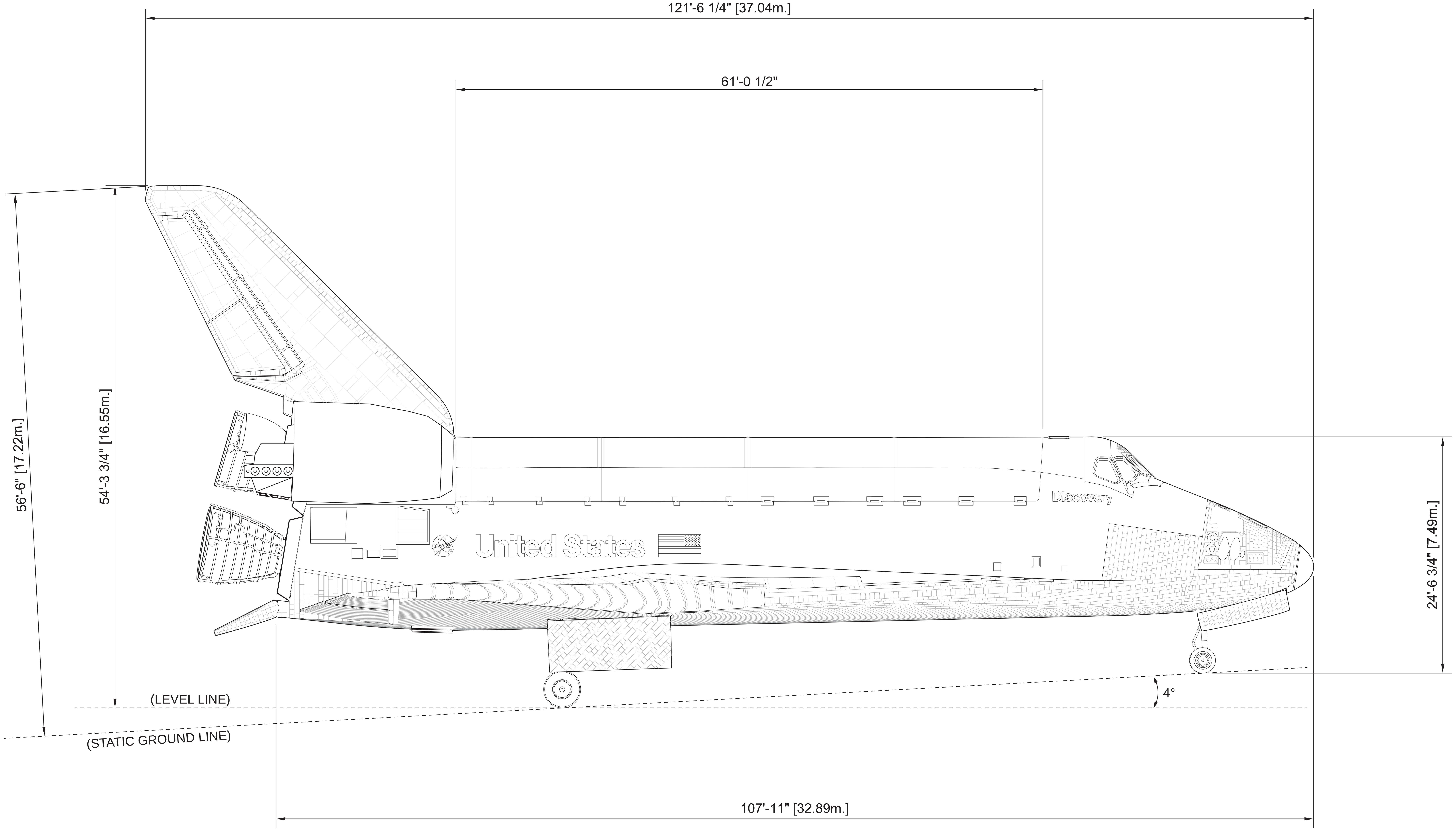

STARBOARD ELEVATION

SCALE: 3/16" = 1'-0"

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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HOUSTON HARRIS COUNTY TEXAS

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HISTORIC AMERICAN ENGINEERING RECORD
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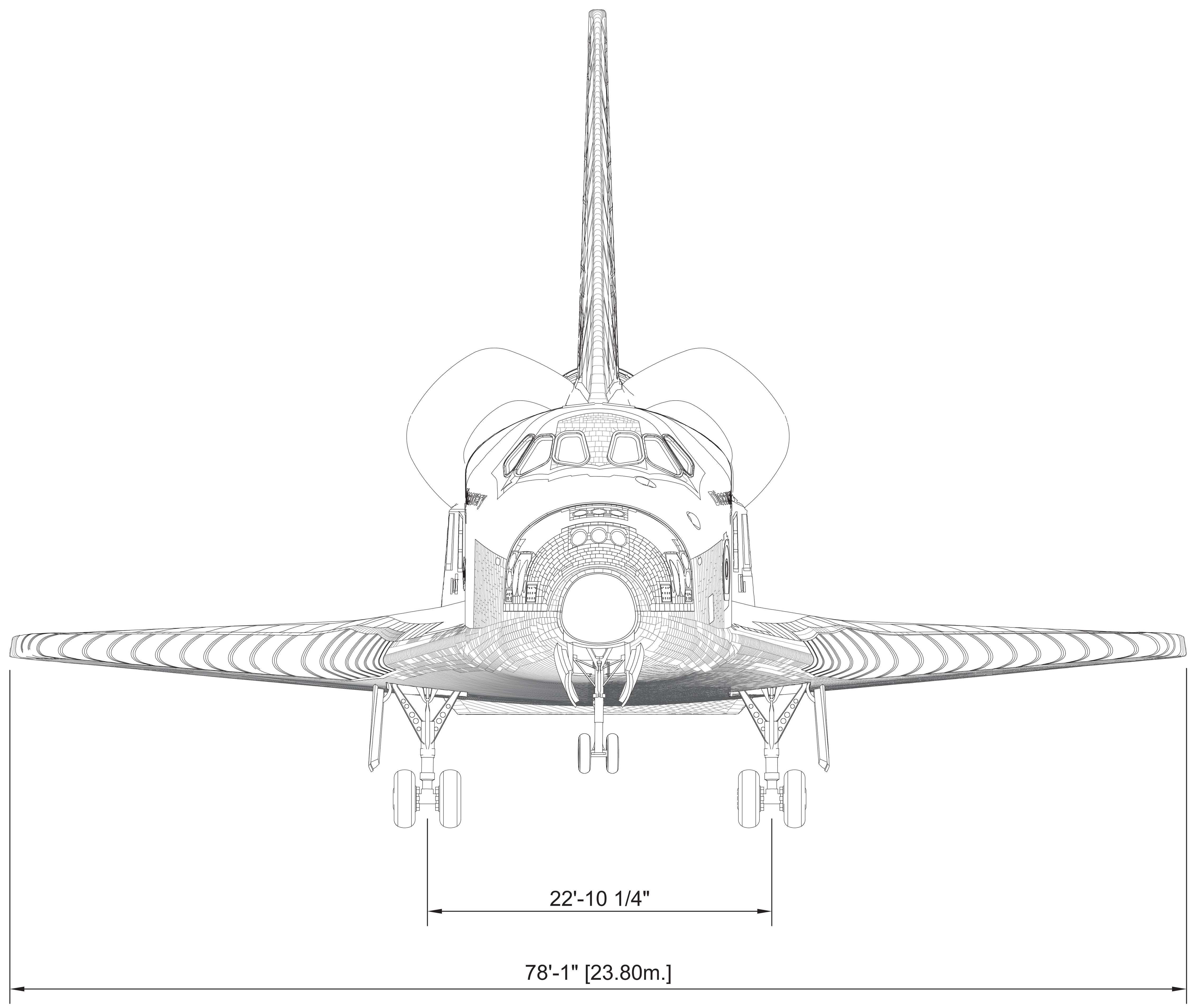

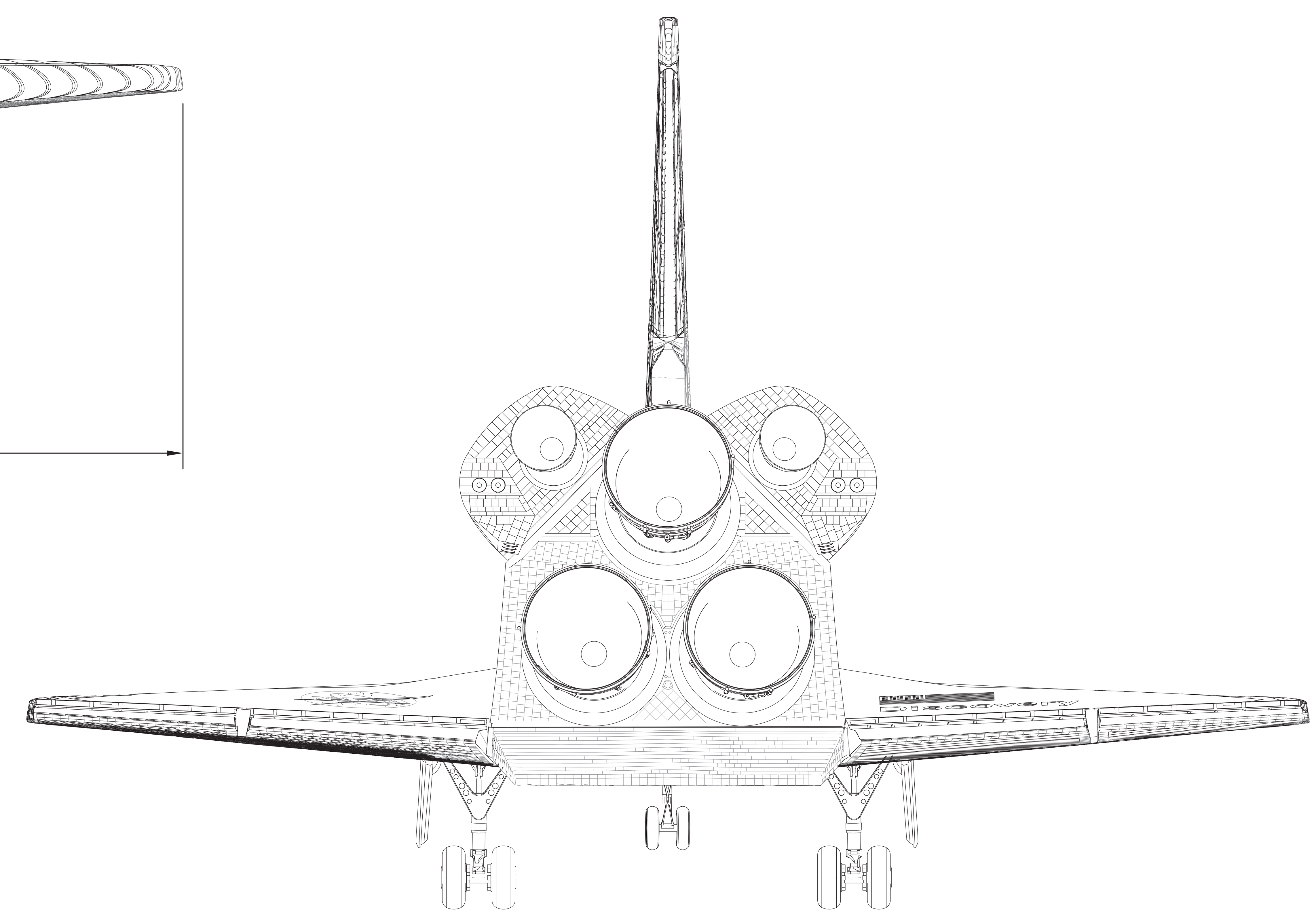

FWD AND AFT ELEVATIONS

SCALE: 3/16" = 1'-0"

0 5 10 20 FEET

0 1 2 3 4 5 METERS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
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SPACE TRANSPORTATION SYSTEM, ORBITER DISCOVERY (OV-103)
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HOUSTON HARRIS COUNTY TEXAS

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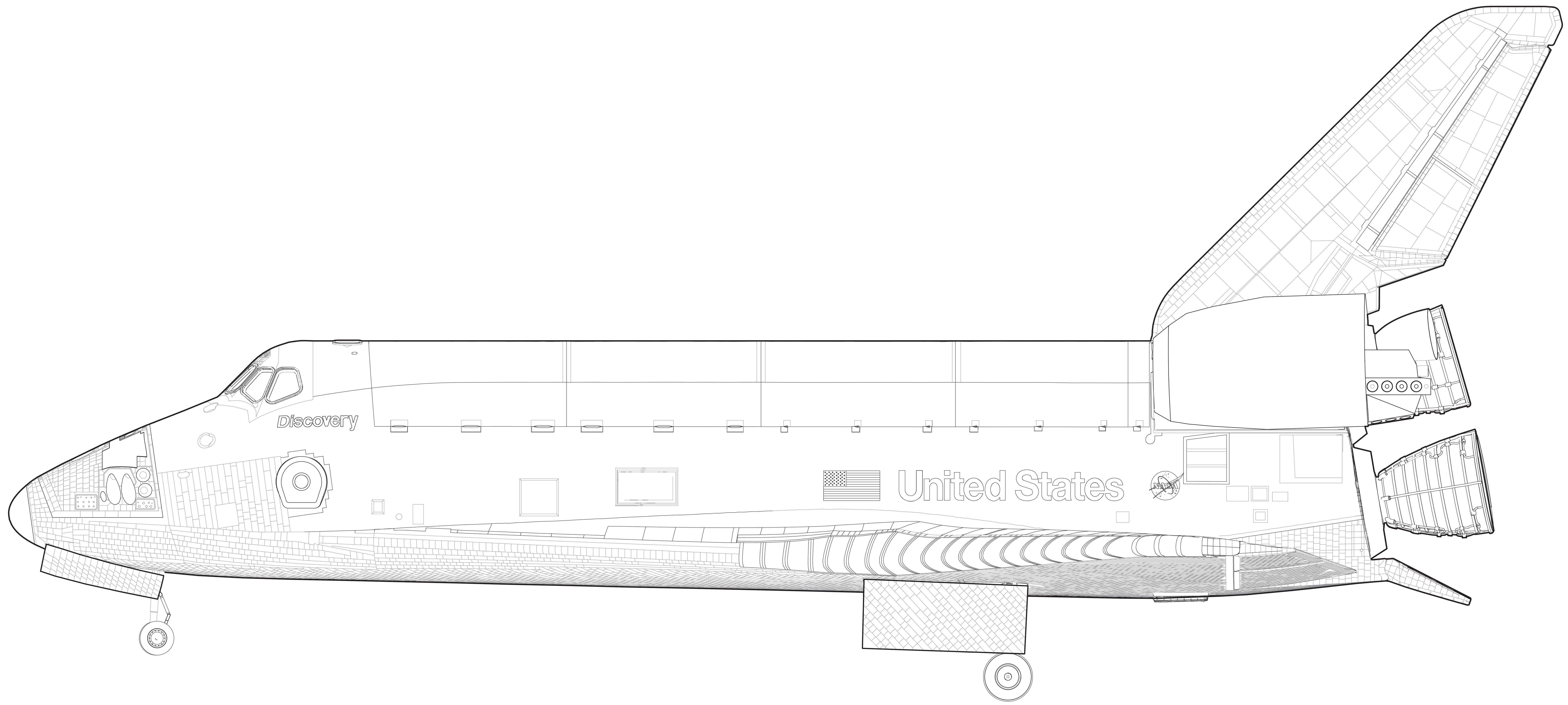

PORT ELEVATION

SCALE: 3/16" = 1'-0"

0 5 10 20 FEET

0 1 2 3 4 5 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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HOUSTON HARRIS COUNTY TEXAS

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HISTORIC AMERICAN ENGINEERING RECORD
TX-116-A

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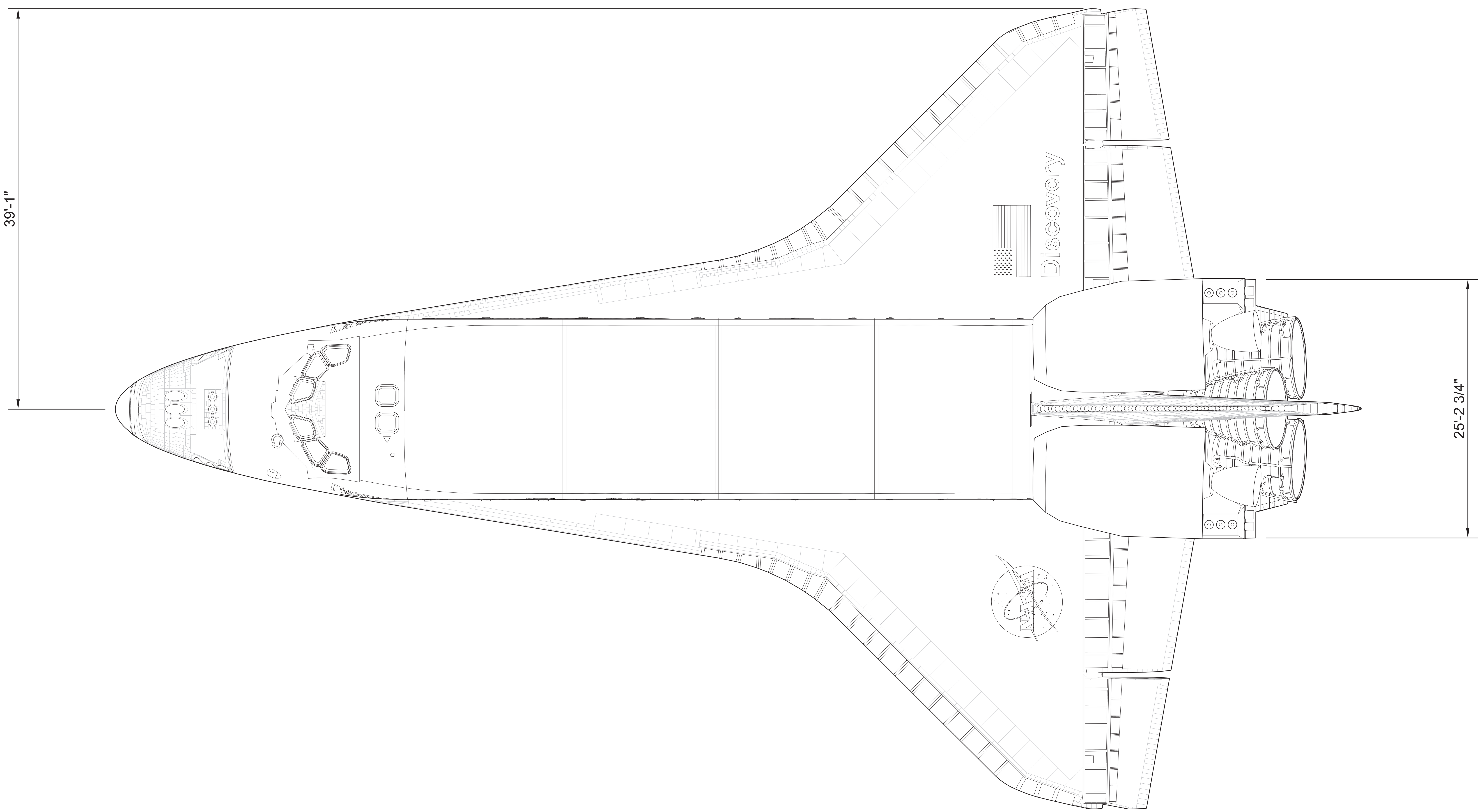


TOP PLAN

SCALE: 3/16" = 1'-0"

0 5 10 20 FEET

0 1 2 3 4 5 METERS

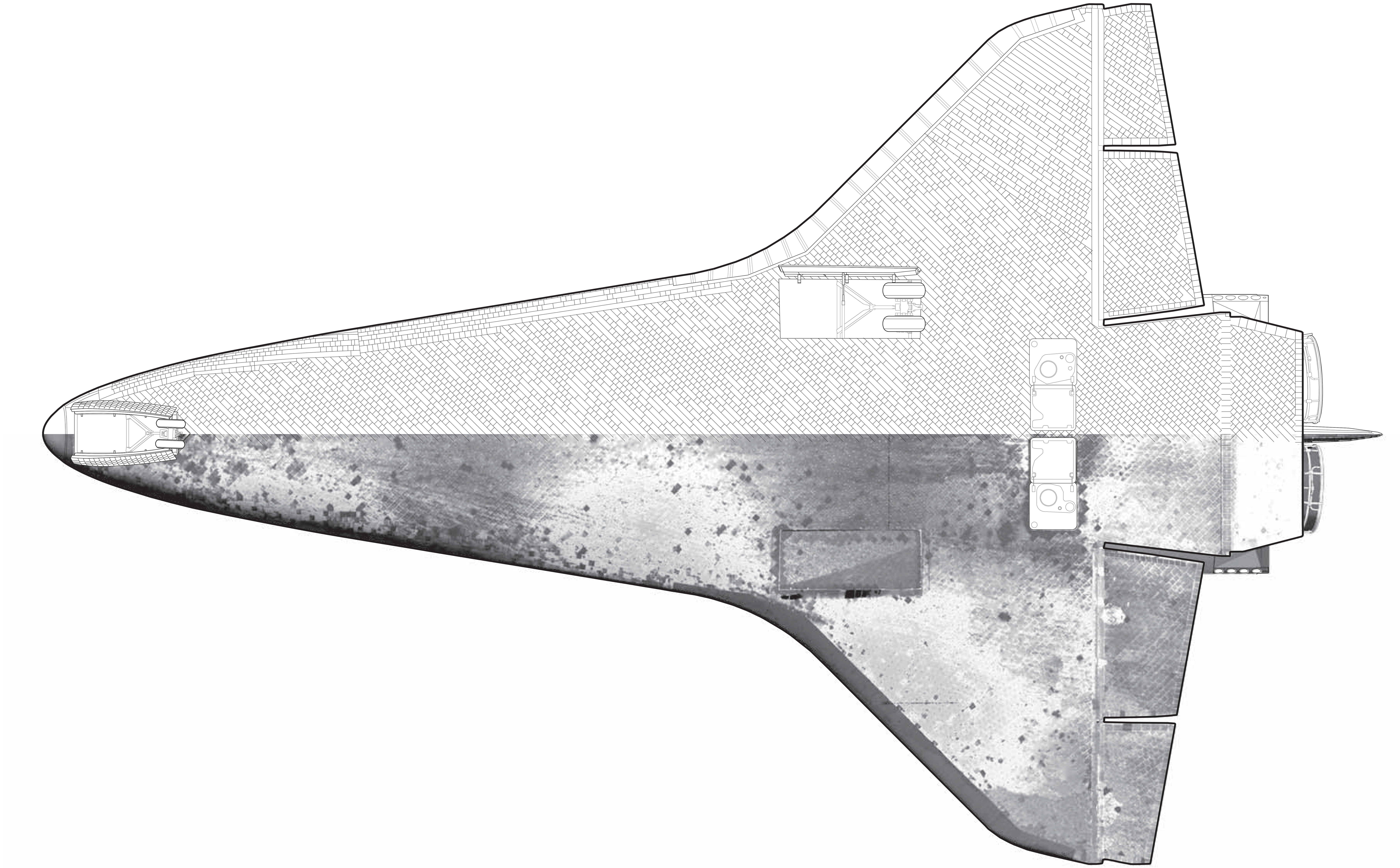
DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

SPACE TRANSPORTATION SYSTEM, ORBITER DISCOVERY (OV-103)
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

SHEET 07 OF 15

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-A



*THE LOWER HALF OF THIS DRAWING SHOWS TILE INFORMATION GATHERED BY THE HIGH DEFINITION LASER SCANNER. THE CONTRAST HAS BEEN MODIFIED TO BETTER ILLUSTRATE THE WEAR OVER TIME.

BOTTOM PLAN

SCALE: 3/16" = 1'-0"

0 5 10 20 FEET

0 1 2 3 4 5 METERS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
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SPACE TRANSPORTATION SYSTEM, ORBITER DISCOVERY (OV-103)
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
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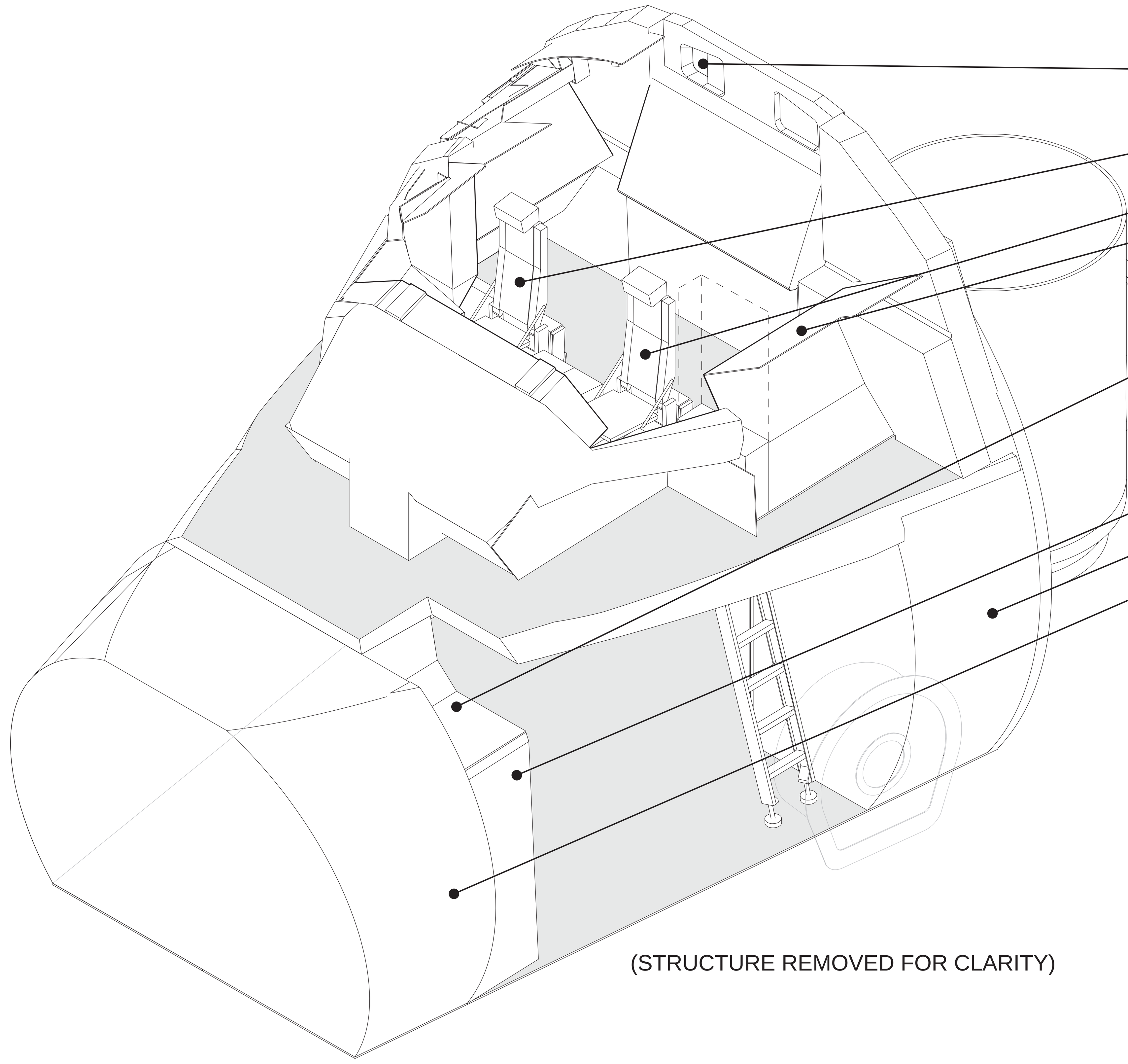

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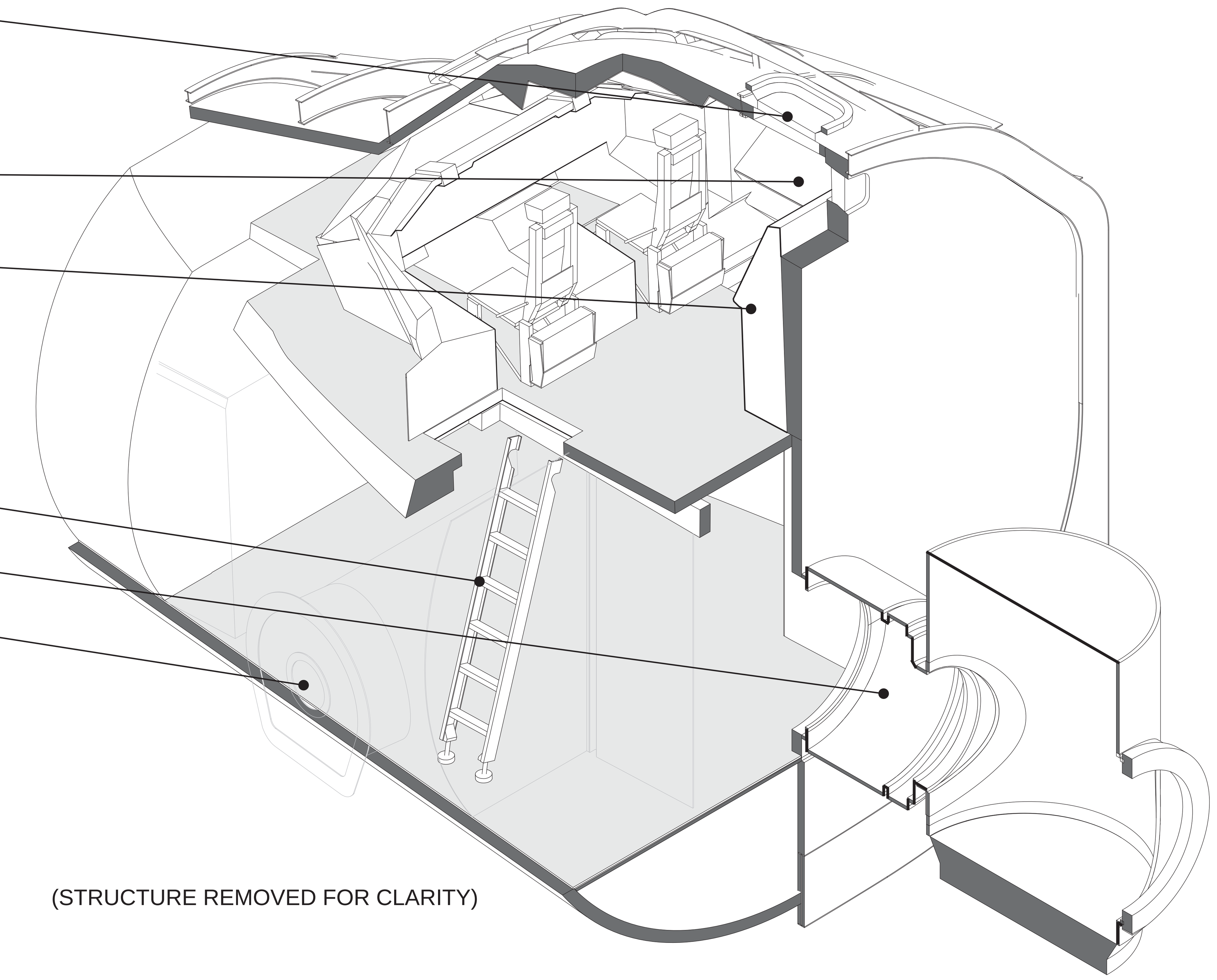

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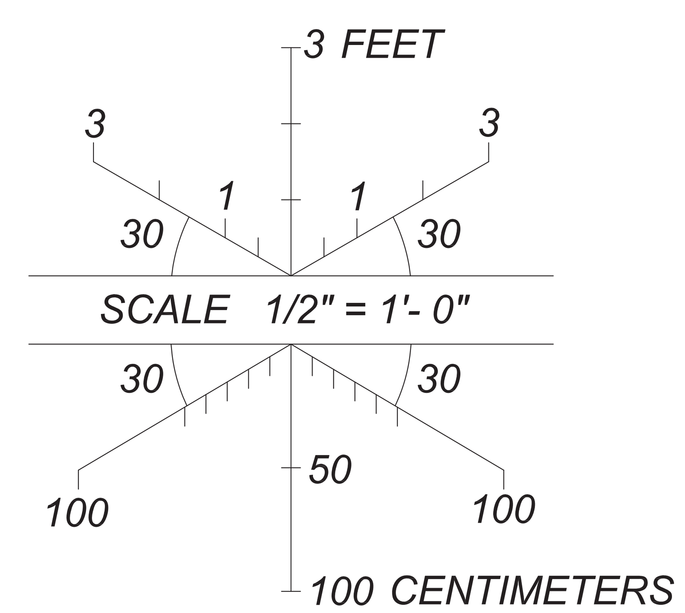
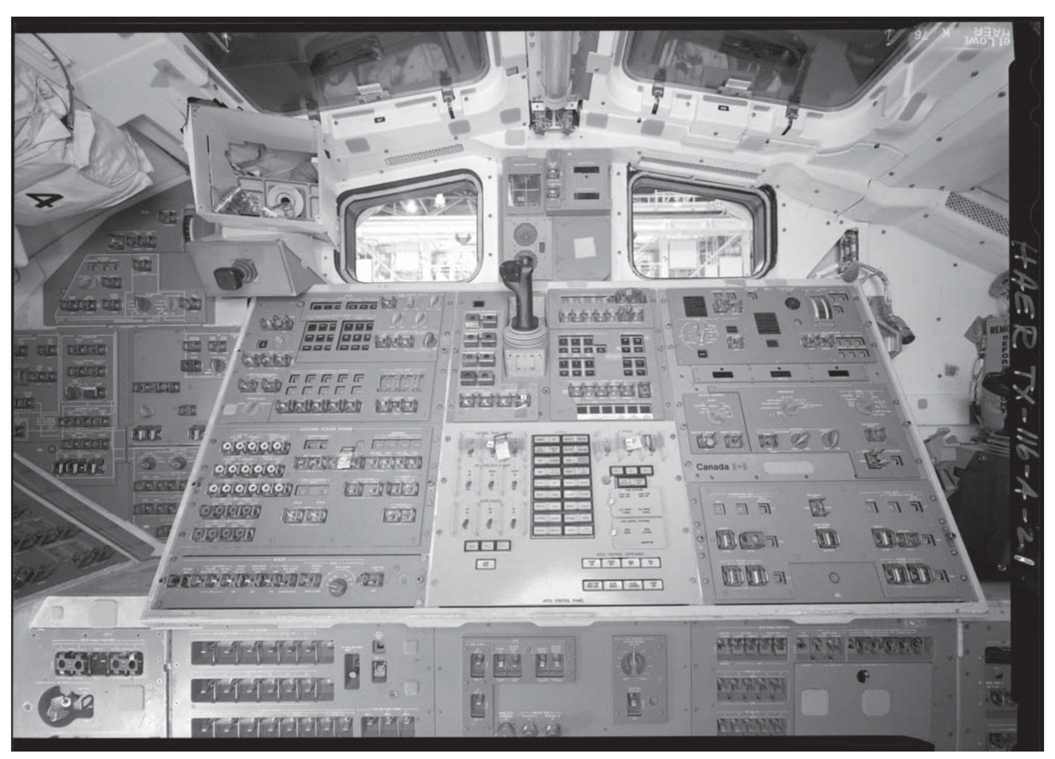
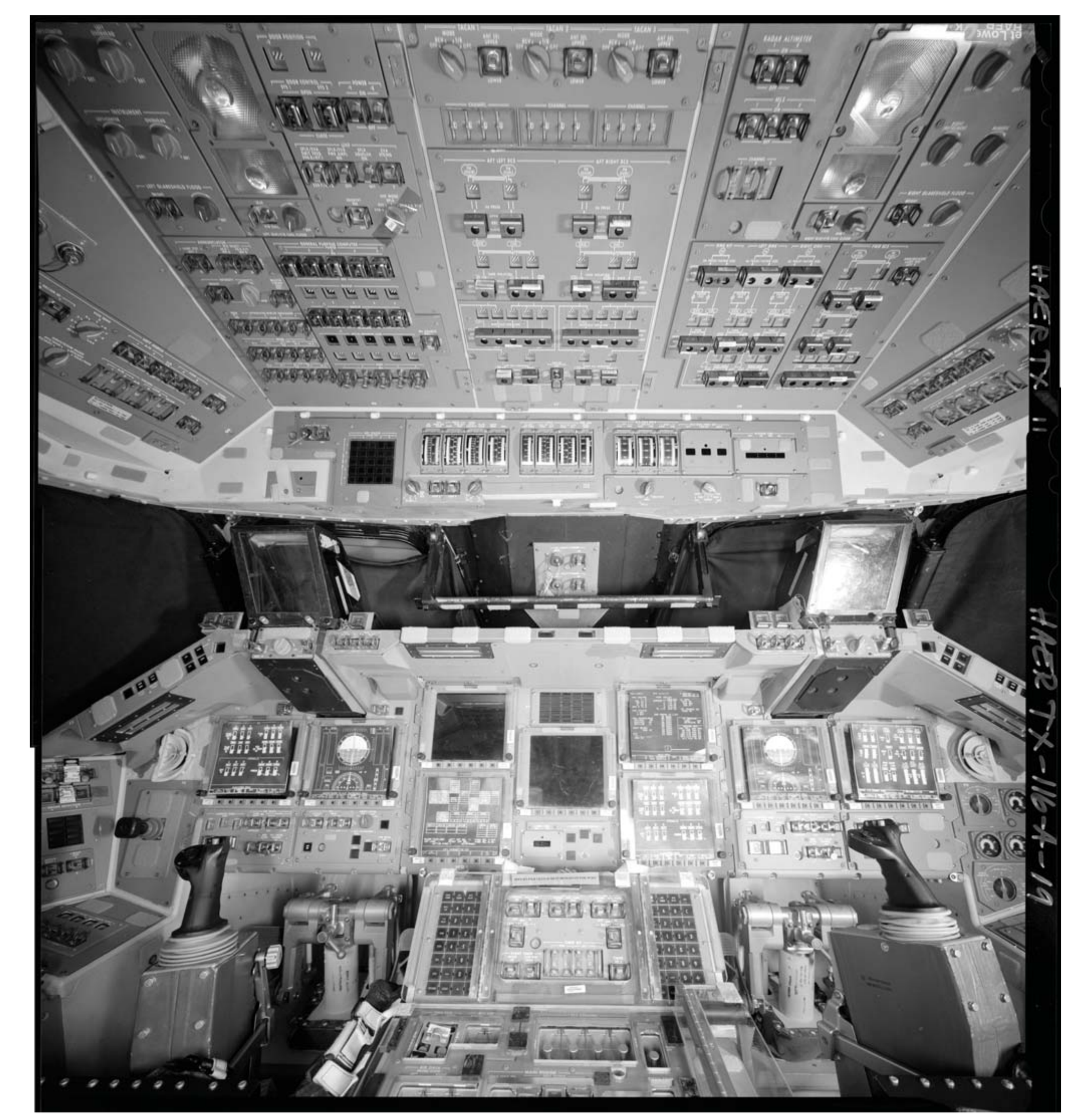




The aft station has two overhead and aft viewing windows for viewing and orbital operations. The aft flight deck station also contains displays and controls for the Reaction Control System, the Orbiter Docking System, Payload Deployment and Retrieval System, including the Remote Manipulator System, Payload Bay Door operations and closed circuit television operations.

Directly beneath the flight deck is the middeck. Access to the middeck is through two inter-deck openings, which measure 26x28 inches. Normally the right inter-deck opening is closed and the left is open. A ladder attached to the left inter-deck access allows passage in 1-G conditions and the Orbiter in horizontal position. The middeck provides the crew's sleep, work and living accommodations and contains three avionics equipment bays. Attached to the aft bay on the port side of the vehicle is the waste management compartment and closeouts which create a stowage compartment known as volume 3B. Just forward of the waste management system is the side hatch. The completely stripped middeck is approximately 160 square feet; the gross mobility are is approximately 100 square feet.



The flight deck is the uppermost compartment of the crew cabin and contained the Orbiter cockpit and aft station. The commander's and pilot's seats and work stations are positioned side by side in the cockpit section of the flight deck. These stations have controls and displays for controlling the vehicle throughout all mission phases in addition to six windows to observe orbit operations. Directly behind and to the sides of the commander and pilot centerline are the mission specialist seats and stations.

CREW CABIN ISOMETRIC

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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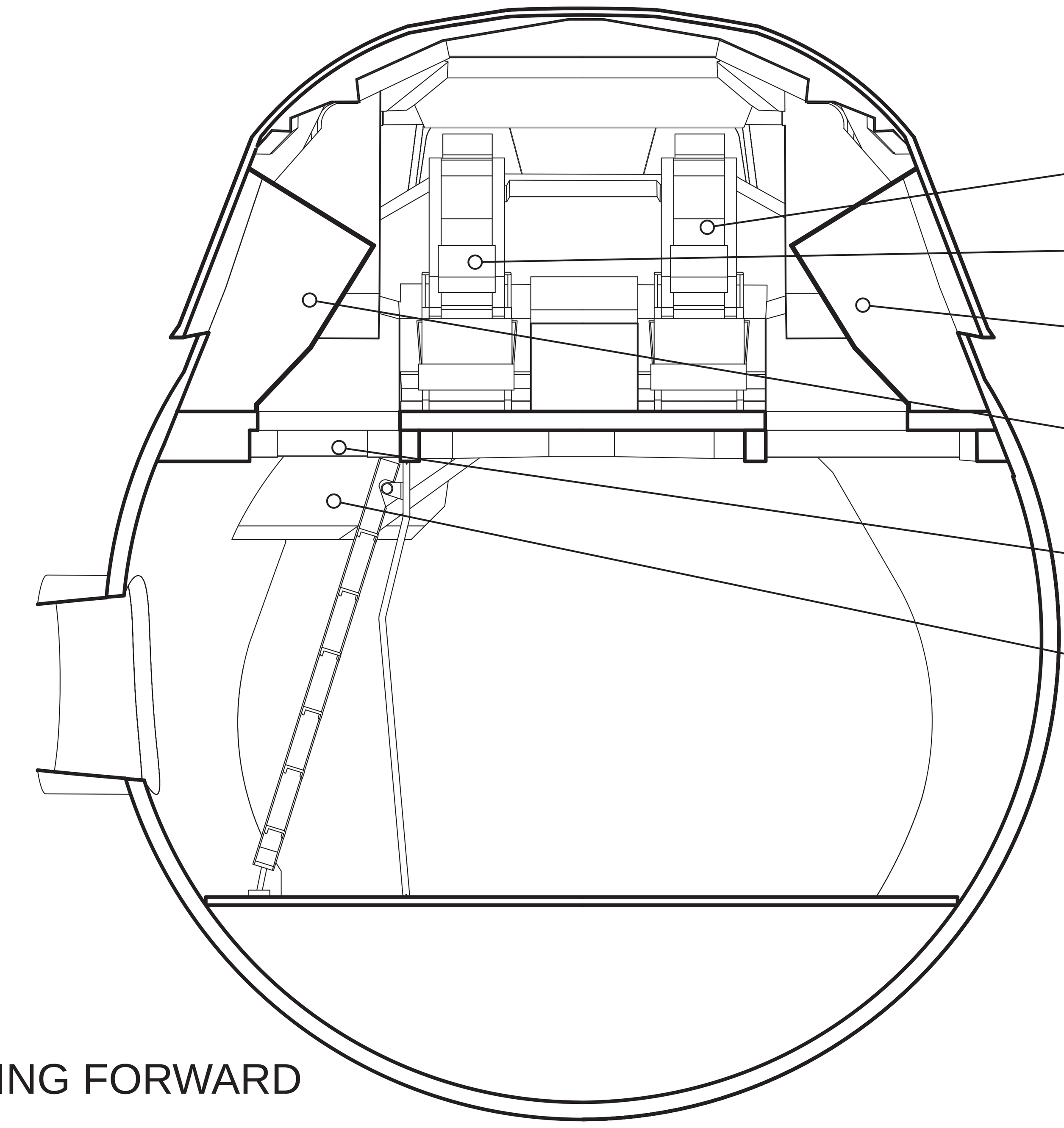
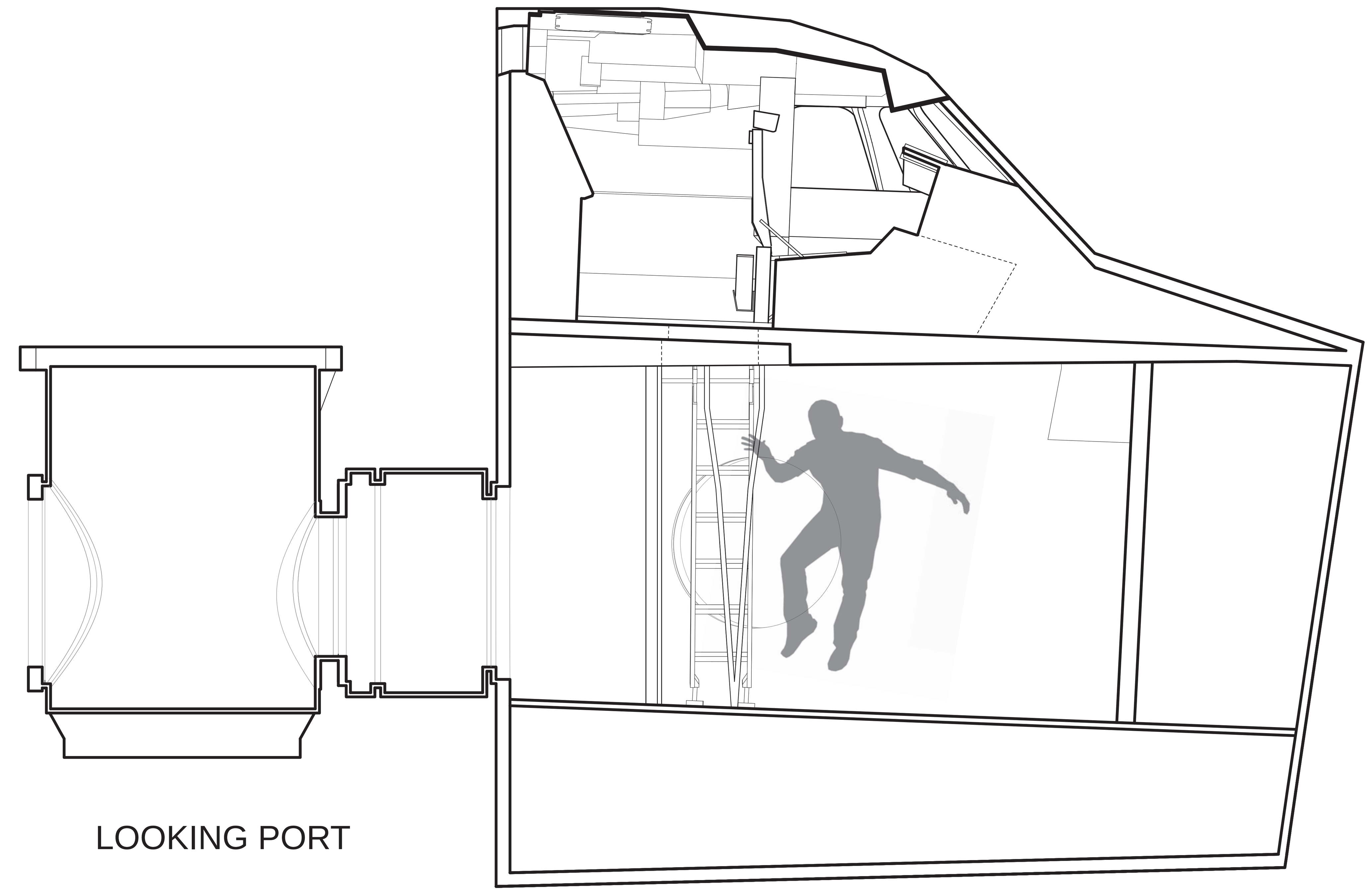
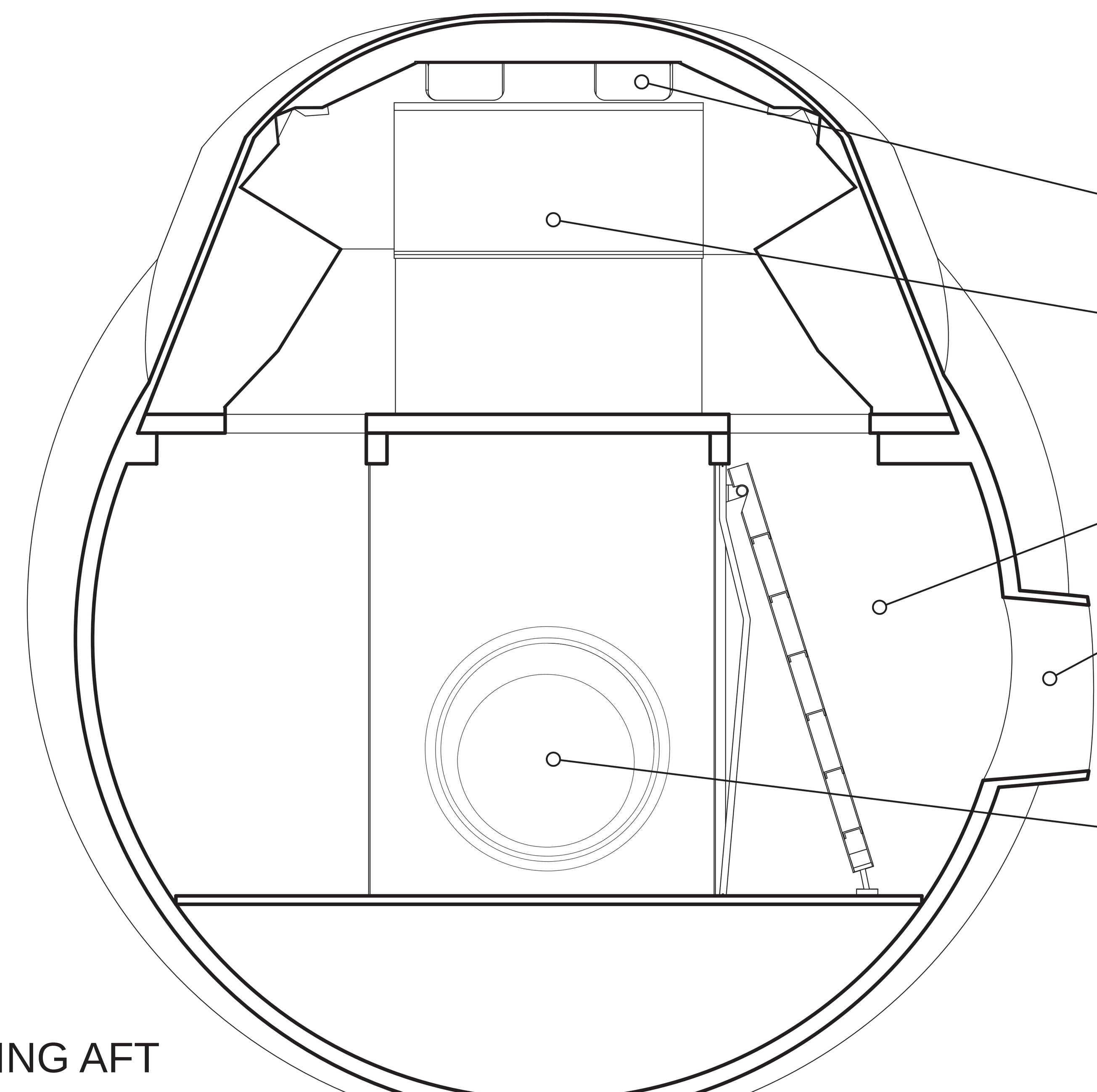


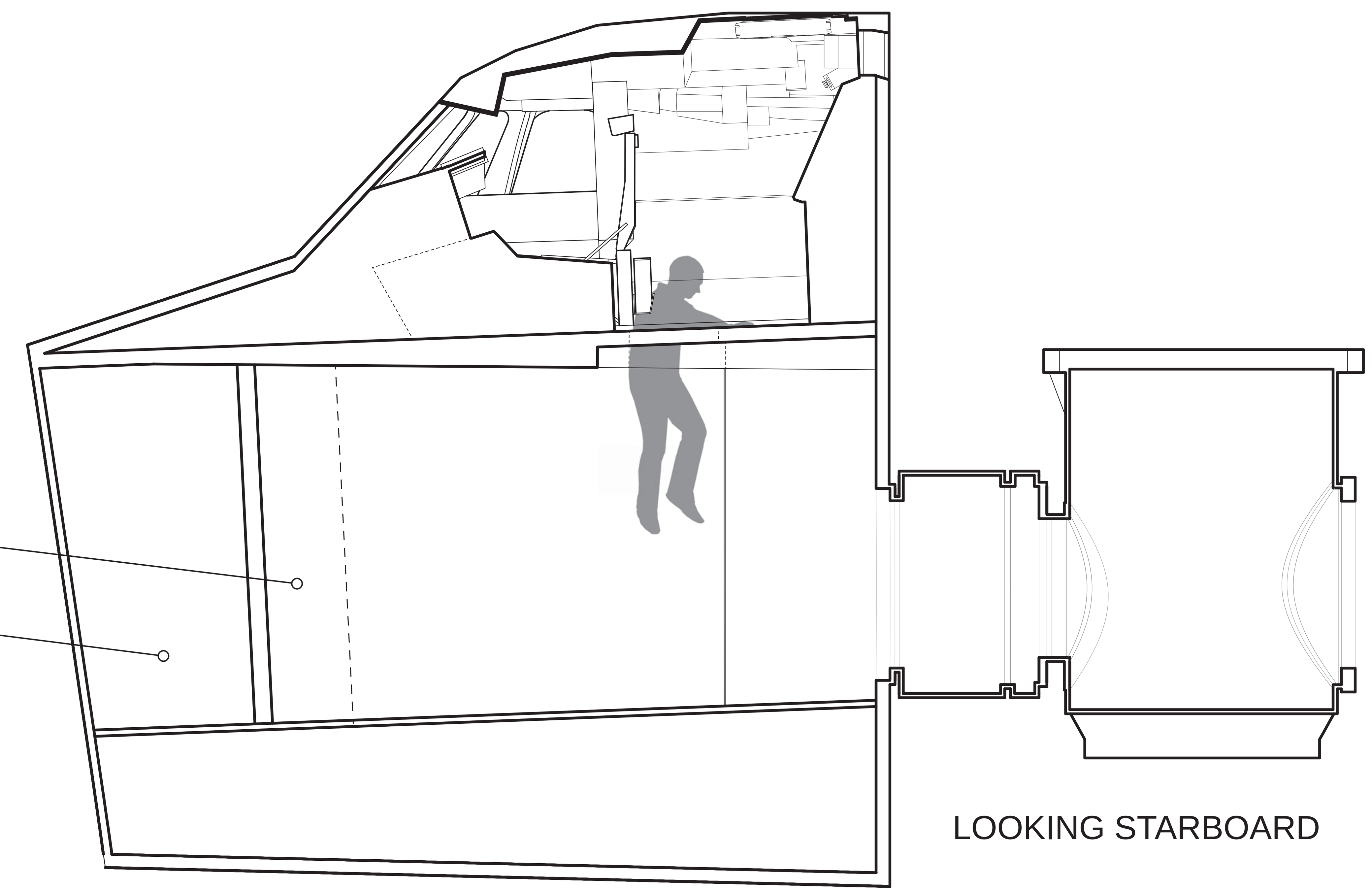
LOOKING FORWARD


LOOKING PORT

0 1 2 3 4 5 FEET
0 50 100 150 CENTIMETERS
SCALE: 1/2" = 1'-0"



LOOKING AFT


LOOKING STARBOARD

CREW CABIN SECTIONS

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PAYLOAD BAY AND PDRS

Ⓐ MANIPULATOR POSITIONING MECHANISM PEDESTALS

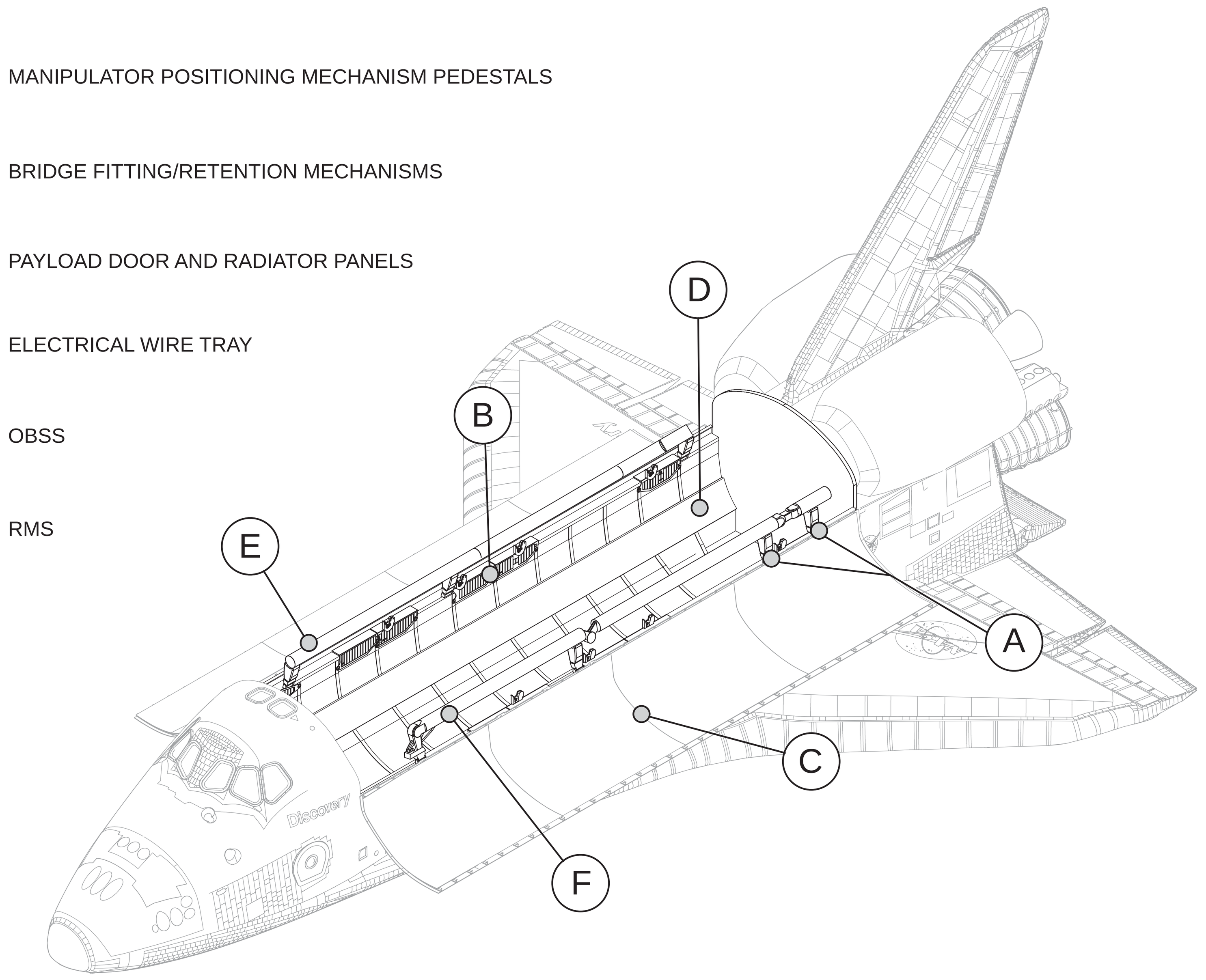
Ⓑ BRIDGE FITTING/RETENTION MECHANISMS

Ⓒ PAYLOAD DOOR AND RADIATOR PANELS

Ⓓ ELECTRICAL WIRE TRAY

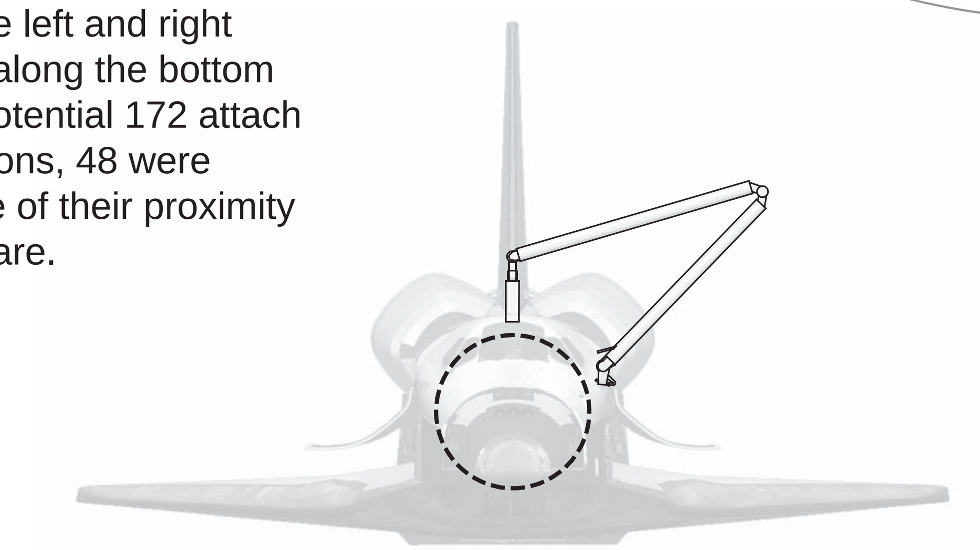
Ⓔ OBSS

Ⓕ RMS

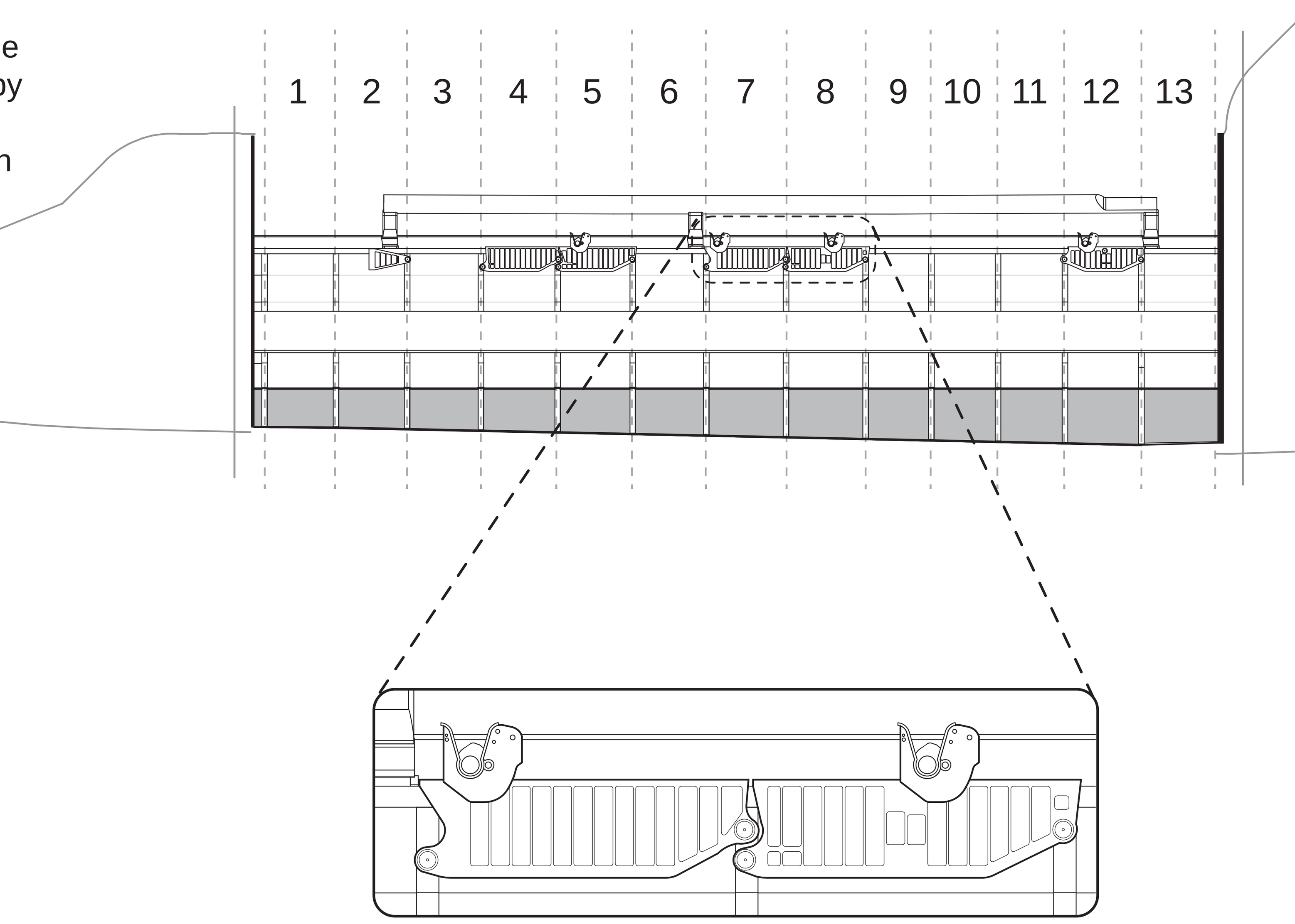


Non-deployable payloads were retained by bolted passive retention devices, and deployable payloads were secured by motor driven active retention devices. Payloads were secured in the orbiter payload bay with the payload retention system or were equipped with their own unique retention systems. Attachment points in the payload bay were in 3.933 inch increments along the left and right side longerons and along the bottom centerline. Of the potential 172 attach points on the longerons, 48 were unavailable because of their proximity to spacecraft hardware.

Bridge fittings were used to react to the load imparted to the orbiter structure by the payload, and provided a structural interface for both the payload retention s latch assemblies (PRLA) and active keel actuators (AKA).



PAYLOAD RETRIEVAL USING THE RMS

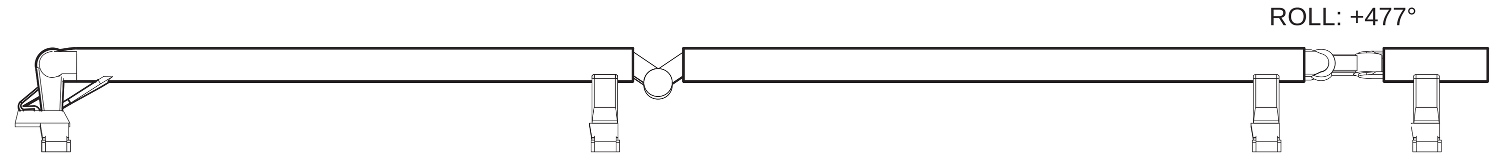


BRIDGE FITTINGS AND RETENTION MECHANISMS

SHOULDER JOINT
PITCH: -2
YAW: -180, +180

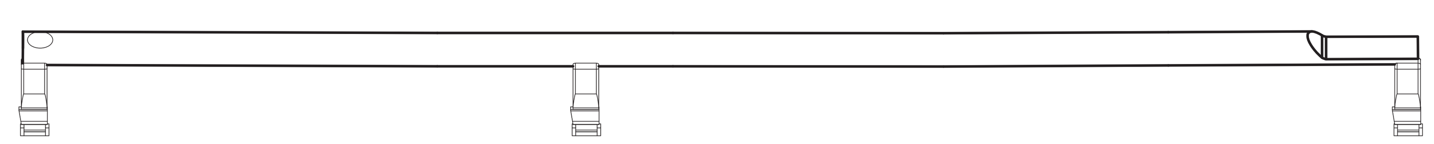
ELBOW JOINT
PITCH: +2, -160

WRIST JOINT
PITCH: +120, -120
YAW: +120, -120
ROLL: +477°

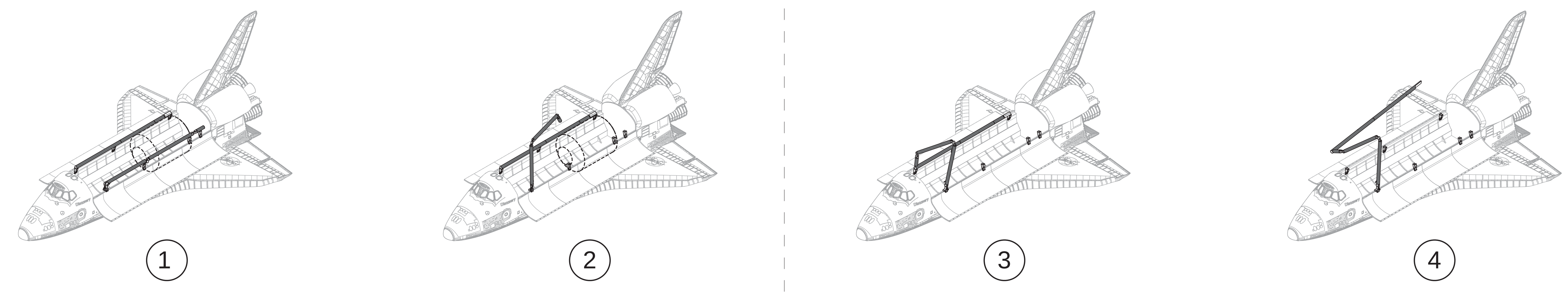


REMOTE MANIPULATOR SYSTEM (RMS)

SCALE: 3/16" = 1'-0" 0 5 10 20 FEET

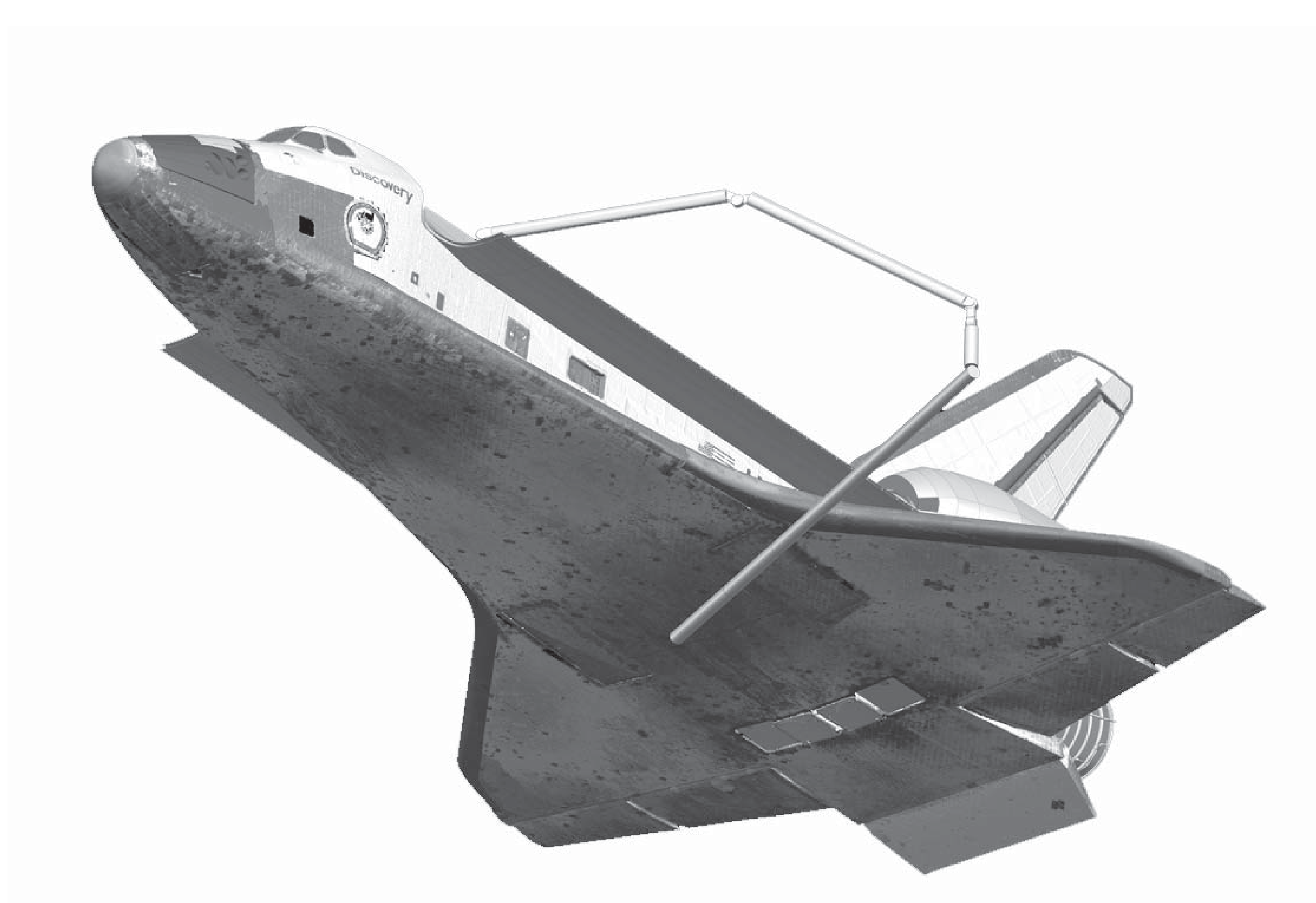


ORBITER BOOM SENSOR SYSTEM (OBSS)



PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM (PDRS)

RMS AND OBSS GRAPPLE AND UNBERTHING



The payload deployment and retrieval system (PDRS) consisted of the hardware, software, and interfaces required to remotely hold and control the movements of a specified object, usually a payload, and to remotely observe or monitor objects or activities.

The Remote Manipulator System (RMS) was installed on the port sill-longeron of the orbiter payload bay for those missions which required it. The RMS was capable of deploying or retrieving payloads weighing up to 65,000 pounds. The RMS could also retrieve and deploy satellites, provide a mobile extension for extravehicular activity (EVA), and be used as an inspection aid along with the orbiter boom sensor system which allowed the crew to view the orbiter or payload's surfaces through television cameras.

POST ASCENT/PRE ENTRY INSPECTION

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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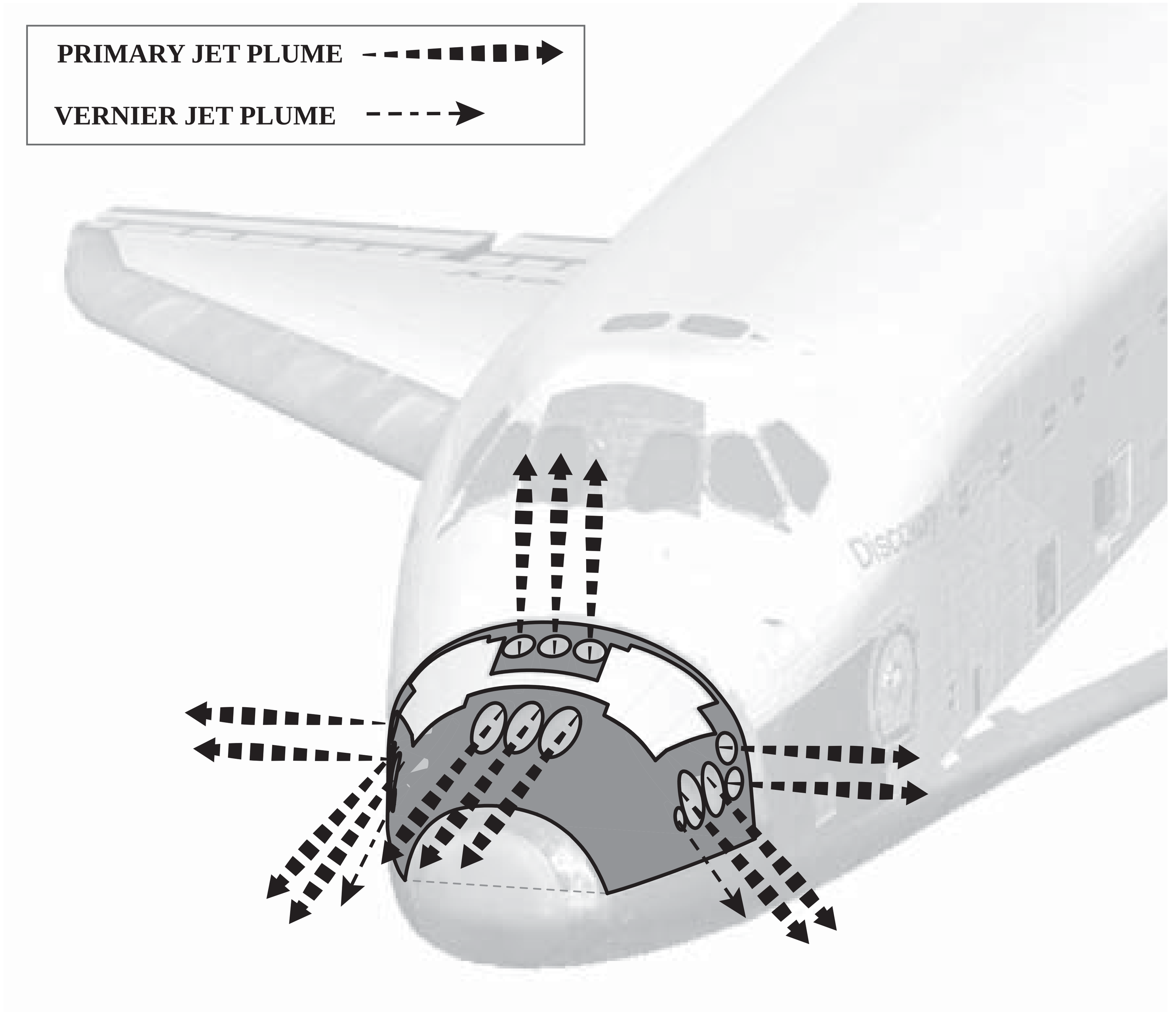
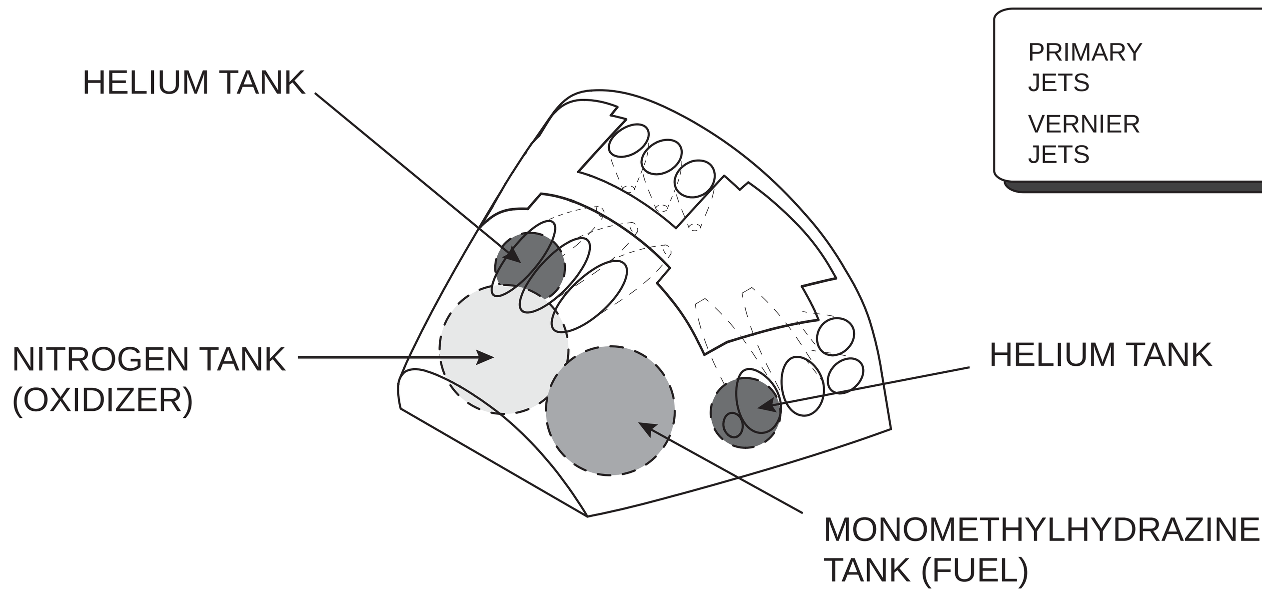


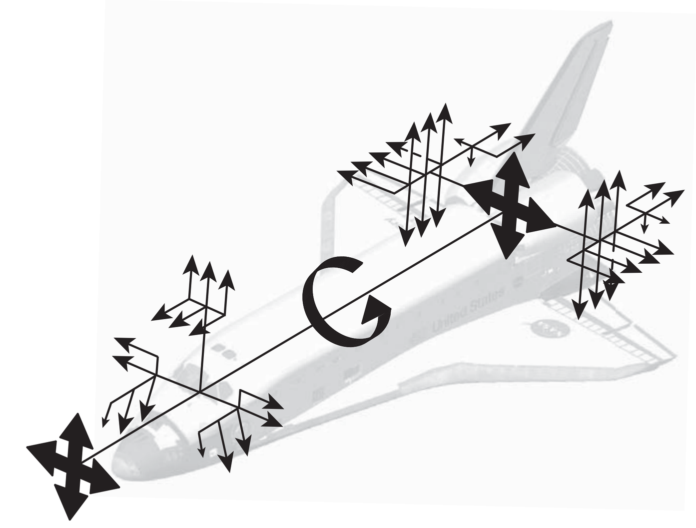
FORWARD REACTION CONTROL SYSTEM (RCS)

FWD RCS

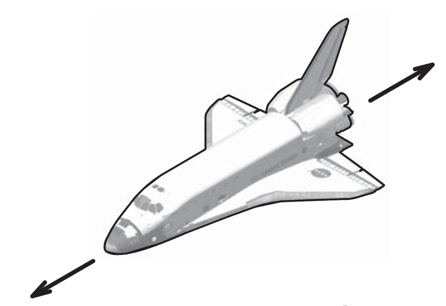
PRIMARY JETS	x14
VERNIER JETS	x2



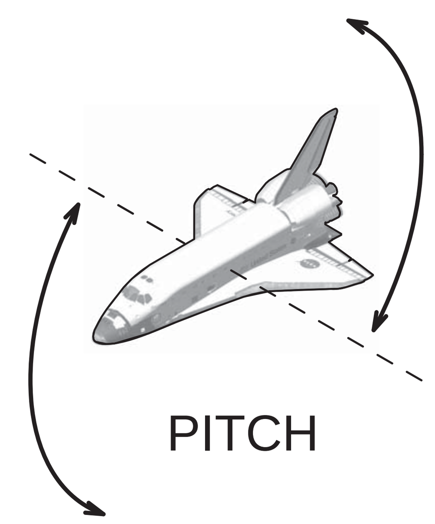
The orbiter's RCS consisted of forward and aft control jets, propellant storage tanks, and distribution networks located in three vehicle modules: forward, left, and right. The forward module was contained in the nose area, forward of the cockpit windows. The left and right (aft) modules were located with the Orbital Maneuvering System (OMS) in the left and right OMS/RCS pods located on the sides of the vertical stabilizer. Each RCS consisted of high pressure gaseous helium storage tanks, pressure regulation and relief systems, a fuel and oxidizer tank, a propellant distribution system, reaction control jets, and electrical jet and pod heaters.



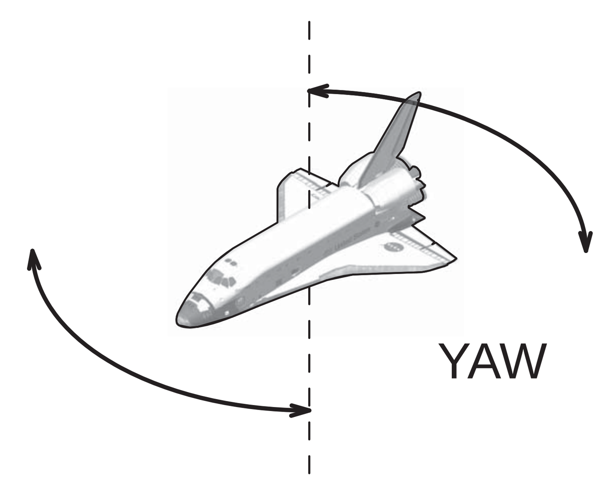
RCS JET MANEUVERS



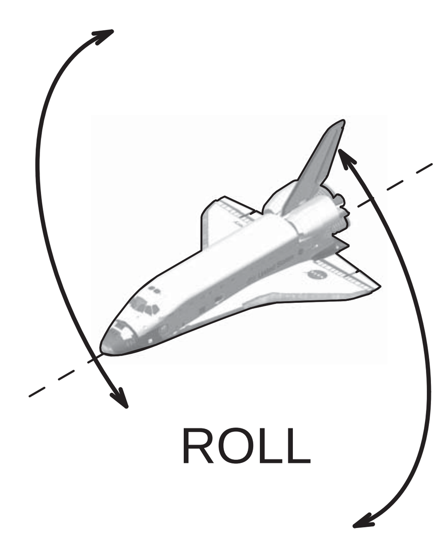
FORWARD/AFT



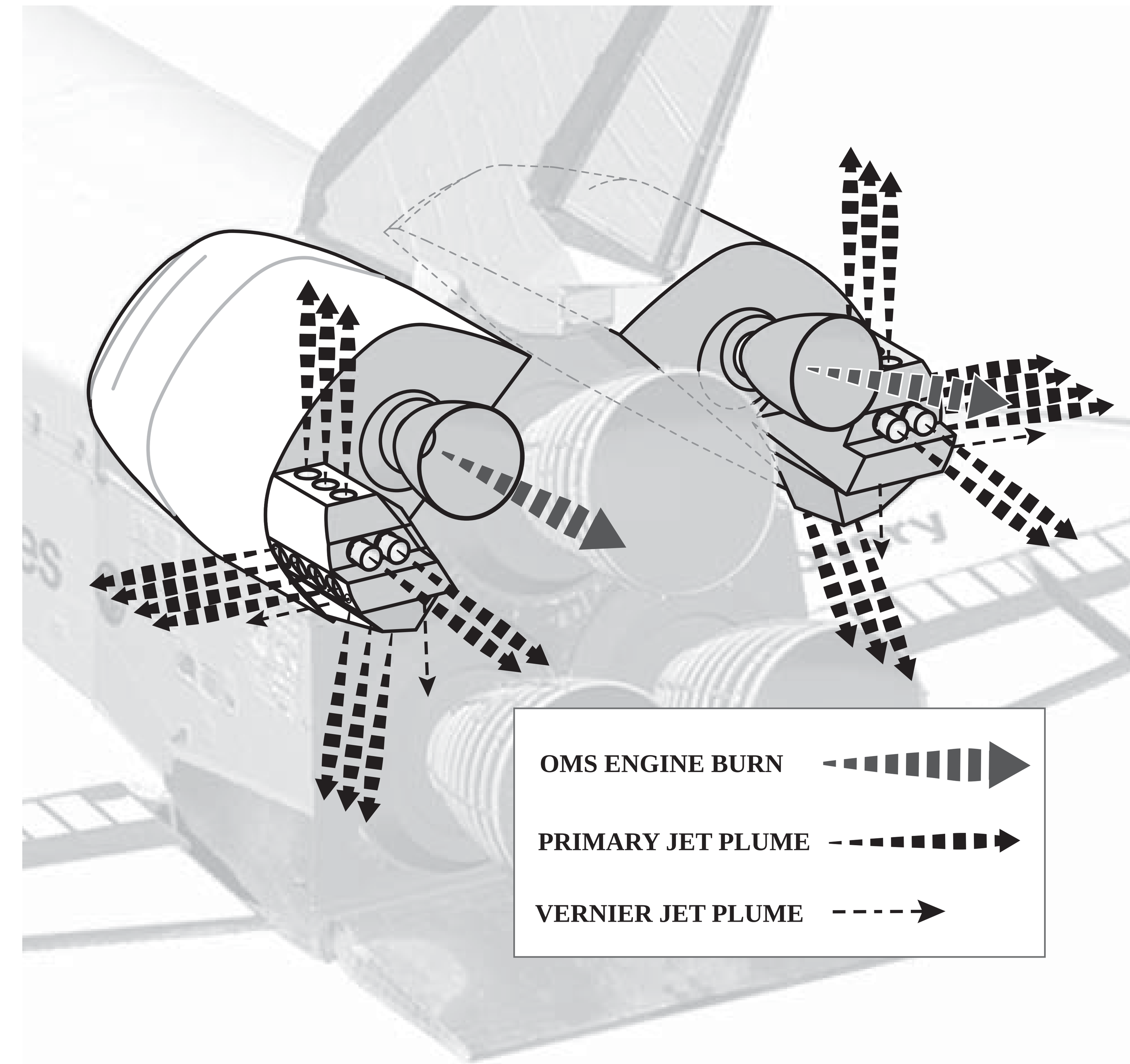
PITCH



YAW



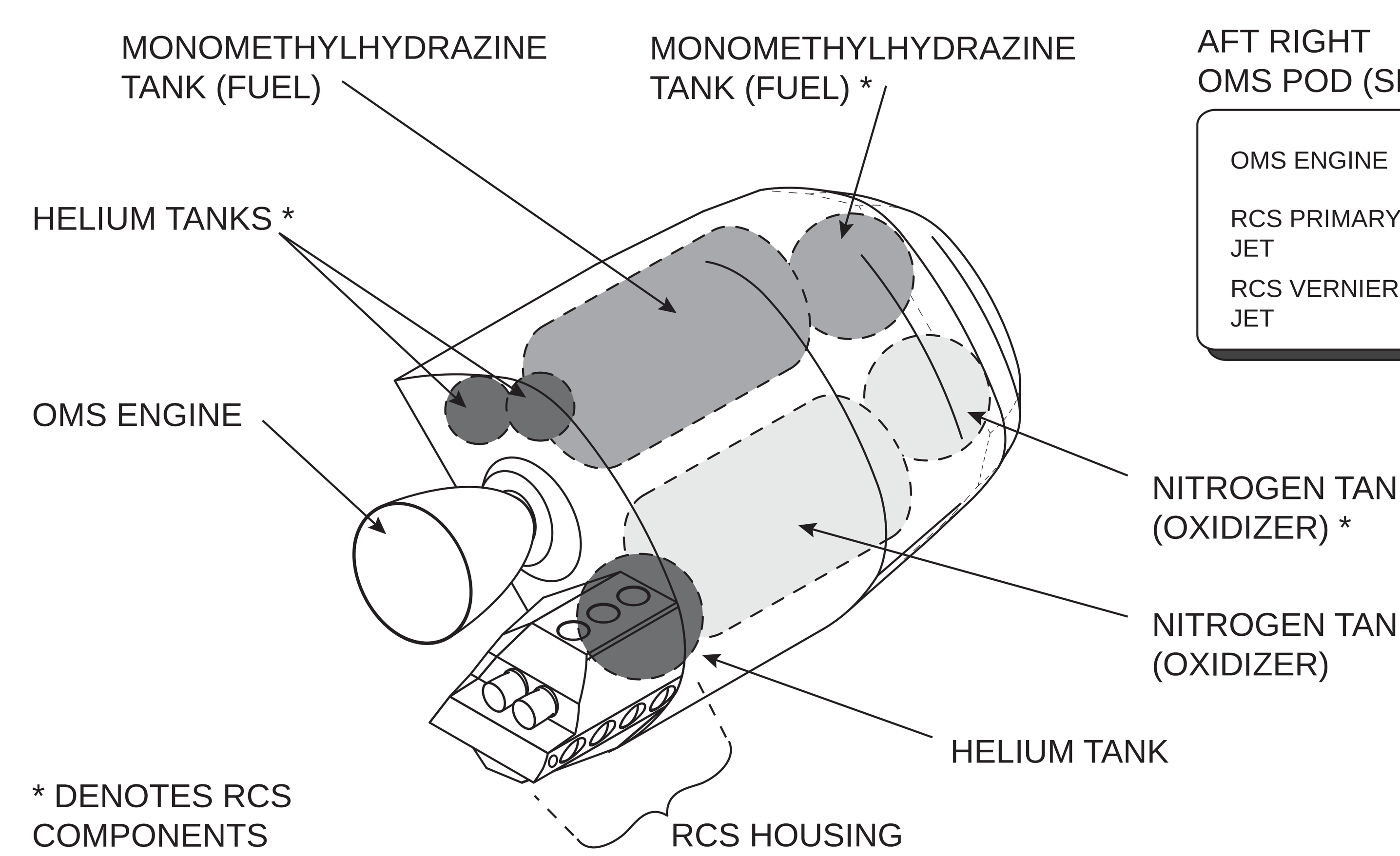
ROLL



ORBITAL MANEUVERING SYTEM (OMS) & AFT REACTION CONTROL SYSTEM (RCS)

AFT RIGHT OMS POD (SHOWN)

OMS ENGINE	x1
RCS PRIMARY JET	x12
RCS VERNIER JET	x2



The OMS provided propulsion for the Orbiter during the orbit phase of flight. The OMS is used for orbit insertion, orbit circulation, orbit transfer, rendezvous, and deorbit. Each OMS pod provided more than 1,000 pounds of propellant to the RCS. Amounts available for crossfeed depended on loading and number of OMS starts during the mission.

OMS AND RCS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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NATIONAL PARK SERVICE
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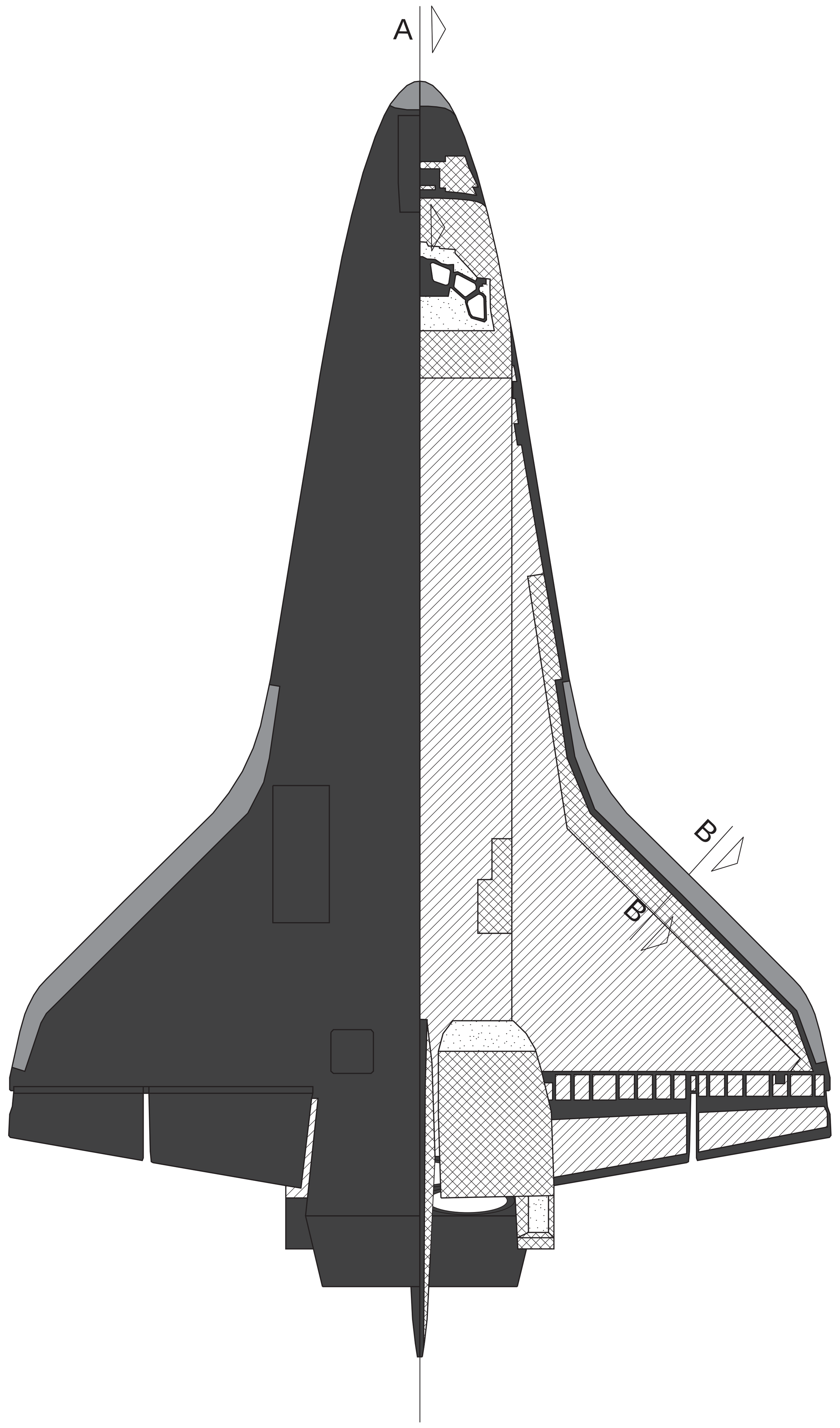
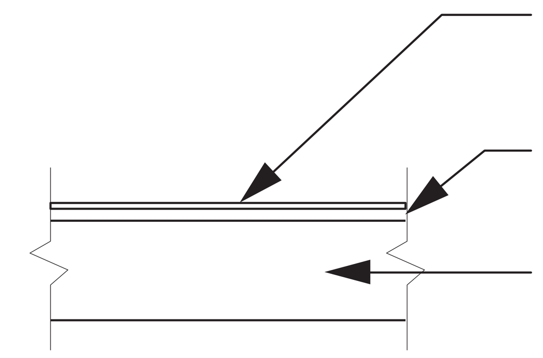
ORBITER TPS: THERMAL PROTECTION SYSTEM

The thermal protection system (TPS) was a passive system that consisted of various materials applied externally to the outer aluminum and graphite-epoxy skin of the Orbiter to prevent the skin from exceeding 350° F, primarily during Orbiter reentry.

The TPS materials were designed to be reusable for up to 100 missions with routine refurbishment and maintenance. In addition to being durable and designed to withstand high reentry temperatures these materials could also withstand the extremely cold temperatures, around minus 250° F, they were exposed to in the space environment. Because the TPS was the outermost layer it also established the aerodynamic profile of the Orbiter in addition to acting as the heat sink.

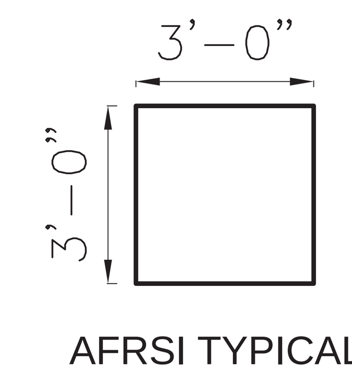


BOTTOM/ TOP TPS COVER
SCALE: 3/32" = 1'-0"

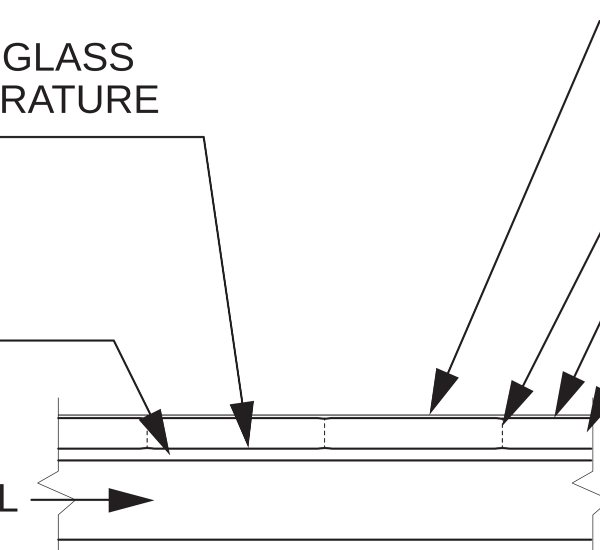


FRSI - FLEXIBLE REUSABLE SURFACE INSULTATION DETAIL
SCALE: 1-1/2" = 1'-0"

KEY:

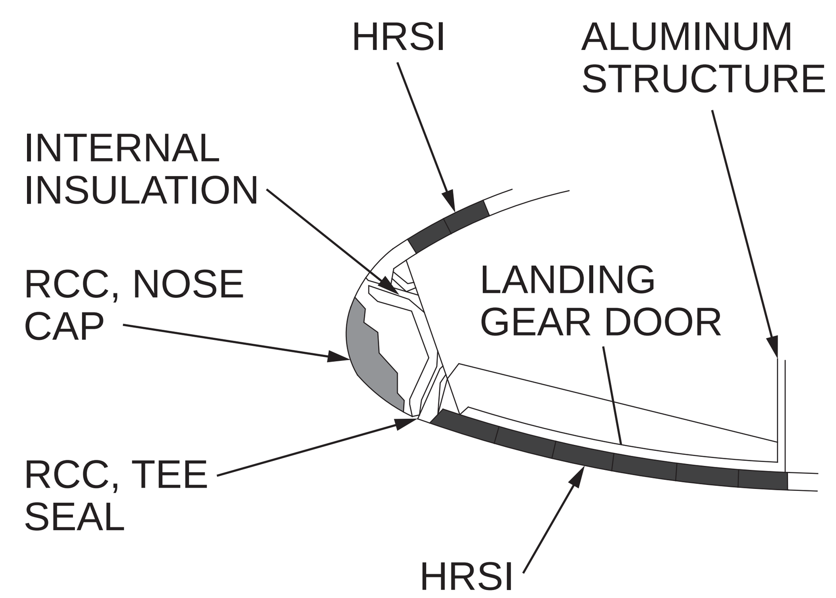


AFRSI TYPICAL BLANKET SIZE

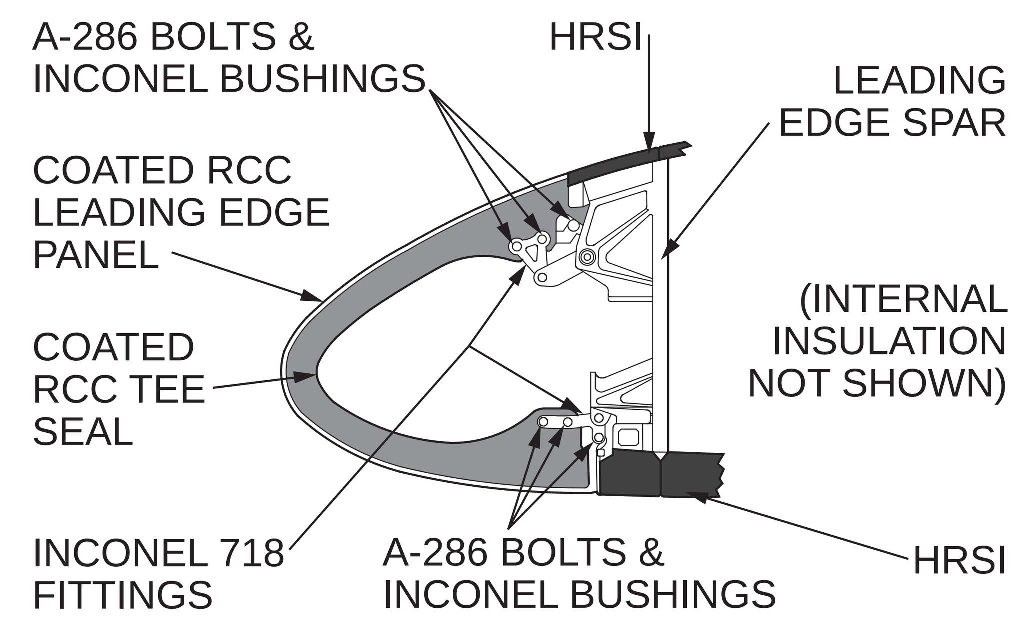


AFRSI - ADVANCED FLEXIBLE REUSABLE SURFACE INSULATION DETAIL
SCALE: 1-1/2" = 1'-0"

KEY:



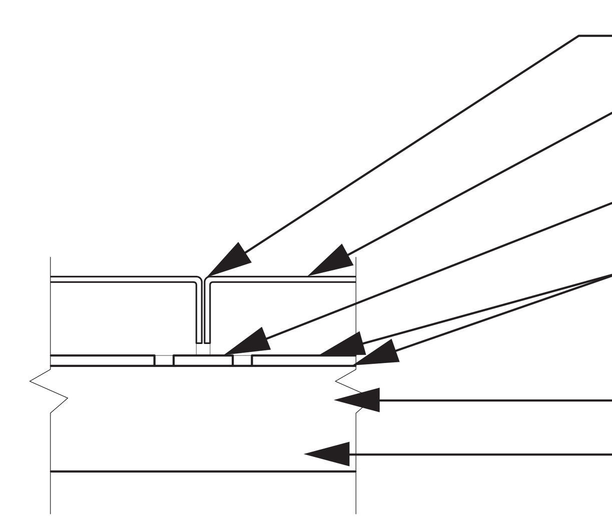
NOSE SECTION A-A



WING SECTION B-B

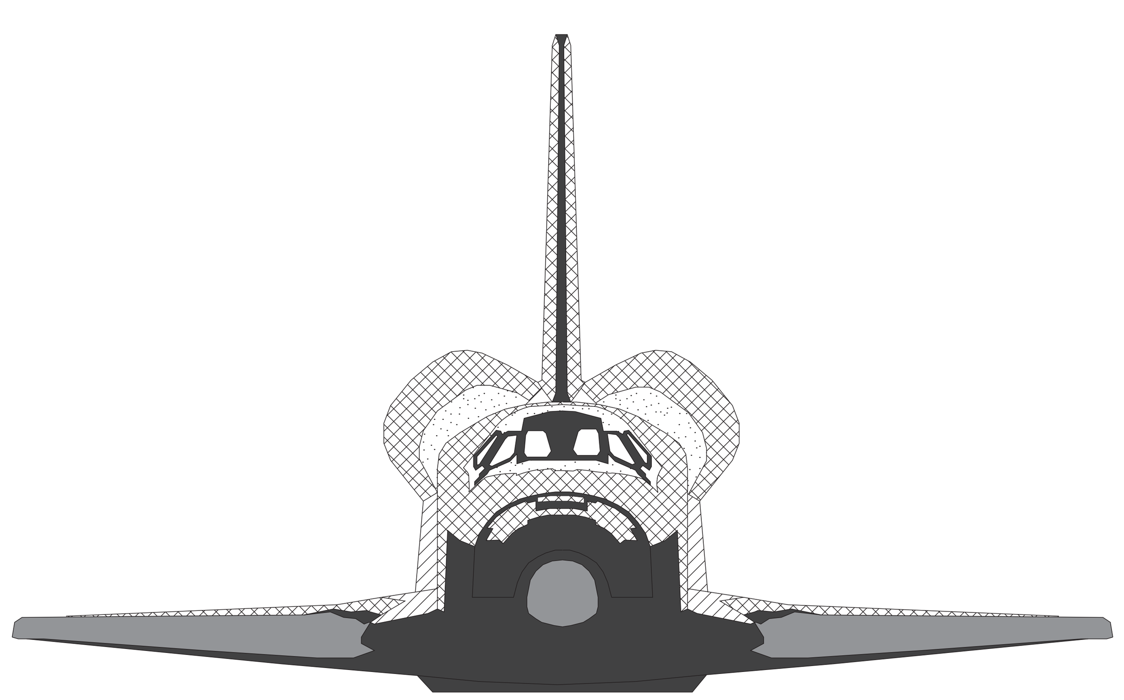
REINFORCED CARBON CARBON (RCC) COVER DETAIL
SCALE: 3/4" = 1'-0"

KEY:

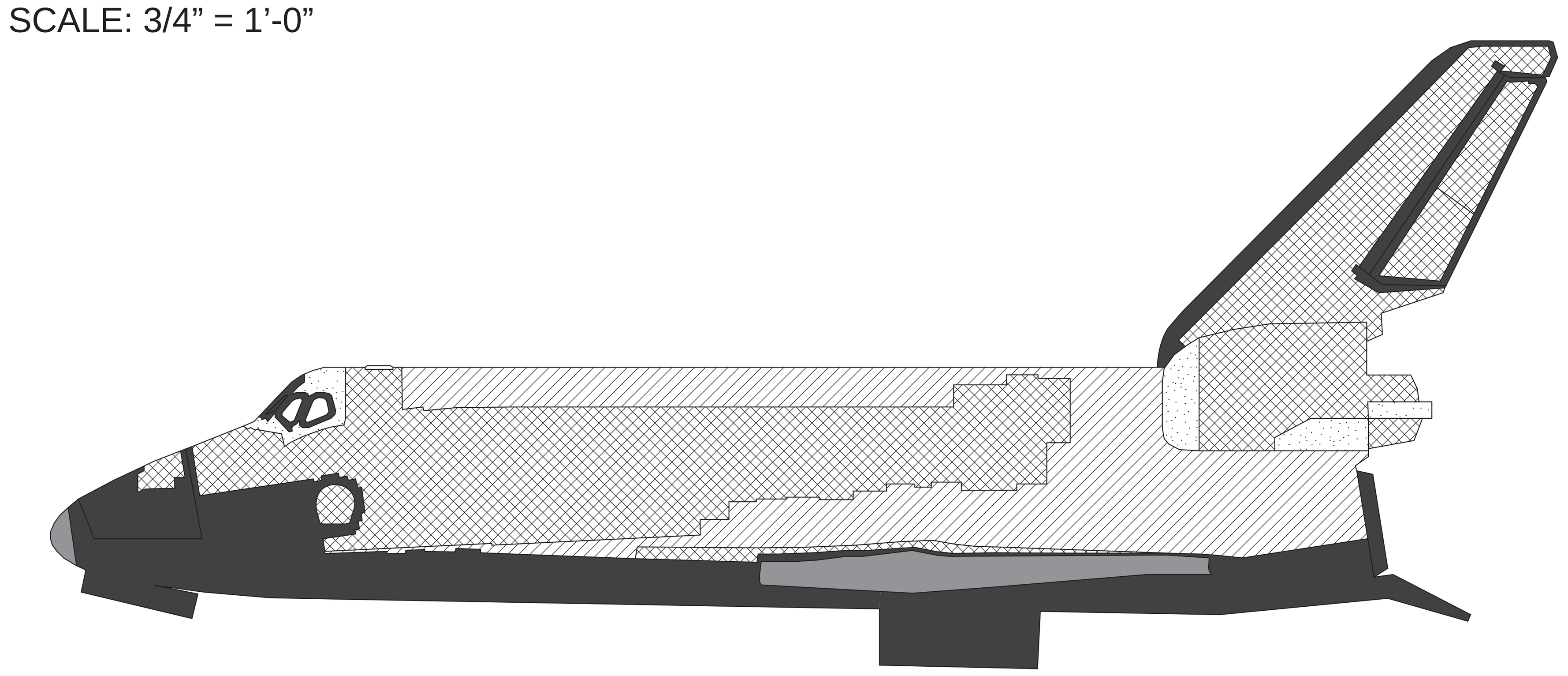


HRSI/ LRSI = HIGH/ LOW TEMPERATURE REUSABLE SURFACE INSULATION DETAIL
SCALE: 1-1/2" = 1'-0"

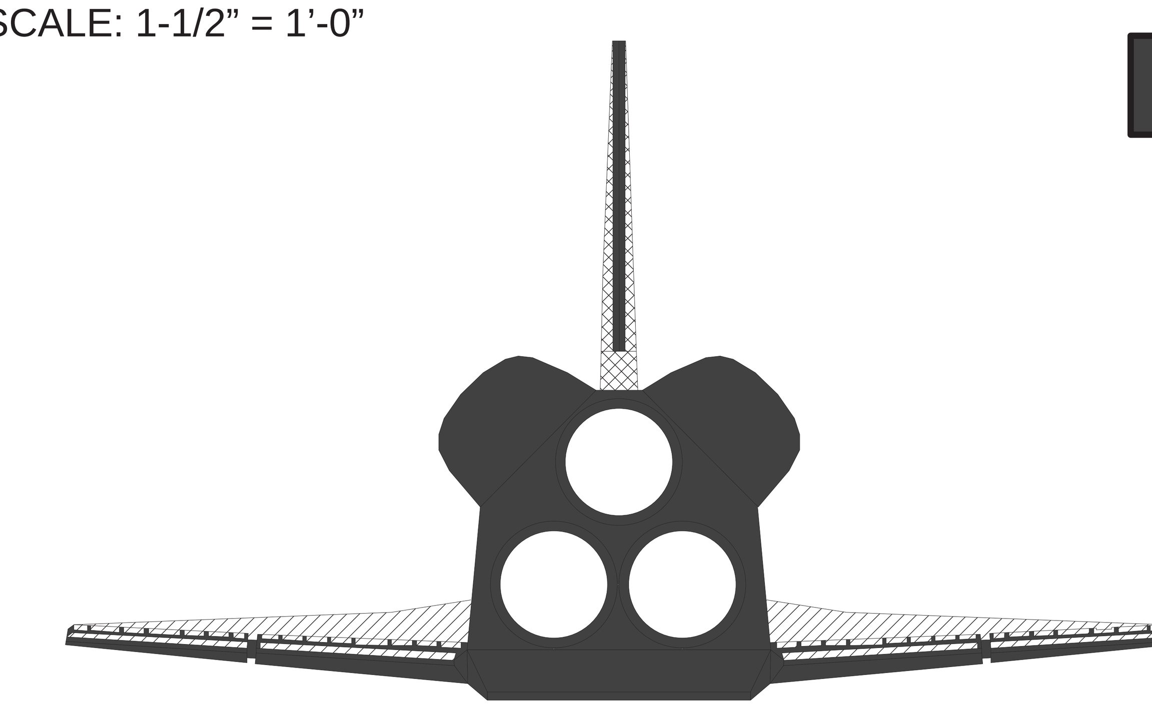
KEY:
LRSI
HRSI



FRONT TPS COVER
SCALE: 3/32" = 1'-0"



PORT TPS COVER (TYP.)
SCALE: 3/32" = 1'-0"



REAR TPS COVER
SCALE: 3/32" = 1'-0"

0 5 15 30 FEET
0 1 5 10 METERS
SCALE: 3/32" = 1'-0"

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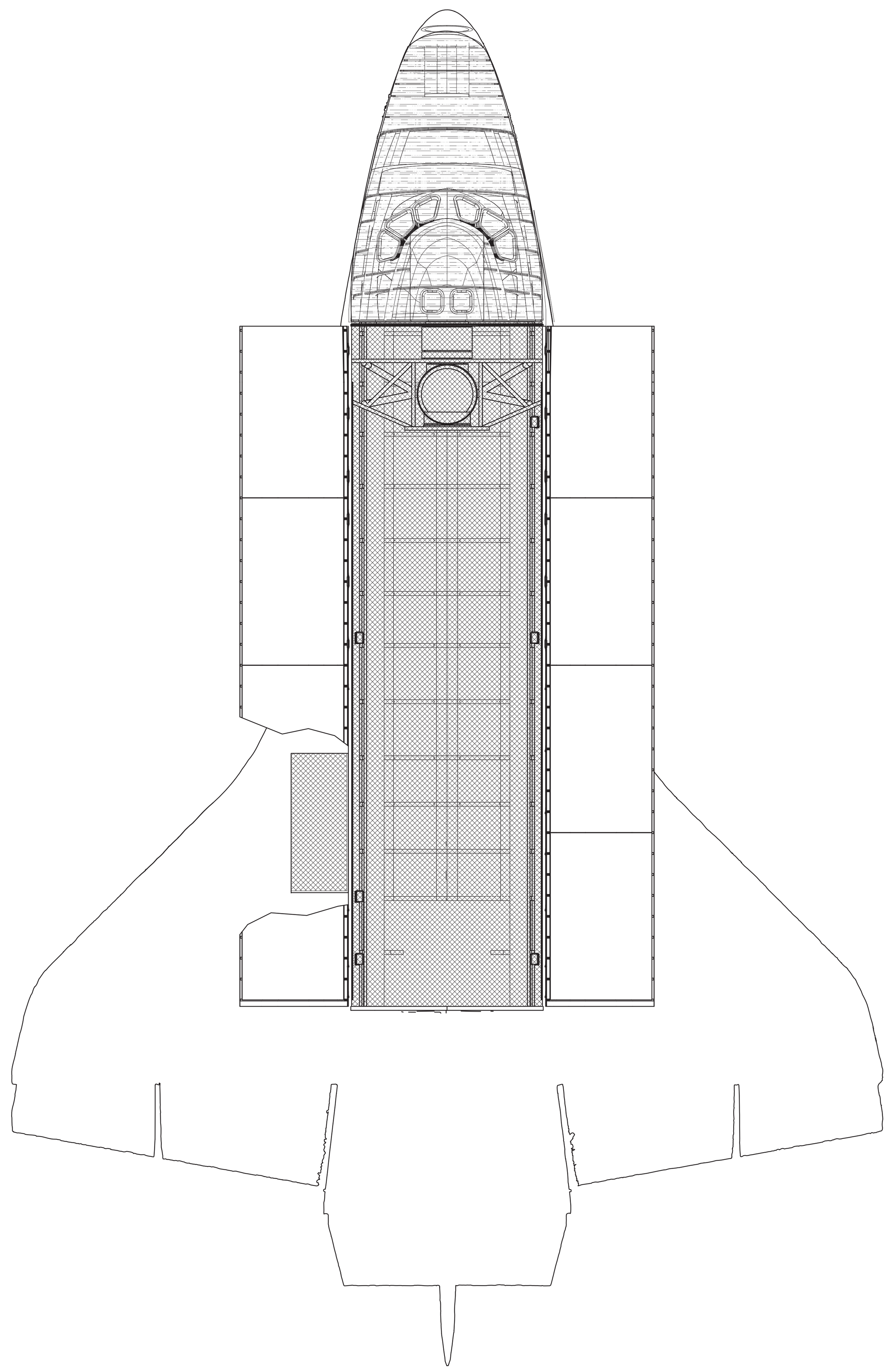
ORBITER TCS:
THERMAL CONTROL SYSTEM

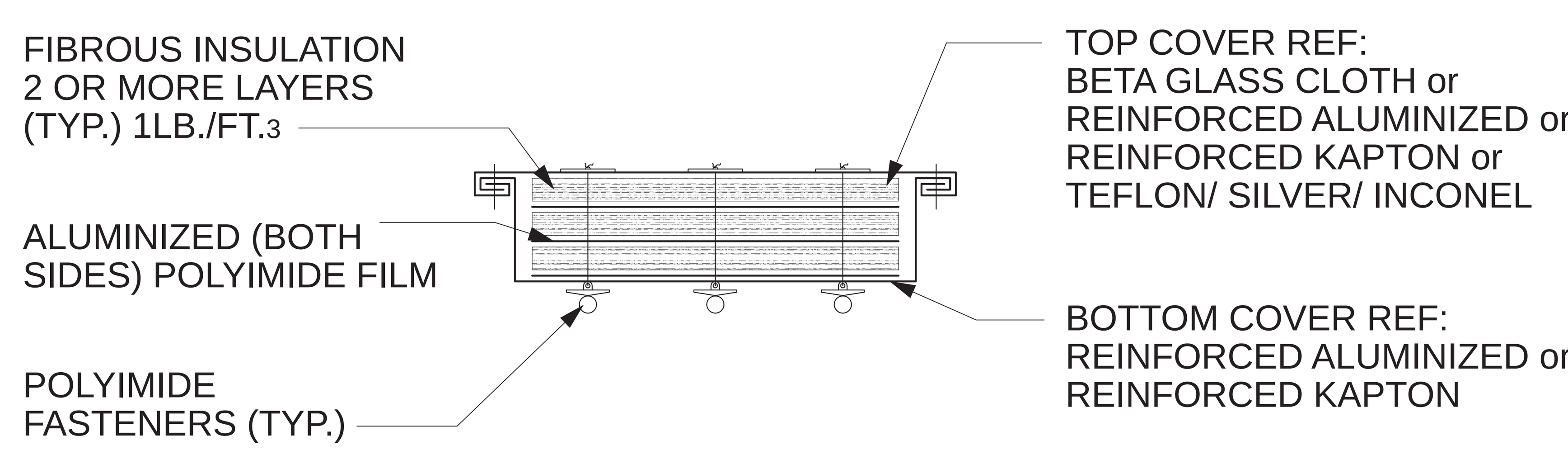
A passive thermal control system helps maintain the temperature of the orbiter spacecraft, systems, and components within their temperature limits. This system uses available orbiter heat sources and sinks supplemented by insulation blankets, thermal coatings, and thermal isolation methods. Heaters are provided on components and systems in areas where passive thermal control techniques are not adequate.

The insulation blankets are of two basic types: Fibrous bulk and multilayer. The bulk blankets are fibrous materials with a density of 2 pounds per cubic foot and a sewn cover of reinforced acrylic film kapton. The cover material has 13,500 holes per square foot for venting. Acrylic film tape is used for cutouts, patching, and reinforcements. Tufts throughout the blankets minimize billowing during venting.

The multilayer blankets are constructed of alternate layers of perforated acrylic film kapton reflectors and Dacron net separators. There are 16 reflector layers in all. The two cover halves counting as two layers. Covers, tufting, and acrylic film tape are similar to that used for the bulk blankets.

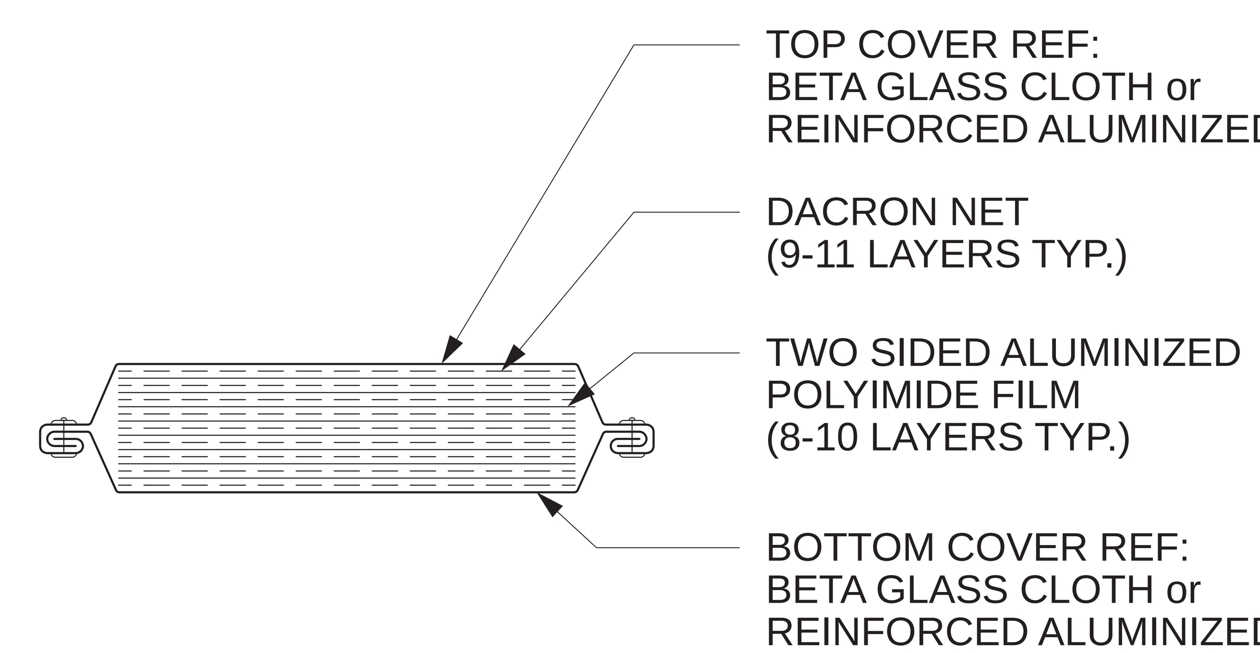


BOTTOM/ TOP TCS COVER
SCALE: 3/32" = 1'-0"



KEY:

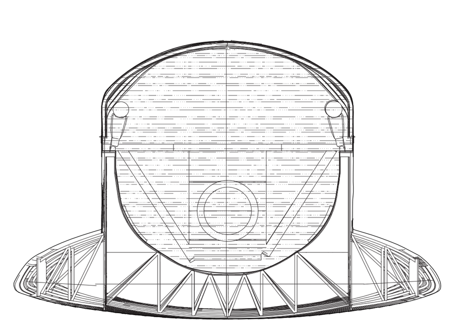
FIBROUS BLANKET DETAIL (TYP.)
SCALE: 1-1/2" = 1'-0"



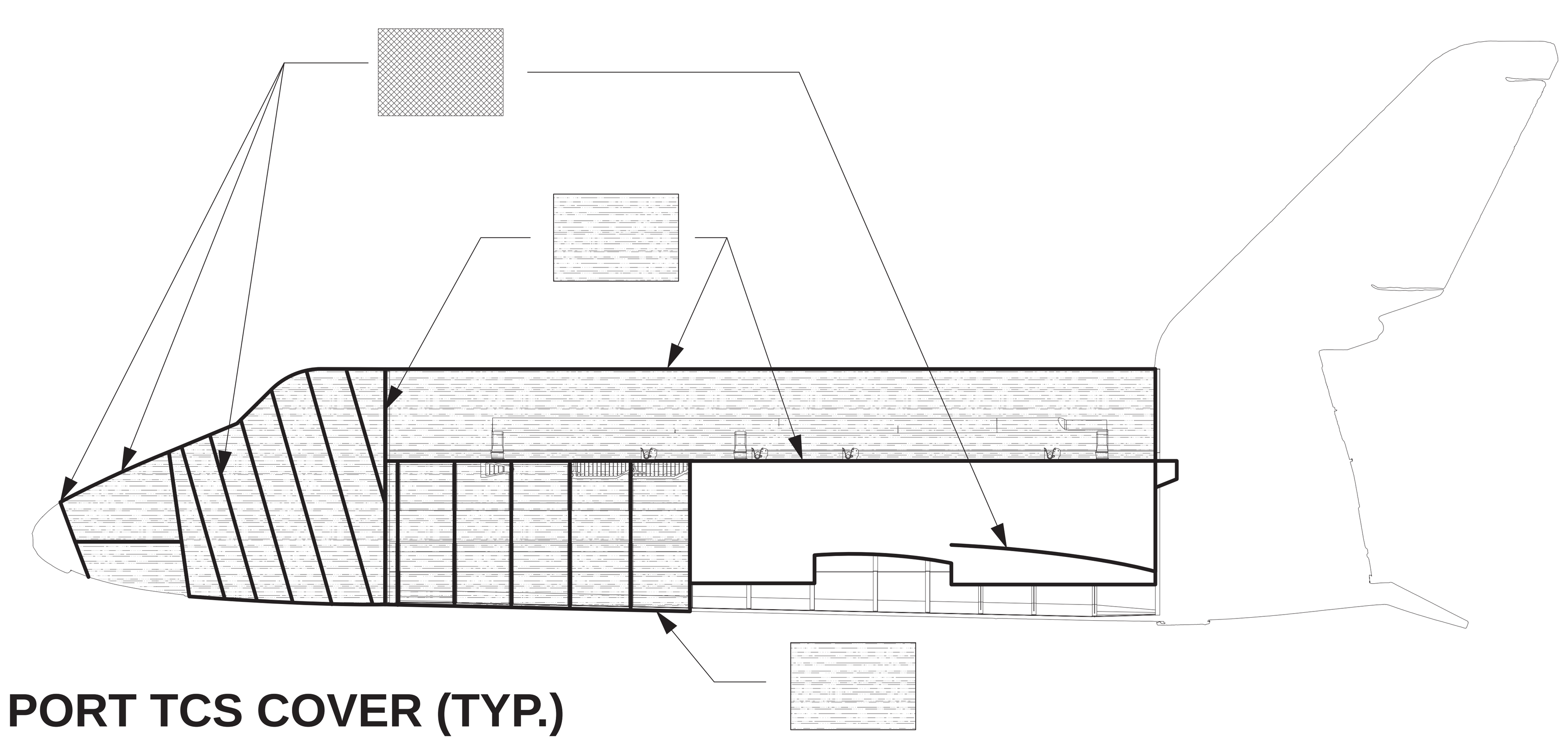
KEY:

MLI - MULTILAYER TCS BLANKET DETAIL
SCALE: 1-1/2" = 1'-0"

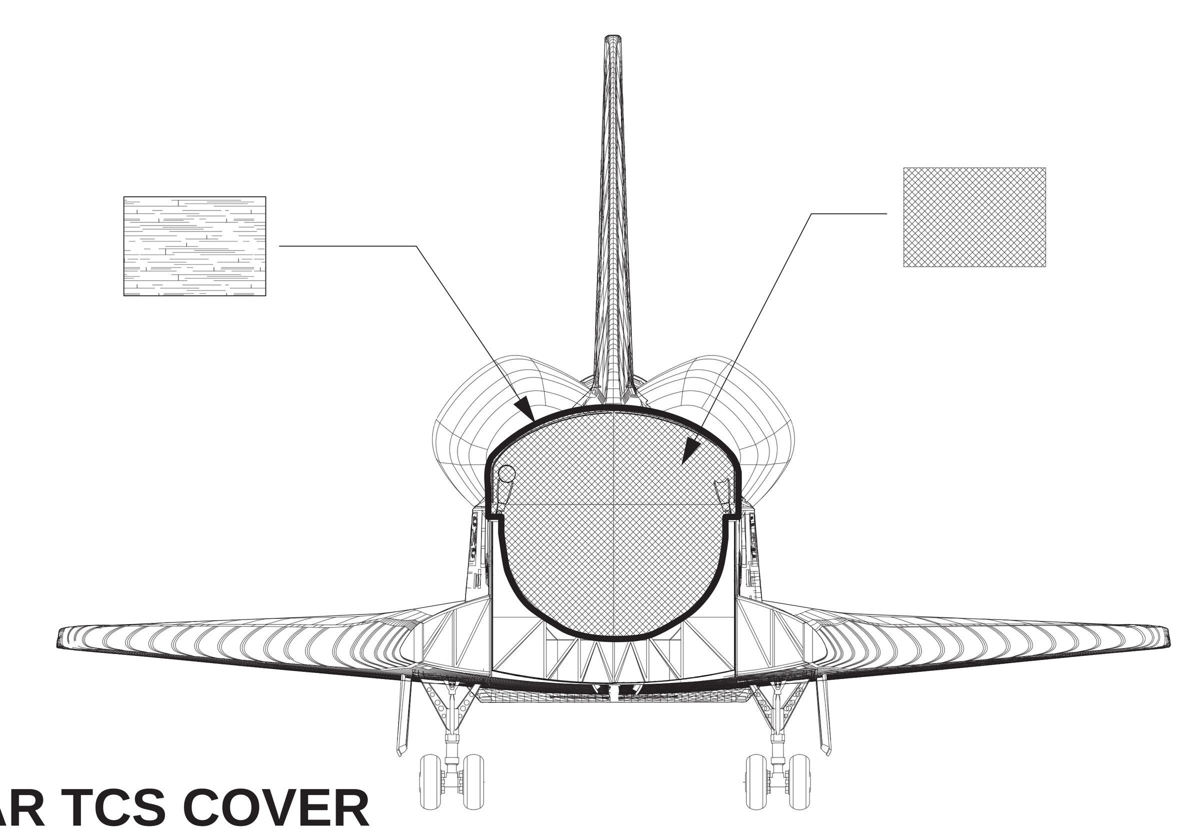
SCALE: 3/32" = 1'-0"



FRONT TCS COVER
SCALE: 3/32" = 1'-0"



PORT TCS COVER (TYP.)
SCALE: 3/32" = 1'-0"



REAR TCS COVER
SCALE: 3/32" = 1'-0"

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SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
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ECLSS AND POWER SYSTEMS

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

PRESSURE CONTROL SYSTEM

THE PRESSURE CONTROL SYSTEM MAINTAINS THE CREW COMPARTMENT AT 14.7 PSIA WITH A BREATHABLE MIXTURE OF OXYGEN AND NITROGEN. NITROGEN IS ALSO USED TO PRESSURIZE THE SUPPLY AND WASTEWATER TANKS.

ATMOSPHERIC REVITALIZATION SYSTEM

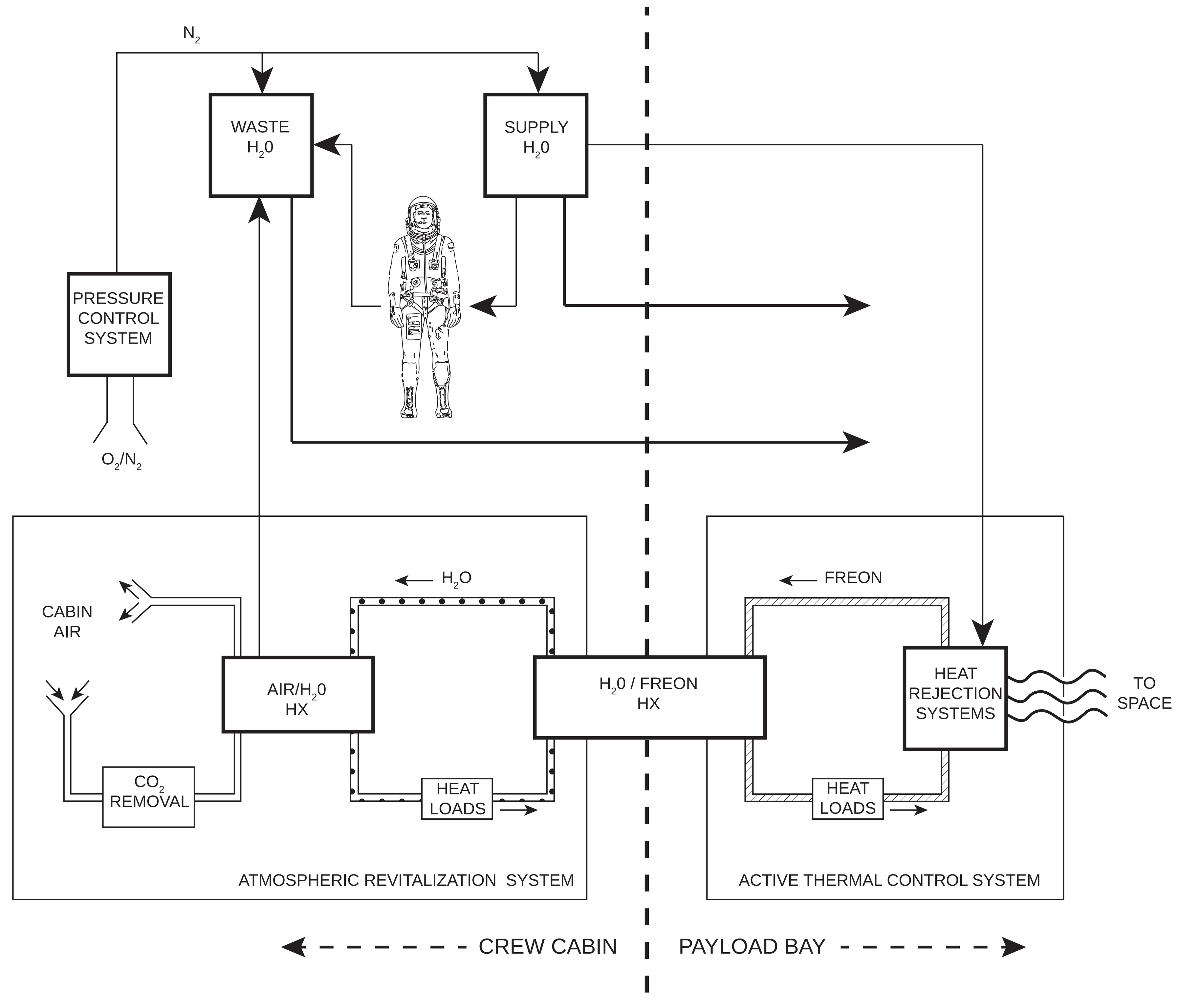
THE ATMOSPHERIC REVITALIZATION SYSTEM USES AIR CIRCULATION AND WATER COOLANT LOOPS TO REMOVE HEAT, CONTROL HUMIDITY, AND CLEAN AND PURIFY CABIN AIR.

ACTIVE THERMAL CONTROL SYSTEM

THE ACTIVE THERMAL CONTROL SYSTEM CONSISTS OF TWO FREON LOOPS THAT COLLECT WASTE HEAT FROM THE ORBITER SYSTEMS AND TRANSFER THE HEAT OVERBOARD.

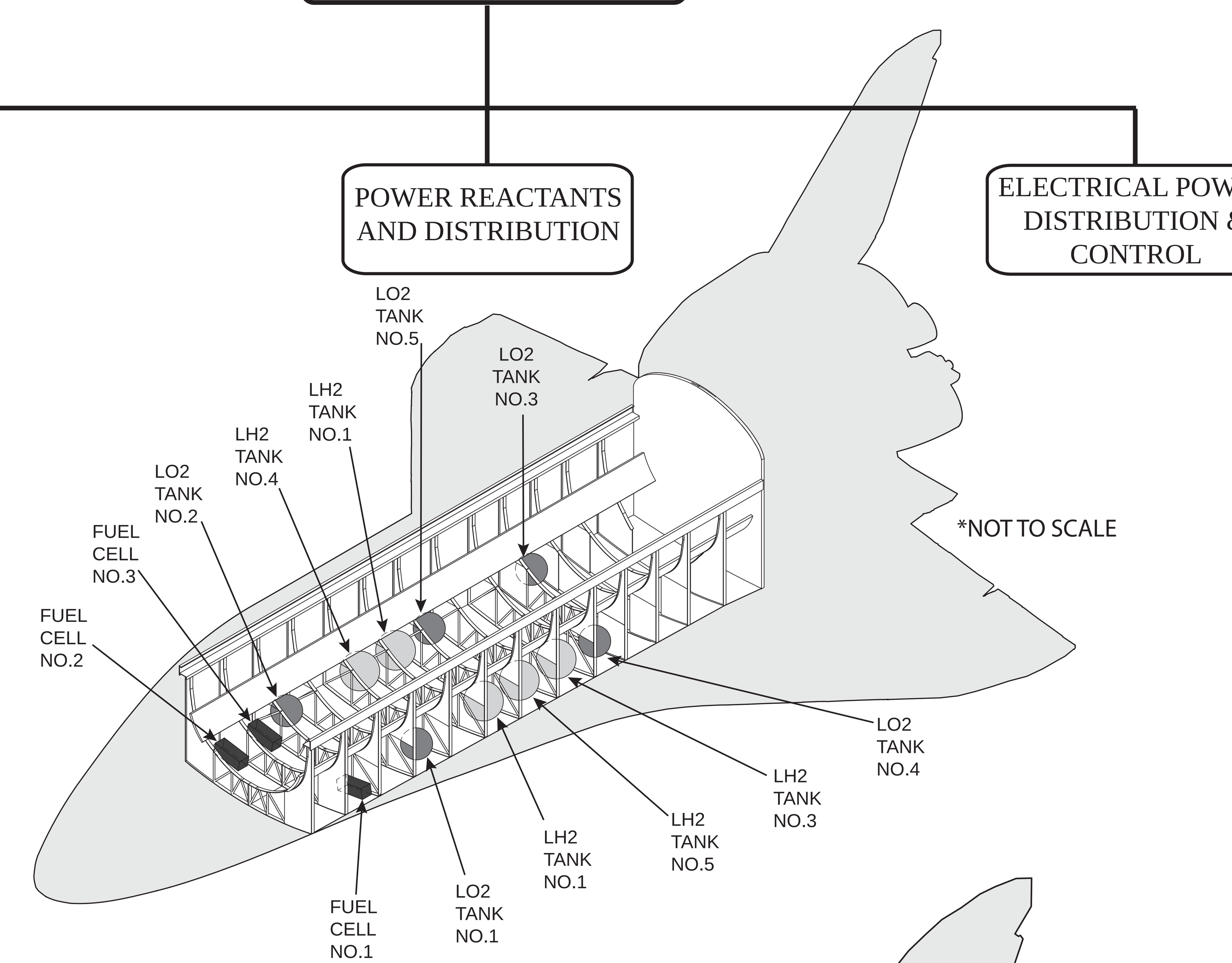
SUPPLY & WASTE WATER SYSTEM

THE SUPPLY AND WASTE WATER SYSTEM STORES WATER PRODUCED BY THE FUEL CELLS FOR DRINKING, PERSONAL HYGIENE, AND ORBITER COOLING. THE WASTEWATER SYSTEM STORES CREW LIQUID WASTE AND WASTEWATER FROM THE HUMIDITY SEPARATOR. THE SYSTEM ALSO HAS THE CAPABILITY TO DUMP SUPPLY AND WASTEWATER OVERBOARD.



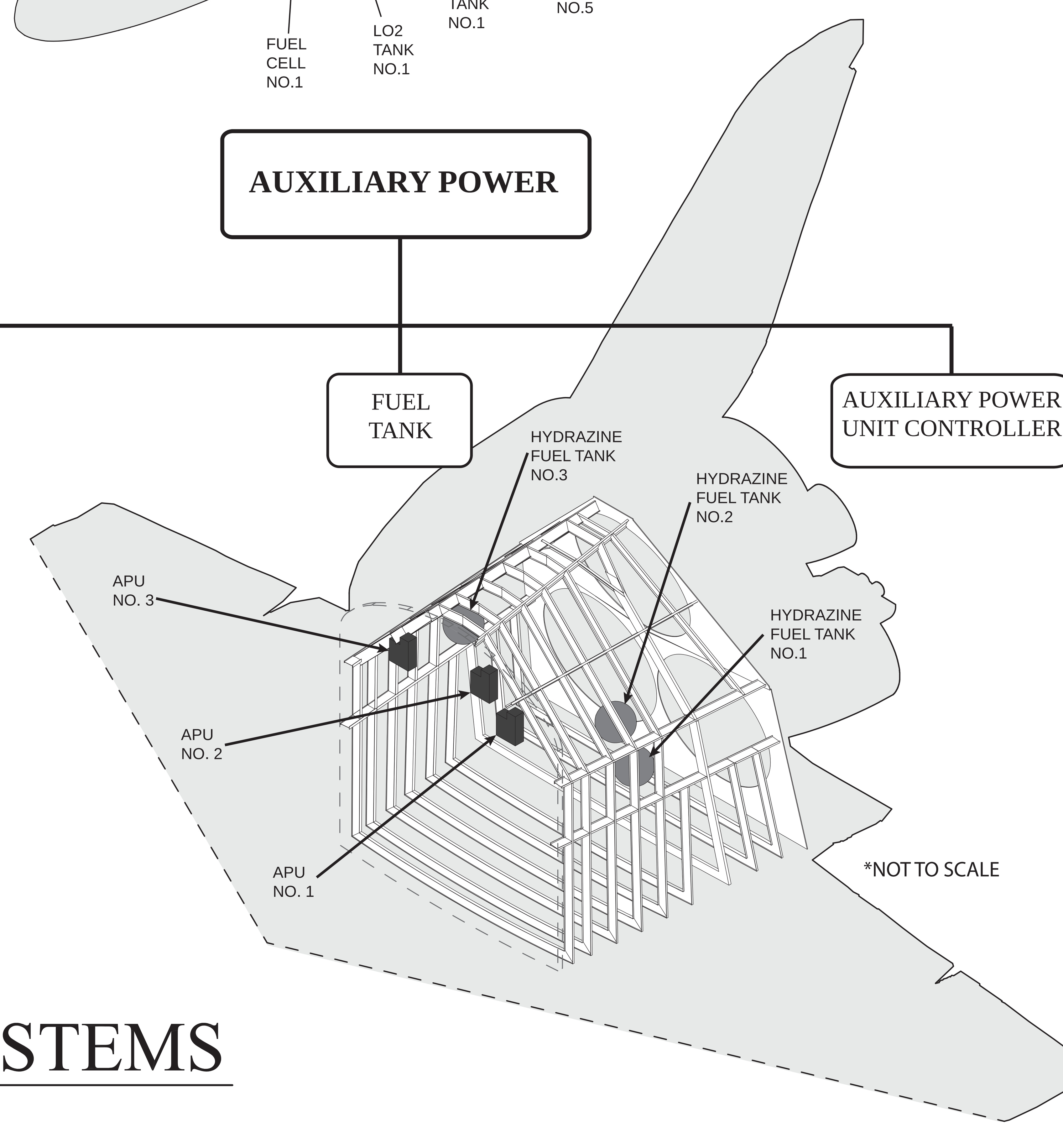
ELECTRICAL POWER SYSTEMS

- FUEL CELL POWER PLANTS
- POWER REACTANTS AND DISTRIBUTION
- ELECTRICAL POWER DISTRIBUTION & CONTROL



AUXILIARY POWER

- AUXILIARY POWER UNIT
  - SSME GIMBAL
  - SSME CONTROL VALVES
  - AEROSURFACES
  - ET UMBILICAL RETRACT
  - LANDING GEAR
  - LANDING GEAR BRAKES
  - NOSE WHEEL STEERING
- FUEL TANK
- AUXILIARY POWER UNIT CONTROLLER



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)
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

SHEET 15 OF 15

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-A

LIBRARY OF CONGRESS INDEX NUMBER

Space Transportation System
Solid Rocket Boosters

Orbiter Discovery just after launch of STS-121 from Kennedy Space Center, Florida. Image courtesy of NASA Johnson Space Center. Photographer unknown

During the thirty-year operation of the Space Transportation System, the Solid Rocket Boosters (SRBs) were the largest solid-propellant rockets ever used, the first designed for reuse, and the only solid-propellant rocket motors ever certified for manned spaceflight.

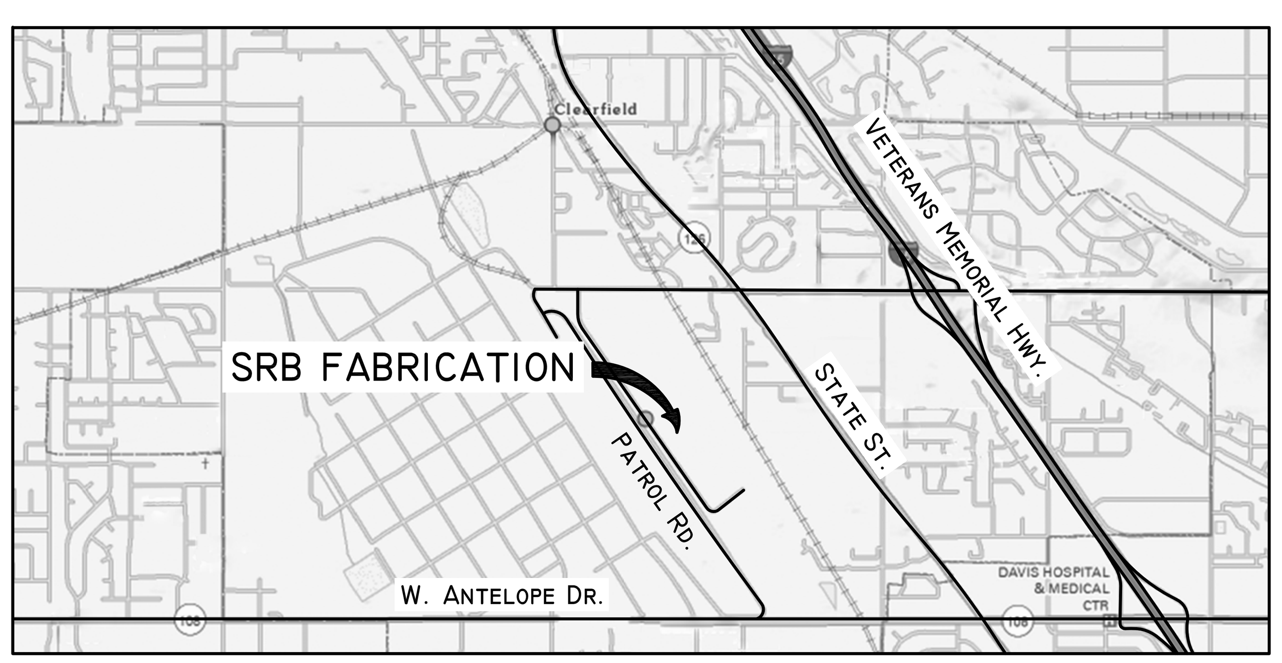
Each SRB measured about 149 feet long and 12 feet in diameter and could generate approximately 3,300,000 pounds of thrust at sea level. The SRBs were used as matched pairs, and each was made up of four solid rocket motor segments. The boosters were matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimize any thrust imbalance. The propellant mixture consisted of: aluminum powder fuel; ammonium perchlorate oxidizer; iron oxide catalyst, a synthetic polymer binding agent and an epoxy curing agent. The propellant was molded in a star-shaped perforation in the forward motor segment and a double-truncated cone perforation in the aft segment and aft closure. This configuration provided high thrust at ignition and reduced thrust approximately 50 seconds after launch, during the period of maximum dynamic pressure on the stack assembly.

The segmented-casing design assured maximum flexibility in fabrication and ease of transportation and handling. Once each segment was insulated, cast with propellant and finalized, the segments were shipped from ATK's manufacturing facility in Utah to Kennedy Space Center (KSC) in Florida, on specially designed, heavy-duty covered rail cars. At KSC, they were stacked and assembled into the flight configuration. In addition to the four fueled segments there was the forward section and an aft section. The forward section contained avionics systems, electronic assemblies integrated with the aft segment and descent parachutes.

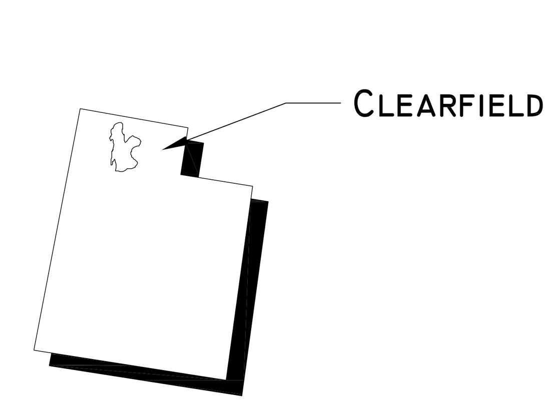
The aft segment contained an electronic assembly that sends and receives signals to and from the avionics system in the forward segment, the rocket motor's expansion nozzle and mechanisms for the gimballing of the nozzles. The SRB nozzles had a an approximate 7.75 to 1 expansion ratio and were lined with a sacrificial carbon cloth that was charred and eroded during flight. The nozzles could gimbal up to 8 degrees for thrust vector control. To actuate the gimbals each SRB had its own auxiliary power unit and hydraulic pumps.

At approximately 2 minutes and 8 seconds after launch the SRBs had consumed their fuel and were jettisoned. At jettison eight small separation rocket motors, four on the forward section and four on the aft section fired for about one second to alter their trajectory to ensure there is no incidental contact with the Orbiter or External Tank. At a predetermined altitude three parachutes were deployed on each SRB assembly to reduce the velocity of their descent to lessen their impact at splashdown. Shortly after splashdown, two booster recovery ships, the Freedom Star and Liberty Star, arrive with crews to plug, drain and prepare the SRBs to be towed back to KSC for post-launch inspection, processing and preparation for transport back to ATK in Utah.

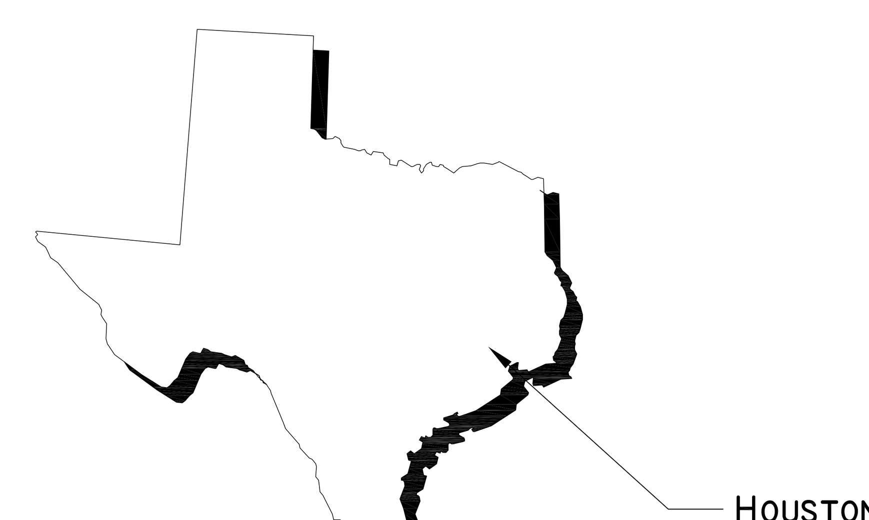
This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. 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.



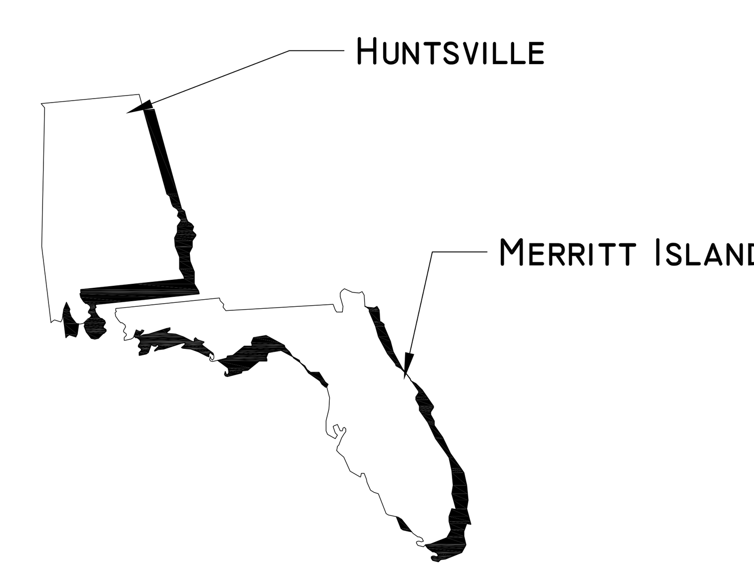
VICINITY MAP CLEARFIELD, UTAH



UTAH



TEXAS



ALABAMA FLORIDA

LIBRARY OF CONGRESS INDEX NUMBER

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-K

SHEET 1 OF 3

SPACE TRANSPORTATION SYSTEM, SOLID ROCKET BOOSTERS
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY
HOUSTON TEXAS

DELINEATED BY: THOMAS M. BEHRENS
SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

Ⓐ NOZZLE AND THRUST VECTOR CONTROL SYSTEM

Ⓑ FWD EXTERNAL TANK ATTACH POINT

Ⓒ AFT EXTERNAL TANK ATTACH RING

Ⓓ 4 SEPARATION MOTORS

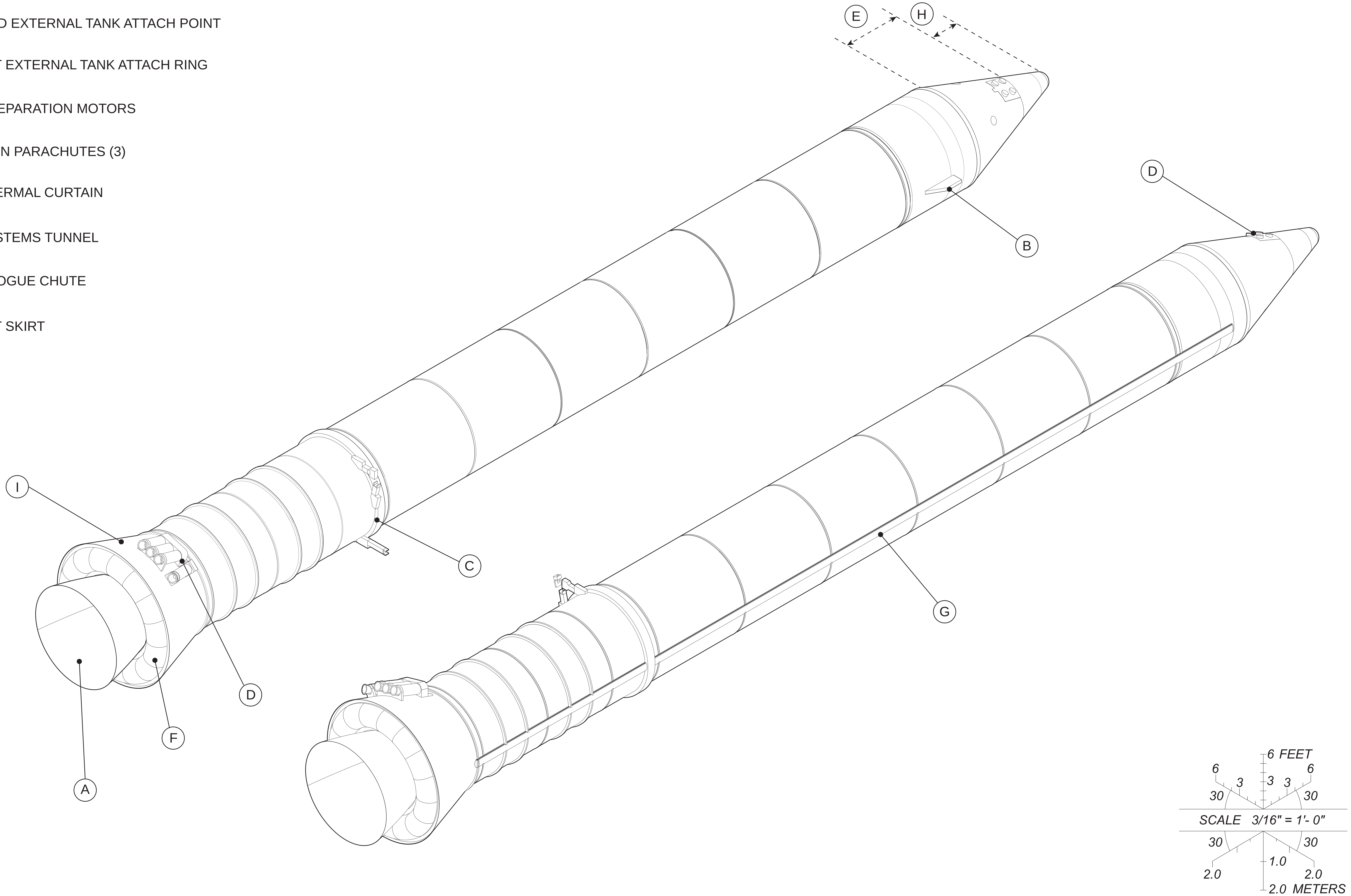
Ⓔ MAIN PARACHUTES (3)

Ⓕ THERMAL CURTAIN

Ⓖ SYSTEMS TUNNEL

Ⓗ DROGUE CHUTE

Ⓘ AFT SKIRT



SOLID ROCKET BOOSTERS

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

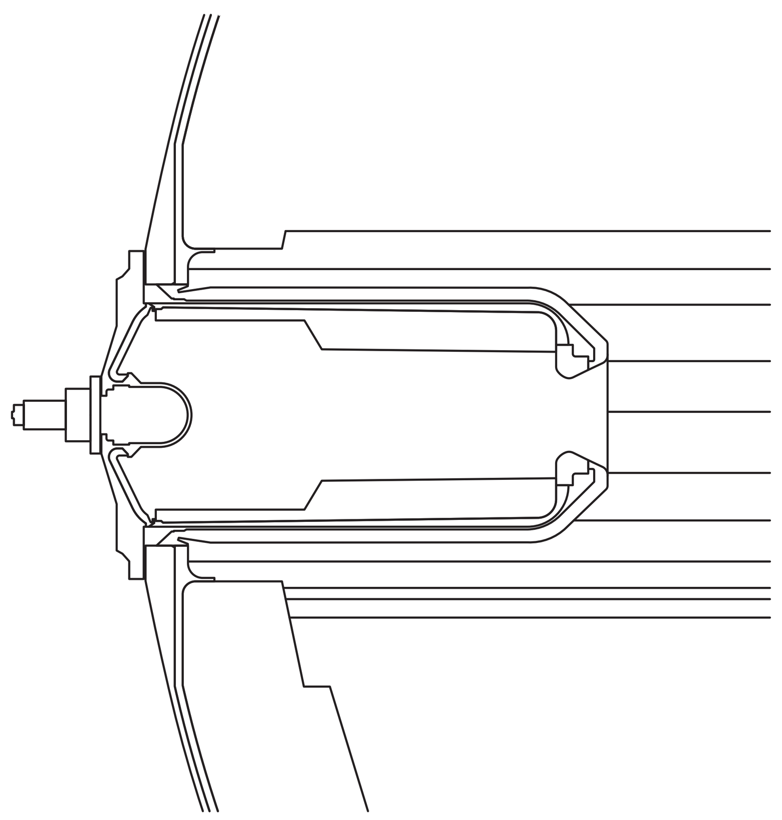
SPACE TRANSPORTATION SYSTEM, SOLID ROCKET BOOSTERS
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

SHEET 2 OF 3

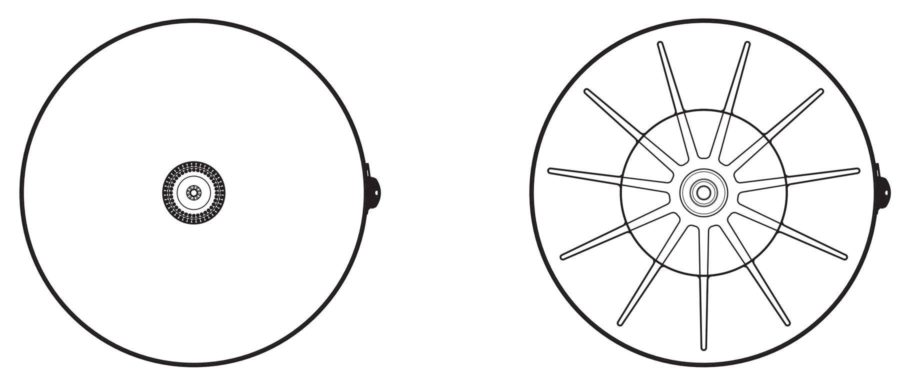
HISTORIC AMERICAN ENGINEERING RECORD
TX-116-K

LIBRARY OF CONGRESS INDEX NUMBER

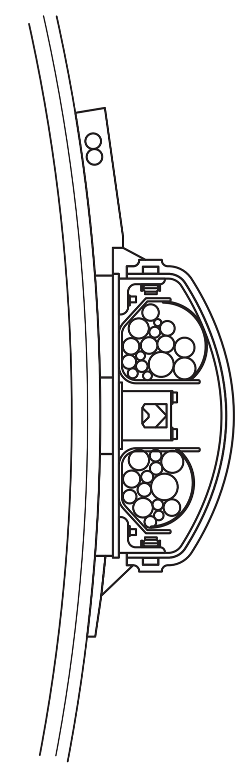
SOLID ROCKET BOOSTER DETAILS



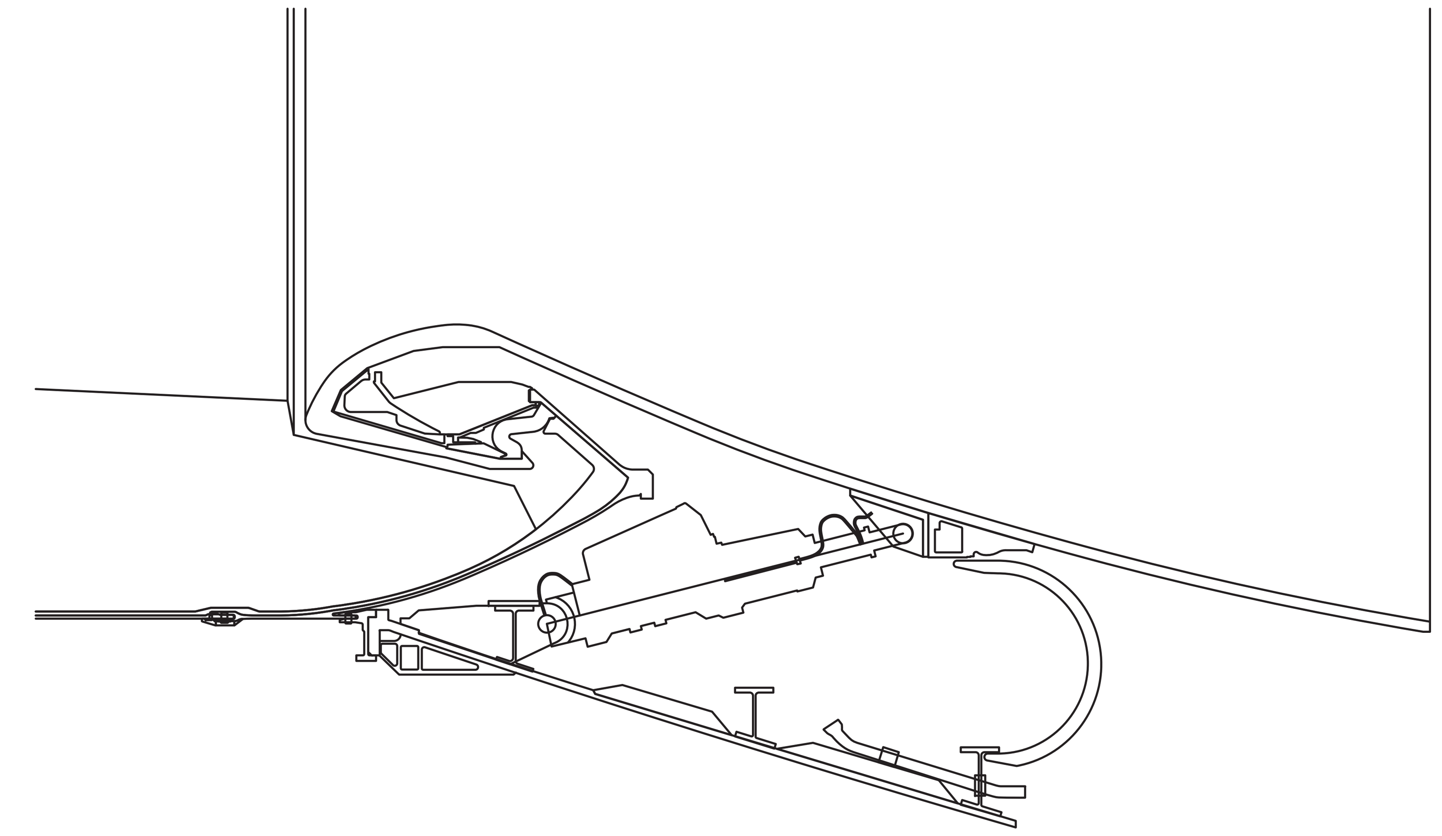
SRB IGNITOR DETAIL
SCALE: 1" = 1'-0"



SRB LATERAL SECTIONS
SCALE: 3/16" = 1'-0"



SYSTEM TUNNEL DETAIL
SCALE: 1" = 6'-0"



SRB ROCKET AFT DETAIL
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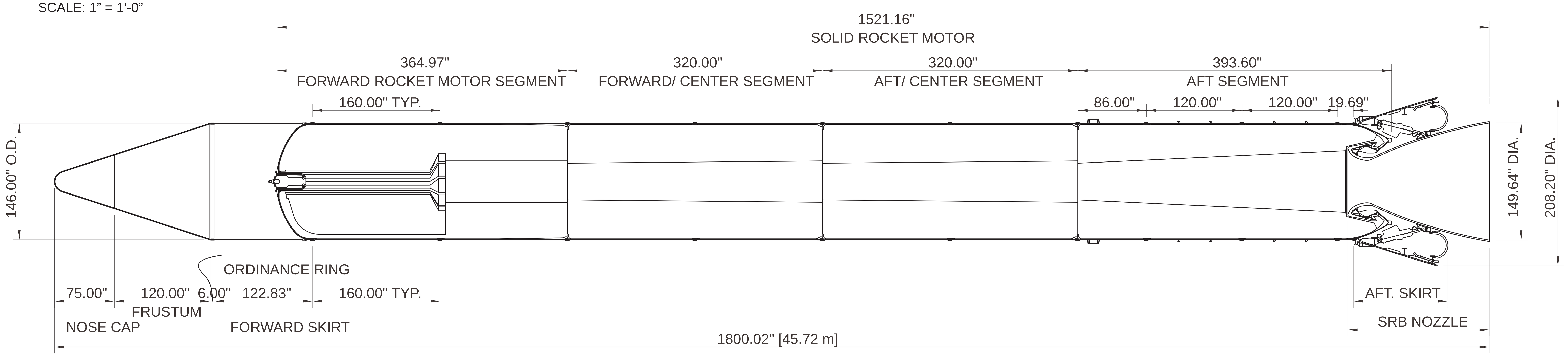
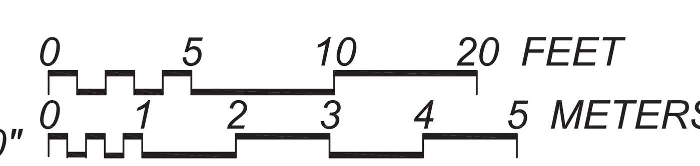
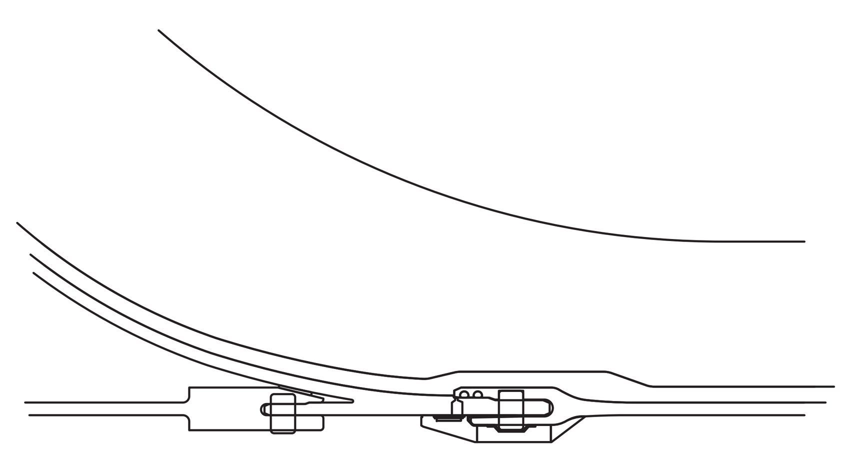


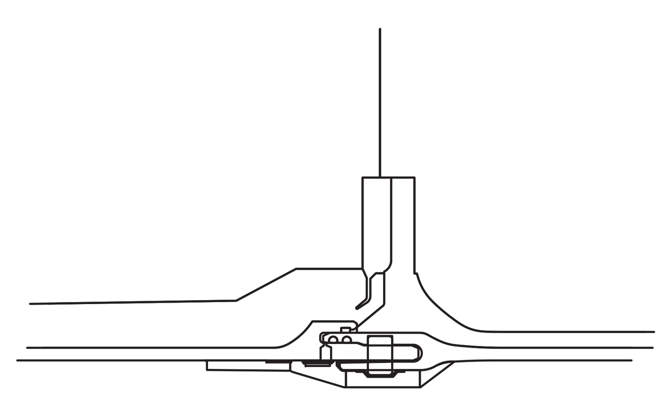
SRB LONGITUDINAL SECTION



SCALE: 3/16" = 1'-0"



NOSE TO TANK
SCALE: 1" = 6'-0"



FIELD WELD JOINT
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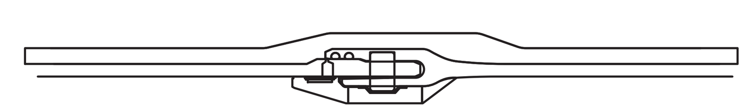

FACTORY WELD JOINT
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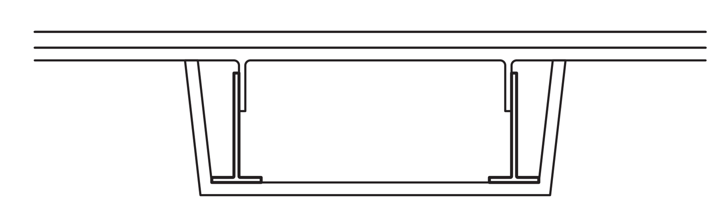

INTEGRATED ELECTRONIC ASSEMBLY (IEA)
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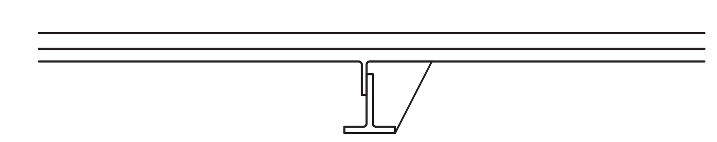


CASE STIFFNER RINGS
SCALE: 1" = 6'-0"

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

SPACE TRANSPORTATION SYSTEM, EXTERNAL TANK
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY

HOUSTON

TEXAS

SHEET
3 OF 3

HISTORIC AMERICAN
ENGINEERING RECORD
TX-116-J

LIBRARY OF CONGRESS
INDEX NUMBER

Space Transportation System
Space Shuttle Main Engine

Orbiter Discovery just after launch of STS-63 from Kennedy Space Center, Florida. Image courtesy of NASA Johnson Space Center. Photographer unknown

The Space Shuttle used three Space Shuttle Main Engines (SSMEs) mounted to the orbiter. The SSME was designed and developed under a contract with the NASA Marshall Space Flight Center, Huntsville, Alabama. The contract was awarded in 1971 to the Rocketdyne Division of North American Rockwell Corp., Canoga Park, California. In late 2005, Pratt & Whitney purchased Rocketdyne from the Boeing Company. Rocketdyne was combined with the rocket engine contingent of Pratt & Whitney, West Palm Beach, Florida to form a division named Pratt & Whitney Rocketdyne.

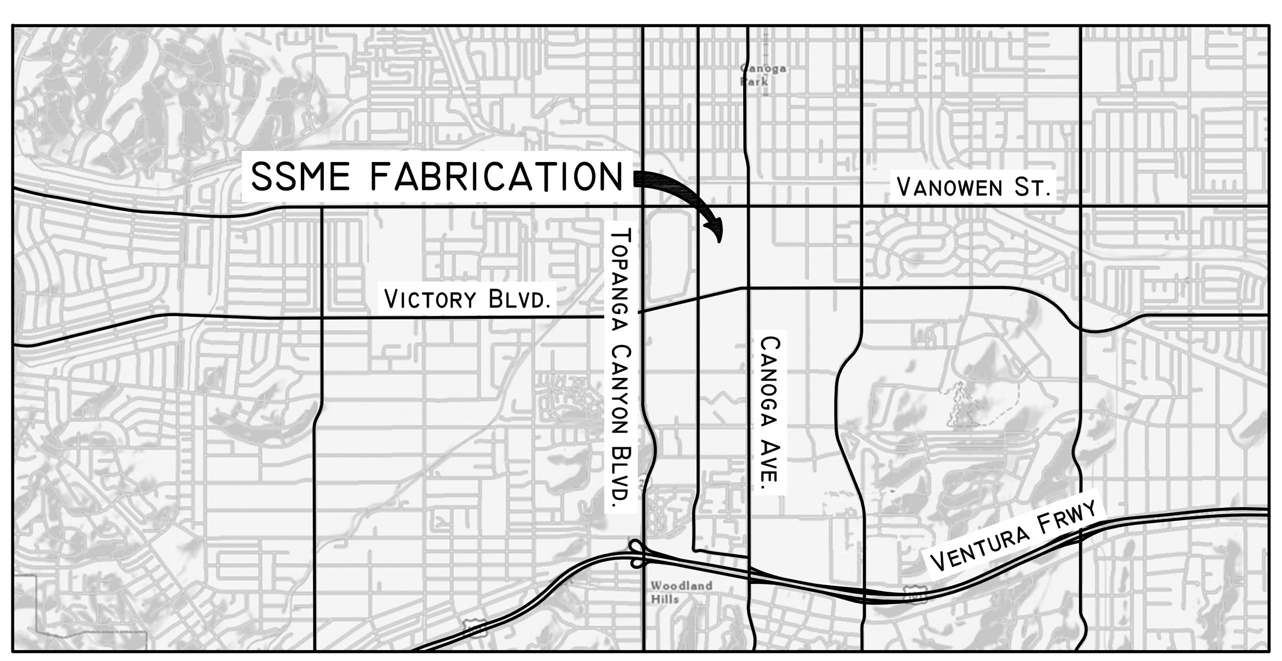
The SSME was a large reusable liquid rocket engine which used liquid hydrogen as fuel and liquid oxygen as oxidizer. Both propellants were stored in the External Tank. The SSME operated using the staged-combustion cycle, meaning propellants were initially burned in preburners in order to power the high-pressure turbopumps and were then burned again at a higher mixture ratio in the main combustion chamber. This cycle yielded a specific impulse substantially higher than previous rocket engines thus minimizing volume and weight for the integrated vehicle. Along with high efficiency and low weight came system complexity, high turbopump speeds, high chamber pressures, and a high thrust-to-weight ratio of sixty-six at full power level.

The SSME had a nominal burn time in flight of approximately 8.5 minutes. The engines were required to operate at any power level between 67% and 109% of rated power level (RPL), though the majority of ascent was spent at 104.5% RPL. The engine was throttled down early in ascent to minimize the structural loads on the vehicle when maximum dynamic pressure was reached. The engines throttled down again near Main Engine Cut-Off when the thrust was reduced in order not to exceed a 3G (three times the force of gravity) acceleration on the crew and cargo. Operation at 109% RPL was required for several abort modes which were never used in flight. The engine employed closed-loop control on both chamber pressure and mixture ratio. The control system employed redundancy known as fail-op/fail-safe which required the engines to operate normally for the first control failure (fail operational or fail-op) and then to shut down safely for the second failure (fail safe).

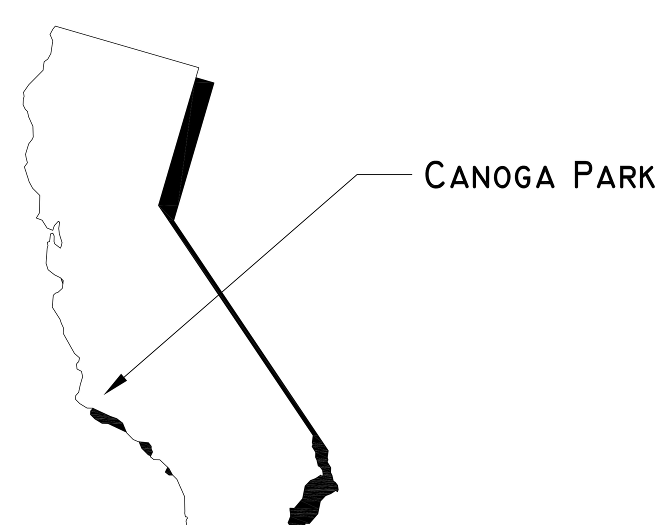
The SSMEs were attached to the vehicle's thrust structure via a gimbal bearing. This bearing provided an attachment point while allowing the engine to pivot on two axes. Each engine had two hydraulic actuators attached from the SSME main combustion chamber to the Orbiter's thrust structure. These were used for vehicle steering (roll, pitch, and yaw) movements. Vehicle steering was accomplished using both the SSMEs and Reusable Solid Rocket Boosters (RSRBs) during first stage operation and by the SSMEs alone after separation of the RSRBs.

The SSMEs operated successfully during all 135 flights due in large part to extensive ground testing which was used to fully characterize performance and to establish acceptable life limits. Over a million seconds of test and flight time were accumulated. The majority of the testing occurred at Stennis Space Center (SSC). Post-flight inspections and data assessment were integral to understanding in-flight performance of the hardware.

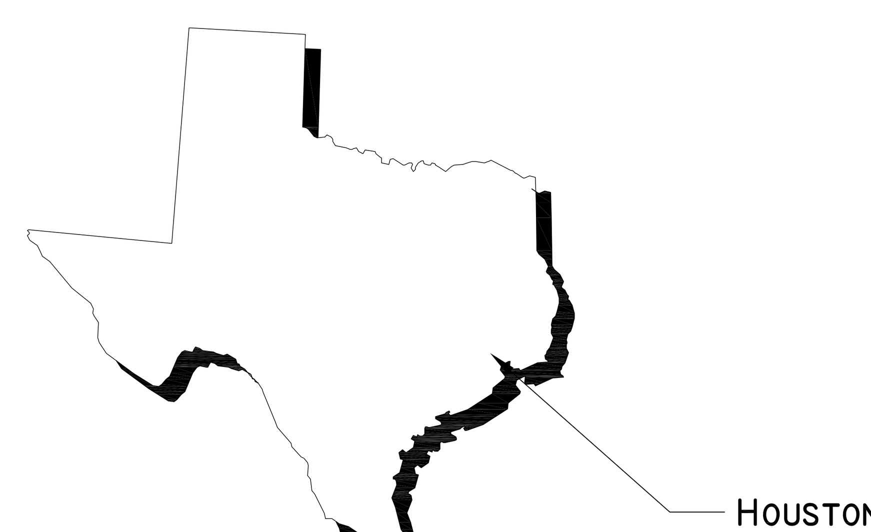
This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. 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 in Houston Texas with supplimental images provided by Jet Lowe, HAER photographer.



VICINITY MAP CANOGA PARK, CA



CALIFORNIA



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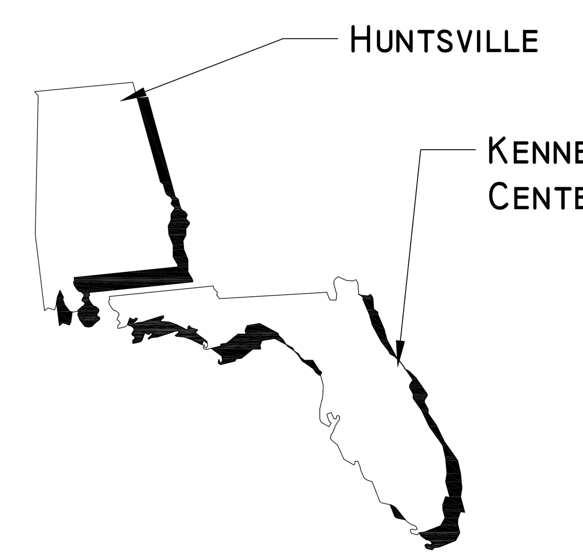


ALABAMA FLORIDA

DELINEATED BY: THOMAS M. BEHRENS

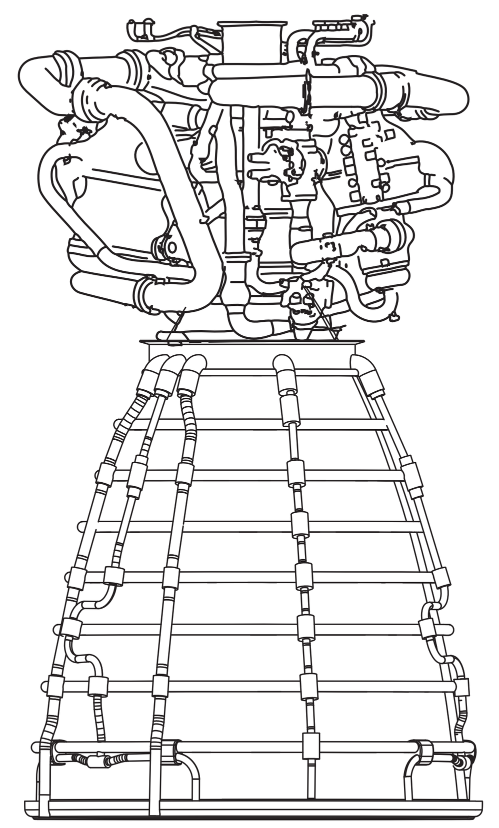
SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SPACE TRANSPORTATION SYSTEM, SPACE SHUTTLE MAIN ENGINE
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

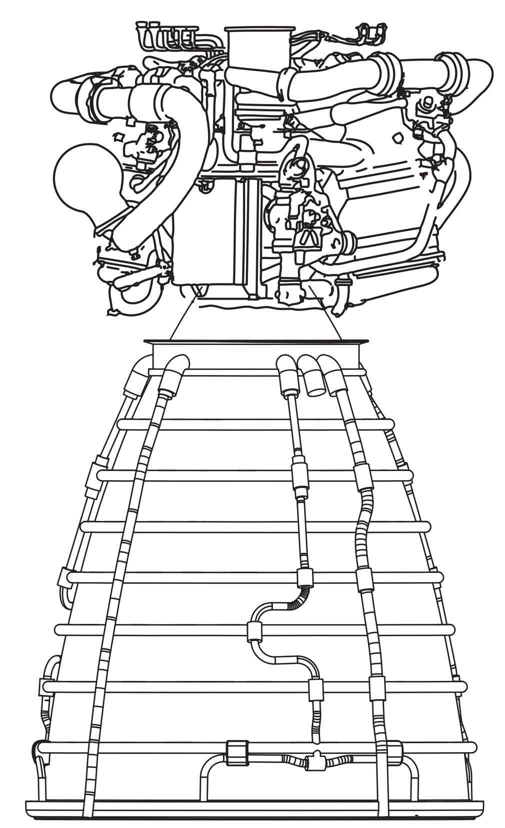
SHEET 1 OF 2

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-I

LIBRARY OF CONGRESS INDEX NUMBER



SSME LOW PRESSURE
OXYGEN TURBOPUMP ELEVATION

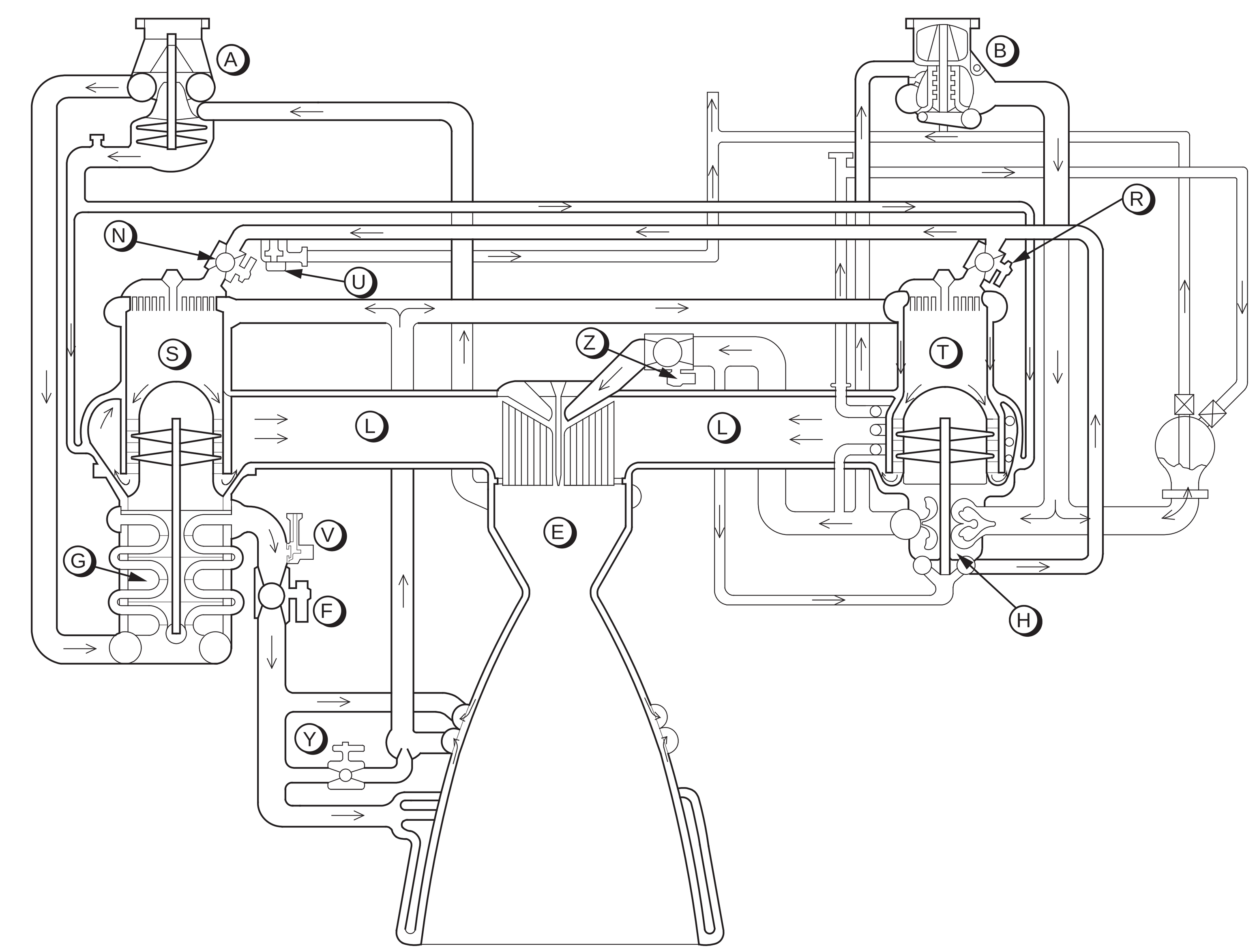


SSME LOW PRESSURE
FUEL TURBOPUMP ELEVATION

SCALE: 3/8" = 1'-0"   0 2 4 8 FEET / 0 1 2 METERS

SSME COMPONENTS

A	LOW-PRESSURE FUEL TURBOPUMP
B	LOW-PRESSURE OXIDIZER TURBOPUMP
C	LOW-PRESSURE OXIDIZER DUCT
D	LOW-PRESSURE FUEL DUCT
E	MAIN COMBUSTION CHAMBER
F	MAIN FUEL VALVE
G	HIGH-PRESSURE FUEL TURBOPUMP
H	HIGH-PRESSURE OXIDIZER TURBOPUMP
I	LPFTP TURBINE DRIVE DUCT
J	LPOTP TURBINE DRIVE DUCT
K	LPFTP TURBINE DISCHARGE DUCT
L	HOT-GAS MANIFOLD
M	CONTROLLER
N	FUEL PREBURNER OXIDIZER VALVE
O	PNEUMATIC CONTROL ASSEMBLY
P	HIGH PRESSURE LOX DUCT
Q	HIGH PRESSURE FUEL DUCT
R	OXIDIZER PRE-BURNER OXIDIZER VALVE
S	FUEL PREBURNER
T	OXIDIZER PREBURNER
U	LOX BLEED VALVE
V	FUEL BLEED VALVE
W	HGM COOLANT DUCT
X	OPB LOX SUPPLY DUCT
Y	CHAMBER COOLANT VALVE
Z	MAIN OXIDIZER VALVE

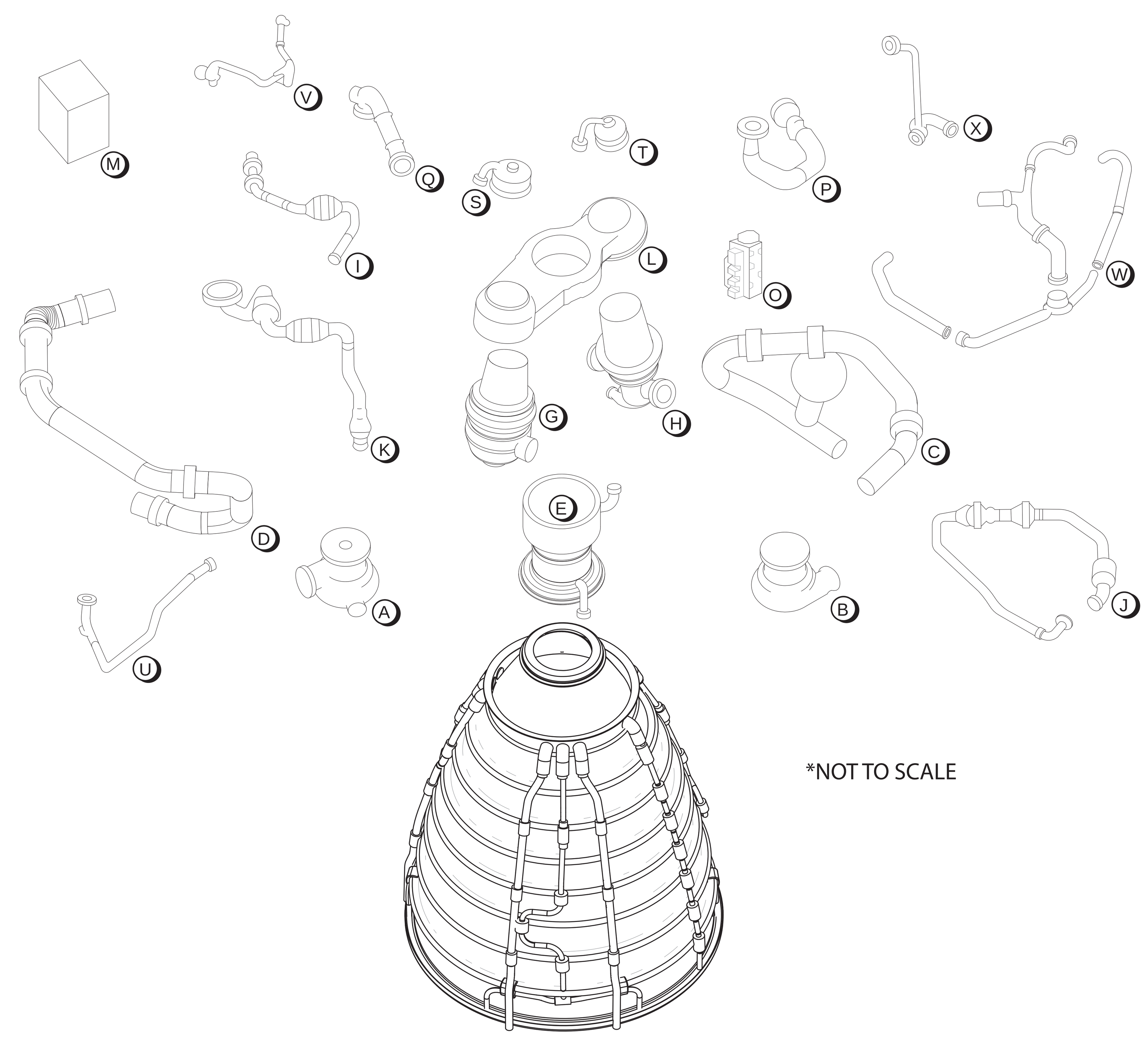


SSME PROPELLANT FLOW SCHEMATIC

The SSME was designed for 55 missions. The engines were generally referred to as the center (engine 1), left (engine 2), and right (engine 3). The SSMEs were 14 feet long and 7.5 feet in diameter at the nozzle exit. Each nozzle had an area ratio of 77.5:1. Each SSME weighed approximately 7,000 pounds.

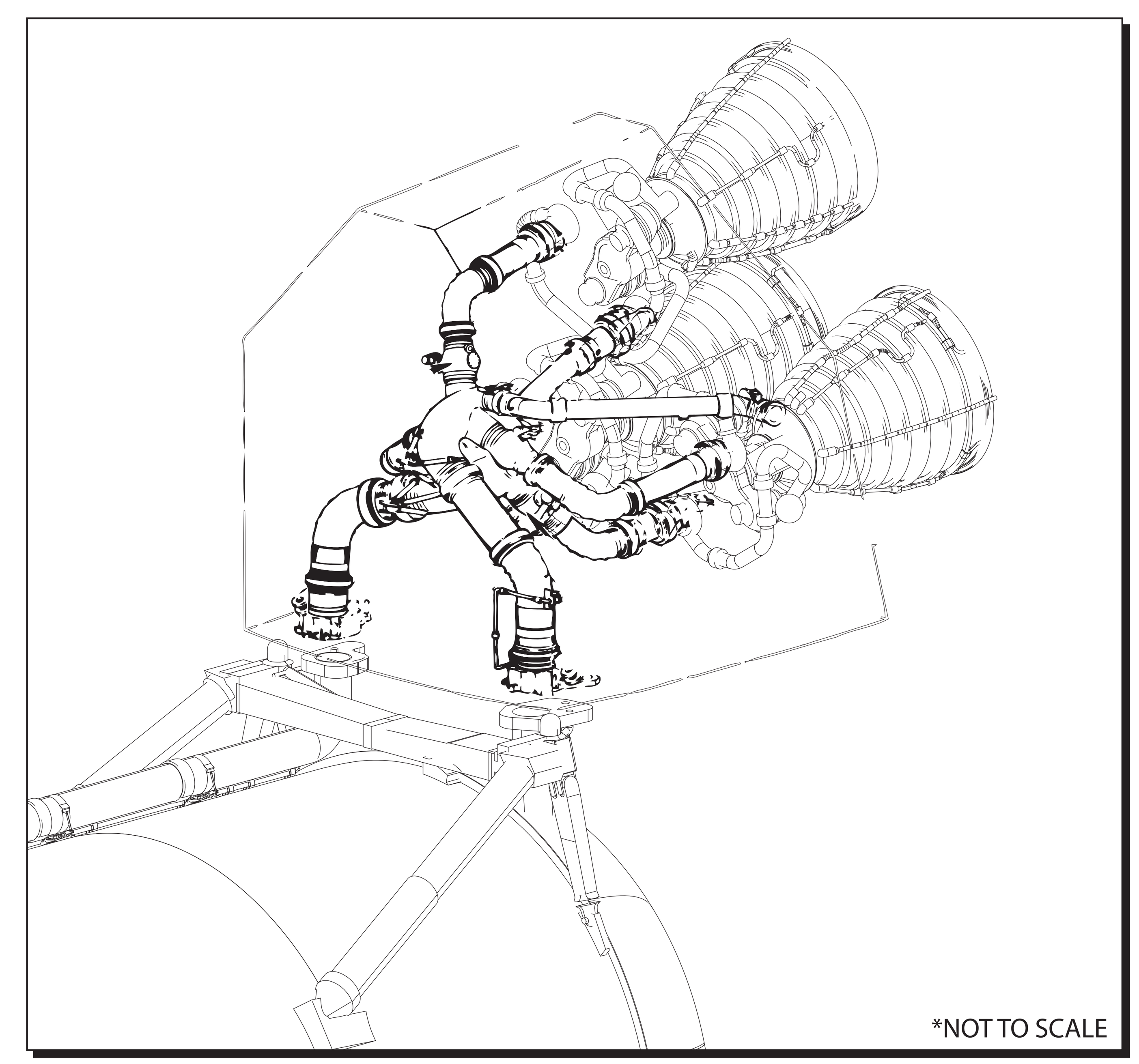
The SSME utilized four turbopumps to boost the pressure of its cryogenic propellants for preburner and main combustion chamber injection. The design incorporated a controller with a health management system. The five main control valves operated under hydraulic pressure and had redundant pneumatic control for failure scenarios. Additionally, the engine featured a passive on-engine POGO oscillation suppression system attached to the low-pressure oxidizer duct (LPOD) to damp and prevent coupling of vehicle-to-engine low-cycle pressure oscillations.

Throughout its history, the SSME incorporated many design improvements. Most large changes were incorporated in block upgrades. Many limitations of the first manned orbital flight (FMOF) engines were addressed by the Phase I design, which first flew on STS-6. Post-Challenger Return-to-Flight (STS-26R) brought the first flight of Phase II, which included modifications to the turbopumps, main combustion chamber, and avionics. The Block I configuration which followed incorporated a new high-pressure oxygen turbopump, an improved powerhead, and a new heat exchanger. The Block I configuration was first flown on STS-70. Block IIA was first flown on STS-89. It incorporated a large-throat main combustion chamber reducing system internal pressures and temperatures. The last block upgrade was Block II, which added a new high-pressure fuel turbopump. Block II first flew on STS-104. The cumulative effects of these modifications were increased safety and reduced maintenance costs between flights. Predicted reliability improved by a factor of four over the life of the program, and maintenance on the Block II engine was 57% less than on the Phase II engines.



COMPONENT ISOMETRIC

SSME CLUSTER UMBILICAL ATTACHMENT TO EXTERNAL TANK



SPACE SHUTTLE MAIN ENGINE

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

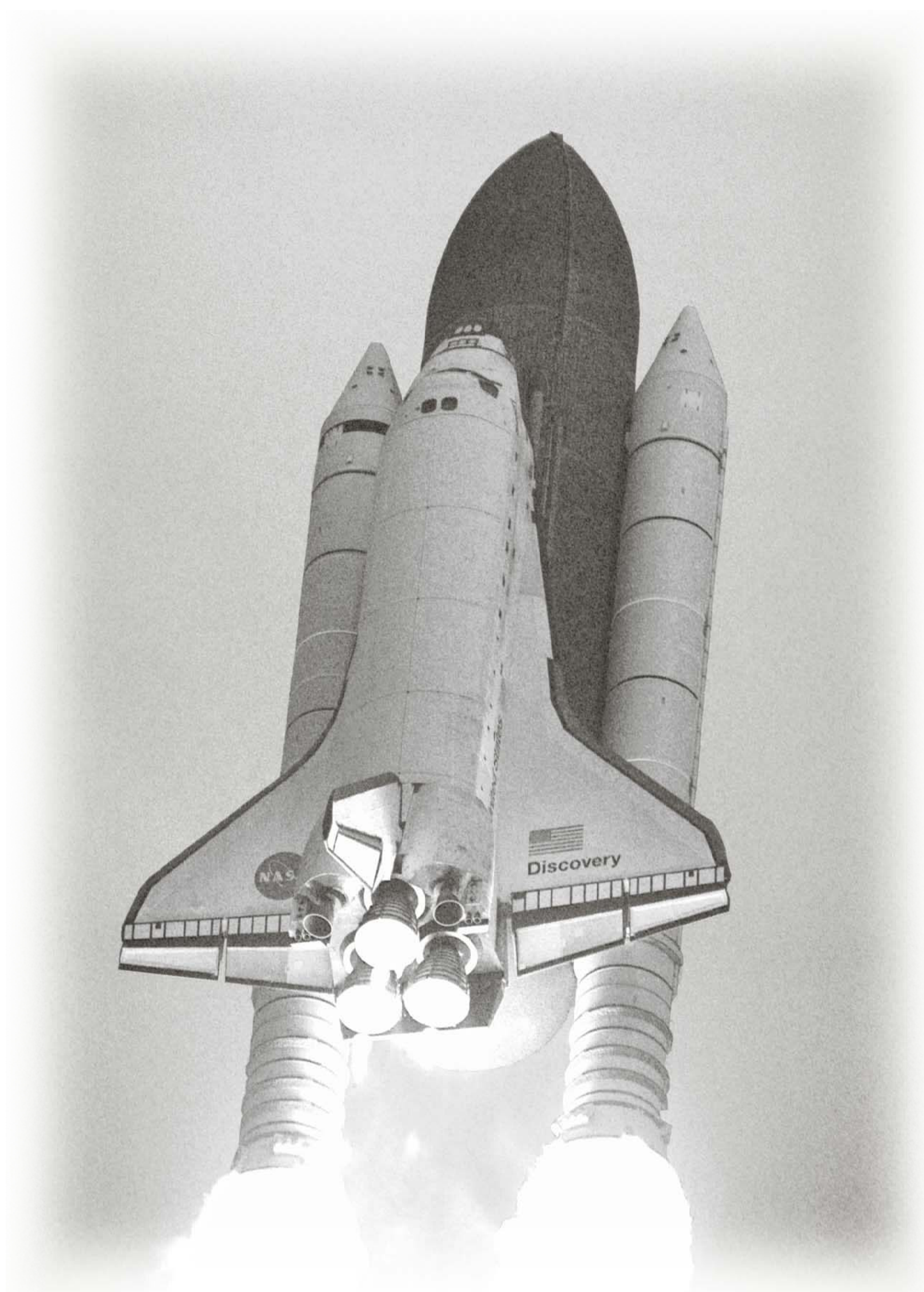
SPACE TRANSPORTATION SYSTEM, SPACE SHUTTLE MAIN ENGINE
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HOUSTON HARRIS COUNTY TEXAS

SHEET 2 OF 2

HISTORIC AMERICAN ENGINEERING RECORD
TX-116-I

LIBRARY OF CONGRESS INDEX NUMBER

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.

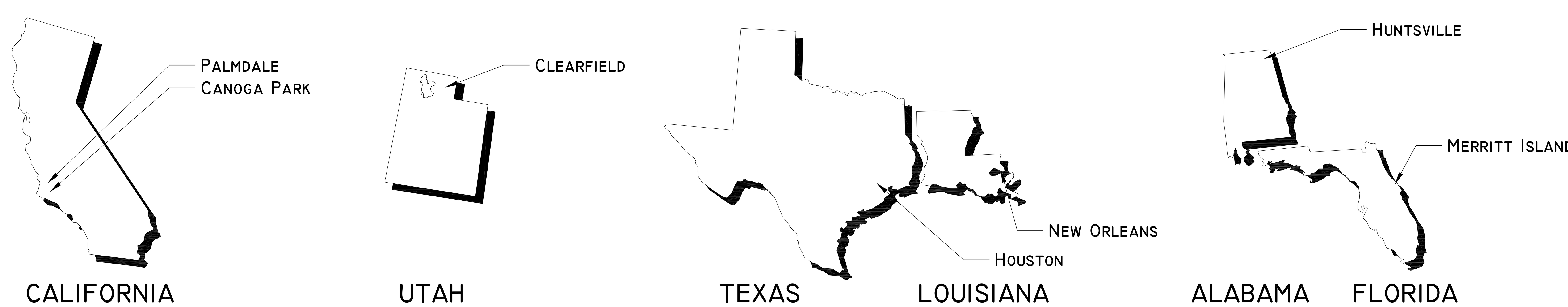
After MECO and ET jettison the SSMEs were no longer used. The shuttle relied on the Orbital Maneuvering System (OMS) and the Reaction Control System (RCS) during the orbital phase for velocity changes. The OMS was located in two pods on the aft section of the Orbiter at the base of the vertical stabilizer.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



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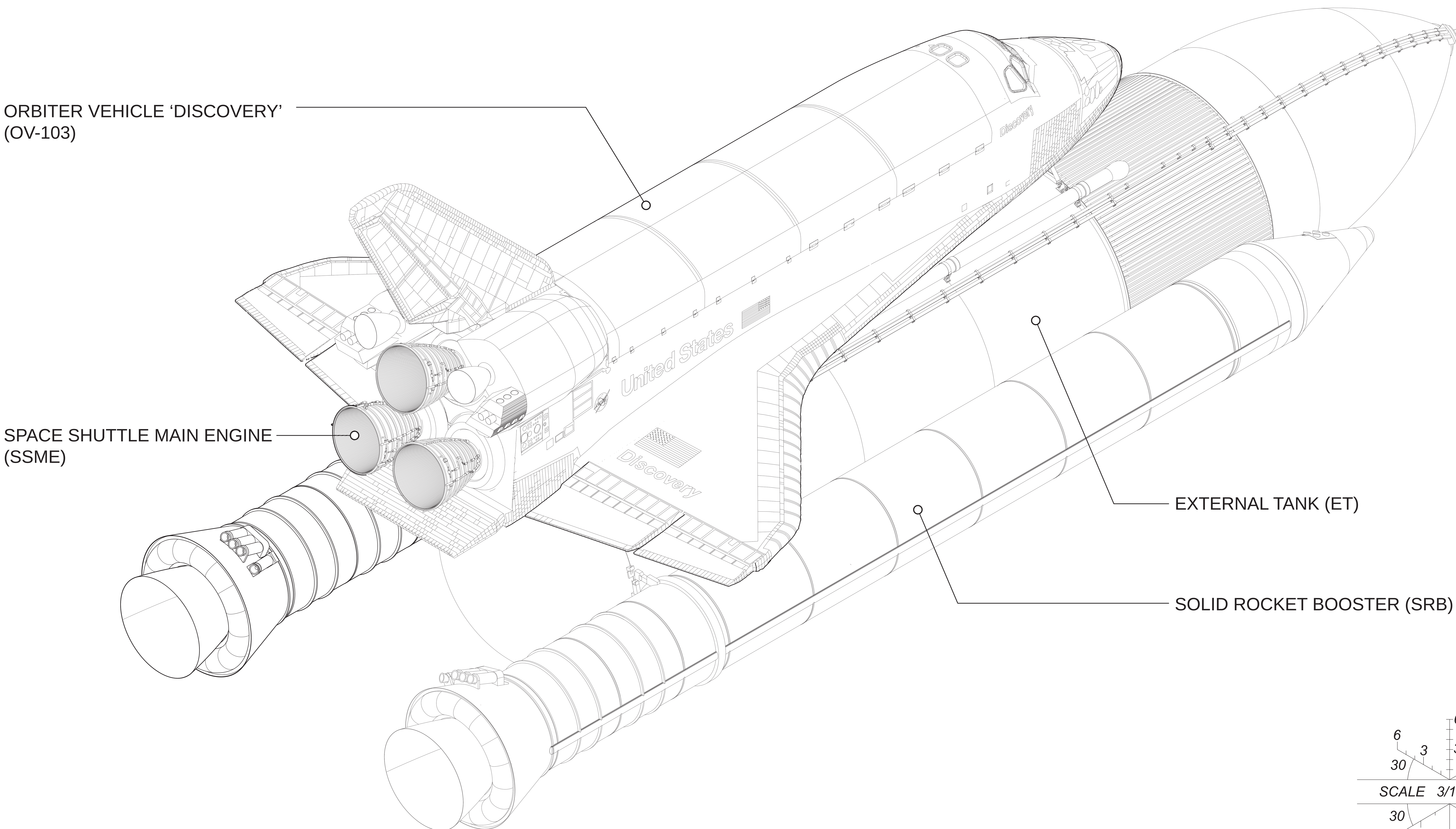
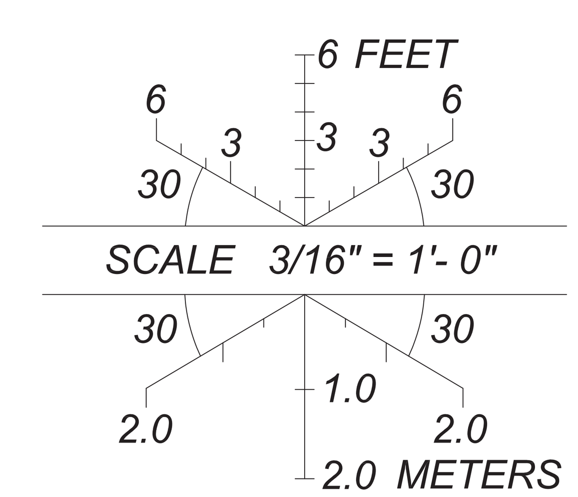
SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
SPACE TRANSPORTATION SYSTEM
Johnson Space Center, 2101 NASA Parkway
HARRIS COUNTY
HOUSTON
TEXAS
SHEET 1 OF 6
HISTORIC AMERICAN ENGINEERING RECORD
TX-116
LIBRARY OF CONGRESS INDEX NUMBER

SPACE TRANSPORTATION SYSTEM (STS)





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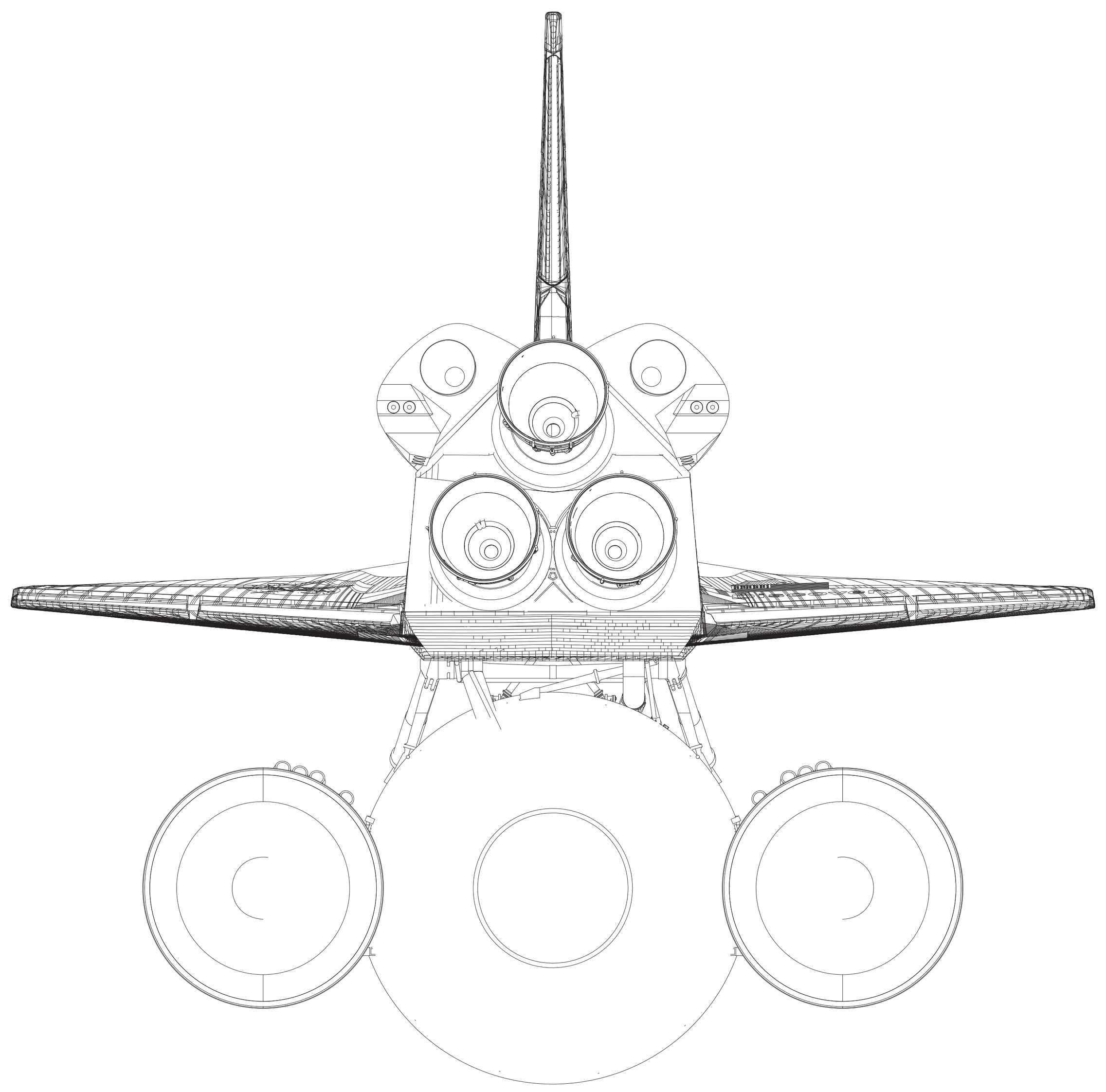
SHEET 2 OF 6

SPACE TRANSPORTATION SYSTEM
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY
TEXAS
HOUSTON

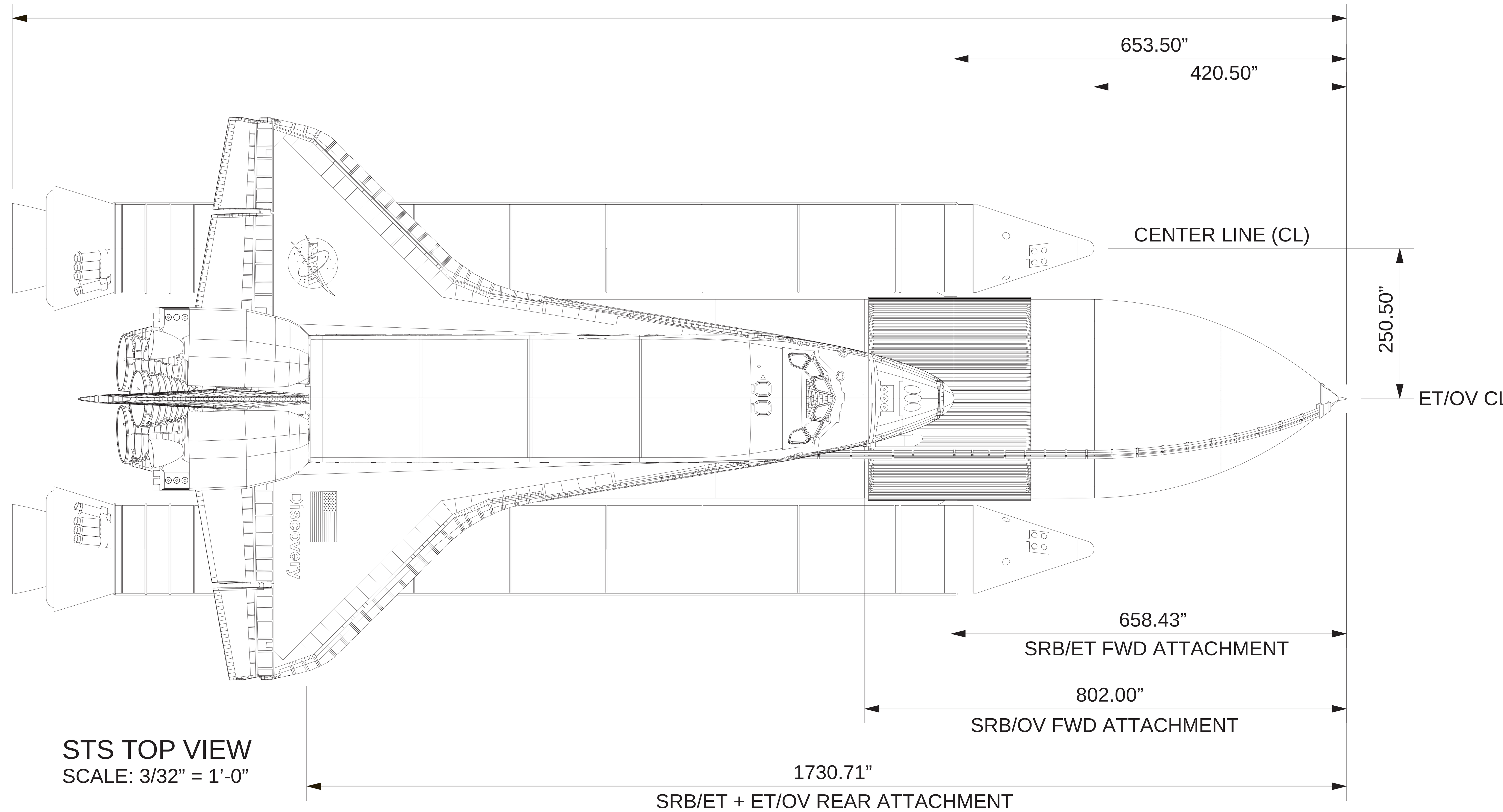
DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

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

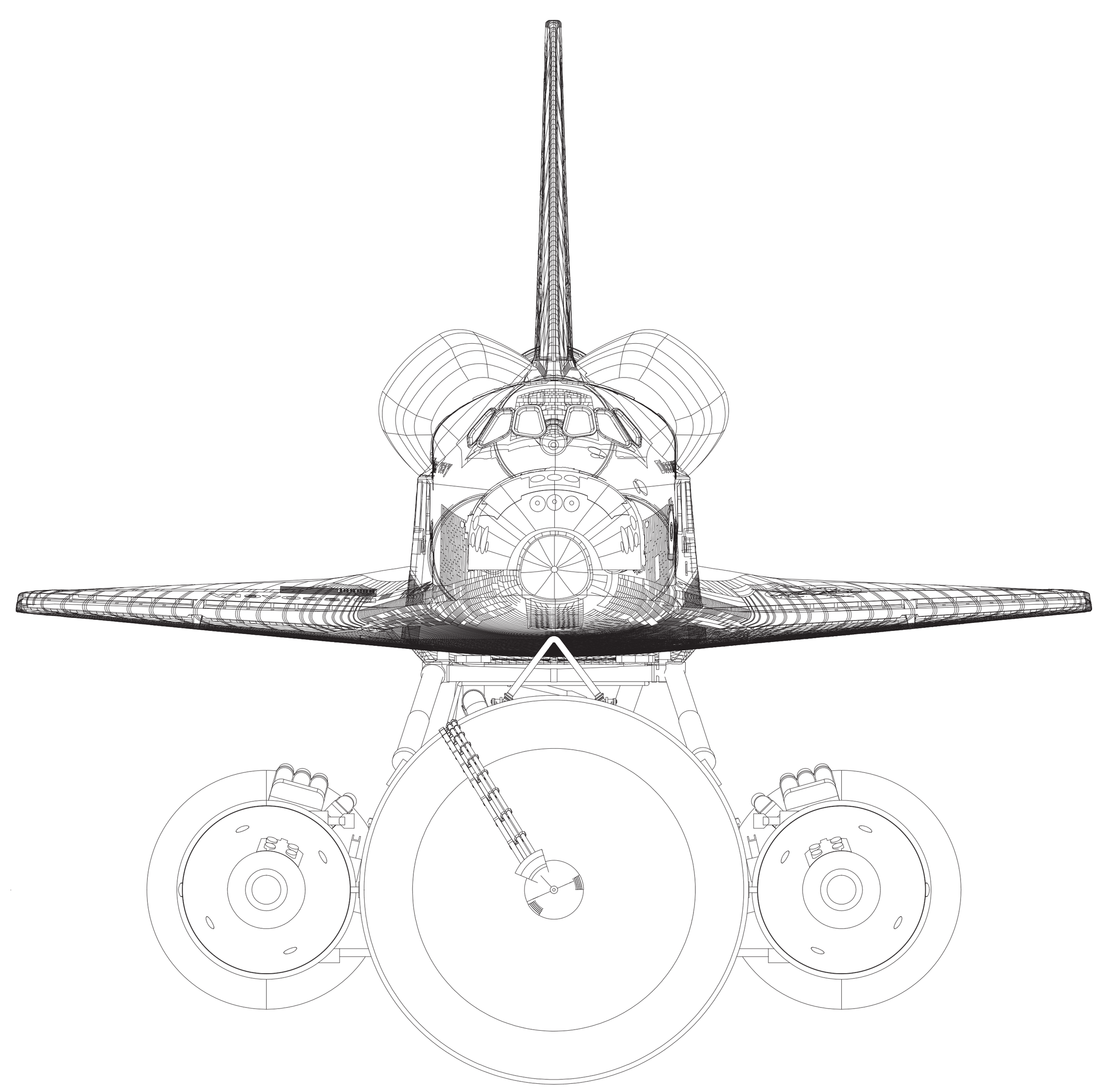
SPACE TRANSPORTATION SYSTEM



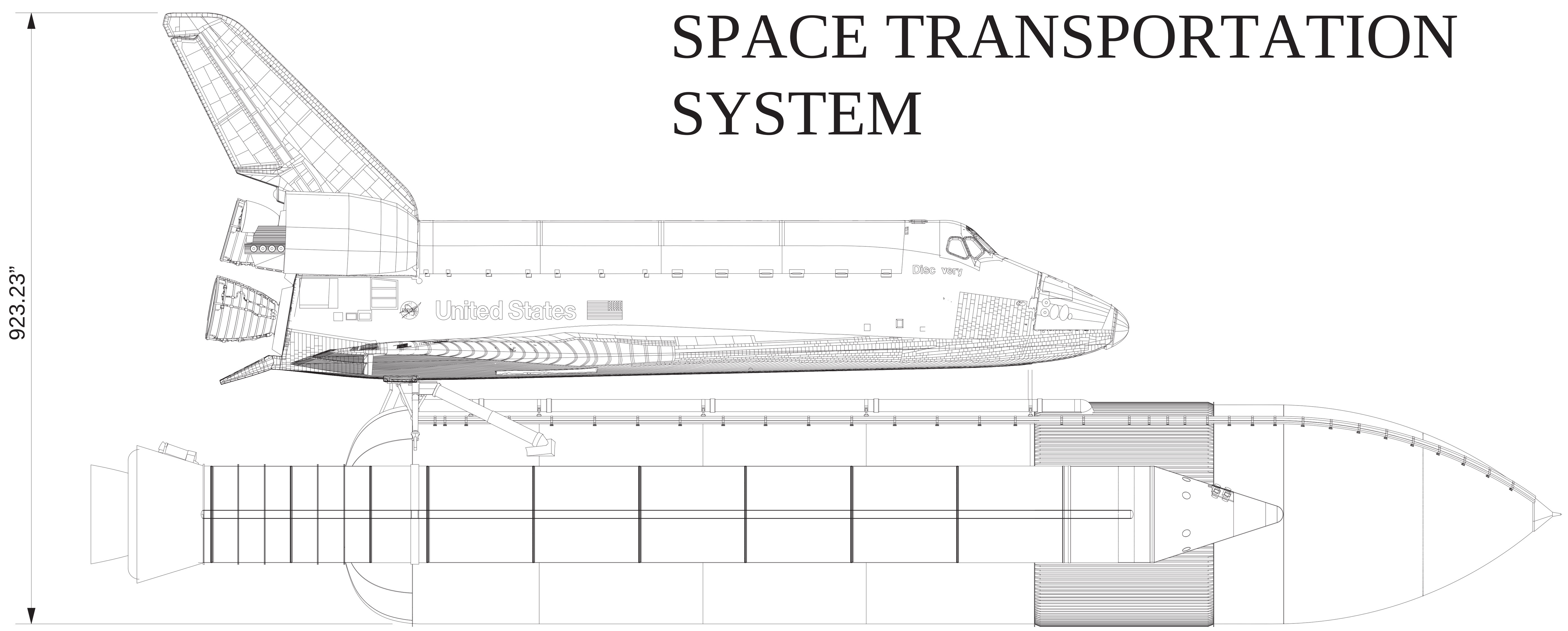
STS REAR ELEVATION
SCALE: 3/32" = 1'-0"



STS TOP VIEW
SCALE: 3/32" = 1'-0"



STS FRONT ELEVATION
SCALE: 3/32" = 1'-0"



STS STARBOARD ELEVATION
SCALE: 3/32" = 1'-0"

SCALE: 3/32" = 1'-0" 0 5 15 30 FEET / 0 1 5 10 METERS

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UNITED STATES DEPARTMENT OF THE INTERIOR

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HARRIS COUNTY

HOUSTON

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SHEET 3 OF 6

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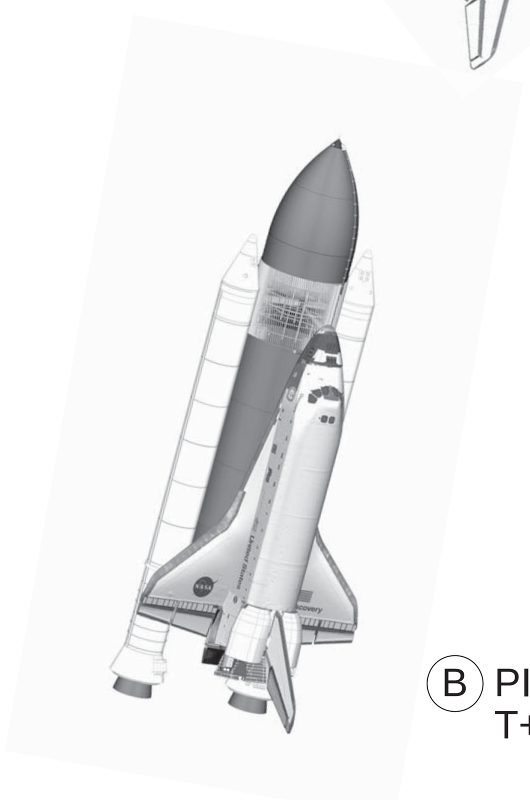
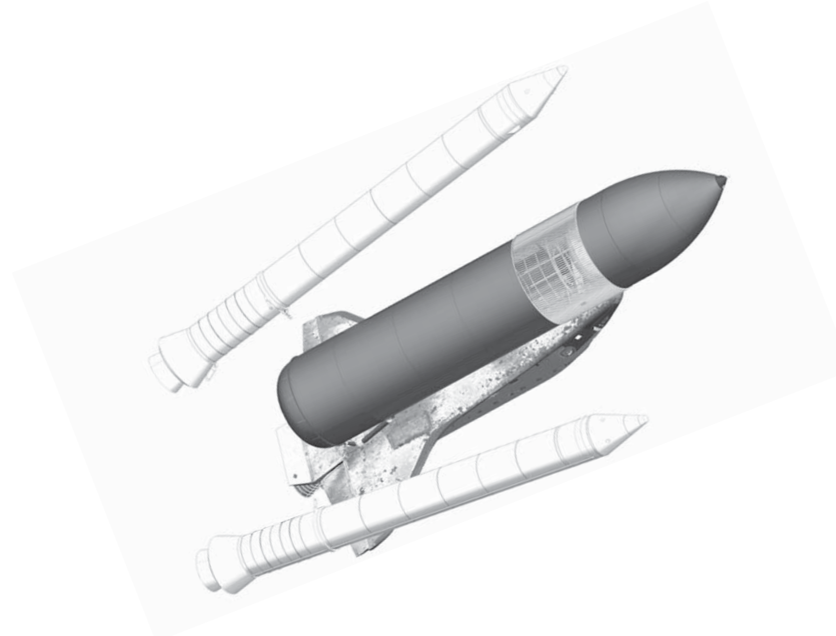
LIBRARY OF CONGRESS INDEX NUMBER

A LAUNCH
T+: 00:00:00

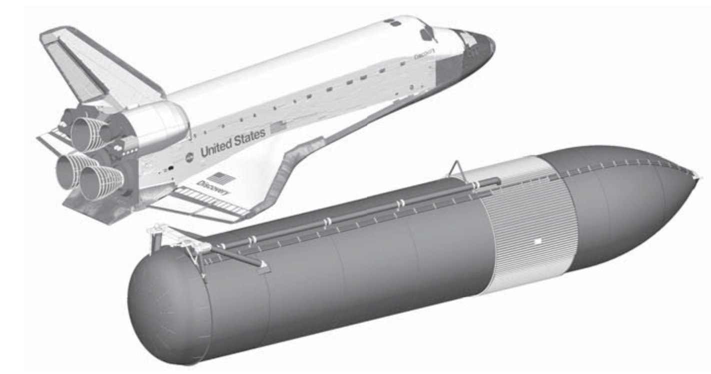


B PITCH + ROLL
T+: 00:00:11 - 18



C SRB STAGING
T+: 00:02:03

D ROLL TO HEADS UP
T+: 00:05:28



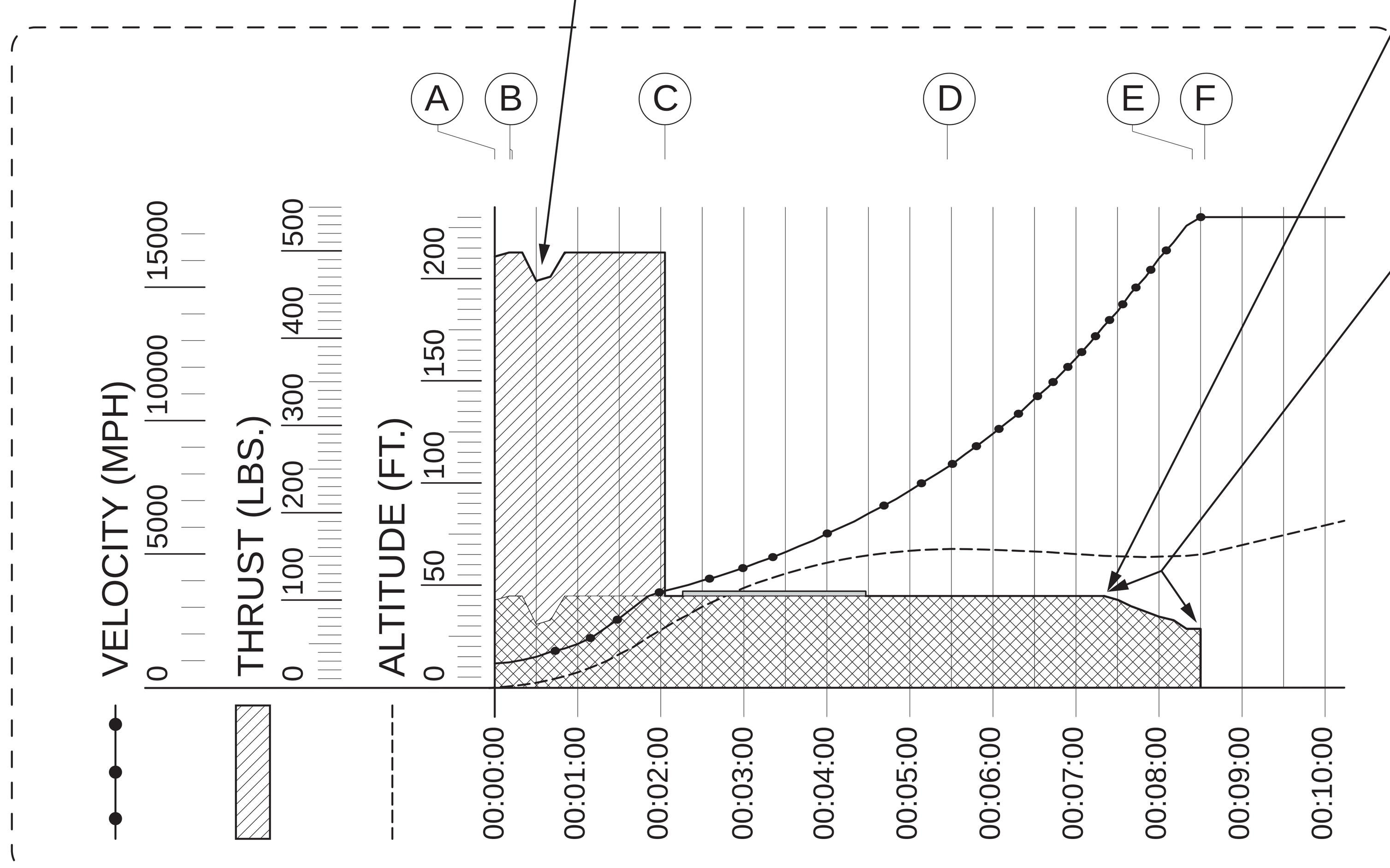
E / F MECO/ ET SEPARATION
T+: 00:08:24/ T+: 00:08:33

G APOGEE (OMS BURN #2)
T+: 00:38:14

H PAYLOAD BAY DOOR OPENING
T+: 01:00:00

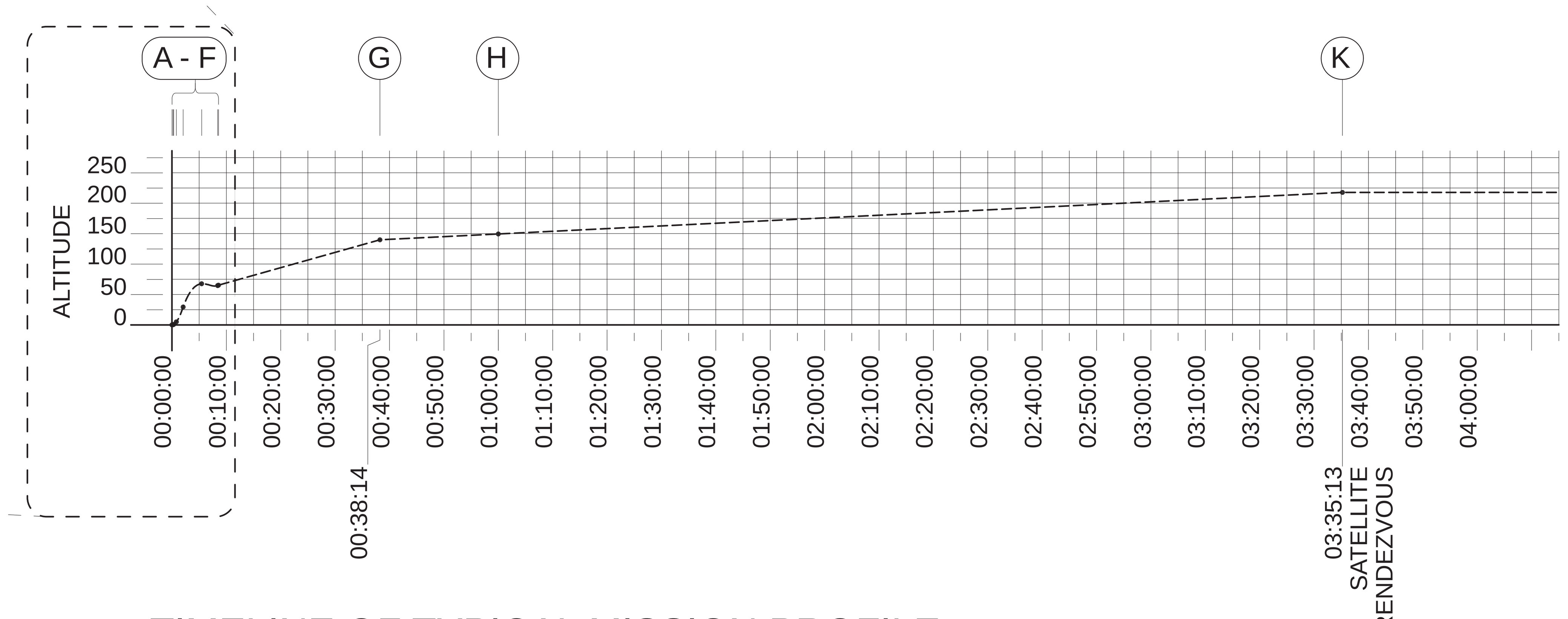
STS FLIGHT LAUNCH MISSION PROFILE

THE FLIGHT LAUNCH MISSION PROFILE COVERS THE LAUNCH OPERATIONS FROM COUNTDOWN TO SPACE STATION RENDEZVOUS.



LAUNCH TO ET SEPERATION
WITH VELOCITY/ THRUST/ ALTITUDE DATA

THRUST - SRB
THRUST - SSME
THRUST - OMS PODS



TIMELINE OF TYPICAL MISSION PROFILE
FROM LAUNCH TO SPACE STATION RENDEZVOUS
T+: 00:00:00 - 03:35:13

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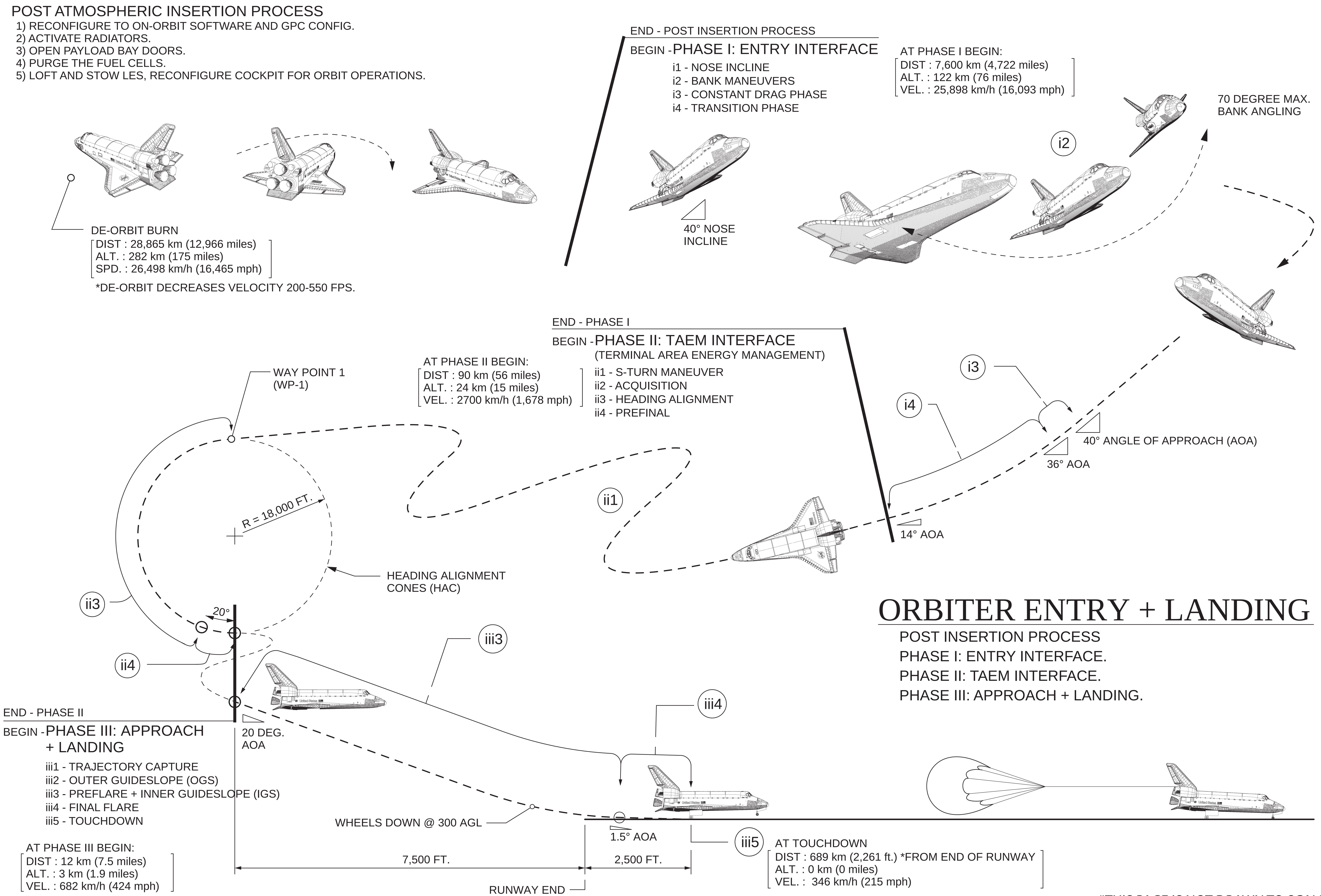
HISTORIC AMERICAN ENGINEERING RECORD
TX-116-J

ORBITER ENTRY + LANDING

POST INSERTION PROCESS
PHASE I: ENTRY INTERFACE.
PHASE II: TAEM INTERFACE.
PHASE III: APPROACH + LANDING.



*THIS PAGE IS NOT DRAWN TO SCALE

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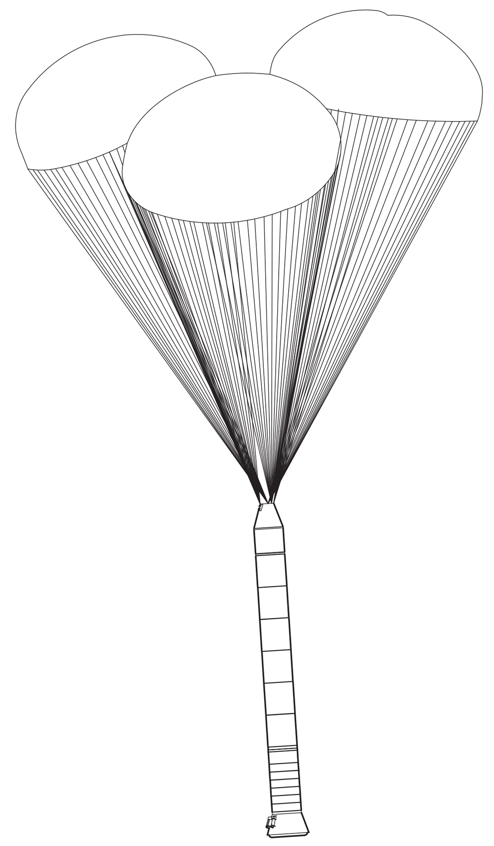
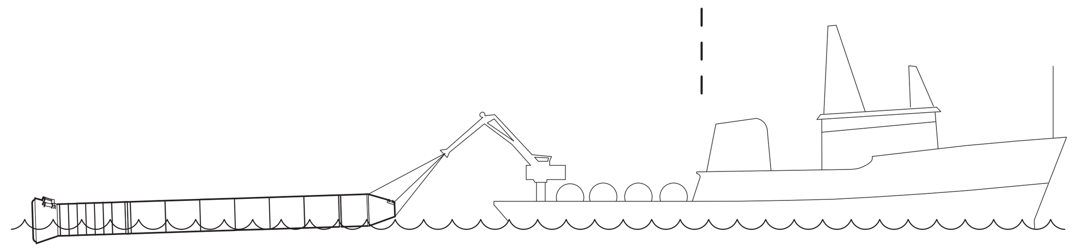
HISTORIC AMERICAN ENGINEERING RECORD
TX-116

SRB RECOVERY & REFURBISHMENT



After the Solid Rocket Booster (SRB) separated from the stack they begin their fall towards the ocean. At a predetermined altitude, parachutes were deployed to lessen the impact of splashdown. Two recovery ships, "Freedom Star" and "Liberty Star", with their crews, recovered and returned the SRBs to KSC for processing.

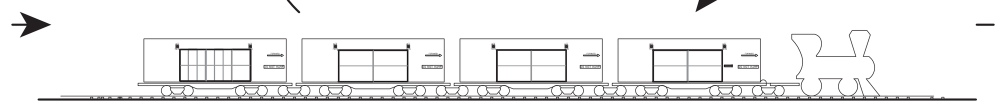


SRB DISASSEMBLY FACILITY

KENNEDY SPACE CENTER (KSC), FL

REFURBISH CENTER

CLEARFIELD & BRIGHAM CITY, UTAH



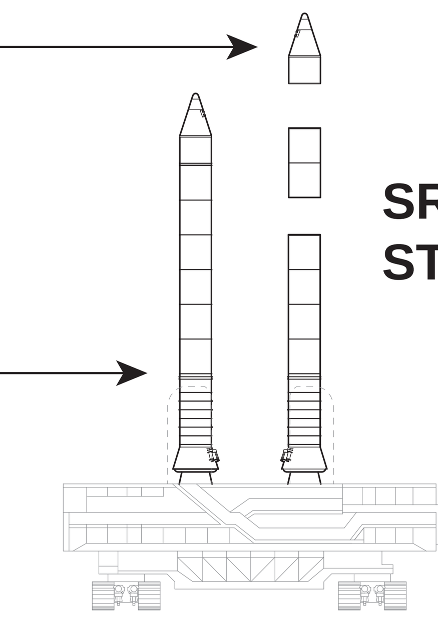
BY RAIL TO UTAH FACILITY

ASSEMBLY REFURBISHMENT FACILITY

KSC, FL

ROTATION PROCESSING AND SURGE FACILITY

KSC, FL

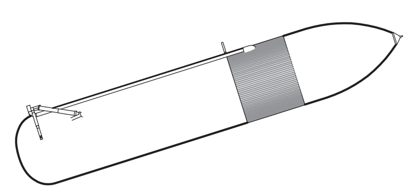


SRB STACKING

VEHICLE ASSEMBLY BUILDING (VAB)

KSC, FL

EXTERNAL TANK DELIVERY



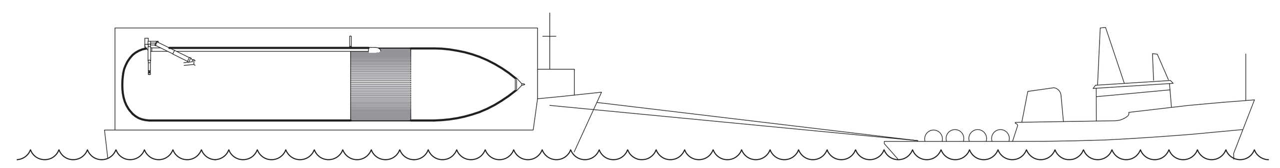
EXTERNAL TANK RE-ENTRY BREAK UP

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

EXTERNAL TANK MANUFACTURING

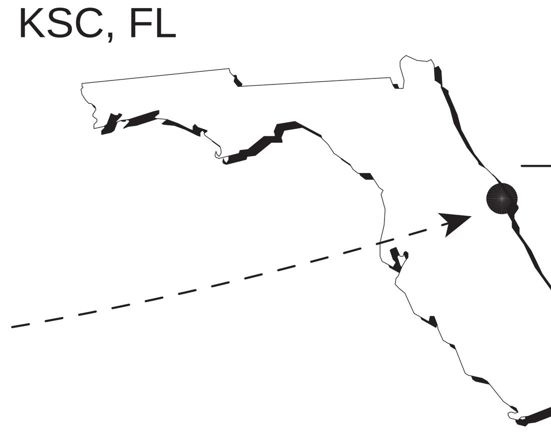
NEW ORLEANS, LA

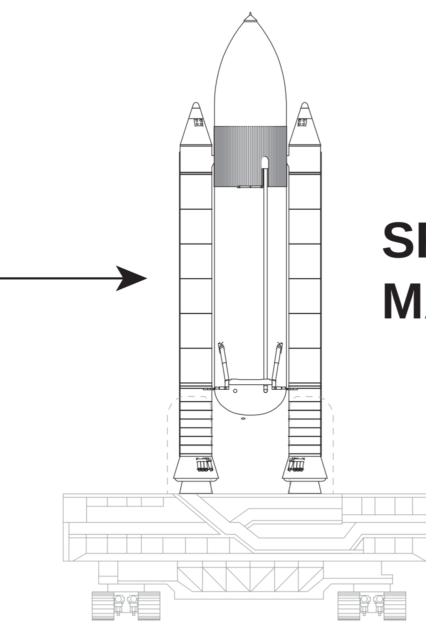
BARGE TRANSPORTATION



VEHICLE ASSEMBLY BUILDING

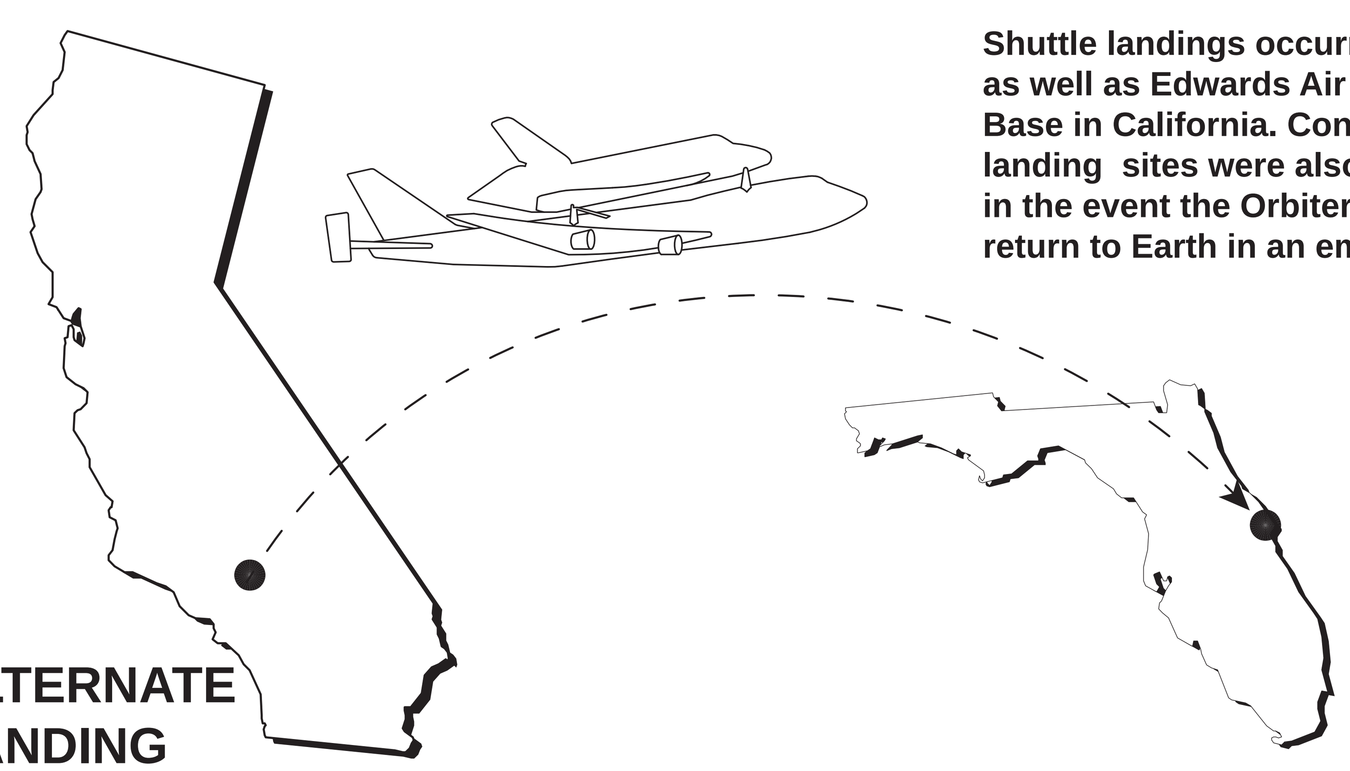
KSC, FL





SRB/ET MATE

SHUTTLE TURNAROUND & TRANSPORT



ALTERNATE LANDING SITE

EDWARDS AIR FORCE BASE, CA

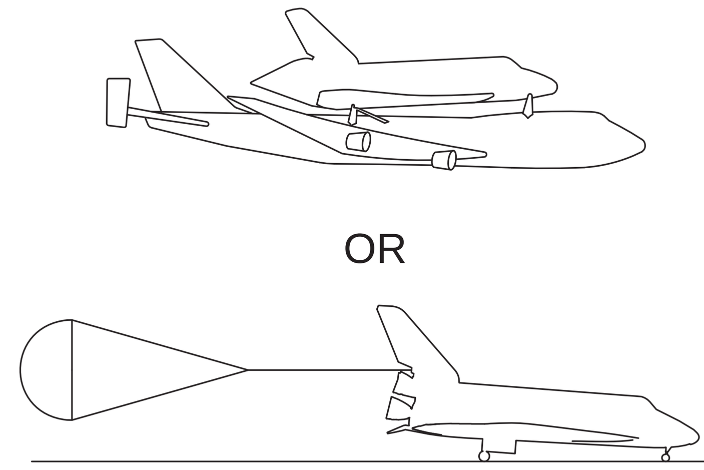
Shuttle landings occurred at KSC as well as Edwards Air Force Base in California. Contingency landing sites were also provided in the event the Orbiter must return to Earth in an emergency.

ORBITER PROCESSING FACILITY (OPF)

KSC, FL

FROM ALT. LANDING SITE

OR

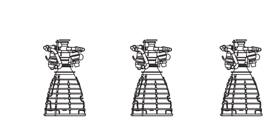


LANDING FROM PREVIOUS MISSION

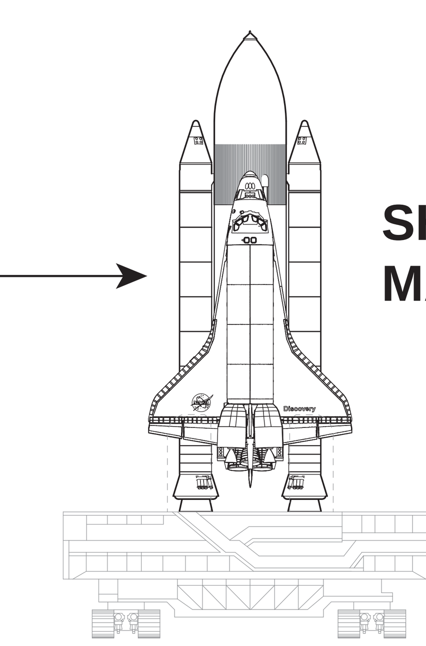
ORBITER PROCESSING FACILITY KSC, FL

SSME PROCESSING FACILITY

KSC, FL



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 for that Orbiter.



SHUTTLE MATE

TO LAUNCH PLATFORM FOR LIFT OFF

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