SSV80-1

SPACE SHUTTLE
System Summary

May 1980

Rockwell International

Space Systems Group

Space Shuttle

System Summary

Space Shuttle Vehicle

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Missions and Capabilities

THE MISSIONS OF THE SPACE SHUTTLE SYSTEM

The Space Shuttle system will reduce the costs of earth orbital operations while improving operational capabilities and flexibility. With a due-east launch from Kennedy Space Center (KSC), the Shuttle can deliver payloads up to 65,000 pounds to a 200-nmi circular orbit at a substantially lower operational cost per flight than the Titan III-C system, which has a payload delivery capability of only 30,000 pounds. In addition, the Space Shuttle can return to earth with up to 32,000 pounds of payload for reuse or evaluation, a capability not provided by expendable launch vehicles.

Other Shuttle capabilities result in payload and mission cost savings. First, the Shuttle has the inherent ability to retrieve payloads that experience early failure before or immediately after deployment for subsequent relaunch and use. Second, the large capacity and benign launch environment of the Shuttle orbiter payload bay relaxes the weight, volume, and g-loading constraints imposed on future satellites, allowing design simplification. Third, the Shuttle, alone, or in combination with an advanced upper stage, permits the retrieval of satellites at the end of their service life for refurbishment and reuse. Fourth, the Shuttle can carry replacement subsystem modules to failed satellites on-orbit and extend their life, eliminating the need to recover the entire satellite. Fifth, the Shuttle can be used to perform dedicated space missions, subsystem development tests and space construction elements, or technology demonstrations on a space-available basis or in the sortie mode.

The Space Shuttle operational capabilities and flexibility permit the on-orbit replacement and/or servicing of malfunctioning satellites, reducing out-of-service time, and increasing operational availability. With the Shuttle, breadboards of devices intended for long-term unattended operation in earth orbit can be deployed and left in space for periods of weeks or months and then retrieved and returned to earth for examination. This process will enhance the reliability of future satellites and extend their useful life at relatively little cost while reducing development time. The capability for on-orbit servicing allows satellites to be updated as the technological state of the art advances, increasing their capability and prolonging their usefulness.

On sortie missions, the Shuttle will transport scientists, technicians, and/or trained observers into low earth orbit and maintain them and their experiments or observation equipment for seven days, or more. Personnel trained in specific scientific disciplines may conduct their own experiments and make their own observations. In addition, experiments can be conducted with combinations of temperature, pressure, and gravity not obtainable in earth-based research centers.

The Missions of the Space Shuttle System
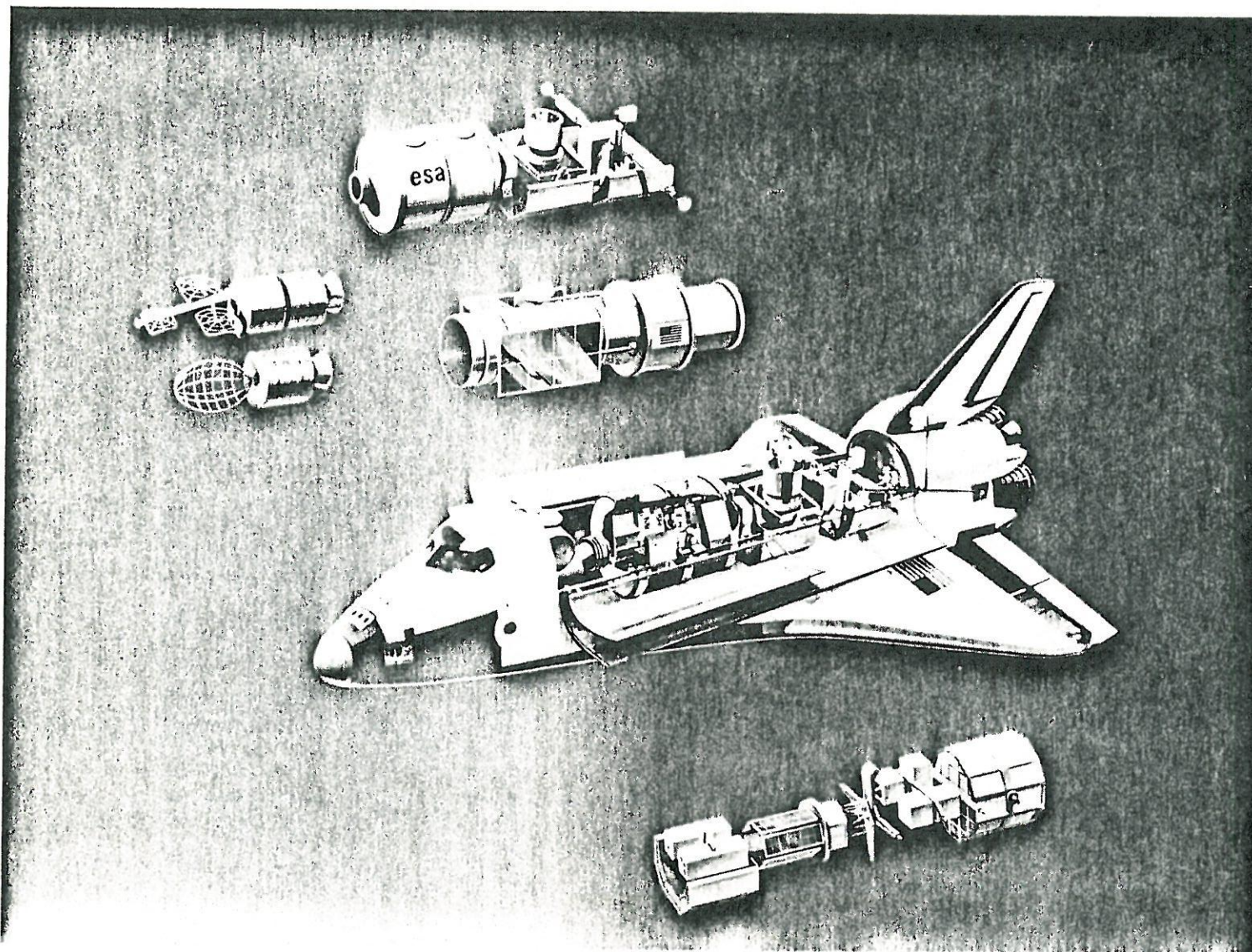
HOW THE SHUTTLE OPERATES

The flight plan and operation of the Space Shuttle differs markedly from that of the now-familiar launch procedures and splashdown of the Apollo missions, which utilized the expendable Saturn-V launch vehicle. The Space Shuttle vehicle provides a relatively comfortable environment for a nominal flight crew of four plus up to three payload specialists. In an emergency, an additional three persons can be provided for. This capability will enable experienced scientists and technicians to accompany their payloads into space. The environmental improvement is a result of the lower levels of launch and entry accelerations and a crew cabin that provides an air environment at shirt-sleeve temperature, pressure and humidity.

As illustrated on the left side of the figure, the integrated Shuttle vehicle ascends from the launch pad to an altitude of about 24 nautical miles, at which point the solid rocket boosters are jettisoned. The SRB's fall in an arc back to earth, are decelerated by parachutes, and are recovered from the ocean for reuse. Shortly before orbital injection, the orbiter main propulsion engines are shut down, and the external tank is separated from the orbiter. The orbital maneuvering system provides thrust to inject the orbiter into orbit while the external tank follows a ballistic trajectory into a remote ocean area for disposal.

Fitted for orbiting missions of from 7 to 30 days, the Shuttle has the capability to perform a variety of tasks such as satellite placement and recovery, propulsive stage and satellite delivery and return, manned orbital laboratory operation, and satellite service and repair. At the end of its mission, the Shuttle, with thrust from its orbit-maneuvering engines, leaves its orbit to reenter the earth's atmosphere, decelerating to make an aircraft-type landing on earth.

After landing, the crew of scientists, technicians, and astronauts leave the Shuttle with their data and equipment. Recovered payloads are unloaded, and the orbiter is serviced for the next flight. The orbiter, loaded with a new payload, is mated with a new propellant tank and the refurbished solid propellant boosters and is then transported to the launch area where the crew boards for the next mission.

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How the Shuttle Operates

LAUNCH
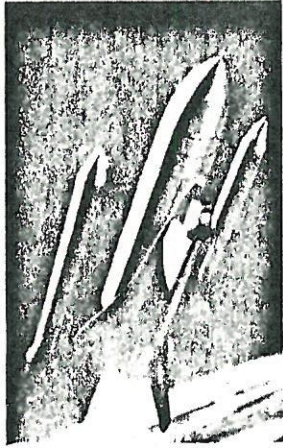
SOLID ROCKET
BOOSTER SEPARATION

EXTERNAL TANK
SEPARATION

ORBITAL INSERTION

ORBITAL OPERATIONS

RETROFIRE
FOR REENTRY

ATMOSPHERIC ENTRY

LANDING
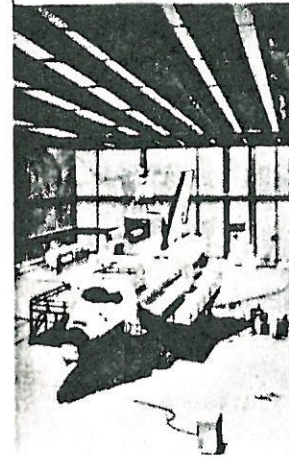
SERVICING
FOR RELAUNCH
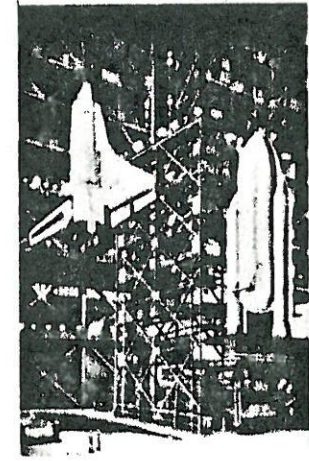
SPACE SHUTTLE
ASSEMBLY

WIDE VARIETY OF MISSIONS

The Space Shuttle has been designed to support a wide variety of space missions, including all those current and planned. This is implicit in the vehicle's capability to orbit 65,000 pounds of payload compared to the current expendable launch vehicle capability of about 30,000 pounds. The Space Shuttle is more than a launch vehicle, however, and can support new missions and operations which will make possible the achievement of higher productivity for the space program and facilitate greater utilization of space resources. The Space Shuttle also has the unique capability to make observations and measurements, particularly those involving real- or short-time opportunities, which can only be accomplished with man-in-the-loop operations.

In addition to its ability to provide more cost-effective launch services, the Shuttle has been designed to service and refurbish low-earth-orbit satellites, retrieve and return to earth payloads weighing up to 32,000 pounds, perform dedicated experimentation and technology development missions, carry passengers in relative comfort, and, with suitable upper stage propulsion, economically launch from orbit satellites and spacecraft whose missions require the attainment of higher orbital velocities.

A group of reusable mission kits to provide special or extended services for payloads will be added when required and will be designed to be quickly installed and easily removed. The major mission kits are as follows: oxygen and hydrogen for fuel cell usage to generate electrical energy; life support for extended missions; added propellant tanks for special on-orbit mission maneuvers; extra or specialized attachment fittings; airlocks, transfer tunnels, and docking modules; a second remote manipulator arm; an extra high-gain antenna; fill, vent, drain, purge, and dump lines; additional radiator panels for increased heat rejection; additional storage tanks; and electrical harnesses.

These capabilities can be used in many ways, some of which are listed in the facing chart as applications. Some of these applications have already evolved into vital programs. Others await the special operational capabilities of the Space Shuttle, mentioned above, to enable their initiation. With its capabilities, economy, and operational flexibility, the Space Shuttle provides the United States and its partners in space ventures the means to develop space resources for everyone's benefit.

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Wide Variety of Missions

SATELLITES
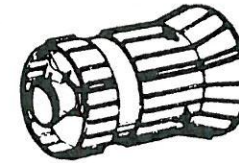
PROPULSION STAGES

OPERATIONS

☐ DELIVERY & PLACEMENT IN EARTH ORBIT OF:
  • SATELLITES/SPACECRAFT
  • PROPULSION STAGES
  • OTHER PAYLOADS OR CARGO

☐ RETRIEVAL OF EXPENSIVE PAYLOADS FOR REUSE

☐ SERVICE & REFURBISHMENT OF SATELLITES IN SPACE

☐ TRANSPORT TO ORBIT, OPERATE, & RETURN
  • SPACE LABORATORIES
  • SHORT-DURATION PAYLOADS

☐ SAFE, COMFORTABLE TRANSPORT OF PASSENGERS

APPLICATIONS

☐ EARTH RESOURCE EXPLORATION, INVENTORY, & DEVELOPMENT IN:
  • MINERALS & FUELS
  • FARM LAND, TIMBERLAND, & RANGE LAND
  • HYDROLOGY & WATER POLLUTION
  • GEOGRAPHY, CARTOGRAPHY, & TOPOGRAPHY
  • OCEANOGRAPHY
  • LAND USE & PLANNING

☐ COMMUNICATIONS

☐ NAVIGATION

☐ METEOROLOGY & WEATHER

☐ GEODETICS

☐ NATIONAL SECURITY

☐ ERECTION OF LARGE SPACE SYSTEMS

☐ SPACE STATION LOGISTICS

☐ PAYLOADS FOR NEW OR UNFORESEEN PROBLEM SOLUTION
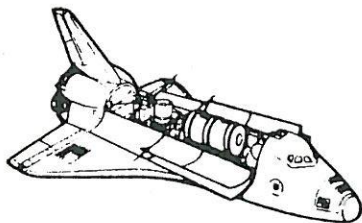
LABORATORIES

☐ LABORATORIES FOR RESEARCH IN:
  • PHARMACOLOGY
  • MATERIALS
  • MANUFACTURING PROCESSES
  • BIOLOGICAL & LIFE SCIENCES
  • SPACE PHYSICS
  • ADVANCED TECHNOLOGY

☐ SCIENCE SATELLITES FOR:
  • ASTRONOMY & PHYSICS RESEARCH
  • PLANETARY EXPLORATION

PLACEMENT AND RECOVERY OF SATELLITES

A principal Space Shuttle mission will be the placement and servicing of satellites in earth orbit. However, on many of these placement missions, a satellite launched on a previous mission can be retrieved and returned to earth for refurbishment and reuse. In a typical placement mission, the satellite and non-deployed experiments are serviced, checked out, and loaded into the Shuttle. The crew which boards the Shuttle from the launch platform consists of Shuttle commander, pilot, and mission and payload specialists. Upon arriving at the desired orbit, the mission and payload specialists will conduct predeployment checks and operations. After determining that the satellite is ready for deployment, the crew will operate the payload deployment system, which lifts the satellite from the cargo bay retention structure, extends it about 50 feet from the orbiter, and releases it. The final activation of the satellite will be a radio command or a timer. The Shuttle will stand-by until the satellite is performing satisfactorily before proceeding with the remainder of the mission. Satellites that fail to check out or activate may be returned to earth for correction of the malfunctions and for subsequent relaunch. Experiments, measurements, and manufacturing operations with nondeployed payloads can be carried out on the same flight with a satellite deployment so as to reduce launch costs.

In recovering a satellite, the orbiter will rendezvous with it, maneuver close, and attach the remote manipulator arm to the satellite. After the satellite is deactivated by radio command, it will be moved into the cargo bay and structurally locked into place in a cradle carried for that particular satellite. The payload bay doors will be closed, and then the orbiter will perform deorbit maneuvers, enter the atmosphere, and land, returning the expensive satellite for reuse.

This unique recovery capability, provided by the Shuttle, offers a new dimension to satellite designers that will substantially reduce the development and production costs of the payloads (satellites).

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Placement and Recovery of Satellites
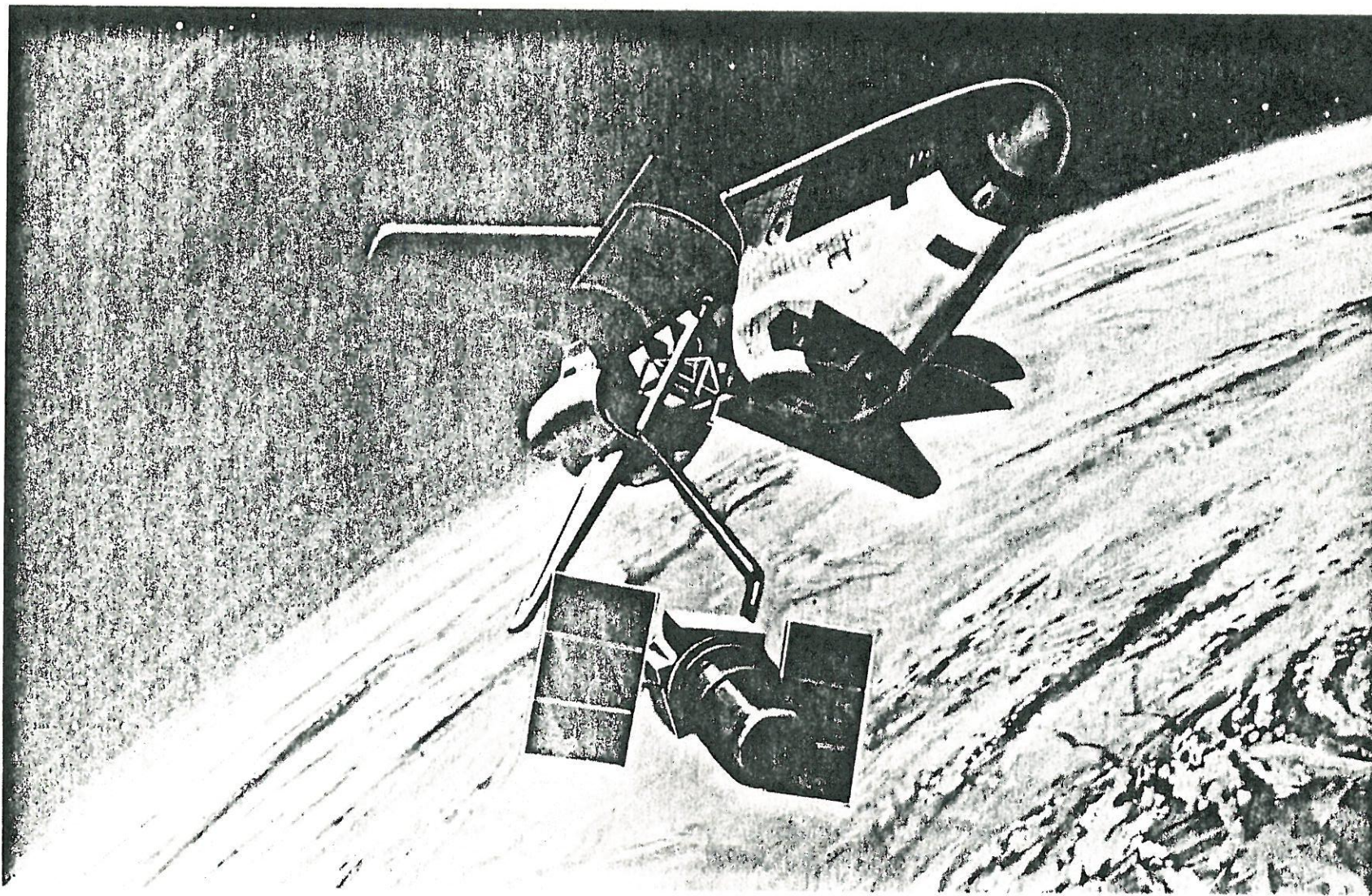
MIXED/MULTIPLE PAYLOAD CARGOES

The carrying of a single payload into orbit will not always utilize the
full capability of the Space Shuttle vehicle. Payload bay volume per-
mitting, excess capability can be used to advantage by adding payloads
to the cargo manifest, allowing flight costs to be shared. Pooling of
payloads can provide economic advantages where mission and schedule
constraints are compatible.

Rockwell International studies of the prospects for mixing payloads show
that the payloads of different agencies (NASA, Department of Defense,
other U.S. government agencies, commercial organizations, and other
nations) can be combined into efficient cargoes for Shuttle flights and
that the opportunities for such combinations are significant. As illus-
trated by the artist concepts in the accompanying chart, a satellite
going to geosynchronous orbit could share launch costs with two naviga-
tion satellites, or flights planned for deployable satellites could
share launch costs with a non-deployable or sortie payload, thus
utilizing the maximum capability of the Shuttle system.

Sortie flights carrying Spacelab elements also offer opportunities to
share costs whenever these flights do not utilize the full Shuttle capa-
bility. The excess capability could be used to launch deployable space-
craft or to carry experiments not planned for the basic sortie mission.
An announcement of flight opportunity (AFO) would be published sufficiently
far in advance to enable other agencies, commercial interests, or the
scientific community to benefit from the sortie flight opportunity.

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Mixed / Multiple Payload Cargoes

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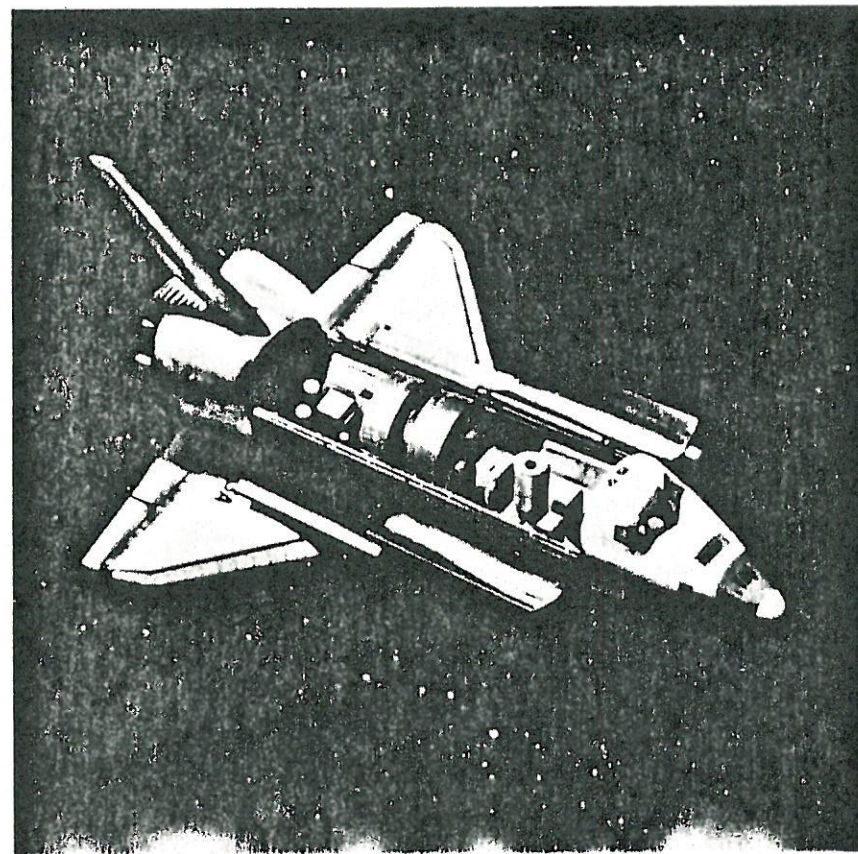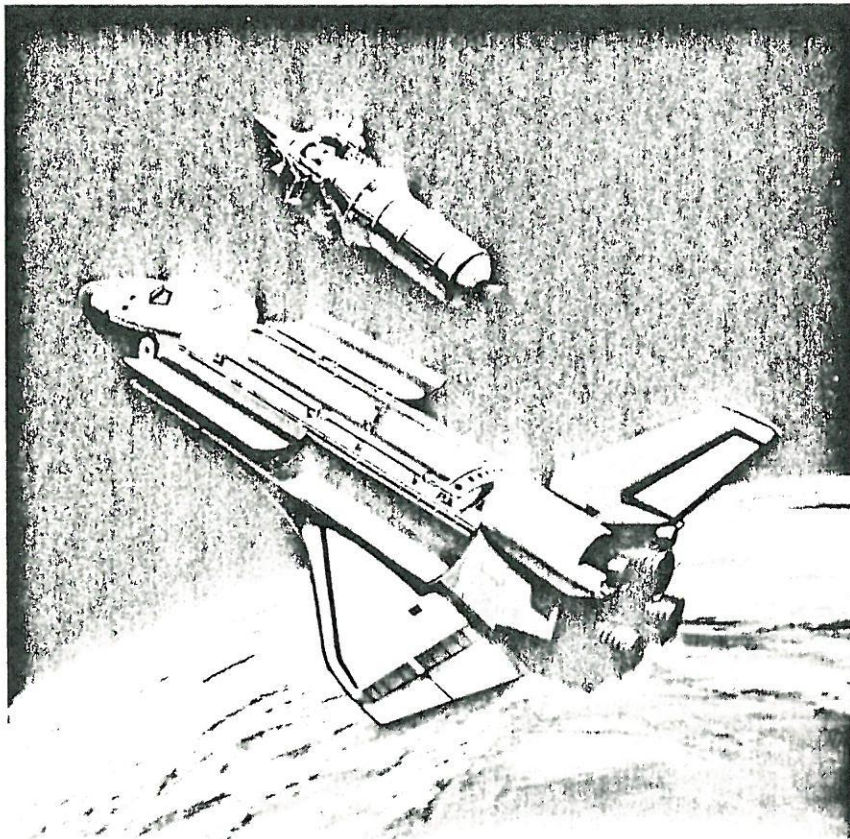
ON-ORBIT RESEARCH SPACELAB

The Shuttle can conduct on-orbit research with Spacelab payloads (being developed by the European Space Agency, ESA, with the support of the countries listed below) as an extension of the orbiter to enhance the Shuttle capabilities. It can supplement the experimenter's ground-based laboratories with the added conditions that only space flight can provide, such as a long-term gravity-free environment, space vacuum, a location where Earth can be viewed and examined as an entity, and where the celestial sphere can be studied free of atmospheric interference.

Several Spacelab system configurations will be flown, one of which is shown in the accompanying artist's concept. This includes a pressurized module where man can work in a shirtsleeve environment. A tunnel gives access to the cabin area of the Shuttle and has an airlock attached which can be utilized in an emergency. Instruments/experiments that require exposure to space vacuum, or because of size or viewing, are mounted on pallets aft of the pressurized module. The Shuttle may be flown in any attitude, to orient the instruments, e.g., toward earth for surveys of earth resources and to conduct geophysical and environmental investigations. For those payloads requiring greater pointing accuracy than that provided by the orbiter ($\pm$0.5 degree), ESA has developed an Instrument Pointing Subsystem (IPS) for payloads ranging up to 4410 pounds (2000 kilograms) in weight and which is capable of maintaining the line of sight within two arc-seconds with respect to a reference star and within one arc-second quiescent stability over a pointing range of up to π steradians ($\pm$60 degrees).

Other Spacelab configurations include those without a pressurized module in which a large number of instruments/experiments are installed on pallets and controlled from the payload specialist's station within the orbiter. Pressure-suit operations in the payload bay are practical when instrument service is required.

Spacelab is an international program. In addition to the manufacture of the Spacelab, the Europeans will also participate in Spacelab operations which will include supplying payloads and crews for many missions. Other nations have also indicated an interest in participating in Spacelab operations. The Shuttle, carrying Spacelabs to orbit, operating them, and returning them to earth, provides an entirely new capability for manned participation which will increase the effectiveness of space research as well as reduce the cost of the application of space technology.

SPACELAB DEVELOPMENT TEAM

Belgium	Spain
Denmark	Switzerland
France	United Kingdom
Italy	West Germany
Netherlands	

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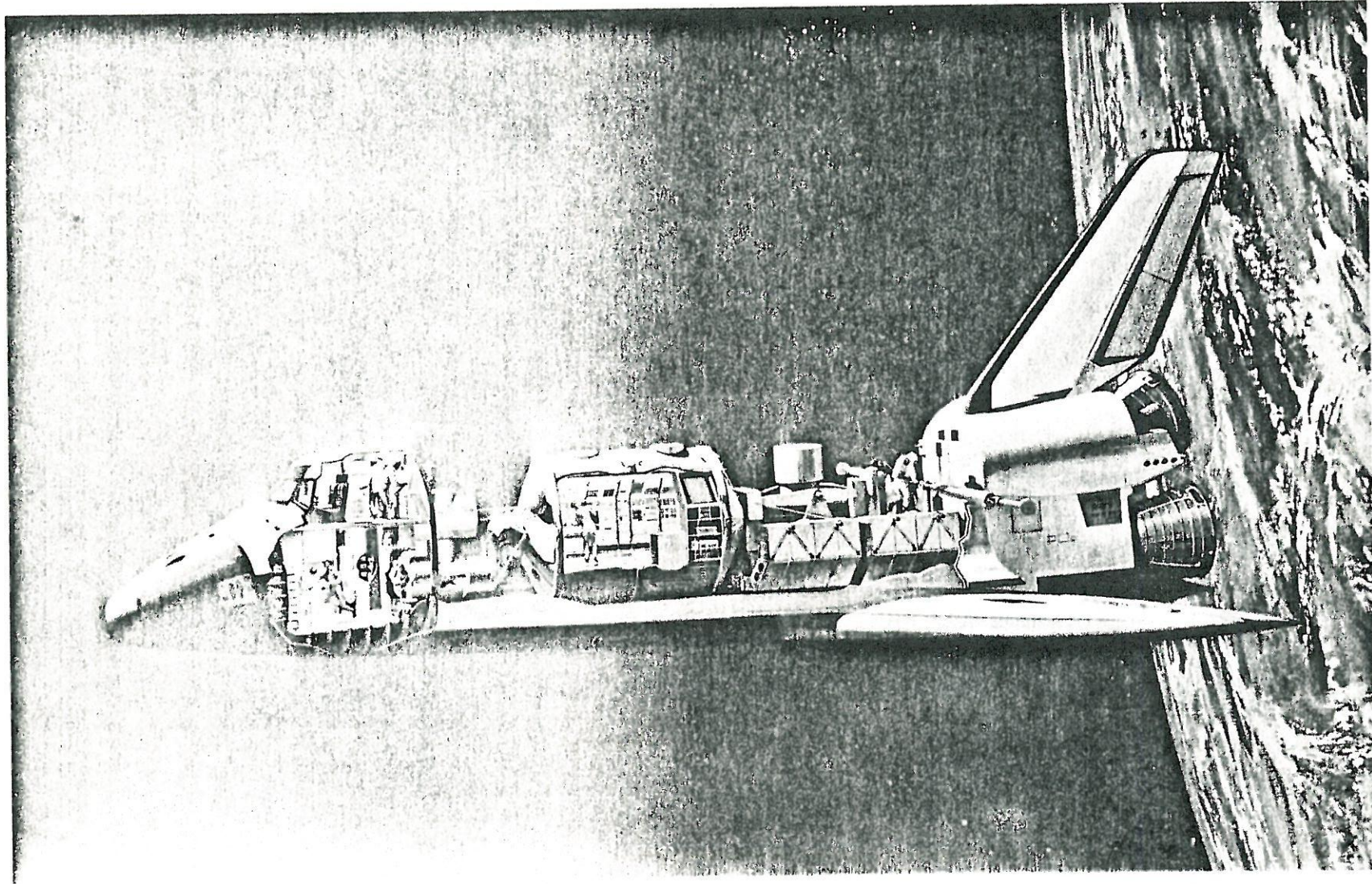
DELIVERY OF SPACECRAFT TO HIGH-ENERGY ORBITS/TRAJECTORIES

Spacecraft and satellites whose missions require altitudes, inclinations, and trajectories beyond the Space Shuttle capability will require the use of an upper-stage system. There are three upper-stage systems currently planned as part of the STS. Each of these basic upper-stage systems can be used for small to large payloads for missions near and far. The smallest, is a solid-propellant, spin-stabilized stage called the spinning solid upper stage (SSUS-D), and the largest is a solid three-axis-stabilized inertial upper stage (IUS). Spacecraft with these upper stages will be carried by the Space Shuttle into low-earth orbit and deployed as shown in the illustration. Prior to release, the combination spacecraft and upper stage may be functionally checked out in preparation for launch, including the initialization/updating of guidance or other parameters required. After the spacecraft/upper stage are separated from the orbiter by a spring release ejection system, the orbiter moves away to a safe position and then by radio command or by a timer enables the upper stage ignition. The ignition of the upper stage propulsion engine will take place when the spacecraft/upper stage is at the proper place in the orbit to proceed to the destination.

The Delta class SSUS-D is designed to be launched vertically from the cargo bay and will place 2000 to 2400 pounds into geosynchronous transfer orbit, and the Atlas-Centaur class SSUS-A will place 4000 to 4400 pounds into geosynchronous transfer orbit. The SSUS and spacecraft are on a spin table in the orbiter, and this spin table provides the spinning motion for stabilization prior to release. Typical SSUS performance data are presented on page 54.

The IUS is designed to deliver 5000 pounds to geosynchronous (19,323-nmi) orbit, 6000 pounds to 12-hour orbit (21,450 nmi by 350 nmi), 10,000 pounds to inner planetary, or 1200 pounds to outer planetary. To accommodate this range of payloads, the IUS consists of a family of 2-, 3-, and 4-stage configurations based on the basic two-stage design. (See page 56 for typical IUS performance data.) This upper stage has a three-axis-stabilized propulsive and avionics system for stability and trajectory control. The spacecraft mounted on the IUS are cantilevered when the assembly is placed in the orbiter. All of the interfaces between spacecraft and orbiter pass through the upper-stage and cradle to the orbiter. The deployment of the spacecraft/upper-stage from the orbiter is by means of a spring ejection system from the mounting cradle.

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Delivery of Spacecraft to High-Energy Orbits / Trajectories
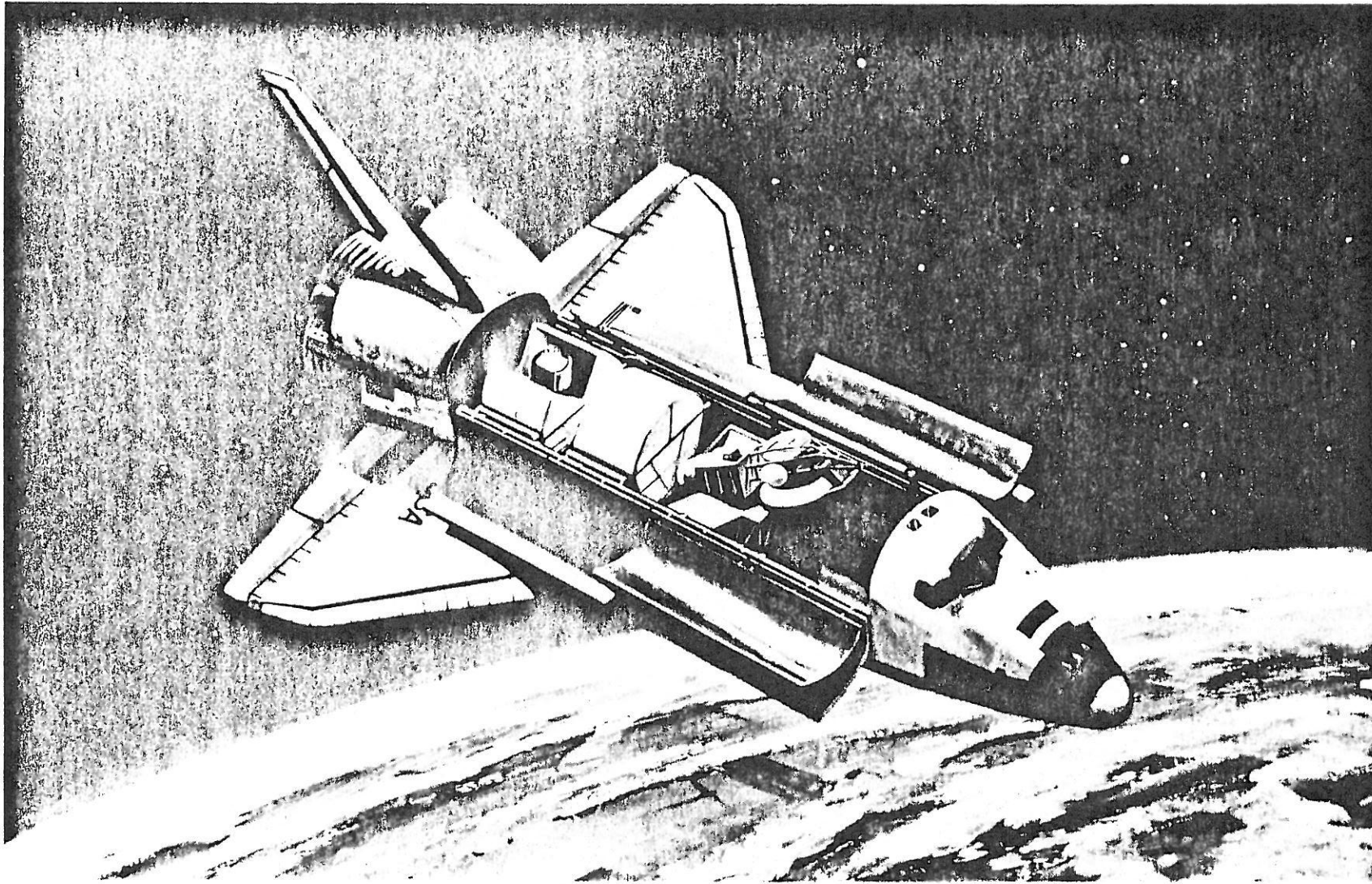
ON—ORBIT SATELLITE SERVICE

Another Shuttle operations capability unique to the space program is on-orbit satellite servicing, refurbishment, or recovery. This capability, combined with the large weight and volume capacity of the Shuttle, provides the payload designer with new freedom in developing and operating satellites to reduce payload costs as well as improve performance. The refurbishment capability is especially cost effective, since these operations can be carried out as ancillary missions because of the low Shuttle payload weight involved.

A typical operational on-orbit service is presented on the facing sheet. The following operational sequences are depicted. (1) The satellite maneuvers from its sun-synchronous or similar orbit to the service orbit. (2) The orbiter is inserted into the service orbit (additional propellant for the Shuttle orbit maneuvering system (OMS) can provide capability for an increase in operational altitude) to rendezvous with the satellite. (3) The satellite is captured/docked by the orbiter remote manipulator system. (4) The satellite is attached to positioning platform. (5) The satellite is serviced. Alternative techniques for on-orbit service are under study. The two concepts shown are manual service and mechanized service; these are discussed in more detail below. (6) The satellite is deployed by the orbiter remote manipulator system if its systems check out. If not, the orbiter provides a contingency retrieval option to return the satellite to earth for extensive repairs as required.

Manual servicing, illustrated in 5 right, is accomplished by crewman operating in an EVA mode. The satellite is docked to the deployed service module, and crewmen then perform resupply from the module. The satellite design allows crewmen to enter a section for refurbishment and service.

The mechanized approach, illustrated in 5 left, is based upon a design with replaceable modules that can be handled by remotely controlled mechanisms. Low-cost refurbishable payloads, such as the Earth Observation Satellite (EOS) depicted, are supported by a positioning system to allow rotation of the satellite to the proper position for servicing. A rotary magazine carries the replacement modules and presents them at the proper time to an exchange mechanism. The exchange mechanism first removes the old module from the satellite and temporily stows it, removes the new module from the magazine and installs it in the satellite, and finally stows the old module back in the magazine.

On-Orbit Satellite Service

① SUN-SYNCHRONOUS ORBIT

SERVICING ORBIT

② LAUNCH, RENDEZVOUS, & STATIONKEEPING

③ CAPTURE SATELLITE WITH REMOTE MANIPULATOR

④ SATELLITE ATTACHED TO POSITIONING PLATFORM

MODULE EXCHANGE MECHANISM

MODULE MAGAZINE

⑤ SATELLITE SERVICING

MECHANIZED SERVICE

⑤ SATELLITE SERVICING

MANUAL SERVICE

DEORBIT & LANDING

STATIONKEEPING

⑥ DEPLOY

TO SUN-SYNCHRONOUS ORBIT

RETENTION CRADLE

OPTION CONTINGENCY RETRIEVAL

LARGE SPACE SYSTEMS

The versatility and reusability of the Space Shuttle orbiter permit the construction and assembly in orbit of systems larger than previously allowed by the limits of a single launch vehicle payload. The orbiter, in addition to its role of transport vehicle, can act as an orbiting construction base itself or provide crew support and other services to a construction facility. Construction capabilities include the remote manipulator system (RMS) using one or two arms, electrical power, communications, data displays, data reduction, computer services, an airlock for extravehicular activity (EVA), a docking port, and support for two manned maneuvering units (MMU). The television cameras and lights associated with the payload bay also can aid some aspects of space construction.

The technology for these construction projects is being developed by NASA. Three general approaches to construction are: (1) deployment of structures which have been folded to fit within the payload bay; (2) piece-by-piece erection of structures using preformed struts and unions which have been compactly packaged into the payload bay; (3) space fabrication. The latter employs machines which form and assemble truss-work beams from composite materials (such as composites or light metals) stored in rolls or in canisters. The required machinery and materials would be brought up in a series of orbiter flights. Besides structure, a major factor in large systems construction is the on-orbit installation of systems components and equipment modules, which may be aided by the orbiter capabilities described above. Systems that could be assembled in space include large communication antennas, multi-purpose satellites, large area solar collectors, transmitters, radiometers, manned laboratories, space processing factories, storage warehouses, large spacecraft assembly facilities, refueling and repair depots, medical research facilities and power modules. A concept for construction of a large solar power platform is shown.

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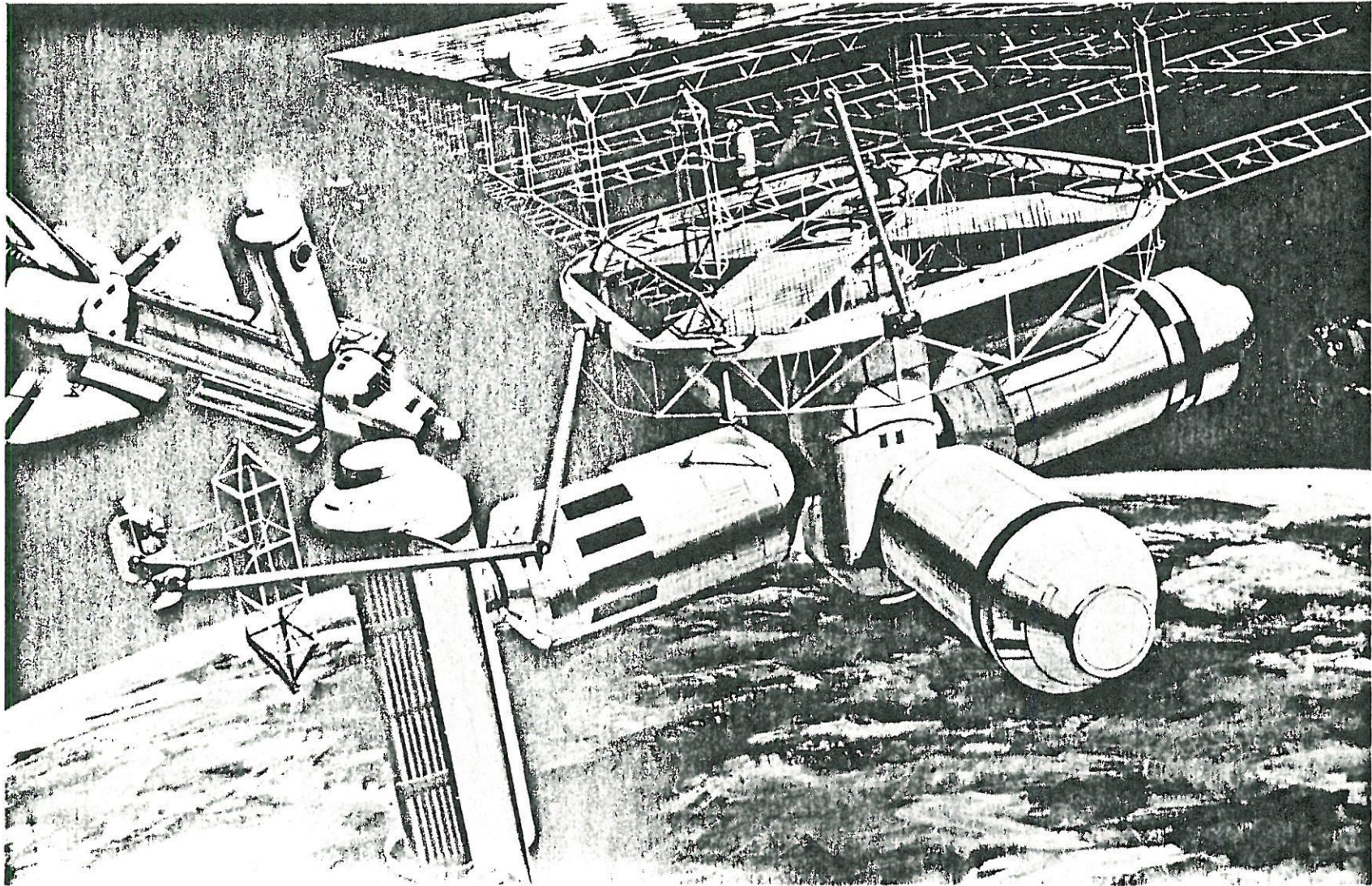
Large Space Systems

THE SPACE TRANSPORTATION SYSTEM (STS)

The Space Transportation System consists of the Shuttle, a variety of standard payload carriers, ground integration and launch facilities, and ground-based payloads and operations control centers. The STS will perform all services formerly accomplished by a variety of unmanned launch vehicles at considerably less cost. It will also routinely perform tasks not possible or practical in the past, such as manned flight operations, in-space servicing/maintenance, payload retrieval and intact mission aborts.

The Shuttle consists of the orbiter vehicle, expendable external tank (ET), and a pair of recoverable solid rocket boosters (SRB). Launches can be made from the Kennedy Space Center (KSC) or the Vandenberg Air Force Base (VAFB) complexes. The orbiter with its large capacity can deliver payloads as much as 65,000 pounds to circular orbits of up to 200 nautical miles. Smaller payloads can be delivered to circular orbits of up to 600 nautical miles or elliptical orbits with apogees of up to 2000 nautical miles.

Missions can be performed in a manned Spacelab module attached to the orbiter or on pallets that are open to space. Manned extravehicular activity (EVA) operations can be utilized to simplify experiment designs. Upper stage solid rocket systems can boost payloads weighing up to 10,000 pounds from the Shuttle orbit to higher earth orbits or planetary trajectories. The Inertial Upper Stage (IUS) can perform maneuvers for accurately placing large spacecraft into high energy orbits. The smaller and lower-cost Spinning Solid Upper Stages (SSUS-A and SSUS-D) are single stages without active guidance; the spacecraft using SSUS must therefore provide their own circularization and final positioning, where applicable.

Payloads may utilize the Multimission Modular Spacecraft (MMS) or Long Duration Exposure Facility (LDEF), both of which are low-earth-orbit free flyers for unmanned long-duration missions. These carriers can be serviced and retrieved. New payload modules can be added/exchanged during orbiter revisits.

Ground communications with payloads are from one of three payload operation control centers (POCC) located at the Jet Propulsion Laboratory (JPL), Goddard Space Flight Center (GSFC), and Johnson Space Center (JSC). Communications are via the world-wide space tracking and data network (STDN) and the tracking and data relay satellites system (TDRS), and via the orbiter and/or carrier command and data handling systems. Direct payload communication is also possible.

The orbiter is transported between ground sites such as VAFB and KSC atop a modified Boeing 747 aircraft.

The efficient utilization of the STS requires integrated planning. The Rockwell STS User Service Center, Downey, California, (Tel. 213-922-3344) is providing planning and integration service to STS users.

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The Space Transportation System
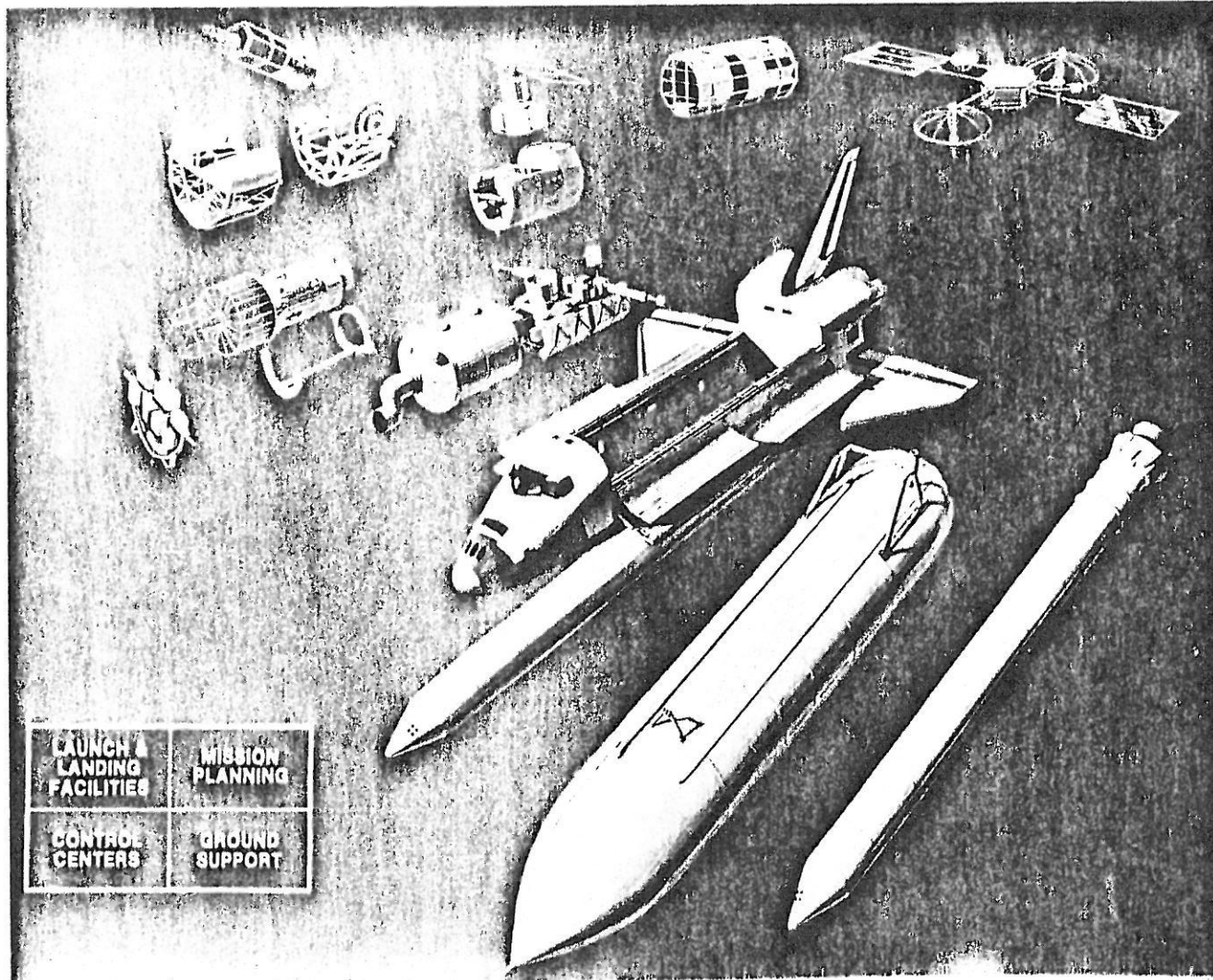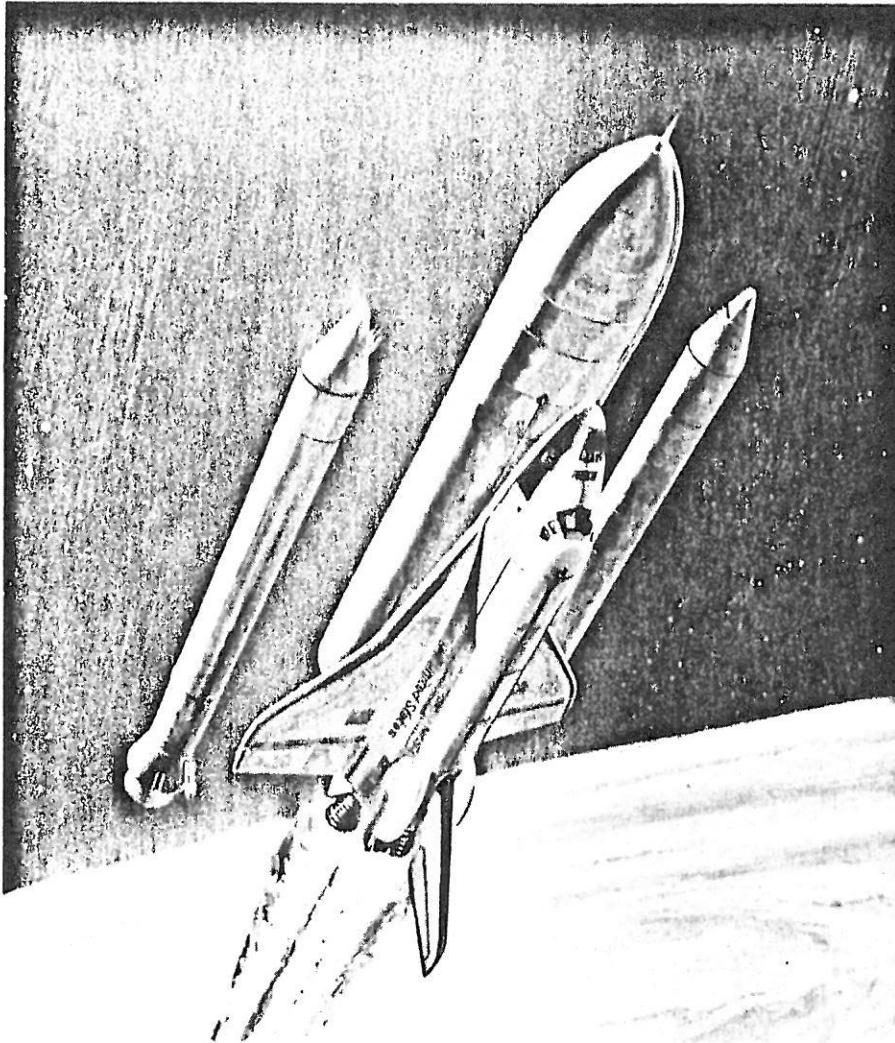
Space Shuttle System

SPACE SHUTTLE VEHICLE

The Space Shuttle flight system consists of an orbiter with Space Shuttle main engines (SSME's), an external tank (ET), and two solid rocket boosters (SRB's). The orbiter with SSME's and the solid rocket booster are reusable elements; the external tank is expended on each launch.

The orbiter normally carries into orbit a crew of four, with provisions for a crew of as many as seven, and payloads. It can remain in orbit nominally for 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 Space Shuttle main engines, used during ascent, obtain their propellants from the external tank. Smaller orbiter rocket engines provide for maneuvering and attitude control during space flight. Aerodynamic surfaces on the wings and vertical stabilizer control the orbiter during atmospheric flight.

The crew occupies a two-level cabin at the forward end of the vehicle. From the upper level flight deck, the crew controls the launch, orbital maneuvering, atmospheric entry, and landing phases of the mission. The crew also performs payload handling. Seating for up to three additional crew members and habitability provisions are provided on the mid deck. The mid deck can be reconfigured to provide an additional three seats in the event of a rescue mission. The load factors experienced by the crew on any of these missions is 3 g's or less.

The solid rocket boosters burn in parallel with the SSME's and are separated from the orbiter/external tank at approximately 150,000 feet. The SRB's descend on parachutes and land in the ocean about 150 nautical miles from the launch site. They are recovered by ships, returned to land, refurbished, and then reused.

After SRB separation, the SSME's continue 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 final desired orbit.

Space Shuttle Vehicle

OVERALL LENGTH (ET + SRB)   183.8 FT
OVERALL WIDTH (WING SPAN)   78.1 FT
OVERALL HEIGHT (ET + ORBITER) 76.6 FT

EXTERNAL TANK (ET)

ORBITER

SPACE SHUTTLE MAIN ENGINES (SSME)

SOLID ROCKET BOOSTERS (SRB)

ORBITER   161K LB (INERT)
           225K LB (LIFT-OFF)
ET   1651K LB (LIFT-OFF)
SRB   2587K LB (LIFT-OFF)

GROSS LIFT-OFF WEIGHT =
4463K LB - 32K LB PAYLOAD
TO 50 X 100 NMI AT 104 DEG
INCLINATION
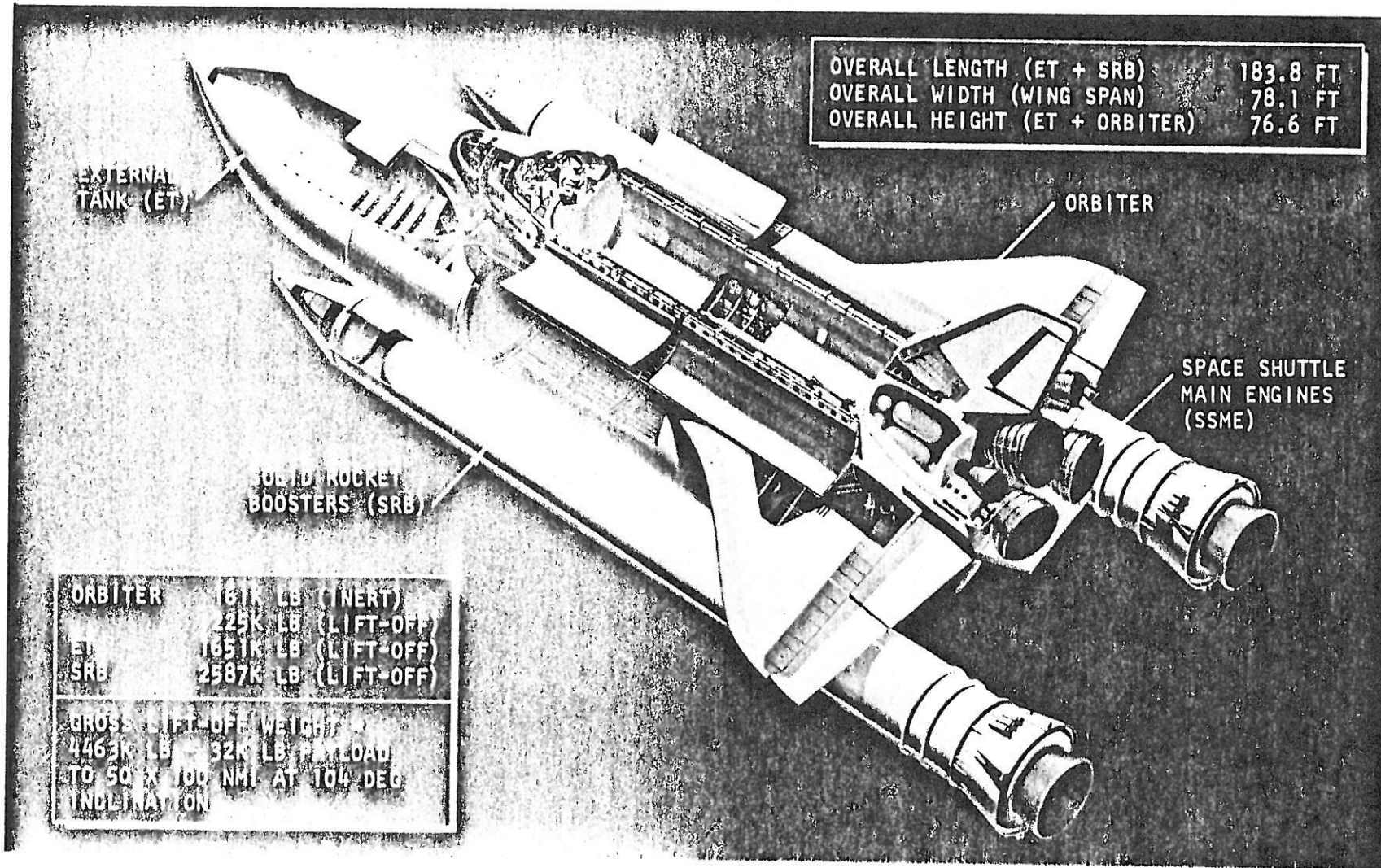
ORBITER VEHICLE

The orbiter vehicle was designed to satisfy the payload/mission requirements:

- Payload maximum size of 15 feet in diameter by 60 feet in length and 65,000 pounds

- Provisions for the payload (protection, support, and handling)

- Maximum acceleration of 3 g's

- Nominal crew of four (maximum of ten in an emergency)

- Provisions for mission duration of seven days (capability of thirty days with kits)

- Provisions for orbital maneuvers, attitude control, etc.

- Land like an airplane

- Provide redundant subsystems for high probability of mission success

- Provide for refurbishment and reflight

The chart shows orbiter vehicle (OV) 101 landing at Edwards Air Force Base. This was the last landing of the approach and landing test (ALT), that took place in October 1977. The Space Shuttle main engines (SSME), simulated on this vehicle, are clearly seen at the rear of the vehicle, as are the simulated orbital maneuvering system (OMS) engines and reaction control system (RCS) engine ports. Note also the split rudder acting as a speed brake.

Additional information on the orbiter is presented in the Orbiter and Subsystem section of this brochure.

SSV68048
(Text)

Orbiter Vehicle

OVERALL LENGTH	121.5 FEET
WINGSPAN	78.0 FEET
HEIGHT (GROUND TO TAIL)	56.6 FEET
ORBITER INERT WEIGHT	161,100 POUNDS
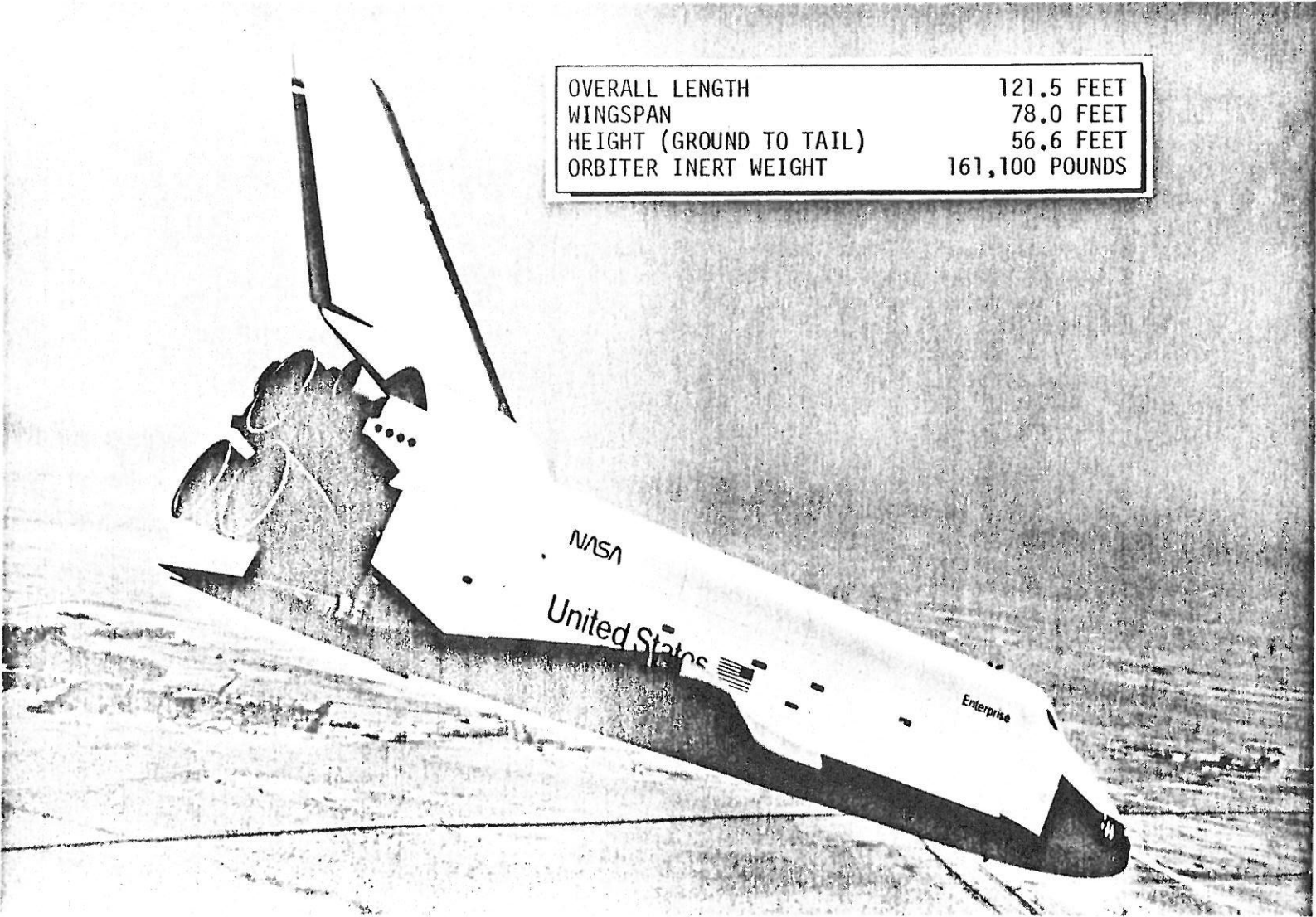
SPACE SHUTTLE MAIN ENGINES

Mounted in a triangular pattern in the orbiter's aft fuselage, the three Space Shuttle main engines (SSME's) produce a total sea-level thrust of 1.125 million pounds (1.41 million pounds at vacuum). Each engine is capable of producing 6.5×10^6 horsepower for a combined total of 19.5×10^6 horsepower. Liquid oxygen (LO_2) and liquid hydrogen (LH_2), cryogenic propellants contained in the external tank, are supplied to the three engines at a total flowrate of 3090 LBM per second. Each engine operates with a fixed nozzle area ratio of 77.5:1 at a mixture ratio (LO_2/LH_2) of 6:1 and a chamber pressure of 2970 psia, producing a rated sea-level thrust of 375,000 pounds and a vacuum thrust of 470,000 pounds. The high chamber pressure (significantly higher than previous engines) and flowrate (1030 LBM per second) for each engine is made possible by the use of the efficient staged-combustion engine cycle. This cycle allows high turbopump propellant discharge pressures (7600 psia for LO_2, and 6200 psia for LH_2) which are necessary to overcome pressure losses within the engine and still maintain the 2970 psia chamber pressure.

The engines can be throttled over a thrust range of 65 to 109 percent of the rated power level, to a maximum thrust of 512,000 pounds per engine. This throttling capability enables the crew to tailor engine thrust to mission needs and limit the orbiter's acceleration to 3 g's. The engines are bearing-mounted and capable of gimbaling $\pm$10.5 degrees in pitch and $\pm$8.5 degrees in yaw for orbiter steering control. The Shuttle main engine is the first to use a built-in electronic digital controller to accept commands from the orbiter for engine start, shutdown, and change in throttle setting. It will also monitor engine operation and, in case of failure, will automatically correct the problem or shut down the engine safely. Able to operate for 7.5 hours of accumulated firing time, SSME's are reusable for up to 55 missions before requiring major maintenance or overhaul.

Space Shuttle Main Engines

LH$_2$ FEEDLINE

LO$_2$ LOW PRESSURE TURBOPUMP

LH$_2$ HIGH PRESSURE TURBOPUMP

LH$_2$ REGEN. COOLANT

NOZZLE

167"

94"
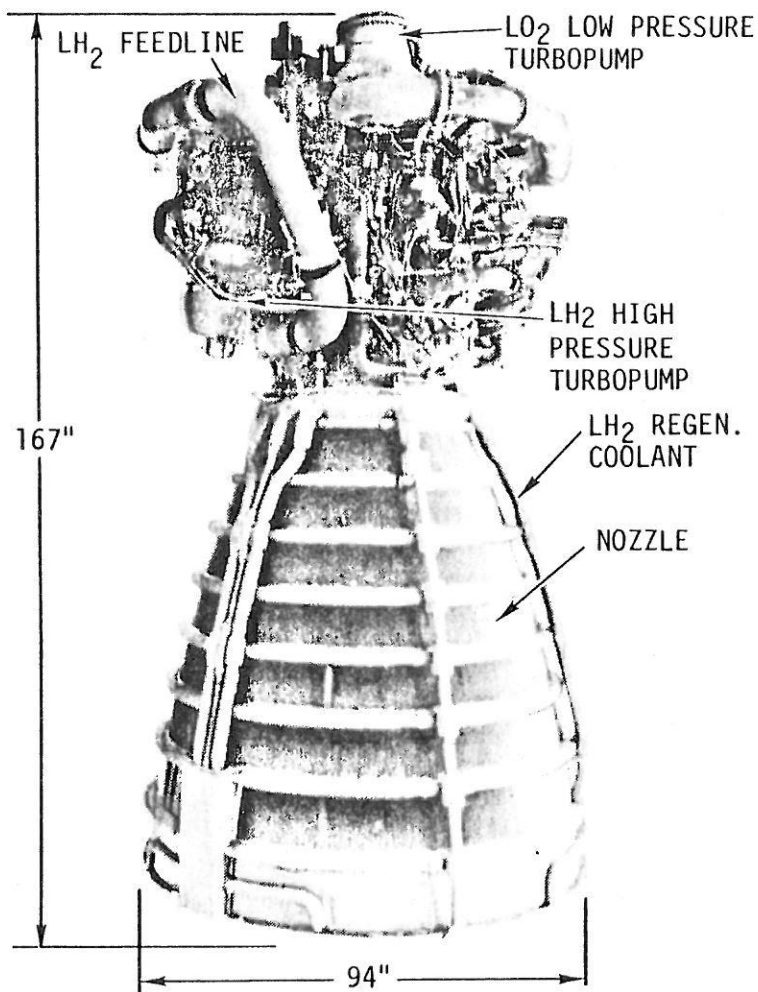
- THRUST (RATED POWER LEVEL)
  - SEA LEVEL — 375,000 LBS
  - VACUUM — 470,000 LBS
- THROTTLING — 65% - 109% RPL
- CHAMBER PRESSURE (RPL) — 2970 PSIA
- AREA RATIO — 77.5:1
- SPECIFIC IMPULSE (RPL)
  - SEA LEVEL — 363.2
  - VACUUM — 455.2
- MIXTURE RATIO (OXYGEN/HYDROGEN) — 6.0:1
- HI PRESS. LH$_2$/LO$_2$ PUMP TURBINE HP 62,000/24,000
- ENGINE FLOWRATE — 1030 LBM/S / 19,600 GPM
- TOTAL ENGINE HORSEPOWER (RPL) — 6,500,000 HP
- WEIGHT — 6668 LBS
- LIFE — 7.5 HRS/55 STARTS
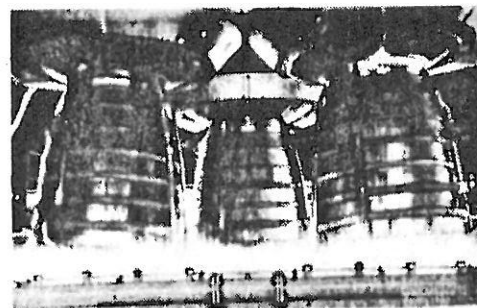
TOTAL THRUST 1,125,000 LBF AT LIFT-OFF

TOTAL FLOWRATE 3090 LBM

Space Systems Group — Rockwell International

20SSV86976A

EXTERNAL TANK

The external tank (ET) supplies the orbiter main propulsion system with liquid hydrogen (LH2) and liquid oxygen (LO2) at prescribed pressures, temperatures, and flow rates. Both the LH2 and LO2 tanks are equipped with vent and relief valves to permit loading, pressurization, and relief functions. Tank level sensors provide for propellant loading and SSME shutdown signals. The ET is thermally protected with a nominal 1-inch-thick spray-on foam insulation (SOFI), employing additional SOFI and a charring ablator (SLA 561) to withstand localized high heating. Since the ET is an expendable element, the ET subsystems are designed for single usage to minimize costs.

The ET reacts the solid rocket booster (SRB) thrust through its intertank structure and provides attach structure to the orbiter to react the Space Shuttle main engine (SSME) thrust. At liftoff, the ET contains approximately 1.58 million pounds of usable propellant. At main engine cutoff (MECO), the ET is separated from the orbiter before orbital velocity is achieved. The ET then proceeds on a ballistic reentry path and breaks up prior to impact in the ocean.

The ET consists of a forward LO2 tank, an unpressurized intertank, and an LH2 tank. The LO2 tank (volume – 19,500 ft^3) is an aluminum alloy monocoque structure composed of a fusion-welded assembly of performed, chem-milled gores, panels, machined fittings, and ring chords. The LO2 tank is designed to operate at a nominal pressure range of 20 to 22 psig. The tank contains antislosh and antivortex baffles as well as an antigeyser system to control conditions. A 17-inch diameter feedline conveys propellant through the intertank and externally aft to the ET/orbiter disconnect. The tank's double wedge nose cone reduces drag and heating, serves as a lightning rod, and contains an ascent air data system.

The intertank is a semimonocoque cylindrical structure with flanges on each end for joining the LO2 and LH2 tanks. The intertank contains the SRB thrust beam and fittings which distribute SRB loads to LO2 and LH2 tanks. The intertank houses ET instrumentation components, and provides an umbilical plate which interfaces with a ground facility arm. The umbilical plate accommodates purge gas supply, hazardous gas detection, and hydrogen gas boiloff during ground operations. The intertank consists of mechanically joined skin, stringers, and machined panels of aluminum alloy. The intertank is vented in flight.

The LH2 tank (volume – 55,552 ft^3) is a semimonocoque structure composed of fusion-welded barrel sections, five beam ring frames, and forward and aft 0.75 ellipsoidal domes. The LH2 tank is designed to operate at a nominal pressure of 32 to 34 psia. The tank contains an antivortex baffle and a siphon outlet to transmit propellant to the ET/orbiter disconnect through a 17-inch-diameter line. The LH2 tank has provisions for the ET/orbiter forward attach strut, two ET/orbiter aft attach fittings, the thrust distribution structure, the aft SRB/ET stabilizing strut attachments, and the aft ET/SRB rear attach fittings.

10SSV87994
(Text)

External Tank

ET/ORBITER AFT ATTACH

PROPELLANT FEED, PRESSURIZATION LINES & ELECTRICAL INTERFACES

ET/ORBITER FORWARD ATTACH

INTEGRAL STRINGERS

ET/SRB FORWARD ATTACH

ET/SRB REAR ATTACH

LO_2 SLOSH BAFFLES

LO_2 VENT VALVE & FAIRING

LH_2 TANK

ASCENT AIR DATA SYSTEM (AADS)

INTERTANK

LO_2 TANK

INTERTANK T-0 UMBILICAL PLATE
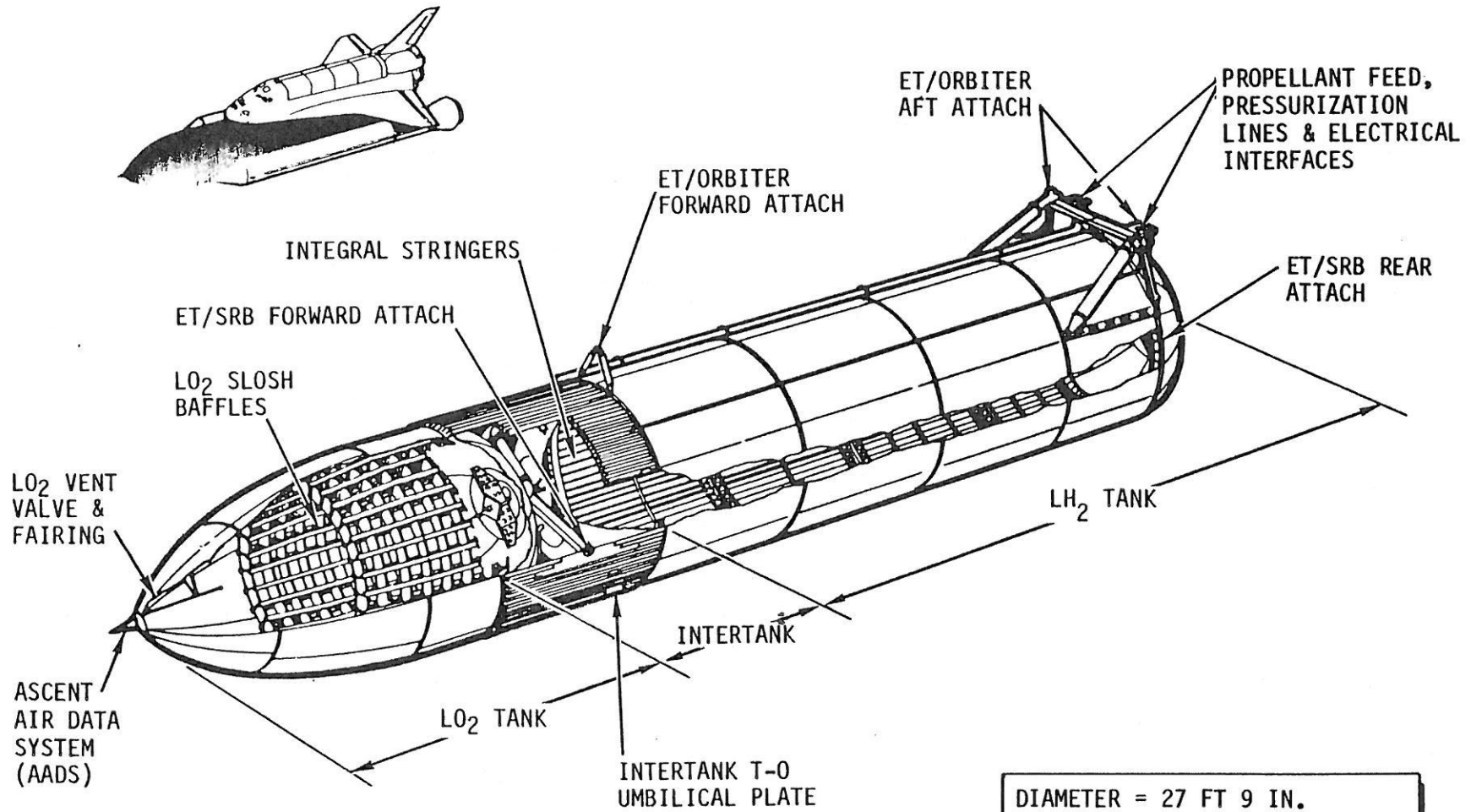
DIAMETER = 27 FT 9 IN.
LENGTH = 154.4 FT
PROPELLANT WT = 1.58×10^6 LB
INERT WT = 71,000 LB

SOLID ROCKET BOOSTER

Two solid rocket boosters (SRB's) burn in parallel with the orbiter main propulsion system (MPS) to provide initial ascent thrust. Primary elements of the booster are the motor, including case, propellant, igniter, and nozzle; structural systems; separation, operational flight instrumentation (OFI), and recovery avionics; separation motors and pyrotechnics; and deceleration system, range safety destruct system, and thrust vector control (TVC) subsystems. Each SRB weighs approximately 1.293 million pounds and produces 2.65 million pounds of thrust at sea level. The propellant grain is shaped to reduce thrust approximately one-third at 55 seconds after liftoff to prevent overstressing the vehicle during the period of maximum dynamic pressure. The grain is of conventional design, employing a star perforation in the forward motor closure and a double truncated cone perforation in each of the segments and aft closure. The contoured nozzle expansion ratio (area of exit to area of throat) is 7.16. The SRB TVC, which is a closed-loop hydraulic system with power provided by redundant APU's and hydraulic pumps, has an omni-axial gimbal capability of 7.1 degrees which, in conjunction with the orbiter main engines, provides the flight control during the Shuttle boost phase.

A segmented case design affords maximum flexibility in fabrication and ease of transportation and handling. A cone-shaped skirt at the aft end of each of the SRB's carries the aft loads between the SRB and the mobile launch pad (MLP). Two lateral sway braces and a diagonal attachment at the aft frame provide the structural attachment between the SRB and external tank. The SRB forward attachment to the external tank is by a single thrust attachment at the forward end of the forward skirt. The same forward skirt is used for attaching the main parachute riser attachments.

The SRB's are released from the ET by pyrotechnic separation devices at the forward thrust attachment and the aft sway braces. Eight separation motors on each SRB, four aft and four forward, separate the SRB from the orbiter and external tank.

The SRB forward section provides installation volume for the SRB electronics, recovery gear, range safety destruct system, and forward separation rockets. It also houses the parachute deceleration subsystem which consists of a pilot parachute, a ribbon drogue parachute, and three ribbon main parachutes.

Solid Rocket Booster

NOZZLE & TVC
$\epsilon = 7.16:1$

4 SEPARATION MOTORS
20,000-LB THRUST EACH

4 SEPARATION MOTORS
20,000-LB THRUST EACH

MAIN PARACHUTE PACK

ET/SRB FORWARD
ATTACH

AFT SKIRT &
LAUNCH SUPPORT

SRB/ET ATTACH RING
& SWAY BRACES

SYSTEMS
TUNNEL

DROGUE
CHUTE

SEPARATION AVIONICS
OPERATIONAL FLIGHT
INSTRUMENTATION
RECOVERY AVIONICS

FORWARD
SKIRT

NOSE FAIRING
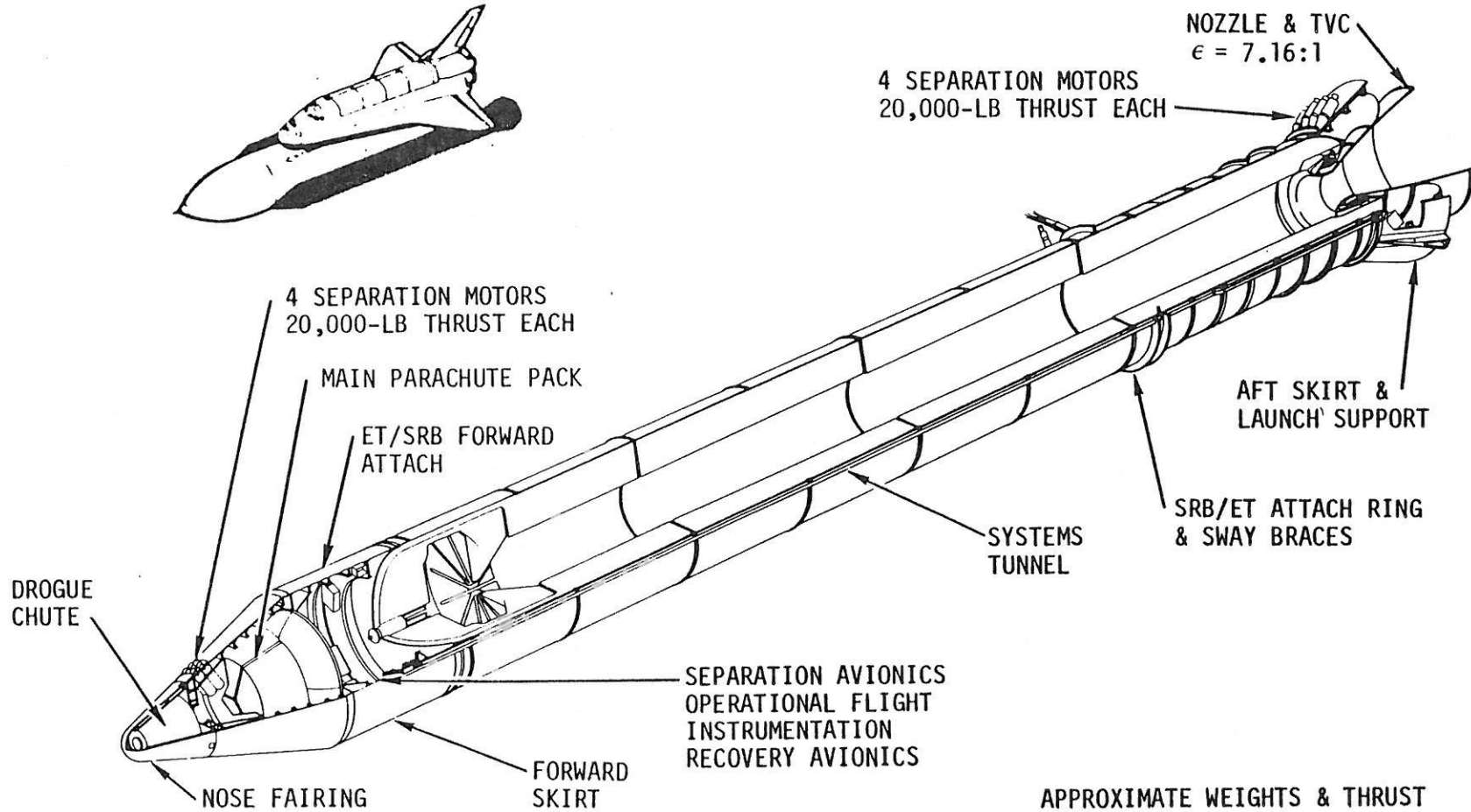
DIMENSIONS

   LENGTH . . . 1790 IN.
   DIAMETER . . 146 IN.

APPROXIMATE WEIGHTS & THRUST

GROSS WEIGHT . . .	1,293,500 LB
INERT WT	184,600 LB
THRUST (SL)	2.65$\overline{M}$ LB

SHUTTLE AVIONICS SUBSYSTEM

The Shuttle avionics system provides command functions and implementation; guidance, navigation, and control capability; communication; computation; displays and control; instrumentation; and electrical power distribution and control for the orbiter, the ET, and the SRB's. Provisions for the management and control of payload functions and for the communication of data to and from payloads have been incorporated into the orbiter design. The orbiter flight deck is the center of both in-flight and ground activities except during hazardous servicing.

During mated checkout and prelaunch countdown, commands, targeting, initialization data, and voice are transmitted from the ground to the Space Shuttle and its payload either by hard line or by RF transmission. Health, status verification data, and voice communication from the Shuttle and payload to the ground are also by wire or by RF links.

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. 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 interfaces with payloads through the mission and payload specialist stations by means of hard-wired controls and displays when the payloads are attached to the orbiter, and by RF links when they are detached. S-band communication links between the orbiter and ground stations permit the orbiter to transmit voice and data and to receive commands, voice, and data. Both S-band and Ku-band can be used for communication through the NASA tracking and data relay satellite (TDRS) system. Communication in DOD missions will be by S-band to stations in the space/ ground link system (SGLS).

Automatic fault detection is provided for all vehicle flight critical functional paths. A caution and warning subsystem monitors payload health and status while the payload is aboard the orbiter.

119SSV87068
(Text)

Shuttle Avionics Subsystem

EXTERNAL TANK

- CONTROLS
  - SEPARATION
- MEASUREMENTS

SRB

- CONTROLS
  - IGNITION
  - STAGING
  - SEPARATION
  - TVC
- MEASUREMENTS
- RECOVERY

ORBITER

- GUIDANCE, NAVIGATION, & CONTROL
- COMMUNICATIONS & TRACKING
- DISPLAYS & CONTROLS
- INSTRUMENTATION
- DATA PROCESSING & SOFTWARE
- ELECTRICAL POWER DISTRIBUTION & CONTROL
- PERFORMANCE MONITOR

GROUND FACILITIES

- CHECKOUT & CONTROL
- COMMUNICATIONS & TRACKING
- AIR TRAFFIC CONTROL
- DATA DISTRIBUTION

SATELLITE COMM (TDRS)

PAYLOADS

- MANAGEMENT
- CONTROL
- COMMUNICATION
- POWER

SSME

- TVC
- IGNITION
- THROTTLING
- MEASUREMENTS

RANGE SAFETY SYSTEM

The Shuttle range safety system (RSS) is an airborne command destruct system for each solid rocket booster (SRB), left and right, and the external tank (ET) of the Shuttle vehicle. The system enables intentional destruction of the booster and tank elements of the Shuttle vehicle in the event of flight path deviation, improper vehicle parameters or inadvertent separation. The system provides protection of personnel and property during launch of a Shuttle vehicle.

The Shuttle RSS provides a high degree of protection against intentional interrogation by unfriendly intruders and against unintentional interrogation by noise. This protection is accomplished by having an RF transmission code that is classified secret and having a design that is inherently resistant to noise influence.

The concept is the same for the SRB RSS and the ET RSS. Both systems have an RF/receiving section, a logic/control section and a pyrotechnic/explosive section. Functional block diagrams of the SRB and ET range safety systems are depicted.

SRB range safety system: each SRB RSS consists of redundant command antennas, a directional and hybrid coupler, redundant command receivers, redundant command decoders, a distributor assembly (redundant and isolated control circuit systems A and B), redundant NASA standard initiator (NSI) detonators, a safing and arming (S&A) device, seven confined detonating fuze (CDF) assemblies, redundant CDF manifolds, a destruct assembly (dual linear shaped charges), redundant power sources, and a harness assembly (all interconnect cabling). The redundant power sources are batteries as follows: one battery is exclusively for SRB range safety A and the other is the SRB recovery battery which is used by the SRB range safety system B. (Note: The recovery system is inactive until after SRB separation). The SRB RSS is safed prior to separation for the recovery operation.

ET range safety system: the ET RSS consists of redundant command antennas, directional and hybrid coupler, command receiver, command decoder, distributor assembly (simplex input from decoder, but dual circuits thereafter), redundant NSI detonators, S&A device, seven CDF assemblies, redundant CDF manifolds, destruct assembly (two linear shaped charges, one for the LH2 tank and one for the LO2 tank), redundant range safety batteries, and harness assembly (all interconnect cabling). Redundancy is achieved in the destruct assembly by initiating the linear shaped charge (LSC) at both ends simultaneously.

10SSV88265
(Text)

Range Safety System (RSS)

SRB RANGE SAFETY SYSTEM BLOCK DIAGRAM

COMMAND ANTENNA

DIRECTIONAL COUPLER → GSE

HYBRID COUPLER

COMMAND RECEIVER A

COMMAND DECODER A

COMMAND RECEIVER B

COMMAND DECODER B

RECOVERY BATTERY SYS B

RSS BATTERY SYS A

SYSTEM A

SYSTEM B

DISTRIBUTOR ASSEMBLY

NSI

S&A DEVICE

NSI

* CDF ASSEMBLY

CDF MANIFOLD

CDF MANIFOLD

* LSC

* LSC

DESTRUCT ASSEMBLY

FWD SKIRT FEED THRU

ET RANGE SAFETY SYSTEM BLOCK DIAGRAM

COMMAND ANTENNA

DIRECTIONAL COUPLER → GSE

HYBRID COUPLER

COMMAND RECEIVER

COMMAND DECODER

RSS BATTERY A

RSS BATTERY B

SYSTEM A

SYSTEM B

DISTRIBUTOR ASSEMBLY

NSI

S&A DEVICE

NSI

* CDF ASSEMBLY

CDF MANIFOLD

CDF MANIFOLD

* LSC

* LSC

DESTRUCT ASSEMBLY

WEIGHT SUMMARY

The Space Shuttle is designed to satisfy three payload missions. Mission 1 is to be launched from KSC, while Missions 3A and 4 are to be launched from VAFB. Mission 1 requires placing the maximum payload (65,000 pounds) into the minimum inclination (28-1/2 deg), 150-nmi circular orbit and return a 32,000-pound payload. Mission 3A deploys a 32,000-pound payload into a 104-degree inclination at first apogee, with a minimum altitude of 100-nmi. The orbiter lands nearly empty at the launch/landing site at the end of the first revolution. Mission 4 calls for the vehicle to launch a 32,000-pound payload into a 98-degree inclination, 150-nmi circular orbit within two revolutions after lift-off and to capture, retrieve, and return a 25,000-pound payload to VAFB.

The weight summary chart shows the breakdown of the pre-lift-off weights for the required missions. The gross weight of the Shuttle Transportation System for Mission 1 is the heaviest at 4.5 million pounds; the gross weights of the other missions are slightly smaller. The variations in the gross weights are due to differences in payloads, crew size, and propellants for OMS, RCS, and electrical power as required for mission altitude, rendezvous/maneuver, and duration. The lift-off weights are slightly less (about 7500 pounds) than the pre-lift-off weights shown, due to the use of about 6300 pounds of ET propellants in engine ignition and increasing thrust level, and about 1200 pounds of propellant in the SRB's from ignition to lift-off thrust level.

20SSV64863C
(Text)

Weight Summary

	REFERENCE MISSIONS		
ELEMENT	1 DEPLOY/RETRIEVE 28-1/2° INCL	3A DEPLOY 104° INCL	4 DEPLOY/RETRIEVE 98° INCL
PAYLOAD (KLB)	65.0	32.0	32.0

ORBITER OV 103 (KLB)
  INERT
  SSMEX3
  PERSONNEL
  THIRD PRSD SET
  NONPROPULSIVE CONSUMABLES
  MPS PROPELLANT
  OMS PROPELLANT
  RCS PROPELLANT
	201.7
	(141.0)
	(20.0)
	(2.6)
	(1.6)
	(3.9)
	(5.4)
	(19.7)
	(7.5)
		193.4
		(141.0)
		(20.0)
		(1.5)
		(0.3)
		(3.9)
		(5.4)
		(15.1)
		(6.2)
			207.1
			(141.0)
			(20.0)
			(2.6)
			(1.6)
			(3.9)
			(5.4)
			(25.1)
			(7.5)

LIGHT WEIGHT ET (KLB)
  INERT
  PROPELLANT
		1650.5
		(71.0)
		(1579.5)	

SRBX2 (KLB)
  INERT
  PROPELLANT
		2587.0
		(369.3)
		(2217.7)	

GROSS LIFT-OFF WEIGHT (KLB)	4504.2	4462.9	4476.6

REF: JSC-09095-51, SHUTTLE SYSTEMS WEIGHT & PERFORMANCE, MONTHLY STATUS REPORT, MARCH 15, 1980

SHUTTLE COORDINATE SYSTEMS AND DIMENSIONS

The Shuttle system and Shuttle elements X, Y, Z coordinate systems are shown on the accompanying chart. The X, Y, Z coordinate systems for the orbiter, external tank, solid rocket booster, and Shuttle system are designated by the subscript letters O, T, B, and S. The unit of measurement is the inch. The Shuttle vehicle dimensions are presented in the inset for reference.

In each coordinate system, the X-axis zero point is located forward of the nose tip; that is, the orbiter nose tip location is 236 inches aft of the zero point (at X_O 236); the ET ascent air data system's most forward point is at X_T 327.2; and the SRB nose tip location is at X_B 200. In the orbiter, the horizontal X_O, Y_O reference plane is located at Z_O 400, which is 336.5 inches above the ET horizontal X_T, Y_T reference plane located at Z_T 400. The SRB horizontal X_B, Y_B reference plane is located at Z_B 0 and coincident with the ET horizontal plane at Z_T 400. The SRB central vertical X_B, Z_B planes are located at $+Y_S$ 250.5 and $-Y_S$ 250.5. Also, note that the orbiter, ET, and Shuttle system center X, Z planes coincide.

From the X = 0 point, aft is positive, and forward is negative for all coordinate systems. Looking forward, each Shuttle element Y-axis point right of the centerplane (starboard) is positive, and left of center (port) is negative. The Z-axis of each point within all elements is positive with Z = 0 located below the element, except for the SRB's in which each Z-coordinate point below the SRB X_B, Y_B reference plane is negative and each point above that plane is positive.

The Shuttle system and Shuttle elements coordinate systems are related as follows: The ET X_T 0 point coincides with X_S 0, the SRB X_B 0 point is located 543 inches aft, and the orbiter Y_O, Z_O reference plane is 741 inches aft of X_S 0.

Space Shuttle Vehicle Dimension

40

Shuttle Coordinate Systems and Dimensions

SUBSCRIPTS

T - EXTERNAL TANK
B - SOLID ROCKET BOOSTER
O - ORBITER
S - SHUTTLE SYSTEM
FRL - FUSELAGE REFERENCE LINE

ORB FRL

SRB C_L

ET C_L

250.5 IN.   250.5 IN.

X_O 0
$+Z_T$, $+Z_S$
X_T 0
X_S 0
236
741
$+Z_O$
$+Y_O$
$+Z_B$
$+Y_B$
$+Z_B$
$+X$
$-Y_O$
$-Z_B$
$+Y_T$, $-Y_S$
Z_O 400
336.5 IN.
Z_S 400
Z_T 400
X_T 327.2
X_B 0
$-Z_B$
200 IN.
$-Y_B$
543 IN.
$-Y_T$, $-Y_S$
X_B 0

MPS UPPER ENGINE ACTUATOR DESIGN VALUES:
PITCH NULL 16 DEG, YAW NULL 0 DEG
PITCH GIMBAL ±10.5 DEG AT X_O 1445, Z_O 443

YAW GIMBAL ±8.5 DEG AT Y_O 0

103 IN.   13 DEG

MPS LOWER ENGINES ACTUATOR DESIGN VALUES:
PITCH NULL 10 DEG
YAW NULL 3 DEG 30 MIN OUT
PITCH GIMBAL ±10.5 DEG
YAW GIMBAL ±8.5 DEG AT $+Y_O$ 53

MAIN ENGINES

Space Systems Group

Rockwell International

119SSV86978

41

TYPICAL MISSION PROFILE

The Shuttle is launched with the three orbiter Space Shuttle main engines (SSME's) burning in parallel with the two solid rocket boosters (SRB's). After approximately two minutes, the SRB propellants are depleted, and the SRB's are staged off to be recovered and returned to the launch site. The orbiter ascent is continued using the three SSME's, which provide thrust vector control until main engine cutoff (MECO) conditions assure a safe disposal of the external tank (ET). The ET is separated immediately after MECO, and the orbital maneuvering system (OMS) engines provide the additional velocity needed to insert the orbiter into an elliptical orbit having a minimum apogee of 150 nautical miles. At first apogee, the orbiter initiates the first of two maneuvers to circularize the orbit at 150 nautical miles. Additional maneuvers may be executed as required for the orbital operations of a specific mission.

Following the completion of orbital operations, the orbiter is oriented to a tail-first attitude, and the OMS provides the deceleration thrust necessary for deorbiting. The orbiter is reoriented nose-forward to the proper attitude for entry. The orientation of the orbiter is established and maintained by the reaction control system (RCS) down to the altitude where the atmospheric density is sufficient for the pitch and roll aerodynamic control surfaces to be effective, about the 250,000-foot altitude. The yaw RCS remains active until the vehicle reaches the 80,000-foot altitude, approximately.

The orbiter entry trajectory provides lateral flight range to the landing site and energy management for an unpowered landing. The trajectory, lateral range, and heating are controlled through the attitude of the vehicle by angle of attack and bank angle. The orbiter has a lateral or cross-range capability of approximately 1150 nautical miles. Terminal Area Energy Management (TAEM) is initiated approximately 50 nautical miles from the landing site and provides the proper vehicle approach to the runway with respect to position, altitude, velocity, and heading. Final touchdown occurs at a nominal landing speed of about 210 knots.

Typical Mission Profile

EXTERNAL TANK SEPARATION

ORBIT INSERTION

ORBITAL OPERATIONS

DEORBIT

STAGING

BOOSTER SPLASHDOWN

EXTERNAL TANK IMPACT

ENTRY

RETURN TO LAUNCH SITE

LAUNCH

TERMINAL PHASE

HORIZONTAL LANDING

KENNEDY SPACE CENTER

PRELAUNCH
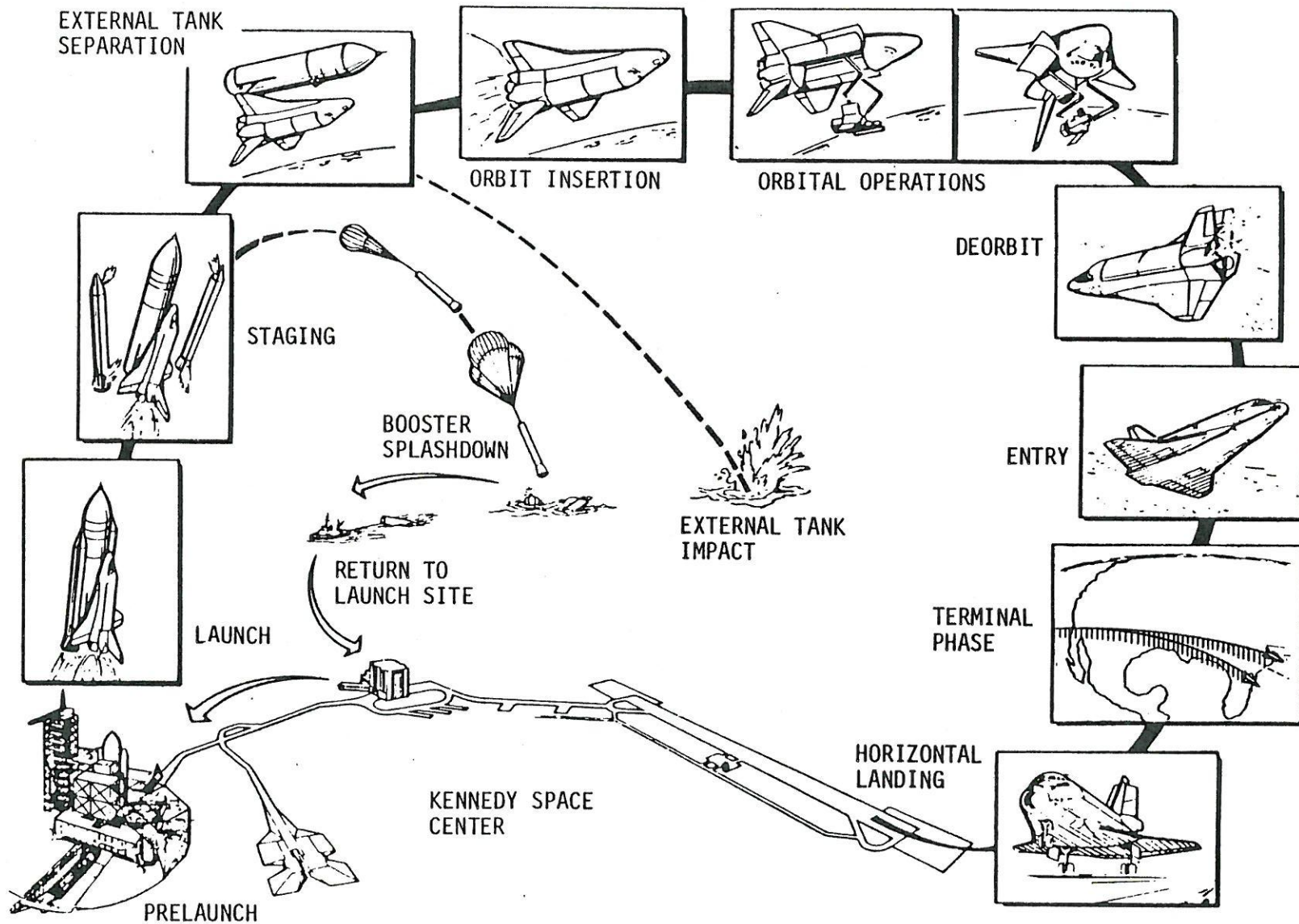
TYPICAL ASCENT AND DESCENT TRAJECTORY PROFILES

Typical Shuttle orbiter ascent and descent trajectory profiles are presented on the chart and illustrate altitude as a function of range. Major events as well as time are noted on the profiles.

Ascent Trajectory

The ascent trajectory reaches a maximum dynamic pressure (Q) of 650 pounds per square foot approximately 60 seconds after launch at an altitude of 33,600 feet. At 108 seconds, the total load factor reaches the first stage maximum value of 2.6 g's. SRB separation occurs at approximately 126 seconds at an altitude of 148,500 feet, 28 nautical miles downrange from the launch site. After SRB separation, the orbiter continues to ascend, using the three SSME's. The total load factor reaches a maximum value of 3.0 g's (longitudinal) at 415 seconds. It remains at that value until 470 seconds, when the main engine cutoff (MECO) sequence is initiated.

MECO takes place 478 seconds after lift-off, when the orbiter has reached an altitude of 361,400 feet. The external tank (ET) separation occurs at MECO. After a short coasting period, the orbital maneuvering system (OMS) engines are fired at 514 seconds to provide the additional velocity needed to insert the orbiter into an elliptical orbit having a minimum apogee of 150 nautical miles. The OMS engine cutoff occurs 648 seconds after launch at an altitude of 407,000 feet, when the orbiter is 1350 nautical miles from the launch site. Additional OMS burn at apogee is required to circularize or increase orbit altitude. Shuttle payload capability as a function of orbit altitude is presented on pages 49 to 56.

Descent Trajectory

The orbiter descent or entry trajectory provides lateral flight range to the landing site and energy management for an unpowered landing. Entry is initiated by a deorbit maneuver and retrofiring the OMS nominally 28 minutes prior to entry interface. The trajectory, lateral range, and heating are controlled through the attitude of the vehicle by angle of attack and bank angle. The angle of attack is established at 40 degrees for the theoretical entry interface of 400,000 feet altitude. The entry flight path angle is -1.18 degrees. The 40-degree angle of attack is held until the speed is reduced to 11,000 feet per second (about 170,000 feet altitude), then is reduced gradually to 13.5 degrees at 2500 feet per second (about 85,000 feet altitude). Tactical Air Navigation (TACAN) acquisition is accomplished at approximately 190,000 feet altitude and 650 nautical miles from the landing site.

During the final phases of descent, flight path control is maintained by using the aerodynamic surfaces. Terminal Area Energy Management (TAEM) is initiated to provide the proper vehicle approach to the runway with respect to position, energy, and heading. Final touchdown occurs at an angle of attack of about 8 degrees, with a nominal touch speed of 210 knots. The maximum landing speed for a 32,000-pound payload, including dispersions for hot day effects and tailwinds, is about 225 knots.

Typical Ascent and Descent Trajectory Profiles

ASCENT

TIME FROM LIFTOFF (SEC)

500 — 400 — 300 — 200 — 100 — 0

660
TO OPERATIONAL ALTITUDE

600
ORBIT INSERTION

540

480

420

360

300

240

180

120

60 LIFTOFF

STAGING

MECO & ET SEPARATION

OMS IGNITION

RANGE (NMI)
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500

ALTITUDE (1000 FT)

DESCENT

TIME FROM ENTRY INTERFACE (SEC)

400 — 300 — 200 — 100 — 0

250

500

750

1000

1200

1500

1800

TACAN ACQ

APPROACH & LANDING

TAEM

RANGE FROM ENTRY INTERFACE (NMI)
0 1000 2000 3000 4000 5000

Space Systems Group

Rockwell International

10SSV86980A   45

ORBIT ALTITUDE MAINTENANCE

Maintaining the orbiter at a reference circular orbit requires an orbit
adjustment maneuver to overcome the effects of aerodynamic drag and return
the orbiter to the reference orbit. The amount of orbital decay that can
be tolerated will determine the time required between orbit adjustment
maneuvers. The orbital decay rate is dependent upon the initial reference
orbit altitude selected. Estimates of the on-orbit velocity decrement
composition and altitude decrease resulting from atmospheric drag on the
orbiter in a free-drift mode of operation are illustrated on the opposite
chart. The chart shows which axis of the spacecraft is perpendicular to
orbit plane (POP) in the three attitude orientations. The ballistic
numbers (BN's) are based on a 200,000-pound (90,718 kilogram) orbiter
having a drag coefficient of 2.0.

ORBITER REFERENCE
COORDINATE SYSTEM

119SSV86981
(Text)

Orbit Altitude Maintenance

VELOCITY INCREMENT PER DAY (m/SEC)
VELOCITY INCREMENT PER DAY (FT/SEC)

X(POP) ±Y NADIR

X(POP) ±Z NADIR

Y(POP) ±Z NADIR

CIRCULAR ORBIT ALTITUDE (NMI)

CIRCULAR ORBIT ALTITUDE, (km)

INITIAL CIRCULAR ALTITUDE (km)
INITIAL CIRCULAR ALTITUDE (NMI)

Y (POP) ±Z NADIR

X(POP) ±Z NADIR

X(POP) ±Y NADIR

DECREASE IN ALTITUDE AFTER 1 DAY (km)

DECREASE IN ALTITUDE AFTER 1 DAY, Km
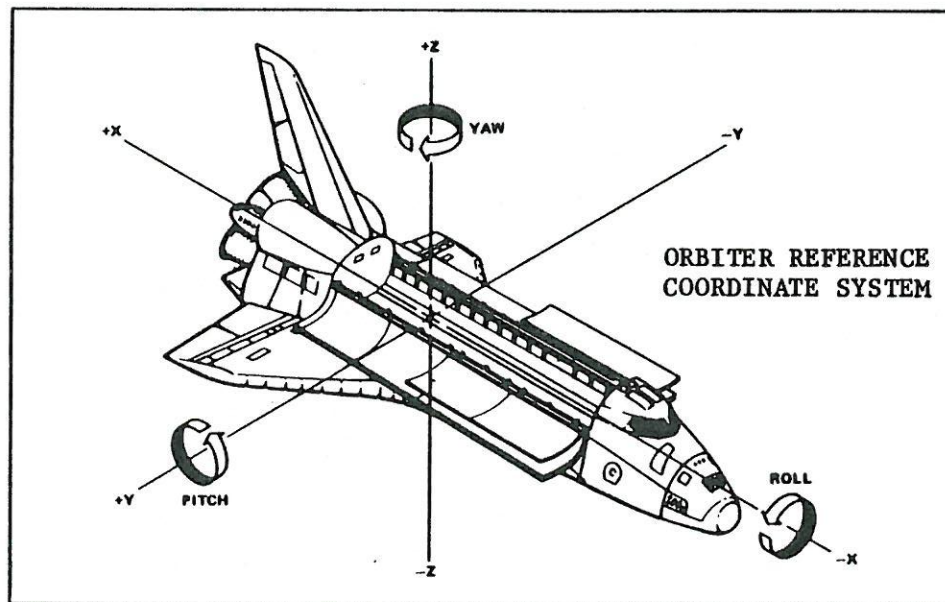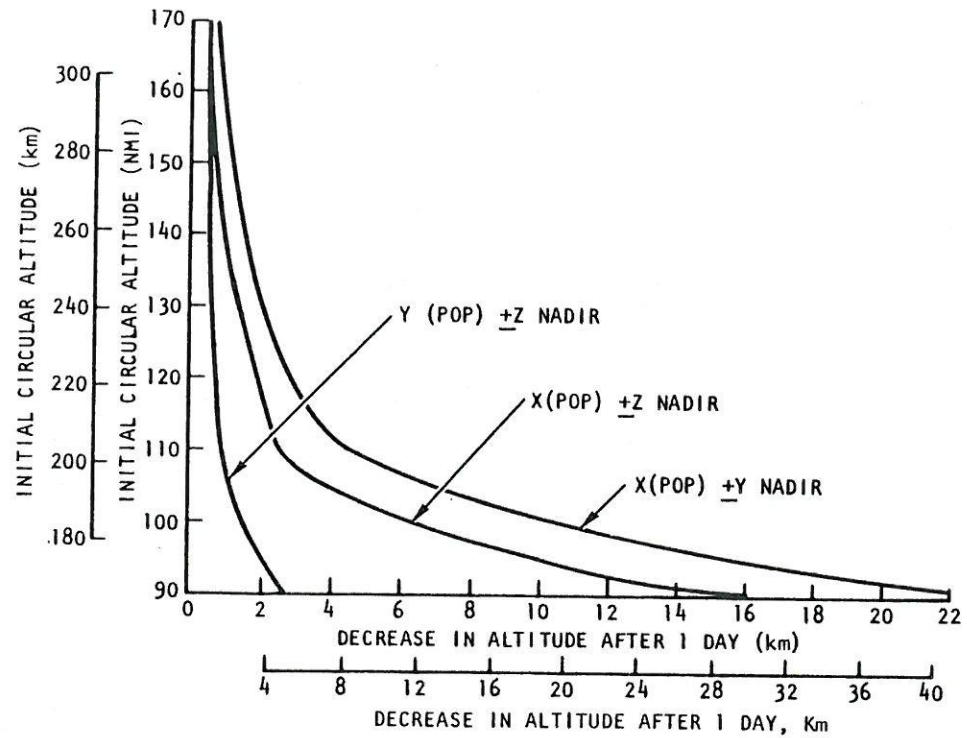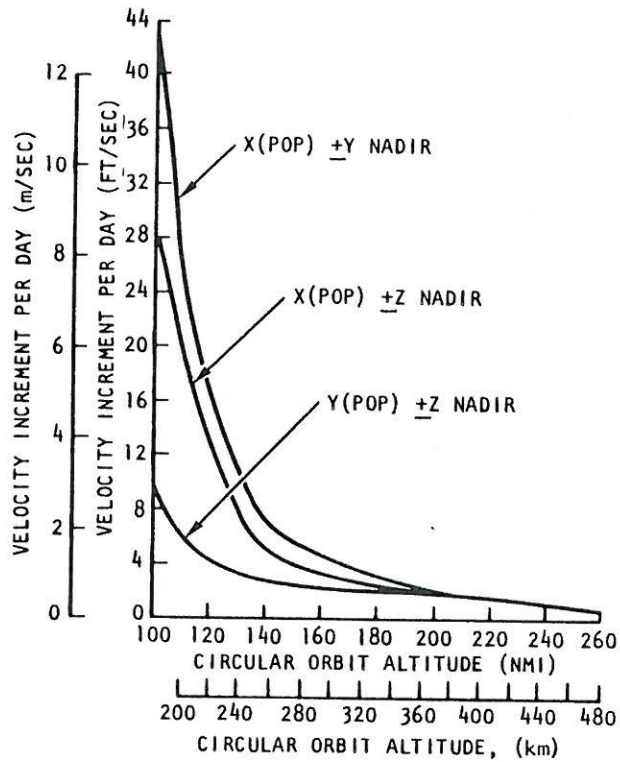
DRAG MAKEUP DELTA-V INCREMENT IN CIRCULAR ORBIT

EFFECTS OF DRAG ON THE ORBITER IN LOW-EARTH CIRCULAR ORBIT
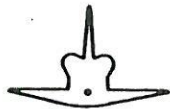
CROSS-SECTIONAL AREA
690 FT^2 (64.1 m^2)
Y(POP) ±Z NADIR
BN 145
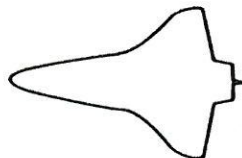
CROSS SECTIONAL AREA
3950 FT^2 (367 m^2)
X(POP) ±Y NADIR
BN 25

CROSS-SECTIONAL AREA
2290 FT^2 (212.7 m^2)
X(POP) ±Z NADIR
BN 45

The chart on the facing page shows the maximum payload weight that can be placed into circular orbit from Kennedy Space Center (KSC) as a function of placement orbit altitude and inclination. Launch azimuth and inclination limits are illustrated in the inset. The payload weights shown on the facing sheet are based on the SSV configuration used in the reference missions and on orbital maneuvers that are limited to a Hohmann transfer from apogee of a 50- by 100-nautical-mile ascent ellipse to the payload placement altitude, circularization at this altitude, and a direct descent deorbit maneuver. A 22-fps orbital reserve of OMS propellant is carried for contingency operations.

The capacity of the integral orbital maneuvering system (OMS) propellant tanks aboard the orbiter permits an empty orbiter to ascend to, and return from, an altitude of approximately 300 nautical miles. This altitude is reduced to approximately 225 anutical miles when the orbiter carries its maximum payload. During ascent, main engine cutoff (MECO) occurs when the orbiter is still at a suborbital velocity. The MECO location and velocity govern the impact geometry of the external tank (ET). OMS propellant is then used to complete the ascent. Low-inclination missions launched from KSC nominally require 100 fps from the OMS to attain the required orbital velocity.

Up to three sets of auxiliary tanks can be added in the cargo bay to permit the orbiter to carry a payload to, and then descend from, higher altitude circular orbits. The additional 12,400 pounds of propellant in each kit, plus the 2978-pound dry weight of the first tank kit installation, and the weights of the second and third kits, have been subtracted from the total payload capability, leaving as true payload the quantities shown on the facing chart. Note that this chart is for a placement mission only and does not provide for rendezvous with previously placed payload(s).
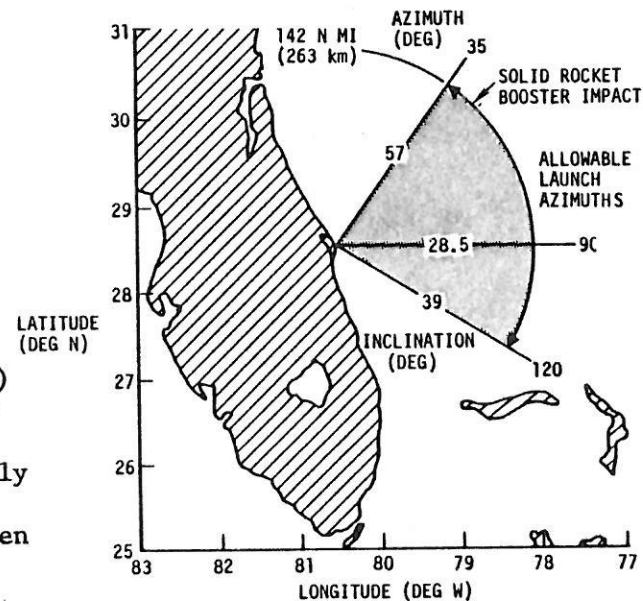
Payload to Circular Orbit
(KSC Launch)

Chart: Payload Weight (1000 LB) vs Circular Orbital Altitude (NMI)

NO RENDEZVOUS
OMS ΔV RESERVE = 22 FPS
OMS ΔV ASCENT = 100 FPS
RCS PROPELLENT LOADING = 3100 LB

INCLINATION, DEG
28.5
45
56

INTEGRAL OMS TANKAGE
FIRST OMS KIT LIMIT
SECOND OMS KIT LIMIT
THIRD OMS KIT LIMIT
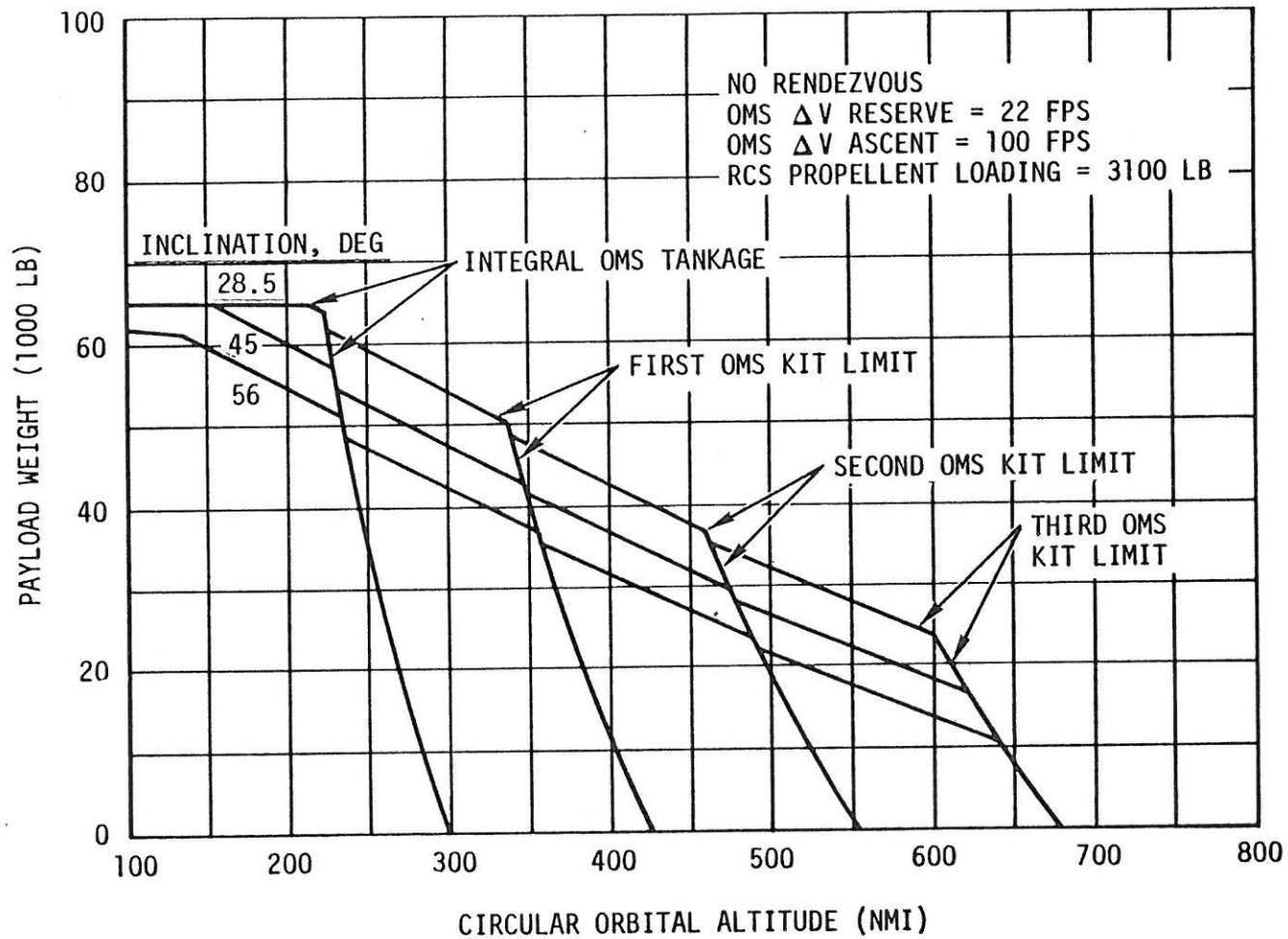
REF: PAGE 3-13 OF JSC 07700 VOL XIV

PAYLOAD TO CIRCULAR ORBIT—VAFB LAUNCH

The maximum discretionary payload weight that the Space Shuttle can deliver into circular orbit after launch from Vandenberg Air Force Base (VAFB) is less than that attainable by a launch from Kennedy Space Center (KSC). The primary reason for the difference in payload capability is the difference in launch azimuths required to attain higher orbital inclinations. Range safety constrains launch azimuths at VAFB to between 140 and 208 degrees, resulting in orbital inclinations of 56 to 110 degrees. Launches on these azimuths utilize less of the earth's rotational velocity vector in attaining orbital velocity, and therefore require a reduction in payload so that the Space Shuttle boost propulsion systems (solid rocket boosters and the Space Shuttle main engines/external tank) can provide the higher increment of velocity.

The facing chart describes Space Shuttle payload capability versus circular orbit altitude and as functions of orbital inclination and OMS kits. The OMS kits, described in the previous chart, will be used to increase the orbital altitude, but they require a decrease in payload. The chart is based on a Space Shuttle mission that delivers and places a payload (satellite) in orbit, or delivers a payload to orbit and returns that payload to earth. In other words, this figure does not allow for the additional propellants for the OMS and reaction control system that are required to perform a rendezvous with a satellite such as that for a service or retrieval mission. Payload capabilities for those service or retrieval missions are provided in the referenced document, "Payload Accommodations," Volume XIV of JSC 07700.

As shown in the inset, missions with inclinations between 56 and 70 degrees require analysis on an individual basis due to external tank disposal problems. The performance shown is "ideal"; for some inclinations in this range, substantial payload penalties may be required to obtain satisfactory tank disposal, and it is possible that some inclinations in this range cannot be flown.

20SSV86983A
(Text)

50

Payload to Circular Orbit
(VAFB Launch)

NO RENDEZVOUS
OMS ΔV RESERVE = 22 FPS
OMS ΔV ASCENT = 350 FPS
RCS PROPELLENT LOADING = 3100 LB

INCLINATION, DEG

56

60

75

90

104

INTEGRAL OMS TANKAGE

FIRST OMS KIT LIMIT

SECOND OMS KIT LIMIT

THIRD OMS
KIT LIMIT

PAYLOAD WEIGHT (1000 LB)

CIRCULAR ORBITAL ALTITUDE (NMI)
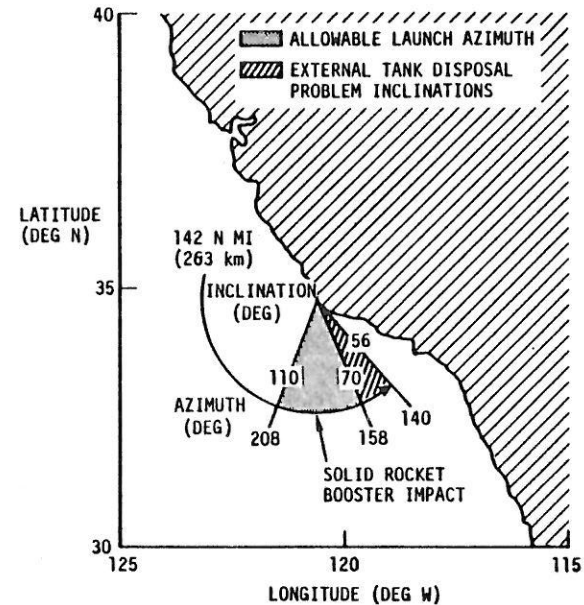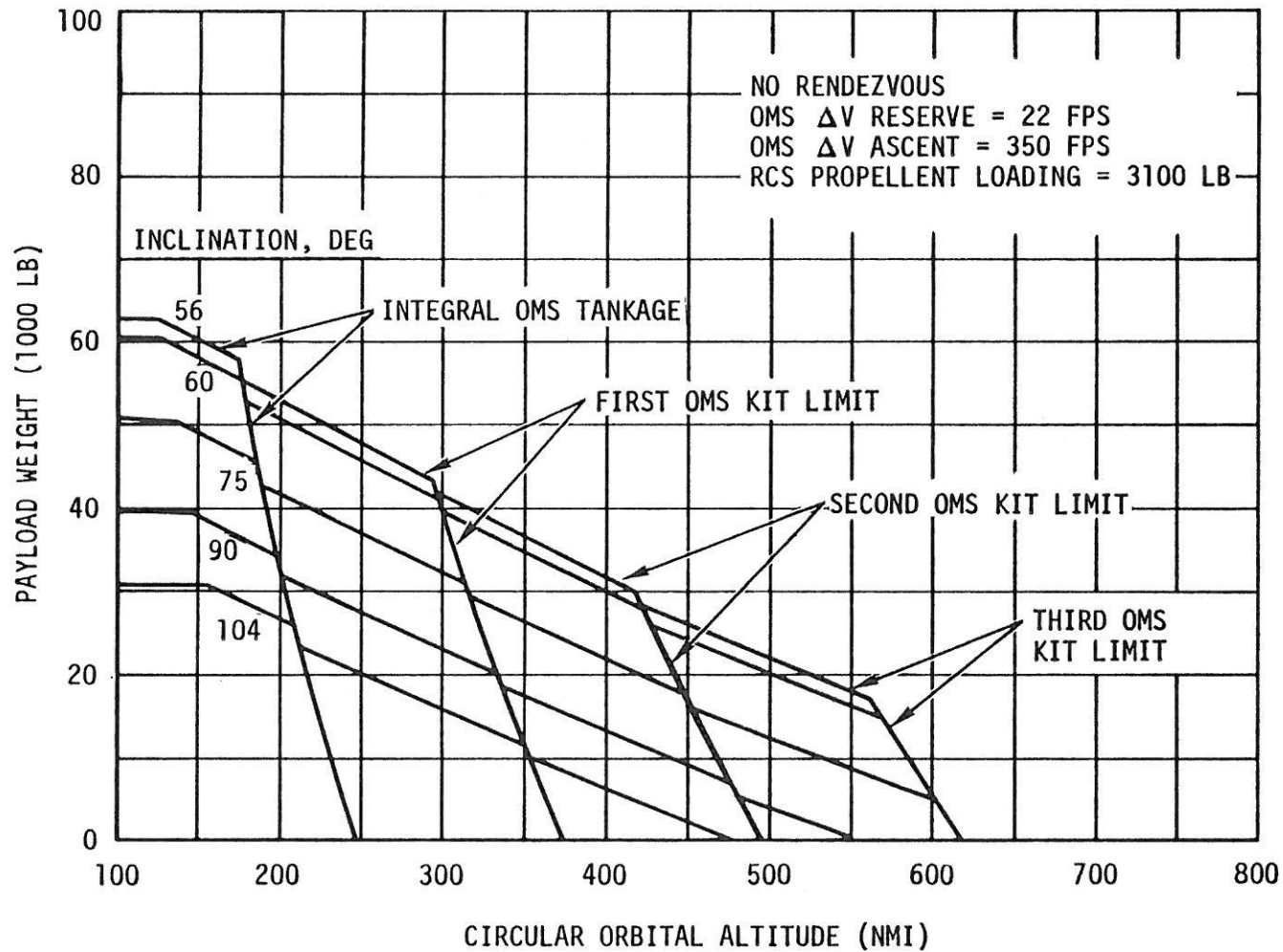
REF: PAGE 3-14 OF JSC 07700 VOL XIV

PAYLOAD TO ELLIPTICAL AND SUN SYNCHRONOUS ORBITS

The Space Shuttle payload capability to elliptical and sun synchronous orbit is illustrated on the chart as a function of orbital altitude, launch site, and orbit inclination.

Payload to Elliptical Orbit

A heavier payload can be delivered into an elliptical orbit than into a circular orbit of the apogee altitude. Elliptical orbit delivery is attractive when the Shuttle mission does not require retrieval of a payload, and the delivered payload requires the elliptical orbit or includes a propulsive stage.

The payload that can be placed in elliptical orbit as a function of apogee altitude and orbit inclination is shown with a perigee altitude of 100 nmi in all cases. Payload weights shown were developed by assuming; (1) a standard Shuttle ascent trajectory to 100 nmi and then a Hohmann transfer, with the orbital maneuvering system (OMS) engines, to deliver the orbiter to apogee of the payload release orbit, (2) direct deorbit from apogee of the elliptical orbit, and (3) transfer down to 100 nmi prior to deorbit. A two-impulse deorbit is required when it is necessary to recircularize at perigee altitude (100 nmi) prior to deorbit. The first burn reduces orbiter apogee to 100 nmi. The second burn causes the orbiter to deorbit from 100 nmi. The true altitude limit for direct entry is a function of orbit inclination, descent payload, and other variables.

The integral OMS propellant tanks aboard the orbiter carry only enough propellant to permit the orbiter to ascend to, and descend from, altitudes between 400 and 460 nmi. Ascent to and return from higher apogee altitudes require the use of auxiliary OMS propellant kits. Up to three sets of kits can be carried in the orbiter cargo bay.

Payload to Sun Synchronous Orbit

Both DOD and NASA have sun synchronous orbit payloads scheduled in the STS mission model. These missions are a special class of circular orbit missions, because there is a unique inclination for each circular orbit altitude. Sun synchronous missions have retrograde inclinations ranging from 96.3 degrees for a 100-nmi circular orbit to 99.2 degrees when the circular orbit altitude is 500 nmi.

The payload weight that can be launched from Vandenberg Air Force Base (VAFB) and placed in sun synchronous orbits of varying altitudes without use of a propulsive upper stage is shown with both the placement and replacement modes. The replacement mode includes the placement of a satellite and rendezvous/retrieval of a previously placed satellite, thus requiring more OMS propellant than for placement only.

At operating altitudes above 200 nmi, mission energy requirements exceed basic vehicle capabilities. Auxiliary kits for OMS propellant must be added to obtain the necessary energy. A second set of kits must be employed when mission operating altitude exceeds 340 nmi and with maximum capability payload.

Payload to Elliptical and Sun Synchronous Orbits

PAYLOAD TO ELLIPTICAL ORBITS

Legend:
- ——— DIRECT DEORBIT FROM APOGEE
- – – – DEORBIT AFTER CIRCULARIZATION TO PERIGEE
- NO RENDEZVOUS
- ON-ORBIT OMS ΔV RESERVE = 22 FPS
- RCS PROPELLANT LOADING = 3100 LB
- (N) OMS MISSION KITS ADDED

Y-axis: PAYLOAD WEIGHT (1000 POUNDS), 0 to 80
X-axis: APOGEE ALTITUDE (NMI), 0 to 2800

Curve labels:
- 28-1/2-DEG INCLINATION (KSC LAUNCH)
- 55 DEG (KSC)
- 104 DEG (VAFB)

PAYLOAD TO SUN SYNCHRONOUS ORBITS
(VAFB LAUNCH)

Y-axis: PAYLOAD WEIGHT (1000 POUNDS), 0 to 24
X-axis: SUN SYNCHRONOUS ORBITAL ALTITUDE (NMI), 200 to 520
Secondary X-axis: SUN SYNCHRONOUS INCLINATION (DEG): 96.9, 97.6, 98.3, 99.2

Legend:
- ——— DIRECT DEORBIT TO ENTRY
- PLACEMENT
- ON-ORBIT OMS ΔV RESERVE = 22 FPS
- RCS PROPELLANT LOADING = 3100 LB
- – – – REPLACEMENT
- ON-ORBIT OMS ΔV RESERVE = 42 FPS
- RCS PROPELLANT LOADING = 4900 LB
- (N) OMS MISSION KITS ADDED

REF:
PAGES 3-19, 20, 21 & 22 OF JSC 07700, VOL XIV

TYPICAL SPACE SHUTTLE/SSUS OPERATIONS

Among the spectrum of STS capabilities is the injection of Delta-class payloads from standard Shuttle orbits into high orbits by use of the Spinning Solid Upper Stage (SSUS). The SSUS is a simple, low-cost propulsion stage which obtains its directional stability gyroscopically through spinning rather than by means of an expensive guidance and attitude control system. Spin-up of the SSUS and its spacecraft payload is done mechanically prior to launch from the orbiter.

The SSUS-D system is mounted vertically and is small enough to permit as many as four in the cargo bay on one flight, and thus results in a substantial cost savings per spacecraft mission compared to expendable Delta launches. The SSUS-D itself is a private commercial development under a general agreement with NASA and is called a Payload Assist Module-Delta (PAM-D). The development includes necessary SSUS/orbiter supporting interface equipment such as interface electronics, structural support cradle, spin table and solar/EMI shield.

The SSUS-A, an upper stage developed for the Atlas launch vehicle, is larger than the SSUS-D and must be stowed horizontally in the orbiter. Prior to deployment, the SSUS-A is erected to a vertical position so that it can be deployed in the same manner as SSUS-D.

Shown on the chart is a typical timeline and trajectory for the transition from low earth orbit to geosynchronous orbit. After launch to standard circular orbit, the SSUS and its spacecraft are checked out (if required), pointed in the proper direction by the orbiter, spun up to required spin rate, and separated from the orbiter by means of springs. The orbiter then performs minor maneuvers to avoid subsequent interaction with the now-free spinning stage, and the SSUS perigee kick motor is fired at the proper time to inject the system into transfer orbit such as a geosynchronous (stationary) orbit. The expended SSUS propulsive stage is then separated so that the spacecraft can continue alone to ultimate destination orbit under ground tracking control. Upon arrival at apogee of the transfer orbit, an apogee kick motor in the spacecraft is fired to circularize the orbit and to make minor course corrections based on the ground tracking results.

Preliminary performance data is illustrated in the inset and shows payload weight in elliptical orbit as function of apogee altitude for both SSUS-A and SSUS-D upper stages. Payload weight to circular orbit would be reduced by the weight of the circularization propulsion required at apogee; i.e., the payload weight at geosynchronous altitude circular orbit is approximately one-half that shown.

ELLIPTIC ORBIT - PERIGEE ALTITUDE 160 NMI

54

Typical Space Shuttle / SSUS Operations

EVENT	ELAPSED TIME HOURS:MINUTES
LIFTOFF	00:00
STAGING, SOLID ROCKET MOTORS	00:02
MAIN ENGINE CUTOFF	00:08
ORBIT INSERTION & CIRCULARIZATION	00:45
OPEN CARGO BAY DOORS	01:00
FIRST CHECKOUT, HAWAII TRACKING STATION	01:18
SECOND CHECKOUT, HAWAII TRACKING STATION	02:53
SSUS CHECK, SPIN, & DEPLOYMENT	03:00
ORBITER VELOCITY 17 TO 25 FPS	03:03
START SSUS SEQUENCER, GOLDSTONE STATION	03:06
PERIGEE IGNITION, SSUS-D	03:45
SSUS-D/SPACECRAFT SEPARATION	
COAST PERIOD TO APOGEE 5.3 HOURS	09:15
APOGEE IGNITION, PAYLOAD	09:15

MAJOR MISSION EVENTS

160 NAUTICAL MILES TO SYNCHRONOUS ORBIT
BY SOLID SPINNING UPPER STAGE (SSUS)

SHUTTLE LAUNCH TO 28.5 DEG INCLINATION

GROUND TRACKS TO EARTH SYNCHRONOUS ORBIT
ORBITER/SSUS
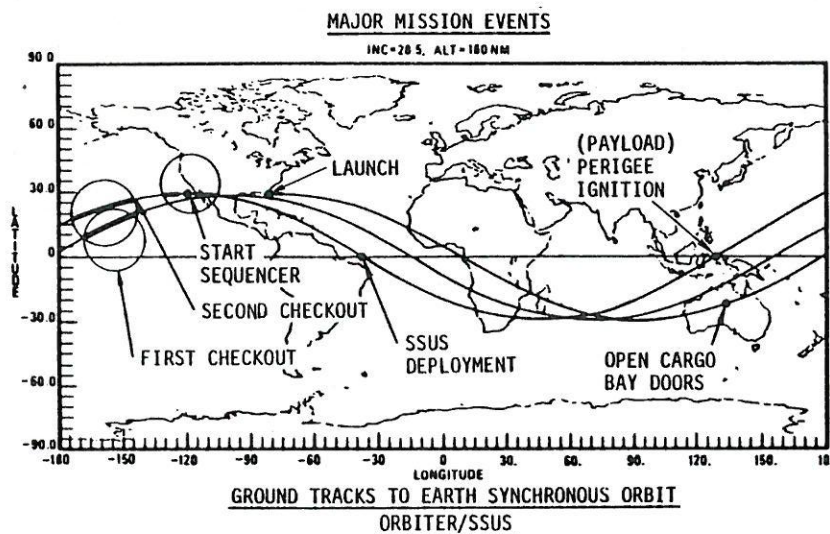
TYPICAL SPACE SHUTTLE/IUS OPERATIONS

The Inertial Upper Stage (IUS) serves as an upper stage of the STS system, boosting payloads from Shuttle low earth orbits to higher operational orbits. The IUS comes in at least two versions, a 2-stage and a 3-stage upper stage system. Shown here is a typical timeline and trajectory for the transition from low earth orbit to geosynchronous orbit for a typical 2-stage IUS.

The IUS currently being developed by the Boeing Company is a solid rocket upper stage vehicle designed for delivering a multitude of payload weights to a variety of higher energy orbits. This is accomplished by using various standard motor combinations.

The 2-stage IUS has the capability of boosting 5000 pounds to geosynchronous orbit. Although it is anticipated that a majority of the IUS missions will be to geosynchronous orbit, the IUS will also have the capability to deliver heavy payloads to intermediate orbit; i.e., nominal 12-hour, 350-by 21,450-nmi eliptical orbit. Still another version of the IUS will be used as the injection stage for interplanetary missions.

Preliminary IUS performance data are illustrated in the inset and show payload weight in circular orbit as function of altitude for both a 2-stage and 3-stage IUS at a 28-1/2-degree inclination orbit. Payload weight for an equatorial inclination for the 2-stage IUS is presented for reference.

Typical Space Shuttle / IUS Operations

ORBITER CHECKOUT OVER TRACKING STATIONS

ORBITER MANEUVERS & IUS DEPLOYMENT
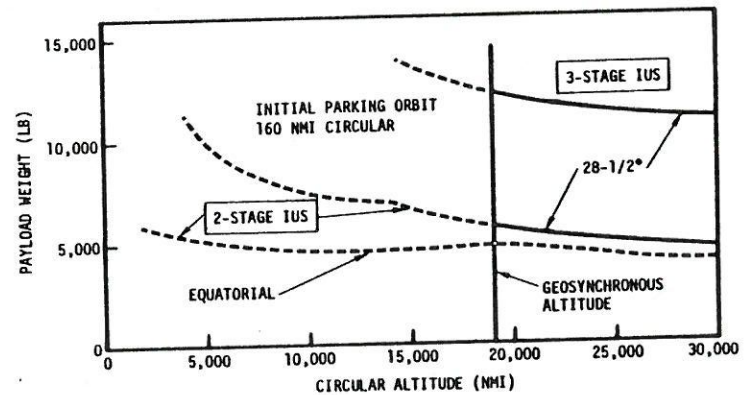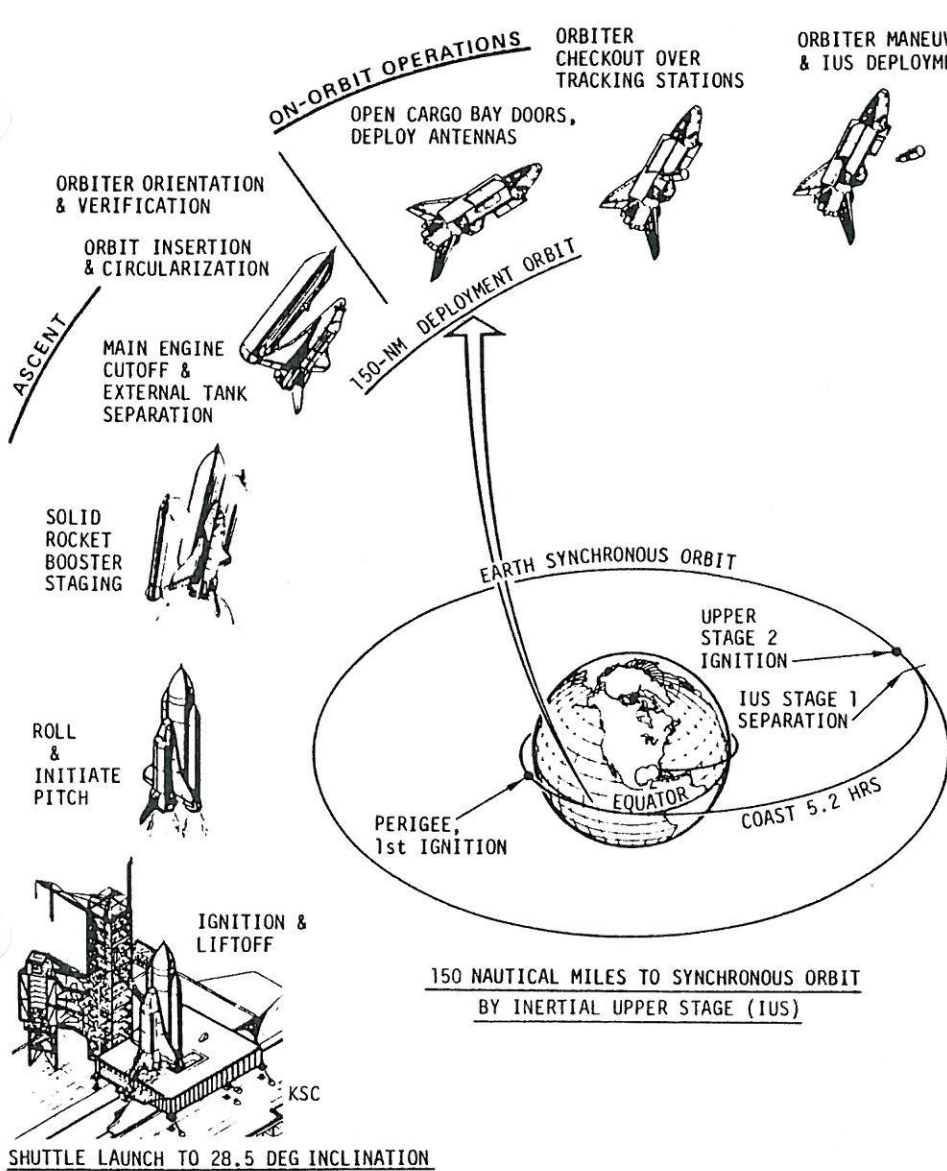
ORBITER-SSUS SEPARATION, VELOCITY/ALTITUDE CHANGE, & SAFETY MANEUVERS

IUS IGNITION

ON-ORBIT OPERATIONS

OPEN CARGO BAY DOORS, DEPLOY ANTENNAS

45-MINUTES (NOMINAL COAST)

ORBITER ORIENTATION & VERIFICATION

ORBIT INSERTION & CIRCULARIZATION

150-NM DEPLOYMENT ORBIT

ASCENT

MAIN ENGINE CUTOFF & EXTERNAL TANK SEPARATION

SOLID ROCKET BOOSTER STAGING

EARTH SYNCHRONOUS ORBIT

ROLL & INITIATE PITCH

UPPER STAGE 2 IGNITION

IUS STAGE 1 SEPARATION

EQUATOR

COAST 5.2 HRS

PERIGEE, 1st IGNITION

IGNITION & LIFTOFF

150 NAUTICAL MILES TO SYNCHRONOUS ORBIT BY INERTIAL UPPER STAGE (IUS)

KSC

SHUTTLE LAUNCH TO 28.5 DEG INCLINATION

EVENT	ELAPSED TIME HOURS:MINUTES
LIFTOFF	00:00
STAGING, SOLID ROCKET MOTORS	00:02
MAIN ENGINE CUTOFF	00:08
ORBIT INSERTION & CIRCULARIZATION	00:45
OPEN CARGO BAY DOORS	01:00
FIRST CHECKOUT, HAWAII TRACKING STATION	01:18
SECOND CHECKOUT, HAWAII TRACKING STATION	02:53
IUS DEPLOYMENT, ORBITER SEPARATION	04:09
START IUS SEQUENCER, HAWAII STATION	04:54
FIRST IGNITION, IUS (PERIGEE)	04:56
VELOCITY, & ATTITUDE CORRECTIONS, COAST (5.2 HOURS)	10:15
SECOND IGNITION, IUS (APOGEE)	10:15

MAJOR MISSION EVENTS

INC=28.5, ALT=160 NM

LAUNCH

ORBITER CIRCULARIZATION

START SEQUENCER

IUS DEPLOYMENT

IUS PERIGEE IGNITION

IUS APOGEE SECOND IGNITION SECOND CHECKOUT

OPEN CARGO BAY DOORS

FIRST CHECKOUT

LONGITUDE
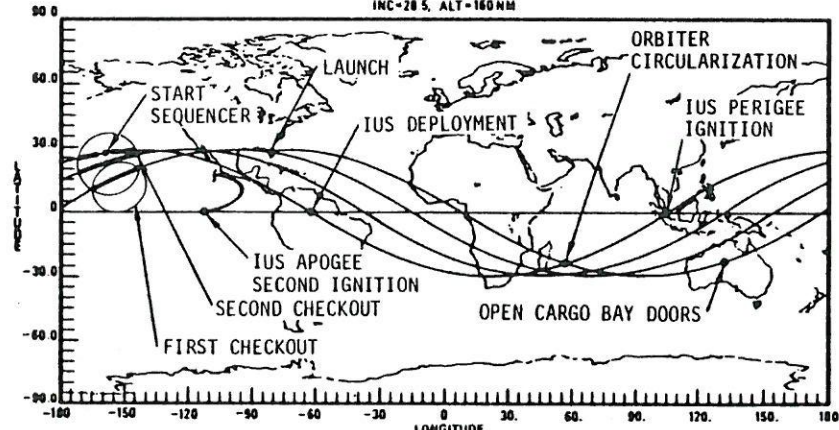
GROUND TRACKS TO EARTH SYNCHRONOUS ORBIT ORBITER/IUS

Space Systems Group

Rockwell International

20SSV66671C

57

SPACELAB AND LDEF PAYLOAD MOUNTING

The potential methods of mounting payload equipment to Spacelab pallets and modules and Long Duration Exposure Facility (LDEF) can be seen from this chart. (Mounting of spacecraft to upper stages and MMS is be conventional-type transition rings and is not shown.)

Payload mounting loads for pallet-mounted equipment are taken at ball and socket hardpoints at each main structural intersection as shown in the chart. Light items of a few pounds can be mounted to the skin sandwich panels. Standard cold plates are available for the mounting bases of payloads. Payload volume "above" the pallet is dictated by the 15-foot diameter orbiter cargo bay envelope.

The Spacelab modules have two double racks and one single equipment rack, for standard 19-inch wide panels, on each side. The two forward racks on each side of the core module are used for Spacelab subsystems. Equipment can also be mounted beneath the floor. Custom shapes can be bolted to the top of the floor, either in the aisle or in the place of a standard single or double rack. A total of 268 cubic feet is available in the core module and 516 cubic feet in the experiment module for payload equipment. The opening in the roof may accommodate a window for optical observations from within the module or an airlock for projecting equipment out into space and retracting it when desired.

The LDEF is a passive, gravity gradient stabilized structure that holds self-contained experiments in trays mounted as part of the LDEF surface. Tray dimensions are shown in the chart. LDEF, which is managed by NASA, Langley RC, can accommodate 72-trays around the periphery and several on each end. A variety of methods can be used to fasten small items or full-sized packages in the trays. The LDEF, which is a passive system, is to be deployed into a 28-1/2-degree inclination orbit using the remote manipulator system (RMS). As a result, payloads/experiments on the LDEF must provide any special service they may require, such as power, data gathering, etc., for six months or longer. Retrieval of the LDEF from orbit is planned utilizing the RMS.

20SSV65233B
(Text)

Spacelab and LDEF Payload Mounting

INNER SKIN SANDWICH PANEL

PAYLOAD MOUNTING HARDPOINTS (TYP)

SILL

LONGERON (TYP)

KEEL

ORBITER ATTACHMENT FITTING

OUTER SKIN SANDWICH PANEL

SPACELAB PALLET

X-AXIS

LONG DURATION EXPOSURE FACILITY (LDEF)

AIRLOCK OR OPTICAL WINDOW

STANDARD 19 IN. RACKS

CREW TUNNEL ACCESS

UNDER FLOOR PAYLOAD VOLUME

SPACELAB MODULE (TYPICAL INSTALLATION SHOWN)

X-AXIS

50 IN. (127 CM)

3, 6, OR 12 IN.

38 IN. (96.5 CM)

175 LB MAX PAYLOAD MASS PER TRAY

EXPERIMENT TRAY

PAYLOAD DESIGN FOR SHARED CARGO OPERATIONS

The majority of STS users will have payload sizes that do not require the full orbiter cargo bay space. The facing chart illustrates a combined cargo arrangement ("cargo" means the combination of all carrier/ payloads and dedicated support items such as OMS kits and cabling). Such payloads may thus share Shuttle flight costs.

Multiple payloads can be mounted on some STS carriers (e.g., Spacelab) to take advantage of further costs and schedule savings. A listing of the choices of standard carriers is shown at the bottom of the chart. Payloads mounted to the carriers generally make all physical interfaces with the carrier. The carrier will receive an allocation of resources from the orbiter, which will be reallocated to the constitutent payloads. Some carriers also provide additional services not directly taken from the orbiter. Added services can include computer control, data handling and storage, and battery power. For some orbiter services, the carrier may act only as a conduit for getting the service to a payload. It can be seen that the resources and services available to a carrier-mounted payload depend upon the number and kinds of payloads on the carrier, the carrier subsystem needs, the carrier-provided services, and the orbiter allocations to the carrier.

To assure adequate support for all payloads on an orbiter while efficiently utilizing available cargo space, advance planning is required to define payload design parameters. While there is considerable flexibility for payload design, there are significant tradeoffs that should be considered regarding ease of obtaining desired flights and reflights, ability to share flight costs, and the utilization of orbiter/carrier services in a cost-effective manner. Additional information on these trades can be obtained from the STS User Service Center.*

Some payloads interface directly with the orbiter, and must provide their own cradles or mounting pro- visions to the orbiter. These equipments, as shown in the right-hand side payload, are then considered part of the payload.

Nominal allocation of orbiter resources will be based upon weight and size. Deviations from nominal allocations will require special arrangements with the STS mission integration planners.

*Telephone: (213) 922-3344 or TWX 910-583-1407 NR, SD, Dny

Payload Design for Shared Cargo Operations

TYPICAL STS CARGO

PAYLOADS

CARGO BAY

SPACELAB
PALLET

SSUS

CARRIERS

SERVICES AVAILABLE FROM ORBITER
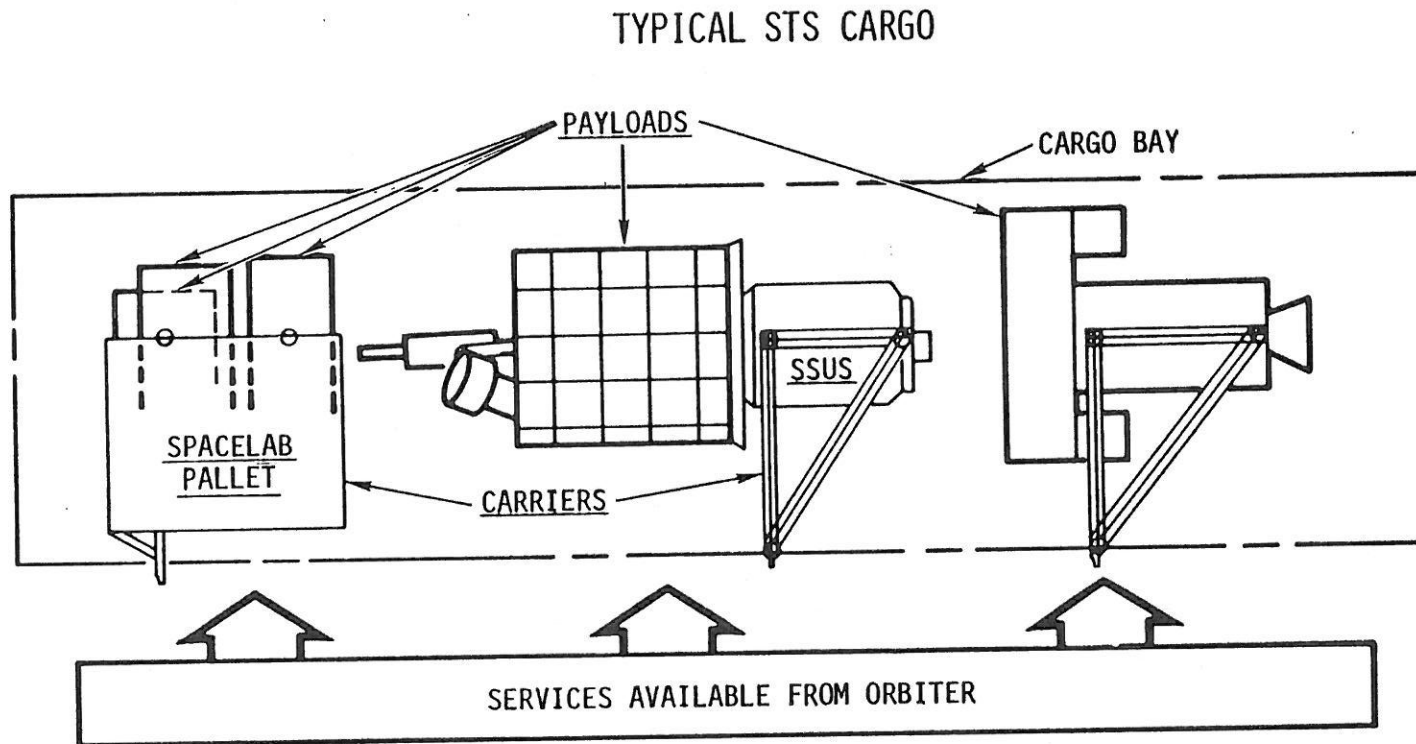
STANDARD STS CARRIERS

- IUS
  - 2-STAGE
  - TWIN STAGE
  - 3-STAGE

- SSUS - A
  SSUS - D

- SPACELAB
  - MANNED MODULES - 1 OR 2 SEGMENTS
  - SPACE EXPOSED PALLETS - 1, 2, 3, 4, OR 5 PALLETS

- LDEF

- MMS
  - PROPULSION MODULE OPTIONS
  - ON-ORBIT MODULE EXCHANGE SYSTEM

PAYLOAD/STS INTEGRATION PROCESS

Payload design or adaptation to the Shuttle system requires coordination with carrier and/or Shuttle cargo mission planners and integrators to assure that the necessary flight support services will be available for the desired mission period and that the payload and its unique ground and flight support equipment are compatible with Shuttle/carrier and STS ground facilities.

The facing chart is representative only. The STS operator (STSO) and integrators begin formal interface monitoring and verifications after the system design approach is finalized. Prior to this, the payload agency and STSO will make necessary contractual agreements on basic payload characteristics, on Shuttle services to be provided, and on safety and compatibility verification requirements. The payload agency may seek assistance from the STS User Service Center* to select the appropriate carrier and to define optimum payload design requirements that assure adequate flight and reflight opportunities with minimum payload and mission complexity (cost).

Once a carrier has been selected, the payload agency must coordinate with the carrier integrator to assure compatibility with the carrier and other payloads on it. The carrier integrator and/or the payload agency must also coordinate with the Shuttle cargo integrator to assure that integrated carrier/payloads operations can be accommodated, i.e., that an appropriate integrated mission plan and cargo manifest are defined to meet the payload mission support requirements. Payload agencies having dedicated carrier/Shuttle flights can handle proportionally more of the compatibility analysis themselves. The payload/carrier agency will need to show evidence to the STSO that the payloads are safe and that physical integration with Shuttle can be accomplished without serious disruptions.

Safety reviews are scheduled to assure that the payload basic design premises are acceptable, that actual payload and carrier/payload design and operations are safe, and that combined Shuttle cargoes are safe.

*Telephone: (213) 922-3344 or TWX 910-583-1407 NR, SD, Dny

Payload / STS Integration Process

- PAYLOAD AGENCY INTERFACES WITH:

  - CARRIER

  - OTHER EXPERIMENTS ON SAME CARRIER

  - OTHER PAYLOADS ON SAME ORBITER FLIGHT

  - ORBITER

- SAFETY REVIEWS:

3 TO 4 YEARS (TYPICAL)

LAUNCH

| PRELIM DESIGN | DESIGN ANALYSIS | INSTL & CHECKOUT |

| DESIGN ANALYSIS | INSTL & CHECKOUT |

| DESIGN & OPNS ANALYSIS | INSTL & CHECKOUT |

| PRELIM DESIGN | COMPATIBILITY ANALYSIS | VERIFICATION ANALYSIS | INSTL & CHECKOUT |
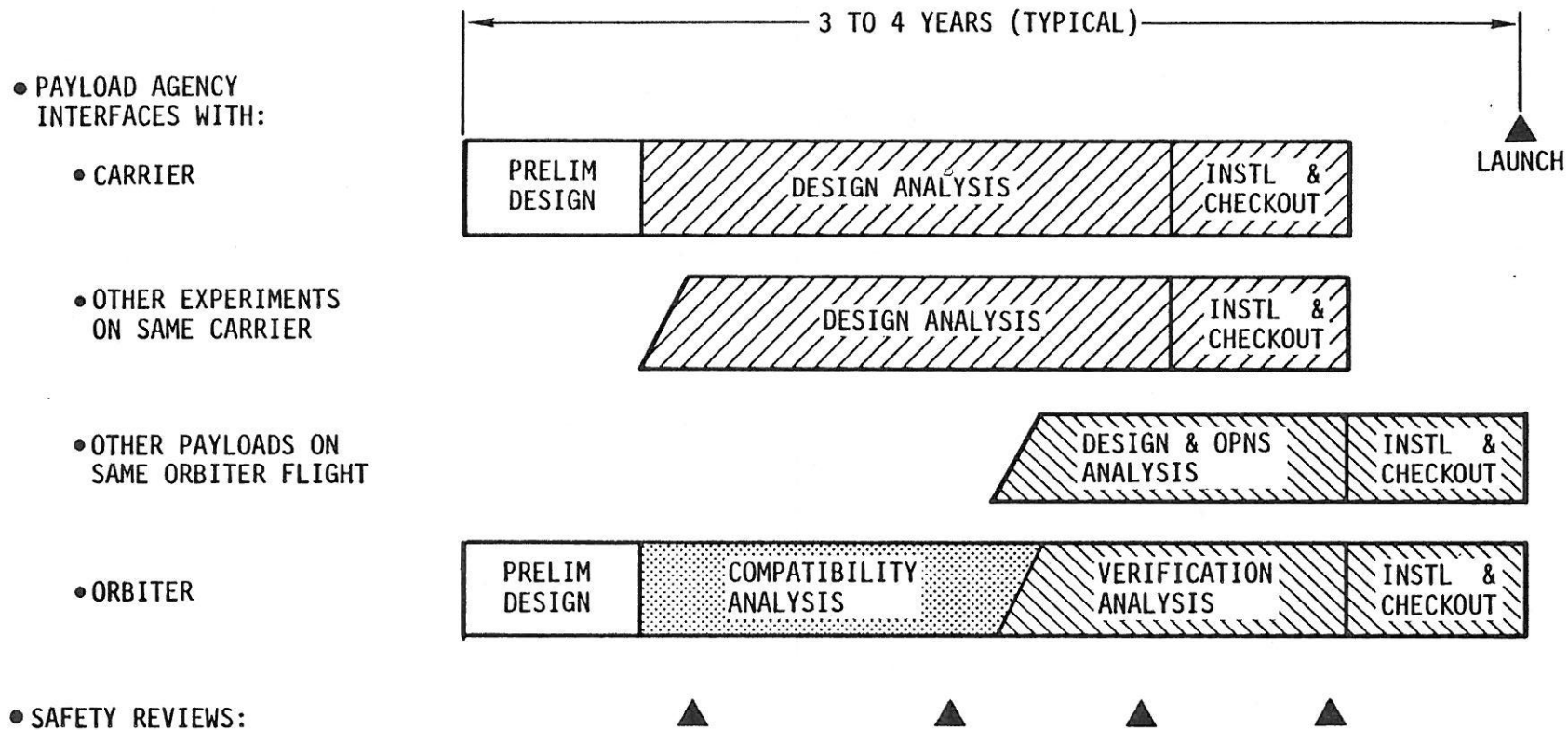
CODE:

- INTEGRATION BY CARRIER INTEGRATOR
- INTEGRATION BY CARGO INTEGRATOR/SPACE TRANSPORTATION SYSTEMS OPERATIONS (STSO)
- PAYLOAD RESPONSIBILITY WITH STSO ASSISTANCE

TYPICAL SHUTTLE FEE DETERMINATION

The facing chart is a Rockwell International interpretation of data contained in NASA documentation. The "Space Transportation System User Handbook" by NASA, dated June 1977, shows the "price per dedicated Shuttle flight" as 19.0 to 20.9 million dollars (in Fiscal Year 1975 dollars) for non-U.S. Government users of Shuttle. The payload capability of that dedicated flight is a function of the inclination and altitude as shown in several previous charts.

Quoting from that same document, "For a payload that will not require an entire flight capability and that can share the cargo bay with others, the cost to the user will be a fraction of the dedicated flight price, calculated as follows:

1. The payload weight is divided by the Shuttle weight capability at the desired inclination to find the weight load factor. The figures shown as examples are for a 160-nautical-mile (296-kilometer) orbit.

Inclination, degrees	Weight Capability, lb (kg)
28.5	65,000 (29,484)
56	57,000 (25,855)
90	37,000 (16,783)
104	30,000 (13,608)

2. The payload length is divided by the length of the cargo bay, 60 feet (18.29 meters), to find the length load factor.

3. The load factor (length or weight, whichever is greater) is divided by 0.75 to determine the cost factor.

4. The calculated cost factor is multiplied by the price of a dedicated Shuttle flight (for the user's class) to determine the price for that payload."

119SSV65231B
(Text)

Typical Shuttle Fee Determination
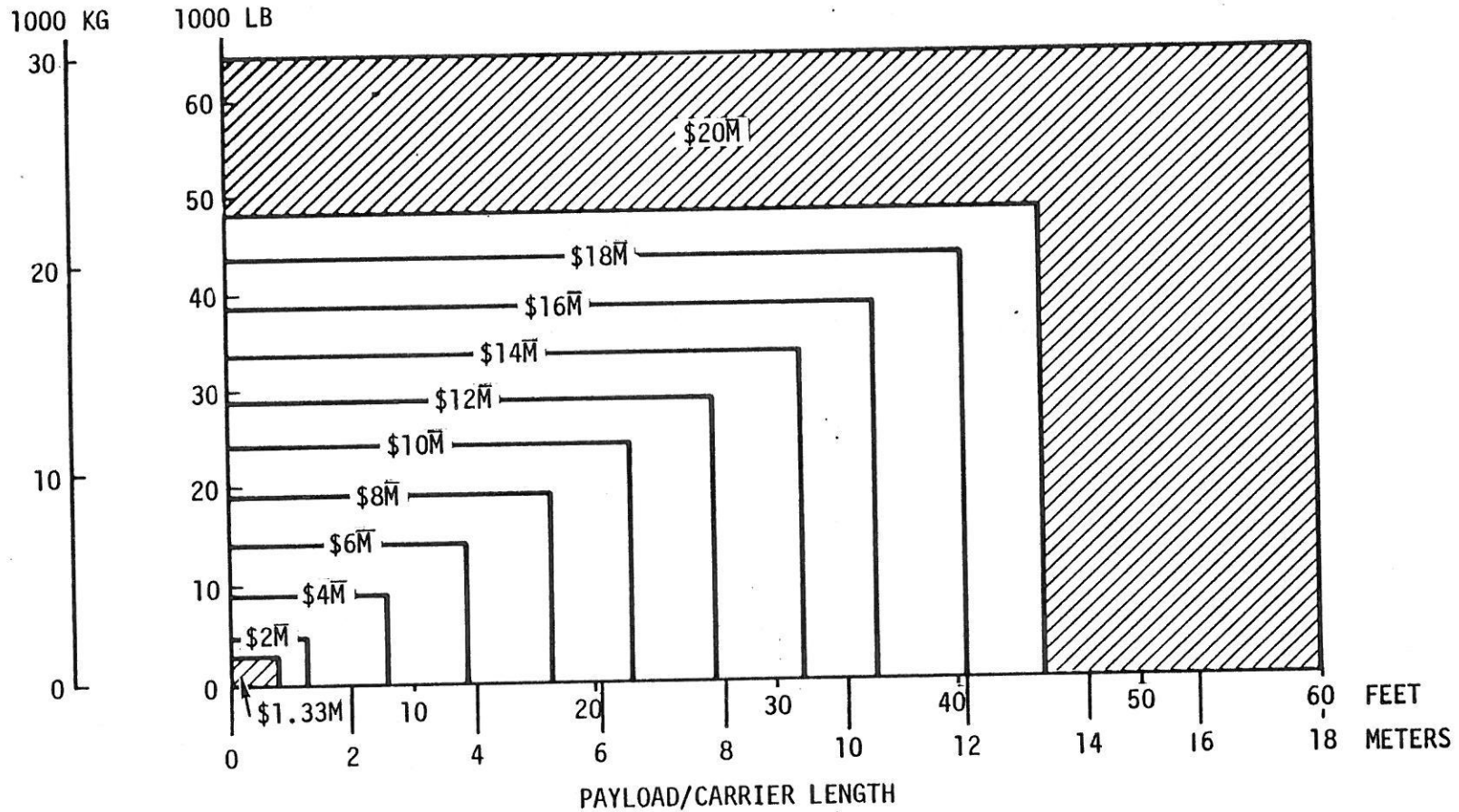
1. BASED ON 1975 $, $20\overline{M}$ PER SHUTTLE FLIGHT, AND A KSC EASTWARD LAUNCH
2. DOES NOT INCLUDE COST OF CARRIERS OR EXTRA SERVICES
3. MULTIPLE CARRIER MOUNTED PAYLOADS ARE CHARGED A PRORATA SHARE OF CARRIER LENGTH/WEIGHT

SPACE SHUTTLE MAJOR CONTRACTORS

The Space Shuttle System consists of the space flight hardware (orbiter, external tank, and solid rocket booster) and the ground support (maintenance, assembly, launch, landing, tracking, communications, control, training, and logistics) facilities, equipment, and personnel. The facing chart shows the major contractors that support NASA in the design and fabrication of the system.

Rockwell International, the contractor for the orbiter vehicle, is also the contractor for the integration of the system. The other major contractors are noted as are the states in which those contractors conduct their business.

10SSV87995
(Text)

Space Shuttle Major Contractors

VEHICLE INTEGRATION & ORBITER

ROCKWELL - SPACE SYSTEMS GROUP, CA

- 21 SUBCONTRACTS OVER $10M̄
- 62 SUBCONTRACTS $1-10M̄
- 228 SMALLER SUBCONTRACTS (JAN 1, 1976 STATUS*)

MAIN ENGINES

ROCKWELL - ROCKETDYNE DIV CALIFORNIA

- CONTROLLER - HONEYWELL: MINN & FLA
- HYDRAULIC ACTUATORS - HYDRAULIC RESEARCH: CAL

EXTERNAL TANK

MARTIN-MARIETTA LOUISIANA

- INTERTANK STR - AVCO: TENN
- TOOLING - LTV: TEX
- GORES & OGIVES - AIRCRAFT HYDROFORMING: CAL
- LH_2 BARREL PANELS - REYNOLDS METAL: ILL

SOLID ROCKET BOOSTER

MSFC

- SOLID ROCKET MOTOR - THIOKOL: UTAH
- AVIONICS - BENDIX: NEW JERSEY
- RECOVERY - MARTIN-MARIETTA: COLO.
- ASSEMBLY - UNITED SPACE BOOSTER: ALA

OTHER MAJOR CONTRACTORS

- KSC DESIGN ENGINEERING & SUPPORT - PRC: FLA
- LAUNCH PROCESSOR SYSTEM SOFTWARE DEVELOPMENT - IBM: NY
- ENGINEERING OPERATIONS SUPPORT - MDAC: MO
- CARRIER AIRCRAFT - AMERICAN AIRLINES: OKLA
- ORBITER SOFTWARE PROGRAMMING - IBM: TEX
- SHUTTLE TRAINING AIRCRAFT - GRUMMAN: NY

*SOME CONTRACTS INVOLVE MULTIPLE ITEMS

SPACE SHUTTLE PROGRAM MILESTONES

This chart shows the key milestones of the Space
Shuttle Program, starting with the authority to pro-
ceed in 1972 to the initial operational capability
in 1982. The blacked-in symbols are completed
actual dates: System Requirements Review in 1973,
Orbiter 101 Preliminary Design Review in 1974, the
Orbital Flight Preliminary Design Review completed
in February 1975; the first orbiter (101) rolled
out of final assembly (Palmdale, California) in
September 1976; after horizontal ground vibration
tests, Orbiter 101 was loaded on the carrier
aircraft at Dryden Flight Research Center, Edwards
Air Force Base, and completed the first captive
flight in February 1977; the first air launch of
Orbiter 101 for the approach and landing test (ALT)
took place on August 12, 1977; and the final ALT
flight was completed successfully on October 26,
1977 (see inset photograph). Orbiter 101 was
delivered to MSFC for mated vertical ground vibra-
tion testing on March 13, 1978, and then to KSC on
April 10, 1979, where it was used as a facilities
checkout vehicle. It was subsequently returned to
Dryden Flight Research Center on August 16, 1979, for further testing.
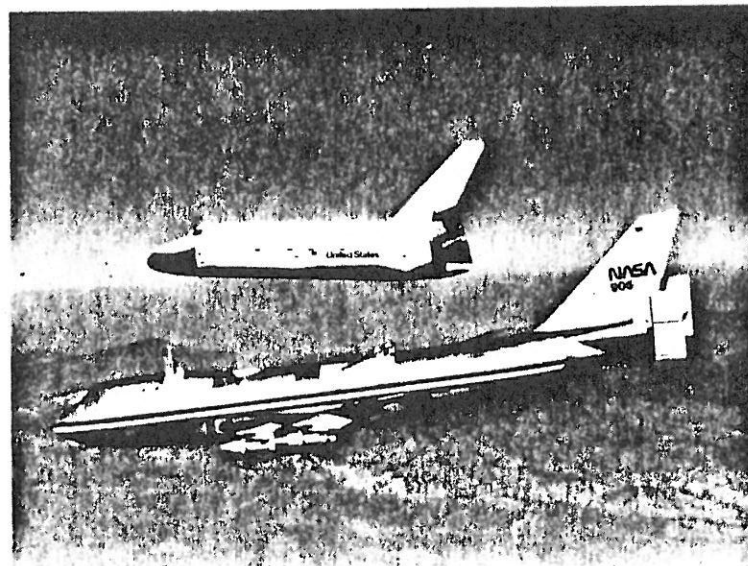
Orbiter 102 fabrication/assembly started in 1975 and rollout at Palmdale completed in March 1979. It was
delivered to KSC in March 1979. Following checkout and mating with the other Shuttle elements, it will
be used for the flight readiness firing test and launched as the first manned orbital flight of the
Shuttle in March 1981. The first four orbital flights of the Shuttle are development/test flights, and
the fifth flight in September 1982 is considered the initial operational capability flight.

The structural test article (STA) is currently being converted to an operational flight vehicle (OV 099);
completion of the static structural tests were completed in November 1979. The OV 099 will be delivered
as the first follow-on orbiter in June 1982. Orbiters 103 and 104 are scheduled for production delivery
in 1983 and 1984, respectively. Orbiter 101 will be modified to participate in VAFB activation. After
it has completed all of the testing required it will be delivered to VAFB in 1983.

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Space Shuttle Program Milestones

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
AUTHORITY TO PROCEED	▲ AUG													
SYSTEM REQ REVIEW		▲ AUG												
OV 101 PRELIM DES REV (PDR)			▲ FEB											
ORBITAL FLT PDR			▲ FEB											
OV 101 ASSY & ROLLOUT					▲ SEP									
FIRST CAPTIVE FLT						▲ FEB								
APPROACH & LANDING TEST						▲ AUG								
OV 102 ASSY & ROLLOUT							▲ MAR							
OV 102 OPF ROLLOUT									△					
FIRST MANNED ORBITAL FLT									△					
INIT OPNL CAPABILITY											△			
OV 099 ASSY & ROLLOUT											△			
OV 103 ASSY & ROLLOUT													△	
FIRST VAFB LAUNCH (OV 102)													△	
OV 104 ASSY & ROLLOUT														△

Space Systems Group   Rockwell International

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NATIONWIDE INVOLVEMENT IN SPACE SHUTTLE PROGRAM

More than 50 percent of the contract dollars for the Shuttle program are subcontracted by Rockwell to other business firms. Today's cost and schedule status on the Shuttle program differs very little from the goals set more than five years ago when the contract was awarded. This position is a credit to NASA, Rockwell, and the Shuttle industrial team management skills.

The chart on the opposite page shows the geographic distribution of major subcontracts managed by Rockwell throughout the United States and the major Shuttle element contractors as indicated in the legend below:

CONTRACTOR LEGEND

1. Radar Altimeter   Honeywell
2. SRM Case Forging   Ladish
3. Display Driver   Collins
4. APU   Sundstrand
5. SRM   Thiokol
6. ET   Martin Marietta, Denver
7. OMS Pod   McDonnell Douglas
8. ET Intertank Structure   AVCO
9. MDM   Sperry Rand
10. White Sands Test Facility
11. Cargo Bay Doors   Rockwell Tulsa Division
12. LESS   Vought
13. ET   Martin Marietta, Michoud
14. Marshall Space Flight Center (MSFC)
15. Filament Wound Tanks   Brunswick
16. Titanium Tubing   Zirtec Corp.
17. Oxidizer for SRM Propellant   Kerr McGee
18. Orbiter Reusable Surface Insulation   Lockheed
19. Frequency Division Multiplexer   Avdin Vector Corp.

  ● Location of Additional Contractors

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(Text)

Nationwide Involvement in Space Shuttle Program
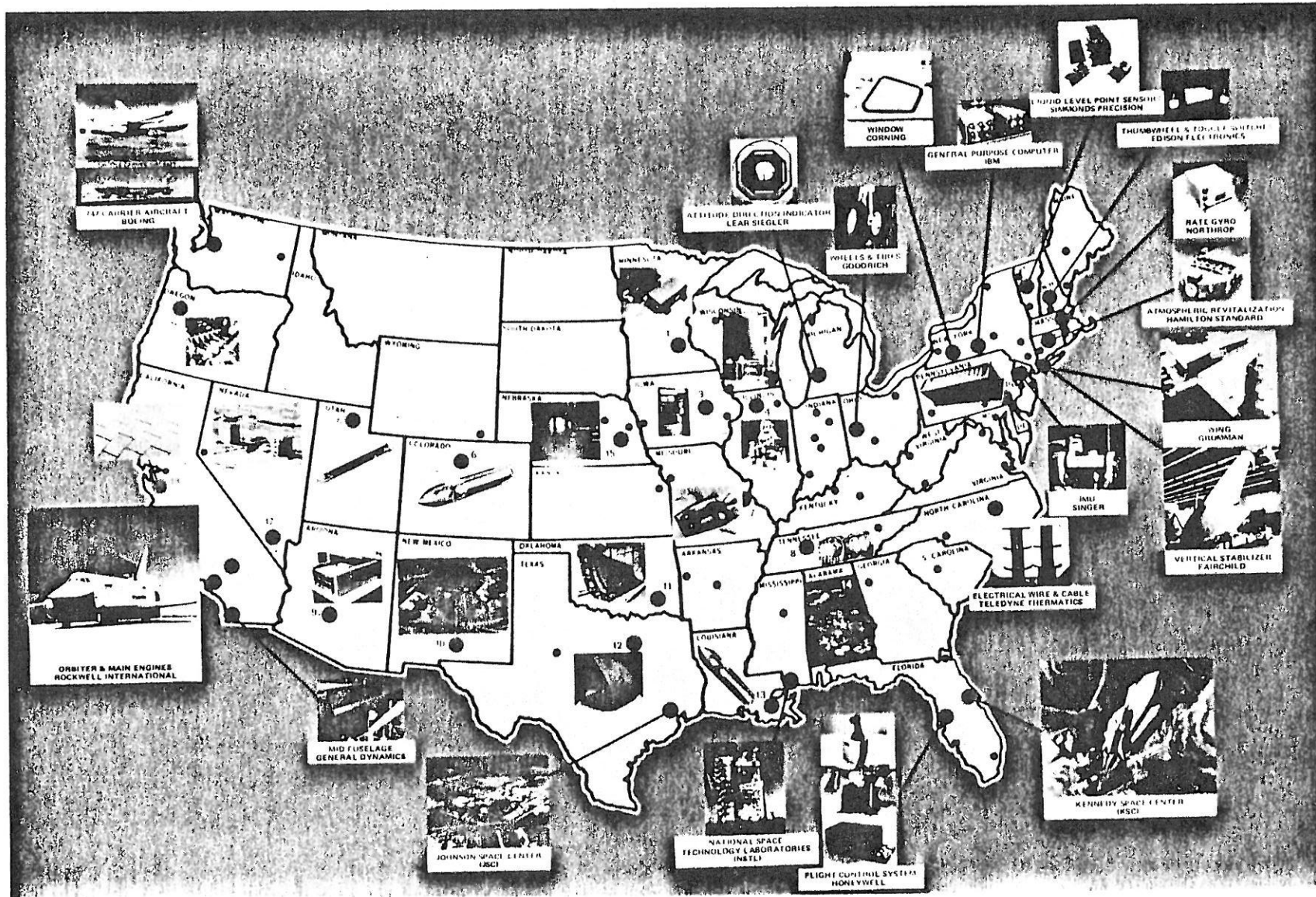
KSC GROUND SUPPORT FACILITIES

The illustration on the left shows an aerial view of the facilities at Kennedy Space Center (KSC) that will be used by the Space Shuttle. This is Launch Complex 39 that was used for the Apollo and Saturn V moon rockets. Launch Pads 39A and 39B will also be modified for use by the Space Shuttle.

The aerial view on the right provides more detail of the area from the Vehicle Assembly Building (VAB) to the runway on which the orbiter will land. The runway shown in both pictures is unique to the Space Shuttle system. It is one of the key elements that make possible the recovery and reuse of complex flight hardware of the type that formerly was used only once. The Space Shuttle orbiter, after landing like an airplane on the runway (15,000 feet long), will be towed to the Orbiter Processing Facility (OPF). Following the maintenance and checkout period, a payload will be installed, and the orbiter will be

RSS Mated to Orbiter

moved to the VAB for assembly with the external tank and solid rocket booster on a mobile launch platform (MLP). The Shuttle assembly and mobile launch platform is then moved to the launch pad on the crawler/transporter. The MLP with the Shuttle assembly is set on pedestals at the launch pad, where servicing and launch preparations are accomplished utilizing the rotating service structure (RSS), as illustrated in the inset.

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(Text)

KSC Ground Support Facilities
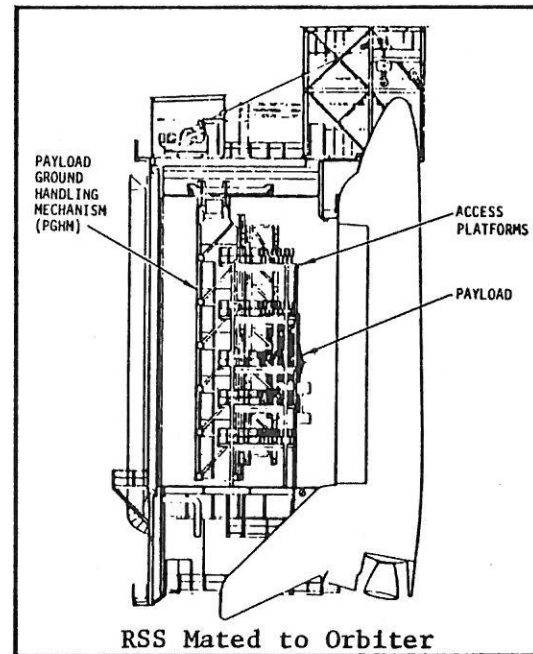
ORBITER PROCESSING FACILITY (OPF)
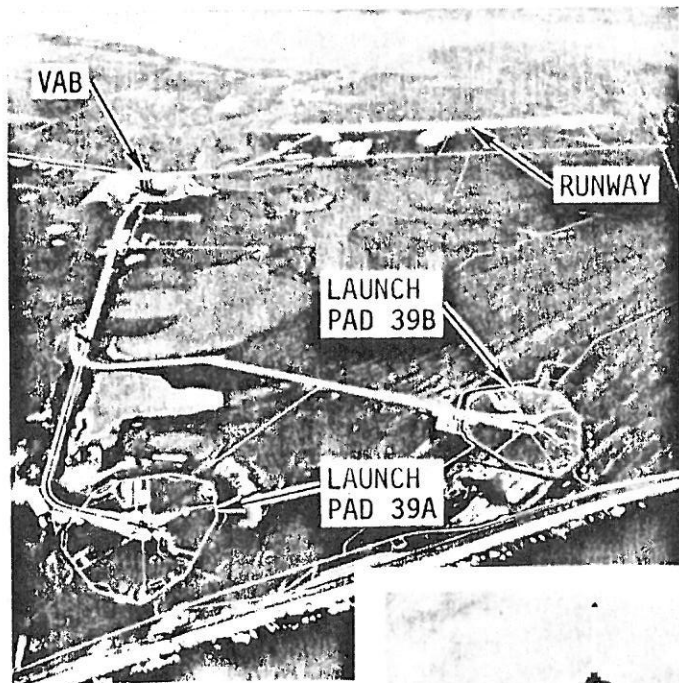
AERIAL VIEWS OF KSC

VAB

RUNWAY

LAUNCH PAD 39B

LAUNCH PAD 39A

RUNWAY

MLP

OPF

VAB
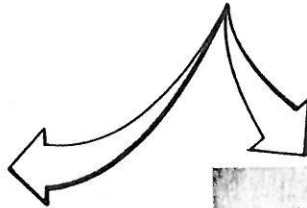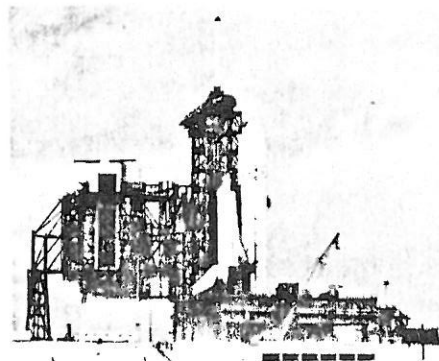
ROTATING SERVICE STRUCTURE (RSS)
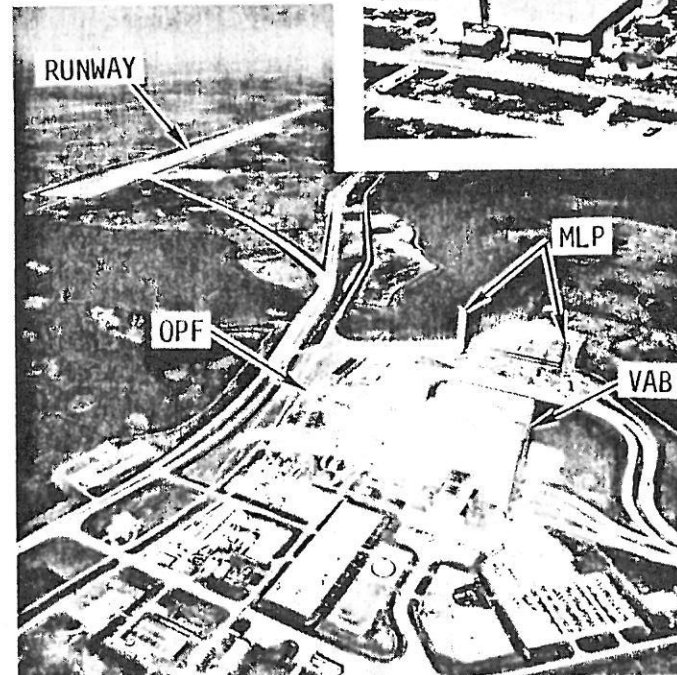
KSC SPACE SHUTTLE GROUND OPERATIONS

The previous chart showed in some detail the ground turnaround of the orbiter. This illustration shows the interrelationship of the Space Shuttle system elements: orbiter, external tank, solid rocket booster, some facilities, and some GSE.

Immediately after landing, selected orbiter and payload systems are secured, and the ground cooling equipment is connected. The vehicle is then towed to the Orbiter Processing Facility where safing, payload removal, maintenance and checkout, and premate operations are performed.

In parallel with orbiter operations, the solid rocket boosters (SRB's) are stacked and aligned on the mobile launch platform in the VAB. This is followed by the mating of the external tank (ET) to the SRB's, and then the mating of the orbiter to the ET and SRB's, after which an integrated systems test is performed and ordnance is installed prior to movement of the vehicle to the launch pad. Launch pad operations include a launch readiness verification test, hazardous servicing operations, and the launch countdown. Payload changeout can also be performed on the launch pad.

After launch and separation, the SRB's descend via parachutes into the ocean where they are recovered and returned to the launch site for disassembly and return to the manufacturing site for refurbishment.

The external tank is expended on each launch, and therefore does not have a closed reuse cycle like the orbiter and solid rocket booster.

The payloads may be loaded into the orbiter during the maintenance and checkout operations or on the launch pad. Payloads returned from orbit will be unloaded from the orbiter in the Orbiter Processing Facility and sent to Payload Operations for disposition.

KSC Space Shuttle Ground Operations

LANDING

SAFING

DOD PAYLOADS

MAINTENANCE & CHECKOUT

(NASA)

PAYLOAD OPERATIONS

ORBITER CYCLE

PRELAUNCH

DOD PAYLOADS INSTALLED ON PAD

VEHICLE ASSEMBLY

ET DELIVERY

SRB RETRIEVAL

SRB CYCLE

SRB REFURBISHMENT
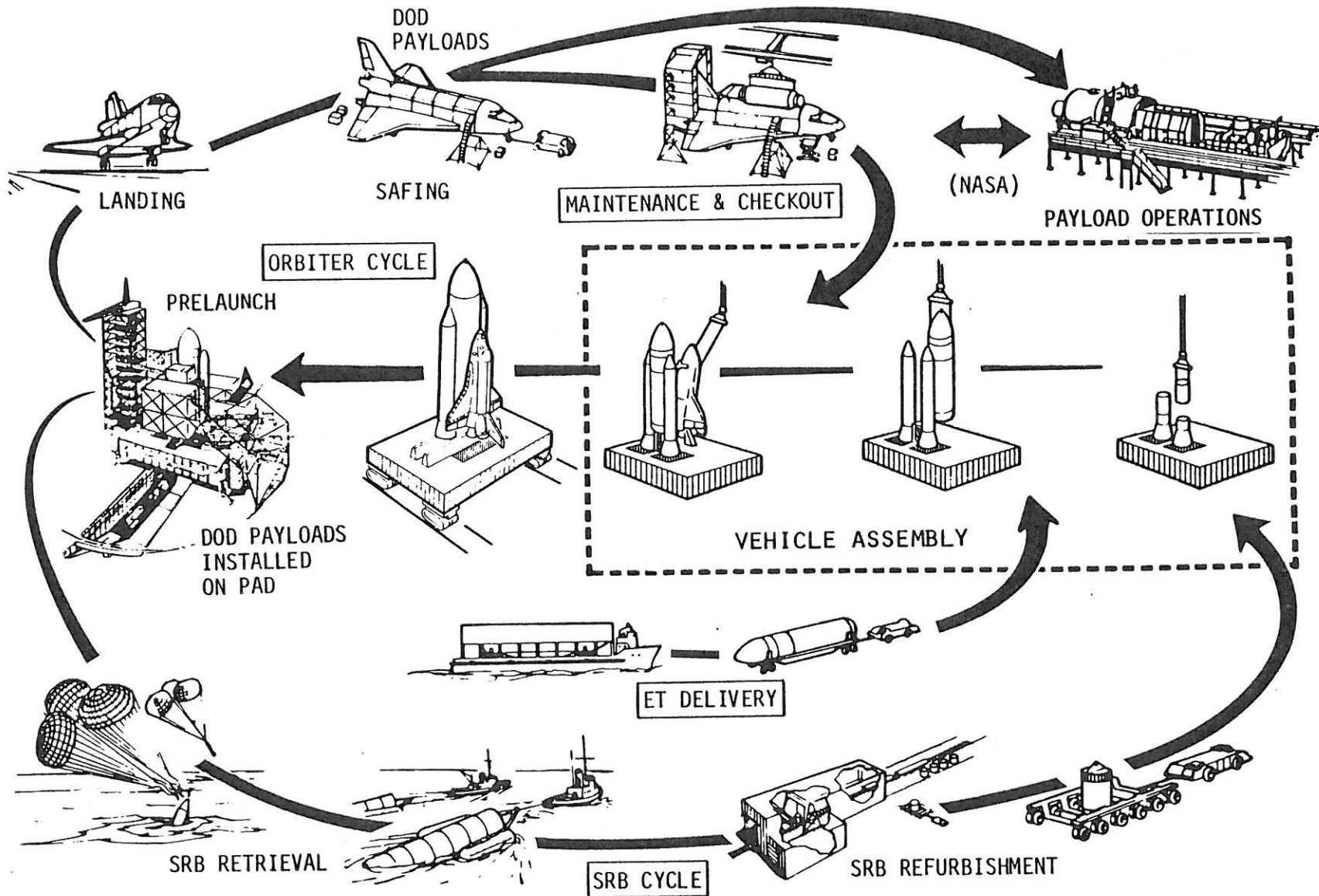
ORBITER GROUND TURNAROUND

A design goal for the Space Shuttle orbiter and the support system is to be able to routinely relaunch the orbiter 160 working hours after it returns/lands from an orbital mission. These 160 working hours are equivalent to 10 working days (8 hours per shift, 2 shifts per day, and 5 days per week) or 14 calendar days. This short ground turnaround time was in the interest of decreasing the maintenance cost (part of the cost per flight), decreasing the inventory of orbiters and support system elements, and increasing the utilization rate of the orbiter.

The first actions after the orbiter lands require about 1 hour to accomplish and are the removal of the flight crew, the attachment of ground cooling and towing equipment and towing to the Orbiter Processing Facility (OPF) where the vehicle is safed (fuels and oxidizers drained, tanks purged, and ordnance removed). Thereafter, the OMS pods/RCS, payload, and OMS propellant kit are removed, and maintenance activity on the vehicle commences. The OMS/RCS are refurbished and reinstalled, the vehicle is checked out, the payload is installed, and the vehicle/payload interfaces checked. This activity in the OPF consumes the bulk (90 working hours) of the 160-hour goal.

The vehicle is then moved to the Vehicle Assembly Building (VAB) where it is lifted, erected, and mated to the SRB/ET that were stacked and mated while the orbiter was still in the OPF. The interfaces and integrated vehicle are checked, and ordnance is installed. The time allocated in the VAB for the orbiter is 38 working hours. When the Space Shuttle vehicle and the mobile launch platform are ready to be moved, they can be moved or maintained in this configuration for a long period.

The move to the launch pad, connecting interfaces, servicing, checkout, and launch are planned to take a minimum of 24 working hours. The system is designed to be capable of launch within two hours after starting the tanking of fuels and oxidizers.

Orbiter Ground Turnaround

PRELAUNCH
- MOVE TO PAD
- INTERFACE VERIFICATION
- PROPELLANT LOADING
- CREW INGRESS
- SYSTEMS CHECK

} 2-HR LAUNCH CAPABILITY

1 HR
24 HR
38 HR
90 HR = 160 HR
7 HR

LANDING
- SAFETY INSPECTION
- CONNECT COOLING GSE
- CONNECT TOW EQUIPMENT
- CREW EXCHANGE
- TOW TO OPF

SHUTTLE ASSEMBLY
- ASSEMBLE SRB's
- ETs MATE TO SRB
- ORBITER MATING
- INTERFACE VERIFICATION
- ORDNANCE INSTALLATION/CONNECTION
- CLOSEOUT

ORBITER SAFING, MAINTENANCE, & C/O
- SAFE & DESERVICE
- REMOVE PAYLOAD
- MAINTENANCE/REFURBISHMENT
- PAYLOAD INSTALLATION
- FUNCTIONAL VERIFICATION

PREMATE PREPARATION
- CONNECT CRANES
- RETRACT LANDING GEAR
- ROTATE TO VERTICAL

Space Systems Group   Rockwell International

20SSV86988A

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VAFB GROUND SUPPORT FACILITIES

The chart illustrates the ground support facilities for the STS at Vandenberg Air Force Base (VAFB), California. Most of the equipment will be similar to that used at the Kennedy Space Center (KSC).

Current plans call for establishing the Orbiter Processing Area on the main base at North Vandenberg Air Force Base (NVAFB). The landing strip (V17) will be extended and additional or modified facilities will be provided to include: orbiter/Shuttle carrier aircraft mate/demate device (V18), orbiter maintenance and checkout (V19), safing and deservicing (V19A), hypergolic maintenance and checkout (V21), flight crew systems (V27), and parachute refurbishment (V30). Orbiters will be transported to the launch pad (V23) via the tow-way (V80).

The integration and launch area will be established at South Vandenberg Air Force Base (SVAFB). The launch pad (V23), consisting of a launch mount, access tower, mobile service tower, payload change-out room, and payload preparation room, is being constructed at the Space Launch Complex (SLC-6). Preliminary modifications are already in process. The launch control center (V28) will be the principal launch pad support facility in the area. Other facilities at SVAFB include the solid rocket booster (SRB) refurbishment and subassembly (V31) and the external tank (ET) processing and storage (V33). Final assembly of the Shuttle, including stacking of SRB segments, ET, and orbiter, and payload installation take place at the launch pad (V23).

External tanks are manufactured in Michoud, Louisiana, and are delivered individually, or four at a time, by NASA barge. At the South Vandenberg Air Force Base docking facility, ET's are off-loaded and transported to the processing and storage facility (V33) for checkout and storage until required at the launch pad (V23).

The SRB disassembly facility (V32) in the Port Hueneme area will receive tug-recovered expended SRB's. The SRB's are disassembled, SRM cases prepared for shipment to Utah for refurbishment with new propellant grains, parachutes shipped to V30 for refurbishment, and other components of the SRB's are transported to V31 for refurbishment and reassembly. New hardware, SRM segments, and expendable SRB components are assembled at V31.

119SSV86989
(Text)

VAFB Ground Support Facilities

SAFING & DESERVICING V19A

LANDING RUNWAY V17

ORBITER MAINTENANCE AND CHECKOUT V19

PARACHUTE V30 REFURBISHMENT

LAUNCH PAD V23

HYPERGOLIC MAINTENANCE V21

MOBILE SERVICE TOWER

ACCESS TOWER

PAYLOAD CHANGEOUT ROOM

ET PROCESSING & STORAGE V33

SVAFB DOCKING FACILITY

LAUNCH MOUNT

PAYLOAD PREPARATION ROOM

Space Systems Group

Rockwell International

40SSV86989

81
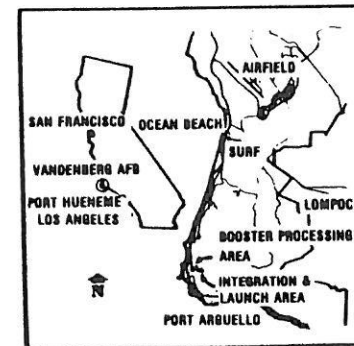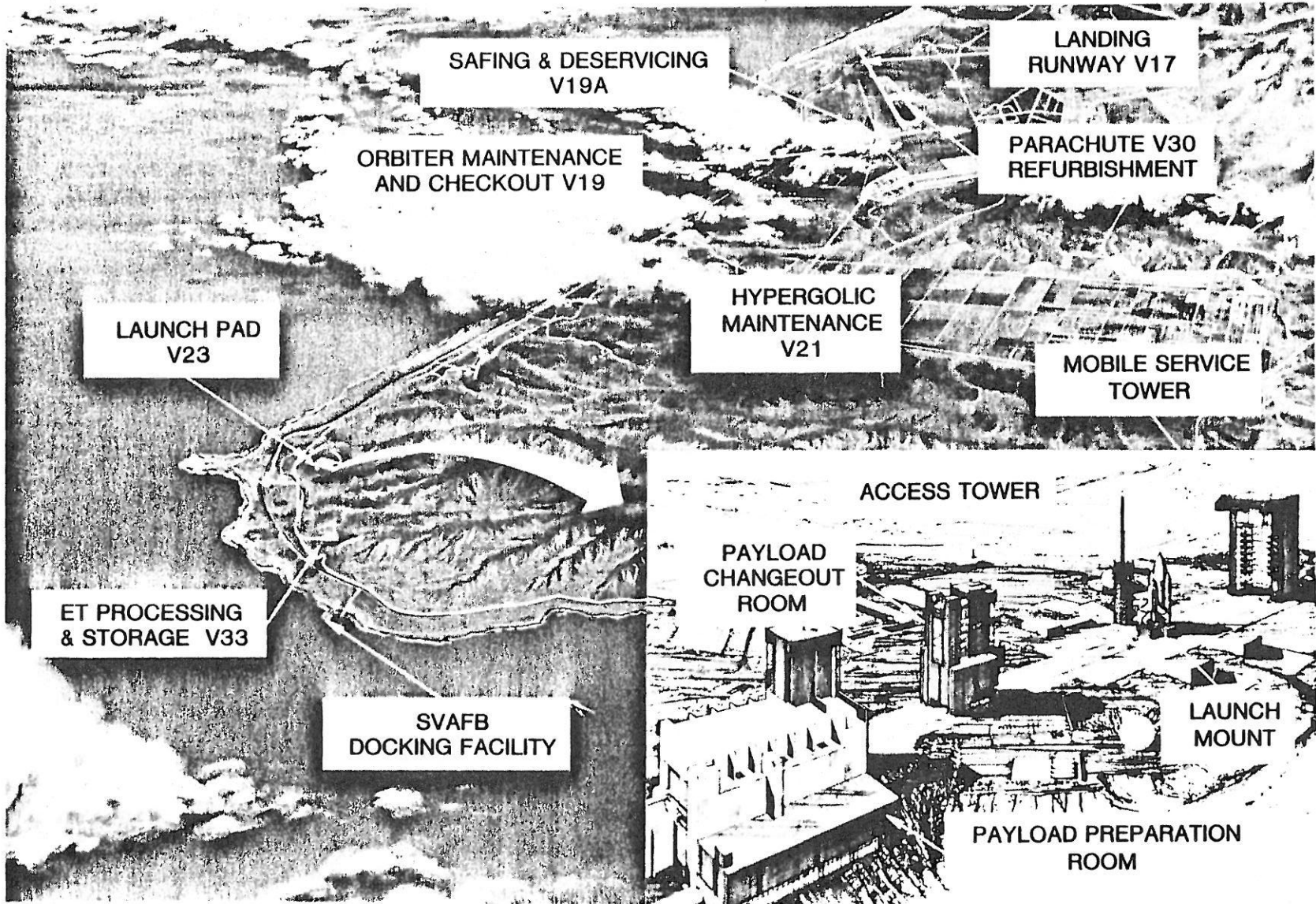
VAFB SPACE SHUTTLE GROUND OPERATIONS

This chart illustrates the ground operations for STS elements at Vandenberg Air Force Base, California. Most of the operations and equipment will be identical to those used at Kennedy Space Center, Florida, but there will be some differences due to physical environment and variations in operating philosophies of NASA and DOD. The elements of the Shuttle (orbiter, ET, and SRB) and payload will be received at VAFB and processed through special element stations. Upon completion of checkout, the elements will be assembled at the launch pad and integrated into the complete Shuttle vehicle.

The orbiter will arrive either by ferry flight aboard the Shuttle carrier aircraft (SCA) or by completion of a mission landing under its own control. An orbiter arriving by ferry will be demated from the SCA at the mate/demate station (V18) and towed to orbiter maintenance and checkout (V19) for processing for a mission. An orbiter returning from a mission on the landing runway (V17) will have ground services connected, nonessential subsystems shut down, flight crew removed, and towed to safing and deservicing (V19A). At V19A all systems will be safed and deserviced. Hypergolic modules will be removed and sent to hypergolic maintenance (V21) for anomaly correction as required. The orbiter will then be towed to orbiter maintenance and checkout (V19) for refurbishment, in preparation for the next mission. The orbiter will be loaded aboard the transporter and moved to the launch pad (V23) via the tow-way, part of transportation station (V80) which is not shown.

The external tank (ET) will arrive by NASA barge at the SVAFB docking facility, loaded on a special transporter, and taken to ET processing and storage (V33). The ET will be readied for flight, reloaded on the transporter, and moved to the launch pad (V23).

The solid rocket boosters (SRB's) retrieved after a launch will be towed to Port Hueneme and disassembled at Station V32. SRM cases will be shipped to Utah for new propellant grains; parachutes will be sent to parachute refurbishment (V30), and other components will be moved to SRB refurbishment and subassembly (V31). New hardware, SRM segments, and other expendable components will be received at Station V31 and assembled for movement to the launch pad.

At the launch pad, the SRB's will be stacked first, the ET added next, and then the orbiter. The payload, processed at the Payload Preparation Room, will be loaded into the orbiter. Shuttle vehicle servicing, integrated checkout, flight crew ingress via the access tower, and launch countdown complete the prelaunch ground operations.

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(Text)

VAFB Space Shuttle Ground Operations

ORBITER PROCESSING

(V19A) SAFING & DESERVICING

NVAFB

HYPERGOLIC MODULES TO HMCF (V21)

ΔV KITS TO HMCF

(V19) ORBITER MAINTENANCE & CHECKOUT

NVAFB

(V18) MATE-DEMATE

VIA SHUTTLE CARRIER AIRCRAFT FROM AIRSTRIP NVAFB

MOVE ORBITER TO SDF

HYPERGOLIC MODULES & ΔV KITS TO OMCF

(V21) HYPERGOLIC MAINTENANCE & CHECKOUT NVAFB

ORBITER TO OMCF

(V27) FLIGHT CREW SYSTEMS NVAFB

(V17) LANDING NVAFB

ORBITER TO OMCF

FLIGHT CREW EQUIPMENT TO OMCF (V19)

FLIGHT CREW TO PAD

EXTERNAL TANK (ET) PROCESSING

ORBITER TO PAD

(V23) LAUNCH PAD SVAFB

PAYLOAD CHANGEOUT ROOM (PCR)

(V33) ET PROCESSING & STORAGE

ET TO PAD

SVAFB

MOBILE SERVICE TOWER (MST)

RECEIVE ETs FROM MFG (MICHOUD, LA) BY BARGE

PAYLOAD PREPARATION ROOM (PPR)

SRB ELEMENTS TO PAD

(V28) LAUNCH CONTROL CENTER (LCC) SVAFB

SOLID ROCKET BOOSTER (SRB) PROCESSING

PAYLOAD TO PPR

(V30) PARACHUTE REFURBISHMENT NVAFB

PARACHUTE

(V31) SRB REFURBISHMENT & SUBASSEMBLY FACILITY SVAFB

OTHER SRB COMPONENTS

RETRIEVED PARACHUTES TO PRF (V30)

ELEMENT CONTRACTOR

SRB RETRIEVAL

TOW SRBs TO PORT HUENEME

SEGMENT CASINGS MOVE TO ELEMENT CONTRACTOR

(V32) SRB DISASSEMBLY

SHUTTLE ORBITER CARRIER AIRCRAFT

Transporting the orbiter from its final assembly site (Palmdale, California) to the operational sites (KSC or VAFB), or between the operational sites, or retrieving the orbiter from an auxiliary landing field (after an emergency landing) back to an operational site, or returning the orbiter to the final assembly site will be accomplished, as shown in the chart, on a specially modified Boeing 747-100 airplane, called the Shuttle carrier aircraft (SCA). Prior to mounting the orbiter on the SCA, the orbiter subsystems are deactivated to a dormant condition, a tail cone is added to reduce wake turbulence and base drag, and control locks are placed on the orbiter's aerodynamic control surfaces.

Modifications to the Boeing 747 aircraft included structural reinforcement of the fuselage to carry the orbiter induced loads and modifications for directional stability. The aircraft-to-orbiter structure attaches to the orbiter fittings that are normally the orbiter-to-external tank fittings; thus there is no change or addition to the orbiter for this transport capability. The SCA with the orbiter has a 778,000-pound maximum gross weight for taxi, a 775,000-pound maximum gross weight for takeoff, and a 564,000-pound maximum landing weight.

On August 12, 1977, at Dryden Flight Research Center, Edwards AFB, California, the SCA was used to carry the first orbiter (OV 101) to altitude, where it was released to perform a near perfect approach and landing. The SCA had some special provisions for the approach and landing tests (ALT) to provide for safe release and communications between the aircraft and orbiter. For effective release, a large incidence angle between the aircraft and orbiter was used and a load measuring system was added in the attach struts. ALT, which consisted of 8 captive orbiter flights and 5 free orbiter flights, was completed in November 1977.

In March 1978, the Enterprise (OV 101) was ferried atop the SCA to MSFC to undergo a series of mated vertical ground vibration tests, and on March 9, 1979, it was ferried to KSC. Also in March 1979, the second orbiter OV 102 (Columbia) was ferried to KSC from Edwards AFB.

Shuttle Orbiter Carrier Aircraft
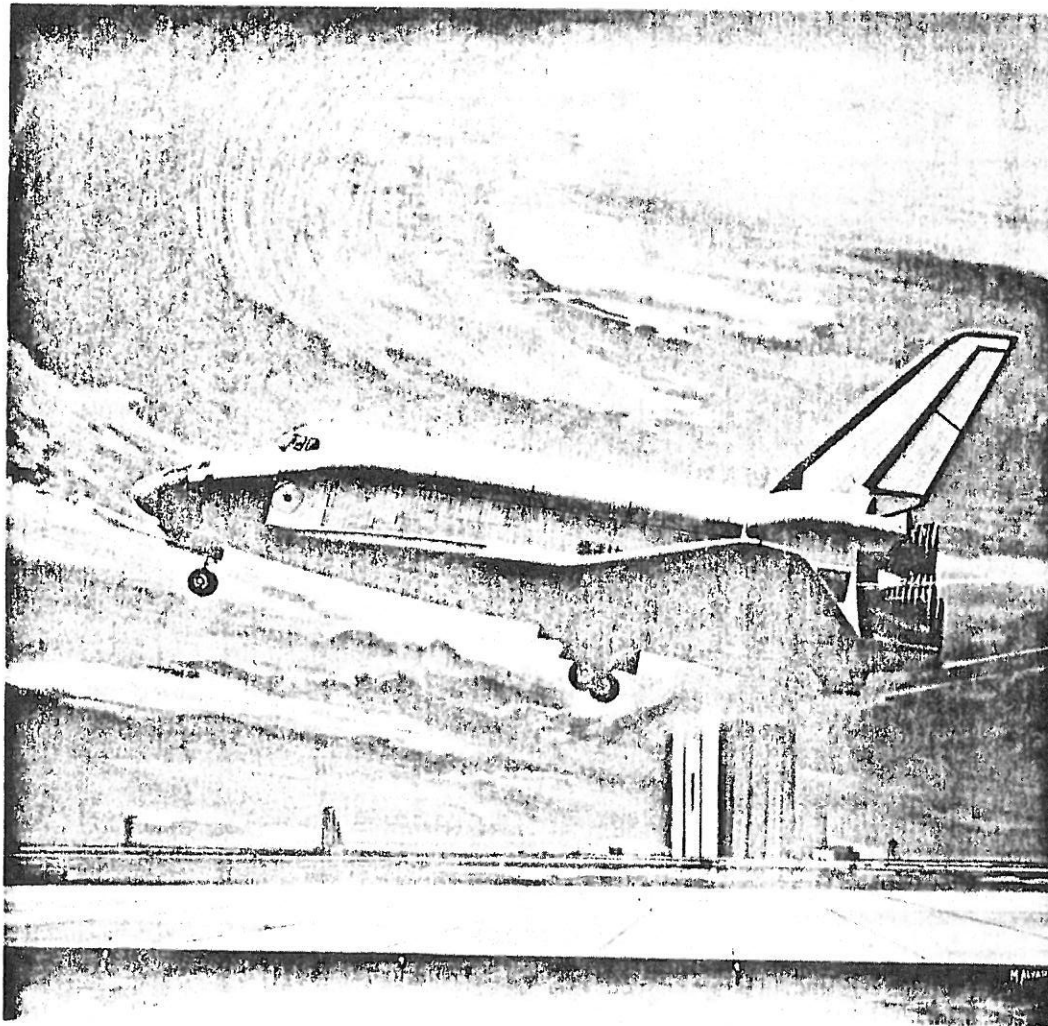
Orbiter
and
Subsystems

ORBITER VEHICLE DIMENSIONS

The orbiter spacecraft contains the crew and payload for the Space Shuttle vehicle system. The orbiter can deliver payloads up to 65,000 pounds, with lengths up to 60 feet and dia- meters to 15 feet. The orbiter crew compartment nominally accommodates a four-man crew; however, a crew of up to seven can be accommodated on a nominal mission. In a rescue mission configuration a crew of 3 and 7 passengers can be accommodated.

The orbiter is comparable in size and weight to modern transport aircraft. It has a dry weight of approximately 160,000 pounds, a length of 122.25 feet, and a wing span of 78.06 feet.

The main propulsion system (MPS) used during launch is contained in the aft fuselage and consists of three rocket engines (SSME's), the external tank, plumbing, and controls. All of the propellant is contained in the external tank, which is jettisoned prior to initial orbit injection. The orbital maneuvering subsystem (OMS) is contained in two external pods on the aft fuselage. These units provide thrust for orbit change, 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 attitude control in space and precision velocity changes for the final phases of rendezvous and docking or orbit modifi- cation. In addition, the RCS, in conjunction with the orbiter's aerodynamic control surfaces, provides attitude control during entry.

The orbiter aerodynamic control surfaces provide control of the orbiter below Mach 2. The orbiter exhibits good aerodynamic flight control characteristics during approach and landing. The design touch-down speed of the orbiter is 210 knots, which parallels the design of current high-performance aircraft.

The orbiter vehicle is trimmed to provide a hypersonic lift-to-drag ratio of approximately 1.3 during entry. At subsonic speed, the maximum trimmed lift-to-drag ratio, with the speed brake closed, is about 4.9

119SSV86992
(Text)

Orbiter Vehicle Dimensions

GLOVE-WING
INTERSECTION
Y_O 188, X_O 1024

X_O 236 OUTER ML

1458.245 IN.
121.52 FT

Z_O 400

1292.3 IN.
107.69 FT
REF BODY LENGTH

X_O 236
(REF)

X_O 1528.3

STATIC GROUND
LINE

556 IN.
46.33 FT

679 IN.
56.58 FT

FRP

Z_O 400

936.68 IN.
78.06 FT
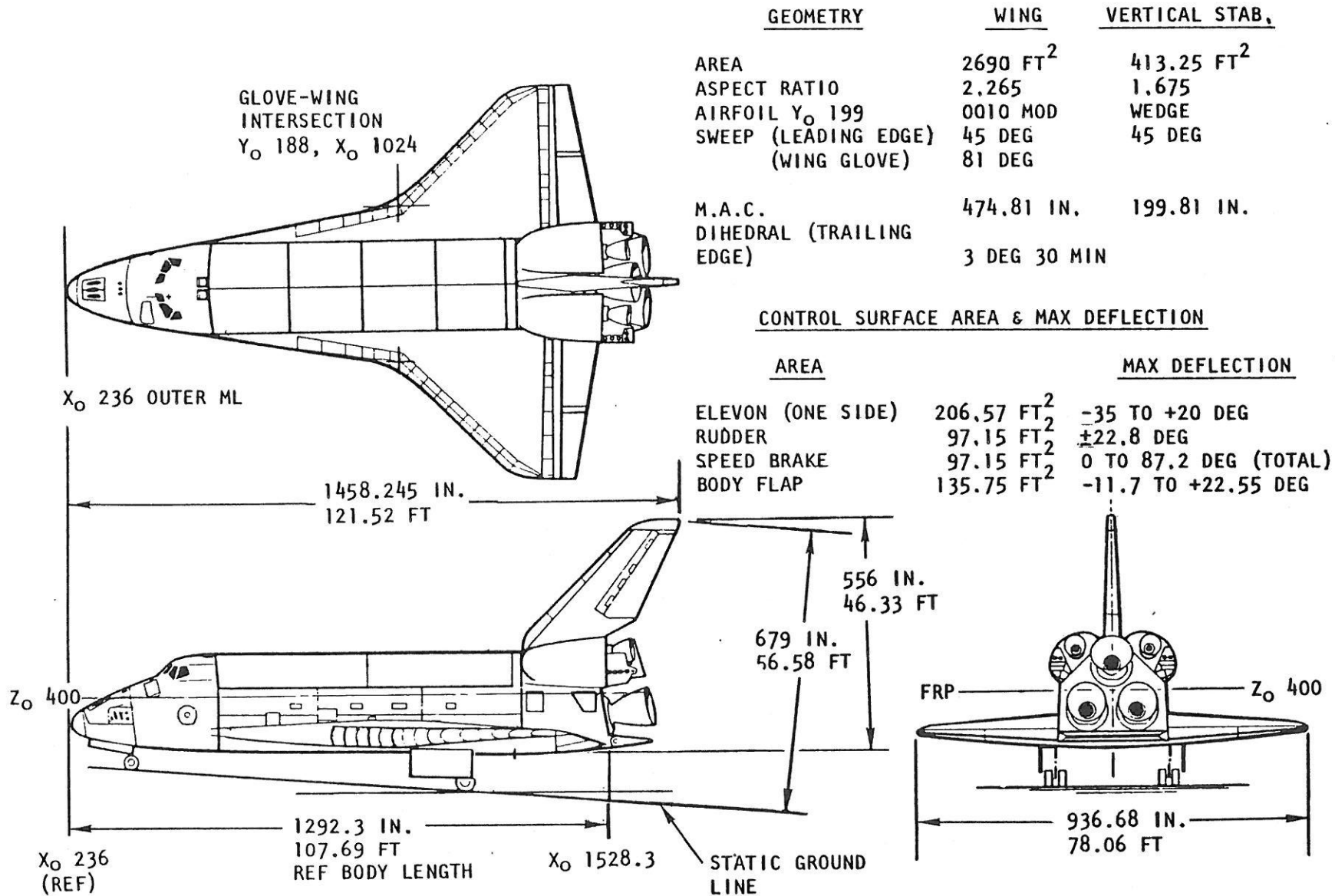
GEOMETRY	WING	VERTICAL STAB.
AREA	2690 FT^2	413.25 FT^2
ASPECT RATIO	2.265	1.675
AIRFOIL Y_O 199	0010 MOD	WEDGE
SWEEP (LEADING EDGE)	45 DEG	45 DEG
(WING GLOVE)	81 DEG	
M.A.C.	474.81 IN.	199.81 IN.
DIHEDRAL (TRAILING EDGE)	3 DEG 30 MIN	

CONTROL SURFACE AREA & MAX DEFLECTION

	AREA	MAX DEFLECTION
ELEVON (ONE SIDE)	206.57 FT^2	-35 TO +20 DEG
RUDDER	97.15 FT^2	±22.8 DEG
SPEED BRAKE	97.15 FT^2	0 TO 87.2 DEG (TOTAL)
BODY FLAP	135.75 FT^2	-11.7 TO +22.55 DEG

ORBITER STRUCTURE

The majority of the orbiter structure is of conventional aluminum construction protected by reusable surface insulation (RSI).

The forward fuselage structure is composed of 2024 aluminum alloy skin/stringer panels, frames, and bulkheads. The crew module, which is supported within the forward fuselage by four attach points, is welded to create a pressure-tight vessel. The module has a side hatch for normal ingress and egress and a hatch from the airlock into the payload bay for EVA and IVA.

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 doors. The skins are integral machined aluminum panels and aluminum honeycomb sandwich panels. The frames are constructed as a combination of aluminum panels with riveted or machined integral stiffeners and a truss structure center section. The upper half of the mid fuselage consists of structural payload bay doors, hinged along the side and split at the top centerline. The doors are graphite epoxy (gr/ep) frames and honeycomb panel construction.

The aft fuselage includes a truss-type internal structure of diffusion-bonded elements that transfers the main engine thrust loads to the mid fuselage and external tank. The external surface of the aft fuselage is of standard construction except for the removable aft propulsion system (APS) pods which are constructed with graphite epoxy skins and frames. An aluminum honeycomb bulkhead heat shield with thermal insulation at the rear of the vehicle provides protection to the main engine systems.

The wing is of conventional aluminum alloy construction. Corrugated spar web, truss-type ribs, and riveted skin-stringer and honeycomb covers are used. The elevons are of alunimum honeycomb construction and are split into two segments to minimize hinge binding and interaction with the wing.

The vertical tail is of conventional aluminum alloy construction consisting of a two-spar, multirib, integrally machined skin assembly. The tail is attached to the aft fuselage by bolted fittings at the two main spars. The rudder/speed brake assembly is divided into upper and lower sections. Each section is also split longitudinally and individually actuated to serve as both rudder and speed brake.

The secondary structure supports all of the interior system equipment including the wiring harness runs and hardline runs. Secondary structure is of conventional aluminum construction, except for those members for which titanium and fiberglass are utilized for thermal isolation purposes.

These major structural assemblies are mated and joined together with rivets and bolts. The mid fuselage is joined to the forward and aft fuselages primarily with shear ties, with the mid fuselage skin overlapping the bulkhead caps at X_O 582 and X_O 1307. The wing is attached to the mid fuselage and aft fuselage primarily with shear ties, except in the area of the wing carry-through where the upper panels are attached with tension bolts. The vertical tail is attached to the aft fuselage with bolts which work in both shear and tension. The body flap, which is constructed with aluminum honeycomb covers, is attached to the aft lower fuselage by four rotary actuators.

119SSV64396C
(Text)

Orbiter Structure

AFT FUSELAGE
- ALUMINUM SKIN/STR SHELL (2124-T851)
- TITANIUM/BORON THRUST STRUCTURE

OMS POD
- GRAPHITE/EPOXY SKIN PANELS

VERTICAL TAIL
- ALUMINUM MACHINED SKINS 2124-T851
- ALUMINUM HONEYCOMB 2124-T81 RUDDER COVERS 2024-T81

X_O 1528

X_O 1307

RSI

MID FUSELAGE
- ALUMINUM SKIN/STR (2124-T851)
- ALUMINUM HONEYCOMB PANELS (2124)
- MISC - 2024-T6

X_O 576

X_O 236

FORWARD FUSELAGE (2024-T81)
&
CREW CABIN (2219-T851)
- ALUMINUM SKIN/STR

PAYLOAD BAY DOORS
- GRAPHITE/EPOXY HONEYCOMB PANELS
- GRAPHITE/EPOXY FRAME W/Ti FTG's
- INCONEL HINGES

WING
- ALUMINUM SKIN/STR & HONEYCOMB COVERS (2024-T81)
- ALUMINUM HONEYCOMB ELEVON COVERS 2024-T81
- ALUMINUM SPAR WEBS 2024-T62
- ALUMINUM RIB (TRUSS TUBES) 2024-T62

BODY FLAP
- ALUMINUM HONEYCOMB COVERS (2024)

FLIGHT

- CONVENTIONAL ALUMINUM STRUCTURE
- MAXIMUM TEMPERATURE 350°F
- PROTECTED BY REUSABLE SURFACE INSULATION

FORWARD FUSELAGE AND CREW MODULE STRUCTURE

FORWARD FUSELAGE

The forward fuselage structure is conventional aircraft construction of 2024 aluminum alloy skin/stringer panels, frames, and bulkheads, and it interfaces with the crew module and the mid fuselage at X_o 582. The entire exterior surface of the forward fuselage is covered with a thermal protection system (TPS) except for the windows.

The nose landing gear is contained in the forward fuselage with large machined beams and struts providing the load reaction. The forward RCS module is secured to the basic structure with 16 fasteners with provisions to accommodate GSE for installation and removal of the module. The forward ET attachment reaction is provided by the X_o 378 bulkhead and skin panel structure. Orbiter jacking and hoisting accommodations are provided by a fitting located on the X_o 582 frame. Structural provisions for the installation of antennas and the air data sensors are provided in the skin panels. The star tracker viewing requirements are provided by an opening in the upper forward structure. A door covers the opening to provide the environmental control of this area. The window and hatch frames are machined parts attached to the structural panels and frames. Purge and vent control is provided with the installation of flexible boots between the forward fuselage and crew module around the windshield windows, overhead observation window, crew hatch window, and star tracker opening. Isolation between the forward fuselage and payload bay is provided by a flexible membrane between the forward fuselage and crew module at X_o 582.

CREW MODULE

The crew module is constructed of 2219 aluminum alloy plate with integral stiffening stringers and internal framing welded together to create a pressure-tight vessel. The module has a side hatch for normal ingress and egress, a hatch into the airlock from the mid deck, and a hatch through the aft bulkhead into the payload bay for EVA and IVA and payload access.

Redundant pressure window panes are provided in the windshield and overhead, aft viewing, and side hatch windows. Approximately 300 penetrations pierce the pressure shell and are sealed with plates and fittings. A large removable panel in the aft bulkhead provides access to the interior of the crew module during initial fabrication and assembly and provides the airlock installation and removal capability. Equipment support is provided for the ECLSS, avionics, D&C, G&N, NAV/star tracker base, and crew accommodations subsystems such as the sleep stations, galley, waste management, and seats.

The crew module is supported within the forward fuselage at only four attach points to minimize the thermal conductivity between them. The two major attach points are located at the aft end of the CM at the flight section floor level. The vertical load reaction link is located on the centerline of the forward bulkhead, and the lateral load reaction links are located on the lower segment of the aft bulkhead.

119SSV86993
(Text)

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Forward Fuselage and Crew Module Structure

STRUCTURAL FEATURES:

CM: FLOATING
NEAR DETERMINANT SUPPORT
WELDED (NO LEAKAGE)
INDEPENDENT ASSY & C/O

FWD FUS: SIDE HATCH SLAVED
TO CM HATCH
FWD RCS CUT-OUT

- INTEGRALLY MACHINED ALUMINUM SKIN/STRINGER PANELS
- WELDED CONSTRUCTION
- MECHANICALLY ATTACHED
  - FRAMES
  - BEAMS
  - FLOORS
  - EQUIPMENT SUPPORT

STAR TRACKER WELL

FLIGHT SECTION FLOOR

MGF ACCESS OPENINGS

SIDE HATCH

AVIONICS BAY PARTITION

MID-SECTION FLOOR

CREW MODULE

- ALUMINUM CONSTRUCTION
- RIVETED SKIN/STRINGER/ FRAME STRUCTURE

STAR TRACKER OPENING

MACHINED WINDOW PANELS

UPPER WINDOW FRAMES

HAT SECTION STIFFENED SKINS

582 FRAME

BUILT-UP FRAMES

FWD RCS CUTOUT

SIDE HATCH OPENING

MACHINED NLG SUPPORT BEAMS

MACHINED 378 BULKHEAD

FORWARD FUSELAGE

MID FUSELAGE STRUCTURE

The mid fuselage structure, which is primarily of aluminum construction, interfaces with the forward fuselage, aft fuselage, and the wing. It runs from X_O 582 to X_O 1307 and supports the oribter payloads, including the payload bay doors. In the forward portion is the forward wing glove fairing, which runs from X_O 582 to X_O 807. The side wall just forward of the wing carry-through structure provides the inboard support for the main landing gear. The total lateral landing gear loads are reacted by the mid fuselage structure.

The mid fuselage skins are integrally machined except the panels above the wing from X_O 1040 to X_O 1307 which are aluminum honeycomb panels. The integrally machined skins have longitudinal T-stringers. The bottom panel between X_O 1191 and X_O 1307 carries transverse wing loads as well as body bending loads and is of waffle contruction. The side skins in the wing interface from X_O 1040 to X_O 1307 are also machined but have vertical stiffeners except from X_O 1278 to X_O 1307, which is a waffle configuration.

There are 12 main frame assemblies which stabilize the mid fuselage structure and react wing and payload loads. The frame assemblies consist of vertical side elements and horizontal elements. The side elements are machined, whereas the horizontal elements have machined flanges with boron/aluminum tube shear trusses. In addition to the 12 main frames, there are 13 side wall stub frames.

In the upper portion of the mid fuselage are the sill and door longerons. The machined sill longerons are not only primarily body bending elements, but serve to take the longitudinal loads from the payloads. Attached to the door longerons and associated backup structure are the 13 payload bay door hinges. These hinges provide the vertical reaction from the payload bay doors, and five of the hinges react the payload bay door shears. The sill longeron also provides the base support for the payload manipulator arms and its storage provisions, rendezvous sensor, and payload bay door actuation system.

The mid fuselage provides the wing carry-through structure between Stations 1191 and 1307. It consists of the previously mentioned lower skin and upper wing box carry-through skin and seven longtudinal rib members. The center rib is integrally machined caps, shear web, and vertical stiffeners, and the other six have boron/aluminum tube truss members. The upper wing box carry-through skin, X_O 1191 to X_O 1307, carries the transverse wing loads and is machined with lateral T-stringers.

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Mid Fuselage Structure

STRUCTURAL FEATURES:
- MACHINED SKINS
- TRUSS FRAME
- BORON/EPOXY TRUSS TUBES

DOOR LONGERON

UPPER WING CARRY-THROUGH

SIDE SKINS

PAYLOAD UMBILICAL

ELECTRICAL WIRE TRAY

PAYLOAD DOOR
HINGE STABILIZER (3)

SILL LONGERON

MAIN FRAMES (12)

STUB
FRAMES (13)

MAIN LANDING GEAR TRUNNION
SUPPORT STRUCTURE

SKIN REMOVED ON OV 103 & SUBS

DOOR HINGE FITTING (13)

WING ATTACH INTERFACE

GLOVE

BOTTOM SKINS

FRAME STABILIZERS
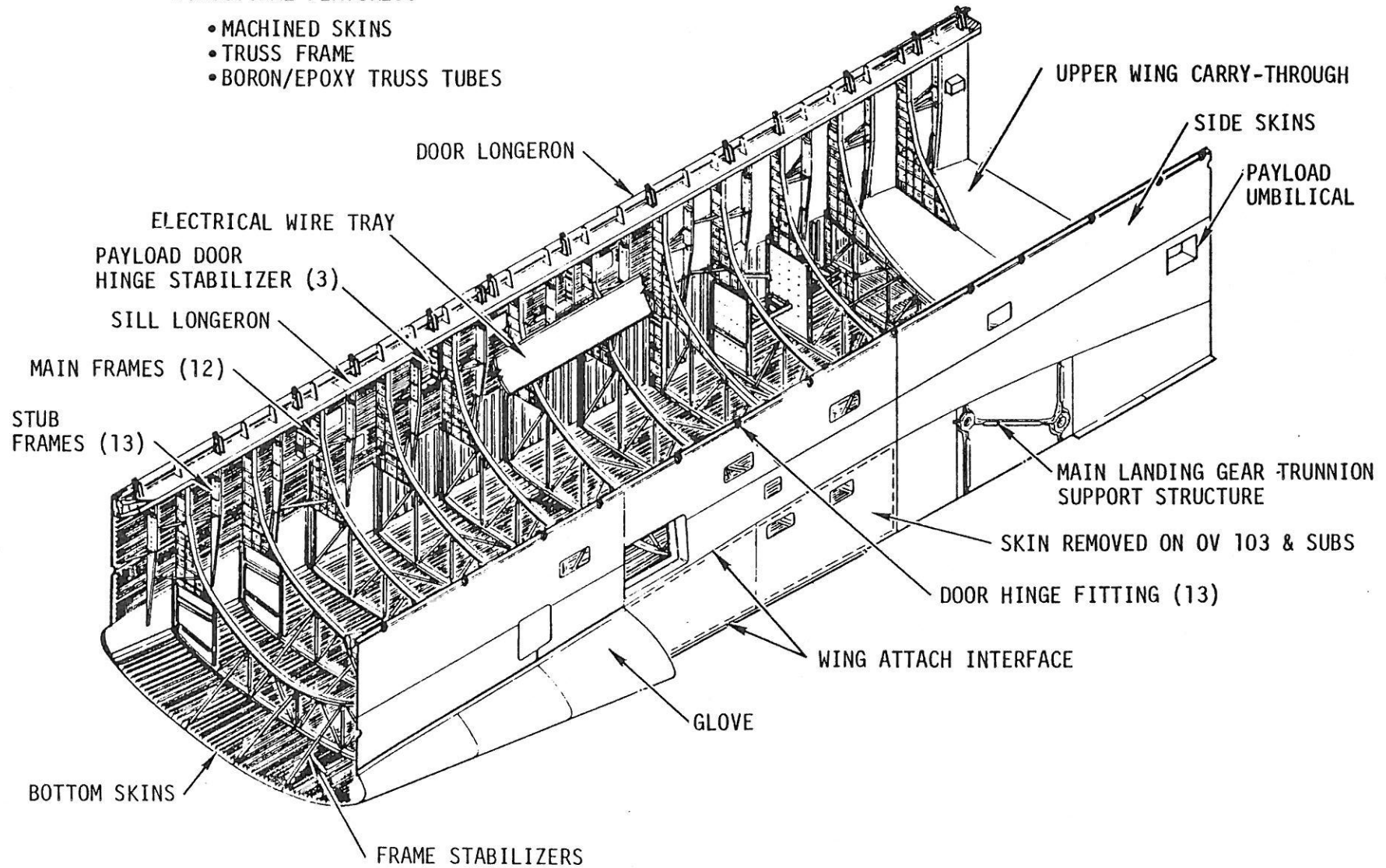
PAYLOAD BAY DOOR

The payload bay door is 61 feet long and has a surface area of approximately 1600 square feet. The door is of constant contour, except for the most forward 100 inches, which exhibit a compound contour. It consists of two panels that open at the upper centerline to fully expose the payload bay. Each panel consists of five segments interconnected by circumferential expansion joints, except for the aftmost 22-inch section of the door.

The forward 30-foot section of the door incorporates deployable radiators that are hinged and latched to the inner surface of the door. The forward radiators can be deployed in orbit. The radiators are latched/unlatched and deployed/stowed by the operation of an electromechanically actuated mechanism system. Fixed aft radiators are attached to the remaining inner surface of the door.

Each side of the door hinges on 13 Inconel-718 external hinges (five shear and eight idlers). The lower half of the hinges attach to the mid fuselage hinge and sill longeron. The hinges rotate on self-aligning dual rotating surface bearings. The door actuation system provides the mechanism to drive each door side to the required open or closed position. Each door mechanism contains an electro-mechanical power drive unit and six rotary gear actuators. The rotary actuators are connected by torque tubes to each other, to the power drive unit, and to the door drive linkage. When closed, the doors are latched to the forward and aft bulkheads (X_O 576 and X_O 1306) and along the upper centerline. The latching system consists of a total of eight gangs of latching mechanisms, two gangs each at the forward and aft bulkheads and four gangs along the upper centerline.

Each gang incorporates four latches, associated bellcranks, pushrods, levers, rollers, and an electro-mechanical actuator. Also, five passive shear pins per side are used to interconnect each door segment at the four expansion joints. Additionally, there are four shear fitting attachments along the door centerline, one per each of the forward four segments.

The door primary structure is of honeycomb and frame construction employing composite materials. The facesheets consist of graphite/epoxy tapes and graphite/epoxy fabric with a 0/+45/0 fiber orientation; total thickness per skin is 0.016 inch. The Nomex honeycomb core is 0.60-inch thick. Adhesive is employed for bonding the core to the facesheets. Lightning strike protection is provided by bonding 200 by 200 calendared aluminum wire mesh to the outer skin. The door frames, which are of multi-ply graphite/epoxy tape and fabric layups, consist of 28 intermediate frames, 8 expansion joint closeout frames, and one forward and one aft closeout frame.

Both thermal and pressure seals are used to close the gaps at fuselage interface, door centerline, and circumferential expansion joints.

Crewman EVA handhold provisions for astronaut transit are attached in the torque box areas.

119SSV86995
(Text)

Payload Bay Door

STRUCTURAL FEATURES:
- 5 SEGMENT DOOR HALVES (ON-ORBIT THERMAL DISTORTION CONTROL)
- GRAPHITE/EPOXY CONSTRUCTION
- TORSION/SHEAR ONLY - NO BODY BENDING
- SUPPORTS RADIATORS

X_o 1306.9

X_o 574.09

DOOR ASSEMBLY ($\approx$ 61 FT)

AFT DOOR ($\approx$ 30 FT)

FORWARD DOOR ($\approx$ 30 FT)

CONSTANT CROSS SECTION

EXPANSION JOINT

HL

COMPOUND CURVATURE

EXPANSION JOINT

INTERMEDIATE FRAME (TYPICAL)

SHEAR HINGES

$\approx$ 6.7 FT

TORQUE BOX

HONEYCOMB PANEL (TYPICAL)

FLOATING HINGES

LATCH DOOR TO AFT BULKHEAD (TYPICAL 8 PLACES)

Z Y X

ORBITER C_L

CLOSEOUT FRAMES

SHEAR HINGES

AFT

$\approx$ 18.75 FT

FWD RADIATOR HINGE FITTINGS (6 PER SIDE - 12 TOTAL)

SHEAR HINGE

FLOATING HINGES

AFT RADIATOR ATTACH FITTINGS (33 PER SIDE - 66 TOTAL)

TORQUE BOX

LATCH-DOOR TO FORWARD BULKHEAD FLOATING (TYPICAL 8 PLACES)

RADIATOR SHEAR FITTINGS (4 PER SIDE - 8 TOTAL)

C_L LATCH ATTACHMENT (4 PER PANEL-16 TOTAL)

C_L CLOSEOUT BEAM

CLOSEOUT FRAMES RADIATOR TORQUE TUBE FITTINGS (4 PER SIDE - 8 TOTAL)

RADIATOR LATCH FITTINGS (12 PER SIDE - 12 TOTAL)

EXPANSION JOINT SHEAR PIN (5 PER SIDE - 10 TOTAL) (TYPICAL 4 PLACES)

C_L SHEAR FITTING ATTACHMENT (1 PER PANEL-4 TOTAL-PASSIVE)

AFT FUSELAGE SHELL AND THRUST STRUCTURE

The aft fuselage structure consists of the outer shell, thrust structure, and internal secondary structure, and is approximately 18 feet long, 22 feet wide, and 20 feet high. The aft fuselage supports and/or interfaces with the removable OMS pod, two wing spars, vertical fin, body flap, two external tank aft attachments, the main propulsion system, two $T = 0$ launch umbilical panels, three aft avionics bays, and other discrete system equipment.

The aft fuselage outer shell is covered with TPS except on the OMS pod decks and consists primarily of integrally machined aluminum skins and frames. In the highly loaded vertical fin support frame and floor fittings, machined diffusion-bonded titanium members are employed. In the less highly loaded areas, conventional aluminum skin-stringer construction is utilized. The forward bulkhead (X_0 1307) closes off the aft fuselage from the mid fuselage, and the base and dome heat shield protects the aft fuselage and its interior equipment (i.e., propulsion, avionics, hydraulics, electrical wiring, etc.) from the ascent and entry environments. The two ET umbilical areas are each closed off for entry by a beryllium door. Both doors are supported from the floor in the open position during ascent. The base heat shield is machined aluminum and honeycomb construction covered with TPS. It includes a flexible seal interface with Inconel honeycomb segments attached to the main engines. The Inconel segments are not covered with TPS, and are removable for access to the engine powerhead.

The thrust structure, which transmits the MPS thrust loads to the orbiter mid fuselage and to the external tank, is a multi-unit assembly consisting of members bolted together and to the outer shell. The thrust structure also supports the MPS low pressure turbopumps and main propellant lines and helps react the shell structure loads, with all interface loads carried through mono-ball joints. The thrust structure is composed of members made of diffusion-bonded, billet and tubular titanium machined to the final structural shape. Most of these members are reinforced with bonded boron epoxy laminates for strength, stiffness, and weight reduction. Welding also is used locally for fitting attachments.

The secondary structure supports all of the interior system equipment including the MPS pressurization lines, APU system, three avionic bays, ECLSS system, hydraulic system, wiring harness runs, and hard line runs. Secondary structure is of conventional aluminum construction, except for those members for which titanium and fiberglass are utilized for thermal isolation purposes.

119SSV86996
(Text)

Aft Fuselage Shell and Thrust Structure

STRUCTURAL FEATURES: SHELL FULLY MACHINED FOR COST   THRUST STRUCTURE: DBT: TRUSS ELEMENTS (BORON/EPOXY REINFORCED)

- DIFFUSION BONDED TITANIUM (DBT)
- BORON-EPOXY REINFORCED

VERTICAL TAIL ATTACH

PAYLOAD BAY DOOR INTERFACE

BASE HEAT SHIELD

OMS POD INTERFACE

UPPER THRUST SHELF

LOW PRESSURE TURBO-PUMP SUPPORT

LOWER THRUST SHELF

BODY FLAP INTERFACE

FWD

ORBITER/ET ATTACHMENT INTERFACE

BULKHEAD X_O 1307

MID FUSELAGE INTERFACE

WING INTERFACE

SHELL STRUCTURE

THRUST STRUCTURE
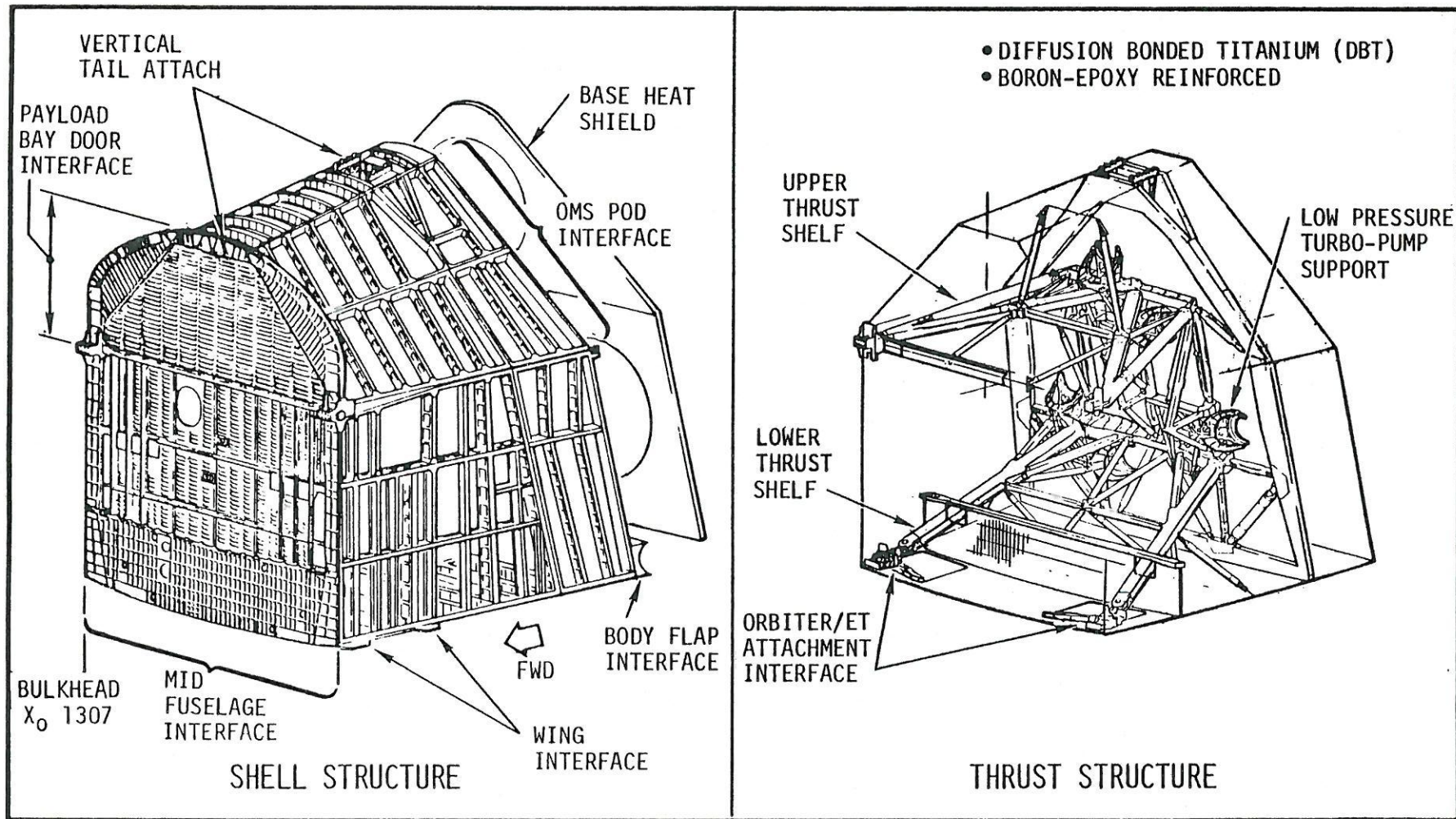
AFT PROPULSION SUBSYSTEM STRUCTURE

The aft propulsion system (APS) structure is fabricated primarily from graphite-epoxy composites and aluminum. It is 21.5 feet long and has a surface area of approximately 435 square feet. The APS structure is divided into two compartments: the orbit maneuvering system (OMS) pod and the reaction control system (RCS) housing.

The OMS pod is the larger of the two compartments and houses all the OMS propulsion components and the RCS propellant tanks and control components. The OMS pod is attached to the aft fuselage shell shoulder panel with 11 bolts and to the X_O 1307 bulkhead with one adjustable turnbuckle. The interface also includes a pressure seal at the shoulder panel and X_O 1307 bulkhead.

The OMS pod structure is constructed of the following elements:

1. Skin panels – graphite-epoxy honeycomb (NOMEX) sandwich

2. Forward bulkhead, aft tank support bulkhead, aft bulkhead and floor truss beam – machined 2124-T851 aluminum plate

3. Center line beam – built-up 2024-T81 aluminum sheet with titanium stiffner and graphite epoxy caps

4. Frames – graphite-epoxy

5. OMS engine thrust structure – conventional 2124-T851 aluminum construction

6. Cross braces – aluminum tubing

7. Attach fittings – the forward and aft fittings are 2124-T851 aluminum, the intermediate fittings are A-286 CRES with PH13-8110 CRES bushings.

The RCS housing, which attaches to the OMS pod structure, contains the RCS thrusters and associated propellant feed lines. The RCS housing is conventional aluminum and titanium sheet metal construction for the inner frames and shelves, machined aluminum for the forward bulkhead and flat outer skin panels, machined titanium skin panels at the thruster exist planes, and the curved outer skin panels are graphite-epoxy honeycomb (NOMEX) sandwich.

Access for maintenance and inspection of the OMS, RCS, and attach points is provided by 24 doors in the APS skins.

119SSV86997
(Text)

Aft Propulsion Subsystem Structure

RCS HOUSING

AFT TANK ALUMINUM SUPPORT BULKHEAD

OMS ENGINE ALUMINUM THRUST STRUCTURE

GRAPHITE EPOXY HONEYCOMB SANDWICH SKINS

TITANIUM THERMAL ISOLATION STRIP

OMS POD

FORWARD BULKHEAD INTEGRALLY MACHINED ALUMINUM

FLOOR TRUSS BEAM

Gr/Ep FRAMES

CROSS BRACE - REMOVABLE

ALUMINUM CENTERLINE BEAM

Gr/Ep "J" MEMBER UPPER CAP

ALUMINUM RCS TANK SUPPORT INTERCOSTAL

INTERMEDIATE TANK SUPPORT FRAME (TITANIUM WEB)

BODY FLAP

The body flap is an aluminum structure consisting of ribs, spars, skin panels, and a trailing edge assembly. The main upper and lower and the forward lower honeycomb skin panels are joined to the ribs, spars, and honeycomb trailing edge assembly with structural fasteners. Addition of the removable upper forward honeycomb skin panels completes the body flap structure.

The body flap structure, covered with RSI on its mold line surfaces, is attached to the lower aft fuselage by four rotary actuators. This assembly, with its aerodynamic and thermal seals, provides the Shuttle pitch trim control and thermally shields the main engines during reentry.

The overall dimensions are approximately 7 feet by 21 feet by 1-1/2 feet maximum thickness. The upper skin panels, aft of the forward spar, and the entire lower skin panels are mechanically attached to the ribs. The forward upper skin consists of five removable access panels attached to the ribs with quick release fasteners. There are four integrally machined aluminum actuator ribs which provide the aft fuselage interfaces through self-aligning bearings. Two bearings are located in each rib for attachment to the four rotary actuators located in the aft fuselage. The remaining ribs consist of eight stability ribs and two closeout ribs constructed of chem-milled aluminum webs bonded to aluminum honeycomb core. The forward spar web consists of chem-milled sheets with flanged lightening holes and stiffener beads. The spar web is attached (riveted) to the ribs through angle stiffeners. The trailing edge assembly includes the rear spar which is composed of piano-hinge half-cap angles, chem-milled skins, a full-depth honeycomb aluminum core, and closeout end plates. The trailing edge assembly attaches to the forward panels, upper and lower, by joining their respective piano-hinge halves to the mating-hinge half on the main panels by hinge pins. Two moisture drain lines and one hydraulic fluid drain line penetrate the trailing edge honeycomb core to meet the orbiter's horizontal and vertical drainage requirements.

An articulating thermal seal attaches to the forward cove area, located on the lower surface of the body flap. This seal blocks air flow and protects the structure from extreme induced temperatures.

Two ground-handling attach points are provided in each outboard actuator rib. Thermal protection plugs are inserted into these openings after installation of the body flap onto the aft fuselage.

119SSV86998
(Text)

Body Flap

AFT FUSELAGE/BODY FLAP INTERFACE

BODY FLAP

ROTARY ACTUATOR

ACCESS DOORS

UPPER MAIN HONEYCOMB PANEL

FULL DEPTH HONEYCOMB TRAILING EDGE

ALUMINUM RUB PLATE

CHAIN SEAL

BODY FLAP UPPER SURFACE

CLOSEOUT RIBS (HONEYCOMB)

LOWER MAIN HONEYCOMB PANEL

AFT FUSELAGE LOWER TRAILING EDGE

BODY FLAP LOWER SURFACE

MACHINED ACTUATOR RIBS

FRONT SPAR WEBS (SHEET METAL)

STABILITY RIBS (HONEYCOMB)

FORWARD LOWER HONEYCOMB SKIN PANELS

119SSV86998

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The wing structure assembly is constructed primarily of conventional aluminum materials with a multi-rib and spar arrangement and skin-stringer stiffened or honeycomb skin covers. Overall dimensions of each wing panel is approximately 60 feet long at the fuselage intersection with a maximum thickness of over five feet and a half-span of approximately 30 feet.

The construction of the most forward section of the wing structure, identified as the glove area, is trussed ribs with longitudinal skin-stringer covers. The forward beam closeout is aluminum honeycomb for OV 101, 099, and 102 and corrugated aluminum for 103 and subs. The most forward section is contoured to accept RSI material and the aft section a flat panel to accommodate installation of the RCC leading edge subsystem.

The intermediate wing section houses the main landing gear compartment and incorporates honeycomb skin covers. These covers are designed primarily by thermal stresses resulting from interaction between the wing covers/ ribs and the large outboard landing gear trunnion support rib which closes out the landing gear compartment.

The wing torque box area incorporates a trussed multi-rib design with castelated rib caps to accommodate the span-wise stringers of the stiffened skin panels, which are sized by a combination of operational flight loads and thermally induced stresses. The four major spars are of full depth web configuration, corrugated to minimize thermal loads. The X_o 1249, 1307, and outboard portion of the 1191 spar webs were changed from aluminum to graphite epoxy for OV 103 and subs. The rear spar provides attachment interfaces for the elevons, hinged upper seal panels, and associated hydraulic and electrical system installations.

The transition area on the upper surface between the torque box and the movable full-span elevons consists of a series of hinged panels which provide a closeout of the wing to elevon cavity. All these panels are of honeycomb sandwich construction. Panels outboard of Y_w = 312.5 are of Inconel material, and inboard of Y_w = 312.5 of titanium material. In each case, the material selected accommodates upper surface temperatures without TPS protection. All other wing external surfaces are covered with TPS.

The two-piece elevons are of aluminum honeycomb construction selected primarily for compatibility with the acoustic environment and thermal interaction considerations. Actuation of the elevons to 40 degrees up and 25 degrees down is accomplished with a single linear hydraulic actuator for each panel. The upper leading edge incorporates titanium rub panels on the inboard elevon and Inconel panels on the outboard elevon without TPS protection in the area of the shadow of the hinged trailing edge panels.

The main landing gear door is a single panel approximately 5 feet wide and 12 feet long. It is supported by three hinges along its outboard edge, three uplatches on the inboard edge and one uplatch on the forward edge. This door is of skin/stringer construction through vehicle OV 102 and of honeycomb construction for OV 103 and subs. OV 099 will be retrofitted to include the honeycomb design.

Attachment of the wing to the fuselage is accomplished with a tension bolt splice along the upper surface and shear splice along the lower surface in the area of the fuselage carry-through structure. A series of drag angles and clips at discrete locations both forward and aft of the carry-through area complete the fuselage attachment interface.

Wing Structure

ALUMINUM HONEYCOMB
1-IN. THICK

WING/ELEVON INTERFACE

ELEVON

ELEVON
SEAL PANELS

5 DEG OVERTRAVEL

40 DEG

55 DEG

25 DEG

5 DEG OVERTRAVEL

ELEVON EXCURSIONS

X_O 1365

X_O 1307

TORQUE BOX

X_O 1249

X_O 1191

INTERMEDIATE SECTION

X_O 1009.75

GLOVE

X_O 807

FEATURES:
- CORRUGATED SPAR WEBS
- TRUSS RIBS

ALUMINUM
SKIN-STRINGER
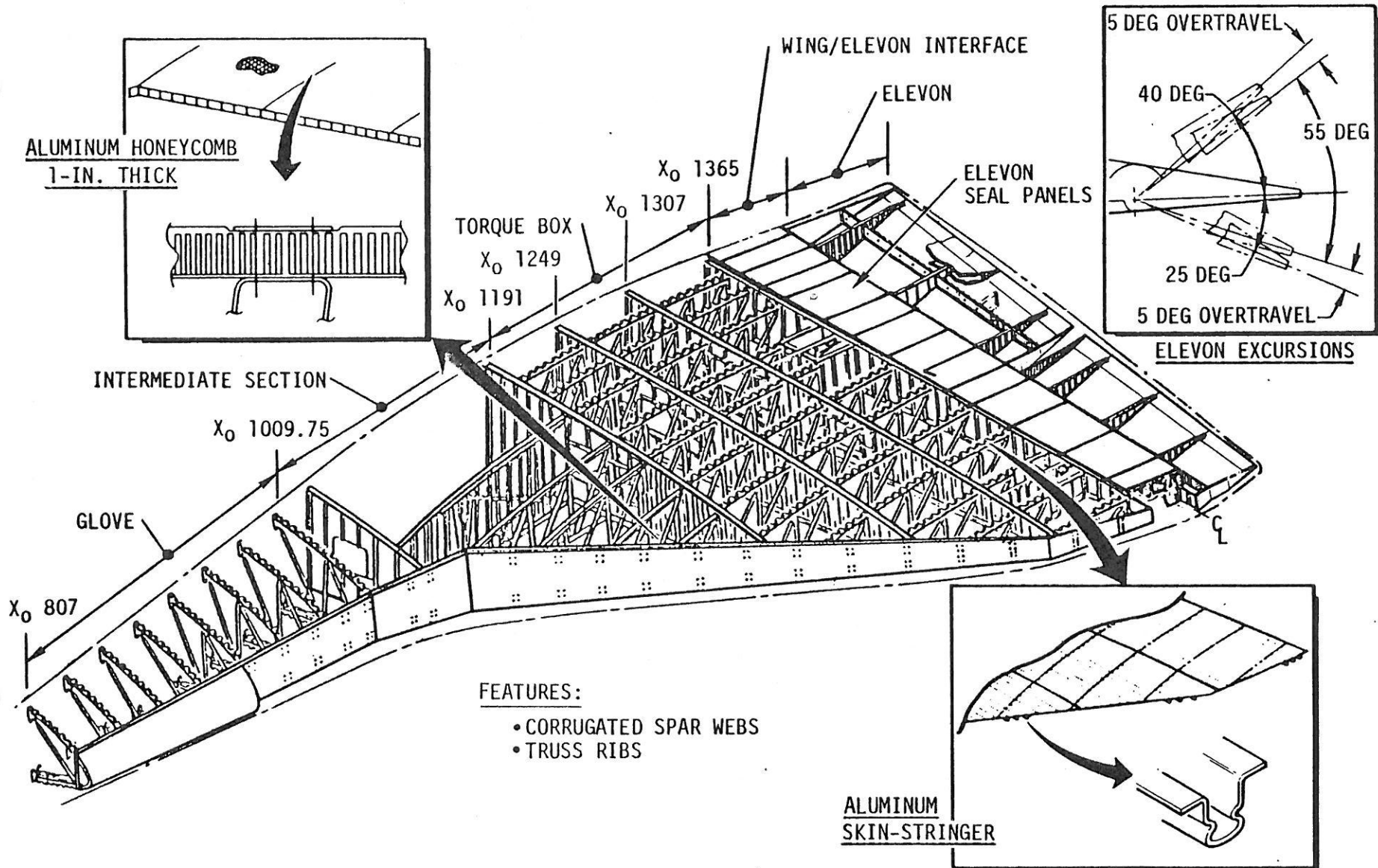
VERTICAL TAIL

The vertical tail structural subsystem consists of an integral machine skin and rib fin box, aluminum honeycomb rudder/speed brake panels, skin-stringer tip and fin box leading edge for OV 101, 102, and 099. An aluminum honeycomb tip is on OV 103 and subs and retrofitted on OV 099. An aluminum honeycomb fin box leading edge is on OV 103 and subs. Aluminum honeycomb lower trailing edge housing the power drive unit and an Inconel honeycomb conical seal housing the rotary actuators. The entire 413 square foot/wetted tail area is covered with TPS except for the conical seal, which is partially exposed and sealed. The fin rear spar is located at the 50-percent chordline with rudder hinge line at the 60-percent chordline. Primary attachment to the aft fuselage is by two tension bolts at the front spar and eight shear bolts at the rear spar (four per side).

Actuation of the rudder speed brake system is provided by the hydraulic power drive unit/mechanical rotary actuator system. Rudder control ($\pm$27 degrees) occurs when left hand and right hand drive shafts turn in the same direction, and speed brake control (49.3 degrees each) occurs when drive shafts turn in opposite directions.

Mission requirements call for a trail position rudder/speed brake during ascent. During reentry, from approximately Mach 10 to Mach 5, the speed brake control is provided. From Mach 5 to landing, rudder and speed brake controls are combined as required. Primary system control is automatic with manual override. Maximum deflection rate of 10 degrees per second control capability is available.

The Shuttle vertical tail structure is designed for 163 dB acoustic environment during launch, appropriate maximum shears, bending and torsion loads for boost reentry and landing conditions; and for maximum aluminum temperatures of 350 F and maximum Inconel temperatures at 1200 F.

Vertical Tail

TIP

FIN BOX

LEADING EDGE

CONICAL SEAL

ROTARY ACTUATORS(4)

RIBS

POWER DRIVE UNIT

AFT ATTACH

FWD ATTACH

RUDDER/SPEED BRAKES (AL HONEYCOMB)

RUDDER RIGHT

LEFT & RIGHT HAND DRIVE SHAFTS

SPEED BRAKE OPEN

INTEGRAL MACHINED SKINS
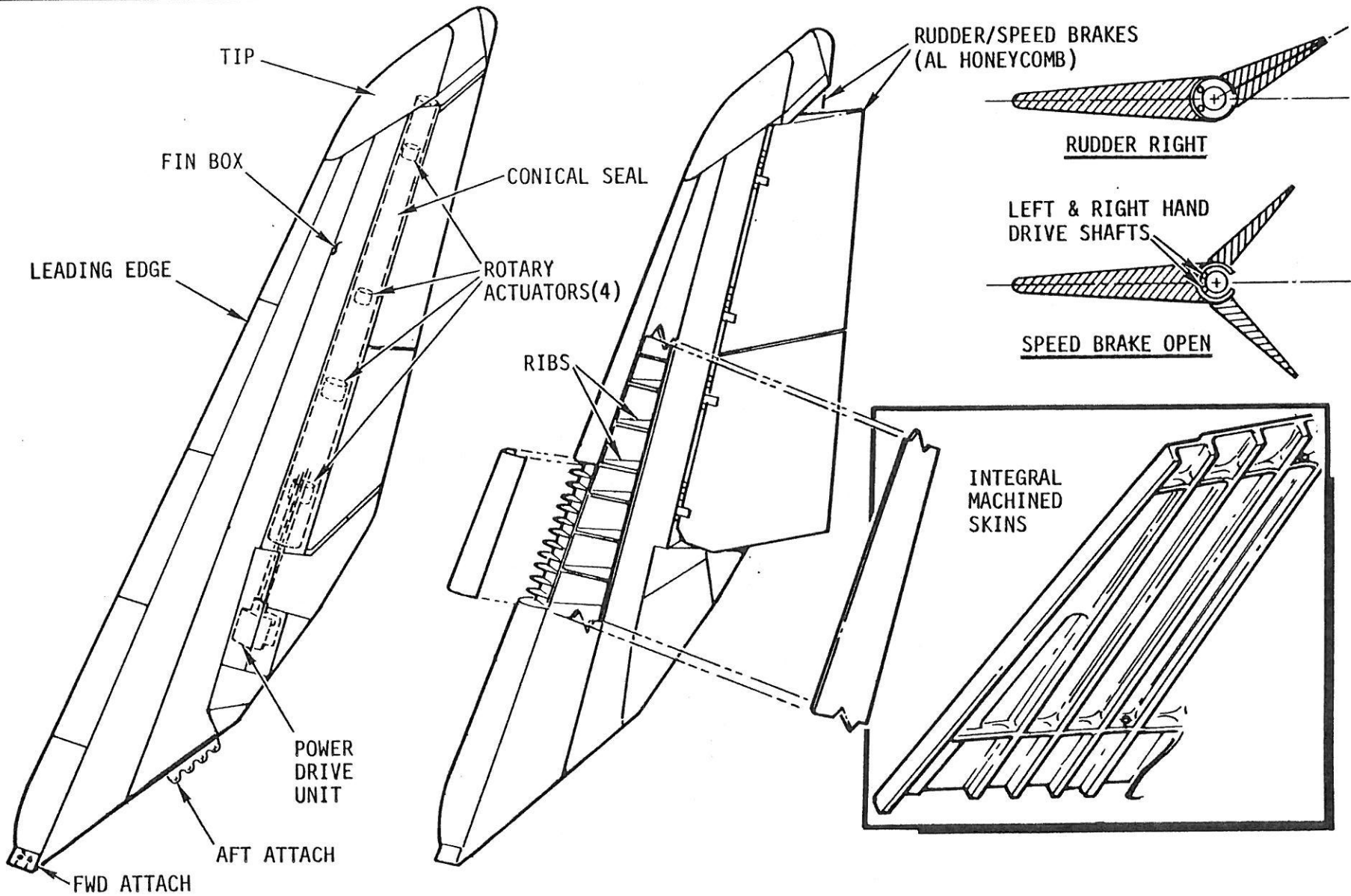
ORBITER ISOTHERMS - TRAJECTORY 14414.1C

Predicted isotherms for ascent and orbiter entry are shown on the
accompanying chart. The isotherms were generated from the normal (no
abort), nominal (no dispersions) ascent trajectory for Mission 3A and the
nominal entry and descent trajectory for Mission 3B. For ascent,
insertion was assumed to take place at an altitude of 60 nautical miles.
The entry interface during descent was assumed along the target line
(nominal entry velocity and flight path angle) at 400,000 feet. Nominal
values of convective heating were assumed during ascent and descent,
based upon the latest available wind tunnel data. Heating from the solid
rocket booster (SRB) and SSME plumes was added during the mated portion
of the Space Shuttle vehicle (SSV) ascent.

119SSV87001
(Text)

Orbiter Isotherms — Trajectory 14414.1C

LOWER SURFACE VIEW

UPPER SURFACE VIEW

*DENOTES ASCENT TEMPERATURES
(MAXIMUM YAW 8 DEG)

2300F
2000F
1800F
2460F
2000F
2000F
2300F
2730F
2300F
1800F
1200F
600F
800F
600F
1200F
800F
1200F

ENTRY/ASCENT
700F / 750F
750F / 830F
850F / 900F

*1000F
1750F
800F
1200F
1680F
*2100F
*2150F
*2220F
*1000F

ENTRY | ASCENT
700F | 750F
750F | 830F
850F | 900F

1200F
800F
800F
600F
2665F
2300F
1800F
2000F
*785F
*795F
*760F
*760F
*805F
*805F
*680F
*830F

SIDE SURFACE VIEW

Space Systems Group

Rockwell
International

20SSV87001A

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THERMAL PROTECTION SUBSYSTEM

The thermal protection subsystem (TPS) is passive and consists of materials applied externally to the primary structural shell of the orbiter. It supports mission requirements by maintaining the outer skin within acceptable temperature limits. Internal insulation, heaters, and purging facilities control interior compartment temperatures but are not part of the TPS. TPS materials and nominal temperatures (100 mission use) are as follows:

1. Coated Nomex felt (FRSI): temperatures less than 700°F for entry and 750°F for ascent

2. Low-temperature reusable surface insulation (LRSI): temperatures below 1200°F and above 700°F

3. High-temperature reusable surface insulation (HRSI): temperatures below 2300°F and above 1200°F

4. Reinforced carbon-carbon (RCC): In areas such as wing leading edge and nose cap, where temperatures exceed 2300°F

5. Thermal window panes and metal for forward RCS fairings and elevon upper surface rub seal panels

6. Thermal barriers around operable penetrations (main egress hatch, landing gear doors, etc.) to protect against aerothermal heating

7. Gap fillers installed in tile-to-tile gaps in areas of high differential pressure to preclude overheating filler bars, strain isolator pad (SIP), and the airframe structure

8. Aerothermal/aerodynamic seals at the wing/elevon, fuselage/body flap interfaces

9. Pressure seals around the payload bay to prevent overpressurization within the bay

The basic RSI materials are of two types: (1) ceramic LI-900 material used for HRSI and LRSI and (2) Nomex felt material used for FRSI. An alternate higher strength ceramic LI-2200 material instead of LI-900 is used for HRSI in areas interfacing with thermal barriers or where temperatures exceed 2500 to 2600 F. HRSI and LRSI differ in the coatings applied for waterproofing, handling, and optical property control. HRSI has a black ceramic coating with a design surface emittance of 0.85 and a solar absorptance of about 0.85; LRSI has a white ceramic coating with a design surface emittance of 0.8 and a design solar absorptance of 0.32. The FRSI has a pigmented silicone coating with design optical properties the same as those for the LRSI coating. The thermal barriers and gap fillers are made of alumina fibers covered by AB-312 ceramic cloth. Where special shapes are required, internal metallic reinforcement may be utilized. The payload bay utilizes fibrous pile thermal barriers. The aerothermal seals are graphite/epoxy and metallic for aerodynamic surfaces, and the payload bay pressure seals are tubular Teflon reinforced with metallic springs.

10SSV75987C
(Text)

Thermal Protection Subsystem

REINFORCED CARBON-CARBON (RCC)

HIGH-TEMPERATURE, REUSABLE SURFACE INSULATION (HRSI)

LOW-TEMPERATURE, REUSABLE SURFACE INSULATION (LRSI)

COATED NOMEX FELT REUSABLE SURFACE INSULATION (FRSI)

METAL OR GLASS
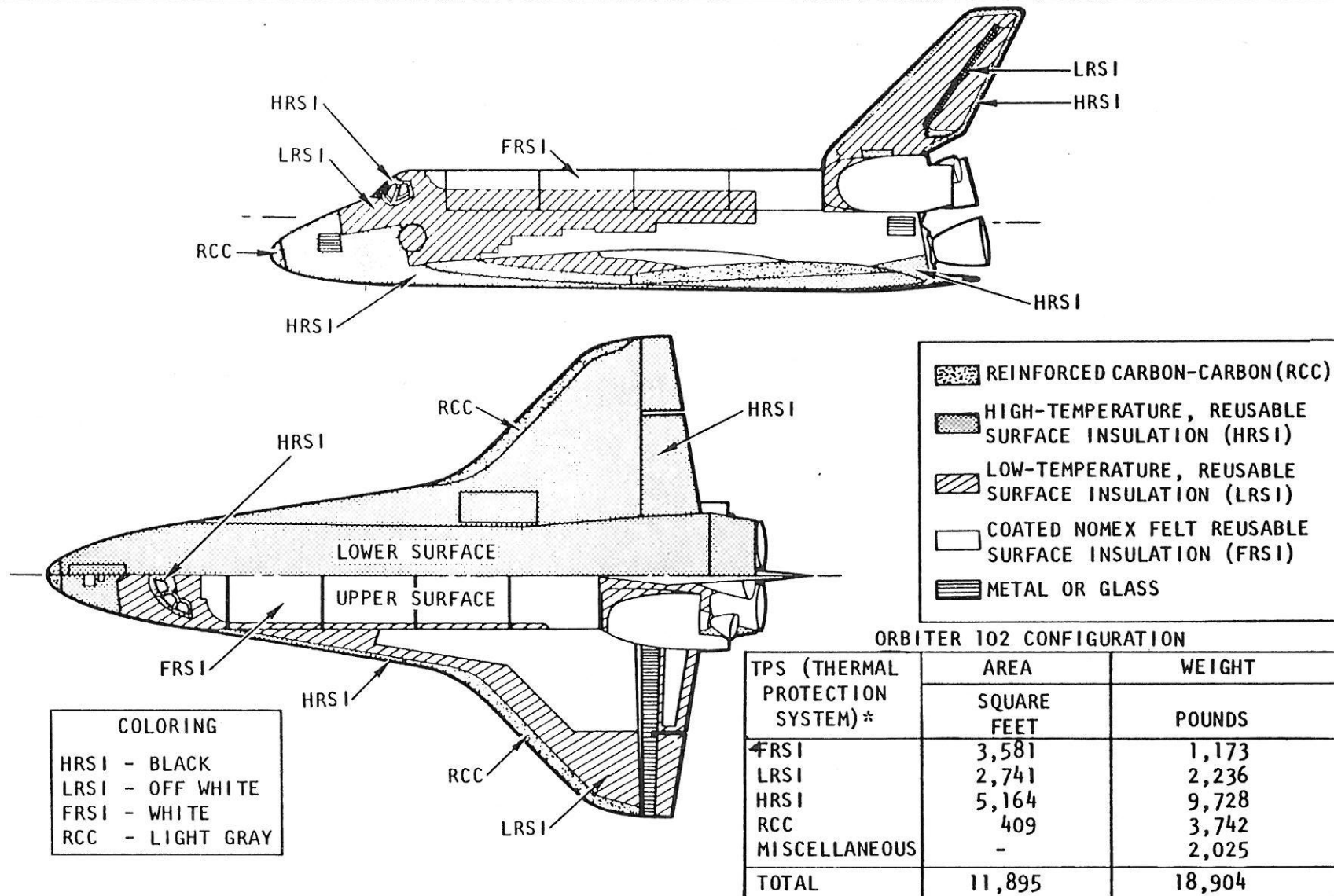
COLORING

HRSI - BLACK
LRSI - OFF WHITE
FRSI - WHITE
RCC - LIGHT GRAY

ORBITER 102 CONFIGURATION

TPS (THERMAL PROTECTION SYSTEM)*	AREA	WEIGHT
	SQUARE FEET	POUNDS
FRSI	3,581	1,173
LRSI	2,741	2,236
HRSI	5,164	9,728
RCC	409	3,742
MISCELLANEOUS	–	2,025
TOTAL	11,895	18,904

*INCLUDES BULK INSULATION, THERMAL BARRIERS, & CLOSEOUTS

THERMAL PROTECTION SUBSYSTEM INTERFACES

Typical thermal protection subsystem (TPS) interfaces are illustrated on
the following page. Transition of the leading edge subsystem (LESS) to
the high-temperature reusable surface insulation (HRSI) is shown for the
nose and outer wing leading edge. A typical joint for the low-temperature
RSI (LRSI) and HRSI tiles is also shown.

As shown, basic HRSI and LRSI tile installations are RSI/RTV bond/SIP/
RTV bond/structure arrangements with filler bars at the intertile gaps;
the filler bars are bonded only to the structure. Where high surface
pressure gradients would cause cross-flow of boundary layer air within
the intertile gaps, tile gap fillers are provided to minimize increased
heating within the gaps.

Thermal Protection Subsystem Interfaces

LESS - NOSE SECTION

- HRSI
- INTERNAL INSULATION
- ALUMINUM STRUCTURE
- LANDING GEAR DOOR
- RCC, NOSE CAP
- RCC, TEE SEAL
- HRSI
- CHINE PANEL & LANDING GEAR DOOR ATTACH

LESS - WING SECTION

- A-286 BOLTS & INCONEL BUSHINGS
- HRSI
- COATED RCC LEADING EDGE PANEL
- LEADING EDGE SPAR (INTERNAL INSULATION NOT SHOWN)
- INCONEL 718 FITTINGS
- COATED RCC TEE SEAL
- A-286 BOLTS & INCONEL BUSHINGS
- HRSI

HRSI OR LRSI

LOWER SIDE	UPPER SIDE
0.025 IN. MIN	0.035 IN. MIN
0.065 IN. MAX	0.075 IN. MAX

- HRSI OR LRSI TILE (COATED LI-900 SILICA)
- 0.0075 RTV 560 ADHESIVE
- STRAIN ISOLATOR PAD (NOMEX FELT)
- ALUMINUM SKIN
- FILLER BAR (COATED NOMEX FELT)

0.50 +0.06 IN.

0.75 +0.03 IN.

THERMAL CONTROL SUBSYSTEM

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

Several methods are used to accomplish thermal control, including the use of available heat sources, heat sinks, thermal coatings, and insulation blankets. The blankets, used extensively throughout the orbiter, are of two basic types: fibrous bulk and MLI (multi-layer insulation). The MLI is a highly efficient insulation at low pressure (5×10^{-4} torr or less) and is used to maintain subsystems within thermal limits during on-orbit phases of the mission. The bulk insulation is a better insulator at higher pressure and is therefore used primarily to attenuate thermal soakback occurring from entry through postlanding phases of the mission.

The MLI blankets are constructed of 8 layers of double goldized kapton reflectors separated by Dacron net plus 2 cover layers for total of 10 layers. The bulk insulation blankets are constructed of 2 lb/ft^3 density fibrous bulk material. Both types of blankets are covered by reinforced double goldized Kapton material, which also includes provisions for venting. In the payload area, all blanket surfaces exposed directly to space (payload bay doors open) are covered with a Teflon-coated beta material. This material meets thermal requirements as well as crew optical requirements.

Thermal Control Subsystem

FIBROUS BULK INSULATION

SIDEWALL

PAYLOAD BAY LINER

OMS/RCS POD

ELEVON ACTUATORS (4)

```
//// BULK INSULATION BASELINE
     2 PCF DENSITY COVER
     * MATERIAL - DGK REINF
```

FORWARD FUSELAGE SHELL

PAYLOAD DOORS

WATER BOILERS

PAYLOAD BAY LINER

RCS MODULE

AFT OF BHD 262

BACK OF BHD 576

AVIONICS BAYS (3)

EQUIPMENT BAY

OMS/RCS POD

GYROS (4)

APU TANKS (3) (3 PCF)

APU DISCONNECT COMPARTMENT

MULTILAYER INSULATION (MLI)

PAYLOAD LINER

WING COVER BOX

```
==== MLI - BASELINE
     REFLECTORS - 8 LAYERS DGK
     SEPARATORS - DACRON NET
     * COVER MATERIAL - DGK REINF
```

FORWARD FUSELAGE SHELL FRAMES

BHD AT X_o 1307

ACTUATOR DRIVE

RCS COMPARTMENT BHDs, FRAMES & NLG WELL

AFT OF BHD 576

PAYLOAD LINER

BHD 273

BHD 378

FORWARD LOWER EQUIPMENT BAY FRAMES

WING BOX COVER

*NOTE: TEFLON COATED BETA CLOTH COVER USED IN AREAS EXPOSED TO SPACE WITH P/L DOORS OPEN

MAIN PROPULSION SUBSYSTEM

The Space Shuttle main propulsion subsystem (MPS) is shown and consists of the Space Shuttle main engines (SSME's), external tank (ET), propellant feed, management, fill and drain, conditioning, pressurization control, penumatic supply, and purge. These subsystems are further illustrated in a subsequent schematic diagram of the MPS.

Each of the three SSME's operates with a fixed nozzle area ratio of 77.5:1 at a mixture ratio (LO_2/LH_2) of 6:1 by weight and a chamber pressure of 3000 psia to produce a rated sea-level thrust of 375,000 pounds and a vacuum thrust of 470,000 pounds. The engines can be throttled over a thrust range of 65 to 109 percent of the rated thrust level. This allows orbiter acceleration to be limited to 3 g's. The engines are capable of being gimbaled $\pm$10.5 degrees in pitch and $\pm$8.5 degrees in yaw for flight control during the orbiter boost phase.

The 1,550,000 pounds of usable ascent propellants required for SSME operation are provided from the external tank. The ET is expended after main engine cutoff (MECO) but prior to achieving orbit. The ET impacts in the ocean after separating from the orbiter and is not reusable. Five MPS fluid lines interface with the ET through disconnects located at the bottom of the orbiter aft fuselage. The three hydrogen disconnects are mounted on a carrier plate on the left side of the orbiter (facing forward), and the two oxygen disconnects are mounted on the right side. Ground servicing of the MPS is accomplished through umbilicals on both sides of the aft fuselage (hydrogen is serviced from the left side facing forward, oxygen from the right side).

The orbiter MPS engines burn for approximately eight minutes, from just prior to liftoff until MECO. For the first two minutes, the MPS engines operate in parallel with the solid rocket booster (SRB) motors. The MPS and SRB provide the velocity increment necessary to almost achieve the initial mission orbit. The final small velocity increment to achieve the desired orbit is provided by the orbit maneuvering subsystem.

119SSV87051
(Text)

Main Propulsion Subsystem

ENGINE NUMBER

① ③ ②

MAIN ENGINES (3);
470 KLB VACUUM THRUST;
375 KLB SEA-LEVEL THRUST

LH₂ PREVALVE

LH₂ FILL/DRAIN DISCONNECT

ORBITER/ET LO₂ DISC

ORBITER/ET LH₂ DISC

LO₂ PREVALVE

MAIN ENGINES

12 IN. FEED

8 IN. LO₂ FILL & DRAIN

17 IN. FEED

8 IN. LH₂ FILL & DRAIN

ORBITER LOWER SURFACE

LO₂ LH₂
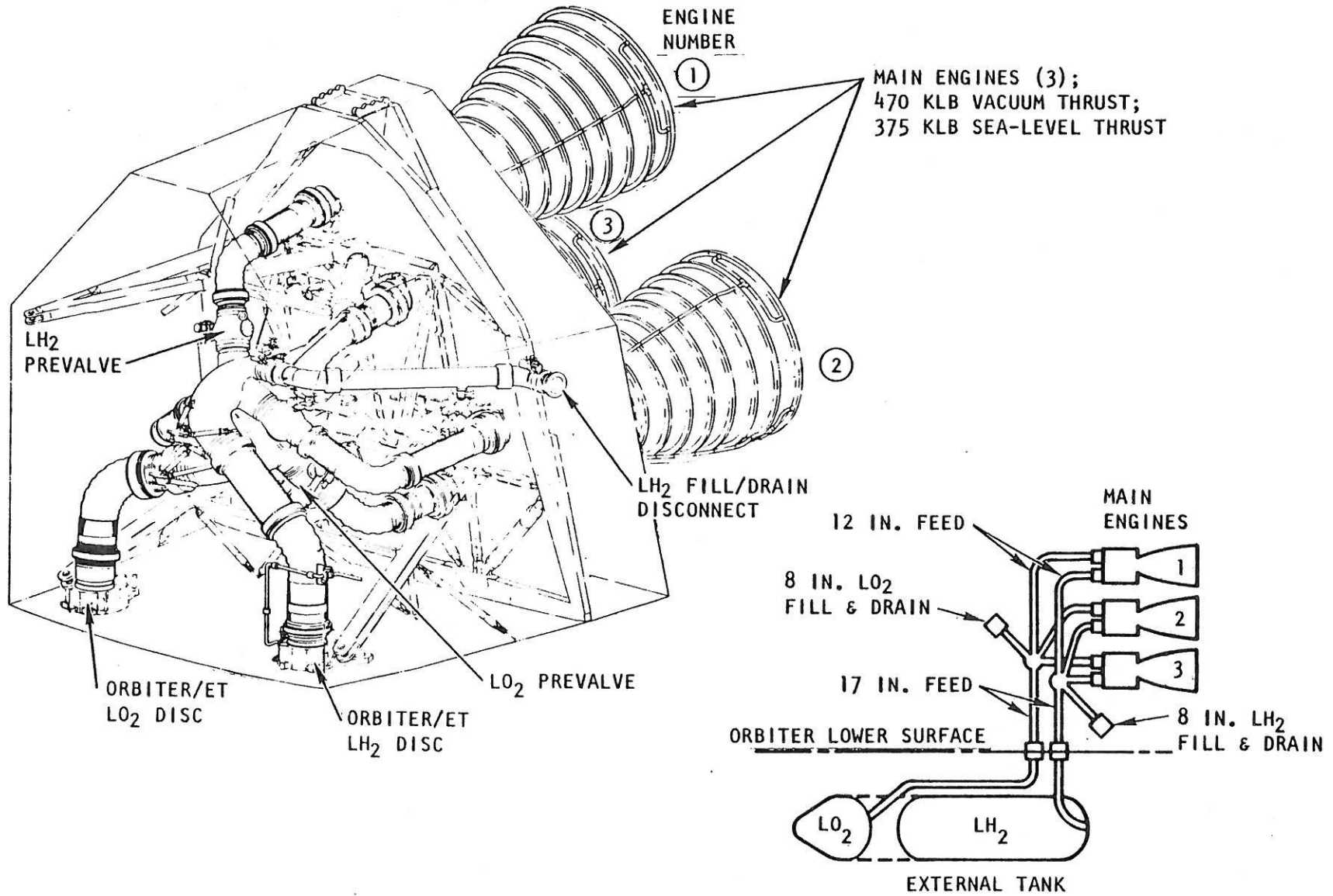
EXTERNAL TANK

MAIN PROPULSION SUBSYSTEM SCHEMATIC

A schematic of the main propulsion subsystem (MPS), which includes the external tank (ET) and the Space Shuttle main engines (SSME), is shown on the facing page. The MPS consists of the following subsystems: propellant feed, propellant fill and drain, propellant conditioning, pressurization control, gaseous helium (GHe) pneumatic supply, gaseous nitrogen (GN_2) purge, propellant management, main engines, and external tank. The schematic does not show the penumatic supply or GN_2 purge.

The propellant feed supplies propellants (LH_2 and LO_2) to the main engines from the ET. The propellant fill and drain provide propellants to the ET during loading and propellant drain capability on the ground. The propellant conditioning system provides conditioned propellants to the SSME's for engine start. The pressurization control maintains the proper pressures in the ET. Tank prepressurization with ground-supplied GHe plus hydrostatic head provides the required pressure to the engine pump inlets for the starting transient. Following engine thrust build up, tank pressure is maintained with vaporized propellants extracted from the engines. The ET ullage pressures during boost operation will be maintained at 20 to 22 psig in the LO_2 tank and 32 to 34 psia in the LH_2 tank. Pneumatics are supplied by a 4000-psi helium storage system with 750-psi regulation for valve actuation, SSME purge, and backup SSME shutdown. Expulsion of residual propellants after main engine cutoff (MECO) and repressurization of MPS lines for reentry are provided by a 20-psi helium regulated supply. The GN_2 purge provides an inerting purge to the SSME's prior to start. The propellant management controls propellant loading and a low-level cutoff which is a backup to the normal velocity cutoff. The three SSME's ignite, burn, and expend the propellants at a mixture ratio of 6:1 (oxidizer/fuel) to provide a vacuum thrust of 470,000 pounds each at normal power level. The ET provides the 1,550,000 pounds of usable ascent propellants required to provide the velocity increment which must be supplied by the MPS.

Main Propulsion Subsystem Schematic
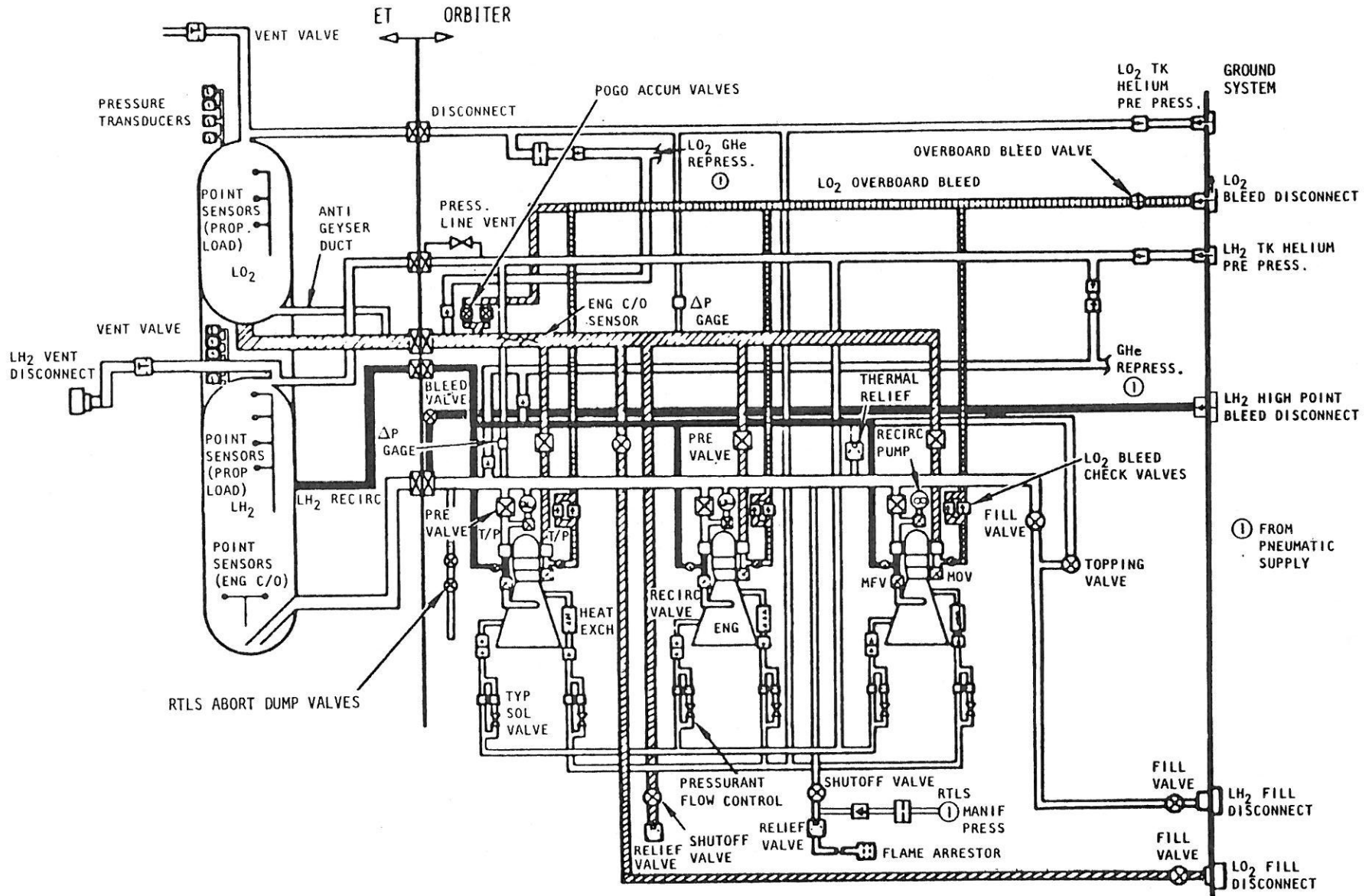
ORBITAL MANEUVER SUBSYSTEM

The orbital maneuver subsystem (OMS) provides the thrust to perform orbit insertion, orbit circularization, orbit transfer, rendezvous, and deorbit. The integral OMS tankage is sized to provide propellant capacity for a delta-V of 1000 feet per second when the vehicle carries a payload of 65,000 pounds. A portion of this delta-V is used during ascent. This propellant quantity (23,876 pounds of usable propellant, plus 1280 pounds of residuals and other allowances) is provided in two pods, one located on each side of the aft fuselage. Each pod contains a high-pressure helium storage bottle, tank pressurization regulators and controls, a fuel tank, oxidizer tanks, and a pressure-fed, regeneratively cooled rocket engine. Each engine produces a vacuum thrust of 6000 pounds, at a chamber pressure of 125 psia, and specific impulse of 313.2 seconds, utilizing nitrogen tetroxide (N_2O_4) as the oxidizer and monomethylhydrazine (MMH) as fuel, at an oxidizer/fuel mixture ratio of 1.65:1. Nozzle expansion area ratio is 55:1.

The OMS and RCS propellant lines are interconnected (1) to supply propellant from the OMS tanks to the RCS thrusters on orbit and (2) to provide crossfeed between the left and right OMS and RCS systems. In addition, propellant lines from optional auxiliary OMS tanks located in the orbiter cargo bay interconnect with the OMS propellant lines in each pod. Propellant and pressure tank features are presented in the table below:

OMS TANK FEATURES

Item	Dia (in.)	Length (in.)	Vol (ft^3)	Press. (PSI)
OMS Fuel & Oxidizer Tank	49.1	94.3	90.0	313
OMS Helium Tank	40.2	—	17.4	4875

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(Text)

Orbital Maneuver Subsystem

RCS HELIUM TANKS (TITANIUM/COMPOSITE)

OMS FUEL TANK (TITANIUM)

OMS ENGINE

RCS PRIMARY THRUSTERS

RCS VERNIER THRUSTERS

RCS FUEL TANK (TITANIUM)

RCS OXIDIZER TANK (TITANIUM)

OMS OXIDIZER TANK (TITANIUM)

OMS HELIUM TANK (TITANIUM/COMPOSITE)

OMS ENGINE CHARACTERISTICS	
THRUST	6000 LB (VACUUM)
SPECIFIC IMPULSE	313.2 SEC
CHAMBER PRESSURE	125 PSIA
MIXTURE RATIO	1.65
GIMBAL CAPABILITY	+6° PITCH ±7° YAW

OMS ΔV CAPABILITY   1000 FT/SEC (65,000 LB PAYLOAD)
USEABLE OMS PROPELLANT: 23,876 LB TOTAL:
                          14,866 LB N_2O_4
                          9010 LB MMH

Orbital Maneuver Subsystem Schematic

LEFT POD
He
He ISOLATION VALVE
A   B
REGULATOR
He FILL
VAPOR ISOLATION VALVE
1
2
CHECK VALVE
RELIEF VALVE
GRD C/O
TANK VENT
MMH
NTO
TANK ISOLATION VALVE
A B
A B
CROSSFEED VALVE
A
B
A
B
ENG CONT VALVE
1
2
TO FUEL MANIFOLD
OME
PURGE VALVE
ENG PRESS VLV
GN2
TO FUEL MANIFOLD
RCS INTERCONNECT (CROSSFEED) VALVE

PAYLOAD BAY KIT
2   He 1   3
A   B
1 2
3 2 MMH 1
1 NTO 2 3
FUEL FILL
BANK B
BANK A
PBK ISOLATION VALVE
OX FILL
AFT FUSELAGE

RIGHT POD
He
A   B
1
2
A B
A B
A
B
A
B
OME
TO FUEL MANIFOLD
GN
TO FUEL MANIFOLD

⊗ MOTOR OP VLV
⊞ BURST RELIEF VALVE
▷◁ SOL VLV W/FILTER

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30SSV87054   123

OMS PAYLOAD BAY KIT

The integral orbital maneuver subsystem (OMS) propellant tanks aboard the orbiter provide approximately 1000 feet per second of velocity on-orbit. Auxiliary propellant kits must be employed whenever mission velocity requirements for the OMS exceed this value. Up to three sets of auxiliary tankage, each providing an additional delta V capability of 500 feet per second, can be added to achieve a total delta V capability of 2500 feet per second. The auxiliary tankage, located in the payload bay, utilizes the same type propellant tanks, helium bottles, and pressurization system components as the pods. The weight and the nominal added delta V are shown in the table below as a function of the number of kits employed. The data presented are the latest values of the baseline design.

| NUMBER OF KITS | TOTAL ADDED WEIGHT * | | NOMINAL ADDED ΔV (fps) |
	DRY (lb)	FILLED** (lb)	
1	2978	15,380	500
2	3955	28,723	1000
3	5275	42,408	1500

*Does not include fittings (additional 397 lb)
**Includes all loaded propellants and gases

OMS Payload Bay Kit

108
PBK MAX ENVELOPE

HELIUM PRESSURIZATION PANEL (REF)

PBK 3

PBK 2

PBK 1

PAYLOAD BAY ENVELOPE

$X_o = 1194$

$X_o = 1249$

$X_o = 1302$

$X_o = 1307$

HELIUM TANK

$Y_o = 0.00$

$Y_o = 17$ TYP

OMS/PROP. PAYLOAD DISCON PANELS

PBK ENVELOPE

180 IN. DIA

HELIUM PRESSURIZATION PANEL

3.00 IN.

PBK 3 OXIDIZER

PBK 3

PBK 3 FUEL

$Y_o = 85.35$

$Y_o = 94$

PBK 2 FUEL

PBK 1

PBK 2 OXIDIZER

PBK 1 OXIDIZER

PBK 1 FUEL

PAYLOAD FUEL SERVICING PANELS

ELECTRICAL PANEL

PROP. TANKS

$Y_o = 52.15$ TYP

$Z_o = 308.4$

VIEW LOOKING FWD
1500 FFS KIT

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REACTION CONTROL SUBSYSTEM

The reaction control subsystem (RCS) employs 38 bipropellant primary thrusters and 6 vernier thrusters to provide attitude control and three-axis translation during the orbit insertion, on-orbit, and entry phases of flight.

The RCS consists of three propulsion units, one in the forward module and one in each of the aft propulsion pods. All modules are used for external tank separation, orbit insertion, and orbital maneuvers. Only the aft RCS modules are used for entry attitude control.

The RCS propellants are nitrogen tetroxide (N_2O_4) and monomethylhydrazine (MMH). The design mixture ratio of 1:6 (oxidizer weight to fuel weight) was set to permit the use of identical propellant tanks for both fuel and oxidizer. The propellant tank internal configuration varies from forward module to aft pod due to the variation of operational requirements; i.e., aft RCS must operate during entry while the forward RCS is inactive during this period. The propellant capacity of the tanks in each module is 928 pounds of MMH and 1477 pounds of N_2O_4. An interconnect between the OMS and the RCS in the aft pods permits the use of OMS propellant by the RCS for on-orbit maneuvers. In addition, the interconnect can be used for cross feeding propellants between the right- and left-hand RCS pods.

Performance
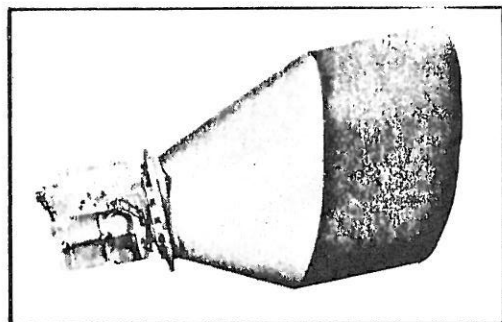
Primary Thruster

	Primary	Vernier
Thrust	870 lb	24 lb
MR	116	116
Life	50,000 starts	500,000 starts
	20,000 sec	125,000 sec
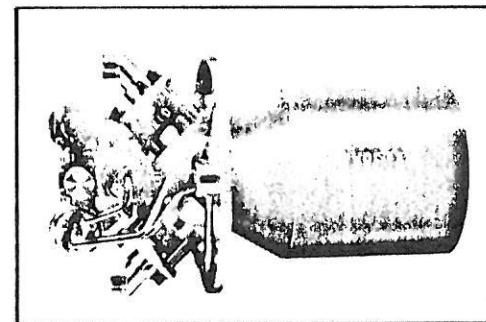
Vernier Thruster

Reaction Control Subsystem

PRIMARY THRUSTER (14)

ELECTRICAL DISCONNECT BRACKET

ACCESS COVER

SERVICING PANEL

OXIDIZER TANK

HELIUM TANK

VERNIER THRUSTER (2)

PURGE & CHECKOUT PANEL

RCS PROPELLANT TANKS

RCS HELIUM TANKS

RCS PROPELLANT MANIFOLD VALVES

OMS ENGINE (2) 6000 LB VACUUM

PRIMARY THRUSTERS (12 PER AFT POD)

VERNIER THRUSTERS (2 PER AFT POD)

OMS HELIUM TANK

OMS PROPELLANT TANKS

RCS PRESSURIZATION COMPONENTS

OMS/RCS ARCS POD

```
                              RCS ONLY
1 FORWARD RCS MODULE, 2 AFT RCS SUBSYSTEMS IN PODS
38 MAIN THRUSTERS (14 FORWARD, 12 PER AFT POD)
    THRUST LEVEL = 870 LB (VACUUM) EACH
    Isp = 280 SEC
6 VERNIER THRUSTERS (2 FORWARD & 4 AFT)
    THRUST LEVEL = 24 LB EACH
    Isp = 260 SEC
```

PROPELLANTS:	OXIDIZER	FUEL
MAXIMUM LOADED	N_2O_4	MMH
AFT (2 PODS)	2954 LB	1856 LB
FORWARD	1477 LB	928 LB

RCS SCHEMATICS

RCS - AFT MODULE

Each aft RCS module contains 12 primary thrusters and two vernier thrusters. Propulsive thrust is generated by pressure-fed, hypergolic fueled rocket engines. The aft right and left hand RCS propellant systems are interconnected to the orbiter maneuvering systems (OMS) propellant systems, in each pod, thus allowing the RCS thrusters to operate from the OMS propellant tanks or opposite RCS tanks.

Each RCS unit contains a propellant storage and distribution system; a helium pressurant gas storage, regulation, and distribution system to pressurize the propellant tanks; multiple thrusters; a thermal control system; and electrical and flight instrumentation systems. Sensing devices are used throughout the RCS modules to provide subsystem operating performance inputs to controls and displays monitored by the crew.

RCS - FORWARD MODULE

The forward RCS module is a removable unit containing 14 primary and two vernier thrusters. High-pressure helium is used to pressurize propellants and tanks through redundant dual pressure regulators and check valves.

A pressure relief system is provided to accommodate a dual regulator failure or pressure rise due to unforeseen thermal excursions.

Propellant storage tanks containing a zero-g propellant acquisition system and an entry sump provide propellant feed-out capability over the orbiter operational g levels and attitudes. Propellant distribution manifolds are independently controlled by tank and manifold isolation valves, providing propellant management capability and system redundancy.

Common components are used, wherever possible, throughout the forward and aft RCS.

119SSV64397A
(Text)

RCS Schematics

AFT MODULE (LEFT)

FORWARD MODULE

MANIFOLD 4
-Z
+Z
+Y

MANIFOLD 3
-Z
+Y
+X

MANIFOLD 2
-Z
+Z
+Y

MANIFOLD 1
+Z
+Y
+X

MANIFOLD 5
-Z
+Y

N_2O_4

He

He

CROSSFEED

MMH

MANIFOLD 5
-Z
-Z

MANIFOLD 4
-Z
-Y

MANIFOLD 3
+Z
-Z
+Y
-X

MANIFOLD 2
+Z
-Z
-Y
-X

MANIFOLD 1
+Z
-Z
+Y
-X

N_2O_4

He

He

MMH

30SSV64397

129
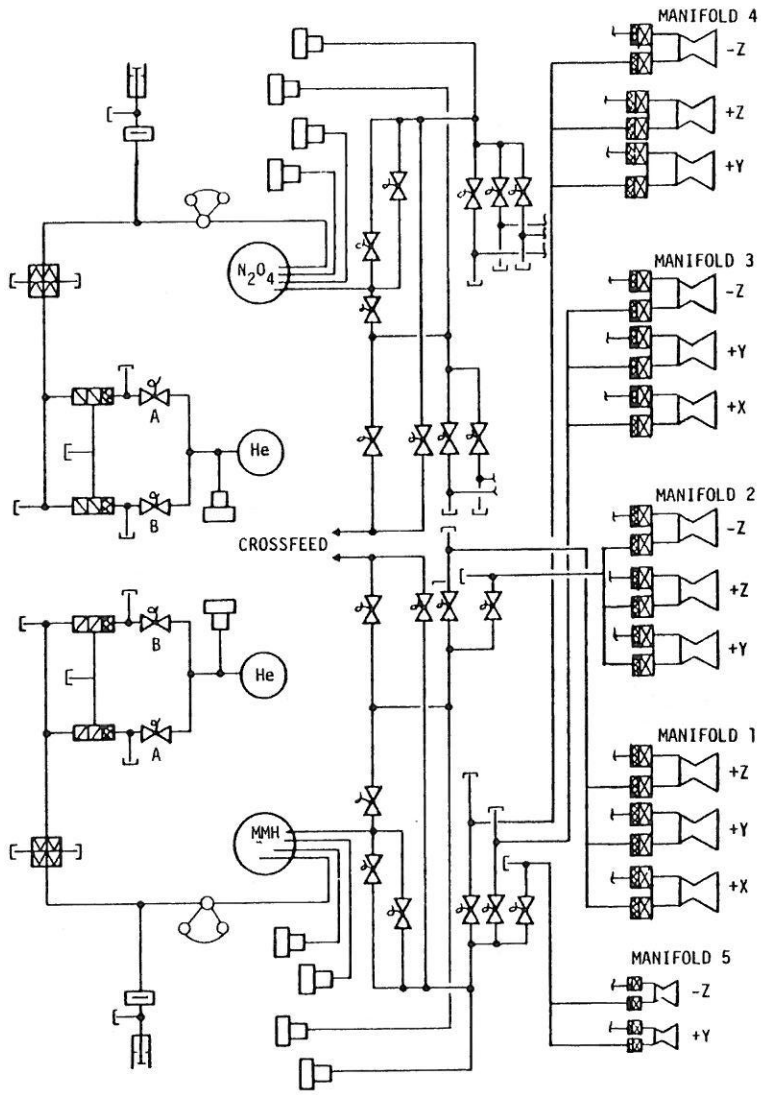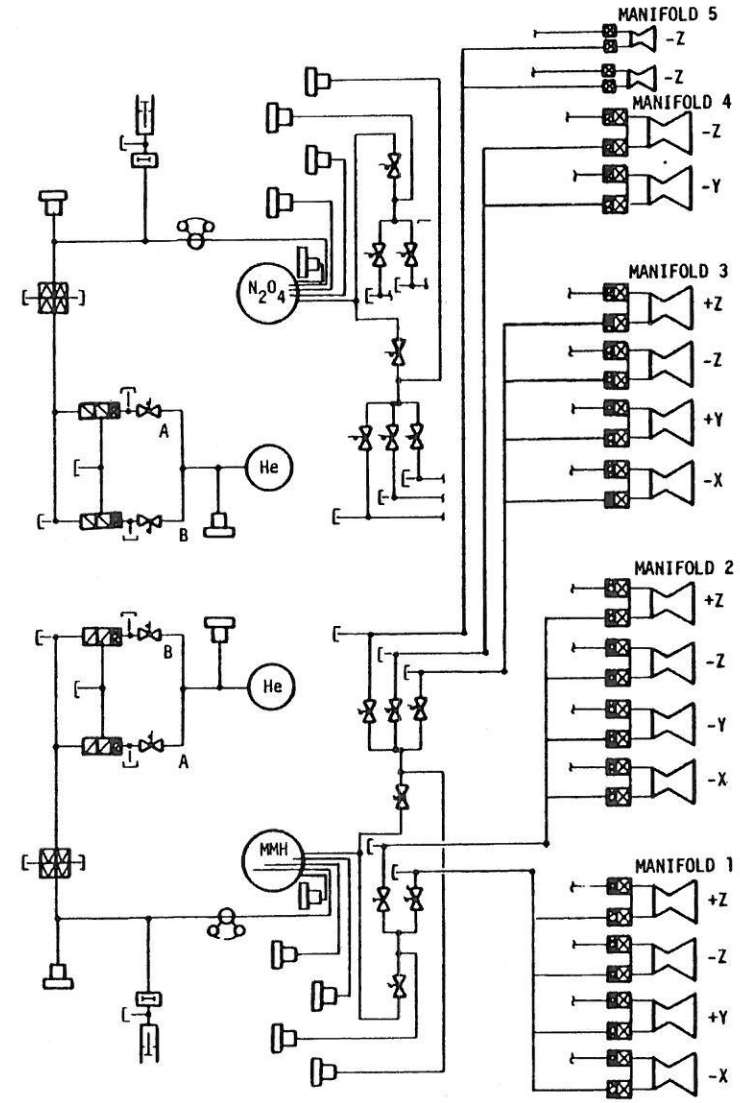
MECHANICAL SUBSYSTEMS

The orbiter mechanical subsystems, with electrical and hydraulic actuators, operate the aerodynamic control surfaces, landing/deceleration system, payload bay doors, deployable radiators, and payload retention and payload handling subsystems. Orbiter/external tank propellant disconnects and a variety of other mechanical and pyrotechnic devices make up the balance of the mechanical subsystems.

Aerodynamic control surface movement is accomplished by hydraulically powered actuators that position the elevons and by hydraulically powered drive units that position the body flap and combination rudder/speed brake through shafting to geared rotary actuators. Three redundant 3000-psi systems supply necessary hydraulic power. Elevon seal panels that provide an aerodynamic/thermal seal between the elevon upper leading edges and upper wing surfaces are actuated by push/pull rod mechanisms attached directly to the elevons.

The landing/deceleration system employs a fully retractable tricycle landing gear designed to provide safe landings at speeds up to 225 knots. The shock struts are of conventional aircraft design with dual wheels/tires. Braking is accomplished using special lightweight carbon-lined beryllium brakes with antiskid protection.

The payload bay doors, deployable radiators, vent doors (forward fuselage, payload bay and wing, aft payload bay, and aft fuselage), star tracker doors, and the external tank separation-system closeout doors are operated by electromechanical actuators that must provide reliable performance after severe environment exposure during ascent and entry and during on-orbit operations. The payload bay doors, when closed and latched, are part of the orbiter structure and react fuselage torsional loads. The separation system separates the orbiter from the external tank at three structural and two umbilical interfaces.

The payload retention subsystem includes remotely controlled retention latches that hold down or release the payload items. Additional information on the payload retention subsystem is presented in the payload accommodation section.

The payload-handling subsystem consists primarily of government-furnished, remotely controlled manipulator arms (one arm normally installed, second arm optional) that can move the payloads out of and/or into the payload bay while in orbit. Additional information on the manipulators is presented in the payload accommodation section.

(Text)

Mechanical Subsystems

RUDDER/SPEED BRAKE (HYDRO-MECHANICAL)

OPTIONAL MANIPULATOR (GFE)

VENT DOOR MECHANISMS (BOTH SIDES)

PAYLOAD RETENTION

PAYLOAD BAY DOORS ACTUATION & LANDING

AFT ET SEPARATION
- STRUCTURE DISCONNECT
- UMBILICAL DISCONNECT
- CLOSEOUT DOOR

RADIATOR DEPLOYMENT & LATCHING

BASELINE MANIPULATOR (GFE)

BODY FLAP (HYDRO-MECHANICAL)

CREW TRANSFER TUNNEL KIT & AIRLOCK HATCHES

CREW EMERGENCY EJECTION (2)

CREW HATCH (LH SIDE)

ELEVON AERO/THERMAL SEAL PANEL ACTUATION

STAR TRACKER DOORS (2)

YAW & BRAKE CONTROL PEDALS

MAIN GEAR
- SHOCK STRUTS
- EXTEND/RETRACT MECHANISMS
- DOOR ACTUATORS
- DUAL WHEELS/TIRES/BRAKES

MANIPULATOR DEPLOY & JETTISON

DEPLOYABLE AIR DATA SENSOR (2)

RENDEZVOUS SENSOR DEPLOYMENT

FORWARD ET SEPARATION

NOSE GEAR
- SHOCK STRUT
- EXTEND/RETRACT MECHANISM
- DOOR ACTUATORS
- WHEELS/TIRES/STEERING/DAMPING

EJECTION ACCESS DOOR (RH SIDE)

- PYROTECHNICS

AUXILIARY POWER UNIT SUBSYSTEM

The auxiliary power unit (APU) subsystem consists of three independent systems, as illustrated in the chart, that provide mechanical shaft power to hydraulic pumps (one pump per APU). APU power is derived from exhaust gases that result from decomposition of hydrogen fuel in a gas generator. The exhaust gases drive a turbine, which in turn drives the hydraulic pump. The pumps transmit hydraulic power to the main engine thrust vector and engine controls, aerodynamic surfaces (elevons, rudder/speed brakes, body flap), landing gear, brakes, and steering controls. The APU subsystem operates during the prelaunch (liftoff minus five minutes), ascent, MPS dump, on-orbit checkout, preentry, entry, and landing phases of the mission.

The APU subsystem is single-failure tolerant and can provide adequate power for safe return after loss of one of its three independent systems. If a failure occurs during entry, power from the remaining two systems is distributed through loss management design to the hydraulic system to maintain aerosurfaces control.

APU-3 PLACES

BULKHEAD X_o 1307

132

Auxiliary Power Unit Subsystem

EXHAUST DUCTS

X_O 1307

APU 2

APU 1

FUEL PUMP
SEAL CAVITY
DRAINS

FUEL LINES

(3) APU
CONTROLLERS
AVIONICS BAYS
4, 5, & 6)

AFT FUSELAGE
ACCESS DOOR
50-1 (REF)

FUEL SERVICING
RECEPTACLES
(APU SYS 1 & 2)

X_O 1418.25
(TYPICAL)

Z_O 365
(TYPICAL)

FORWARD

OIL COOLING
LOOP LINES

(2) FUEL
ISOLATION
VALVES &
FILTERS

APU SYS 1
FUEL TANK

APU SYS 2
FUEL TANK

WATER
TANKS

APU 3

(3) WATER BOILER PACKAGES (REF)

FUEL PUMP
SEAL CAVITY
DRAIN

AFT FUSELAGE
ACCESS DOOR 50-2
(REF)

FUEL LINE
(2) FUEL ISOLATION
VALVE & (1) FILTER

APU SYS 3
FUEL TANK

FUEL SERVICING
RECEPTACLES (APU SYS 3)

APU

AUXILIARY POWER UNIT SUBSYSTEM SCHEMATIC

The auxiliary power unit (APU) subsystem schematic illustrates one of three independent systems, which consists of a fuel tank, fuel distribution and servicing system, APU and controller, lubrication system, exhaust duct assembly, fuel/lubrication oil drain system, gas generator cooling system, fuel pump and fuel control valve (gas generator valve module - GGVM), and a thermal control system. Displays, controls, and sensing devices permit crew and ground stations to monitor its operation.

Monopropellant hydrazine is supplied to the APU fuel pump from a positive expulsion tank pressurized with nitrogen gas, which provides bootstrap starting capability. The fuel distribution system includes a filter, a valve to control fuel flow, fill and drain service couplings, and test port couplings for checkout. The APU controller provides speed control through the fuel valves, overspeed and malfunction protection, signal conditioning, cooling water control, and the logic for startup and shutdown. The APU automatically shuts down if turbine speed (74,160 rpm nominal) falls outside prescribed limits. A ground test connector provides fault isolation and APU subsystem electrical closeout verification.

The APU gear-driven fuel pump supplies fuel at increased pressure to a catalyst bed gas generator whose exhaust drives a turbine which in turn drives the hydraulic pump (3,918 rpm nominal) through a speed reduction gearbox Each APU produces 135 shaft horsepower (nominal) with a maximum capability of 148 horsepower. The fuel pump includes a drain system to collect fuel leakage. The gearbox lubrication oil is circulated through the hydraulic subsystem water spray boiler for cooling. The gas generator cooling system, which is utilized for hot restarts, incorporates a single positive expulsion water tank, pressurized with N_2 gas, for all three generators. The fuel pump (GGVM) water cooling system is actuated after APU shutdown in orbit to prevent gas formation in the fuel system during thermal soakback. Two systems are provided for redundancy. Each system consists of a positive expulsion water tank pressurized with GN_2 lines, control valves and water spray nozzles on each APU fuel pump and GGVM. Each turbine exhausts through a separate duct which vents overboard near the vertical fin.

The thermal control system consists of redundant thermostatiscally controlled heaters and insulation which maintain the fuel, lube oil, and cooling water between 45 and 150°F.

Auxiliary Power Unit Subsystem Schematic

SYMBOL LEGEND

⬓▭ COUPLING (INC FILTER)
⊗ SHUT-OFF VALVE (TWO-WAY)
⊗ SHUT-OFF VALVE (THREE-WAY)
〰 FLEXIBLE HOSE/BELLOWS
▨ FILTER
⬠ CHECK VALVE
⬠ PRESSURE RELIEF
⊏ QUICK DISCONNECT
—I— ORIFICE
⬤ SPRAY MANIFOLD

WATER TANK (2) TYP

GN₂
H₂O

TO APUs 2 & 3

TO 2ND TANK

WATER CONTROLLER

APU CONTROLLER

PRI SPEED CONTROL

SEC SPEED CONTROL

SAFETY MONITOR

LUBE OIL

DRAIN

WATER BOILER

VENT

GN₂ BOTTLE
GN₂ FILL

N.C.

HYDRAULIC PUMP

VALVE MODULE

N.O.   N.C.

PUMP

TURBINE

GEARBOX

VENT

DRAIN

MAGNETIC PICKUP UNITS

ISOLATION VALVES

DIAPHRAGM

GN₂
N₂H₄

FUEL TANK

FILTER

CATCH BOTTLE

MANUAL DRAIN VALVE

VENT

RELIEF VALVE

ORIFICE

FUEL PUMP SEAL CAVITY DRAIN

GAS GENERATOR

EXHAUST DUCT

N.C.

N
H₂O   WATER TANK

TO APU CONTROLLER

HYDRAULIC SUBSYSTEM

As shown in the figure, aeroflight control is provided to the elevon by linear servoactuators and to the rudder, speed brake, and body flap by hydraulic motors (which operate mechanical rotary actuators). Three independent hydraulic pump and supply line systems service each actuator.

The four elevon panels are each operated by a single, balanced-piston servoactuator and are controlled by four electrohydraulic servovalves (4-channel) integral with the actuator. The servovalves are force summed to drive the actuator's power spool valve. The speed brake function is provided by a split rudder. Mechanical rotary actuators, which are connected to the two panels, are driven by servo-controlled hydraulic motors to provide both rudder and speed brake control.

Main engine thrust vector control is provided by linear balanced-piston servoactuators, one for the pitch axis and one for the yaw axis of each of the three main engines. The servoactuator is controlled by four electrohydraulic servovalves (4-channel) integral with the actuator and force summed in a manner similar to the elevon actuators.

Located in the main landing gear (MLG) wheel well area are the MLG strut and uplock linear actuators, the MLG and nose landing gear (NLG) control valves, and the MLG brake/antiskid valves. The nose wheel well area contains the nose wheel steering, NLG strut, and uplock linear actuators.

The orbiter/external tank propellant umbilicals are retracted by hydraulic actuators located around the outside of each main propellant line near the vehicle lower skin. Hydraulic power is also provided to the SSME for propellant valve actuation.

Hydraulic power is generated by auxiliary power unit (APU) driven pumps which operate during the boost and entry/landing phases. Each of three APU's provides 135 hydraulic HP for total of 405 HP.

119SSV87060
(Text)

Hydraulic Subsystem

RUDDER/SPEED BRAKE
ROTARY ACTUATORS

MAIN ENGINE VALVE CONTROL

MAIN POWER-PUMPS,
RESERVOIRS, H2O BOILER,
& MISC VALVES

EXTERNAL TANK
UMBILICAL RETRACTOR
ACTUATORS

RUDDER/SPEED BRAKE
HYD MOTOR/SERVO VALVES

SSME TVC FOUR-CHANNEL
SERVOACTUATORS

BODY FLAP ROTARY ACTUATORS
HYDRAULIC MOTOR-DRIVEN,

ELEVON FOUR-CHANNEL
SERVOACTUATORS

MAIN LANDING GEAR
STRUT ACTUATOR

MAIN LANDING GEAR
UPLOCK ACTUATOR

NOSE LANDING
GEAR UPLOCK
ACTUATOR

NOSE LANDING
GEAR STRUT
ACTUATOR

MAIN LANDING GEAR
BRAKE/ANTISKID VALVES

MAIN LANDING GEAR &
NOSE LANDING GEAR VALVES

NOSE WHEEL
STEERING
ACTUATOR

HYDRAULIC SUBSYSTEM SCHEMATIC

The hydraulic subsystem consists of the components required for generation, control, distribution, monitoring, and use of hydraulic power. A simplified schematic of the hydraulic subsystem is presented on the chart, which presents only one of the three orbiter systems. Hydraulic power operates the aerosurface controls (elevons, rudder/speed brake, and body flap) and the Space Shuttle main engine (SSME) control valves. Hyd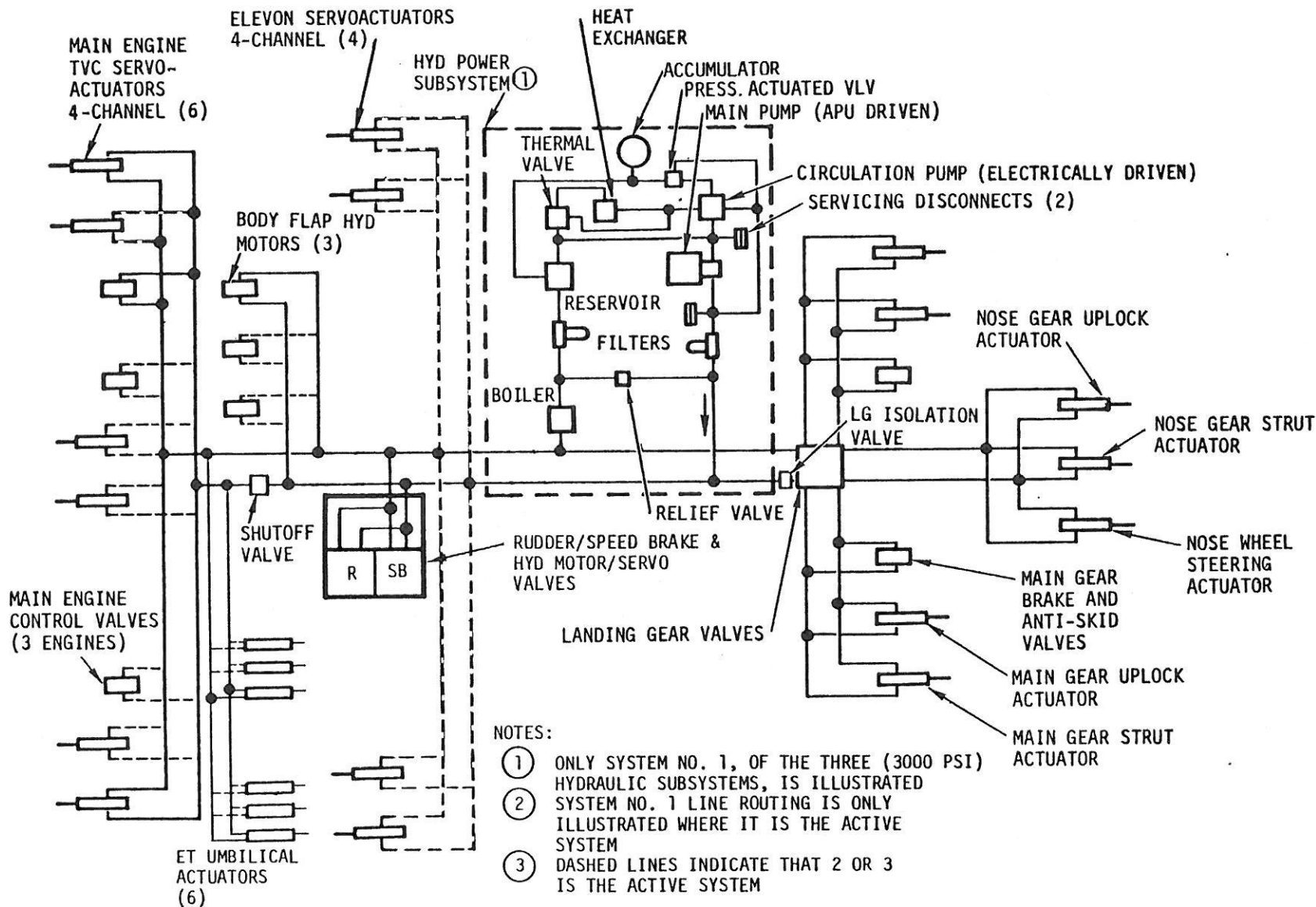raulic power is also provided to retract the orbiter/external tank umbilicals; to gimbal the SSME; provide on-orbit thermal control; retract, extend, lock up and unlock the landing gear; operate main wheel brakes; and provide nose wheel steering. Hydraulic power is generated by nominal 3000-psi variable delivery pumps. The pumps are driven by auxiliary power units (APU's). The hydraulic subsystem is made up of three independent hydraulic systems, each with its own pumps, reservoir, oil cooler, controls, displays, and distribution system. The orbiter can perform a mission from MECO to rollout with any two of its three hydraulic systems operational. However, two operational systems are required to provide the maximum aerosurface rotational rates needed for worst-case descent conditions. The hydraulic subsystem is therefore considered to be "fail safe" rather than "fail operational/fail safe."

During prelaunch operations, the orbiter utilizes hydraulic power from onboard electrically driven circulation pumps until APU activation. In the boost phase, hydraulic power is provided by each APU-driven pump for SSME gimbaling and valve control. After ascent boost, the umbilicals are retracted into the orbiter prior to external tank separation. Following propellant dump, the APU's are shut down. Temperature control of the systems is provided on-orbit by electrical heaters and by a low-pressure/flow electrically driven circulation pump in each system. During the deorbit/entry phase, hydraulic power is generated by the APU-driven hydraulic pump for aerosurface operation. Hydraulic power is shut off for umbilical retracting, SSME gimbaling, and SSME controls. The landing gear is unlocked and free-falls as the primary mode to the lowered position before touchdown. After touchdown, deceleration provisions include the main wheel braking system, with steering accomplished by the nose wheel steering actuator.

Hydraulic Subsystem Schematic

MAIN ENGINE TVC SERVO-ACTUATORS 4-CHANNEL (6)

ELEVON SERVOACTUATORS 4-CHANNEL (4)

HYD POWER SUBSYSTEM ①

HEAT EXCHANGER

ACCUMULATOR

PRESS. ACTUATED VLV

MAIN PUMP (APU DRIVEN)

THERMAL VALVE

CIRCULATION PUMP (ELECTRICALLY DRIVEN)

SERVICING DISCONNECTS (2)

BODY FLAP HYD MOTORS (3)

RESERVOIR

FILTERS

BOILER

NOSE GEAR UPLOCK ACTUATOR

LG ISOLATION VALVE

NOSE GEAR STRUT ACTUATOR

SHUTOFF VALVE

R   SB

RUDDER/SPEED BRAKE & HYD MOTOR/SERVO VALVES

RELIEF VALVE

LANDING GEAR VALVES

NOSE WHEEL STEERING ACTUATOR

MAIN GEAR BRAKE AND ANTI-SKID VALVES

MAIN ENGINE CONTROL VALVES (3 ENGINES)

MAIN GEAR UPLOCK ACTUATOR

MAIN GEAR STRUT ACTUATOR

NOTES:

① ONLY SYSTEM NO. 1, OF THE THREE (3000 PSI) HYDRAULIC SUBSYSTEMS, IS ILLUSTRATED

② SYSTEM NO. 1 LINE ROUTING IS ONLY ILLUSTRATED WHERE IT IS THE ACTIVE SYSTEM

③ DASHED LINES INDICATE THAT 2 OR 3 IS THE ACTIVE SYSTEM

ET UMBILICAL ACTUATORS (6)

ELECTRICAL POWER SUBSYSTEM

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)

2. Power reactant storage and distribution (PRSD) subsystem

The EPS, FCP, and PRSD are illustrated in the three charts that follow.

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. Under certain conditions, namely, a +40°F environment, the third FCP can be shut down and disconnected from the bus and can be restarted and reconnected to the bus within 15 minutes as required to support higher loads. For conditions where the environment will be lower than 40°F, the third FCP can be placed on standby and disconnected from the bus and can be reconnected as required. Excess heat from the fuel cells is transferred to the Freon cooling loop through heat exchangers.

The electrical power requirements of a payload will vary throughout a mission. During the 10-minute launch-to-orbit phase and the 30-minute deorbit-to-landing phase, when most of the experiment hardware is in a standby mode or completely turned off, 1000 watts average to 1500 watts peak are available from the orbiter. During payload equipment operation on-orbit, the capability exists to provide as much as 7000 watts maximum average to 12,000 watts peak for major energy-consuming payloads. For the 7-day-mission payload, 50 kilowatt-hours of electrical energy are available.

Electrical Power Subsystem

693   750   807   863   919   980   1040   1090   1141   1191   1249

O$_2$ H$_2$ O$_2$

O$_2$ H$_2$ H$_2$
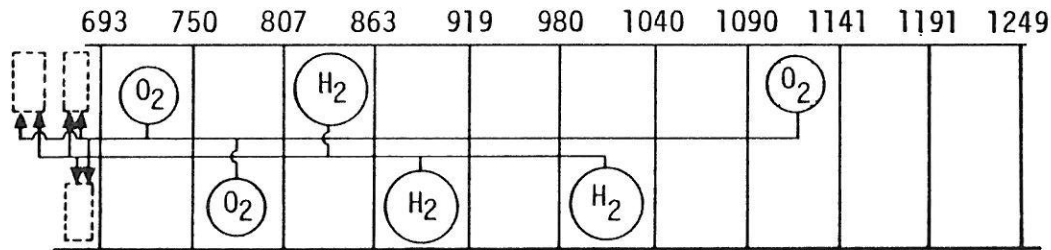
FCP SUBSYSTEM (2 FCP's)

- 14 KW CONTINUOUS/24 KW PEAK
- 27.5 TO 32.5 VDC

REACTANT STORAGE (3 TANK SETS)

- 2370 KWH DELIVERED ENERGY*
- 168 POUNDS O$_2$ FOR ECLSS
- 92 LB H$_2$/TANK   } TOTAL LOADED
- 781 LB O$_2$/TANK   } QUANTITY/TANK

*Does not include PRSD blowdown

HYDROGEN DEWARS

OXYGEN DEWARS

FCP/ECLSS
HEAT EXCHANGER

WATER RELIEF
VALVE PANEL

H$_2$O VENT

MAIN BUS DISTRIBUTION
ASSEMBLIES - TYPICAL
3 PLACES

FUEL CELL
POWER PLANTS (3)

OXYGEN DEWARS

COOLANT LOOP
SERVICE PANEL

PRELAUNCH
UMBILICAL
(DISCONNECTED
AT T-4 HOURS)
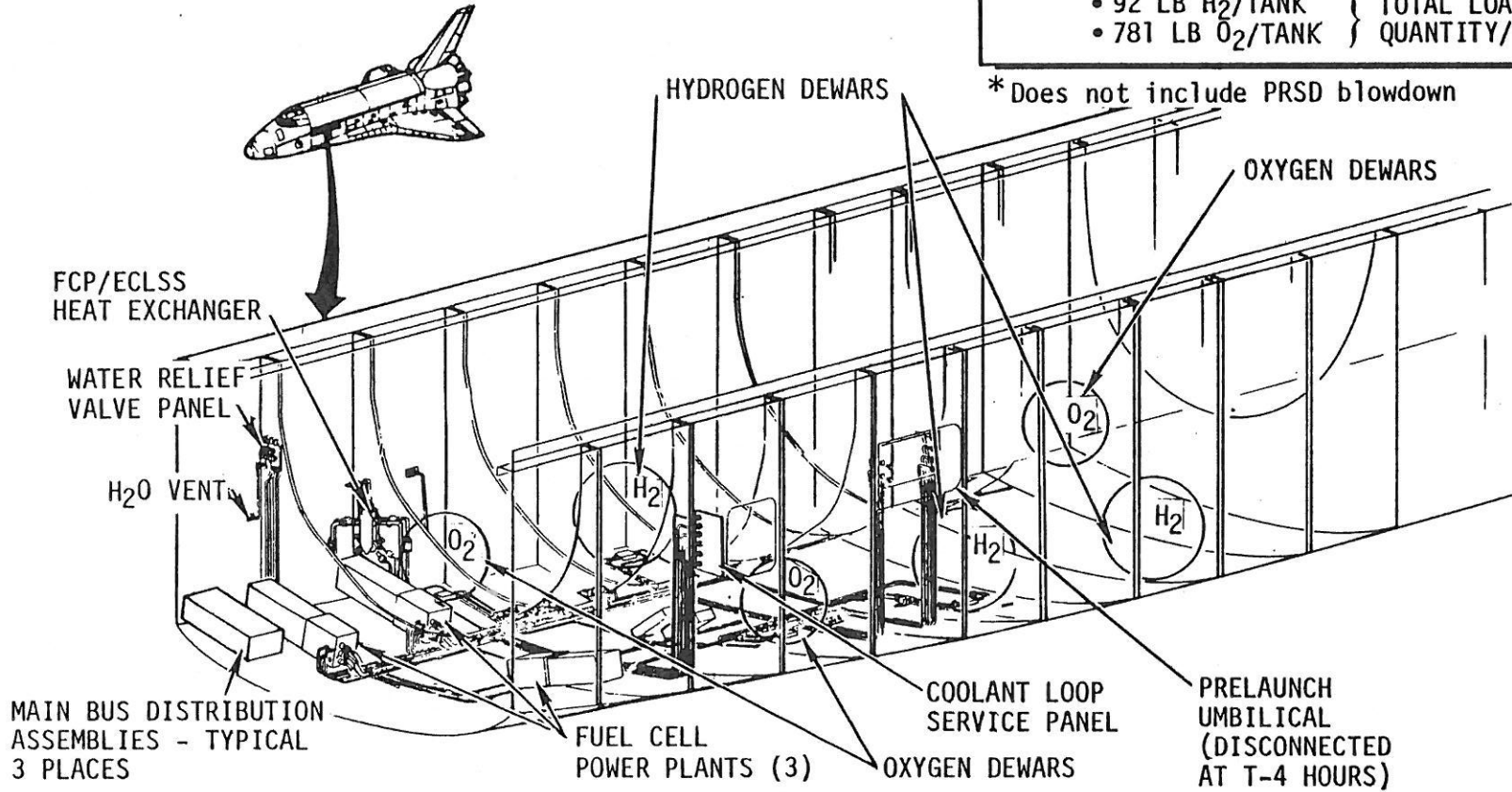
FUEL CELL SUBSYSTEM SCHEMATIC

Three fuel cell powerplants (FCP's), generating direct current electricity through the reaction of hydrogen and oxygen, are each rated at 7 kW continuous maximum power and 12 kW peak for up to 15 minutes, over an energy range of 27.5 to 32.5 volts. Two FCP's can supply normal orbiter operational requirements after loss of one FCP. Thermal control is provided by heaters and a coolant system which transfers heat from the FCP to the orbiter environmental control and life support system (ECLSS) heat exchangers. Coolant return temperatures are maintained between 40° and 140°F. Above 40°F ambient temperature, the third FCP can be shut down and disconnected from the bus and then reactivated within 15 minutes to support higher loads. Below 40°, it may be placed on standby, disconnected from the bus, and then reconnected as required.

Potable water first forms as vapor at the reaction interface in the hydrogen electrode. The vapor is circulated to a gas-liquid separator and then discharged from the FCP to the ECLSS storage tanks at a maximum rate of 21.6 lb/hr. If the ECLSS cannot accept the water, it is discharged overboard through a relief valve.

Design life of the FCP is 2000 hours without maintenance, or 9,000 kWh at an average power level of 4.5 kW. Operation at increased power will reduce life nonlinearly. At 6.7 kW average power, for example, life is reduced 50 percent to 1000 hours or 6,700 kWh.
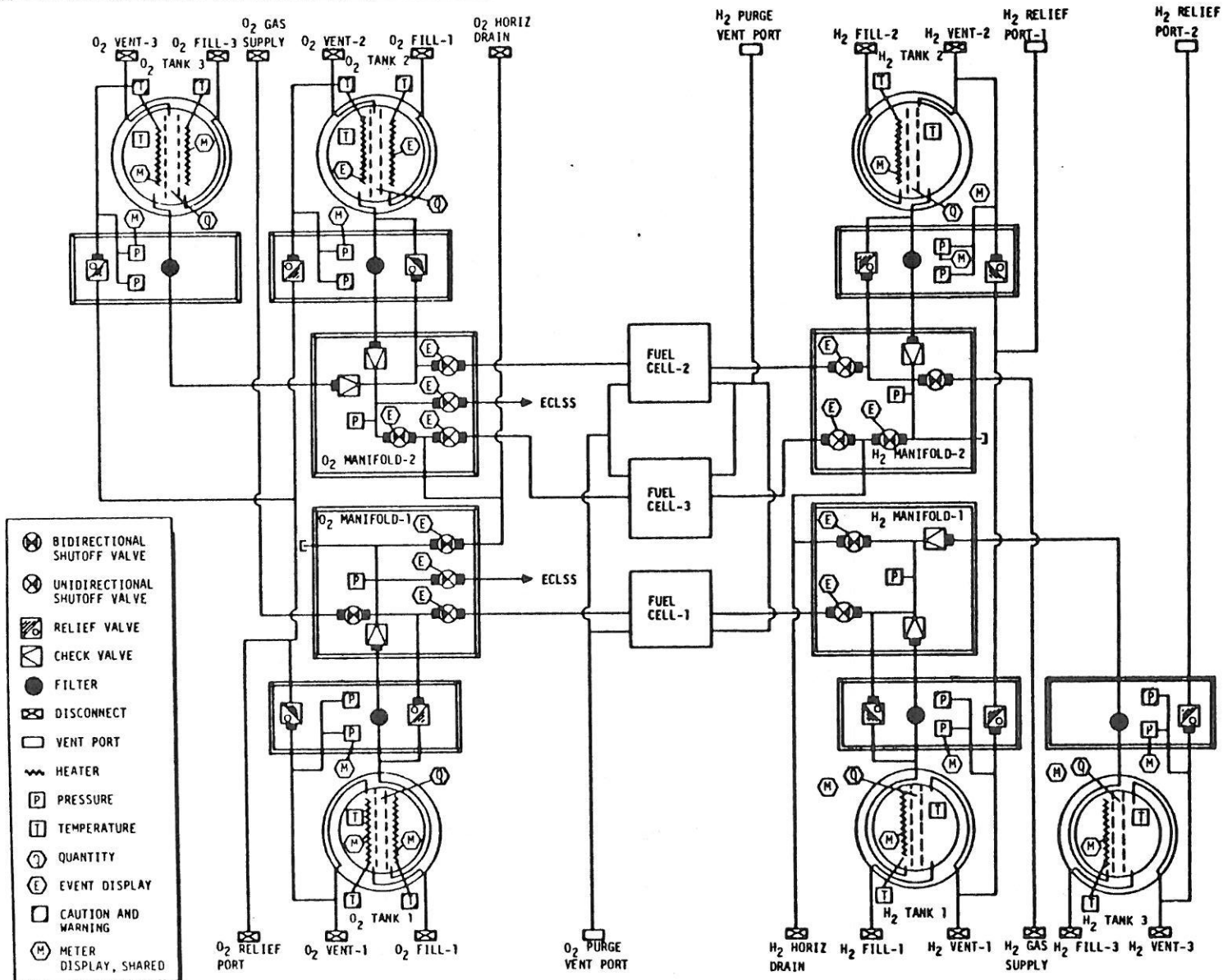
Fuel Cell Subsystem Schematic
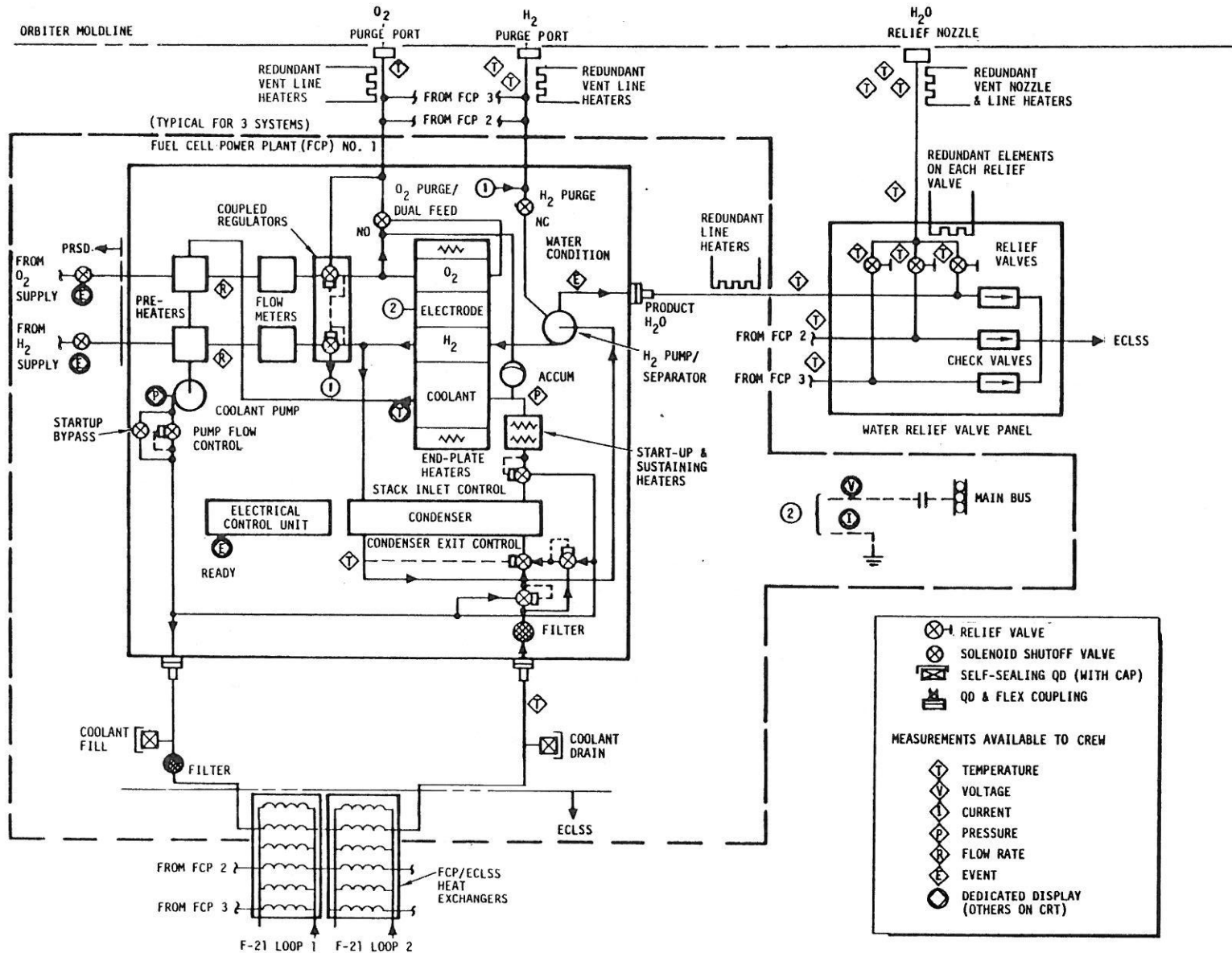
POWER REACTANT STORAGE AND DISTRIBUTION SUBSYSTEM SCHEMATIC

The power reactant storage and distribution subsystem (PRSD) contains the components which supply oxygen and hydrogen to the fuel cell powerplants (FCP) and oxygen to the ECLSS during all mission phases. The cryogenic reactants are stored in a super-critical condition in insulated double-walled tanks with a vacuum annulus. The PRSD supplies oxygen at a nominal pressure of 900 psia and hydrogen at 250 psia, in a single-phase, to the FCP which regulates pressures to a normal range of 55 to 65 psia. Automatic controls, activated by pressure, energize internal tank heaters which add heat energy to the reactants to maintain pressure during depletion. The heaters are controlled by the instrumentation and control subassembly. Each tank has relief valves to prevent overpressurization from abnormal operating conditions.

Each tank has a filter, check valve, and relief valve mounted on panels adjacent to each tank. Redundancy is provided by having two components for each major function or by providing manual override for the automatic controls. The distribution shutoff valves are arranged so that any tank can be used to feed any of the FCP or ECLSS lines, or, in case of failure, can be isolated at the distribution manifolds.

Approximately 276 pounds of hydrogen and 2343 pounds of oxygen are stored in the three sets (one hydrogen and one oxygen tank per set) of storage dewars. Each of the oxygen dewars carries, in addition to the fuel cell energy requirement, 56 pounds of oxygen for the orbiter ECLSS. The tanks also carry a reserve for emergency requirements.

119SSV87064
(Text)

Power Reactant Storage and Distribution Subsystem Schematic

Legend:

- ⊗ BIDIRECTIONAL SHUTOFF VALVE
- ⊗ UNIDIRECTIONAL SHUTOFF VALVE
- ▨ RELIEF VALVE
- ◊ CHECK VALVE
- ● FILTER
- ⋈ DISCONNECT
- ▭ VENT PORT
- ∿ HEATER
- P PRESSURE
- T TEMPERATURE
- Q QUANTITY
- E EVENT DISPLAY
- ▢ CAUTION AND WARNING
- M METER DISPLAY, SHARED

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The atmospheric revitalization subsystem (ARS) will 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, 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 the pre-EVA and post-EVA and conditioned air to manned payloads (carried in the payload bay).

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 smoke detection and fire suppression subsystem is designed to detect smoke in the avionics bays and the crew compartment and extinguish fires utilizing Freon 1301. Portable fire extinguishers are provided for the crew compartment. Fixed fire extinguishers located in each avionics bay are actuated from the flight deck.

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

The air lock support subsystem is designed to provide air lock pressurization and EVA support in five functions: air lock pressurization and depressurization, EVA equipment recharging, waste-water transfer, prebreathing, and emergency breathing. These operate on demand during all orbital phases.

119SSV87065
(Text)

Environmental Control and Life Support Subsystem

CABIN TEMP CONTROL DUCTING

ATMOSPHERE REVITALIZATION UNIT

AVIONICS FANS/HEAT EXCHANGER

ECLSS CONTROL PANEL

SPACE RADIATOR PANELS DEPLOYED

AMMONIA BOILER & TANKS (ATMOSPHERE HEAT SINKS)

AVIONICS BAY DUCTING

FOOD MANAGEMENT

WASTE MANAGEMENT

FREON COOLANT PUMP PACKAGES (2)

N_2 STORAGE

O_2 STORAGE

AVIONICS BAYS COOLING

FLASH EVAPORATOR

SPACE RADIATOR FORWARD PANELS

AFT PANELS

FORWARD PANELS RADIATE FROM BOTH SIDES

SIMPLIFIED ECLSS SCHEMATIC

The ECLSS contains four subsystems: (1) atmosphere revitalization subsystem (ARS), (2) food, water, and waste subsystem (FWW), (3) active thermal control subsystem (ATCS), and (4) airlock support.

The ARS maintains a habitable environment for the crew and a conditioned thermal environment for avionics equipment. The cabin heat exchanger, together with the heat sink properties of the cabin structure, maintains cabin temperature below 90°F during ascent and entry. Condensation on the cabin walls is minimized by maintaining the wall temperature above 61°F. Cabin oxygen partial pressure is maintained at 3.2 psia. Nitrogen is added to achieve total pressure of 14.7 psia. Oxygen required for metabolic and normal cabin leakage makeup is obtained from supercritical cryogenic storage. Nitrogen for normal operation and oxygen for emergency pressure maintenance are obtained from 3300-psi storage vessels. Approximately 1400 pounds/ hour of cabin atmosphere is ducted through the cabin heat exchanger and carbon dioxide removal assemblies where carbon dioxide and odors are removed, and temperature and humidity control is accomplished. Avionics equipment in the three forward fuselage avionics bays is cooled both by forced air convection and by coldplates. Mid fuselage and aft fuselage avionics are all coldplate cooled. Controls and displays are cooled by ducting cabin air over the electronic packages.

The FWW group provides the basic life support functions for the crew. The galley (GFE) is equipped with an oven and will provide hot and cold water for the preparation of freeze-dried foods. The water management subsystem provides for storage, distribution, and disposal of potable water. The waste management subsystem collects, processes, and stores solid and liquid wastes. The feces waste collector is exposed to space vacuum for drying of feces. Liquid waste storage tanks store both urine and humidity condensate.

The ATCS provides an active heat source for the hydraulic subsystem and cabin oxygen supply, and removes heat from the cabin coolant loop and selected avionics coldplates, the payload, fuel cell subsystem and, in addition, OFT avionics on OV 102. The baseline ECLSS radiators contain 1195 square feet of effective area. The forward panels are double-sided while the aft panels are single-sided. During prelaunch operations, ECLSS thermal control is accomplished via a GSE heat exchanger in the Freon loop. The full-up flash evaporator in the Freon loop provides thermal control until the radiators are deployed. The space radiators are active during on-orbit operations, cooling the majority of orbiter equipment. Their cooling capability is augmented by the topping function of the flash evaporator. The flash evaporator is activated again from the time the payload bay doors are closed until an altitude of 100,000 feet is reached. The ammonia boiler is operated from 100,000 feet altitude to touchdown and during postlanding periods until a GSE cooling system is connected.

20SSV87066A
(Text)

Simplified ECLSS Schematic
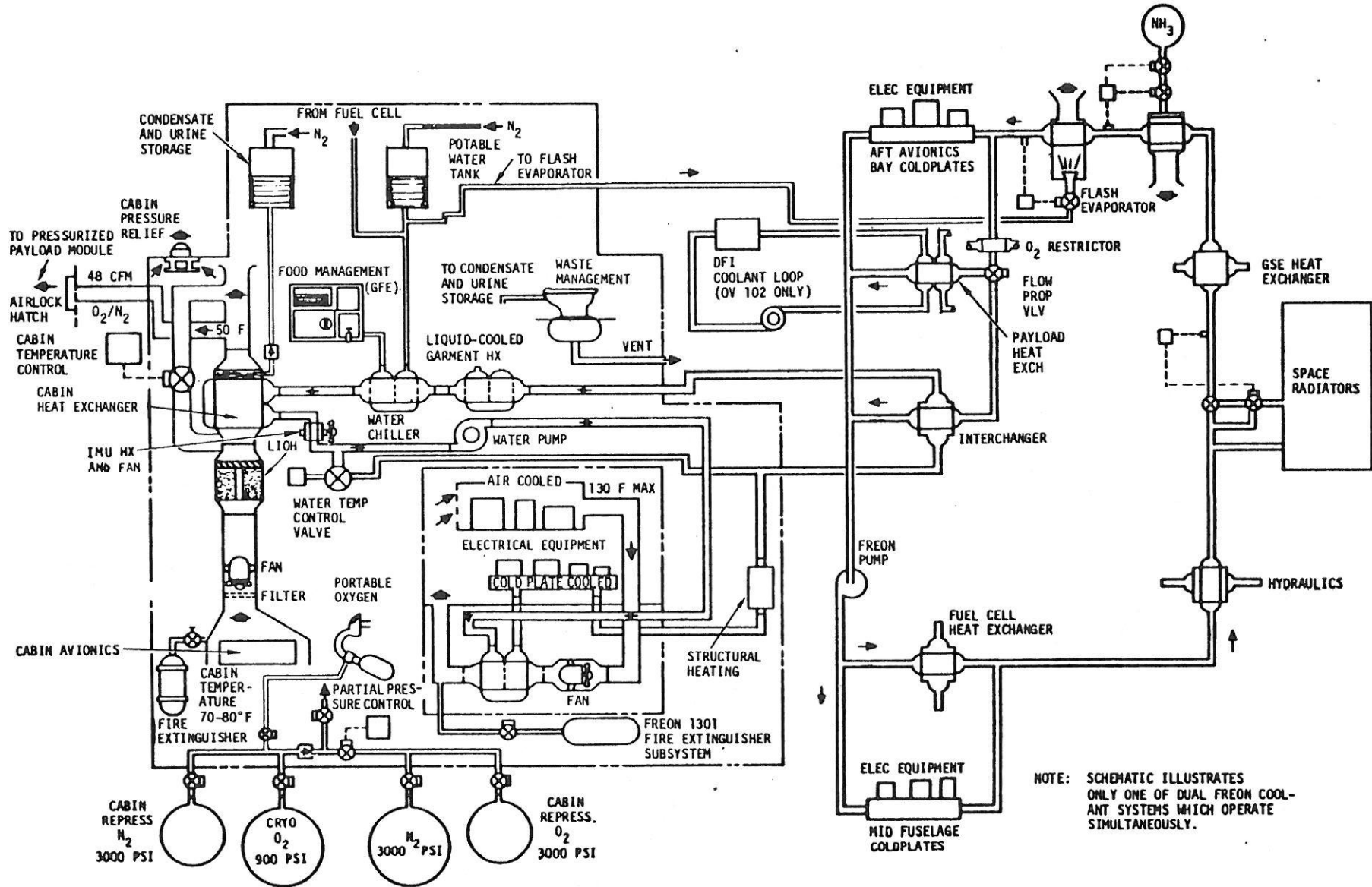
PURGE, VENT, AND DRAIN SUBSYSTEMS

The purge, vent, and drain (PVD) subsystems include the window cavity conditioning (WCC) and hazardous gases detection subsystems (HGD). These five subsystems provide environmental control of the orbiter's unpressurized structural cavities. Since the crew module is the only pressurized structure of the orbiter, these five subsystems must provide for nearly the entire orbiter structure, including purging and venting of payloads.

The purge subsystem provides conditioned gas from the ground support system to the orbiter cavities for maintenance of proper thermal, humidity, hazardous/toxic gases, and contamination considerations. This purge is provided only during preflight and postflight via the right-hand T-0 disconnect and the ground systems. Purge gas is provided to three major separate and dedicated sets of distribution plumbing: (1) forward fuselage, OMS pods, wings, and vertical stabilizer, (2) mid fuselage, and (3) aft fuselage. A fourth system provides purge gas to the external tank/orbiter disconnect cavities to prevent cryo-pumping of air and freezing of water vapor.

The vent subsystem provides flow area for control of pressure during purge, depressurization during ascent, molecular venting in orbit, and repressurization during descent. Eighteen vent ports are provided in the fuselage skin and dedicated to specific orbiter cavities. Vent doors are closed during the maximum noise of launch and during the heat pulse of orbiter entry. The purge and vent outlets are located and sized to provide venting of the cavities within structural, hazards, and purge limitations.

The drain subsystem provides flow paths and systems to drain or remove accumulated water. Flow paths are provided through a series of limber holes that allow drainage to the lowest point for removal. A system of tubing and disconnects provides for evacuation, by a ground system, of locations that cannot be served by limber holes.

The window cavity conditioning subsystem prevents moisture ingress to the window cavities, provides for depressurization and repressurization during flight, and provides for purge conditioning (drying) during ground operations.

The hazardous gases detection subsystem provides for the detection of hazardous levels of explosive or toxic gases. The primary system is a ground-based mass spectrometer at the launch pad and depends on the purge gas to transport the hazardous gases to them. On-board sample lines duct the compartment gases to the GSE interface on the T-0 fuel umbilical panel and on to the mass spectrometer for analysis.

Purge, Vent, and Drain Subsystems

RH T-0 DISCONNECT

3 SPECIAL OUTLETS FOR PAYLOAD
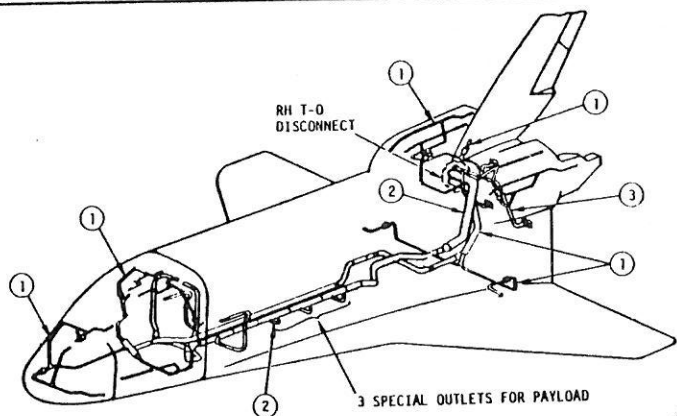
PURGE (PREFLIGHT & POSTFLIGHT)

GROUND-SUPPLIED AIR OR GN$_2$
AT TEMPERATURE, HUMIDITY, &
CLEANLINESS

ACTUATOR

P/L BAY VENT FILTER

EMI SHIELD

TYP MID FUSELAGE VENT PORT
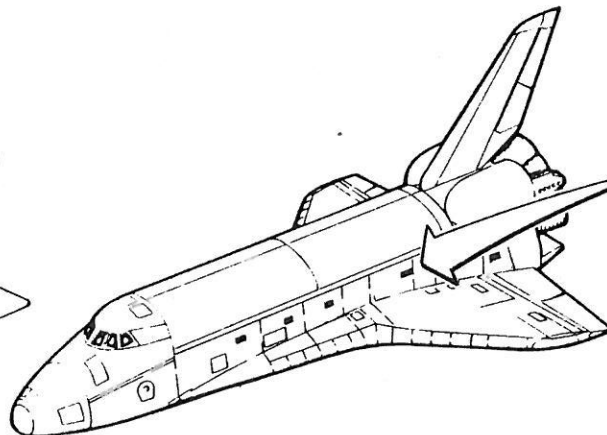
VENT (ALL PHASES)

VENTS-OUT WITH PURGE &
LAUNCH TO MAINTAIN ΔP
VENTS-IN WITH REENTRY

• DRAIN PORTS
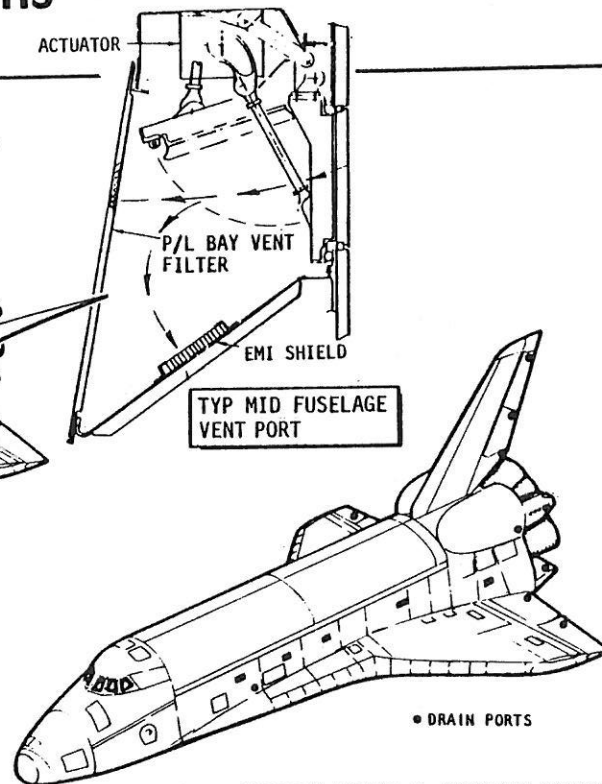
DRAIN (PREFLIGHT & POSTFLIGHT)
REMOVE CONDENSED WATER

WINDOW CAVITY CONDITIONING

INNER CAVITY
OUTER CAVITY
AIRFRAME
CREW MODULE

VENT OUTLET (THRU OML)
(VENTS LH & RH SIDE &
OVERHEAD WINDOWS)

VENT LINE

DESICCANT CANISTER (2)
PURGE LINE
VENT LINE

CHECK VALVE (2)

SIDE HATCH
DESICCANT CANISTER
CHECK VALVE

CHECK VALVE (4)

DESICCANT CANISTER

PURGE LINES

OUTER CAVITY SYSTEM

P/L OBSERVATION WINDOW CAVITIES

HATCH CAVITY SYSTEM

DESICCANT FILTER CANISTERS

VENT OUTLET (PLENUM)
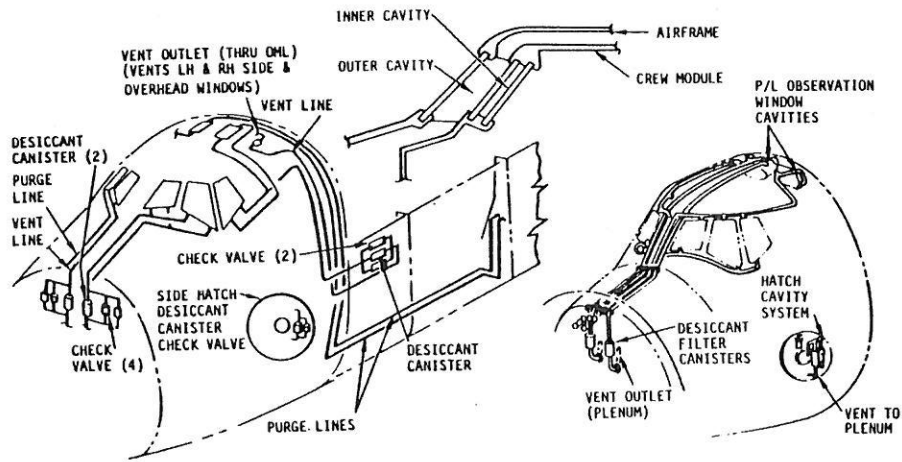
VENT TO PLENUM

INNER CAVITY SYSTEM

GROUND SENSORS FOR DETECTION OF HAZARDOUS GASES

HAZARDOUS FLUIDS

OMS PODS
N$_2$O$_4$
MMH

FORWARD RCS
N$_2$O$_4$
MMH

MID FUSELAGE

PAYLOAD $\begin{cases} N_2O_4 \\ MMH \\ H_2, O_2 \end{cases}$ OV BILGE

AFT FUSELAGE
N$_2$H$_4$, H$_2$, O$_2$
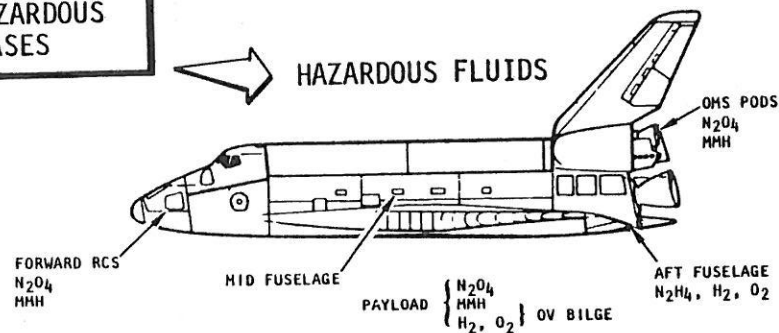
ORBITER AVIONICS SUBSYSTEM

The avionics equipment is arranged to facilitate checkout and for easy access and replacement with minimal disturbance to other subsystems. The majority of orbiter electrical and electronic equipment is installed in three areas: the flight deck, 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. All of the equipment in the unpressurized aft avionics bays is mounted on coldplates. Inertial measurement units (IMU's) on the navigation base are cooled by forced air convection. Exposed equipment (e.g., star sensors) is thermally protected by insulating material applied to exterior surfaces.

All antennas, except those used exclusively for satellite tracking and EVA communication, are flush mounted on the top, bottom, and sides of the orbiter forward fuselage. Two S-band antennas, for PM communication with SGLS and STDN ground stations and the NASA tracking and data relay satellites (TDRS), are mounted on each side of the forward fuselage. One S-band FM antenna is mounted on the top and one on the bottom surfaces of the forward fuselage. Four C-band horns for the radar altimeter and a UHF antenna for EVA/air traffic control (ATC) voice communication are also located on the underside of the forward fuselage. Six (three each, top and bottom) L-band TACAN antennas supply three redundant on-board TACAN receivers. The top and bottom antennas provide coverage to both landing site and side TACAN transmitters during vehicle roll and pitch maneuvers. TACAN acquisition occurs above 130,000 feet. Three Ku-band microwave scan beam landing system (MSBLS) antennas are mounted in the upper surface of the orbiter nose. They provide precise azimuth angle, elevation angle, and range information with respect to the runway. Antenna radiation patterns allow acquisition at 14,000 feet (minimum).

A Ku-band rendezvous radar antenna, which is also used for TDRS Ku-band communication, is located in the orbiter cargo bay. A second antenna/communication kit can be added as a payload option.

UHF voice communication for EVA is maintained by an antenna located in the orbiter airlock.

Orbiter Avionics Subsystem

AVIONICS SUBSYSTEMS

- GUIDANCE & CONTROL
- COMM/TRACKING
- DISPLAYS & CONTROLS
- ELECTRIC POWER DISTRIBUTION
- INSTRUMENTATION
- DATA PROCESSORS

EQUIPMENT MOUNTED BOTH SIDES OF SHELVES
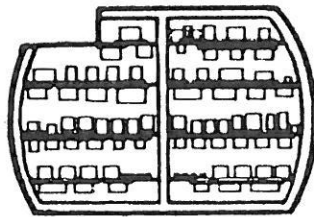
BAY 1   BAY 2
(LOOKING FORWARD)
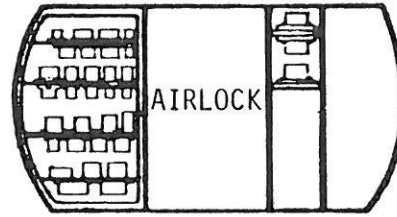
BAY 3   BAY 3B
(LOOKING AFT)
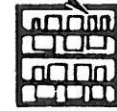
FORWARD AVIONICS BAYS
PRESSURIZED CABIN AREA

BAY 4   BAY 5

BAY 6
(ROTATED)

AFT AVIONICS BAYS

NAV BASE
(LOOKING FORWARD)

IMU

Y_O0

STAR TRACKER

BAY 2
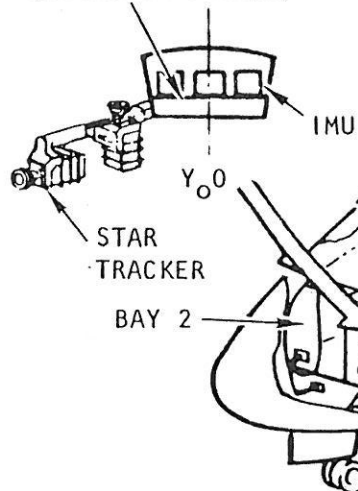
DISPLAYS & CONTROLS

BAY 5

BAY 4

BAY 6

BAY 1   BAY 3

MID FUSELAGE CABLE WIRE TRAYS

GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM

The guidance, navigation, and control (GN&C) subsystem provides (1) automatic and manual control capability for all mission phases except docking, which is manual only; (2) guidance commands that drive control loops and provide steering displays for the crew; and (3) inertial navigation updated by star sensors or Doppler signals, and by radio frequency (RF) navigation aids for approach and landing.

The basic aerodynamic stability of the orbiter is augmented with body-mounted rate gyros and accelerometers. Side-stick rotation controllers, rudder pedals, and trim controls allow manual control, and the GN&C computer provides commands for automatic flight control functions, such as automatic landing.

Attitude information is obtained from the inertial measuring unit (IMU). Air data are provided by redundant probes deployed at lower altitudes. Gimbaled IMU's provide the navigation reference with star sensors for autonomous alignment and state vector update. During rendezvous, a rendezvous radar is used to obtain range and bearing information.

Automatic landing is accomplished by means of a computer flight path generated in the GN&C computer. The inertial navigation system is used for reference, with continuous updates from tactical air navigation (TACAN) and microwave scan beam landing system (MSBLS). Radar altimeter updates are used near touchdown.

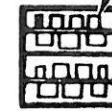Three independent, redundant IMU's are mechanized to supply vehicle attitude information and incremental velocity change information. Each consists of an all-attitude, four-gimbal, inertial-stabilized platform with the associated platform electronics, power supply, interface electronics, BITE (built-in-test-equipment), thermal control circuitry, digital coding and decoding circuitry, and housing and mounting provisions. The IMU's are under control of the general-purpose computers and have a leveling and gyrocompassing capability in addition to the flight-monitoring function. They are rigidly mounted on a navigation base.

Two star trackers are also mounted to the navigation base and are mechanized to provide star-angle measurements for alignment of the IMU.

119SSV87070
(Text)

Guidance, Navigation, and Control Subsystem
Functional Block Diagram
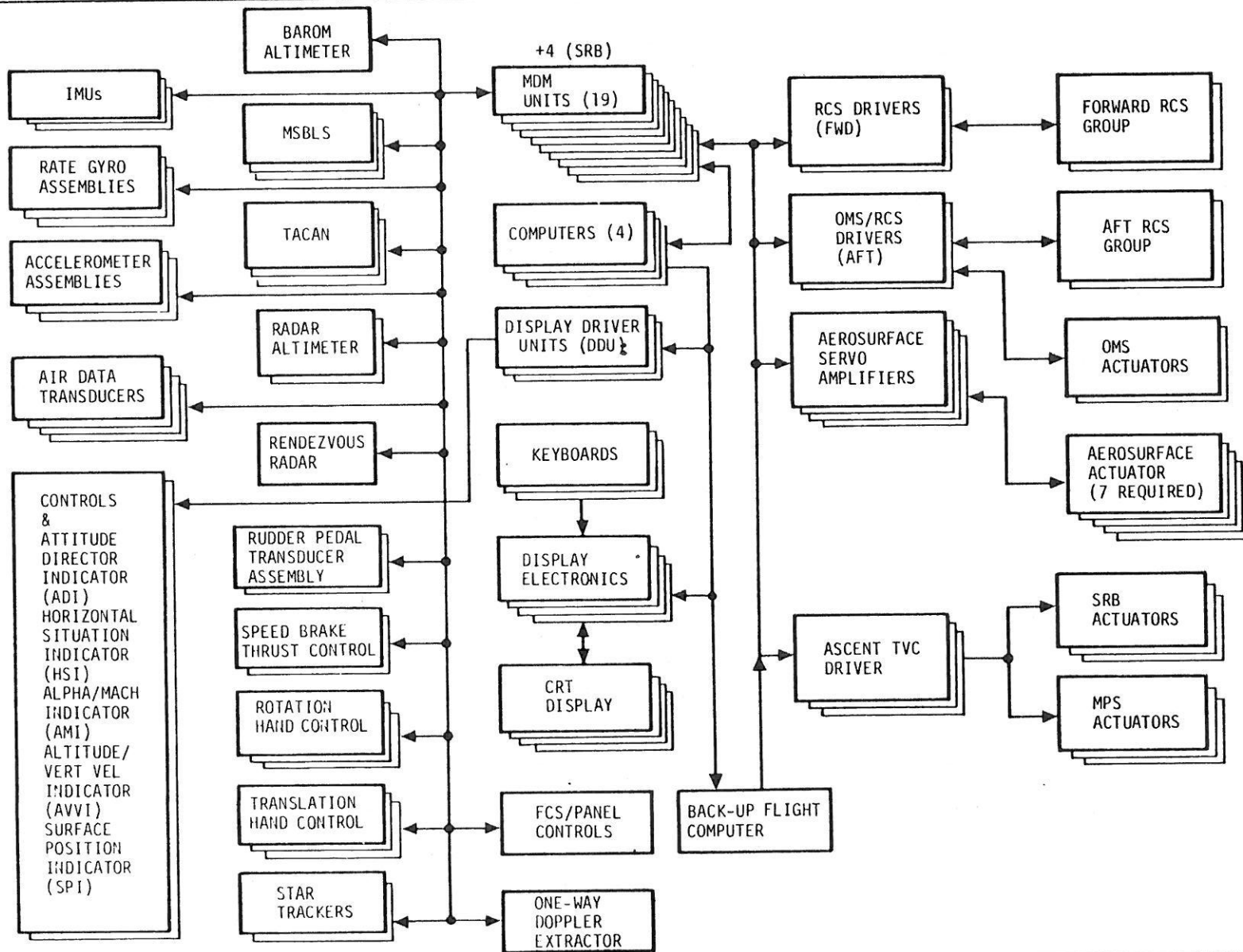
COMMUNICATIONS AND TRACKING SUBSYSTEM

On operational missions, the communications and tracking (C&T) subsystem can perform the following functions:

1. Selects and maintains operationally required RF communication links to support orbiter missions and processes and distributes command signals and data received for use by the supporting avionics.

2. Coherently returns RF communications link carriers for two-way doppler velocity tracking by ground stations and provides a turnaround ranging tone modulation to the ground during ascent, reentry, and landing operations.

3. Provides for location, operation, and interfacing of government-furnished equipment (GFE) decryptors and ecryptors for processing (a) voice and data from and to ground stations directly for DOD missions and (b) data received from and transmitted by detached DOD payloads.

4. Generates RF NAVAID information and air traffic control (ATC) voice for atmospheric flight.

5. Provides audio/voice communications among crew stations within the orbiter, to attached manned payloads via hardwire, to ground stations, and to manned released payloads via RF links.

6. Generates, transmits, and distributes closed-circuit television (CCTV) and generates and transmits color TV or CCTV to the ground via the RF link.

7. Acquires and tracks passive and cooperative targets for supporting rendezvous.

8. Acquires, tracks, receives data from, and transmits data to, NASA Tracking and Data Relay Satellites (TDRS).

Communications and Tracking Subsystem
Functional Block Diagram

OPERATIONAL
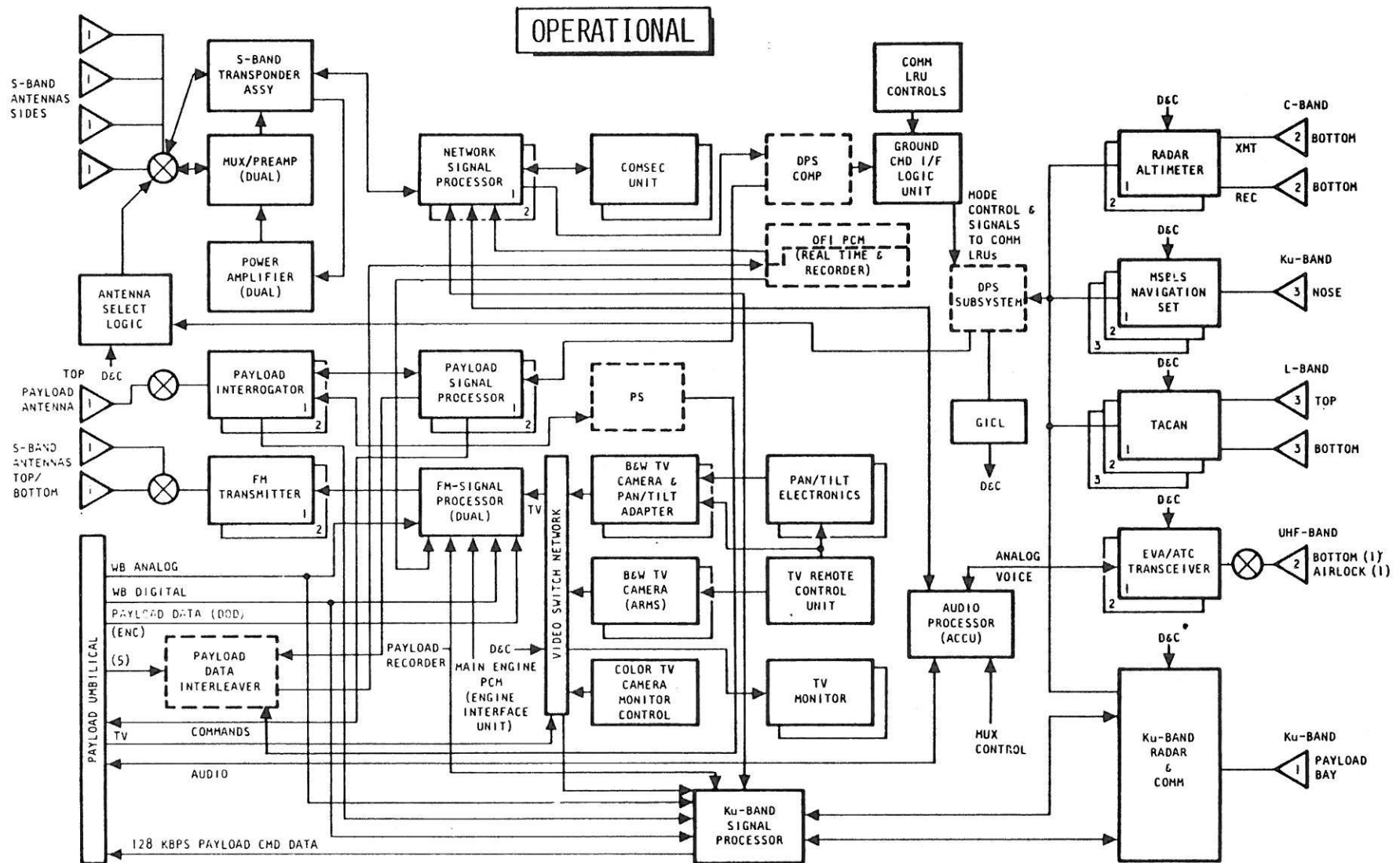
RADIO FREQUENCIES

The orbiter carries up to 23 antennas for communication with ground stations, detached payloads, and crewmen undertaking extravehicular activities (EVA). Through these antennas, information is both transmitted and received at S-, Ku-, L-, C-, and P-band frequencies.

Phase-modulated (PM) data can be transmitted to STDN or SCF ground stations on two S-band carrier frequencies. Two additional S-band carrier frequencies are employed for ground-to-orbiter transmission of FM data. In addition, frequency-modulated (FM) signals from the orbiter to ground go on an S-band carrier, as do the FM data from the development flight instrumentation (DFI) carried aboard the Shuttle test flights. Multichannel two-way communication between the orbiter and attached or detached payloads is accomplished within the S-band regime. The intelligence carried on these channels includes scientific and engineering data, commands, digital voice, caution and warning and performance monitoring information, and video signals.

The Ku-band link between ground stations and the orbiter via the Tracking and Data Relay Satellite System (TDRSS) carries the same kinds of information as the S-band subsystem, but a wider bandwidths and higher data rates. The orbiter rendezvous radar and the microwave scan beam landing system (MSBLS) also work in the Ku-band.

During orbiter approach and landing phases of a mission, standard L-band tactical air navigation (TACAN) units will be employed, as well as C-band radar altimeters and P-band analog voice links for air traffic control (ATC). EVA voice communications will also be at P-band frequencies.

Radio Frequencies

FUNCTION/SYSTEM	ORBITER TRANSMIT	ORBITER RECEIVE
STDN PM-1	2287.5 MHz	2106.4/1831.8 MHz
STDN PM-2	2217.5 MHz	2041.9/1775.7 MHz
STDN/FM	2250.0 MHz	NONE
DFI FM	2205.0 MHz	NONE
NASA PAYLOADS	2025.8 TO 2119.8 MHz	2200.0 TO 2300.9 MHz
DOD PAYLOADS	1763.7 TO 1839.8 MHz	2202.5 TO 2297.5 MHz
EVA COMMUNICATIONS	296.8 MHz	259.7/279.0 MHz
RENDEZVOUS (RADAR)	13.679 TO 13.887 GHz	13.679 TO 13.887 GHz
Ku-BAND COMM	15.0034 GHz	13.775 GHz
RADAR ALTIMETERS	4.3 GHz BAND	4.3 GHz BAND
TACAN	1025 TO 1150 MHz	962 TO 1213 MHz
ATC VOICE	296.8 MHz	259.7 MHz
MSBLS	15.460 GHz	15.4 TO 15.7 GHz

S-BAND INFORMATION TRANSMISSION COMBINATIONS

Various combinations of voice, commands, and telemetered data can be sent to or from the orbiter over S-band transmission links. Phase-modulated (PM) signals, beamed directly to the orbiter from STDN or SCF stations or relayed through the TDRS, can be transmitted at two different bit rates. In the high bit-rate mode, two digital voice channels at 32 kbps per channel, and 8 kbps of command data, are interleaved into a 72-kbps digital data stream. The low bit-rate mode consists of one 24-kbps digital voice channel plus the 8 kbps of command data. Transmissions through the TDRS are convolutionally encoded and have a spread spectrum signal with a rate of 11.2 megachips.

Two bit-rate modes are available for the transmission of PM carrier signals from the orbiter directly to SCF or STDN ground stations or by relay through the TDRS. The high bit-rate mode will accept two channels of digital voice at 32 kbps per channel, interleaved with 128 kbps of telemetered information to form a 192-kbps digital data stream. Up to 64 kbps of the telemetry data can be from a payload. In the low bit-rate mode, one channel of digital voice plus 64 kbps of telemetry are interleaved for transmission. Transmissions through the TDRS are convolutionally coded.

The orbiter can also transmit frequency-modulated (FM) S-band signals directly to the ground. Payload and orbiter data with bandwidths up to 4.5 MHz can be transmitted to STDN stations. The data can include recorded voice, PCM and main engine data, real time CCTV, and digital or wideband analog data from payloads. On DOD missions, FM transmissions to SCF ground stations can consist of recorded voice and encrypted PCM data, 256 kbps of encrypted payload data, and unencrypted main engine data.

The orbiter can transmit or relay a 2-kbps command signal to attached or detached NASA payloads.

Commands to free-flying DOD payloads are sent at a 1 or 2 kilobaud rate by using a ternary frequency shift keyed (FSK), amplitude modulated signal. A 500 or 1000 Hz synchronization signal is provided as the amplitude modulated signal.

Attached or detached payloads can transmit of encrypted or unencrypted data to the orbiter.

S-Band Information Transmission Combinations (KBPS)

RF Link	Voice 1	Voice 2	** CMD	** TLM	Total Uncoded	Channel Encoding	Total Coded	Spread Spectrum
To Orbiter From Ground								
STDN Direct								
High Bit Rate	32	32	8	–	72	No	–	No
Low Bit Rate	24	–	8	–	32	No	–	No
STDN Relay – TDRS								
High Bit Rate	32	32	8	–	72	Yes	216	Yes
Low Bit Rate	24	–	8	–	32	Yes	96	Yes
SCF Direct								
High Bit Rate	32	32	8	–	72	No	–	No
Low Bit Rate	24	–	8	–	32	No	–	No
From Orbiter To Ground								
STDN Direct								
High Bit Rate	32	32	–	128	192	No	–	No
Low Bit Rate	32	–	–	64	96	No	–	No
FM	–	–	–	*	*	No	–	No
STDN Relay – TDRS								
High Bit Rate	32	32	–	128	192	Yes	576	No
Low Bit Rate	32	–	–	64	96	Yes	288	No
SCF Direct								
High Bit Rate	32	32	–	128	192	No	–	No
Low Bit Rate	32	–	–	64	96	No	–	No
FM (Encrypted)	–	–	–	256	256	No	–	No

From Orbiter To Payload	Command Channel – Unmanned NASA	Command Channel – Unmanned DOD
	2000, 1000, 500, 250, 125, 125/2, 125/4, 125/8, 125/16 BPS (16 KHz Subcarrier)	1 or 2 K–Band Ternary FSK/AM

To Orbiter From Payload	TLM – Unmanned NASA	TLM – Unmanned DOD
	16, 8, 4, 2, 1 KPS (1.04 MHz Subcarrier) Data to 4.5 (1.024 or 1.7 MHz Subcarrier)	64, 32, 16, 10, 8, 4, 2, 1 KPS – 500, 250 BPS (1.024 MHz Subcarrier) Data 0.125 to 256 KBP (1.7 MHz Subcarrier)

*4.5 MHz, Maximum

**Maximum Rate

Space Systems Group

Rockwell International

20SSV87073A

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Ku-BAND RADAR/COMMUNICATION SUBSYSTEM

The orbiter Ku-band radar/communication subsystem, Radar/Comm A, is carried aboard the orbiter as standard equipment. Radar/Comm A consists of a deployable antenna assembly and an electrical assembly located in avionics Bay 3A. The antenna is mounted on the starboard payload bay door longeron at Station X_0 662. During ascent, the antenna is stowed in the space between the payload bay door radiator panels and the 15-foot-diameter payload bay clear volume. The antenna is deployed outboard of the orbiter mold line after the payload bay doors have been opened.

In the radar mode, the Ku-band subsystem can detect, acquire, and automatically track at a range of 19 kilometers passive targets with equivalent radar cross-sections of one square meter and Swerling Case 1 scintillation characteristics. The maximum tracking range increases to 560 kilometers when the target is equipped with an appropriate beacon transponder. The radar can acquire a target in 60 seconds, or less, after being directed along the expected target vector, and can provide line-of-sight (LOS) range to the target, range rate, angles relative to the orbiter rendezvous axis (-Z axis), and angle rates, from the maximum range down to a minimum range of 30 meters.

The Comm A Ku-band communications unit shares the radar antenna and pedestal. Two different modes are available for the transmission of data to the ground through tracking and data relay satellites (TDRS). In Mode 1, up to 50 megabits per seconds (mbps) of wideband data from an attached payload, plus up to 2 mbps of operational, stored, or experiment data, and 192 kbps operational data can be transmitted. Mode 2 transmissions can consist of 4.5 mbps of analog (TV) data from either the orbiter or an attached payload, or 4 mbps of payload digital data, plus up to 2 mbps of stored or experiment data and 192 kbps of real-time operational data from the orbiter. The forward (ground-to-orbiter) link can carry 216 kbps of data, consisting of 72 kbps of operational data for the orbiter, 128 kbps for the payload, and 16 kbps of overhead. The forward link can also have 72 kbps of encrypted data convolutionally coded at a 3 times rate as a special mode of operation.

119SSV87074
(Text)

Ku-Band Radar / Communication Subsystem

RADAR RENDEZVOUS RANGE

- 12 NMI, MAX - PASSIVE PAYLOAD
- 300 NMI, MAX - ACTIVE PAYLOAD

PAYLOAD

MODE 1

- 50 MBPS - WIDEBAND DATA
- 2 MBPS - OPERATIONAL, STORED, OR EXPERIMENTAL DATA
- 192 KBPS - OPERATIONAL DATA

TRACKING & DATA RELAY SATELLITE (TDRS)

MODE 2

- 4.2 MHz ANALOG, TV OR PAYLOAD - OR 4 MBPS DIGITAL PAYLOAD DATA
- 2 MBPS - STORED OR EXPERIMENTAL DATA
- 192 KBPS - OPERATIONAL DATA

AVIONICS BAY 3B

Ku-BAND DEPLOYED ASSEMBLY A (RIGHT SIDE)

Ku-BAND RADAR; COMM A

Ku-BAND SIGNAL PROCESSOR

Z_0 332

- 216 KBPS - MEDIUM BANDWIDTH & OPERATIONAL DATA

TRACKING & DATA RELAY SATELLITE GROUND STATION

DATA PROCESSING AND SOFTWARE SUBSYSTEM

The data processing and software subsystem (DP&S) provides data processing capabilities for guidance, navigation, and control (GN&C); communications and tracking (C&T); displays and controls (D&C); system performance monitoring; payload management; payload handling; subsystem sequencing; and selected ground functions with sufficient provision so as not to limit the performance of the subsystems which it supports. The DP&S accepts input commands and/or data from the crew, on-board sensors, and external sources; performs computations and processing; and generates output commands and data as necessary to accomplish the requirements specified for GN&C, C&T, D&C, instrumentation, electrical power distribution and control, computers, performance monitor function, and payload handling and management.

The DP&S equipment configuration is organized around a computer complex consisting of five general-purpose computers which are interconnected so that they may be operated in redundant groups for critical services. Memory capacity of each computer is 104,000 32-bit words. Additional storage of programs and fixed data is provided by two mass memory units having a data capacity of 134 megabits each.

Data transfer between the computer complex and data users employs a data bus network composed of serial, half-duplex data channels operating at one megabit per second.

Interface adaptation between the data bus network and the orbiter subsystems is accomplished by multiplexer/demultiplexer (MDM) units. These units provide signal conversion capability, digital-to-analog as well as analog-to-digital, in addition to the multiplexing/demultiplexing function.

Engine interface units provide operational control of the main engines from GN&C commands or, during ground checkout, via ground checkout MDM's, and provide response data back to the GN&C. The units also provide main engine data for recording, telemetry, or GSE.

119SSV87075
(Text)

Data Processing and Software Subsystem
Block Diagram
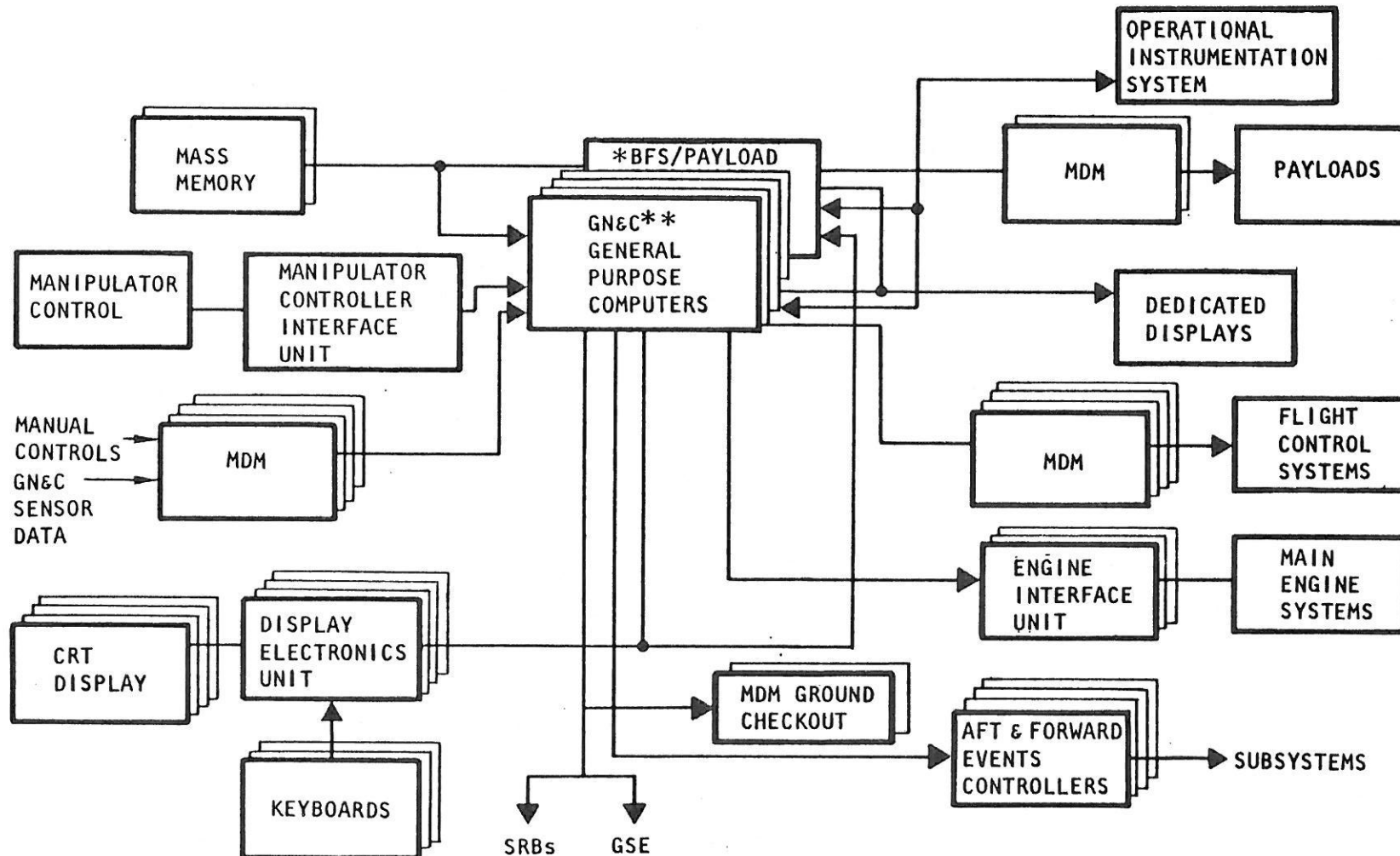
*BACKUP FLIGHT SYSTEM - SEQUENCING, SYSTEM MANAGEMENT, GN&C
**FOUR COMPUTERS DEDICATED TO GN&C DURING CRITICAL FLIGHT PHASES.
ONE OR MORE CAN BE RECONFIGURED FOR OTHER USES DURING NONCRITICAL
FLIGHT PHASES

CREW CABIN ARRANGEMENT AND CREW FUNCTIONS

The crew cabin module is a pressurized compartment of about 2500 ft^3 and is divided into three levels or decks, an upper level or flight deck, a mid-deck (both of which are illustrated), and a lower compartment (not shown). The nominal four-man crew consists of commander, pilot, mission specialist, and payload specialist.

The flight deck contains the controls and displays used to pilot the orbiter, monitor performance of the integrated Shuttle vehicle and payloads, and handle payloads on orbit. It is organized into four functional areas:

1. Two forward-facing flight stations for the commander and pilot permit vehicle control from either seat, including one-man emergency return. Manual controls include orbiter rotation/translation hand controllers, rudder pedals, and speed brakes. The commander and pilot are responsible for the overall vehicle and crew safety and payload operations. Both are proficient in all phases of vehicle flight, payload handling, docking, and subsystem operations, including payload systems as they relate to flight operations, communications and data handling, and vehicle safety. The pilot's duties and capabilities, while second in command, are essentially the same as those of the commander.

2. Two aft-facing stations, one for payload handling (port side) and the other for vehicle control, are operated on-orbit by the commander and pilot. Though both are capable of operating either station, the commander generally controls the vehicle while the pilot handles the payloads.

3. The mission station (facing starboard) is manned by the mission specialist, who is responsible for management of payload operations and their interfaces with orbiter operations. He is proficient in vehicle and payload subsystems, flight operations, and payload communications data management. The crew may include more than one mission specialist.

4. The payload station (facing port side) is manned by the payload specialist, who is responsible for payload applications, technology, and instrumentation operations. He has detailed knowledge of payload operations and requirements, supporting equipment, and payload mission objectives. The crew may include more than one payload specialist, possibly provided by the organization supplying the payload.

The middle level, or mid-deck, contains a galley, four sleep stations, (Three horizontal, one vertical), personal hygiene and waste management facilities, four avionics compartments, and an airlock which provides external access to the payload bay, or which may alternately be located in the bay itself, and provisions for three seats for additional crewmen or passengers. For a rescue mission, the mid-deck can be reconfigured, adding three additional seats in place of sleeping provisions, thus accommodating a rescue flight crew of three and a rescued crew of seven.

The lower level, or equipment bay, contains environmental control equipment and additional crew storage provisions and is accessible through the mid-deck floor.

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Crew Cabin Arrangement and Crew Functions

FLIGHT DECK

LAUNCH/ENTRY

PILOT

PAYLOAD-CRITICAL DISPLAYS AND CONTROLS

MISSION SPECIALIST

PAYLOAD SPECIALIST

COMMANDER

PRIMARY INTERDECK ACCESS
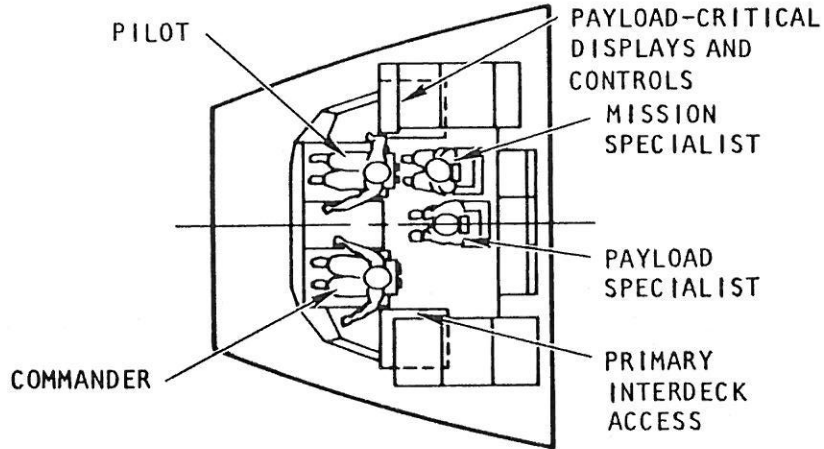
ON-ORBIT

- FIVE OPERATIONAL STATIONS
- SPECIALIST SEATS STOWED IN MID DECK

MISSION STATION

MISSION SPECIALIST

PILOT STATION

VEHICLE CONTROLLER } ON-ORBIT STATIONS

PAYLOAD HANDLER

COMMANDER

PAYLOAD SPECIALIST

PAYLOAD STATION
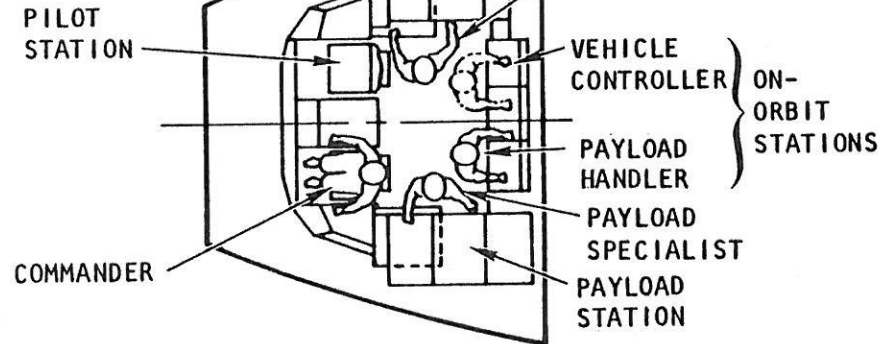
MID DECK

(SLEEP STATIONS REMOVED FOR INSTALLATION OF THREE RESCUE SEATS)

MODULAR STOWAGE

SECONDARY INTERDECK ACCESS

AVIONICS BAY

3A

MODULAR STOWAGE

AVIONICS BAYS

2

1

AIRLOCK

PASSENGER SEATS (3)

AVIONICS & STOWAGE BAY

3B

WASTE MANAGEMENT COMPARTMENT

GALLEY

SIDE HATCH

PRIMARY INTERDECK ACCESS
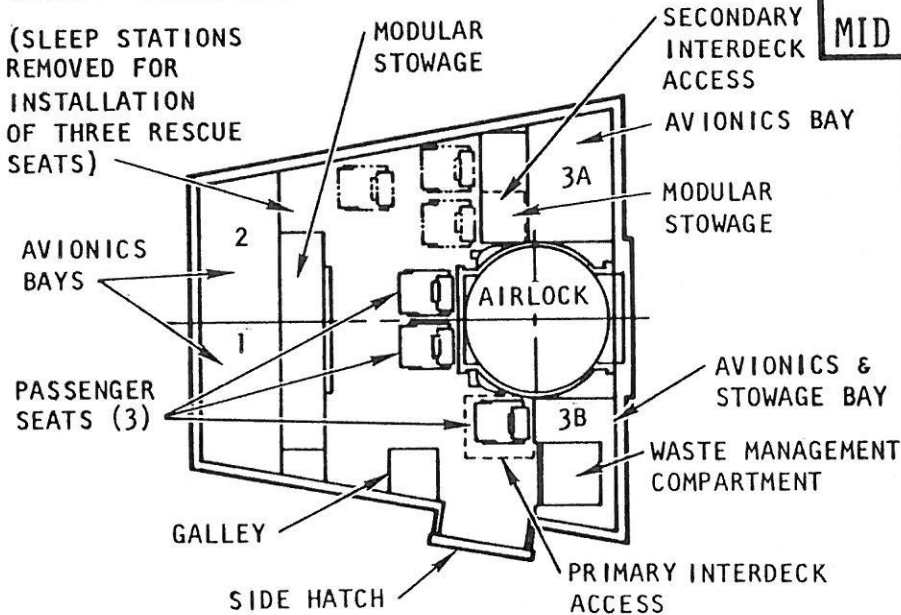
- WORKING/HABITABILITY PROVISIONS FOR FOUR PERSONNEL (NOMINAL)

FOUR SLEEP STATIONS

MODULAR STORAGE

MODULAR STOWAGE

AIRLOCK

UNDER TABLE STOWAGE

STOWAGE/ AVIONICS

DINING/WORK STATION

INTERDECK ACCESS PROV

WINDOW SHADE STOWAGE

GALLEY

WASTE MANAGEMENT COMPARTMENT

PERSONAL HYGIENE STATION (PHS)

DOOR

PRIVACY CURTAIN
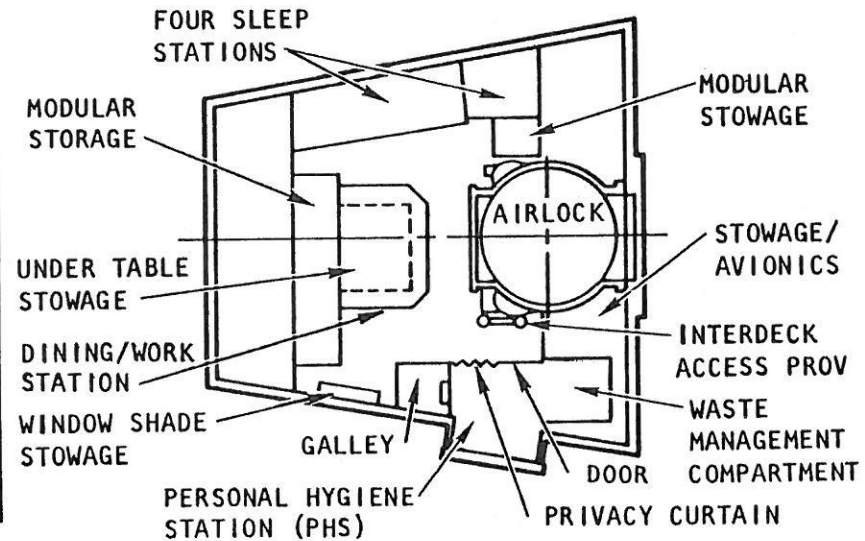
FORWARD FLIGHT DECK

The forward flight deck is organized in the familiar pilot-copilot relationship with suffi-
cient duplication of displays and controls to permit the vehicle to be piloted from either
seat and permit one-man emergency return. The commander's station is on the port side and
the pilot's station on the other. Manual flight controls include rotation hand controllers,
rudder pedals, and speed brake controllers at each of the two forward stations. A rotation
hand controller is provided at the commander's station. The photograph shown is of the
Rockwell flight deck simulator, configured for the first manned orbital flight vehicle,
Oribter 102.

The displays and controls on the forward flight deck are designed to provide the flight
crew with the monitor, command, and control capabilities required for the management of all
normal and contingency flight operations. Provisions are incorporated at the forward flight
deck for selection of either manual or automatic flight control modes to meet mission
objectives, override of automated critical command functions, management of all flight-
critical command functions, display of vehicle caution and warning data, safing of hazardous
conditions arising from vehicle malfunctions, and display and control of critical payload
functions.

Dedicated instruments are used to provide primary flight data during both space and aero-
dynamic flight phases. A cathode ray tube (CRT) display and keyboard are located at both
flight stations, and a third CRT is centrally located between the crewmen. The CRT displays
and keyboards provide the crew with the capability of addressing the orbiter computers,
displaying critical guidance, navigation, and control data, display of supplementary flight
graphics, and monitoring of orbiter subsystem status. A set of centrally located caution
and warning annunciators and master alarm reset push buttons provide the crew with malfunc-
tion identification. Dedicated hardwired displays and controls are provided for the
management of critical subsystem functions.

119SSV87077
(Text)

Forward Flight Deck
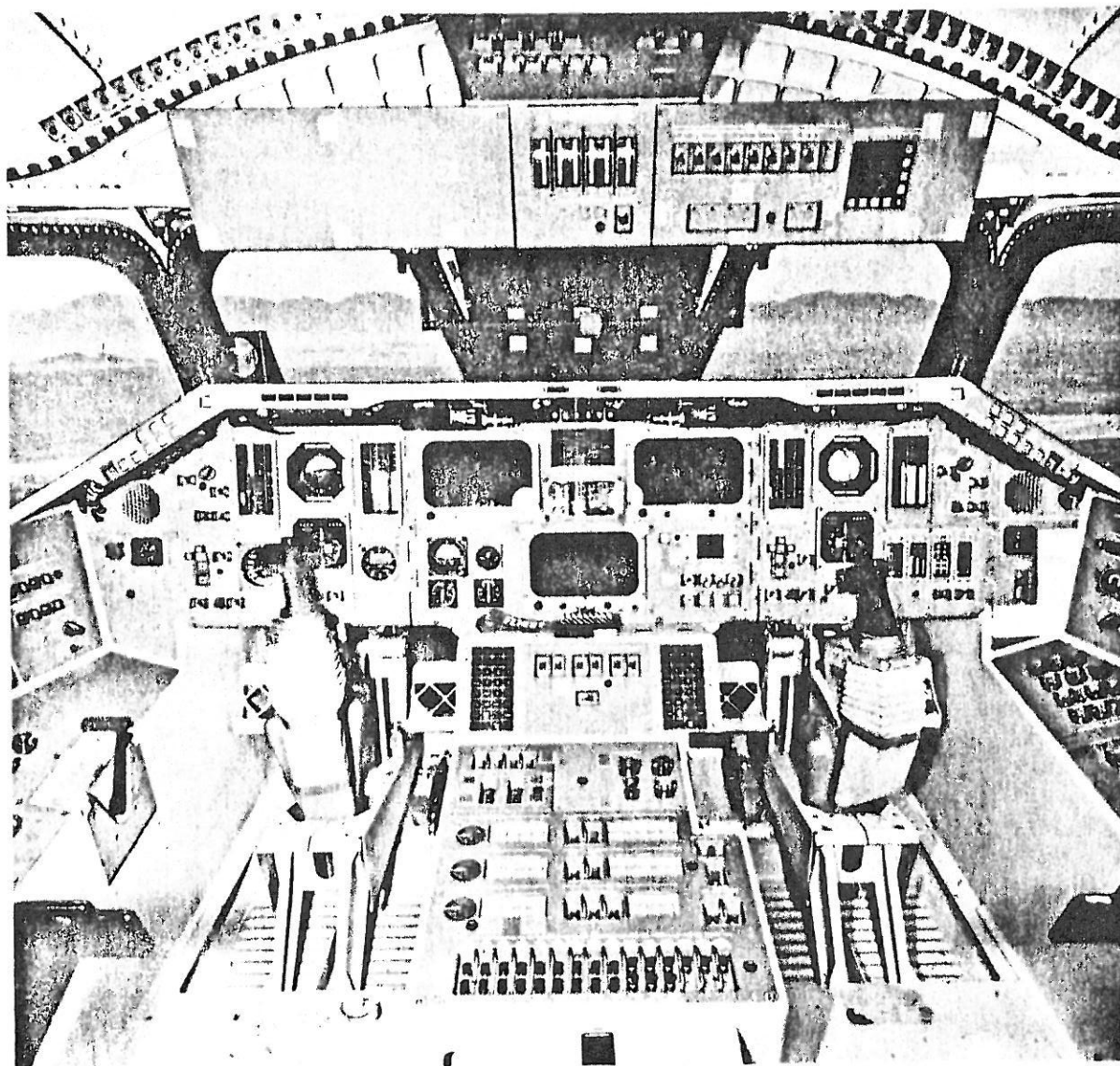
AFT FLIGHT DECK

The chart shows the on-orbit displays and controls at the aft end of the flight deck/crew compartment as seen looking aft. The displays and controls left of center (starboard side) are for operation of the orbiter mission, while those right of center are for operating and handling the payload.

The mission station is located aft of the pilot's station on the starboard side. This station contains the displays and controls required to manage orbiter-to-payload interfaces and payload subsystems that are critical to the safety of the orbiter. An auxiliary caution and warning (C&W) display is provided at this station to detect and alert the crew of critical malfunctions in the payload systems. The station provides for on-orbit housekeeping functions and for the management of nonflight-critical orbiter subsystem functions, which do not require immediate access. All controls are hardwired, as are the critical payload measurements for display and C&W. A CRT display and keyboard are located at this station for monitoring payload interfaces and for orbiter subsystem performance monitoring. Payload conditions critical during ascent and entry can also be displayed at the forward flight stations via C&W and CRT displays.

The rendezvous and docking portion of the on-orbit station contains the displays and controls required to execute orbiter attitude/translation maneuvers for terminal-phase rendezvous and docking. Rendezvous radar controls and displays and cross pointer displays of pitch and roll angles and rates are provided at this station, as well as rotation and translation hand controllers, flight control mode switches, and attitude direction indicators.

The payload handling portion of the on-orbit station contains those displays and controls required to manipulate, deploy, release, and capture payloads. Displays and controls are provided at this station to open and close payload bay doors; deploy radiators; deploy, operate, and stow the payload manipulator arm; and operate payload-bay-mounted lights and TV cameras. Two closed-circuit TV monitors display the payload bay video pictures of payload manipulation operations.

The payload station is located aft of the commander's station on the port side. This incorporates standardized provisions for the installation of payload-unique GFE displays and controls required for monitoring and operating the various payloads. A CRT display and associated keyboard may be added, as an optional provision, for communication with payloads via the orbiter data processing subsystem. Standardized electrical interfaces are provided for payload power, monitoring, command, and control.

Aft Flight Deck

RENDEZVOUS &
DOCKING
CONTROLS

PAYLOAD HANDLING
CONTROLS

DOCKING ROTATIONAL
HAND CONTROLLER

AFT VIEWING WINDOWS

DOCKING TRANSLATION
HAND CONTROLLER

RMS TRANSLATION
HAND CONTROLLER

CCTV MONITORS

RMS ROTATIONAL
HAND CONTROLLER (RHC)

MISSION
STATION

PAYLOAD
STATION

FLIGHT DECK
STOWAGE

VIEW LOOKING AFT

Space Systems Group

Rockwell
International

119SSV87078

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AIRLOCK/EVA PROVISIONS

A versatile extravehicular activity (EVA) capability is provided by the airlock and its associated equipment. As illustrated in the chart, the airlock can be located inside the orbiter in the mid-deck area. The airlock may also be attached in series with the tunnel adapter that can connect the pressurized Spacelab module with the orbiter cabin. When docking is planned, an available docking module (not shown) can serve as an EVA airlock.

The airlock, two extravehicular mobility units (spacesuits), expendables for two 6-hour payload EVA's and one contingency or emergency EVA, and mobility aids such as handrails, enable the crew to perform a variety of tasks.

The airlock is cylindrical with an inside diameter of 63 inches (160 cm) and a length of 83 inches (211 cm). This is sufficient to allow two crewmen room to put on and take off the spacesuits. The hatches are D-shaped. The flat side of the D makes the minimum clearance 36 inches (91 cm). The shape, size, and location of hatches allow the two crewmen to transport a package 18 x 18 x 50 inches (45 x 45 x 127 cm) through the airlock.

20SSV87079A
(Text)

Airlock / EVA Provisions

• ARRANGEMENT SAME FOR ALL CONFIGURATIONS EXCEPT FOR NOTED FOOT
  RESTRAINT & BULKHEAD MANHOLD

AIRLOCK

AFT

LIGHTS

FOOT RESTRAINT
(RELOCATABLE)
AIRLOCK OUT & OUT WITH
ADAPTER CONFIGURATIONS

FOOT RESTRAINT
AIRLOCK IN
CONFIGURATION

INTEGRATED EMUs (2)

SERVICE & COOLING (2)
UMBILICALS

PORTABLE OXYGEN
SYSTEM (2)
(ON-ORBIT ONLY)

HATCH CRANK &
HANDHOLD (REF)

ORBITER HATCH

HANDHOLD

AVIONICS D&C PANELS
(REF)

ECLSS D&C PANELS (REF)

HATCH OMITTED
FOR CLARITY

HATCH HANDHOLD
(2 HATCHES)

HANDHOLD

$+Y_{AL}$ $+X_{AL}$

HANDHOLD
AIRLOCK IN
CONFIGURATION

RELOCATABLE HANDHOLD
AIRLOCK OUT & OUT WITH
ADAPTER CONFIGURATIONS

$+Z_{AL}$

LIGHTS

EVA

EVA

SPACE LAB

AIRLOCK

MID DECK

T/A

AIRLOCK INSIDE

AIRLOCK INSIDE WITH TUNNEL ADAPTER

AIRLOCK OPTIONS

ORBITER SUBCONTRACT DISTRIBUTION

In its position of responsibility for the design and fabrication of the
orbiter, Rockwell International has subcontracted both major (over $10
million) and minor subsystems and elements to contractors throughout the
United States. The chart shows the distribution of those subcontracts as
functions of the subsystems and elements.

Orbiter Subcontract Distribution

- FLIGHT CONTROL SYSTEMS _____ HONEYWELL-MINNESOTA/FLORIDA
- DATA PROCESSING & SOFTWARE REQUIREMENTS_____ IBM-NEW YORK
- OMS/RCS AFT INTEGRATED MODULE _____ MDAC-MISSOURI
- VERTICAL STABILIZER _____ FAIRCHILD-NEW YORK
- WING _____ GRUMMAN-NEW YORK
- MID-FUSELAGE _____ GENERAL DYNAMICS-CALIFORNIA
- REUSABLE SURFACE INSULATION _____ LOCKHEED-CALIFORNIA
- LEADING EDGE THERMAL PROTECT. SUBSYSTEM_____ LTV-TEXAS
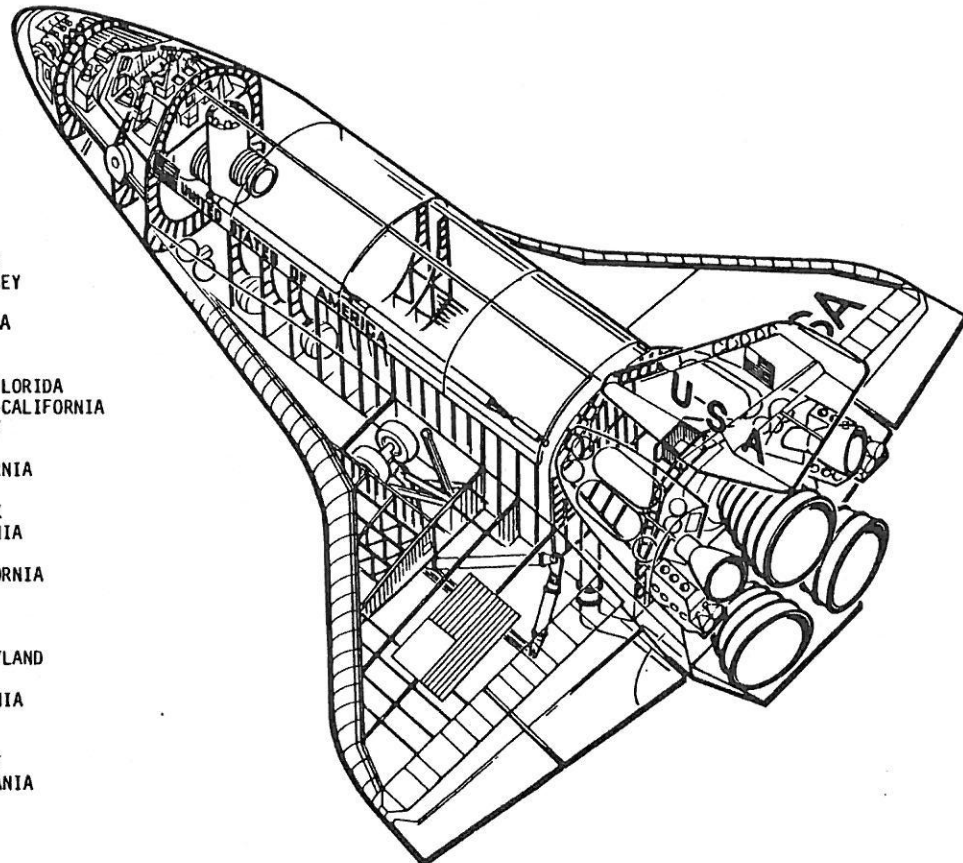- ATM.REVITALIZATION-THERMAL HEAT TRANSPORT___ HAMILTON STANDARD-CONNECTICUT
- FUEL CELL POWER PLANT _____ PRATT & WHITNEY-CONNECTICUT

- ONBOARD COMPUTER INPUT/OUTPUT BUFFER_____ IBM-NEW YORK
- POWER REACTANT STORAGE ASSEMBLY_____ BEECH AIRCRAFT-COLORADO
- ORBITAL MANEUVERING SYS (OMS) ENGINES_____ AEROJET-CALIFORNIA
- AUXILIARY POWER UNIT_____ SUNDSTRAND-ILLINOIS
- MULTIPLEXER DEMULTIPLEXER _____ SPERRY RAND-ARIZONA
- REACTION CONTROL SYS (RCS) THRUSTERS_____ MARQUARDT-CALIFORNIA
- CARRIER AIRCRAFT MODIFICATION_____ BOEING-WASHINGTON
- STRUCTURAL TEST_____ LOCKHEED-CALIFORNIA
- S-BAND SYSTEM_____ TRW-CALIFORNIA

- AUTO LAND_____ SPERRY-ARIZONA
- WINDOWS/WINDSHIELDS_____ CORNING-NEW YORK
- INERTIAL MEASUREMENT UNIT_____ SINGER-KEARFOTT-NEW JERSEY
- ANALOG COMPUTER SYSTEM_____ ELECTRONICS ASSOC-NEW JERSEY
- DIGITAL COMPUTER SYSTEM_____ XEROX-CALIFORNIA
- GROUND MAINTENANCE & OPERATIONS SUPPORT_____ AMERICAN AIRLINES-OKLAHOMA
- MAIN & NOSE LANDING GEAR STRUCTURE_____ MENASCO-CALIFORNIA
- WHEELS & BRAKES_____ B.F. GOODRICH-OHIO
- DATA ACQUISITION SYSTEM_____ MODULAR COMPUTER SYSTEMS-FLORIDA
- SERVO ACTUATORS_____ HYDRAULIC RESEARCH & MFG.-CALIFORNIA
- MULTIPLEXER INTERFACE ADAPTER_____ SINGER-KEARFOTT-NEW JERSEY
- RUDDER/SPEED BRAKE ACTUATOR_____ SUNDSTRAND-ILLINOIS
- SMOKE DETECTION SYSTEM_____ CELESCO INDUSTRIES-CALIFORNIA
- MAIN ENGINE GIMBAL ACTUATOR_____ MOOG, INC.-NEW YORK
- NAVIGATION SET_____ AIL/CUTLER-HAMMER-NEW YORK
- POTABLE & WASTE TANKS_____ METAL BELLOWS CO.-CALIFORNIA
- RCS TANKS_____ MARTIN-MARIETTA-COLORADO
- TACAN_____ HOFFMAN ELECTRONICS-CALIFORNIA
- PULSE CODE MODULATOR_____ HARRIS ELECTRONCS-FLORIDA
- RATE GYRO ASSEMBLY_____ NORTHROP-MASSACHUSETTS
- ATTITUDE DIRECTION INDICATOR_____ LEAR SIEGLER-MICHIGAN
- MASTER TIMING UNIT_____ WESTINGHOUSE ELECTRIC-MARYLAND
- ENGINE INTERFACE UNIT_____ CONRAC CORP.-NEW JERSEY
- AMMONIA BOILER_____ FAIRCHILD STRATOS-CALIFORNIA
- THERMAL CIRCUIT BREAKERS_____ AIKEN INDUSTRIES-MICHIGAN
- POWERSTATIC INVERTER_____ WESTINGHOUSE-OHIO
  PROPELLANT SENSORS_____ SIMMONDS PRECISION-VERMONT
  WASTE COLLECTION SYSTEM_____ GENERAL ELECTRIC-PENNSYLVANIA

*OVER $10M̄

Orbiter Subsystem Component Locations
(Elevation View)

MONOMETHYL-HYDRAZINE (CH₃NHNH₂) TANK

ESCAPE PANEL

RMS SEPARATION PYROTECHNICS

INDUCED ENVIRONMENTAL CONTAMINATION MONITOR

SPACE RADIATORS

MONOMETHYL-HYDRAZINE (CH₃NHNH₂) TANK

MECHANICAL ACTUATORS

RUDDER SPEEDBRAKE POWER DRIVE UNIT

MONOMETHYL-HYDRAZINE (CH₃NHNH₂) TANK

HELIUM (He) TANK

EJECTION SEAT OV 102

NITROGEN (N₂) TANKS

RMS SEPARATION PYROTECHNICS

ELECTRICAL CABLE TRAY

RMS SEPARATION PYROTECHNICS

NITROGEN TETROXIDE (N₂O₄) TANKS

HELIUM (He) TANKS

AVIONICS BAY

LIQUID OXYGEN (LO₂) TANK

ELECTRICAL POWER DISTRIBUTION BOX

ELECTRICAL POWER SYSTEM FUEL CELL

LIQUID HYDROGEN (LH₂) TANKS

LIQUID OXYGEN (LO₂) TANK

HYDRAZINE (N₂H₄) TANKS

HELIUM (He) TANKS

HELIUM (He) TANKS

WATER (H₂O) TANKS (5)

FREON PUMPS

Orbiter Subsystem Component Locations
(Top View)

ELEVON ACTUATORS

MANIPULATOR ARM
(OPTIONAL)

SPACE RADIATORS

DEVELOPMENTAL
FLIGHT
INSTRUMENTATION (DFI)
EQUIPMENT (OV 102)

NITROGEN
TETROXIDE (N_2O_4)
TANKS

MONOMETHYL-
HYDRAZINE (CH_3NHNH_2)
TANKS

PRIMARY TRHUSTERS
REACTION CONTROL SUBSYSTEM

HELIUM (He)
TANK

NITROGEN
TEXTROXIDE (N_2O_4)
TANK

EJECTION
SEATS
(OV 102)

ORBITAL
MANEUVERING
ENGINE

HELIUM (He)
TANKS

HELIUM (He)
TANKS

MONOMETHYL-
HYDRAZINE
CH_3NHNH_2
TANK

STAR
TRACKER

ORBITAL
MANEUVERING
ENGINE

PRIMARY THRUSTERS
REACTION CONTROL SUBSYSTEM
(RIGHT HAND TYPICAL)

HELIUM (He)
TANK

MANIPULATOR ARM

MONOMETHYL-
HYDRAZINE (CH_3NHNH_2)
TANKS

NITROGEN
TETROXIDE (N_2O_4)
TANKS

WATER SPRAY BOILERS (3)

ELEVON ACTUATORS

Orbiter Subsystem Component Locations
(Bottom View)

AVIONICS HEAT EXCHANGER (BAY NO. 3)

STOWAGE COMPARTMENTS

CABIN FAN AND DEBRIS TRAP ASSEMBLY

STOWAGE COMPARTMENTS

AVIONICS HEAT EXCHANGER (BAY NO. 1)

EXTERNAL TANK ORBITER FWD ATTACH FITTING

AVIONICS HEAT EXCHANGER (BAY NO. 2)

COOLANT (WATER) PUMPS

CO_2 ABSORBER & TEMPERATURE CONTROL ASSEMBLY

CO_2 ABSORBER STORAGE

WATER TANKS (5)

ELECTRICAL POWER SYSTEM FUEL CELL

FREON PUMPS

NITROGEN (N_2) TANK

ELECTRICAL POWER SYSTEM FUEL CELL

LIQUID OXYGEN (LO_2) TANK

NITROGEN (N_2) TANK

ELECTRICAL POWER SYSTEM FUEL CELL

NITROGEN (N_2) TANKS

LIQUID OXYGEN (LO_2) TANK

LIQUID HYDROGEN (LH_2) TANK

GASEOUS OXYGEN (GO_2) TANK

LIQUID HYDROGEN (LH_2) TANKS

HELIUM (He) TANK

LIQUID OXYGEN (LO_2) TANKS

HELIUM (He) TANKS

HELIUM (He) TANKS

ELEVON ACTUATOR

HELIUM (He) TANKS

ELEVON ACTUATOR

HYDRAULIC LINES

LIQUID HYDROGEN (LH_2) EXTERNAL TANK UMBILICAL

HELIUM (He) TANKS

BODY FLAP POWER DRIVE UNIT

HELIUM (He) TANKS

LIQUID OXYGEN (LO_2) EXTERNAL TANK UMBILICAL DISCONNECT

JACK PAD (LH TYP)

EXTERNAL TANK / ORBITER AFT ATTACH FITTING (LH TYP)

Space Systems Group

Rockwell International

10SSV87279

Payload Integration and Accommodations

SCOPE OF ORBITER PAYLOAD ACCOMMODATIONS

The Space Shuttle orbiter and its standard payload carriers are designed to accommodate a wide range of payload missions. The chart identifies those orbiter subsystems which support, directly or via carrier systems, the satellites, modules, and other scientific or applications payloads to be flown. The remote manipulator system, docking module, and payload retention system are 100 percent dedicated to payloads. Additional flexibility is gained with EVA capabilities and mission extension kits. Kits can augment crew support, orbiter propulsion, primary power supply energy, and heat rejection capability. Limits on power availability, heat rejection capability, c.g. requirements, etc., presented here apply to the cargo, i.e., the total complement of payloads and associated hardware carried on a given flight. Provisions will be provided for trimming cargo c.g. and for managing and isolating services provided to the payloads in order to minimize these concerns for payload design.

Payloads may be designed to interface directly with orbiter hardware or with an STS carrier. The environments seen, services available, and STS fees for carrier-mounted payloads depend upon the carrier as well as the Shuttle.

The charts which follow describe selected payload environments and support capabilities, where payloads are taken to interface directly with the orbiter. Therefore, the information applies most directly to carriers with their integrated payloads and directly mounted payloads. These data may be modified due to attachment to carriers (e.g., c.g. control).

More information on payload accommodations can be found in the NASA's "Space Transportation System Users Handbook." Rockwell's STS User Service Center provides assistance to users in selecting and arranging for appropriate carriers, determining users' design requirements, and arranging for Shuttle flights. Rockwell also provides services for designing and integrating payloads into carriers and the Shuttle.

119SSV87139
(Text)

Scope of Orbiter Payload Accommodations

ΔPASSENGERS & ΔEQUIPMENT

DISPLAY & CONTROL PANELS

DISCONNECT PANEL & LINES

ΔRCS

AVIONICS SERVICES

RETENTION MECHANISMS

DOCKING MODULE

ΔOMS

CONTAMINATION CONTROL

RMS

CONNECTIONS WIRING & CONTROLS

ΔECLS

PAYLOAD COOLANT LOOP

DATA BUS INTERFACE

ELECTRICAL POWER

- SMALL SELF-CONTAINED PAYLOADS
- SPACELAB MODULE
- SPACELAB PALLETS
- INTERMEDIATE CLASS PAYLOAD CARRIERS
- LONG DURATION EXPOSURE FACILITY
- SPACE TELESCOPE
- MULTIMISSION MODULAR SPACECRAFT

SPACECRAFT
- HIGH ALTITUDE
- GEOSYNCH
- PLANETARY

UPPER STAGES
- INTERIM UPPER STAGE (IUS)
- SOLID SPINNING UPPER STAGE (SSUS)

- DOD PAYLOADS

CANDIDATE PAYLOADS

CARRIER/PAYLOAD INSTALLATION (KSC)

The concepts for carrier/payload installation and removal with the orbiter in a horizontal position at the Orbiter Processing Facility (OPF) or in the vertical position at the Rotating Service Structure (RSS) at the launch pad for KSC are illustrated in this chart.

Upon installation of mission kits and orbiter checkout, the cargo bay will be cleaned and carriers/payloads installed. Interfaces between the orbiter and carriers/payloads will be verified by integrated tests. It may be necessary to provide for simulating equipment functions not operable in the earth environment; as a result, carrier/payloads should facilitate simple and end-to-end functional tests. Unique carrier/payload ground support equipment should be easily integratable into integrated orbiter-cargo checkout operations. Payloads should be designed to minimize the need for ground servicing, calibration, and operation, and operation once installed in the orbiter. Payloads are not normally accessible after closure of the cargo bay doors except through the orbiter cabin.

A carrier/payload can also be installed with the orbiter in the vertical position at the Rotating Service Structure, which encloses the cargo bay. Installation or removal of carrier/payloads at the RSS is with the use of the Payload Ground Handling Mechanism (PGHM).

In both the OPF and RSS, cargo bay temperature and humidity are controlled using filtered air at $70 \pm 5°F$ and 45 ± 5 percent RH. The final purge on the launch pad prior to launch is performed using dry nitrogen.

On the launch pad, following installation, payload signals can be monitored via an umbilical interface.

30SSV87140A
(Text)

Carrier / Payload Installations (KSC)

STRONGBACK

PAYLOAD

PAYLOAD CANISTER

ROTATING SERVICE STRUCTURE
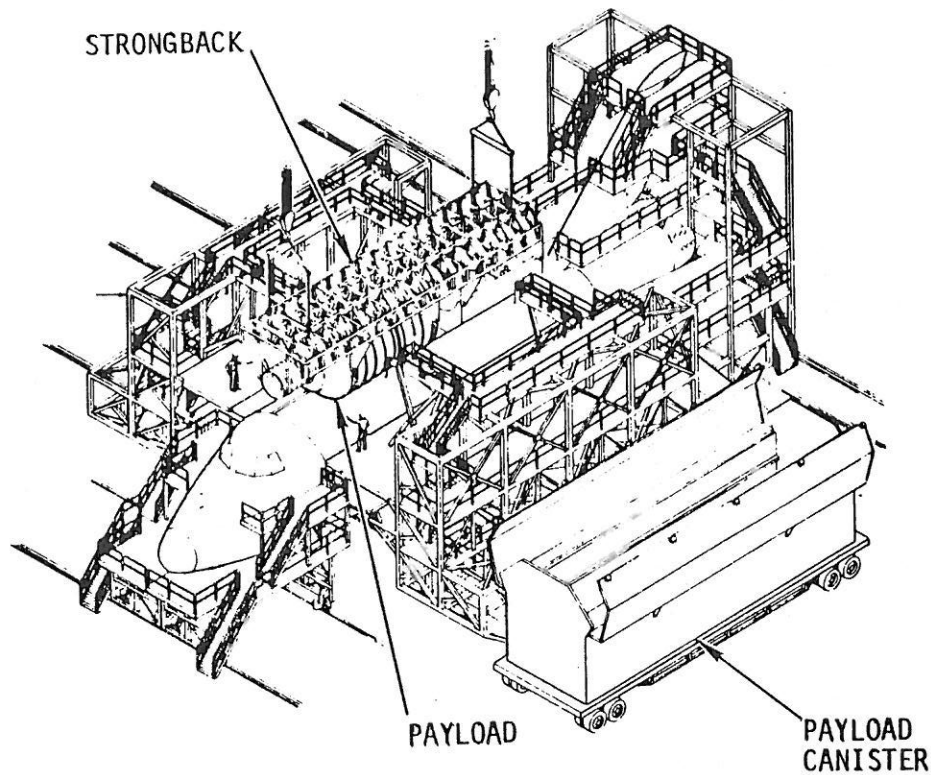
HORIZONTAL PAYLOAD INSTALLATION/REMOVAL IN ORBITER PROCESSING FACILITY (OPF)
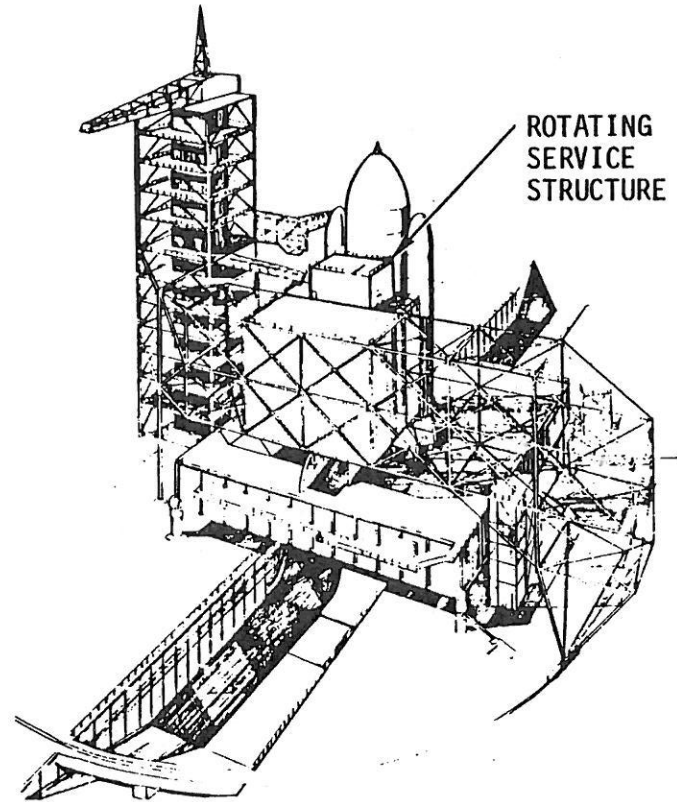
VERTICAL PAYLOAD INSTALLATION/REMOVAL AT THE LAUNCH PAD

ORBITER/PAYLOAD ATTACHMENT LOCATIONS AND CARRIER/PAYLOAD RETENTION SYSTEM

Orbiter/Payload Attachment Locations

The orbiter provides structural support attachment points for carrier/payloads along the length of the cargo bay as indicated on the accompanying chart. The forward end of the bay has a bulkhead at Station 576, and the aft end has a bulkhead at Station 1307. The available cargo envelope is 60 feet long and 15 feet in diameter (constrained between Stations 582 and 1302). The attachment points are located at 3.933-inch increments along the main longerons and along the bottom centerline of the cargo bay on bridge fittings spanning adjacent fuselage frames. Of the potential 171 attach points on the longerons, 47 are not available due to the proximity of orbiter hardware and the need to allow for motion, thermal expansion, and structural deflections; 124 may be used for carrier/payload attachment, and of these, 111 may be used for deployable payloads. 104 attach points are available along the keel, any of which may be used for deployable payloads. Arrangements for thermal expansion and determinate support are provided by the selection of the proper fittings. Longeron and keel attach points normally utilize the attach fittings described on the attach fitting chart (page 187). Should the need arise, unique attach points could be provided on payload-supplied special bridge fittings.

Carrier/Payload Retention Systems

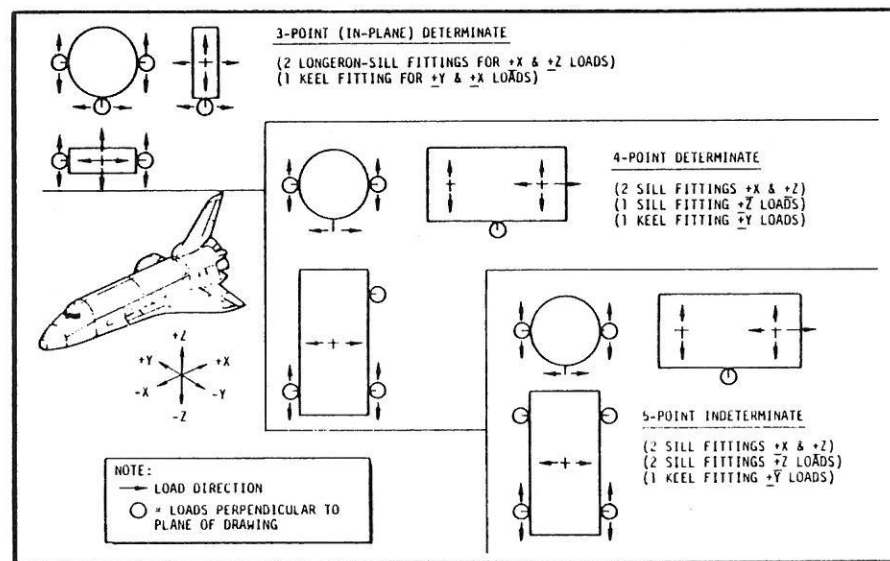Illustrated in the inset, are the three principal payload retention system concepts. Longeron/sill attach fittings react either $+X_O$ and $+Z_O$ axes loads (primary) or Z_O axis loads only (stabilizing, on either side of the fuselage). The keel fitting (auxiliary, generally located near the payload c.g.) reacts Y_O axis loads, except as shown on the left in three-point determinate. The orbiter baseline, four-point determinate system with three longeron and one keel fittings, is shown in the middle. Addition of a second stabilizing longeron fitting makes the system indeterminate with four fittings on the longeron and one at the keel, as shown on the right side in the five-point system. Two longeron fittings in-plane with a keel fitting are presented in the three-point system on the left. Keel fitting has $+X_O$ axis load capability as well as $+Y_O$ axis as required by this three-point approach.

3-POINT (IN-PLANE) DETERMINATE
(2 LONGERON-SILL FITTINGS FOR +X & +Z LOADS)
(1 KEEL FITTING FOR +Y & +X LOADS)

4-POINT DETERMINATE
(2 SILL FITTINGS +X & +Z)
(1 SILL FITTING +Z LOADS)
(1 KEEL FITTING +Y LOADS)

5-POINT INDETERMINATE
(2 SILL FITTINGS +X & +Z)
(2 SILL FITTINGS +Z LOADS)
(1 KEEL FITTING +Y LOADS)

NOTE:
→ = LOAD DIRECTION
○ = LOADS PERPENDICULAR TO PLANE OF DRAWING

10SSV87141
(Text)

Orbiter / Payload Attachment Locations and Carrier / Payload Retention System

612.73

1281.40

124 ATTACH POINTS BETWEEN THESE LOCATIONS AT 3.933 IN. (NOMINAL) SPACING

BULKHEAD X_o 576

$Y_o \pm 94.0$

TYPICAL LONGERON BRIDGE FOR PITCH (+Z) LOADS (5-POINT INDETERMINATE)

$\mathcal{C}_L$

NOTE: ADDITIONAL BRIDGES MAY BE ADDED FOR MULTIPLE PAYLOADS

TYPICAL KEEL BRIDGE FOR +Y LOADS

X_o 1307 BULKHEAD

TYPICAL LONGERON BRIDGE FOR +Z & +X LOADS

FUSELAGE FRAME STATIONS (TYP)

582   693   807   919   1040 1140.67 1249

CABIN   636   750   863   979.5   1090.33 1191   1301.5

Z_o 414

$\mathcal{C}_L$

LATERAL LOAD RETENTION POINTS LOWER $\mathcal{C}_L$ Z_o 305, EXCEPT AFT OF 1179

1179

Z_o 308.4 AFT OF 1179

ATTACH FITTINGS FOR CARRIER/PAYLOAD

Payloads are supported along both sides of the cargo bay at points 14 inches above the bay centerline and along the bottom at the orbiter keel centerline. All attach fittings are outside the 93-inch radius of the orbiter dynamic envelope, except for keel fittings over the wing box (aft of X_O 1179).
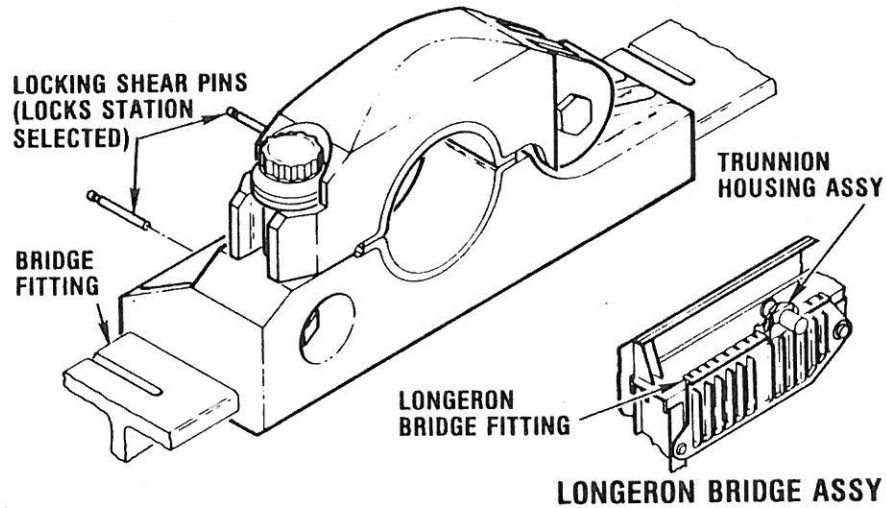
The longeron (side) attach fittings are situated above the cargo bay sill longerons on detachable bridges that distribute the fitting loads into orbiter structure. The keel bridges also span adjacent fuselage frames and are detachable.

The carrier/payload attachments are of the trunnion/bearing/journal type. The longeron attach fitting has a split self-aligning bearing and is available either as a nonreleasing fitting whose hinged upper half is bolted closed before launch, or as a remotely actuated fitting which releases/secures the carrier/payload trunnion for on-orbit deployment and retrieval. The deployable fitting has a flared alignment guide to assist in retrieval, which is retracted when not in use. Both types of attach fitting engage the longeron bridge by a tee and slot which allow sliding in the X direction. Since these trunnions must support both X and Z loads, shear pins are installed in one pair of fittings to prevent X motion and thus transmit X loads into the bridge and thereby into the orbiter. The other longeron attach fitting(s) remains free to slide and transmits only Z loads.

The keel attach fitting also uses a tee-slot arrangement which makes it free to slide in the X direction. The carrier/payload will provide a keel trunnion, nominally 3 inches in diameter, which will fit within a split bearing in the keel attach fitting. For 4- and 5-point installations, the trunnion will be free to move in the X and Z direction but will be restrained in the Y direction. For 3-point installations, shear pins are installed to constrain the ±X motion. The keel attach fitting may be remotely actuated open and closed to facilitate payload deployment and retrieval.

129SSV87142
(Text)

Attach Fittings for Carrier / Payload

NONDEPLOYABLE PAYLOAD ATTACH FITTING

LOCKING SHEAR PINS
(LOCKS STATION
SELECTED)

BRIDGE
FITTING

TRUNNION
HOUSING ASSY

LONGERON
BRIDGE FITTING

LONGERON BRIDGE ASSY

5-POINT INSTALLATION (INDETERMINATE)

SILL
LONGERON

LONGERON
BRIDGE

STABILIZING
FITTING

$\pm Z_0$ LOADS

PRIMARY
FUSELAGE
FRAME

PRIMARY
FITTING

$\pm Z_0$
LOADS

$\pm X_0$
LOADS

C.G. TYPICALLY OVER KEEL
BRIDGE ASSY

$\pm X_0$
LOADS

$\pm Z_0$ LOADS

KEEL BRIDGE
FITTING $\pm Y_0$ LOADS
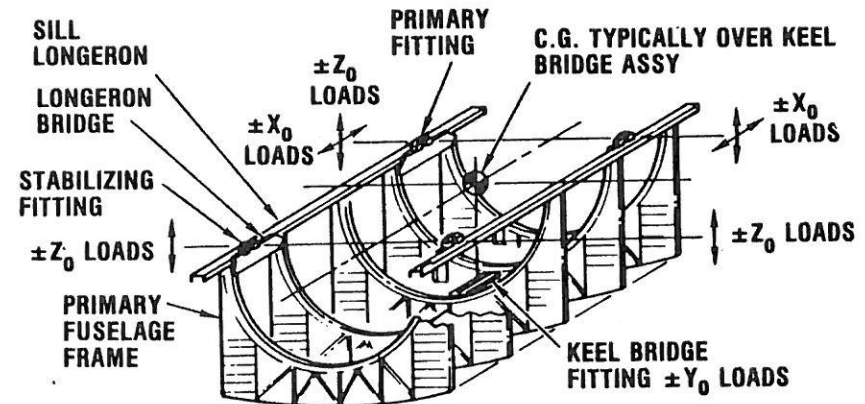
TYPICAL BEAM RETENTION FITTING
(DIVIDES LOAD INTO 2 FUSELAGE FRAMES)

DEPLOYABLE PAYLOAD ATTACH FITTING / MECHANISM

TRUNNION GUIDE

FORWARD

SPLIT
BEARING

OUTBOARD
PORT SIDE

CARRIER / PAYLOAD KEEL FITTING

ORBITER MIDBODY
FRAME INTERFACE

KEEL
BRIDGE
(TYP)

KEEL
CLOSEOUT
COVER

ACTIVE
KEEL
FITTING

CARGO CENTER-OF-GRAVITY ENVELOPE REQUIREMENTS

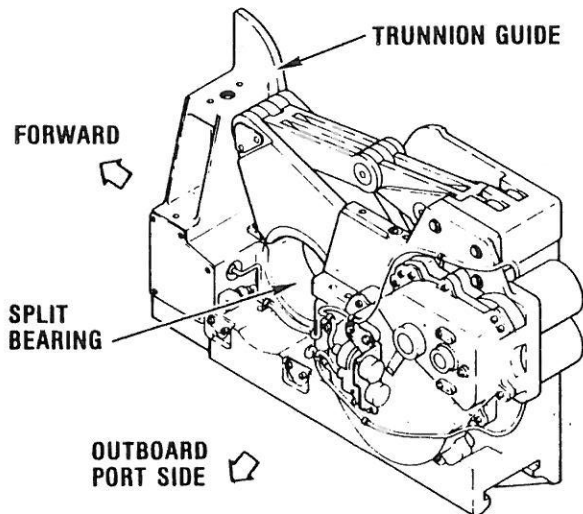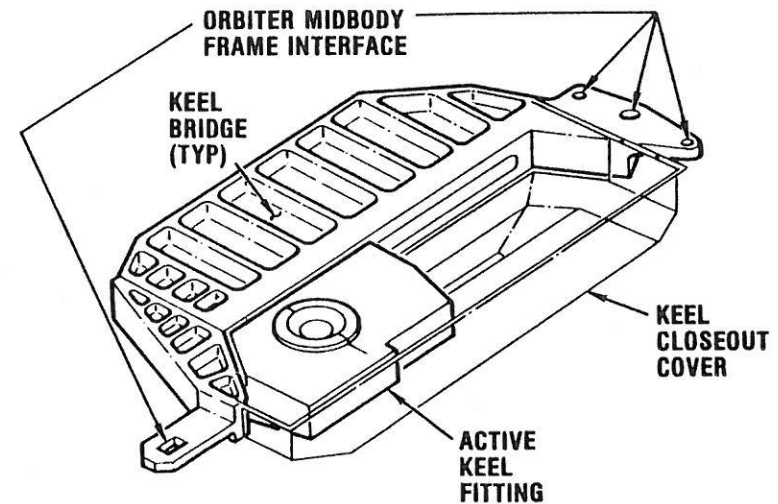Carriers/payloads must be integrated into cargoes which meet the c.g. constraints of the facing page due to orbiter aerodynamics. All payload chargeable items (e.g., orbiter maneuvering system kits, electrical power subsystem kits, spare parts) regardless of location (e.g., cargo bay, beneath the bay, in the cabin) must be included in the computation to obtain the location of the cargo center of gravity, which must be within the specified envelope for normal or abort reentries and landings. The envelope for weights above 32,000 pounds must be maintained for potential emergency landings. Typical payloads will not be individually required to control their centers of gravity within these limits. Except for large unique payloads, the cargo integrator will be able to manage cargo distribution to achieve an acceptable center of gravity for the entire cargo. This c.g. constraint will usually influence the order in which payloads may be deployed and the associated use of consumables.

LONGITUDINAL CONSTRAINTS (X-AXIS)

The current vehicle is designed to reenter and land with the total vehicle c.g. located between 65 and 67.5 percent of the body length. With a design-landing cargo weight of 32,000 pounds, the cargo c.g. must fall between 32 and 45 feet from the forward end of the cargo bay.

VERTICAL CONSTRAINTS (Z-AXIS)

The vertical c.g. envelopes are measured in inches from the centerline of the cargo bay for cargo up to 65,000 pounds. The outer envelope constraint is for the entire cargo, whereas the inner envelope (shaded) applies to cargo elements mounted in the cargo bay.

LATERAL CONSTRAINTS (Y-AXIS)

The lateral cargo c.g. envelope is symmetrical about the orbiter centerline. Allowable excursions within this envelope are measured in inches rather than feet. The lateral c.g. excursion limit for a 10,000-pound cargo is +8 inches. As the weight increases, the allowable excursion decreases; it is +3.5 inches for a 32,000-pound cargo and only +2.5 inches for a 65,000-pound cargo.

Cargo Center-of-Gravity Envelope Requirements

LONGITUDINAL (X AXIS)

CARGO WEIGHT (1000 LB)

70, 60, 50, 40, 30, 20, 10, 0

DESIGN ASCENT CARGO

DESIGN LANDED CARGO

CARGO C.G. POSITION (FEET)

0 10 20 30 40 50 60

VERTICAL (Z AXIS)

DISTANCE FROM PAYLOAD BAY C_L (IN.)

96, 72, 48, 24, 0, -24, -48, -72, -96

C.G. OF CARGO HARDWARE MOUNTED ON PAYLOAD BAY ATTACHMENTS MUST BE WITHIN CROSSHATCHED AREA

C_L $Z_0 = 400$

PAYLOAD WEIGHT (1000 LB)

0 10 20 30 40 50 60 65

C.G. FOR TOTAL CARGO WEIGHT MUST BE WITHIN OUTSIDE ENVELOPE

COORDINATE SYSTEM

$$\begin{cases} X_0 = 582 \\ Y_0 = 0 \\ Z_0 = 400 \end{cases}$$

400 IN.

Z

X

Y

LATERAL (Y AXIS)

CARGO WEIGHT (1000 LB)

70, 60, 50, 40, 30, 20, 10, 0

MAXIMUM DESIGN CARGO WEIGHT 65,000 LB

MAXIMUM DESIGN CARGO WEIGHT AT LANDING 32,000 LB

ALLOWABLE CARGO CENTER-OF-GRAVITY ENVELOPE

2000 LB

-12 -10 -8 -6 -4 -2 0 2 4 6 8   32.82

$Y = 0$

LATERAL DISTANCE FROM VEHICLE CENTERLINE (INCHES)

CARRIER/PAYLOAD DESIGN LIMIT-LOAD FACTORS

The preliminary limit-load factors/angular accelerations shown on the facing page apply to rigid payloads attached directly to the orbiter at any location in the cargo bay. These load factors shall be used for preliminary design of carrier/payload primary structure and for determination of preliminary orbiter/carrier interface loads. Load factors at specific points within the payload will depend upon payload design characteristics and mounting methods. Payloads that are cantilevered or that have substantial internal flexibility may experience higher load factors than those shown in the table.

Typical load factors for lift-off, boost, TAEM (terminal approach energy management), and landing are presented. However, during these events, external forces are highly transient and significant elastic response occurs. Carrier/payload responses will depend upon carrier/payload geometry, stiffness, and mass characteristics. Therefore, until sufficient carrier/payload case history is collected, final design values for orbiter/carrier/payload interface forces and carrier/payload design loads must be determined by coupled orbiter/carrier/payload dynamic analyses for these transient flight events.

Emergency Landing Ultimate Load Factors:

To provide for crew safety during emergency landing, the large equipment items, pressure vessels, payload attachments, and supporting structure must withstand the loads associated with the following ultimate load factors, acting separately:

Cargo Weight (lb)	Longitudinal (+ Aft)	Lateral (+ Right)	Vertical (+ Up)
Up to 32,000	+4.5 -1.5	+1.5 -1.5	+4.5 -2.0
65,000	+4.5 -0.738	+.738 -.738	+2.215 -0.985

Carrier / Payload Design Limit-Load Factors

FLIGHT EVENT	LIMIT-LOAD FACTOR,* g			ANGULAR ACCELERATION** RAD/SEC²			CARRIER/ PAYLOAD WEIGHT
	N_X (+ AFT)	N_Y (+ RIGHT)	N_Z (+UP)	$\ddot{\theta}_X$ (+ RIGHT WING DN)	$\ddot{\theta}_Y$ (+ NOSE UP)	$\ddot{\theta}_Z$ (+ NOSE LEFT)	
ASCENT							
• LIFTOFF	$\begin{cases} -0.2 \\ -3.2 \end{cases}$	±1.4	±2.5	±1.4	±3.2	±0.8	
• BOOST HIGH-Q ENVELOPE	-1.9	+0.4	+0.25 -0.5	±0.1	±0.15	±0.15	UP TO 65K LB
• BOOST MAX, N_X INTEG VEHICLE	$\begin{cases} -2.9 \\ -2.6 \end{cases}$	+0.06 ∓0.02	-0.15 -0.2	±0.2	±0.25	±0.25	
• SRB POST-STAGING	-1.1	∓0.12	-0.59	0	0	0	
• BOOST MAX, N_X ORBITER	$\begin{cases} -3.17 \\ -3.05 \end{cases}$	0.0 0.0	-0.6 -0.8	±0.20	±0.25	±0.25	
DESCENT							
• TAEM: PITCH MANEUVER	$\begin{cases} 1.01 \\ -0.15 \end{cases}$	0	2.5	0	0	0	
	0.25	0	2.5	0	-0.11	0	UP TO 32K LB
	0.97	0	-1.0	0	0	0	
• TAEM: ROLL MANEUVER	0.65	+0.12	1.98	±1.28	0.02	+0.13	
• TAEM: YAW MANEUVER	$\begin{cases} 0.60 \\ 0.56 \\ 0.61 \end{cases}$	∓0.85 ∓0.49 ∓0.002	1.0 1.44 0.92	0 0 0	0 0 0	0 ±0.044 ∓0.056	
• LANDING	$\begin{cases} 1.8 \\ -2.0 \end{cases}$	±1.5	4.2 -1.0	±1.5	±2.5	±0.75	

*LIMIT-LOAD FACTOR IS DEFINED AS THE TOTAL EXTERNALLY APPLIED LOAD PER UNIT WEIGHT AT THE c.g.
OF THE CARRIER/PAYLOAD & CARRIES THE SIGN OF THE EXTERNALLY APPLIED LOAD.
**CENTER OF ROTATION IS AT CARRIER/PAYLOAD c.g.

MAXIMUM ALLOWABLE CARRIER/PAYLOAD-IMPOSED LIMIT LOADS

The carrier/payload load factors and maximum allowable carrier/payload-imposed limit loads are related for identical flight and landing conditions. Hence, if the payload weight and its c.g. position are known, the payload attachment point reactions can be estimated and compared with the allowable limit loads at the designated attach points. This in turn will guide the positioning of a payload within the cargo bay, the design of the appropriate payload cradle, and/or the payload design.

Representative maximum axial, vertical, and lateral limit loads, which can be imposed on the longeron and keel bridges of the orbiter during the various flight events, are presented in the facing table. To determine allowable loads for discrete payload attach points, refer to Appendix I of JSC 07700, Volume XIV, Attachment I, Shuttle Orbiter/Cargo Standard Interfaces.

Allowable Axial (+X) Limit Loads: During ascent, critical longeron compression loading occurs (1) at SRB post-staging, where payload inertial loads combine with thrust misalignment loads and (2) at orbiter maximum g. During descent, critical longeron local tension loading occurs at TAEM and at landing where payload inertial loads combine with thermal and maneuvering loads.

The noted axial load capability applies at every point along the longeron bridge. However, during ascent, if X loads are applied to a longeron at two or more attach points, the +X loads are cumulative, and their sum cannot exceed the allowable load for the aftmost employed payload attach point.

Allowable Vertical (+Z) Limit Loads: The tabulated $\pm Z_V$ loads apply only near, or at the center of, each bridge span, are valid for all flight conditions, and are noncumulative; whereas the $-Z_S$ values, which are valid only during landing, apply at any position along the bridge and are cumulative about the main landing gear station at X_0 1180 (Z_S loads are cumulative forward or aft to this station from the ends of the cargo bay).

Allowable Lateral (+Y) Limit Loads: The values in the facing table are valid for all flight and landing conditions and are noncumulative. The $\pm Y$ capability is limited by the axial load capability of the bridge support structure, where an axial load results from the friction force between the payload attach fitting and the bridge.

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Maximum Allowable Carrier / Payload-Imposed Limit Loads

BRIDGE SPAN FRAME TO FRAME	LIMIT LONGERON BRIDGE LOAD PER VEHICLE SIDE, 1000 LB							LIMIT KEEL BRIDGE LOAD, 1000 LB*
	ASCENT, +X		TAEM, -X		VERTICAL LOADS, ALL FLIGHT CONDITIONS		VERTICAL SHEAR LOADS, LANDING	
	SRB POST-STAGING	MAXIMUM g ORBITER	SYM PITCH MANEUVER	UNSYM YAW MANEUVER & LANDING	$+Z_V$	$-Z_V$	$-Z_S$**	ALL FLT & LANDING CONDITIONS, $+Y$
582-636	5.9	17		±7	53	-60	-19.3	9
636-693	5.9	17		±7	58	-85	-57.2	18
693-750	5.9	17		±7	61	-84	-59.5	33
750-807	11.4	33		±15	70	-83	-67.9	46
807-863	11.8	34		±15	64	-76	-73.9	56
863-919	18.7	54		±19	60	-76	-73.9	57
919-979.5	19.0	55	TBD	±27	70	-76	-83.2	70
979.5-1040	19.7	57		±25	74	-78	-90.5	80
1040-1090.33	24.2	70		±33	71	-79	-96.9	46
1090.33-1140.67	36.0	104		±50	100	-109	-105.4	72
1140.67-1191	41.6	120		±76	121	-121	-111.9	68
1191-1249	41.6	120		±76	121	-121	-103.9	56
1249-1301.5	38.1	110		±50	121	-121	-94.0	56

*LIMITED BY CAPABILITY OF KEEL BRIDGE SUPPORT STRUCTURE IN $\pm X$ DIRECTION FOR FRICTION-INDUCED LOADS

**GIVEN Z_S VALUE IS AT FORWARD FRAME OF BRIDGE SPAN (i.e., $-Z_S$ = -19.3 AT FRAME 582)

PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM

A simplified block diagram of the payload deployment and retrieval system (PDRS) shows the major elements, consisting of mechanical, electrical, displays and controls (D&C), and computer software subsystems.

The mechanical arm subsystem consists of a six-degree-of-freedom remote manipulator system (RMS), jettison subsystem, and positioning mechanism for stowing the RMS. The RMS is 50 feet, 3 inches in length and is mounted along the port side of the payload bay, outside of a 15-foot diameter envelope reserved for cargo. A second arm can be installed on the starboard side, if required. The two arms must be operated sequentially, with one holding while the other moves. The RMS can deploy/retrieve payloads up to 65,000 pounds in weight. Retrieval of payloads exceeding 32,000 pounds, however, is considered a contingency operation. The RMS can deploy a 32,000-pound payload in less than nine minutes and retrieve a 25,000-pound payload in less than seven minutes.
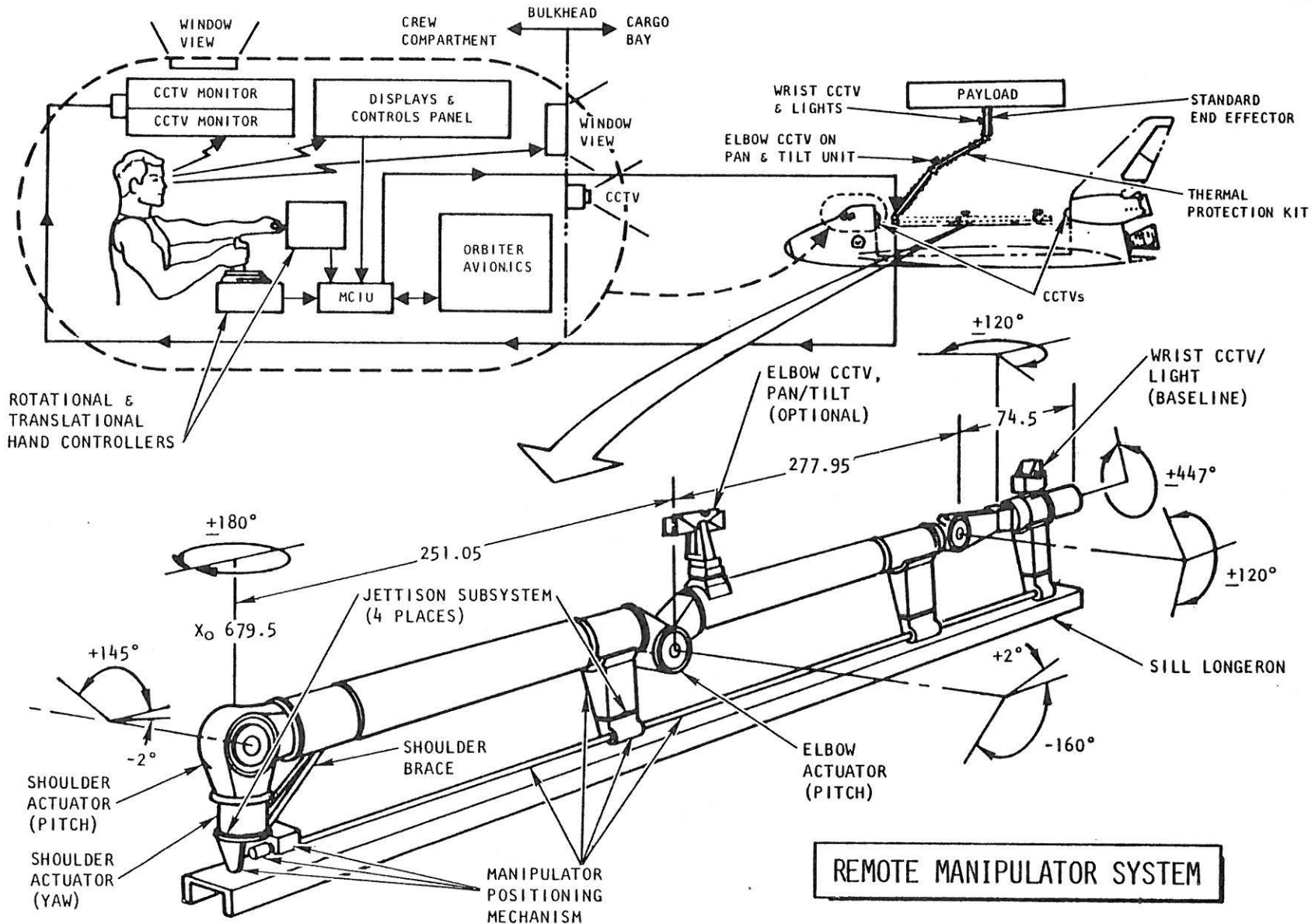
The electrical subsystem consists of the manipulator controller interface unit (MCIU) and arm-mounted electronic assemblies. The MCIU routes signals from the two hand controllers to the orbiter computer which generates arm joint servo demand signals.

The displays and controls subsystem, together with orbiter avionics enables PDRS operation in normal and contingency modes. The hand controllers each produce outputs proportional to deflection in three degrees of freedom and include tactile force feedback to the operator. Among twelve available operating modes are four pre-stored payload handling sequences, an automatic sequence created on orbit by the operator, and four coordinate reference modes. As examples of the latter, the end effector may be commanded to move along a line parallel to its own centerline, a payload reference line, or an orbiter axis. An emergency backup channel provides for single joint control via direct hardwire command and includes payload release. Caution lights and audible alarms warn of anomalies in the MCIU, arm electronics, and computer, and of any joint reaching full travel.

The software subsystem performs, via the orbiter general purpose computer, mathematic and logic functions in support of the PDRS and is nonredundant. Among these are coordinate transformation from the selected reference coordinate system to that of the arm, resolution of end effector rate commands into joint rates, control of pre-stored and operator-stored automatic sequences, and arm deactivation on receipt of erroneous signals or during self-test and control mode transition, or during the direct drive mode.

The RMS is designed and produced for NASA by SPAR Aerospace Limited, Toronto, Ontario, Canada, under contract to the National Research Council of Canada.

Payload Deployment and Retrieval System

WINDOW VIEW

CREW COMPARTMENT

BULKHEAD

CARGO BAY

CCTV MONITOR

CCTV MONITOR

DISPLAYS & CONTROLS PANEL

WINDOW VIEW

CCTV

ORBITER AVIONICS

MCIU

ROTATIONAL & TRANSLATIONAL HAND CONTROLLERS

WRIST CCTV & LIGHTS

PAYLOAD

STANDARD END EFFECTOR

ELBOW CCTV ON PAN & TILT UNIT

THERMAL PROTECTION KIT

CCTVs

+120°

ELBOW CCTV, PAN/TILT (OPTIONAL)

74.5

WRIST CCTV/ LIGHT (BASELINE)

277.95

+447°

251.05

+120°

+180°

JETTISON SUBSYSTEM (4 PLACES)

X_O 679.5

+2°

SILL LONGERON

+145°

-2°

SHOULDER BRACE

ELBOW ACTUATOR (PITCH)

-160°

SHOULDER ACTUATOR (PITCH)

SHOULDER ACTUATOR (YAW)

MANIPULATOR POSITIONING MECHANISM

REMOTE MANIPULATOR SYSTEM

REMOTE MANIPULATOR SYSTEM REACH ENVELOPE

The chart illustrates the remote manipulator system (RMS) reach capability outside the orbiter with the arm fully extended and reach capability within the orbiter cargo bay.

UPPER HEMISPHERE

The maximum reach envelope of one manipulator arm is shown on the chart. Only the hemisphere above the manipulator mounting point is described. The envelope is a true hemispherical surface except in the quadrant where the arm must clear the crew cabin roof. If the manipulator is mounted on the cargo bay port longeron, as illustrated, then this quadrant would be on the starboard side of the orbiter forward of the manipulator mount Y-axis.

The portion of the manipulator maximum reach envelope that can be viewed through the upper windows of the payload handling station is indicated. The field of view shown is from the payload handler reference eye position (X_0 551.75, $-Y_0$ 15.0, Z_0 487.0). Payloads usually will be captured and released by the manipulator arm within this field of view. However, this field of view can be increased over that shown by moving the eye position or by the use of a television camera.
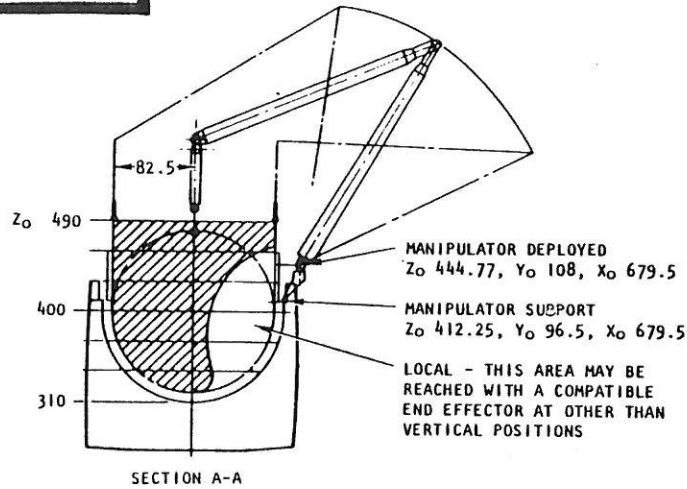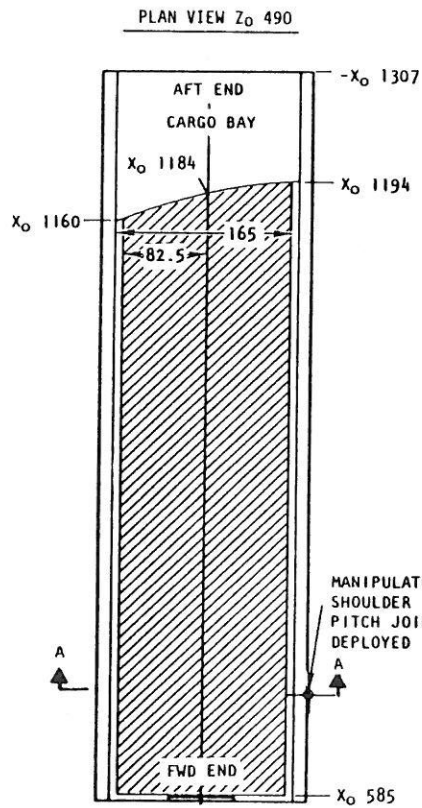
CARGO BAY

The manipulator arms have been designed to sweep the maximum cargo bay volume in which a payload/RMS attach point could be located. For example, the facing diagram shows that the manipulator reach in the Z_0 490 plane covers nearly the full width of the payload envelope and approximately 80 percent of its length. In the Z_0 400 plane, the reach envelope is approximately the same, except that the area within the radius of the manipulator pivot mounting point cannot be reached with the manipulator end effector in a vertical position. The RMS can reach the bottom of the cargo bay volume, Z_0 310, from the front of the bay back to X_0 1184.
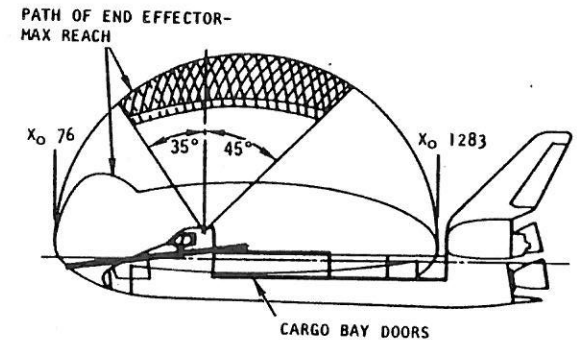
Within the envelope described for the cargo bay, the manipulator and effector are in a vertical position, permitting the attached payload to be moved along the orbiter Z-axis when being withdrawn from or placed in the cargo bay.

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Remote Manipulator System Reach Envelope

CARGO BAY

PLAN VIEW Z_o 490

AFT END
CARGO BAY

$-X_o$ 1307

X_o 1184

X_o 1194

X_o 1160

165

82.5

A

A

MANIPULATOR
SHOULDER
PITCH JOINT
DEPLOYED

FWD END

X_o 585

82.5

Z_o 490

400

310

MANIPULATOR DEPLOYED
Z_o 444.77, Y_o 108, X_o 679.5

MANIPULATOR SUPPORT
Z_o 412.25, Y_o 96.5, X_o 679.5

LOCAL – THIS AREA MAY BE
REACHED WITH A COMPATIBLE
END EFFECTOR AT OTHER THAN
VERTICAL POSITIONS

SECTION A-A

UPPER HEMISPHERE – ARM EXTENDED

Y_o 461

$-Y_o$ 711.5

MANIPULATOR

OPERATOR FIELD-OF-
VIEW THROUGH UPPER
WINDOW (TYP)

Z_o 1048.4

33° 43°

CABIN ROOF
CLEARANCE

RADIATOR

BODY VIEW LOOKING AFT

PATH OF END EFFECTOR-
MAX REACH

X_o 76

35° 45°

X_o 1283

CARGO BAY DOORS
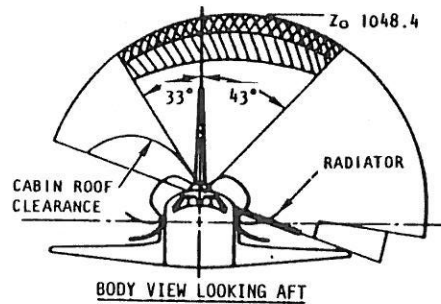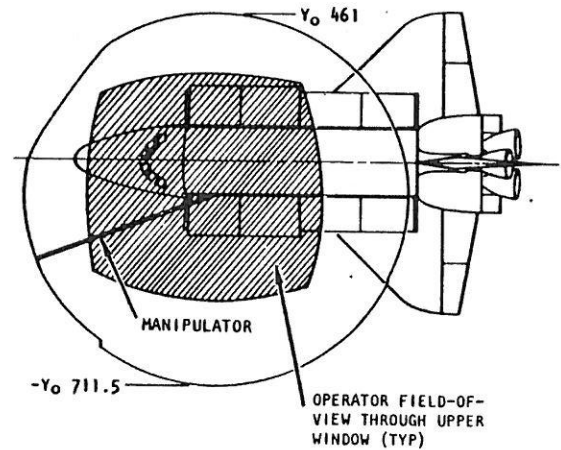
VISUAL OBSERVATION OF PAYLOADS AND PAYLOAD FIELD OF VIEW

The chart illustrates the field of view from the manipulator operator's station (visual observations of payloads) and the field of view of the payload when operated in the orbiter payload bay (payload field of view).

VISUAL OBSERVATION OF PAYLOADS

The payload handling/docking station uses external lighting, direct-vision, video, and alignment aids to ensure successful payload handling and manual operations. There are aft-facing windows and overhead windows for direct viewing of the payload from the handling station on the orbiter flight deck, and television cameras and lights mounted on the manipulator arms and in the cargo bay area for remote viewing. The television cameras provide a magnified view (10:1 zoom) for the following tasks:

1. Remove payloads from cargo bay and deploy

2. Retrieve and stow free-flying payloads

3. Dock/undock payloads to/from orbiter

4. Inspect payloads and orbiter

5. Deploy solar arrays and antennas

6. Position/remove shields and covers

The television cameras also augment or replace direct vision where tasks occur in areas that cannot be seen directly or at distances that render direct vision useless for close-tolerance requirements.

Each manipulator arm has one television camera and one light attached near its end effector. Since only one arm is normally required for payload handling, the second, if installed, can function as a remote viewing and lighting boom during payload operations.

PAYLOAD FIELD OF VIEW

The orbiter has the capability of exposing the entire length and width of the cargo bay. With the payload bay doors and radiators open, the orbiter provides an unobstructed 180-degree lateral field of view, except for localized interference due to the manipulator supports and the door hinges, for any point along the line $Y_O = 0$, $Z_O = 429.5$ between $X_O = 582$ and $X_O = 1302$.

From the mid-point of the payload envelope ($X_O = 942$, $Y_O = 0$, $Z_O = 400$), the clearance angles shown on the facing chart are maintained.   :

Visual Observation of Payloads and Payload Field of View

VISUAL OBSERVATION OF PAYLOADS

UPPER OBSERVATION WINDOWS

FIELDS OF VIEW FROM MANIPULATOR OPERATOR STATION*

BAY-MOUNTED FLOODLIGHTS
6 IN BAY LINER - 1
ON FWD BULKHEAD

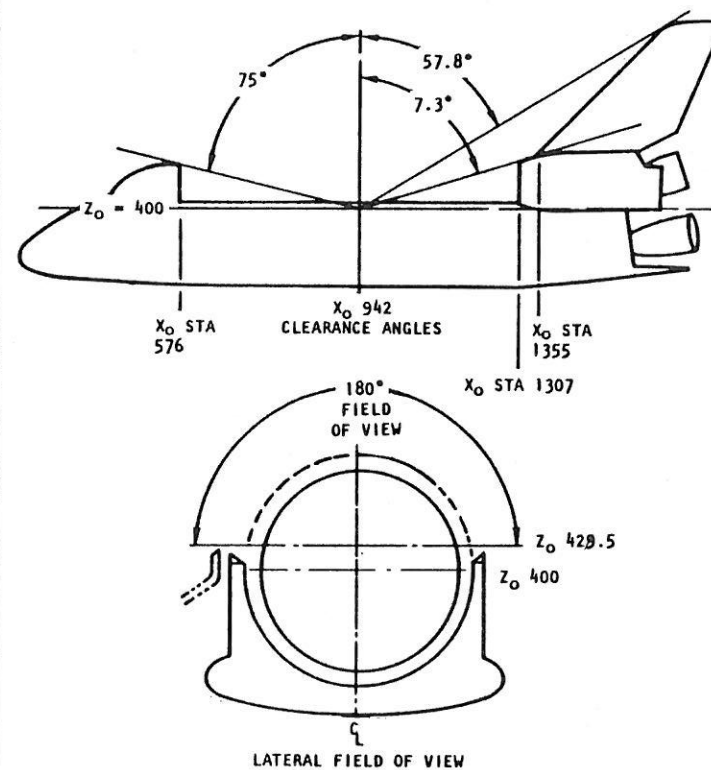35 DEG   45 DEG

30 DEG

AFT OBSERVATION WINDOWS

32 DEG

FLIGHT DECK

OPTIONAL RMS

EYE POSITIONS

UPPER WINDOW X_O 551.75, $-Y_O$ 15.0, Z_O 487.0

AFT WINDOW X_O 566.72, $-Y_O$ 15.0, Z_O 483.63

*FIELD OF VIEW CAN BE INCREASED BY MANIPULATOR OPERATOR HEAD MOVEMENT- DESIGN LOCATION SHOWN

TV CAMERA MOUNTED ON PAN/TILT MECHANISM ON FORWARD & AFT BULKHEADS

RMS TV CAMERA & SPOTLIGHT

PAYLOAD FIELD OF VIEW

75°   57.8°   7.3°

Z_O = 400

X_O STA 576

X_O 942 CLEARANCE ANGLES

X_O STA 1355

X_O STA 1307

180° FIELD OF VIEW

Z_O 429.5

Z_O 400

LATERAL FIELD OF VIEW

Space Systems Group

Rockwell International

30SSV87147A

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PAYLOAD/MID-FUSELAGE INTERFACE VIBRATION AND ACOUSTIC SPECTRA

The Space Shuttle vehicle will be subjected to fluctuating pressure loading on its exterior surfaces caused by engine exhaust-generated acoustic noise during lift-off and aerodynamic noise during atmospheric flight. These fluctuating pressure loads are the principal sources of structural vibration.

The predicted maximum random vibration spectrum for the payload/mid-fuselage interface, due to these external fluctuating pressure loads, is shown. However, actual vibration input to payloads will depend upon the transmission characteristics of the mid-fuselage, the payload support and retention structure, and the specific stiffness, c.g., and weight characteristics of each payload. Consequently, payload random vibration will be caused primarily by the internal acoustic field that is unique to each payload. The predicted maximum payload bay acoustic spectrum developed without a payload in the bay is also shown.

Installation of even a small payload in the cargo bay will produce a large drop in the vibration level. For example, a hundred-pound force at the longeron attach point will reduce the acoustic power spectral density (PSD) level approximately 80 percent. Acoustic effects will be further modified where payloads are enclosed in a protective shroud. A coupled analysis is required for each unique payload to determine the resulting acoustic field.

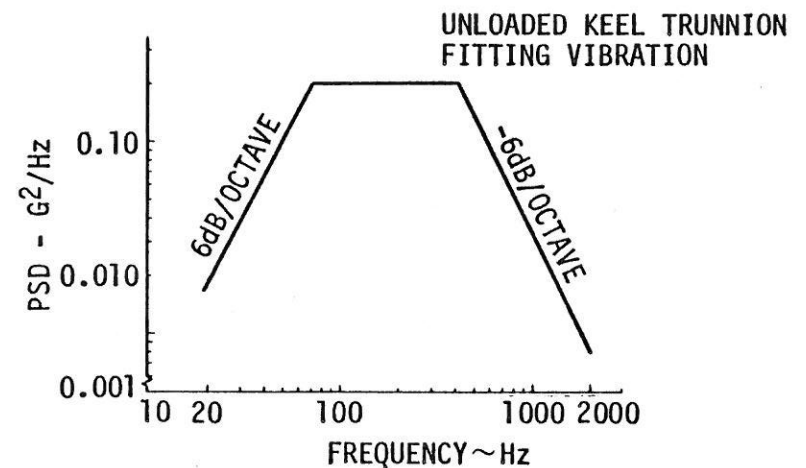# Payload / Mid Fuselage Interface Vibration and Acoustic Spectra

MID FUSELAGE
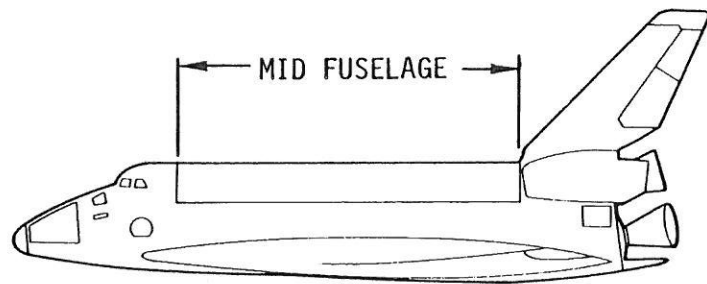
ORBITER PAYLOAD BAY INTERNAL
ACOUSTIC SPECTRUM DESIGN SPEC

OCTAVE BAND CENTER FREQ (Hz)	SOUND PRESSURE LEVEL (dB)
31.5	124.5
63	130.5
125	137.0
250	140.0
500	139.5
1000	134.0
2000	128.0
4000	122.0

MAX SOUND PRESSURE WITHOUT
PAYLOAD ≤145 dB OVERALL

PREDICTED RANDOM VIBRATIONS
AT PAYLOAD/MID FUSELAGE INTERFACE

UNLOADED MAIN LONGERON
TRUNNION FITTING VIBRATION

(0.015)

6dB/OCTAVE   −6dB/OCTAVE

PSD − G^2/Hz

0.01

0.001

0.0001

10 20   100   1000   2000

FREQUENCY ~ Hz

UNLOADED KEEL TRUNNION
FITTING VIBRATION

6dB/OCTAVE   −6dB/OCTAVE

PSD − G^2/Hz

0.10

0.010

0.001

10 20   100   1000 2000

FREQUENCY ~ Hz
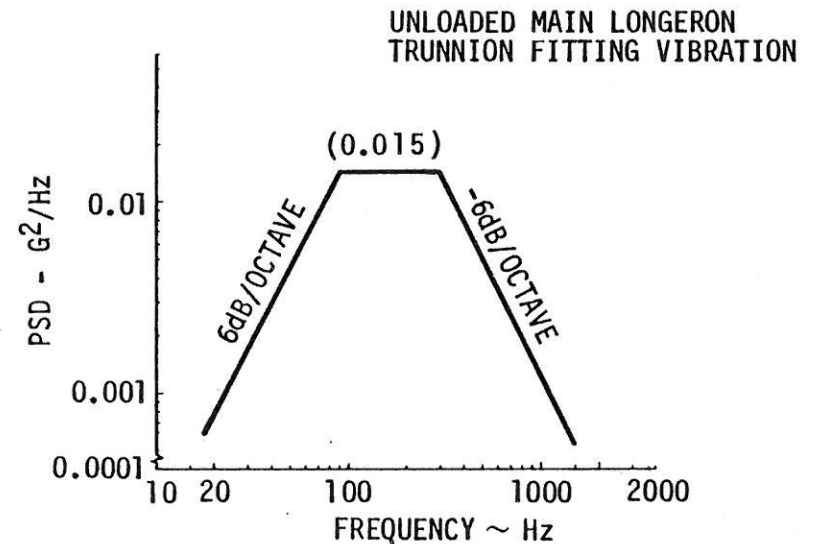
PAYLOAD BAY ENTRY THERMAL ENVIRONMENT

The cargo bay wall temperature history during entry and post-landing is illustrated for three points on the cargo bay wall at about the midpoint along its length. These temperature profiles are representative for the entire payload bay. The resultant thermal environment is influenced by various factors.
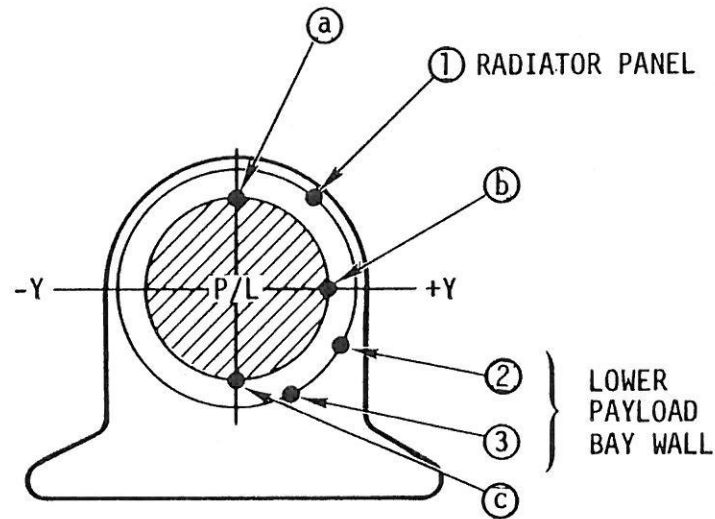
Aerodynamic heating during entry can raise cargo bay wall temperatures to a maximum of 180°F. Payload characteristics also influence wall temperatures as indicated by the temperature profile for an adiabatic payload as compared to a fixed-temperature (70°F) payload. These represent the limiting cases. The adiabatic payload represents the upper temperature case for which there is no heat exchange between the payload and payload bay wall. This limit is approached by a payload, or portion of a payload, that has a surface with high reflectivity or emissivity, that is thermally isolated from other structure, and that has very small thermal capacitance. The fixed temperature (70°F) payload represents the lower boundary, which is an infinite heat sink. This limit is approached by a payload with high thermal capacitance or a component connected to the surface with a high efficiency heat path.

The payload bay wall design is another factor affecting wall temperatures. The radiator panels represent about 45 percent of total wall area. They have relatively large thermal capacitances and thus respond slowly (1) to the influence of the temperature of air entering the bay when vent doors are opened prior to touchdown. Similarly, the temperature decreases slowly during the post-landing period when GSE purge gas is flowing through the bay. The remainder of the payload bay wall, about 55 percent, consists of insulation which has surface or top sheets with very small thermal capacitance. This surface responds rapidly, (2) and (3), to the temperature of the air in the payload bay, as evidenced by the rapid temperature drop when vent doors are opened and cold air enters. As the entering air temperature increases, and under the influence of the higher temperature radiators, the insulation surface temperature makes a rapid recovery and reaches its maximum value, or about 160°F, when the GSE purge is connected. Again, this insulation surface responds rapidly to the 70°F purge gas, and its temperature drops rapidly and approaches the purge gas temperature.

Typical heat fluxes on the fixed temperature (70°F) payload are illustrated for three circumferential locations (a), (b), and (c). These represent the upper range. The fluxes to an adiabatic-type payload are zero by definition.

An accurate determination of payload temperatures requires a coupled thermal analysis that adequately accounts for all payload, carrier, and orbiter heat sinks, sources, thermal resistivities, and capacitances. The use of thermal shields and blankets as well as mass of the payload will have a major effect on equipment temperatures.

Payload Bay Entry Thermal Environment

DATA POINT LOCATIONS (~ X_0 940)

① RADIATOR PANEL

ⓐ
ⓑ

② ⎫
③ ⎬ LOWER PAYLOAD BAY WALL
ⓒ ⎭

IMPRESSED HEAT FLUX

FIXED TEMP (70F) PAYLOAD

VENT DOORS OPEN

TOUCHDOWN

INITIATE GROUND PURGE (T + 15)

400,000' ALT
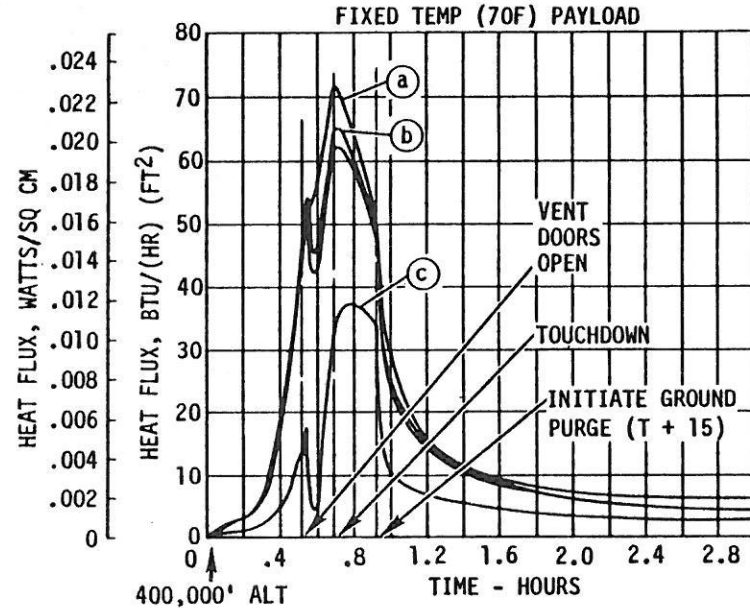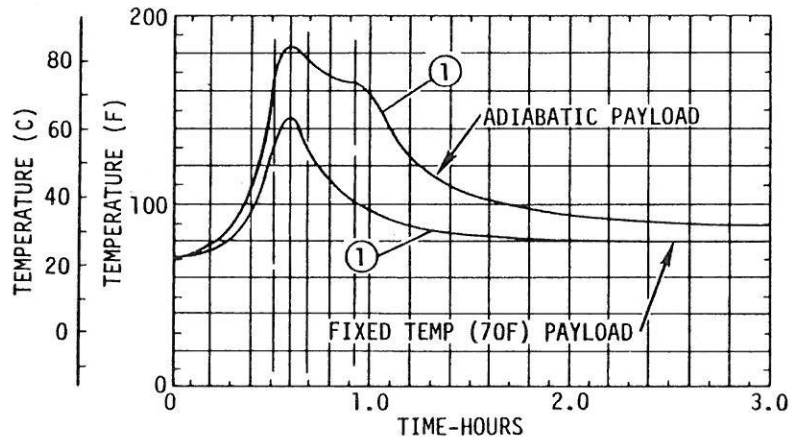
TYPICAL PAYLOAD BAY TEMPERATURE RESPONSE

ADIABATIC PAYLOAD

FIXED TEMP (70F) PAYLOAD

TOUCH-DOWN

ADIABATIC PAYLOAD

FIXED TEMP (70F) PAYLOAD

VENT DOORS OPEN

INITIATE GROUND PURGE (T + 15)

400,000' ALT
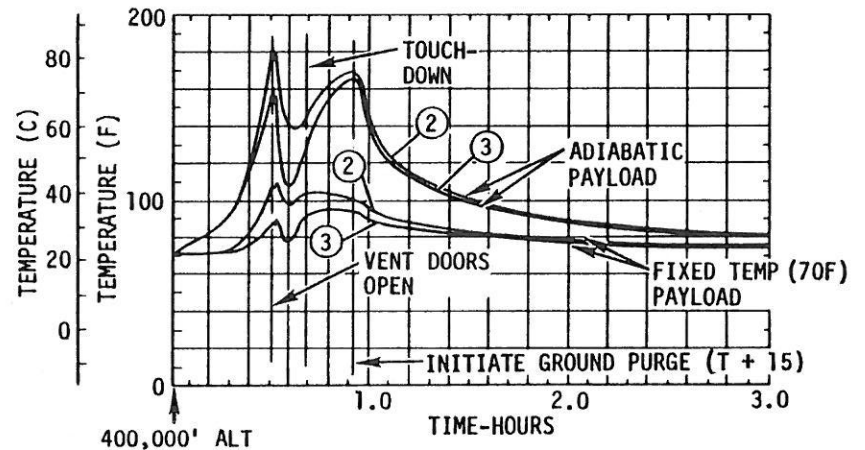
The orbiter three-bus, three-fuel cell (FC) system provides direct current (dc) power for all payloads. The fuel cells are located in the lower outboard section of the mid fuselage between Stations X_O 638 and 693. Electrical power can be supplied to payloads in the payload bay through four different interfaces. The mid-bay and auxiliary power connectors are located below the starboard door longeron at Station X_O 645. Two secondary interfaces are provided at Station X_O 1307 on the cargo bay aft bulkhead. Payload unique equipment in the crew cabin receives power from two additional interfaces. In instances where two payloads share the same orbiter power bus, protected feeder lines with independent switching where required can be provided to each.

The mid-bay power connector is connected to the orbiter main bus through a remote switching subsystem controlled by the crew. The mid-bay power connector can be switched to connect directly with FC No. 3. The dedicated FC mode is employed only when the orbiter electrical power-using subsystems are configured for on-orbit operations, all three FC's are operating, and the cargo bay doors are fully opened.

Maximum power available at the mid-bay connector, in the dedicated fuel cell mode (with a two-panel payload chargeable radiator kit supplementing the baseline six-panel unit), is 7 kW continuous with up to 12 kW peak available for 15 minutes of each three hours of operation. Without the radiator kit available, power is 6 kW maximum continuous with 12 kW peak for 15 minutes every three hours. Each of the two aft bulkhead interfaces can provide up to 1500 watts continuous and 2000 watts peak power. Power from the two aft interfaces, mid-bay power connector, auxiliary power, and aft flight deck can be used simultaneously. Buses must be isolated on the payload side of the interface except for the auxiliary buses. Total power available at the mid-bay power connector, auxiliary power, and aft buses cannot exceed the value specified for the mid-bay connector alone. This power is limited to 1 kW during orbiter power-up mode, i.e., ascent and checkout.

If a FC failure occurs during on-orbit operation, the cargo power will be supplied from the orbiter bus and time shared with orbiter subsystems at a reduced level of 5 kW continuous and 8 kW peak.

When the orbiter subsystems are operating in their ascent or descent configuration, total power available to the cargo is limited to 1350 watts continuous. Up to 350 watts of this may be consumed by payload-unique equipment in the crew cabin. A peak power of 1920 watts can be made available for two minutes during ascent or descent. Payload-unique equipment in the crew cabin can use up to 420 watts of the total peak power. Maximum average power from the four payload bay interfaces is 1000 watts; the two-minute peak is 1500 watts. Orbiter subsystems are in the ascent or descent operational configurations during a portion of prelaunch checkout, throughout the launch, ascent to orbit, entry, and landing phases of a mission, and up to 30 minutes of post-landing time.

A payload may experience a total loss of power if operating on a dedicated FC which fails, or if the FC powering the orbiter bus connected to the payload fails. Power is manually restored to the bus by the orbiter crew within a maximum of 5 minutes.

Use of power from all sources is limited by the heat rejection capability as described elsewhere in this document.

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(Text)

Orbiter / Cargo Power Interface Characteristics

INTERFACE	ORBITER STATION	MISSION PHASE	VOLTAGE RANGE (VOLTS)**	POWER (KW) MAXIMUM CONTINUOUS	PEAK	TIME LIMITATION ON PEAK POWER	ATCS CONFIGURATION	COMMENTS
MID-BAY POWER CONNECTOR	645	GROUND OPERATION (GSE POWER)	27.2-32	1.0	1.5	15 MIN/3 HR	5200 BTU/HR	NORMAL CHECKOUT
			27.2-32	6	TBD	15 MIN/3 HR	W/O RAD KIT	ORBITER POWERED DOWN
			27.2-32	7	12	15 MIN/3 HR	WITH RAD KIT	ORBITER POWERED DOWN
AUXILIARY POWER A & B	645 AFT FLIGHT DECK		26.2-32	0.4	25 AMP	2 SEC*	ANY	0.4 KW MAX AUX A & B COMBINED
			25.7-32	0.2				0.2 KW MAX AUX A & B COMBINED IN AFT FLIGHT DECK
AFT BUS B & C	1307		28-32	1.5	2	15 MIN/3 HR	ANY	(SEE TEXT ON FACING PAGE)
CABIN PAYLOAD BUS	TBD		25.7-32	0.35	0.42	15 MIN/3 HR	ANY	NORMAL CHECKOUT
			25.7-32	0.75	1	15 MIN/3 HR	ANY	ORBITER POWERED DOWN
			115 +5 VAC	690 VA (3φ)	1000 VA	2 MIN/3 HR	ANY	ORBITER POWERED DOWN
MID-BAY POWER CONNECTOR	645	PRELAUNCH/ ASCENT/ DESCENT/ POST-LANDING	27-32	1	1.5	2 MIN/PHASE	ANY	
AUXILIARY POWER A&B	645 AFT FLIGHT DECK		26.1-32	0.4	25 AMP	2 SEC*	ANY	0.4 KW MAX AUX A & B COMBINED
			25.7-32	0.2				0.2 KW MAX AUX A&B COMBINED IN AFT FLIGHT DECK
AFT BUS B & C	1307		25.7-32	1	1.5	2 MIN/PHASE	ANY	
CABIN PAYLOAD BUS	TBD		24.2-32	0.35	0.42	2 MIN/PHASE	ANY	AC POWER NOT AVAILABLE, PRELAUNCH & ASCENT
			115 +5 VAC	0.35	0.42	2 MIN/PHASE	ANY	
MID-BAY POWER CONNECTOR NORMAL	645	ON-ORBIT PAYLOAD OPERATIONS	27.2-32	7	12	15 MIN/3 HR	WITH RAD KIT	DEDICATED FC MODE—ORBITER POWERED DOWN
			27.2-32	6	TBD	15 MIN/3 HR	W/O RAD KIT	DEDICATED FC OR TIME SHARE ORBITER BUS WITH 3 FCs OPERATING—ORBITER POWERED DOWN
BACKUP	645		26.8-32	5	8	15 MIN/3 HR	ANY	TIME SHARE POWER—1 FC FAILED
AUXILIARY POWER A & B	645 AFT FLIGHT DECK		26.1-32	0.4	25 AMP	2 SEC*	ANY	0.4 KW MAX AUX A & B COMBINED
			25.7-32	0.2				0.2 KW MAX AUX A & B COMBINED IN AFT FLIGHT DECK
AFT BUS B & C	1307		24-32	1.5	2	15 MIN/3 HR	ANY	(SEE TEXT ON FACING PAGE)
CABIN PAYLOAD BUS	AFT FLIGHT DECK		24.2-32	0.75	1.0	15 MIN/3 HR	ANY	
			115 +5 VAC	690 VA (3φ)	1000 VA	2 MIN/3 HR	ANY	

*REMOTE POWER CONTROLLERS (RPC) WILL AUTOMATICALLY OPEN CIRCUIT WHEN 25 AMP IS REACHED.   **SUBTRACT ΔV BETWEEN ORBITER & PAYLOAD

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ENERGY/POWER AVAILABLE TO PAYLOAD(S)

The electrical energy potentially available to payloads is shown in the facing chart. As shown, energy availability is a function of the number of power reactant storage and distribution (PRSD) fuel cell tank sets (total energy available), orbiter energy demand, mission duration, and payload power. The nominal or baseline PRSD complement is three tank sets. Assuming the payload(s) uses only the 50 kWh of energy made available through the standard payload user charge, mission duration can reach about 6.8 days. As the payload energy allocation is increased, mission duration declines. If the payload(s) requires the maximum continuous 7 kW power, mission duration would be about 4.4 days. The above durations depend strongly on the daily orbiter energy requirements which could exceed the 300 kWh value for missions requiring, e.g., substantial on-orbit attitude change/control.

If mission energy requirements exceed that provided by the three baseline PRSD tank sets, additional tank sets can be installed with cost and weight penalties. The additional sets are called kits, with kit one being the fourth PRSD tank set. The baseline PRSD system is designed to accommodate kit one. The addition of tank set five and beyond will require new development.

The number of tank sets that can be accommodated beneath the payload bay is limited to five. However, current conceptual design studies suggest that when more than four PRSD tank sets are needed, the additional sets should be placed in the payload bay in clusters of up to four sets each. Penalties for this approach to energy extension are payload bay length as well as ascent and descent payload weight and cost.

Another concept for extending orbiter energy is through the addition of a solar array that can be deployed on-orbit to supplement fuel cell/PRSD delivered energy. Durations with such a system could exceed 30 days provided the mission is flown at high β angles. The concept under study is called Power Extension Package (PEP).

Energy / Power Available to Payload(s)

ENERGY AVAILABLE WITH THREE PRSD TANK SETS*:   2370 kWh
NOMINAL ASCENT, DESCENT & DISPERSION ENERGY REQD: 270 kWh
NOMINAL ON-ORBIT ORBITER ENERGY REQUIRED/DAY**:   300 kWh
ENERGY AVAILABLE FROM EACH ADDITIONAL PRSD KIT: 840 kWh

*AFTER ACCOUNTING FOR 96-HOUR CONTINGENCY RESERVES
**SORTIE TYPE MISSION

BOTTOM OF PAYLOAD BAY
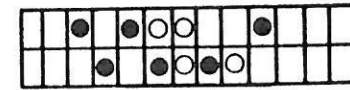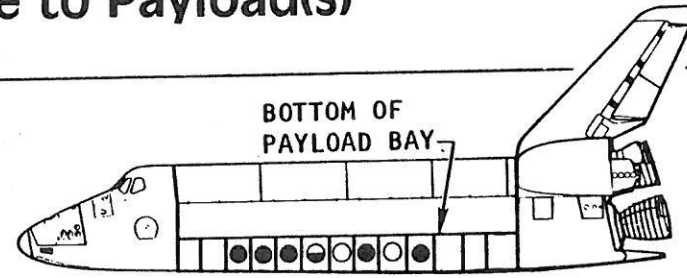
TOP VIEW

● BASELINE PRSD TANKS (3 SETS)
○ ADDITIONAL TANK POSITIONS

KIT WEIGHTS (LB)		
KIT NO.	1	2
LANDED	473	959
EXPENDED	844	844
TOTAL	1317	1803

ENERGY AVAILABLE TO PAYLOAD(S) (kWh)

KITS IN PAYLOAD BAY

KITS BELOW PAYLOAD BAY

PRSD KIT NUMBER

NUMBER OF PRSD TANK SETS

MAXIMUM CONTINUOUS POWER

AVERAGE PAYLOAD(S) POWER

ENERGY PROVIDED TO PAYLOAD WITHOUT ADDITIONAL CHARGE (50 kWh)

MISSION DURATION (DAYS)

PAYLOAD HEAT REJECTION

The active thermal control subsystem (ATCS) will provide a baseline on-orbit heat rejection capability of up to 21,500 Btu/hr (6.3 kW) with the payload bay doors open and coolant temperatures of 45°F (7.2°C) maximum to the payload and 130°F (54.4°C) returned from the payload. The payload bay doors are rotated to a full open position to allow the radiators to provide the maximum heat rejection on orbit. The on-orbit heat rejection capability can be increased to 29,000 Btu/hr (8.5 kW) by the addition of a payload chargeable radiator kit on the aft portion of the payload bay doors prior to launch. Coolant temperatures will be 45°F (7.2°C) to the payload and 104°F (40°C) returned from the payload. A simplified radiator subsystem schematic and payload heat exchanger installation concept is illustrated on the chart.

The ATCS will provide an ascent, on-orbit, entry, and post-landing heat rejection capability of 5200 Btu/hr (1.52 kW) with the payload bay doors closed and coolant temperatures of 45°F (7.2°C) to the payload and 100°F (37.8°C) returned from the payload. When the payload bay doors are closed, the maximum heat rejection provided for payloads is provided by the orbiter flash evaporator above 140,000-ft altitude. During orbiter entry and post landing, orbiter cooling requirements below 100,000-ft altitude are satisfied by an ammonia boiler until GSE cooling is connected.

The orbiter also provides 48 ft^3/min of conditioned air for removal of metabolic sensible and latent heat and CO_2 of four crew members while working in a manned payload module.

Payload Heat Rejection

AMMONIA BOILER

GSE HEAT EXCHANGER

FLASH EVAPORATOR

FIXED RADIATORS

DEPLOYABLE RADIATORS
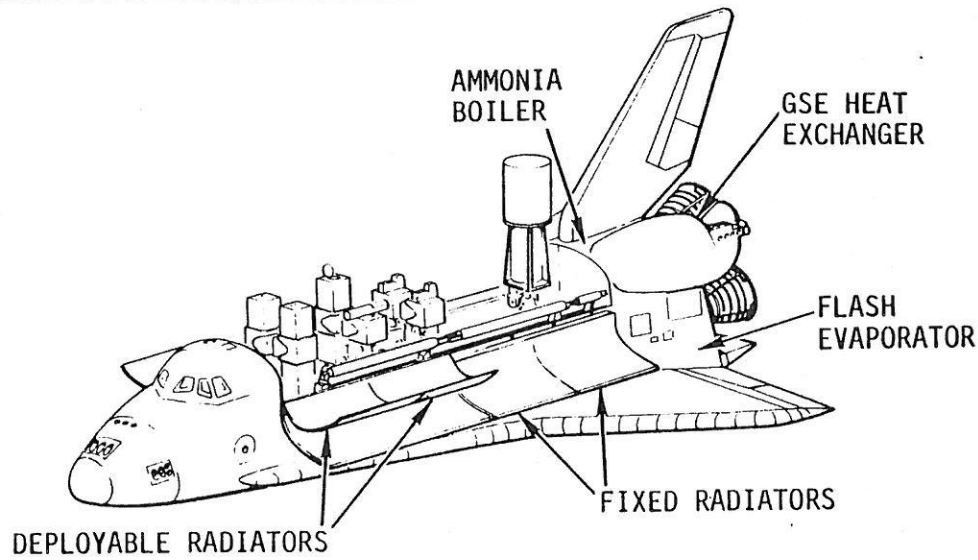
PAYLOAD HEAT REJECTION CAPABILITY

- 5200 BTU/HR DURING ASCENT & ENTRY (DOORS CLOSED)
- 21,500 BTU/HR ON ORBIT BASELINE (DOORS OPEN)
- 29,000 BTU/HR ON ORBIT WITH KITTED RADIATOR (DOORS OPEN)

BASELINE RADIATOR

KITTED PAYLOAD RADIATOR

FLOW CONTROL ASSEMBLY

RETURN

SUPPLY

RADIATOR SUBSYSTEM

PAYLOAD INTERFACE PANEL

PAYLOAD HEAT EXCHANGER

O_2 SUPPLY

N_2 SUPPLY

PRIMARY SUPPLY

PRIMARY RETURN

COOLANT

SECONDARY SUPPLY

SECONDARY RETURN

PAYLOAD INTERFACE PANEL
X_o 636
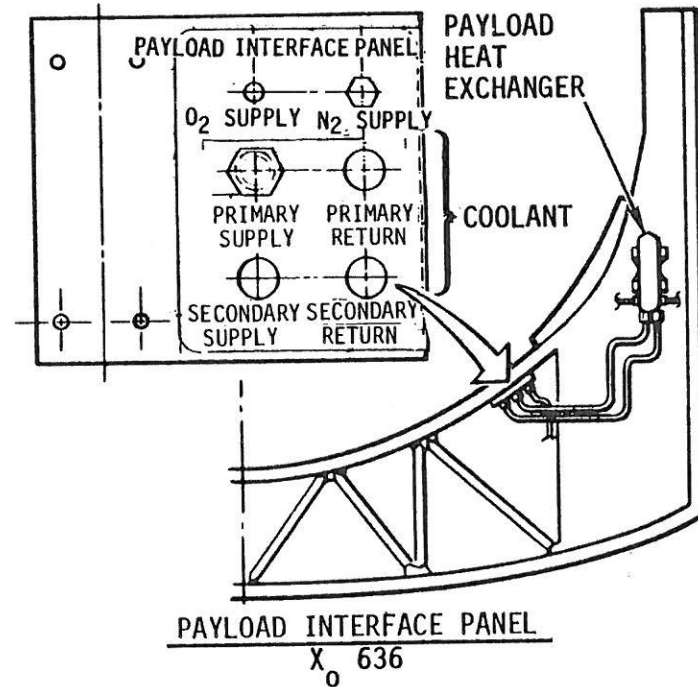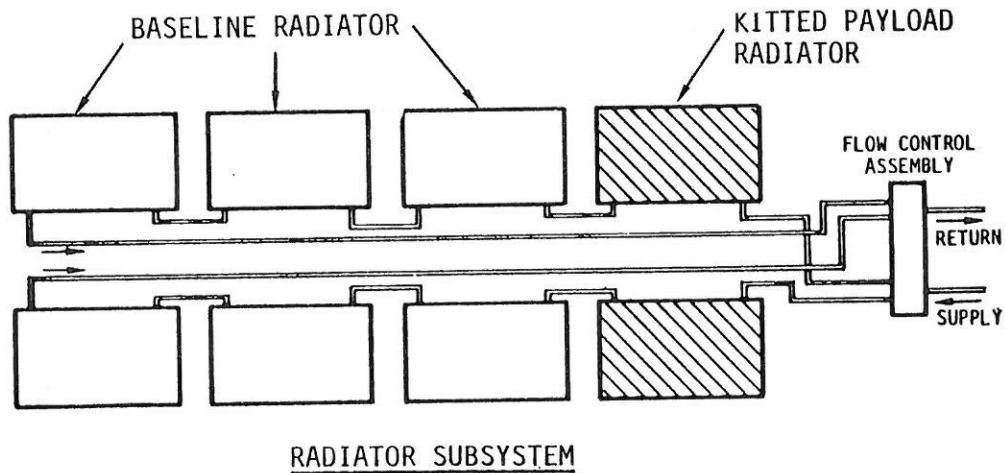
MID FUSELAGE/PAYLOAD BAY PURGE SUBSYSTEM

The basic payload bay purge system is shown schematically on the adjacent figure. The purge gas enters the system via the T-O umbilical disconnects, is ducted through the aft fuselage and the lower mid fuselage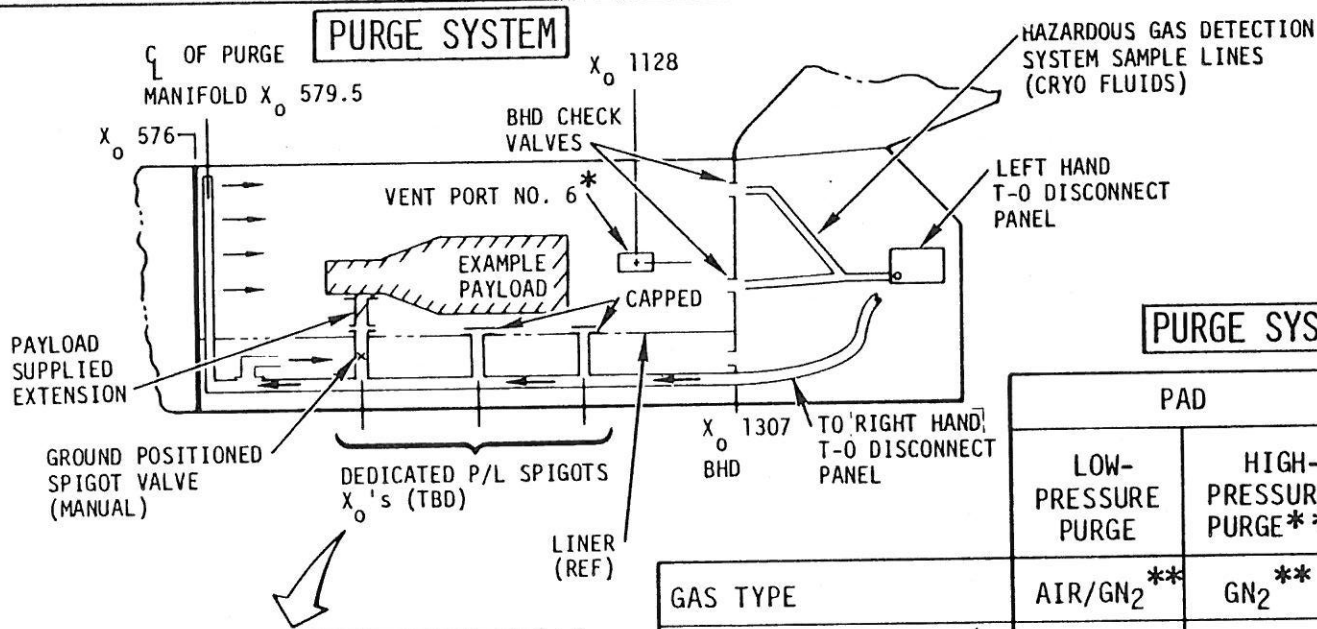, and enters the payload bay via the purge manifold located on the forward bulkhead, X_O 576. The gas will be nominally class 100, guaranteed class 5000 (HEPA) filtered air with 15 ppm or less hydrocarbons based upon a methane equivalent, followed by GN_2 just prior to launch. Three spigots are provided to supply additional conditioned purge gas to meet unique payload thermal conditioning requirements. The purge gas exits the payload bay via check valves on the X_O 1307 bulkhead for flows up to 180 pounds per minute. For greater flow rates, the excess exits via vent port No. 6 (left and right side). Distribution of the purge gas from the spigots to the required areas on/in a payload is by means of payload-supplied, payload weight-chargeable ducting attached to any one, all, or any combination of the three spigots.

The payload bay purge system supplies conditioned air to the payload bay during prelaunch operations until 80 minutes prior to orbiter cryogenics loading. Continuous purging will be supplied during closed payload bay operations except during switch-over between mobile and facility GSE at the OPF, VAB, PAD, and during towing from the OPF until orbiter mating operations are complete in the VAB. Starting 80 minutes prior to orbiter cryogenics loading, GN_2 will be supplied to provide an inert payload bay atmosphere through lift-off. Two supply pressure systems are provided just upstream of the ground portion of the umbilical disconnect:

1. The 2.5-psig system supplies either air or GN_2 to the payload bay during all operations not involving cryogenic payloads.

2. The high pressure system (11 psig or 5.3 psig) supplies only GN_2 and is used for cryogenic payloads.

Within 15 minutes following touchdown, the ground support equipment supplies 2.0 psig conditioned air to the payload bay through the purge system.

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Mid Fuselage / Payload Bay Purge Subsystem

PURGE SYSTEM

C_L OF PURGE MANIFOLD X_0 579.5

X_0 576

X_0 1128

BHD CHECK VALVES

VENT PORT NO. 6 *

EXAMPLE PAYLOAD

CAPPED

HAZARDOUS GAS DETECTION SYSTEM SAMPLE LINES (CRYO FLUIDS)

LEFT HAND T-0 DISCONNECT PANEL

PAYLOAD SUPPLIED EXTENSION

GROUND POSITIONED SPIGOT VALVE (MANUAL)

DEDICATED P/L SPIGOTS X_0's (TBD)

LINER (REF)

X_0 1307 BHD

TO RIGHT HAND T-0 DISCONNECT PANEL

- 3 INLET SPIGOTS PROVIDED
- MAX FLOW 100 LB/MIN ANY SINGLE INLET SPIGOT (150 TOTAL)
- NOMINAL: 50 LB/MIN EACH INLET
- ALL INLET SPIGOTS NORMALLY CAPPED OFF UNLESS REQUIRED BY PAYLOAD

* SIDE VENT (NO. 6) OPENS TO ACCOMMODATE FLOW GREATER THAN 180 LB/MIN (i.e., WHEN SPIGOTS UNCAPPED). THIS CORRESPONDS TO A FLOW RATE OF > 144 LB/MIN TO THE PAYLOAD BAY

PURGE SYSTEM CHARACTERISTICS

	PAD		POST-LANDING & RUNWAY TO OPF	OPF, VAB OPF TO VAB VAB TO PAD
	LOW-PRESSURE PURGE	HIGH-PRESSURE PURGE ***		
GAS TYPE	AIR/GN$_2$ **	GN$_2$ **	AIR	AIR
TEMP RANGE ±2°F	45-100	45-100	45-100	65-85
HUMIDITY (GRAINS/LB) AIR GN$_2$	0-29 0-1	— 0-1	0-34 —	0-34 —
SPIGOTS CLOSED FLOW RATE (LBM/MIN)	110	364	115	115
SPIGOTS OPEN FLOW RATE (LBM/MIN) MANIFOLD SPIGOTS	110 (MIN) 150 (MAX)	215 (MIN) 150 (MAX)	101 (MIN) 136 (MAX)	101 (MIN) 136 (MAX)

*** PRESSURE WITH SPIGOTS OPEN: 5.3 PSIG
PRESSURE WITH SPIGOTS CLOSED: 11 PSIG

** INITIATE GN$_2$ PURGE 80 MIN PRIOR TO CRYO TANKING TO PROVIDE INERT PAYLOAD BAY ATMOSPHERE

MID FUSELAGE/PAYLOAD BAY VENT SUBSYSTEM

The orbiter active vent system is designed to minimize structural delta pressures during ascent depressurization and descent pressurization and to provide on-orbit molecular venting. Principal characteristics of the active vent system are (1) automatic in-flight operation based on mission elapsed time, mission event, altitude, and vehicle velocity; (2) intermediate door position required for ground purge only; and (3) no in-flight manual operation required from crew, except deorbit preparations.

During ascent, the active vents on the orbiter will be opened, permitting the orbiter to vent to ambient while maintaining a small positive pressure to prevent contamination of payloads, payload bay interior, orbiter windows, optical surfaces, or orbiter TPS surfaces. During reentry and descent, the active vents will remain closed until the orbiter velocity is reduced to 2400 fps (between 94,000 and 70,000 feet altitude). At this time, the vents will open, and the cargo bay will be repressurized with filtered atmospheric air.

129SSV87154
(Text)

Mid Fuselage / Payload Bay Vent Subsystem

FULL OPEN

ACCEPTABLE
VENT
OPENING
REGIME

AREA-TO-VOLUME RATIO (A/V)

TIME FROM LAUNCH (SEC)

q = 145 PSF

94,000 FT

q = 330 PSF

q = 375 PSF (max z)

VENTS OPEN
ABOVE 70,000 FT

73,000 FT

VENT CUE TO OPEN 2400
FPS GROUND RELATIVE
POSITION TOLERANCE
= $\pm$ 100 FPS AT q = 330
  $\pm$ 200 FPS AT q = 145

PRESSURE ALTITUDE (1000 FT)

ENTRY VELOCITY (FPS)

- ASCENT: VENTS CLOSED T-4 HOURS → T + 10 SEC FOR
  ACOUSTICS SUPPRESSION
- VENT DOORS OPERATE AGAINST 0.25 PSID (MAX) DURING ASCENT
- VENT DOORS OPERATE AGAINST 0.4 PSID (MAX) DURING DESCENT

ALL SHOWN VENTS ARE ON BOTH SIDES OF ORBITER

DOOR ACTUATION	NO.	COMPARTMENT
COUPLED	3	
	4	PAYLOAD BAY
	5	LOWER MID-FUSELAGE
SEPARATE	6	
	7	WING

DRIVE SHAFT

ACTUATOR

P/L BAY VENT FILTER

EMI SHIELD

TYP MID FUSELAGE VENT PORT
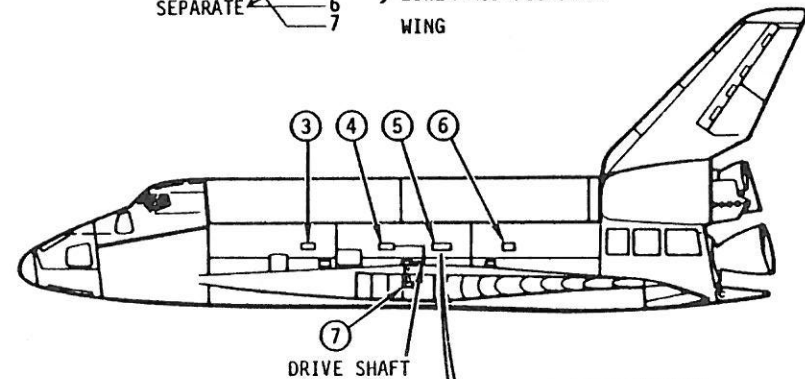
VENT NO.	COMPARTMENT VENTED
3 4 5 6	MID FUSELAGE
7	WING (DEDICATED VENT DUCT)
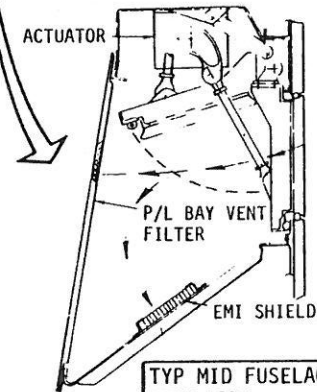
FILTER: DOUBLE DUTCH
TWILL WEAVE
40 MICRON GLASS
BEAD RATING

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129SSV87154

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ORBITER AVIONICS SERVICES TO PAYLOADS

The Space Shuttle orbiter is equipped to provide a variety of avionic services to both attached and detached payloads. Scientific data from attached payload sensors and experiments can be transmitted to STDN or SCF ground stations by the orbiter S-band communication subsystem, or relayed through a tracking and data relay satellite (TDRS) on S- or Ku-band. The orbiter can also record and store scientific information sent over hard line from attached payloads, or relay text and graphics data sent via TDRS to an attached payload.

Engineering health and status data from both attached and free-flying payloads can be monitored and recorded on-board, sent to STDN or SCF ground stations (S-band), or relayed through the TDRS. Engineering data from the ground can also be transferred to attached payloads.

The orbiter audio subsystem is designed to permit three-way conversations between the orbiter crew, the ground, and personnel aboard attached payloads. Audio can constitute part of the digital data stream to and from the orbiter.

Video signals from attached payloads can be monitored on-board the orbiter or sent to the ground by either FM S-band or Ku-band links except for the space ground link subsystem (SGLS) service.

Ground-initiated commands for either attached or detached payloads can be transferred through the orbiter communication system. Commands to both attached and detached payloads can also be initiated by the orbiter crew.

The orbiter can initialize a payload GN&C system or update its state vector, using on-board data or information transmitted from the ground. GN&C data from an attached payload may be monitored and recorded by the orbiter crew.

Up to five safety-critical status parameters can be hardwired from an attached payload to the orbiter. The orbiter crew monitors these parameters and can take the necessary timely remedial actions. These parameters, plus others, are also monitored and can be recorded as part of the orbiter performance monitoring function (PMF). Payload C&W data can be transmitted to the ground through the orbiter.

The orbiter also provides master timing signals to attached payloads.

Rendezvous with detached payloads is accomplished using the orbiter Ku-band rendezvous radar.

Orbiter Avionics Services to Payloads

TRACKING & DATA RELAY SATELLITE

SPACE SHUTTLE ORBITER

DETACHED PAYLOAD

GROUND STATION
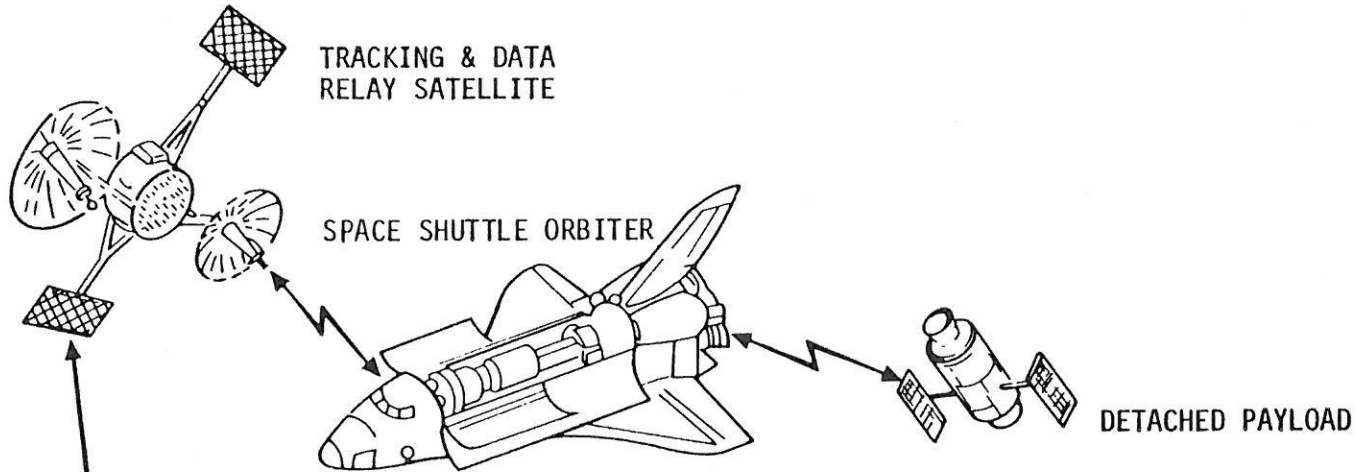
FUNCTION	DIRECT OR VIA TDRS		HARDLINE		RF LINK	
	PAYLOAD TO GROUND VIA ORBITER	GROUND TO PAYLOAD VIA ORBITER	ORBITER TO ATTACHED PAYLOAD	ATTACHED PAYLOAD TO ORBITER	ORBITER TO DETACHED PAYLOAD	DETACHED PAYLOAD TO ORBITER
SCI DATA	X	X		X		
ENGRG DATA	X	X	X	X	X	X
AUDIO	X	X	X	X		
TELEVISION	X		X	X		
COMMAND		X	X		X	
GN&C		X	X	X	X	
C&W	X			X		X
MASTER TIMING			X			
RENDEZVOUS					X	X
UPLINK DATA		X	X			

The chart shows orbiter communication, tracking, and data management interfaces with attached and detached NASA payloads. The orbiter rendezvous radar tracking range is 10 nmi with passive payloads and 300 nmi with cooperative payloads. The communication and tracking (C&T) subsystem in the orbiter incorporates RF communication links with detached payloads and hardwire provisions that support orbiter-to-attached-payload communications. The RF links also permit the transfer of payload telemetry, uplink data commands, and voice signals to and from the space ground networks. Orbiter transmitters, receivers, and signal structure are compatible with the established characteristics of NASA's space tracking and data network (STDN), tracking and data relay satellite (TDRS), and the Air Force's space-ground link subsystem (SGLS). The orbiter is equipped to communicate with ground stations, TDR satellites, and detached payloads at S-band frequencies, and with the TDRS at S- and Ku-band frequencies.
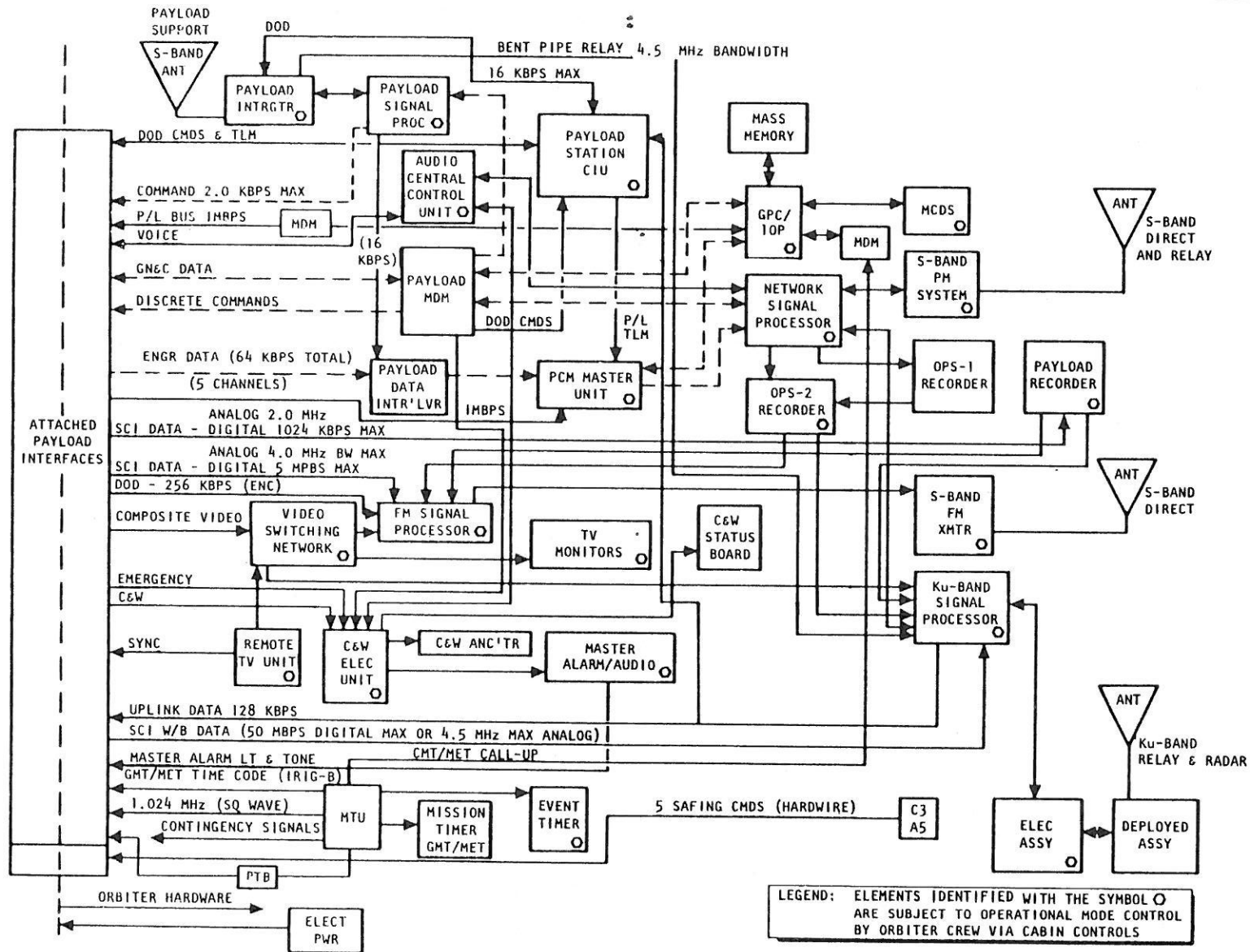
For NASA payloads, the command data rate to all payloads via the orbiter is 2000, 1000, 500, 250, 125, 125/2, 125/4, 125/8, or 125/16 bps on a 16-kHz subcarrier, on one of 808 STDN channels, or one of 23 Deep Space Network (DSN) channels. The telemetry data rate to the orbiter from detached payloads is 16, 8, 4, 2, or 1 kbps maximum on 1.024 MHz subcarrier. The C&T subsystem accepts PM data from attached payloads. Wideband data will be transferred from attached payloads to an orbiter-supplied tape recorder, or wideband data or television pictures will be transferred to the C&T subsystem's S-band FM transmitter for direct transmission to STDN ground stations or to the Ku-band subsystem for transmission to ground stations via the TDRS. The voice-distribution system provides orbiter-payload and ground-orbiter-payload duplex voice service, including conference capabilities in the attached mode. There are no provisions for voice communication between the orbiter and detached payloads.

For DOD payloads, commands to attached or detached payloads can be forwarded from the ground via the orbiter or generated on board. Telemetry from detached payloads is received at the payload station via the payload interrogator over any one of 20 S-band selectable channels. Data rate is constrained by payload interrogator bandwidth. The payload data, when received by the orbiter, are processed in the communication interface unit (CIU) and interleaved with orbiter operational telemetry for transmission to ground. The capability is also provided to receive DOD encrypted data from an attached payload at a rate of 256 kbps for direct transmission via the FM S-band link when in clear line of sight to ground stations.

The orbiter provides the capability to transmit guidance, navigation, and control (GN&C) data to the payload and receives attitude reference data from a payload-mounted sensor to improve the payload pointing accuracy. The orbiter computer will provide state vector data words to the payload. The data words will include the orbiter position vector, velocity vector, MET, GMT, and attitude information.

The data processing and software subsystem furnishes the on-board digital computation required to support the payload management (PLM) and payload-handling (PLH) functions. The PLM function is used during pre-launch and orbital phases for payload checkout and status monitoring (passive). The PLH function controls the operation of the manipulator arm(s) and interfaces with the GN&C computer to ensure vehicle stability. Flight-deck stations for payload management and handling have provisions for data displays, CRT's, and keyboards for monitoring and controlling payload operations.

10SSV87156
(Text)

Avionics Provisions for Payloads
Functional Diagram

PAYLOAD SUPPORT

S-BAND ANT

DOD

BENT PIPE RELAY 4.5 MHz BANDWIDTH

PAYLOAD INTRGTR

16 KBPS MAX

PAYLOAD SIGNAL PROC

PAYLOAD STATION CIU

MASS MEMORY

DOD CMDS & TLM

COMMAND 2.0 KBPS MAX

AUDIO CENTRAL CONTROL UNIT

GPC/ IOP

MCDS

P/L BUS IMBPS

MDM

MDM

VOICE

(16 KBPS)

S-BAND PM SYSTEM

ANT S-BAND DIRECT AND RELAY

GN&C DATA

PAYLOAD MDM

NETWORK SIGNAL PROCESSOR

DISCRETE COMMANDS

DOD CMDS

P/L TLM

ENGR DATA (64 KBPS TOTAL)

(5 CHANNELS)

PAYLOAD DATA INTR'LVR

PCM MASTER UNIT

OPS-1 RECORDER

PAYLOAD RECORDER

ANALOG 2.0 MHz

IMBPS

OPS-2 RECORDER

SCI DATA - DIGITAL 1024 KBPS MAX

ANALOG 4.0 MHz BW MAX

SCI DATA - DIGITAL 5 MPBS MAX

DOD - 256 KBPS (ENC)

COMPOSITE VIDEO

VIDEO SWITCHING NETWORK

FM SIGNAL PROCESSOR

TV MONITORS

C&W STATUS BOARD

S-BAND FM XMTR

ANT S-BAND DIRECT

EMERGENCY

C&W

Ku-BAND SIGNAL PROCESSOR

SYNC

REMOTE TV UNIT

C&W ELEC UNIT

C&W ANC'TR

MASTER ALARM/AUDIO

UPLINK DATA 128 KBPS

SCI W/B DATA (50 MBPS DIGITAL MAX OR 4.5 MHz MAX ANALOG)

ANT Ku-BAND RELAY & RADAR

MASTER ALARM LT & TONE

CMT/MET CALL-UP

GMT/MET TIME CODE (IRIG-B)

1.024 MHz (SQ WAVE)

MTU

MISSION TIMER GMT/MET

EVENT TIMER

5 SAFING CMDS (HARDWIRE)

C3 A5

CONTINGENCY SIGNALS

ELEC ASSY

DEPLOYED ASSY

ATTACHED PAYLOAD INTERFACES

PTB

ORBITER HARDWARE

ELECT PWR

LEGEND: ELEMENTS IDENTIFIED WITH THE SYMBOL ○ ARE SUBJECT TO OPERATIONAL MODE CONTROL BY ORBITER CREW VIA CABIN CONTROLS

Space Systems Group

Rockwell International

129SSV87156

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ORBITER/PAYLOAD CAUTION AND WARNING AND
PERFORMANCE MONITORING INTERFACE

The baseline caution and warning (C&W) and performance monitoring interface between a payload and the orbiter is described in the chart on the facing page. Up to five warning parameters are hardwired from sensors on-board the attached payloads to the orbiter C&W electronics. Movement of any of these parameters outside the limits pre-set in the C&W electronics will activate the master alarm tone, master alarm lights (4), and the payload warning annunciator on the C&W annunciator matrix. Up to 50 caution parameters (25 each, analog and digital) are hardwired to a multiplexer/demultiplexer (MDM) for limit sensing by a general purpose computer (GPC). Up to five hardwire and up to 36 computer-controlled safing commands are provided to safe payload components.

Detection by the GPC of the violation of a pre-set limit for any of the 50 parameters will result in the issuance of a discrete output to the orbiter C&W electronics. Detection of the presence of the GPC-issued discrete signal will activate the master alarm tone, master alarm lights (4), and the payload caution annunciator on the C&W annunciator matrix. Data on these same parameters form part of the digital data stream from the payload to the orbiter performance monitoring function (PMF). Detected out-of-tolerance conditions will cause the backup caution and warning annunciator to illuminate. Potentially hazardous conditions in the attached payload should be evident from both the hardwired/software C&W parameters and the backup from the PMF; i.e., both the dedicated C&W annunciator and the backup annunciator will illuminate. Health and status information from additional payload sensors can also form part of the telemetry data stream to the orbiter PMF. Unfavorable conditions appearing in any of this housekeeping data are signaled by an illumination of the system management (SM) indicator. The C&W tones, from the audio central control unit (ACCU), and the master alarm visual annunciator, via a switch closure, can be made available to an attached, manned payload. The PMF can also be employed to monitor the status of detached payloads.

The capability for in-flight reset of a trip threshold for any hardwired C&W parameter is provided at the mission specialist station (MSS) using the C&W status board. A similar capability for the software backup is provided at the multifunctional cathode ray tube display system (MCDS). Payload C&W shall be limited to out-of-tolerance measurements which may, if uncorrected, lead to the loss of the orbiter vehicle and/or crew. Those payload parameters that cannot have an impact upon the orbiter or crew, even though the effect may result in compromising the payload, are not presently candidates for the orbiter C&W system.

Orbiter / Payload Caution and Warning and Performance Monitoring Interface
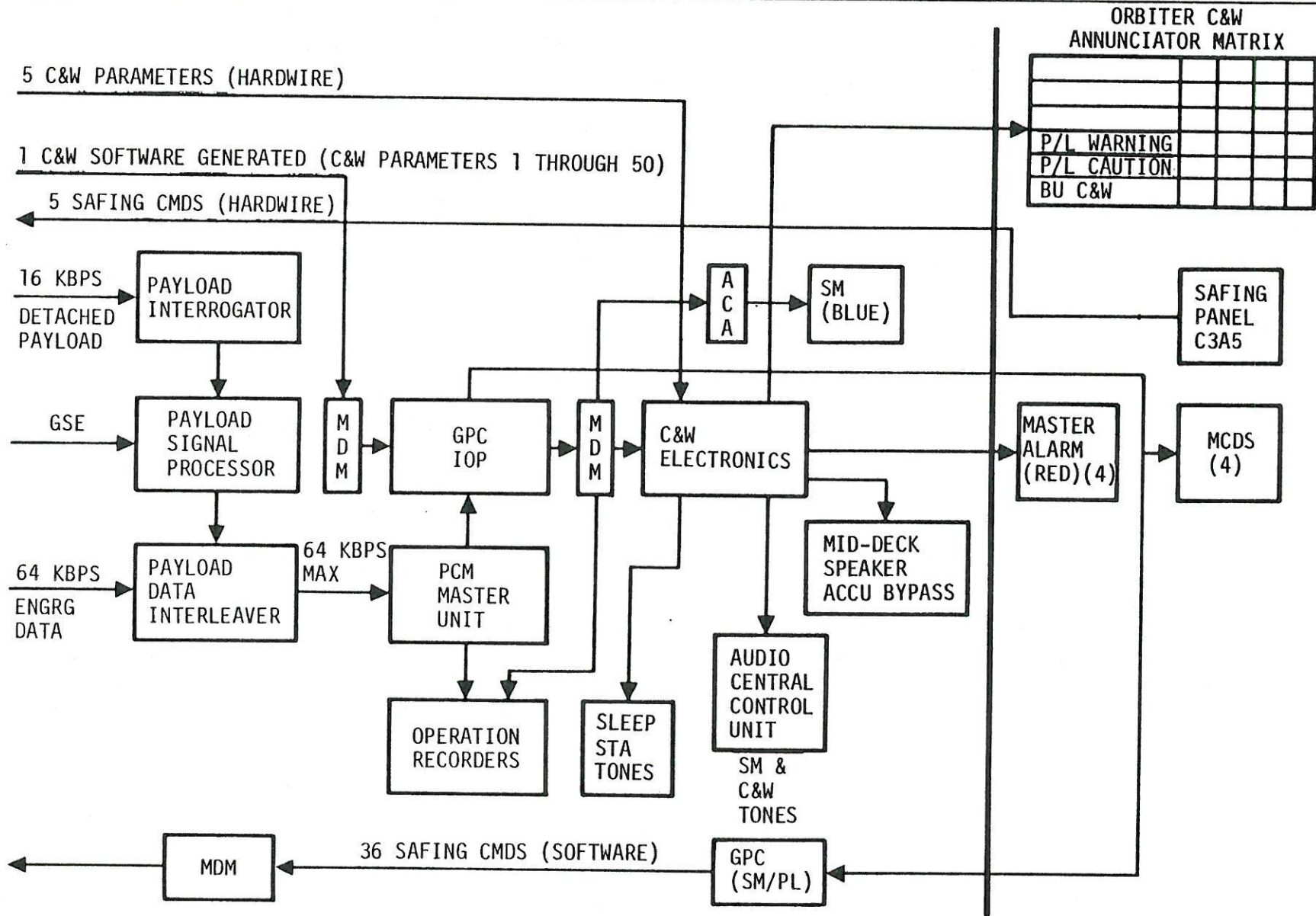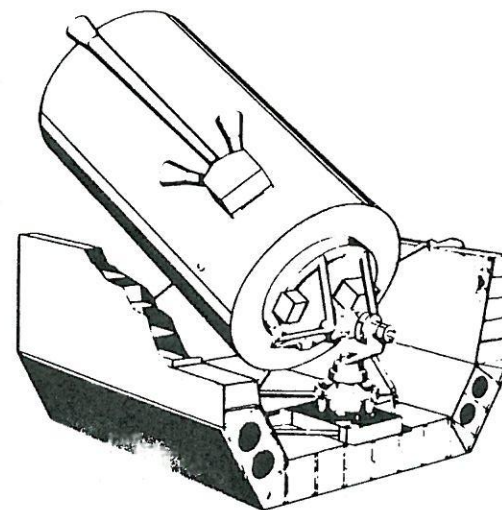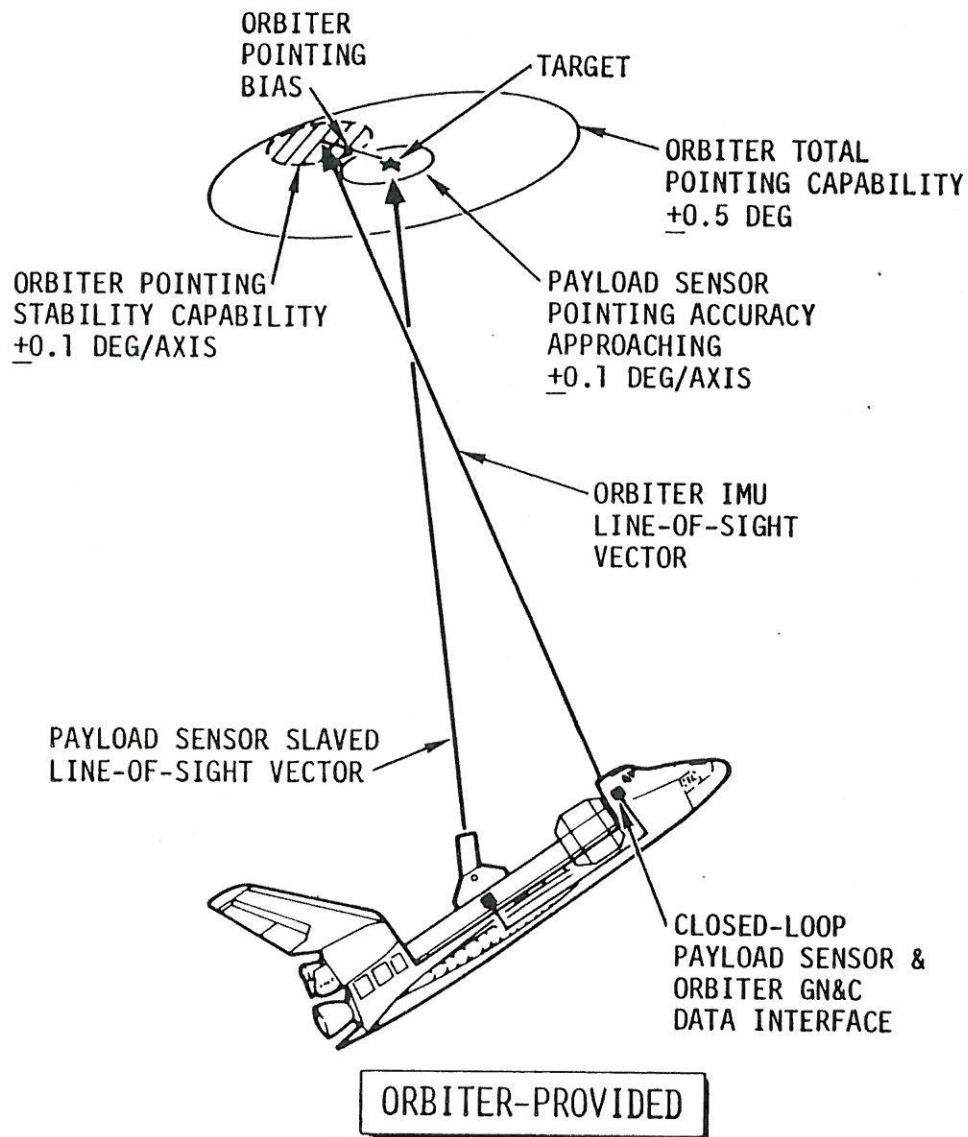
ORBITER POINTING AND STABILIZATION OF PAYLOADS

The orbiter guidance, navigation, and control (GN&C) subsystem is capable of achieving any desired vehicle attitude and initiating a pointing vector, defined in its sensor-fixed axis system, to any ground or celestial object, within an accuracy of ±0.5 degree. The procedure typically followed begins with acquisition of a pair of target stars by the orbiter star trackers, thus establishing vehicle attitude with respect to the celestial sphere. This attitude vector can then be maintained by the orbiter inertial measuring unit (IMU) and the star trackers disabled. The vehicle can now be reoriented, if desired, using its reaction control system (RCS) jets; and the payload pointing vector can be initiated, using as reference the previously established IMU pointing vector.

The IMU drift error requires it be periodically realigned, using the star trackers. The ±0.5 degree pointing accuracy can be maintained for about an hour between updates, when viewing celestial targets or maintaining local-vertical pointing, and this can be extended by inflight IMU calibration. When viewing fixed ground targets, the IMU must be updated about every half-hour. In the special case where the payload target allows continuous operation of the orbiter star tracker, IMU drift error is essentially eliminated and pointing accuracy can be maintained within ±0.44 degree for an indefinite period.

Pointing accuracy for the case of an open loop between the payload sensor-fixed axis system and the orbiter pointing system is not exact because significant misalignment due to structural deformation can result in an error exceeding two degrees between sensors in the two systems. However, when the vehicle pointing system and sufficiently accurate payload sensors are operated in a closed loop, as indicated on the chart, payload pointing accuracy approaching that of the orbiter is possible. The stability (deadband) capability of the RCS to maintain attitude with respect to the IMU pointing vector is ±0.1 degree/axis. Whether open or closed loop, the vernier RCS can maintain a stability rate as low as ±0.01 degree/second/axis. Payloads requiring more stringent pointing and stability accuracies must provide their own control system. Orbiter GN&C subsystem interfaces are provided to accommodate these types of payloads. An example of such a payload is included on the chart and further information on this type of auxiliary pointing system is available in the Missions and Capability section discussion of Spacelab.

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Orbiter Pointing and Stabilization of Payloads

ORBITER
POINTING
BIAS

TARGET

ORBITER TOTAL
POINTING CAPABILITY
+0.5 DEG

ORBITER POINTING
STABILITY CAPABILITY
+0.1 DEG/AXIS

PAYLOAD SENSOR
POINTING ACCURACY
APPROACHING
+0.1 DEG/AXIS

ORBITER IMU
LINE-OF-SIGHT
VECTOR

PAYLOAD SENSOR SLAVED
LINE-OF-SIGHT VECTOR

CLOSED-LOOP
PAYLOAD SENSOR &
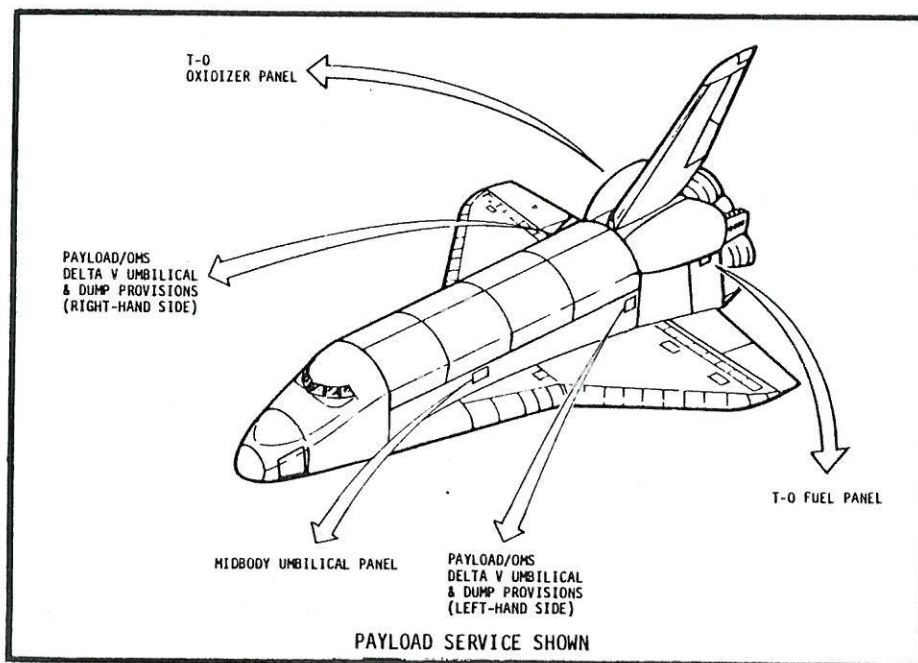ORBITER GN&C
DATA INTERFACE

TYPICAL CONCEPT FOR
THREE-AXIS EXPERIMENT
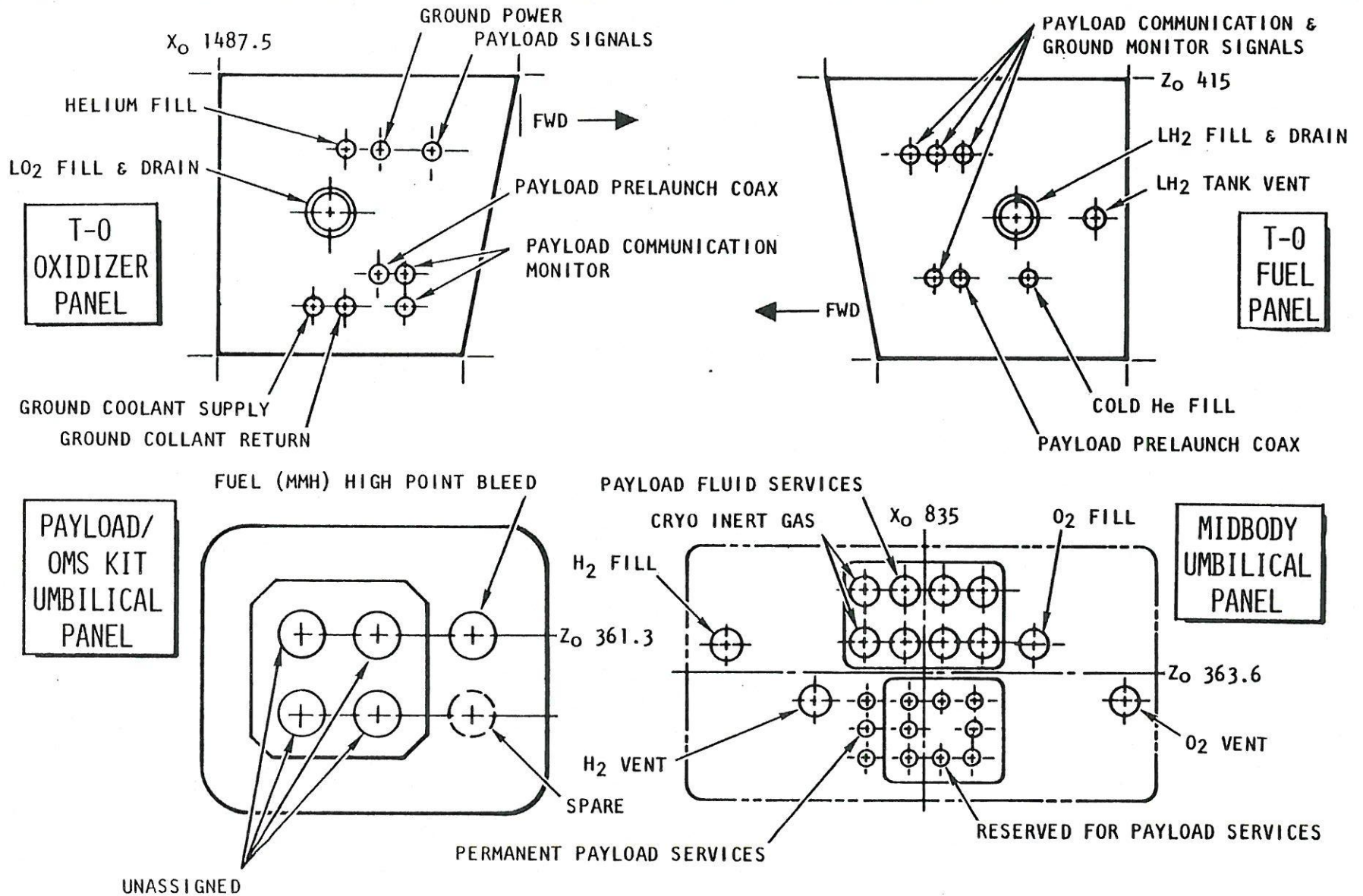POINTING BASE

ORBITER-PROVIDED

PAYLOAD-PROVIDED

PAYLOAD UMBILICAL SERVICE PANELS

The T-0 launch, midbody, and payload/OMS kit umbilical service panels are shown on the facing page. The T-0 umbilicals are primarily for the servicing of cryogenic propulsive payloads and for those fluid and electrical interfaces that are required to be maintained until launch. The connectors on these panels interface with the cargo bay service panels located on the X_O 1307 bulkhead. The midbody umbilical panel includes an area reserved for payload fluid and electrical interfaces. No permanently configured and installed payload service connectors have been identified, and the area may be used as needed by payloads for special fluid or electrical requirements. Access to the T-0 umbilical requires that the payload changeout room be in the extended position. The midbody umbilical will be manually disconnected at approximately T-4 hours.

T-0 OXIDIZER PANEL

PAYLOAD/OMS DELTA V UMBILICAL & DUMP PROVISIONS (RIGHT-HAND SIDE)

T-0 FUEL PANEL

MIDBODY UMBILICAL PANEL

PAYLOAD/OMS DELTA V UMBILICAL & DUMP PROVISIONS (LEFT-HAND SIDE)

PAYLOAD SERVICE SHOWN

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Payload Umbilical Service Panels

T-O OXIDIZER PANEL

X_O 1487.5

GROUND POWER
PAYLOAD SIGNALS
HELIUM FILL
LO$_2$ FILL & DRAIN
FWD
PAYLOAD PRELAUNCH COAX
PAYLOAD COMMUNICATION MONITOR
GROUND COOLANT SUPPLY
GROUND COLLANT RETURN

T-O FUEL PANEL

PAYLOAD COMMUNICATION & GROUND MONITOR SIGNALS
Z_O 415
LH$_2$ FILL & DRAIN
LH$_2$ TANK VENT
FWD
COLD He FILL
PAYLOAD PRELAUNCH COAX

PAYLOAD/OMS KIT UMBILICAL PANEL

FUEL (MMH) HIGH POINT BLEED
Z_O 361.3
SPARE
UNASSIGNED

MIDBODY UMBILICAL PANEL

PAYLOAD FLUID SERVICES
CRYO INERT GAS
X_O 835
O$_2$ FILL
H$_2$ FILL
H$_2$ VENT
Z_O 363.6
O$_2$ VENT
PERMANENT PAYLOAD SERVICES
RESERVED FOR PAYLOAD SERVICES

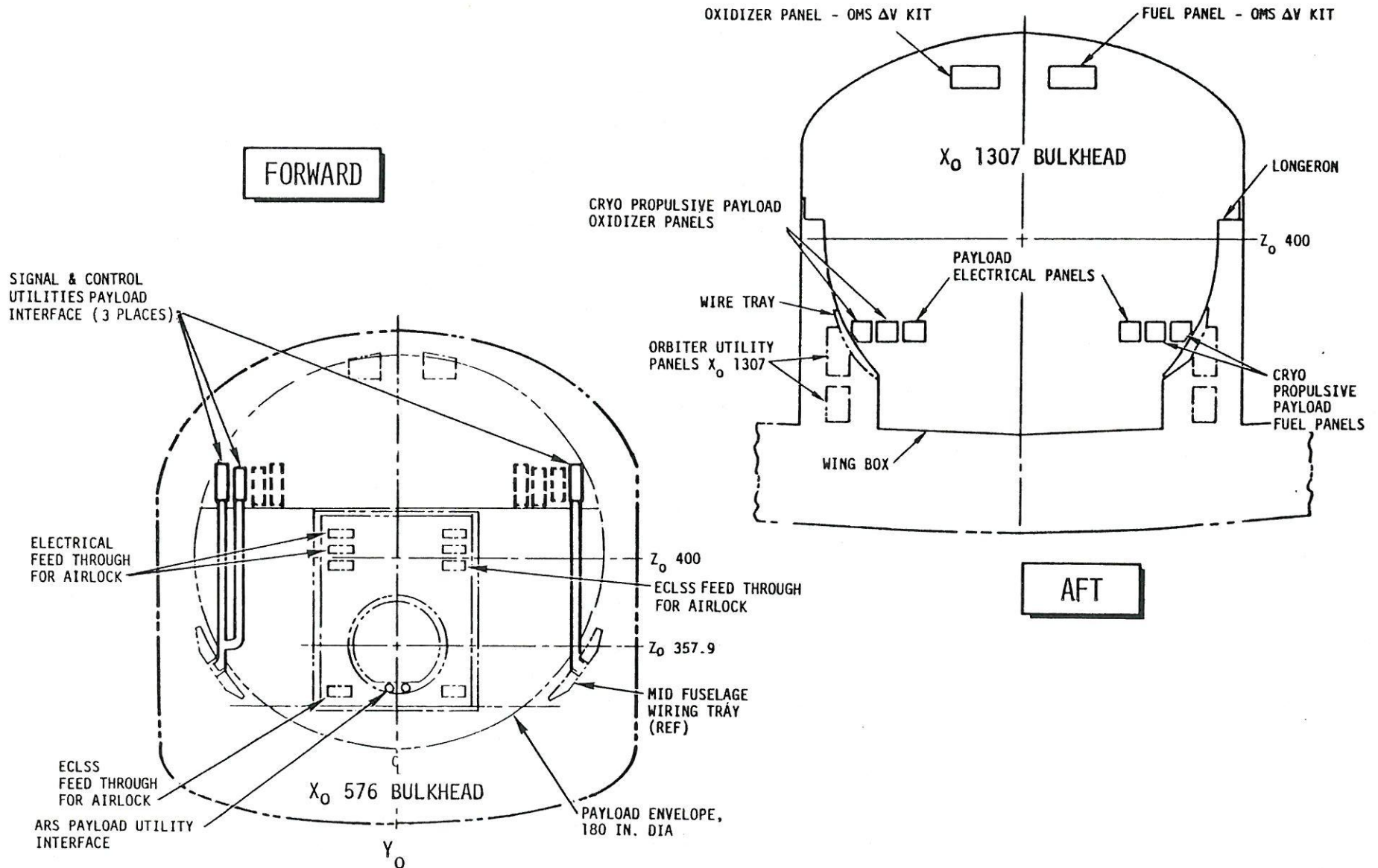### FORWARD AND AFT BULKHEAD PAYLOAD BAY SERVICE PANELS

The facing chart shows the carrier/payload services and utilities panels on the forward (X_O 576) and aft (X_O 1307) payload bay bulkheads. These panels are the interfaces through which electrical, communications, data, and fluid services are provided to the carrier/payload from the orbiter.

Standardized electrical services are provided to carrier/payloads from the orbiter subsystems at approximately $\pm Y_O$ 60 and Z_O 425 on the forward bulkhead. The interfaces provided include redundant caution/warning, data, communication, command, and performance monitoring connectors, and the air revitalization system (ARS). Fluid interface connections are TBD. These connectors may be engaged or disengaged during ground operations.

The aft service panels provide for interfacing the payload with the external umbilical service panels. The lower panels interface with the T-0 umbilical; the upper panels interface the OMS kits with the OMS. Provisions are included for routing and installing of payload cables along both sides of the aft bulkhead.

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Forward and Aft Bulkhead Payload Bay Service Panels

FORWARD

SIGNAL & CONTROL
UTILITIES PAYLOAD
INTERFACE (3 PLACES)

ELECTRICAL
FEED THROUGH
FOR AIRLOCK

Z_o 400

ECLSS FEED THROUGH
FOR AIRLOCK

Z_o 357.9

MID FUSELAGE
WIRING TRAY
(REF)

ECLSS
FEED THROUGH
FOR AIRLOCK

ARS PAYLOAD UTILITY
INTERFACE

X_o 576 BULKHEAD

PAYLOAD ENVELOPE,
180 IN. DIA

Y_o

OXIDIZER PANEL - OMS ΔV KIT

FUEL PANEL - OMS ΔV KIT

X_o 1307 BULKHEAD

LONGERON

CRYO PROPULSIVE PAYLOAD
OXIDIZER PANELS

Z_o 400

PAYLOAD
ELECTRICAL PANELS

WIRE TRAY

ORBITER UTILITY
PANELS X_o 1307

CRYO
PROPULSIVE
PAYLOAD
FUEL PANELS

WING BOX

AFT

Requests for planning and information concerning potential use of the
Space Shuttle Space Transportation System should be made to:

Space Transportation Systems Operations Office, MO,
NASA, Washington, D.C. 20546
Telephone: 202/755-2344

or

Space Transportation System User Service Center
Department 702, Mail Code FC77
Rockwell International
Space Systems Group
12214 Lakewood Boulevard
Downey, California 90241
Telephone: 213/922-3344

For information concerning the material contained in this brochure,
please contact:

Special Services
Department 108, Mail Code AB52
Rockwell International
Space Systems Group
12214 Lakewood Boulevard
Downey, California 90241
Telephone: 213/922-1591

This document was assembled and edited by W.H. Morita of the Advanced
Systems Department, Space Systems Group of Rockwell International.