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Space Shuttle Orbiter And Subsystems

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Considerable progress has been made in designing the Space Shuttle orbiter and defining its subsystems since the development contract was awarded by NASA to Rockwell International in August, 1972. During the past two years, NASA and Rockwell International, Space Division have been engaged in an intensive effort to refine orbiter preliminary design concepts and to translate them into reality. This paper describes the orbiter's configuration and its major subsystems. The general arrangement of the vehicle and its major assemblies are described. Orbiter flight characteristics and mission profiles are summarized. Selected subsystems including structure, thermal protection, propulsion, power, reaction control, orbital maneuvering, environmental control and life support, hydraulics, avionics, and accommodations for crew and payloads are described.
**Figure 1**

**SPACE SHUTTLE VEHICLE**

**SHUTTLE VEHICLE**
- DESIGN LAUNCH WEIGHT (LB) 4369K*
- PAYLOAD (LB) DUE EAST 65K
  DESIGN (104°) 32K

**ORBITER**
- PAYLOAD BAY 15 FT DIA X 60 FT LG
- 3 MAIN ENGINES 470K LB VAC THRUST, EA
- 2 OMS ENGINES 6000 LB VAC THRUST, EA
- 40 RCS ENGINES 900 LB VAC THRUST, EA
- 6 RCS VERNIER ENGINES 25 LB VAC THRUST, EA
- WEIGHT (LB)
  DRY 150K
  DESIGN LANDING 187K

**SOLID ROCKET BOOSTER**
- LENGTH (FT) ~ 149
- DIAMETER (IN.) ~ 146
- WEIGHT (LB, EA)
  LAUNCH 1267K
  RECOVERY 183K
- THRUST (LB, EA)
  LAUNCH 2.65M

**EXTERNAL TANK**
- LENGTH (FT) 154
- DIAMETER (IN.) 330
- WEIGHT (LB)
  LAUNCH 1631K
  USABLE PROP 1553K

*PRELIMINARY VALUES*
The Space Shuttle flight system consists of an orbiter, external tank, and two solid rocket boosters. The orbiter and solid rocket boosters are reusable elements; an external tank is expended on each launch. This configuration, which evolved from Shuttle studies, was defined on the basis of minimizing the cost-per-flight, but with constraints on the costs of design development, test, and evaluation.

The orbiter, as the name implies, is the vehicle that carries the crew of four plus up to six additional scientific or technical personnel and payload into orbit. It can remain in orbit for a nominal seven days (up to 30 days with special payloads), return to earth with personnel and payload, land like an airplane, be refurbished for a subsequent flight in 14 days, and provide for a rescue mission launch within 24 hours after notification (from standby status). The orbiter main rocket engines for launch propulsion use propellants from the large external tank. Small spacecraft-type rocket engines provide maneuvering and control during space flight while the conventional wings and vertical stabilizer provide maneuvering and control during aerodynamic flight and landing.

The crew occupies a two-level cabin at the forward end of the vehicle with the pilots using the flight deck (on the upper level) to control the launch, orbital maneuvering, atmospheric entry, and landing phases of the mission. The crew also performs payload handling. Seating for up to six passengers and habitability provisions are provided on the lower deck. The load factors experienced by the crew or passengers on any of these missions is 3 g's or less. The Shuttle's safe, comfortable transportation allows almost any physically fit person to go into space.

The solid rocket boosters (SRB's) which burn in parallel with the orbiter main propulsion system, are separated from the orbiter/external tank. The SRB's descend on parachutes, land in the ocean about 138 nautical miles from the launch site to be recovered by ships, returned to land, refurbished, and reused.

After SRB separation, the orbiter main propulsion continues to burn until the orbiter is injected into the required ascent trajectory. The external tank then separates and falls ballistically into the little used areas of the Indian Ocean or the South Pacific Ocean, depending on the launch site and mission. The orbital maneuvering system completes insertion of the orbiter into the desired orbit.
FIGURE 2
SPACE SHUTTLE MISSION PROFILE
DUE EAST LAUNCH FROM KSC
(MISSION 1)

- External Tank Separation & Disposal
- Drogue Parachute: h = 25,000 ft
- Main Parachutes: h = 16,000 ft
- Booster Splashdown: t = 5 sec, h = 280 ft
- Vertical Landing: Touchdown Velocity = 185 knots, Max a = 15 deg
- Horizontal Landing: Touchdown Velocity = 185 knots
- Return to Launch Site
- Maintenance & Refurbishment 14-Day Turnaround
- Maintenance & Refurbishment
- Ocean Impact of Tank
- Earth Orbit Operations
- OeOrbit
- Entry
  - \( \gamma_e = 1.2 \text{ deg} \)
  - \( v_e = 25,769 \text{ FPs} \)
  - \( \beta = 30 \text{ deg} \)
  - \( h_e = 400,000 \text{ ft} \)
- Terminal Phase
  - Downrange = 4500 nm
  - \( h = 50,000 \text{ ft} \)
- Ignition & Liftoff
- Tower Clearance
  - Initiate Roll
  - Initiate Pitch
  - t = 15 sec, h = 136,200 ft
- Staging
  - t = 125 sec
  - v = 4715 FPs
  - \( \gamma = 25.2 \text{ deg} \)
- ORBIT INSERTION & CIRCULARIZATION

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Major events of a typical Space Shuttle mission are depicted in the accompanying chart. Approximately five seconds after liftoff, when the vehicle has cleared the tower, the vehicle is rolled to orient the Z axis (vertical) of the vehicle to the launch azimuth (as required for orbital inclination). After roll is completed, the vehicle starts the pitch program. Maximum loads normal to the flight path can be expected about 60 seconds after liftoff for the due-East mission illustrated.

Upon SRB burnout, the SRB's are separated by using small solid rocket motors. They force the empty cases away from the orbiter and external tank (ET), which continue toward orbit. The SRB's fall in an arc and are decelerated by drogue parachutes deployed at 25,000 feet. The main parachutes are deployed at 16,000 feet. The SRB cases and recovery system are recovered from the ocean for refurbishment and reuse.

Shortly before orbital injection, the orbiter main propulsion engines are shut down and the ET is separated from the orbiter. The orbital maneuvering system (OMS) engines provide thrust to inject the orbiter into elliptical orbit while the ET follows a ballistic trajectory into a remote ocean area for disposal.

At apogee, 100 nautical miles altitude, the orbit is modified to the one desired by using the orbital maneuvering subsystem. Orbital operations involving payload deployment, observation, experiments, or other activity are then performed. In a typical mission deploying a space tug and satellite, the orbiter maneuvers to a 150-n.m. altitude and deploys the tug. The orbiter remains at that altitude while the tug proceeds to higher altitude. The tug returns to a 160-n.m. altitude orbit; the orbiter vehicle then rendezvous with the tug and retrieves it.

After orbital operations have been completed, the OMS provides the velocity change necessary to deorbit and enter the atmosphere. The orbiter enters at a flight path angle of approximately one degree with an angle of attack of 30 degrees. A decelerating glide is then performed to reach the desired landing site. The orbiter can reach landing sites as far as 1085 nautical miles on either side of an initial Polar inclination flight path. After the orbiter glides into position, an unpowered landing is made.
**Figure 3**
**Orbiter Vehicle Dimensions**

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Wing</th>
<th>Vertical Stab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>2690 ft²</td>
<td>413.25 ft²</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>2.265</td>
<td>1.675</td>
</tr>
<tr>
<td>Airfoil $Y_o = 199$</td>
<td>0010 MOD</td>
<td>Wedge</td>
</tr>
<tr>
<td>Sweep (Leading Edge) $\theta$</td>
<td>45°</td>
<td>45°</td>
</tr>
<tr>
<td>(Wing Glove) $\theta$</td>
<td>81°</td>
<td></td>
</tr>
<tr>
<td>M.A.C.</td>
<td>474.81 in.</td>
<td>199.81 in.</td>
</tr>
<tr>
<td>Dihedral (Trailing Edge)</td>
<td>3°30'</td>
<td></td>
</tr>
</tbody>
</table>

**Control Surface Area and Max Deflection**

<table>
<thead>
<tr>
<th>Control Surface</th>
<th>Area</th>
<th>Max Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevon (One Side)</td>
<td>210 ft²</td>
<td>-40° to +15°</td>
</tr>
<tr>
<td>Rudder</td>
<td>98.4 ft²</td>
<td>+22.8°</td>
</tr>
<tr>
<td>Speed Brake</td>
<td>98.4 ft²</td>
<td>0° to 87.2°</td>
</tr>
<tr>
<td>Body Flap</td>
<td>135.0 ft²</td>
<td>-11.7° to +22.55°</td>
</tr>
</tbody>
</table>

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The orbiter spacecraft contains the crew and payload for the Space Shuttle system. The orbiter can deliver payloads of up to 65,000 pounds to orbit and return payloads up to 32,000 pounds from orbit; the payload can have lengths of up to 60 feet and diameters of up to 15 feet. The orbiter crew compartment can accommodate up to ten persons.

The orbiter is comparable in size and weight to modern transport aircraft. It has a dry weight of approximately 150,000 pounds, a length of 122 feet, and a wing span of 78 feet. The 60-foot cargo bay extends from 26.3 to 82.8 percent of the reference body length.

The three Space Shuttle main engines (SSME's) are contained in the aft fuselage. Ascent propellant is contained in the external tank (ET), which is jettisoned prior to initial orbit injection. The orbital maneuvering subsystem (OMS) is contained in two external pods above the wing on the aft fuselage. These units provide thrust for changing orbit, rendezvous, and deorbit.

The reaction control subsystem (RCS) is contained in the two OMS pods and in a module in the nose section of the forward fuselage. These units provide for attitude control in space and precision velocity changes for the final phases of rendezvous and docking or orbit modification. In addition, the RCS, in conjunction with the orbiter's aerodynamic control surfaces, provides attitude control during entry.

The orbiter rudder augments control of the integrated Space Shuttle vehicle provided by the gimbaled engines and solid rocket motors during boost, and all aerodynamic surfaces provide control of the orbiter during the latter part of entry, the terminal phase maneuver, and approach and landing. The design touchdown speed of the orbiter is 169 knots.

The orbiter vehicle is trimmed to provide a hypersonic lift-to-drag ratio of approximately 1.3 ($\alpha = 34$ degrees) during entry, and a maximum trimmed lift-to-drag ratio of about 4.6 ($\alpha = 12$ degrees) subsonically.
ORBITER FORWARD FUSELAGE STRUCTURE SUBSYSTEM
(Figure 4 Text)

The forward fuselage structure carries the basic body-bending loads, supports the crew module, and reacts the nose landing gear loads. It provides support for the reaction control subsystem module and the nose landing gear, and provides the landing gear doors. It also provides for attachment of the thermal protection and control subsystems, including the thermal protection and control subsystems, including the thermal window panes.

The forward fuselage structure is composed of 2024 aluminum alloy skin/stringer panels, frames, and bulkheads. The window frames are machined parts attached to the structural panels and frames.
Figure 5
ORBITER MID FUSELAGE STRUCTURE AND PAYLOAD BAY DOOR SUBSYSTEM

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ORBITER MID-FUSELAGE AND PAYLOAD BAY DOORS SUBSYSTEMS  
(Figure 5 Text)

MID-FUSELAGE

The mid-fuselage is a 61-foot section of primary load carrying structure between the forward and aft fuselages. It includes the wing carry-through structure and the payload bay liner. The skins and stringers are machined as integral aluminum panels. The frames are constructed as a combination of aluminum panels with riveted or machined integral stiffeners and a truss structure center section.

A crawlway through the structure is provided for access to every bay. External access doors are provided on both sides of the mid-fuselage.

A payload bay liner serves as a contamination barrier between the payload and the fuselage interior. It also separates the payload from the fuselage purge and vent subsystems.

PAYLOAD BAY DOORS

The upper half of the mid-fuselage consists of structural payload bay doors of aluminum honeycomb skin with frames construction. They are hinged along the side and split at the top center line and vertically at the midpoint. The external aft surface of the rear doors are partially covered with aerodynamic fairings that align with the orbital maneuvering subsystem (OMS) pod on the aft fuselage. All doors are actuated electromechanically.
Figure 6
ORBITER AFT FUSELAGE STRUCTURE SUBSYSTEM

- UPPER THRUST SHELF
- LAUNCH UMBILICAL PLATE (REF)
- LOWER THRUST SHELF

ROUND TUBING
The aft fuselage structure extends aft from the bulkhead. It supports the vertical tail, the main propulsion system, and the orbital maneuvering subsystem-reaction control subsystem pods while incorporating a base heat shield and a body flap which acts as a trim surface during entry. The aft fuselage also provides a major portion of the wing carry-through structure supporting wing spars and provides the main structural interface with the external tank. The launch umbilical panels are located in the aft fuselage sidewalls, and the external tank umbilical panels are located in the floor.

Aft fuselage design features are:

- **Outer shell and floor structure**: Integ rally stiffened aluminum construction with built up aluminum frames
- **Forward bulkhead**: Machined aluminum frame segments and bead-stiffened sheet metal web
- **Thrust structure**: Machined diffusion-bonded titanium truss members, reinforced by boron-epoxy laminations
- **Base heat shield**: Aluminum sandwich panels attached to aluminum sidewalls, both covered with reusable surface insulation (RSI). Separable aluminum sandwich panels with RSI cover main engines and interface with the main engine mounted spherical segments
- **Body flap**: Bonded aluminum honecomb covered by RSI
Figure 7
ORBITER WING STRUCTURE AND VERTICAL TAIL SUBSYSTEMS

- Primarily aluminum
- Sheet metal skins & stringers
- Pratt truss ribs
- Corrugated spar webs
- Aluminum honeycomb elevons

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WING

The wing structure is of conventional aluminum construction.

The spars adjacent to the wheel well are stiffened tension webs which provide sealing. The heavily loaded inboard end of the spar is also webbed. The wing front spar is of conventional aluminum honeycomb construction. The upper and lower covers are riveted skin-stringer assemblies. The covers are spliced to a continuous torque box carry-through structure in the mid fuselage.

Elevons are split into two segments to avoid hinge binding and interaction with the wing. Three hinges support each segment. The outboard hinge of the inboard segment and the inboard hinge of the outboard are designed to "float", which further reduces interaction. The elevon torque cell has aluminum honeycomb covers with a full depth honeycomb trailing edge wedge. Spars and the ribs at hinge and actuator supports are conventionally stiffened diagonal tension webs.

The main landing gear doors are provided as part of the wing structure and are of corrugated aluminum sandwich construction.

VERTICAL TAIL

The vertical tail consists of two structural segments, the vertical fin and the rudder/speed brake assembly. The vertical fin is of conventional aluminum construction; it consists of a two-spar, multirib, stiffened skin box assembly. The vertical fin is attached to the aft fuselage at the front and rear spars.

The rudder/speed brake assembly consists of an upper and a lower section, each consisting of two segments. The structure is of conventional aluminum construction; it consists of spars, multiribs, and stiffened skin.
The crew module has a habitable environment for crew and passengers. The module is pressurized to a shirtsleeve environment. Crew vision is provided by windows. The crew module has a volume of 2571 cubic feet divided into three levels or sections. Support structure is provided for the installation of the crew equipment and accommodations, food preparation and hygiene facilities, avionics equipment, the environmental control and life support subsystem (ECLSS), and other subsystems, as required. The airlock is for extravehicular and intravehicular activities (EVA and IVA).

The crew module is machined from 2219 aluminum alloy plate with integral stiffening stringers and internal framing. The assembly is welded to create a pressure tight vessel. The basic shape is conical with flat forward and aft bulkheads. The canopy intersects the cone at the upper floor level. The module has a side hatch for normal ingress and egress, a hatch into the airlock from the mid-deck, and a hatch from the airlock into the payload bay for EVA and IVA. The entire module is supported by four attach points on the forward fuselage structure.
ORBITER CREW STATION AND EQUIPMENT SUBSYSTEM
(Figure 9 Text)

The crew station and equipment subsystem consists of the furnishings and equipment for the crew and passengers in the orbiter vehicle cabin.

The cabin is configured to accommodate a crew of four for a seven-day mission duration. Additional stowage capacity for a total 42 man-day duration without system changes is provided. Including the airlock, the cabin has three habitable areas, an environmental control and life support subsystem (ECLSS) equipment bay, and three avionics bays. The flight section is the uppermost compartment of the cabin. It contains six crew work stations that are used by the four crewmen during various mission phases. Directly below the flight section is the mid-deck, which provides crew accommodations, avionics bays, and food, water, and waste management accommodations. Stowage areas with a total stowage volume of 140 cubic feet are provided in the mid-deck, and an additional 10 cubic feet are provided in the flight deck. In the open areas of the midsection are the eating, sleeping, exercising, and relaxing accommodations for the crewmen. Removable seating for up to six passengers can be provided in this open area. The equipment bay is below the midsection and accommodates the major portion of the ECLSS atmospheric revitalization and waste management subsystems.

Crew accommodations include items such as crew mobility aids and devices and vehicle seats and restraints for crew and passengers. Crew equipment items include loose equipment such as restraint devices, emergency egress devices, sleep restraint and attachments, stowage provisions, curtains, shades, crew life support and communications umbilicals, emergency equipment, visual aids, extravehicular activity (EVA) support equipment, and flight data files.
Figure 10
ORBITER THERMAL PROTECTION SUBSYSTEM

<table>
<thead>
<tr>
<th>140B CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TPS</strong></td>
</tr>
<tr>
<td>LRS1</td>
</tr>
<tr>
<td>HRSI</td>
</tr>
<tr>
<td>RCC</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>

*INCLUDES 550-LB BASE HEAT SHIELD AND HINGE LINE INSULATION

LESS-NOSE SECTION
- HRSI INSULATION
- SUPPORT FITTING
- RCC & HRSI SEPARATION PLANE
- HRSI LANDING GEAR DOOR
- ALUMINUM BULKHEAD
- GAP FILLER
- INTERNAL INSULATION
- CHIN PANEL & LANDING GEAR DOOR ATTACH

LESS-WING SECTION
- FORWARD SPAR PLANE ACCESS PANEL (HRSI)
- RCC & HRSI SEPARATION PLANE
- HRSI REINFORCED CARBON
- CARBON (RCC)
- THERMAL BARRIER
- GAP FILLER
- CHIN PANEL & LANDING GEAR DOOR ATTACH

HRSI & LRSI
- HRSI COATING
- SILICA TILE
- AERO ML
- STRUC ML
- 0.050 - 0.015
- 0.050 + 0.015
- 0.010 RTV BOND THERMAL BARRIER
- 0.015 RTV BOND THERMAL BARRIER
- 0.090 STRAIN ISOL PAD OVER FLUSH FASTENERS
- 0.160 STRAIN ISOL PAD OVER PROTRUDING HEAD FASTENERS
- WHERE t ≥ 0.75
- WHERE t < 0.75

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ORBITER THERMAL PROTECTION SUBSYSTEM
(Figure 10 Text)

The thermal protection subsystem (TPS) consists of materials applied externally to the primary structural shell of the orbiter vehicle and maintains the airframe outer skin within acceptable temperature limits, e.g., 350°F for aluminum structure. Neither the internal insulation and heaters nor any of the purging facilities are considered part of the subsystem. The TPS supports mission requirements by having the following required subassemblies maintain acceptable primary structure temperatures:

1. Low temperature reusable surface insulation (LRSI) and structural attachment components, including joints and interface to special function singularities, when exposed to temperatures below 1200°F under design heating conditions.

2. High temperature reusable surface insulation (HRSI) and structural attachment components, including joints and interface to special function singularities, when exposed to temperatures between 1200°F and 2300°F under design heating conditions.

3. Reinforce carbon-carbon (RCC) on areas such as leading edge, nose cap, chine, and structural attachments along with internal insulation, when exposed to temperatures greater than 2300°F under design heating conditions.

4. Thermal window panes.

5. Thermal seals as required to protect against aerodynamic heating.

The TPS is a passive system requiring no inputs from other systems to operate successfully. It has been designed for ease of maintenance and for flexibility of ground and flight operations while satisfying its primary function of maintaining acceptable airframe outer skin temperatures.
FIGURE 11
ORBITER THERMAL CONTROL SUBSYSTEM

TYPICAL INSULATION INSTALLATION
(ALL INSULATION VENTED)

MLI (20 LAYERS)
MLI RETENTION
TG 15000
STRUCTURE

TYPICAL SECTION

CABIN
(PRESSURIZED)

FORWARD OMS/RCS PROPELLANT STORAGE

FORWARD BODY AREA

ALUMINUM HONEYCOMB STRUCTURE
BASE HEAT SHIELD

MLI (20 LAYERS)

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ORBITE TERMINAL CONTROL SUBSYSTEM
(Figure 11 Text)

The thermal control subsystem (TCS) consists of the equipment required to maintain thermal control of all compartments inboard of the spacecraft inner mold line. This control applies during all mission phases, including boost, earth orbit, orbital activities, entry, atmospheric flight, postlanding, and quiescent periods. Specifically excluded from thermal control are those subsystems which are inherently self-controlled.

The TCS can be divided into four basic functional categories:

1. Thermal attenuation, insulation and isolation
2. Absorption, heat sinks
3. Thermal augmentation, heaters
4. Thermal transfer, passive compartment-to-compartment thermal transfer devices

Thermal attenuation in general consists of insulation affixed to the inner mold line of the spacecraft. This insulation further attenuates the thermal transfer through the thermal protection subsystem and airframe to levels consistent with equipment and crew requirements.

Heat sinks are provided in strategic locations where transient thermal levels are incompatible with steady-state requirements.

Heaters are provided in compartments where other means of thermal control are unable to maintain minimum temperature requirements.

Passive thermal transfer devices are employed to regulate the temperatures in contiguous compartments in order to minimize overall on-board energy consumption.
ORBITER ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM
(Figure 12 Text)

The atmospheric revitalization subsystem (ARS) is designed to provide the flight crew and passengers with a conditioned environment that is both life supporting and within crew comfort limitations. The ARS is operated continuously during all mission phases. During this operating period, the subsystem provides the following major functions for the crew: (1) atmospheric pressure control; (2) humidity, \( \text{CO}_2 \), odor, and temperature control; and (3) avionics equipment temperature control. In addition, the ARS provides cooling to two crewmen liquid-cooling garments during pre-EVA and post-EVA.

The food, water, and waste management subsystems are designed to support hot and cold food preparation; provide sterilization, storage and dispensing of hot and cold potable water; and collect and store condensates, disinfected urine, and feces for return to earth. The fire detection and suppression subsystem is designed to detect smoke or fire in the avionics bays and smoke in the crew compartment and to extinguish fires in the avionics bays. Portable fire extinguishers are provided for the crew compartment.

The active thermal control subsystem (ATCS) provides thermal control for several subsystems during mission phases. The ATCS consists of following major assemblies: Freon heat transport loop, radiator system, and ammonia evaporative system.

The airlock support subsystem is designed to provide airlock pressurization and EVA/IVA support in five functions: airlock pressurization and depressurization, EVA/IVA equipment recharging, waste water transfer, prebreathing, and emergency breathing. These operate on demand during all mission phases.
**FIGURE 13**

**ORBITER MECHANICAL SUBSYSTEMS**

- **DRAG CHUTE AND MORTAR**
- **BODY FLAP ELECTROMECHANICAL ACTUATOR SYSTEM**
- **ELEVON SERVO ACTUATORS**
- **MANIPULATOR (OPTIONAL)**
- **PAYLOAD RETENTION KIT**
- **CARGO DOOR ACTUATION AND LATCHING**
- **MANIPULATOR**
- **CREW TRANSFER TUNNEL KIT HATCHES (LEFT SIDE AND UPPER)**
- **STAR TRACKER DOOR**
- **AEROFIGHT CONTROL**
  - Rudder Pedals
  - Speed Brake
- **LANDING/DECELERATION**
  - Landing Gear Deploy
  - Brakes
  - Nose Gear Steering
  - Drag Chute Deploy
- **MAIN GEAR**
  - Brakes
  - Wheels & Tires
  - Antiskid
- **MANIPULATOR DEPLOY & RETENTION**
- **DOCKING MODULE KIT MECHANISMS**
- **RENDZEVOUS SENSOR DEPLOYMENT**
- **DEPLOYABLE AIR DATA SENSORS (BOTH SIDES)**
- **SEPARATION**
  - Structure Disconnect
  - Systems Disconnect
  - Separation System Closeout Door
- **Nose Gear**
  - Wheels and Tires
  - Steering
  - Dampers
- **SUPPORT TO EXTERNAL TANK AND SRB SEPARATION**
- **RCS DOOR**
  - Deploy
  - Latching

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The orbiter mechanical subsystems, together with their electrical and hydraulic actuators, operate the aerodynamic control surfaces, landing/deceleration system, payload bay doors, and payload accommodation and payload handling subsystems. Orbiter/external tank propellants disconnects and a variety of other mechanical and pyrotechnic devices are also part of the mechanical subsystems.

Aerodynamic control surface operation is accomplished by single-balanced, dual-switching servo-actuators for the control of elevons, rudder, and speed brake. A 3000-psi hydraulic system supplies the power for these control functions.

The landing/deceleration system and its mechanical components are designed to facilitate safe landing to velocities up to 250 mph (217 knots) for which 40,000-pound rated tires and 750 hp/pound brakes (280 x 10^6 foot-pounds) are under development.

The cargo bay doors, RCS doors, and separation system closeout doors are operated by actuators that must provide predictable performance after exposure to the severe environment during ascent and/or entry.

The payload accommodation subsystem includes retention latches that are remotely controlled to hold down or release the payload or cargo items. Their design is such that they cannot transmit orbiter stresses, such as bending, to the payload.

The payload handling subsystem consists primarily of remotely controlled manipulator arms that can move the payloads out of and/or into the cargo bay while the orbiter is in orbit. Additional information on the manipulators is presented in the payload accommodation section.

The orbiter/external tank propellants disconnects are designed to accommodate approximately 484 pounds per second flow of liquid hydrogen (49,400 gpm), and approximately 2900 pounds per second flow of liquid oxygen (18,400 gpm). Both are equipped with positive acting poppet valve devices to eliminate accidental spillage of residue propellants during disconnect.
Figure 14
ORBITER LANDING AND DECELERATION SUBSYSTEM

DECELERATION PARACHUTE
MAIN PARACHUTE: 44 FT DIA RIBBON
PILOT PARACHUTE: 7.2 FT DIA RING SLOT

NOSE LANDING GEAR
TIRE SIZE: 32 X 8.8
TIRE TYPE: VII
ROLLING RADIUS: 13.3 IN.
FLAT RADIUS: 10.9 IN.
STROKE: 22 IN.

MAIN LANDING GEAR
TIRE SIZE 44.5 X 16-21
TIRE TYPE: NEW DESIGN
ROLLING RADIUS: 18.4 IN.
FLAT RADIUS: 13.6 IN.
STROKE: 16 IN.
The landing and deceleration subsystem (LDS) consists of the components and controls required functionally for: (1) a stable rolling platform for ground maneuvering and all landing operations, (2) shock attenuation of landing impact, (3) deceleration/directional control during landing rollout, and (4) retraction/extension of the nose and main landing gear.

The LDS components required to perform the basic landing gear functions are categorized as follows:

1. Retraction/extension: actuation, lock, and release mechanisms; doors and door linkages, and controls and displays
2. Deceleration/directional control: main wheel brakes, skid control system, nose wheel steering system, deceleration parachutes and deployment mechanism, nose and main gear shock struts, wheels, tires, drag braces, and attachment fittings.

For orbital missions, the landing gear is retracted, locked, and checked out before launch. Throughout the mission, until reentry is completed and preparations to land are initiated, the LDS remains essentially dormant (actuators nonpressurized). Crew selection of landing gear "down" removes the hydraulic isolation and initiates gear extension. After the runway is acquired, drag parachute deployment and brake application by crew provide deceleration of the orbiter, with nose wheel steering supplementing the directional control provided by aerodynamic forces on the rudder. Before landing rollout is completed, the deceleration parachute is jettisoned by crew control.

The landing gear is configured in a conventional tricycle gear arrangement. Both the nose and wing-mounted main gears are equipped with dual wheels and both retract forward, thereby maintaining free-fall extension capabilities. Each of the four main wheels is equipped with a carbon-lined beryllium brake and a fully modulated skid control system. Incorporated in the nose gear design is a combined shimmy damping/steering system. Brakes and nose wheel steering are controlled electrically through the brake and rudder pedals, respectively.
FIGURE 15
ORBITER HYDRAULIC SUBSYSTEM

- Rudder/speed brake rotary actuators
- Rudder/speed brake hydraulic motor/servo valves
- TVC three-channel servo actuators
- Elevon four-channel servo actuators
- Main landing gear brake/antiskid valves
- Main landing gear and nose landing gear valves
- Main power—pumps, reservoirs, H2O boiler, and miscellaneous valves
- Main landing gear strut actuator
- Main landing gear uplock actuator
- Nose landing gear uplock actuator
- Nose landing gear strut actuator
- Nose wheel steering actuators

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The hydraulic subsystem consists of the components required for generation, control, distribution, monitoring, and usage of hydraulic power. Hydraulic power is used to operate the aerosurface controls (elevons and rudder/speed brake) and the Space Shuttle main engine (SSME) control valves, to gimbal the SSME, to provide on-orbit thermal control, to retract, extend, and lock up the landing gear, to operate main wheel brakes, and to provide nose wheel steering. The hydraulic subsystem supplies power for these functions during orbital missions. Hydraulic power is generated by nominal 3000-psi variable delivery pumps. The pumps are driven by auxiliary power units (APU's). The hydraulic subsystem comprises four independent hydraulic systems, each with its separate pumps, reservoir, oil cooler, controls, displays, and distribution system. The four independent hydraulic systems connect to the various actuators in a manner that provides the required degree of redundancy for flight safety in event of a malfunction of up to two systems.

A typical orbital mission consists of prelaunch operations, boost to orbit, on-orbit operations, deorbit/entry, and landing. The prelaunch phase utilizes hydraulic power from a ground source until APU's start, shortly before lift off. The boost phase provides hydraulic power for SSME gimbaling, SSME controls, and rudder operation. After orbit insertion, the APU's are shut down. Circulation of the hydraulic fluid in the four systems for temperature control is provided in the on-orbit portion of the mission. This is accomplished by a low-pressure/flow electrically driven pump in each system. During the deorbit/entry phase, hydraulic power is generated by the APU-driven variable volume hydraulic pump for aerosurface operation. Hydraulic power is shut off to the SSME gimbaling and SSME controls. The landing gear free falls to the lowered position before touchdown. After touchdown, deceleration provisions include the main wheel braking system, with steering accomplished by the braking system and/or nose wheel steering.
**Figure 16**
ORBITER MAIN PROPULSION SUBSYSTEM

- **LO₂ FEED LINE**
- **LO₂ PRESSURIZATION**
- **LO₂ VENT**
- **MPS LO₂ TANK**
- **EXTERNAL TANK**
- **LH₂ FEED LINE**
- **LH₂ PRESSURIZATION**
- **MPS LH₂ TANK**
- **LH₂ VENT LINE**
- **LO₂ FILL/DRAIN DISCONNECT**
- **LH₂ FILL/DRAIN DISCONNECT**
- **ORBITER/EXTERNAL TANK LO₂ DISCONNECT**
- **ORBITER/EXTERNAL TANK LH₂ DISCONNECT**

Legend:
- 3 MAIN ENGINES
- 470k lb vac thrust ea

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Space Division Rockwell International
The orbiter main propulsion subsystem (MPS) provides the major ascent velocity increment by operating in parallel with the solid rocket boosters (SRB's) during the initial ascent phase and continuing to burn after SRB separation.

Each of the three GFE rocket engines operates at a mixture ratio ($\text{LO}_2/\text{LH}_2$) of 6:1 and a chamber pressure of 3000 psia to produce a nominal sea level thrust of 375,000 pounds and a vacuum thrust of 470,000 pounds with a fixed nozzle area ratio of 77.5:1. The engines are throttleable over a thrust range of 50 to 109 percent of the design thrust level. This allows limiting orbiter acceleration to 3 g's and provides a higher emergency thrust level for use during aborted flights. The engines are gimbaled to deflect $\pm 11$ degrees for pitch, $\pm 9$ degrees for yaw and roll control during the orbiter boost phase.

The orbiter contains five fluid lines, which interface with the external tank (ET) through self-sealing disconnects. All disconnects are located on the bottom of the orbiter engine compartment. The three fuel disconnects are mounted on a carrier plate on the left side, and the two oxidizer disconnects are mounted on the right side.

Subsystem design features include installation of most operating components within the orbiter to reduce expendable component costs. The components in the main propulsion subsystem are designed for maximum reusability.
**Figure 17**

**ORBITAL MANEUVERING SUBSYSTEM**

**PAYLOAD BAY KITS**  
(ΔV = 1500 FPS)

**OMS ENGINE CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust</td>
<td>6,000 LB VAC</td>
</tr>
<tr>
<td>Isp</td>
<td>313 SEC</td>
</tr>
<tr>
<td>Pₚ</td>
<td>125 PSIA</td>
</tr>
<tr>
<td>Area Ratio</td>
<td>72:1</td>
</tr>
<tr>
<td>Mixture Ratio</td>
<td>1.65:1</td>
</tr>
</tbody>
</table>

**OMS TANKAGE CAPACITY**  
1,000 FT/SEC ΔV

- Fuel Weight - MMH: 9,292 LB
- Oxidizer Weight - N₂O₄: 15,302 LB

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The orbital maneuvering subsystem (OMS) provides the propulsive thrust to perform orbit insertion, orbit circularization, orbit transfer, rendezvous, and deorbit. The OMS tankage is sized to provide a delta velocity ($\Delta V$) of 1000 feet per second with a vehicle payload of 65,000 pounds. This propellant is housed in two auxiliary propulsion subsystem aft pods, one located on each side of the aft fuselage. Each pod contains OMS components which include a high-pressure helium storage bottle, tank pressurization regulators and controls, a fuel tank, an oxidizer tank, a pressure-fed regeneratively cooled rocket engine and the aft reaction control subsystem (RCS) components. The OMS and RCS propellant lines are interconnected (1) to provide propellant from the OMS tanks to be supplied to the RCS thrusters on orbit and (2) to provide crossfeed between the left and right RCS systems.

Provisions are also included for up to three sets of auxiliary tankage, each providing an additional $\Delta V$ capability of 500 feet per second to achieve an overall $\Delta V$ capability of 2500 feet per second. The auxiliary tankage, located in the cargo bay, utilizes the same type propellant tanks, helium bottles, and pressurization system components as the pods.

Parameters and design features of the basic OMS are:

| Number of engines | 2 |
| Nominal vacuum thrust | 6000 lb/engine |
| Nominal chamber pressure | 125 psia |
| Nominal specific impulse | 313.2 seconds |
| Fuel | Monomethylhydrazine (MMH) |
| Oxidizer | Nitrogen tetroxide ($N_2O_4$) |
| Nominal mixture ratio | 1.65:1 |
| Gimbal capability | $\pm 8$ degree yaw; $\pm 4$ degree pitch |
**Figure 18**

**ORBITER REACTION CONTROL SUBSYSTEM**

- 1 FWD RCS MODULE, 2 AFT RCS SUBSYSTEMS IN PODS
- 40 MAIN THRUSTERS (16 FWD, 12 PER AFT RCS)
  - THRUST LEVEL = 900 LB
  - ISP = 289 SEC
  - MIB = 15.8 Lbf SEC
- 6 VERNIER THRUSTERS (FWD & AFT RCS)
  - THRUST LEVEL = 25 LB
  - ISP = 228 SEC
  - MIB = 0.75 Lbf SEC
- BIPROPELLANTS: $\text{N}_2\text{O}_4$ 3708 LB
  - MMH 2317 LB

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The orbiter reaction control subsystem (RCS) provides vehicle attitude control and translational capability for small velocity increments from just before external tank separation through all on-orbit maneuvers and during entry. The RCS is sized to furnish translational delta velocity (ΔV) of 190 feet per second for +Z axis rendezvous and the required rotational control accelerations for Mission 3B in fail-operational/fail-safe modes.

The RCS is grouped in three modules—one in the orbiter nose and one in each of the auxiliary propulsion subsystem (APS) aft pods, which also contain the orbital maneuvering subsystem (OMS). To minimize propellant requirements for extended missions and payload contamination, six vernier thrusters are located in the forward module. These vernier thrusters are used for limit cycle deadband control on all missions. The RCS employs fixed thrust, pressure-fed thrusters, and hypergolic propellants.

The RCS parameters and design features are:

<table>
<thead>
<tr>
<th>Primary Thruster</th>
<th>Vernier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>40 per vehicle</td>
</tr>
<tr>
<td>Thrust level</td>
<td>900 lb</td>
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<tr>
<td>Vacuum specific impulse</td>
<td>289 sec</td>
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<tr>
<td>Expansion ratio</td>
<td>20:1</td>
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<td>Minimal chamber pressure</td>
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**Table:**

<table>
<thead>
<tr>
<th>Primary Thruster Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>Thrust level</td>
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<tr>
<td>Nominal chamber pressure</td>
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<tr>
<td>Fuel</td>
<td>MMH</td>
</tr>
<tr>
<td>Oxidizer</td>
<td>N₂O₄</td>
</tr>
<tr>
<td>Nominal mixture ratio</td>
<td>1.60:1</td>
</tr>
</tbody>
</table>
FIGURE 19
ORBITER ELECTRICAL POWER SUBSYSTEM

FUEL CELL POWER PLANT (FCP) (3)

NI-CD BATTERIES (3)

EQUIPMENT ACCESS

UMBILICAL SERVICE

HYDROGEN DEWARS (2)

OXYGEN DEWARS (2)

CRAWLWAY

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ORBITER ELECTRICAL POWER SUBSYSTEM
(Figure 19 Text)

The electrical power subsystem (EPS) consists of the equipment and reactants required to supply electrical power to the electrical buses. Electrical power distribution and conditioning equipment beyond the power generation equipment terminals is not considered a part of this subsystem. Power is supplied to fulfill all orbiter requirements when it is not connected to GSE power.

The EPS can be functionally divided into two major subsystems:

1. Power generation subsystem: Fuel cell power plants (FCP), orbiter batteries, and development flight instrumentation (DFI) batteries.

2. Power reactant storage and distribution (PRSD) subsystem.

The EPS supplies power during the peak, average, and minimum load periods of the mission. It supplies oxygen to the environmental control and life support subsystem (ECLSS). The peak power and average power requirements are supplied by the three FCP's with each FCP connected to one of the three main dc buses. The minimum power requirements are supplied by two of the three FCP's with one FCP connected to two buses. The third FCP is shut down and disconnected from the bus. The shutdown FCP can be restarted and reconnected to the bus within 15 minutes to support higher loads. The orbiter batteries provide capability for emergency reset of the electrical power generation and distribution equipment from a power interruption state.
Figure 20
ORBITER AUXILIARY POWER UNIT SUBSYSTEM

HYDRAULIC PUMP
GEAR BOX
TURBINE (WITH BURST PROTECTION)
LUBE PUMP

(TYPICAL APU)

APU EXHAUST DUCTS (4)
HYDRAULIC PUMPS
FUEL SUPPLY MODULE

ACCESS DOOR

APU FUEL TANKS (2 EACH SIDE)
FILL, DRAIN, VENT, & PURGE RECEPTACLE
INSULATION

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The orbiter auxiliary power unit (APU) subsystem consists of four independent APU subsystems. The APU subsystem provides mechanical shaft power for hydraulic pumps during prelaunch, ascent, main propulsion system (MPS) purge, entry, and landing. Each APU drives a hydraulic pump that supplies hydraulic power for each of four hydraulic systems.

The hydraulic pumps provide power to actuate the aerodynamic surfaces (elevons and rudder/speed brakes, and body flap), main engine thrust vector controls, main engine controls, landing gear, brakes, and steering.

Four independent APU's are used to achieve minimum weight and high reliability. Any three systems will provide full operational capability. Two systems are required for safe operation.
Figure 21
ORBITER AVIONICS SUBSYSTEM

- Primary Flight
- Orbital Operations
- Development Flight Instrumentation Canisters
- Forward Cabin Area Navigation Base
- Flight Deck Consoles
- Forward Avionics Bays
- Aft Avionics Bays
- Communications & Tracking, Computers, EPD&C, GN&C, & Operational Instrumentation
- Rendezvous Radar Antenna Assembly (RH Only)
- Shock Mounted Shelves
- Coldplate-Cooled Avionics Equipment
The avionics subsystem provides guidance, navigation, and control; communications, computations; displays and controls; instrumentation; and electrical power distribution and control for the orbiter. The cockpit is the center of both in-flight and ground activities except during hazardous servicing.

The avionics equipment is arranged to facilitate checkout and for easy access and replacement with minimal disturbance to other subsystems. Almost all electrical and electronic equipment is installed in three areas of the orbiter: the crew compartment, the forward avionics equipment bays, and the aft avionics equipment bays. Redundant subsystems are installed in separate bays whenever possible. Cooling by both forced air and coldplate is available in the forward avionics equipment bays.

The orbiter avionics provide subsystems management, determination of vehicle status and operational readiness, and required sequencing and control functions to the external tank and the solid rocket booster during mated ascent. Major ground links during checkout are hard-line digital command data to the vehicle and PCM measurement data from the vehicle via hard-line and RF transmissions. Automatic vehicle flight control is provided for all mission phases except docking; manual control options are available at all times. A fail-operational/fail-safe capability is provided by a combination of hardware and software redundancy. Orbiter avionics interface with payloads is provided through the mission specialist station by means of hard-wired controls and displays when attached and RF links when detached.

Automatic fault detection and correction are provided for flight-critical functional paths. The avionics subsystem consists of the following subsystems:

- Guidance, navigation, and control
- Communications and tracking
- Displays and controls
- Computers
- Instrumentation
- Data processing and software
- Electrical power distribution and control
- Performance monitoring
Figure 22
ORBITER COMMUNICATIONS AND TRACKING

EXTRAVEHICULAR ACTIVITY
- Telemetry, Voice (Hardwire or RF)
- Attached Payload Voice, Commands, Payload Data, Wide-Band Data
- TACAN Tracking Data
- MSBLS

NASA DETACHED PAYLOAD
- S-Band Data, Commands, Voice
- Sensor Tracking Data
- Uplink Voice, Commands
- Downlink Voice, Wide-Band Data, Payload Data
- One Way Doppler

DOD DETACHED PAYLOAD
- S-Band Data, Commands
- Sensor Tracking Data
- Uplink Voice, Commands
- Downlink Voice, Data
- One Way Doppler

Payload

ATC
STDN (DIRECT)
AFSCF (SGLS)
STDN (TDRS)

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ORBITER COMMUNICATIONS AND TRACKING
(Figure 22 Text)

The communications and tracking (C&T) subsystem provides RF communications (voice, commands, and data) and tracking links for orbital and rendezvous modes, navigational aids for atmospheric flight, audio intercommunications, and television.

Provisions are included for voice and data encryption and decryption government-furnished equipment (GFE). The C&T subsystem provides the RF interface between the orbiter and (1) other space vehicles, (2) extravehicular astronauts, (3) prelaunch checkout facilities, (4) navigational aids, (5) the Space Tracking and Data Network (STDN), which includes the Tracking and Data Relay Satellite (TDRS), (6) the USAF Space Ground Link Subsystem (SGLS), and (7) Air Traffic Control (ATC) facilities.

The hardware consists of (1) STDN/TDRS compatible transponders for tracking, telemetry, commands and voice (TTVC), television transmission and payload voice and data relay to ground, (2) SGLS-compatible S-band equipment for satellite control facility (SCF) TTVC, (3) tracking aids and communication equipment for aerodynamic flight and automatic landing throughout rollout, (4) antennas, switched automatically, (5) audio processing and distribution equipment, and (6) color and black and white payload observation TV cameras.

The STDN/TDRS direct telemetry link processes and delivers 128 kbps of telemetry including up to 25 kbps of interleaved payload data and two duplex voice channels.

The Air Force telemetry link processes and delivers 128 kbps and two duplex voice channels of data to the ground via the SGLS. TV, DFI, 256 kbps payload encrypted data, and main engine data, during ascent, is provided to the ground by a separate S-band wideband FM link.
Figure 23
PAYLOAD ACCOMMODATIONS SUMMARY

- **PAYLOAD MANIPULATOR STATION**
- **FREE-FLYING PAYLOAD**
- **PAYLOAD RETENTION LATCHES**
- **PAYLOAD RETENTION PROVISIONS**
- **TRANSFER TUNNEL**
- **DOCKING MODULE**

**SUPPORTING SUBSYSTEMS**
- GUIDANCE & NAVIGATION
- COMMUNICATIONS & TRACKING
- DISPLAYS & CONTROL
- DATA PROCESSING
- UTILITIES: POWER/FLUID/GAS
- ENVIRONMENTAL
- PAYLOAD ATTACHMENTS
- DOCKING MODULE

North American Aerospace Group
Rockwell International
PAYLOAD ACCOMMODATIONS SUMMARY  
(Figure 23 Text)

The orbiter can accommodate a variety of payloads. The orbiter payload accommodations, previously described under orbiter subsystems, include structural support, environmental protection, manipulator arms, controls and displays, and manned access. Other payload-support provisions include guidance and navigation; communications and tracking; data processing; pointing and stabilization, electrical power, fluids, and gases; and auxiliary propulsion. There are three stations in the orbiter for the operation, control, handling, and displays associated with the payload.

Structural supports for the payloads have retention latches that can be remotely controlled to release or hold down the payloads. They will minimize transfer of orbiter stresses, such as bending, into payloads. The payload bay doors protect the payloads from aerodynamic and thermodynamic loads during launch and entry. The payload bay is not pressurized. An access port connects the crew cabin and the payload bay. A docking module kit can be attached at this port for use on missions in which the orbiter must dock with other spacecraft. A transfer tunnel will permit the crew and passengers to move between the cabin and the pressurized payloads in a shirt-sleeve atmosphere.

The remotely controlled manipulator arms will move payloads out of or into the payload bay. One arm is installed in the basic vehicle; provisions are made for adding a second arm should orbital operations demand it. The manipulator arms, which are remotely controlled by an operator in the crew cabin, will be used in deploying or retrieving payloads and in docking the orbiter. The operator can manually override the computer programmed control operations.

The orbiter supplies both hardwire and RF links to the payload for monitoring its condition, controlling it, and checking it out. The orbiter RF system can also patch in the ground communication system to the payload. Provisions to meet payload requirements for electrical power, fluids, and gases can be installed in the payload bay. The average electrical power profile available to the payload is 1.0 kw, with peak power of 1.5 kw.
Figure 24
PAYLOAD RETENTION SUBSYSTEM

VERTICAL & LONGITUDINAL (X) LOADS ONLY

180-IN. DIA PAYLOAD ENVELOPE

SECTION

PAYLOAD/STATION 649 774 892 951 1010 1128 1246
Z₀ 414
LOWER RETENTION FITTING (TYPICAL 12 PLACES)

PAYLOAD 1069 1187 1293
Z₀ 414
SPECIAL TUG FITTING
RETENTION FITTING (TYPICAL 12 PLACES)

ALIGNMENT GUIDE DEPLOYED
RETAINED
RETRACTED
JETTISON PLANE
LATCH CLOSED
LATCH CLOSED
STRUCTURAL MOLD LINE
BRIDGE FITTING LONGERON

SIDE LOAD ONLY

CLEARANCE R = 93
PAYLOAD R = 90

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The payload retention mechanism (PRM) secures the payload within the payload bay during all phases of the orbiter mission. The PRM accommodates payloads up to 15 feet in diameter and 60 feet long. Retention lugs on the payload extend outside of the 15-foot diameter envelope. The system permits angular and dimensional misalignments within the constraints of the payload bay clearance envelope.

A set of four retention devices, three of which contain extendible guides, makes up the PRM. Three of the retention devices (active latch mechanisms) are located on the upper longeron; two of the devices react against loads in both the vertical and horizontal planes, and the third reacts against loads in the vertical plane only. The fourth (passive mechanism) is located at the lower centerline of the payload bay and reacts against side loads only. The guide system is erected when the retention latches are open and is used to facilitate installation and removal of payloads in space.
FIGURE 25
PAYLOAD BAY PURGE SUBSYSTEM

PAYLOAD BAY PURGE AND VENT GROUND DISCONNECT (AFT FUSELAGE)

PAYLOAD BAY DOOR

REPRESSURIZATION VENTS
- AIR TEMPERATURE CONTROL

LINER (PAYLOAD CONTAMINATION CONTROL AND INSULATION)
- STATION 410
- STATION 400

FRAME

LOOKING FORWARD

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ORBITER PURGE, VENT AND DRAIN SUBSYSTEM
(Figure 25 Text)

The purge, vent, and drain (PV&D) subsystem supports the orbiter mission requirements by providing compartment environmental control (thermal, contamination, and moisture) and safety/hazardous control (explosive, corrosive, and toxic). The subsystem is subdivided into four major areas:

1. **Purge.** The purge subsystem distributes ground-supplied environmental controlled air/GN₂ purge to the orbiter primary unpressurized structural cavities. Independent purge systems are provided for areas requiring specific purge characteristics. These areas are the pay/load bay, window/windshield cavities, and cryogenic external tank/orbiter disconnects.

2. **Vent.** The vent subsystem maintains the orbiter unpressurized structural cavities at, or as near as possible to, external atmospheric pressure throughout the mission. It supports structural requirements by minimizing delta pressures between orbiter compartments and external atmospheric pressure. The orbiter cavities are repressurized by ingestion of atmosphere through the vents.

3. **Drain.** During the prelaunch and postlaunch phases, the drain subsystem collects moisture and/or hazardous toxic or contaminating liquids and disposes of them. Compartmentation is maintained by providing isolation and dedicated drainage to each compartment, thus eliminating the mixing of liquids and gases via the drain provisions.

4. **Window/Windshield Conditioning.** The window/windshield conditioning subsystem, which is a separate subsystem, vents and repressurizes the window cavities and eliminates or controls fog, frost, and ice in the window cavities.

The PV&D subsystem interfaces with the orbiter subsystems to monitor and control the window/windshield conditioning subsystem, and with ground support equipment for orbiter purge.
Figure 26
PAYLOAD DEPLOYMENT AND RETRIEVAL SUBSYSTEM
SHUTTLE ATTACHED MANIPULATOR SYSTEM (SAMS)

PAYLOAD BAY ILLUMINATION
- COMMANDABLE LIGHTS ON BOOMS
- APPROPRIATE PHOTOMETRIC LIGHT LEVELS TO PROVIDE MANIPULATOR DEXTERITY & EFFICIENT ASTRONAUT WORKING CONDITIONS
PAYLOAD DEPLOYMENT AND RETRIEVAL SUBSYSTEM
(Figure 26 Text)

The payload deployment and retrieval mechanism (PDRM) consists of the Shuttle attached manipulator subsystem (SAMS), the manipulator retention latches (MRL), the manipulator deployment mechanism (MDM), and the manipulator jettison subsystem. The PDRM is located in the payload bay and on the flight deck of the orbiter and provides capability for payload deployment handling, and storage and satellite retrieval and servicing. It also provides capability for payload inspection, EVA support, and payload docking assistance. The MRL locks the manipulator boom in the stowed position, and the MDM deploys/stows the manipulator and the MRL.

The SAMS consists of a control servo input (CSI) and a follow-up output (FUO). The FUO in this case consists of the manipulator boom and end effector, whose function is to handle payloads while in orbit. The CSI transmits the operator's commands to the FUO, which, in turn, performs the work and feeds back its status to the operator.

One manipulator system is provided for all orbital missions. Full accommodations for installation and control of a second arm are provided to meet individual payload mission requirements. Each manipulator has remotely controlled television and lights for work viewing and inspection tasks. One manipulator can provide side viewing and depth perception for tasks being performed by the working manipulator, and either arm can perform the functions of the other.

The terminal end of each manipulator is a remotely controlled collet surrounding a drive shaft. The collet engages with a variety of tools and payload handling end effectors, which can be exchanged in flight. The internal drive shaft can power the end effectors mechanically. The wrist collet also can engage with payload flight support equipment such as deployment platforms to actuate them or to payload appendage devices to stow or deploy them.

The manipulators are stowed on the longerons in the payload bay. The system is designed to operate in a zero-g environment. Limited ground checkout is to be accomplished with a counterbalanced device.
THE SPACE TRANSPORTATION SYSTEM DEVELOPMENT IS WELL UNDER WAY

- SYSTEM DESIGN SELECTED ON FIRM TECHNICAL & ECONOMIC CONSIDERATIONS
- SYSTEM ELEMENTS & ORBITER ASSEMBLIES ANALYSIS, DESIGN, PROCUREMENT & MFG PROGRESSING ON SCHEDULE

IN THE 80'S - A MAJOR CHANGE IN THE NATURE OF & CAPABILITIES FOR SPACE OPERATIONS

- INCREASED MISSION FLEXIBILITY & RESPONSIVENESS
  QUICK TURNAROUND
  RETURN TO LAUNCH SITE IN ONE ORBIT
  A WIDE VARIETY OF MISSIONS
- NEW WAYS OF OPERATING IN SPACE
  SATELLITE RECOVERY/REFURBISHMENT
  MANNED PARTICIPATION IN PAYLOAD OPERATIONS
- INCREASED LAUNCH CAPABILITY
  NEW SATELLITE CONCEPTS POSSIBLE
  PAYLOAD SIZE & WEIGHT
- REDUCED LAUNCH & PAYLOAD COSTS

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The orbiter and subsystems are being designed in accordance with Shuttle program objectives of low cost, routine space transportation operation for the 1980's and beyond. The design approach and operational concepts are chosen to allow mission flexibility. The needs of all potential users are being considered as well as a wide range of mission parameters to assure maximum utility.

The operational Space Shuttle of the 1980's will bring into existence a new economical era in space operations. Greater mission flexibility, together with new payload concepts, including satellite recovery and reuse, will make possible practical exploration and use of space. The Shuttle's large payload weight and volumetric capacity, together with its versatile payload accommodations capability will permit it to serve a variety of payloads. It will carry into space virtually all of the Nation's civilian and military payloads, manned and unmanned. It will launch and return communications, weather, Earth resources and navigation satellites. It will place instruments into Earth orbit and deep space for scientific investigations. Payloads will be repaired on orbit or retrieved and returned to the ground for refurbishment and reuse. The Space Shuttle will have the capability of carrying passengers into space. The present stringent physical standards for space flight will be relaxed. Passengers may include scientists, engineers, technicians, journalists, television crews or others whose business takes them into space. Manned participation in payload operations and space exploration will greatly enhance the success of a wide variety of missions.

The orbiter which is the key to Space Shuttle system development, is rapidly moving from the technical-feasibility study toward hardware. Since the orbiter contract was received, the Shuttle team of government and industry personnel has built a solid base for continued development. This successful start increases our confidence that the orbiter—and the total Shuttle system—will meet both performance and cost goals.