SPACE SHUTTLE

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SPACE SHUTTLE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

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A NEW ERA IN SPACE

On December 17, 1903, Orville and Wilbur Wright successfully achieved sustained flight in a power-driven aircraft. The first flight that day lasted only 12 seconds over a distance of 37 meters (120 feet), which is about the length of the Space Shuttle Orbiter. The fourth and final flight of the day traveled 260 meters (852 feet) in 59 seconds. The initial notification of this event to the world was a telegram to the Wrights' father.

Sixty-six years later, a man first stepped on the lunar surface and an estimated 500 million people throughout the world saw the event on television or listened to it on radio as it happened.

Historic events *ARE* spectacular. The space program, however, has always been much more than a television spectacular. Today, space transportation is working in many ways for us all, and we have come to expect this.

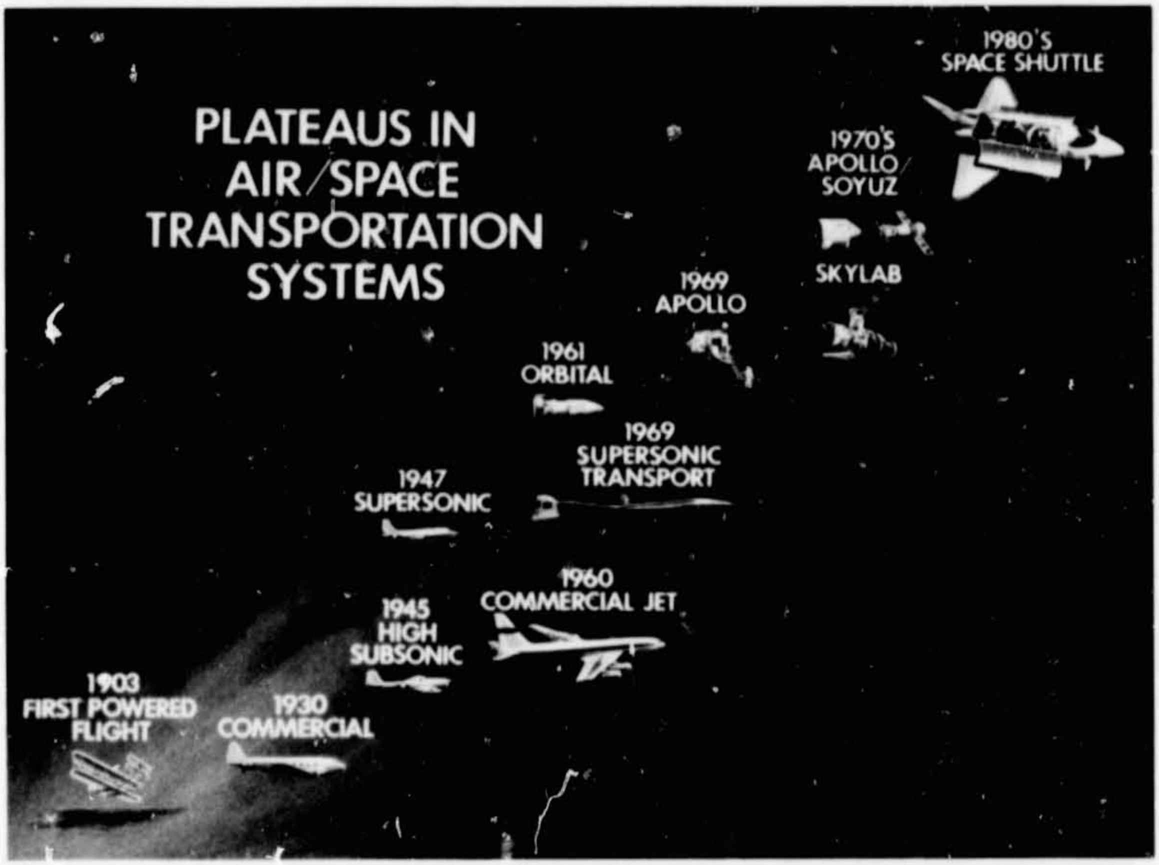
A whole new era of transportation will come into being in the 1980's with the advent of the Space Shuttle and its ability to inexpensively transport a variety of payloads to orbit. It is designed to reduce the cost and increase the effectiveness of using space for commercial, scientific, and defense needs.

With its versatility and reusability, the Space Shuttle will truly open the door to the economical and routine use of space. As a transportation system to Earth orbit, it will offer the workhorse capabilities of such earthbound carriers as trucks, ships, and airlines and will be as vital to the nation's future in space as the more conventional carriers of today are to the country's economic life and well-being.

So often have the man-machine relationships in space been proven to be highly effective that the Space Shuttle is being designed and built to take advantage of the most efficient characteristics of both humans and complex machines. This combination, coupled with the flexible characteristics of Shuttle, will provide an efficient system for our future national space program activities. The Shuttle will truly provide our nation with routine space operations in near-Earth orbit that can contribute substantially to improving the way of life for all the peoples of our world.

The Space Shuttle era will begin approximately 20 years after the first U.S. venture into space, the launching of Explorer I on January 31, 1958. Since that date, unmanned satellites have probed the near and distant reaches of space. Manned systems have been used to explore the lunar surface and expand the present knowledge of the Earth, the Sun, and the adaptability of man to extended space flight in near-Earth orbit. To serve the future needs of space science and applications, the technological and operational experience underlying these accomplishments is being applied to the development of the Space Shuttle. This vehicle is the basic element in a space transportation system that will open a new era of routine operations in space.

The primary design and operations goal for the Space Shuttle Program is to provide low-cost transportation to and from Earth orbit. Spacelabs will be carried aloft by the Shuttle in support of manned orbital operations. Free-flying or automated satellites will be deployed and recovered from many types of orbits. Automated satellites with propulsive stages attached will be deployed from the Space Shuttle and placed in high-energy trajectories. This approach to space operations will provide many avenues for conducting investigations in space. Many participants, representing diverse backgrounds and capabilities, will work routinely in these space operations of the future.



SPACE SHUTTLE SYSTEM AND MISSION PROFILE

The Space Shuttle flight system is composed of the Orbiter, an external tank (ET) that contains the ascent propellant to be used by the Orbiter main engines, and two solid rocket boosters (SRB's). The Orbiter and SRB's are reusable; the external tank is expended on each launch.

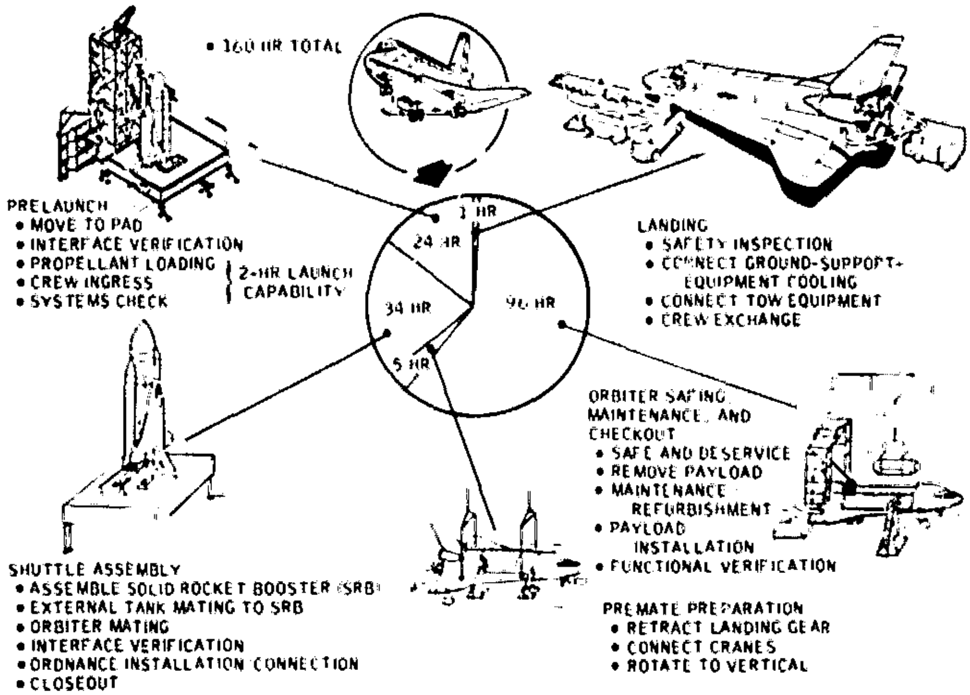
The Space Shuttle mission begins with the installation of the mission payload into the Orbiter payload bay. The payload will be checked and serviced before installation and will be activated on orbit. Flight safety items for some payloads will be monitored by a caution and warning system.

The SRB's and the Orbiter main engine will fire in parallel at lift-off. The two SRB's are jettisoned after burnout and are recovered by means of a parachute system. The large external tank is jettisoned before the Space Shuttle Orbiter goes into orbit. The orbital maneuvering system (OMS) of the Orbiter is used to attain the desired orbit and to make any subsequent maneuvers that may be required during the mission. When the payload bay doors in the top of the Orbiter fuselage open to expose the payload, the crewmen are ready to begin payload operations.

After the orbital operations, deorbiting maneuvers are initiated. Reentry is made into the Earth atmosphere at a high angle of attack. At low altitude, the Orbiter goes into horizontal flight for an aircraft-type approach and landing. A 2-week ground turnaround is the goal for reuse of the Space Shuttle Orbiter.

The nominal design duration of the initial missions is 7 days. The mission duration can be extended to as long as 30 days if the necessary consumables are added.

GROUND TURNAROUND



PROFILE OF SHUTTLE MISSION

SEPARATION OF EXTERNAL TANK

ORBIT INSERTION AND CIRCULARIZATION

HEIGHT:
215 km (115 N. MI. - TYPICAL)
VELOCITY:
28 300 km/HR (17 600 MPH)

ORBITAL OPERATIONS

HEIGHT:
185 TO 1100 km
(100 TO 600 N. MI.)
DURATION:
UP TO 30 DAYS

SEPARATION OF SOLID ROCKET BOOSTERS

HEIGHT:
50 km (27 N. MI.)
VELOCITY:
5170 km/HR (3213 MPH)

SHUTTLE LAUNCH

SHUTTLE CHARACTERISTICS

(VALUES ARE APPROXIMATE)

LENGTH

SYSTEM: 56 m (184 FT)
ORBITER: 37 m (122 FT)

HEIGHT

SYSTEM: 23 m (76 FT)
ORBITER: 17 m (57 FT)

WINGSPAN

ORBITER: 24 m (78 FT)

WEIGHT

GROSS LIFT-OFF:
2 000 000 kg (4 400 000 LB)
ORBITER LANDING:
85 000 kg (187 000 LB)

THRUST

SOLID ROCKET BOOSTERS (2):
11 800 000 N (2 650 000 LB)
OF THRUST EACH
ORBITER MAIN ENGINES (3):
2 100 000 N (470 000 LB)
OF THRUST EACH

CARGO BAY

DIMENSIONS:
18 m (60 FT) LONG, 5 m (15 FT)
IN DIAMETER
ACCOMMODATIONS:
UNMANNED SPACECRAFT TO
FULLY EQUIPPED SCIENTIFIC
LABORATORIES

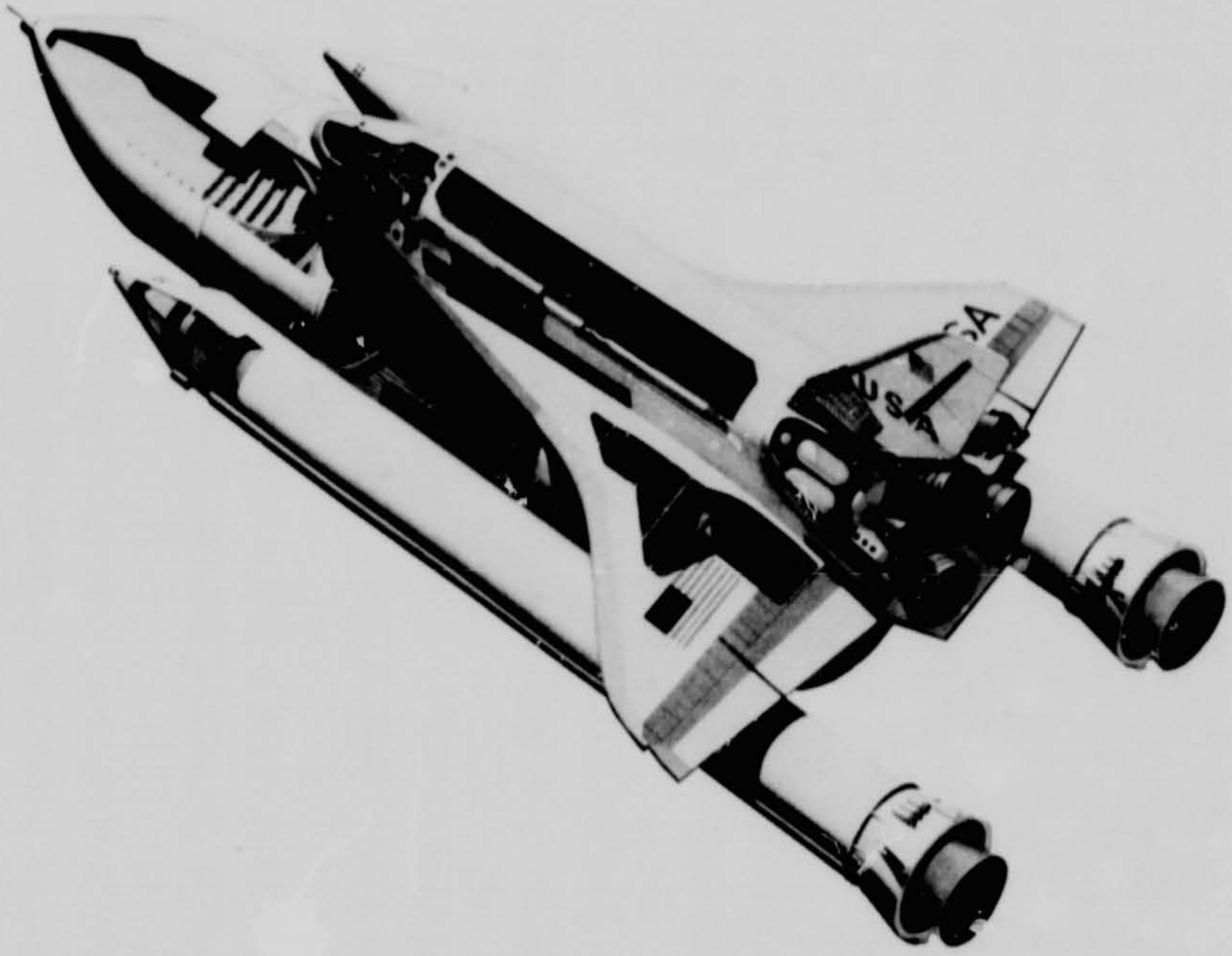
ATMOSPHERIC ENTRY

HEIGHT:
140 km (76 N. MI)
VELOCITY:
28 100 km/HR (17 500 MPH)

LANDING

CROSSRANGE:
±2000 km (±1085 N. MI.)
VELOCITY:
346 km/HR (215 MPH)
(FROM ENTRY PATH)

SPACE SHUTTLE VEHICLE



The Orbiter is designed to carry into orbit a crew of seven (the current baseline calls for four), including scientific and technical personnel, and the payloads. The rest of the Shuttle system (SRB's and external fuel tank) is required to boost the Orbiter into space. The smaller Orbiter rocket engines provide maneuvering and control during space flight; during atmospheric flight, the Orbiter is controlled by the aerodynamic surfaces on the wings and by the vertical stabilizer.

On a standard mission, the Orbiter can remain in orbit for 7 days, return to Earth with personnel and payload, land like an airplane, and be readied for another flight in 14 days. The Shuttle can be readied for a rescue mission launch from standby status within 24 hours after notification. For emergency rescue, the cabin can accommodate as many as 10 persons; thus, all occupants of a disabled Orbiter could be rescued by another Shuttle.

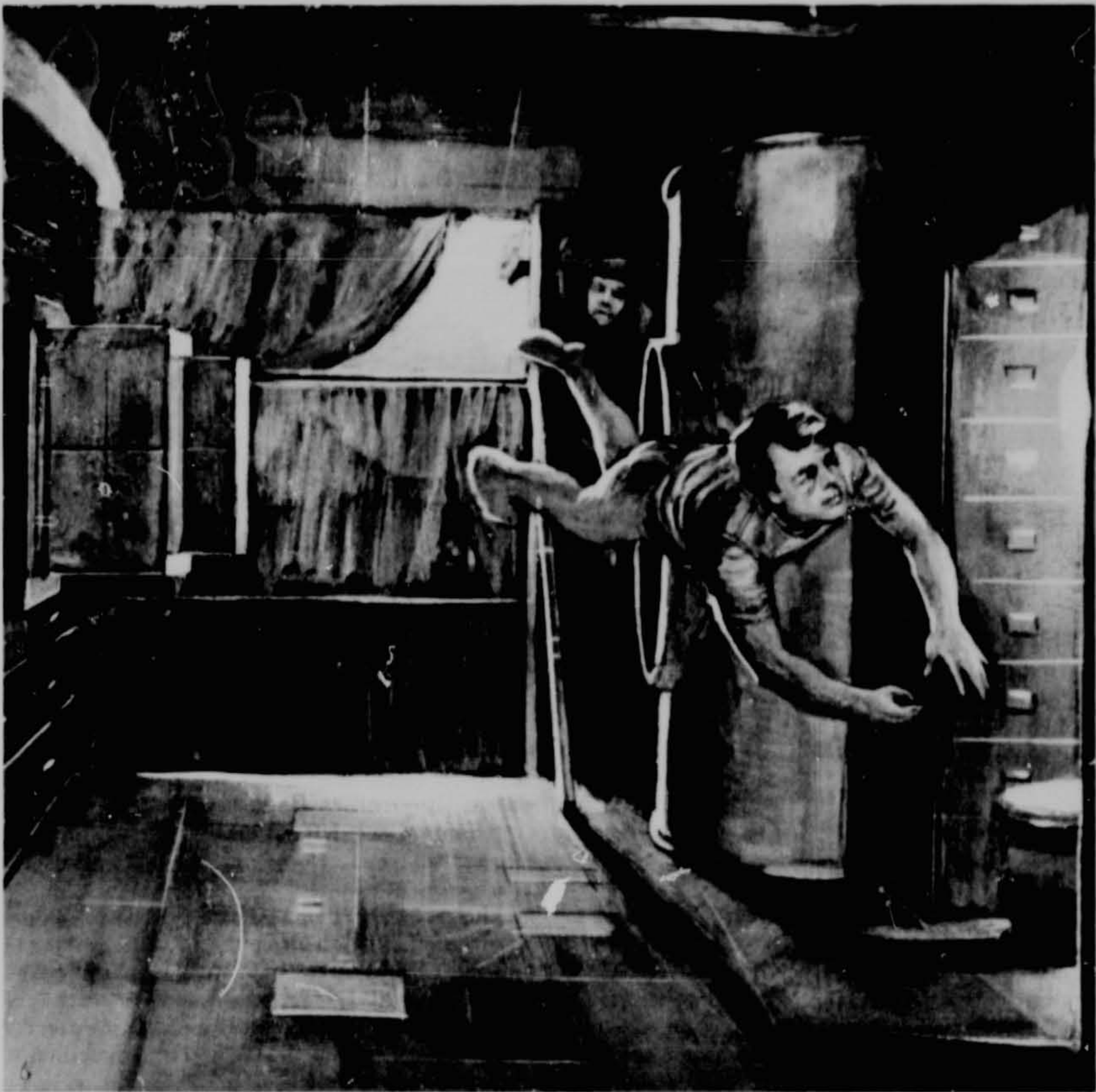
The SRB's, which burn in parallel with the Orbiter main propulsion system, are separated from the Orbiter/external tank at an altitude of approximately 50 kilometers (27 nautical miles), descend on parachutes, and land in the ocean approximately 278 000 meters (150 nautical miles) from the launch site. They are recovered by ships, returned to land, refurbished, and then reused.

After SRB separation, the Orbiter main propulsion system continues to burn until the Orbiter is injected into the required ascent trajectory. The external tank then separates and falls ballistically into a remote area of the Indian or the South Pacific Ocean, depending on the launch site and mission. The OMS completes insertion of the Orbiter into the desired orbit.

CREW AND PASSENGER ACCOMMODATIONS

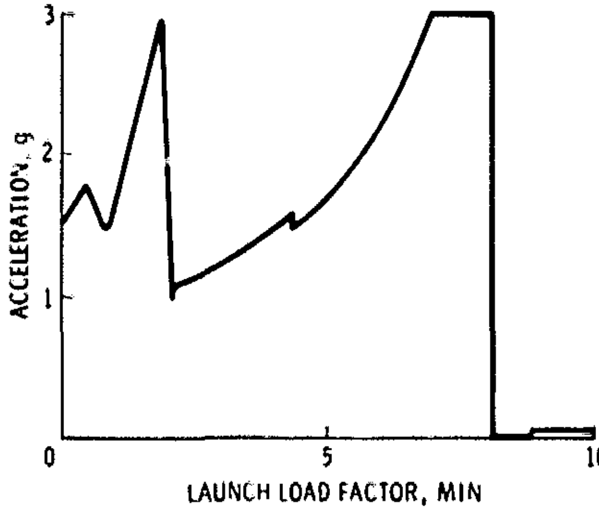
The crew and passengers occupy a two-level cabin at the forward end of the Orbiter. The crew controls the launch, orbital maneuvering, atmospheric entry, and landing phases of the mission from the upper level flight deck. The crew also performs payload handling.

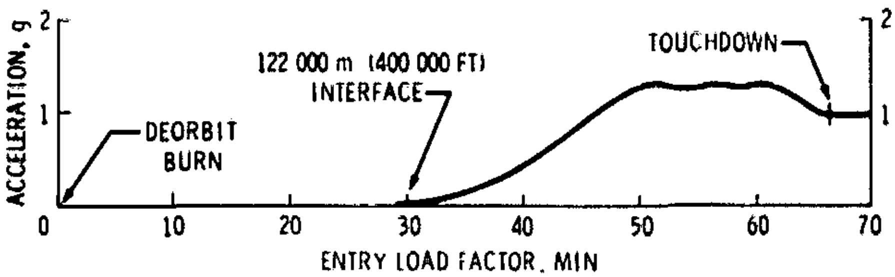
Seating for passengers and a living area are provided on the lower deck. The cabin will have a maximum of utility; mission flexibility is achieved with a minimum of volume, complexity, and weight. Space flight will no longer be limited to intensively trained, physically



perfect astronauts but will now accommodate experienced scientists and technicians.

Crewmembers and passengers will experience a designed maximum gravity load of only 3g during launch and less than 1.5g during a typical reentry. These accelerations are about one-third the levels experienced on previous manned flights. Many other features of the Space Shuttle, such as a standard sea-level atmosphere, will welcome the nonastronaut space worker of the future.





WIDE VARIETY OF MISSIONS

The Space Shuttle has the capability to conduct space missions in response to currently projected national and worldwide needs and the flexibility to respond to policy, discovery, and innovation. The primary mission for the Space Shuttle is the delivery of payloads to Earth orbit. The Shuttle system can place payloads of 29 500 kilograms (65 000 pounds) into orbit. Payloads with propulsion stages can place satellites into high Earth orbit or into lunar or planetary trajectories.

The Space Shuttle is more than a transport vehicle. The Orbiter has the capability to carry out missions unique to the space program: to retrieve payloads from orbit for reuse; to service or refurbish satellites in space; and to operate space laboratories in orbit. These capabilities result in a net savings in the cost of space operations while greatly enhancing the flexibility and productivity of the missions.

Among the multifaceted uses of Space Shuttle during its operational life, which will extend beyond the 1990's, will be a wide range of applications of the environment of space and of space platforms. The applications can be achieved through operation of satellites, satellites with propulsion stages, space laboratories, or combinations as appropriate to the specific objectives and requirements. The Shuttle also provides a laboratory capability to do research and to develop techniques and equipment that may evolve into new operational satellites.

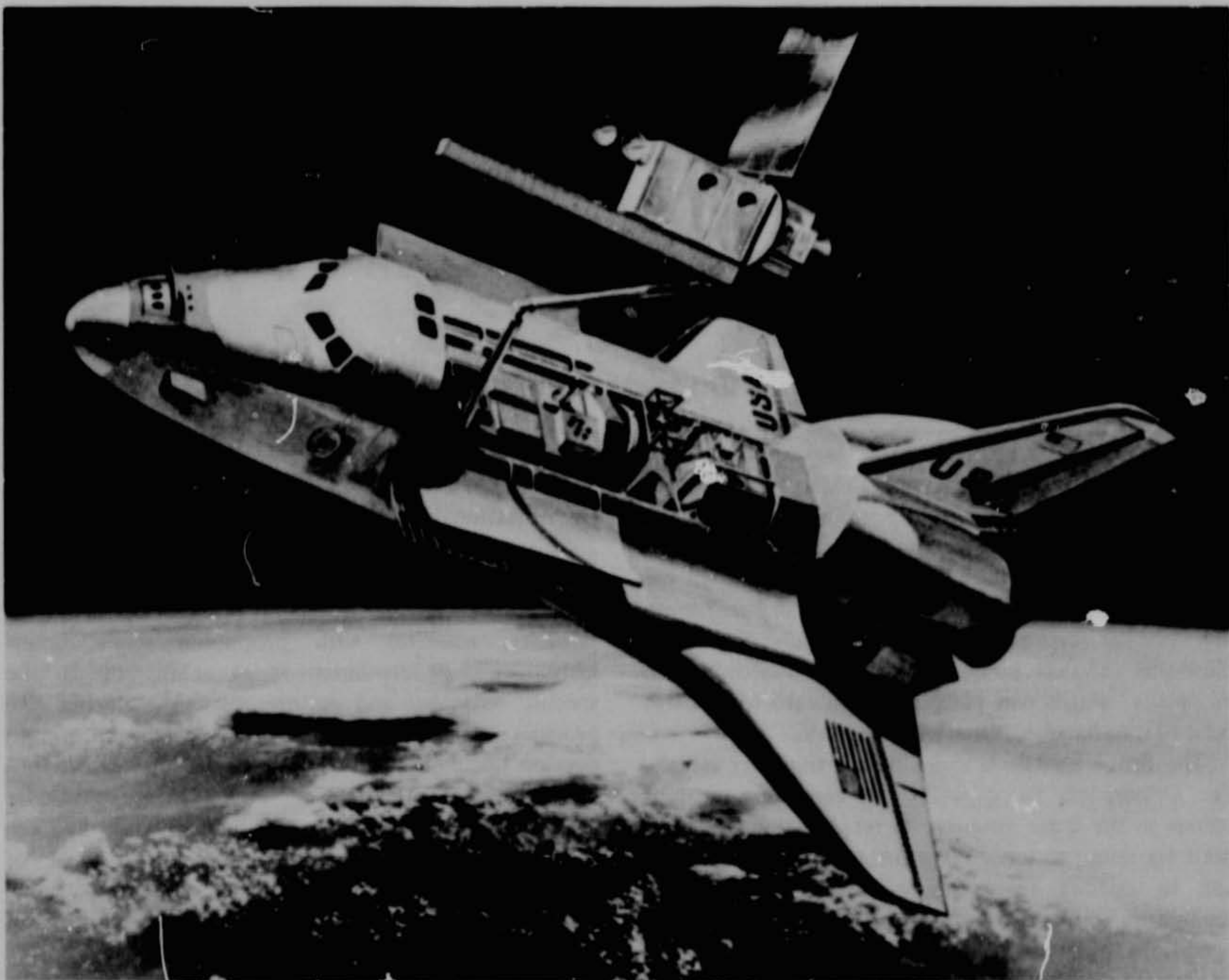
The Space Shuttle will not be limited to uses that can be forecast today. The reduction in the cost of Earth-orbital operations and the new operational techniques will enable new and unforeseen solutions of problems.

PLACEMENT AND RECOVERY OF SATELLITES

One important Space Shuttle mission will be the placement of satellites in Earth orbit. A satellite launched on a previous mission can be retrieved and returned to Earth for refurbishment and reuse.

As many as five individual satellites may be delivered on a single mission. The satellites are serviced, checked out, and loaded into the Orbiter. The crew will consist of Shuttle pilots and mission and payload specialists. Upon reaching the desired orbit, the mission and payload specialists will conduct predeployment checks and operations. After determining that the satellite is ready, the crew will operate the payload deployment system, which lifts the satellite from the cargo-bay retention structure, extends it away from the Orbiter, and releases it. The final activation of the satellite will be by radio command. The Orbiter will stand by until the satellite is performing satisfactorily before proceeding with the remainder of the mission.

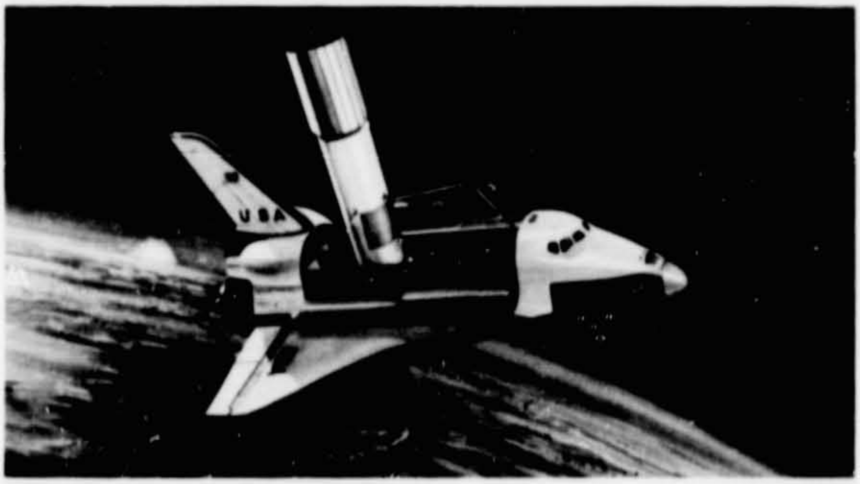
To recover a satellite, the Orbiter will rendezvous with it, maneuver close, and grab it with the remote manipulator arm. After the satellite is deactivated by radio command, it will be lowered into the cargo bay and locked into place. The Orbiter will perform deorbit maneuvers, enter the atmosphere, and land, returning the expensive satellite for reuse.

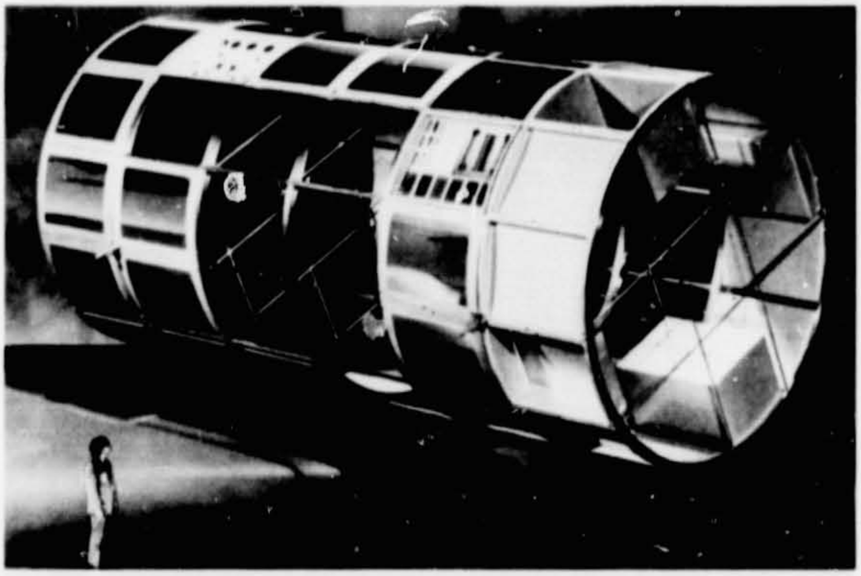


PLACEMENT OF FREE-FLYING SCIENTIFIC LABORATORIES IN SPACE

The large space telescope represents an international facility for on-orbit space research controlled by the investigating scientists on the ground. Design studies are now being conducted and sponsored by the NASA Marshall Space Flight Center and the Goddard Space Flight Center. The Space Shuttle will deliver the telescope to orbit, and the crewmen will assist in preparing the facility for operation. During scheduled revisits to the facility, the Space Shuttle crewmen will service supporting subsystems, exchange scientific hardware, and, several years later, return the facility to Earth at the end of its mission.

The long duration exposure facility (LDEF) is a basic research project being implemented by the NASA Langley Research Center. The LDEF is a reusable, unmanned, low-cost, free-flying structure on which a variety of passive experiments can be mounted to study the effects of their exposure to space over a relatively long period of time. After an extended period in orbit, the LDEF will be retrieved by an Orbiter and returned to Earth for experiment analysis.





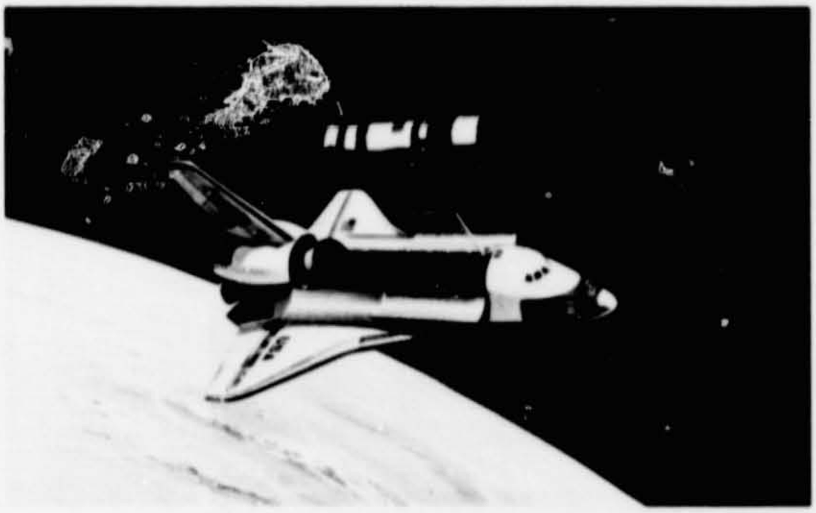
DELIVERY OF PAYLOADS THAT USE PROPULSION STAGES

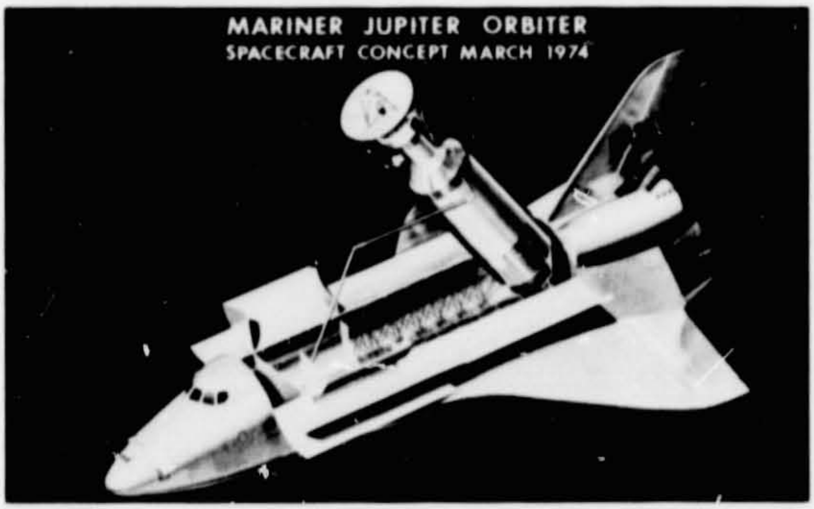
Major activity is forecast for geosynchronous orbits, deep-space missions, elliptical orbits, and higher circular orbits. Payloads with such destinations will require a propulsion stage in addition to the Shuttle. Both the satellite and the propulsion stage will be delivered to orbit and deployed as illustrated. Before release, the combined propulsion-stage/satellite system will be checked and readied for launch, and guidance information will be updated. The Orbiter will move a safe distance away before ground control gives radio command signals to fire the propulsion stage engines.

The Shuttle payload crew can do both visual and remote monitoring. In the event of a malfunction, the stage and satellite can be retrieved for inspection and possible repair. Should it be determined that repair is beyond the onboard capability, the stage propellants would be dumped and the entire payload (propulsion stage and satellite) returned to Earth for refurbishment.

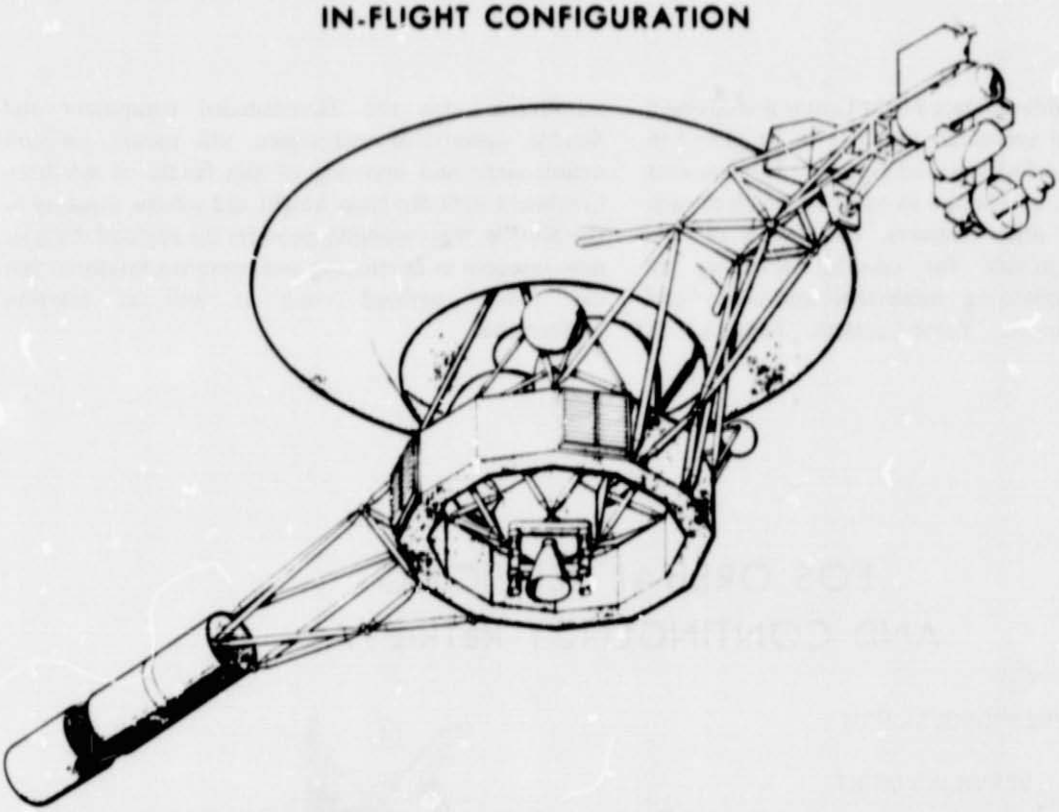
Initially, an existing propulsion stage will be adapted for this on-orbit launch. An advanced reusable propulsion stage called the Space Tug is being studied for later inclusion in the space transportation system.

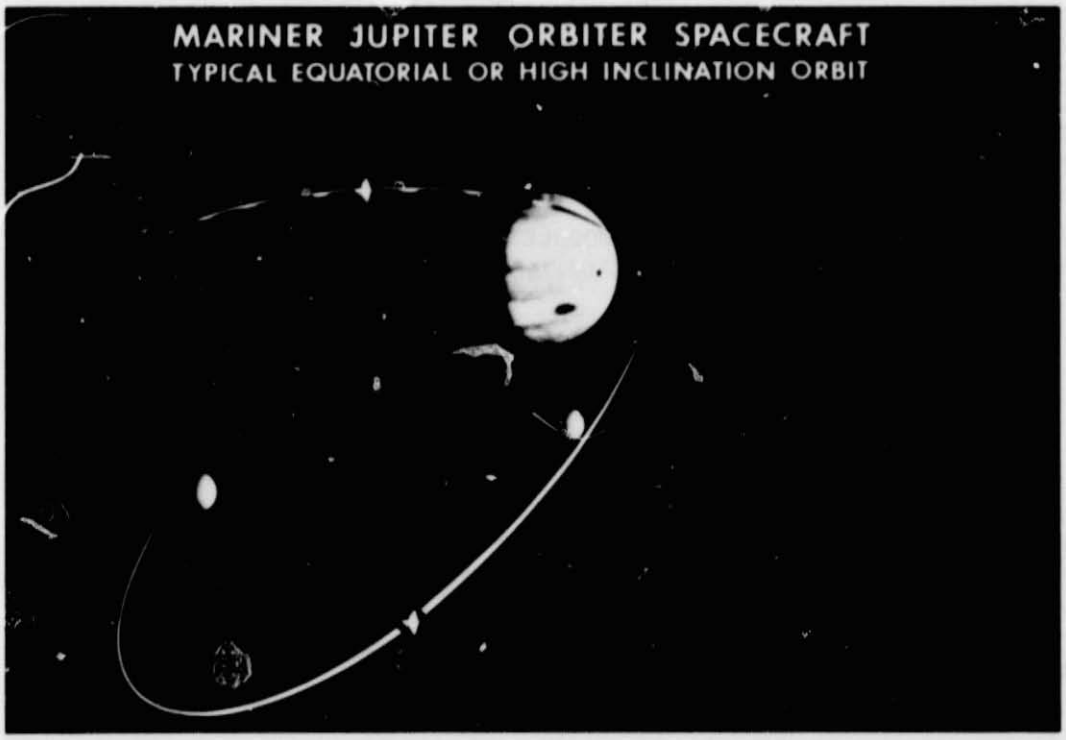
The Mariner Jupiter Orbiter/interim upper stage (IUS) may be launched by the Shuttle in 1981 or 1982 for the purpose of obtaining additional data about the planet Jupiter, its satellites, and the space surrounding it.





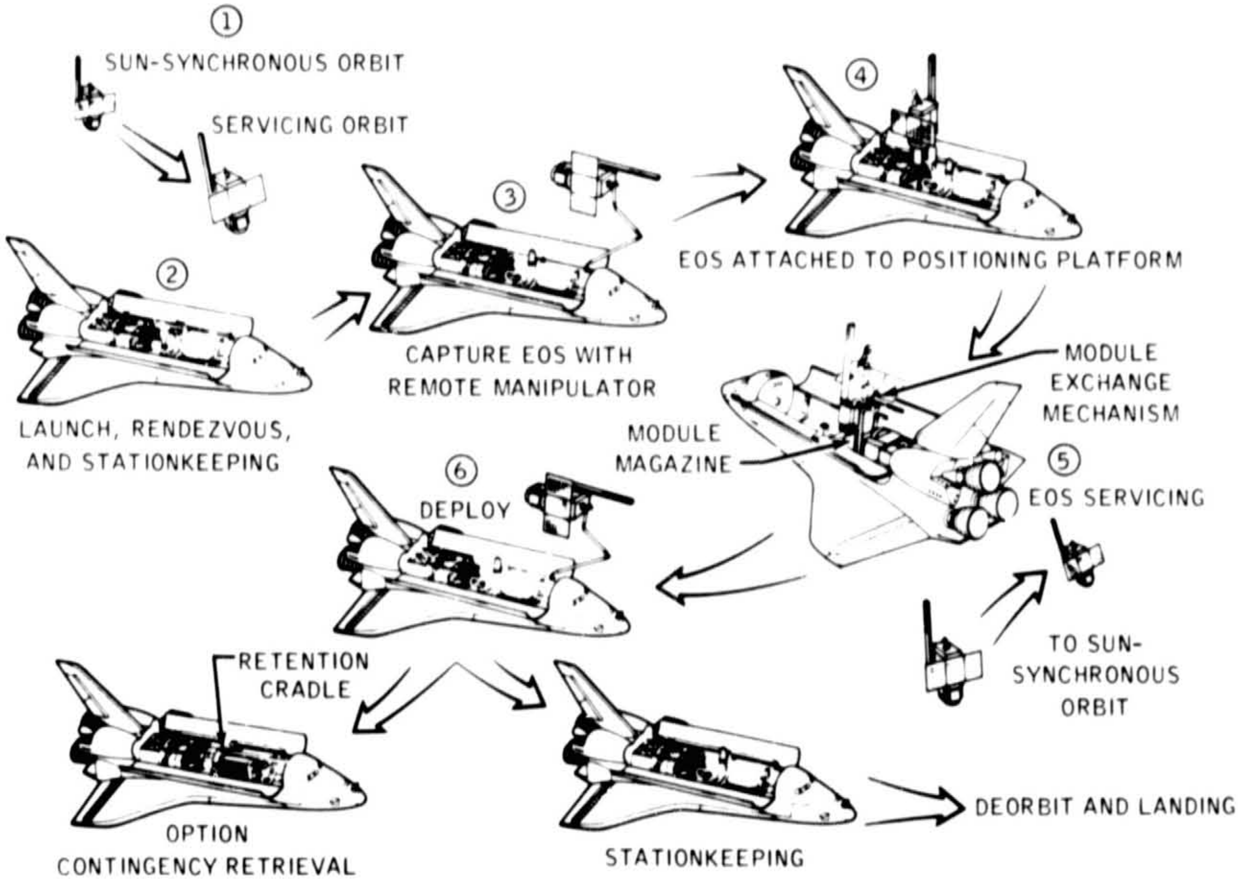
MARINER JUPITER ORBITER SPACECRAFT CONCEPT
IN-FLIGHT CONFIGURATION



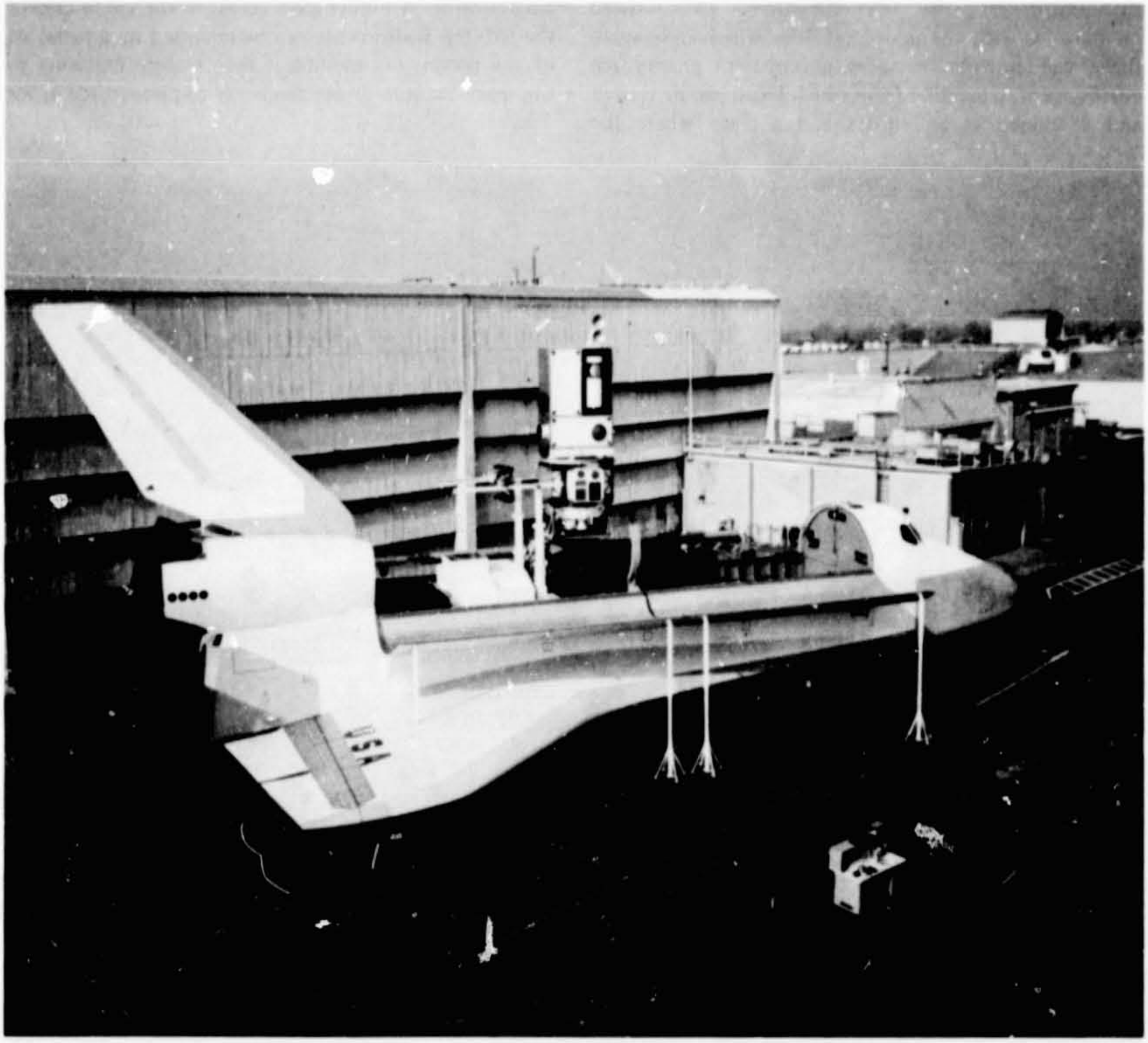


The NASA Goddard Space Flight Center is studying a family of modular spacecraft satellites to be placed in orbits of various inclinations and altitudes. This low-cost standard hardware is expected to comprise much of each satellite. Among other features, the design of this hardware will provide for on-orbit servicing by changeout of supporting subsystem assemblies and applications sensors. These system features, in association with the Shuttle-based equipment and Shuttle operational techniques, will permit on-orbit maintenance and updating of this family of satellites. Combined with the large weight and volume capacity of the Shuttle, this capability provides the payload designer new freedom in developing and operating satellites that can reduce payload costs as well as improve performance.

EOS ORBITAL SERVICING AND CONTINGENCY RETRIEVAL



Alternative techniques for on-orbit servicing of satellites are under study. The approach illustrated is based on current simulations of prototype hardware with replaceable modules. Low-cost refurbishable payloads, such as the Earth Observation Satellite (EOS) in the photograph, are carried by a retention system which reacts all boost, reentry, and landing loads. The retention system pivots a docking ring to allow rotation of the satellite in and out of the cargo bay. Deployment away from the Orbiter or capture and berthing of a stabilized EOS are accomplished by the manipulator arms attached to the Orbiter. To replace the payload, a rotary magazine carrying the replacement modules presents them at the proper time to an exchange mechanism. The exchange mechanism removes the old module from the satellite and stows it temporarily, removes the new module from the magazine and installs it in the satellite, and then stows the old module in the rotary magazine.



"The Shuttle development is one of the great technological undertakings of this decade, indeed of this century .... This is a challenge to be shared by NASA and private industry. This joint challenge is to demonstrate and use the Shuttle and particularly the Spacelab in the 1980's to produce valuable new products and techniques ..." – Dr. James C. Fletcher, NASA Administrator, October 18, 1974.

Spacelab is an international program being developed by the European Space Research Organization (ESRO). The large pressurized Spacelab module with an external equipment pallet will be a frequent payload carrier during the Space Shuttle era. Spacelab will provide an extension of the experimenter's ground-based laboratories with the added qualities which only space flight can provide, such as a long-term gravity-free environment, a location from which Earth can be viewed and examined as an entity, and a place where the celestial sphere can be studied free of atmospheric interference.

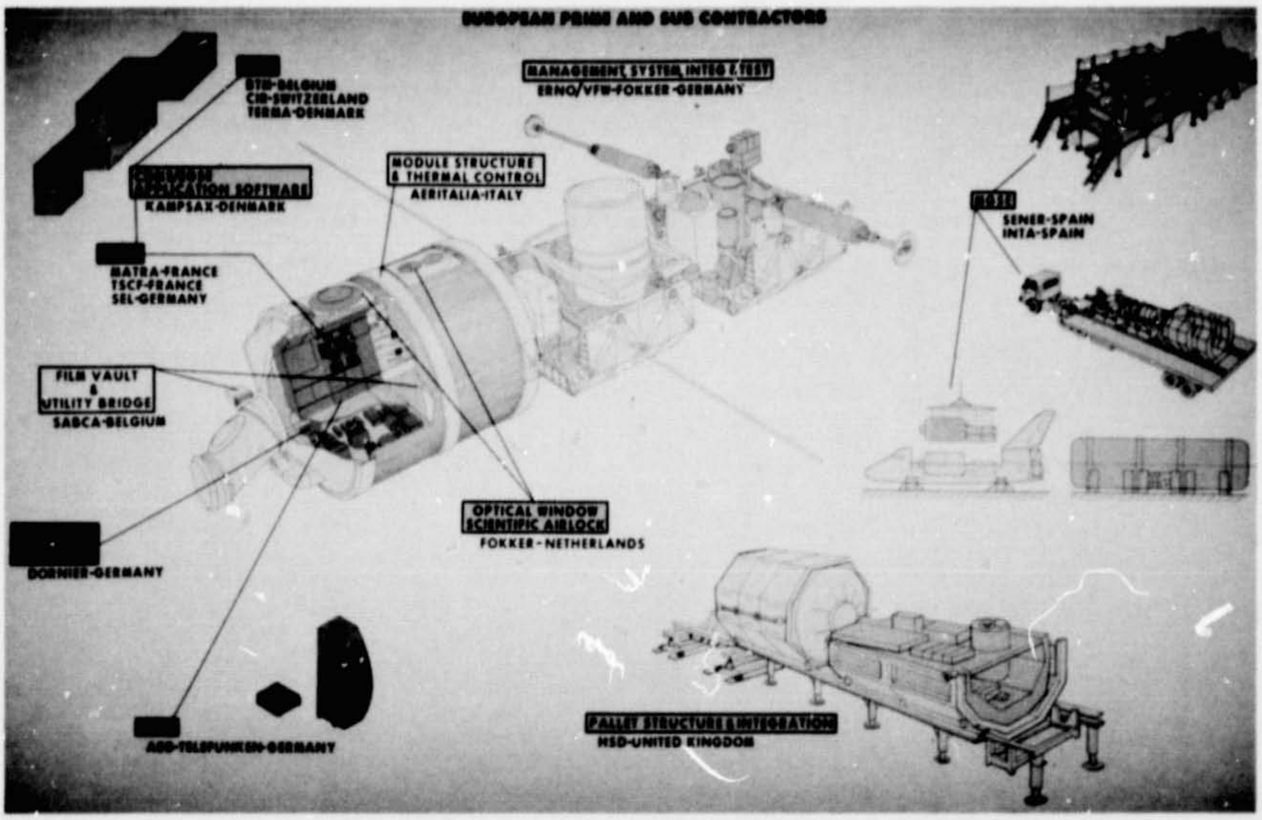
Several Spacelab system configurations will be flown. The configuration illustrated includes a pressurized module where experimenters can work in a shirt-sleeve environment. A tunnel gives access to the cabin area of the Orbiter. Instruments can be mounted on a pallet aft of the pressurized module if they require exposure to the space vacuum or are too bulky to place inside or for

convenience in viewing. The Orbiter may be flown in an inverted attitude to orient the instruments toward Earth for surveys of Earth resources and for investigations of geophysical and environmental parameters.

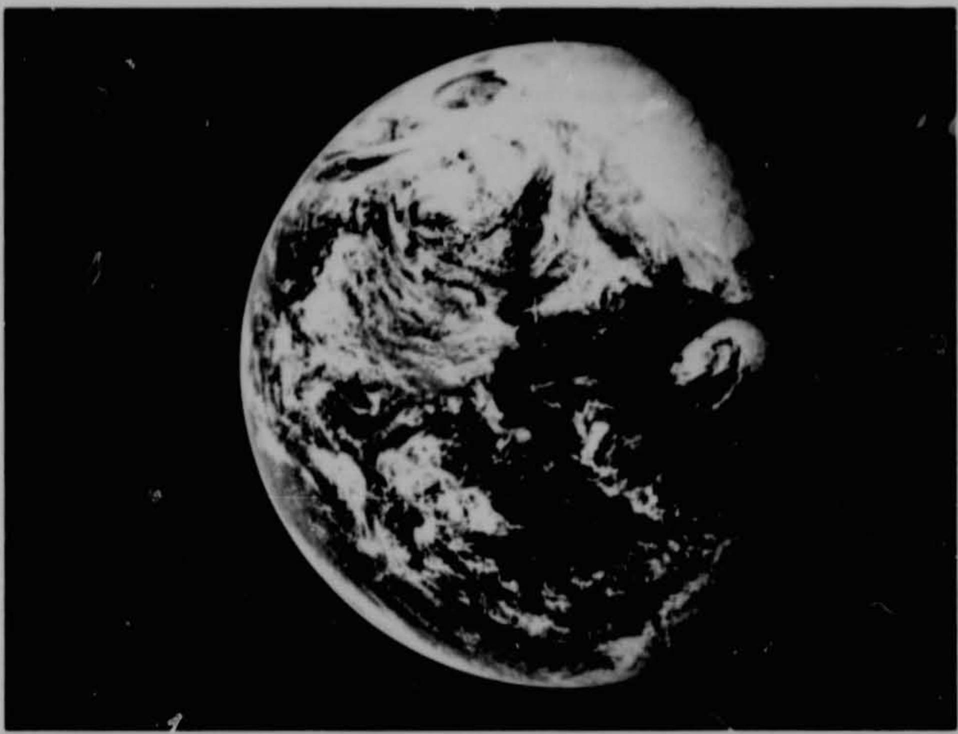
Other Spacelab configurations include those which, in place of a pressurized module, have a large pallet on which numerous instruments are installed and controlled from the payload specialist's station within the Orbiter. Pressure-suit operations in the payload bay are practical when instrument service is required.

Ten member nations of the European space community have agreed to commit almost $400 million to design and deliver one flight unit to the United States. Agreements provide for purchase of additional units by the United States. Cooperating nations are West Germany, Italy, France, United Kingdom, Belgium, Spain, the Netherlands, Denmark, Switzerland, and Austria. Many types of scientific, technological, medical, and applications investigations can be accomplished with this flight hardware. Each Spacelab may be flown as many as 50 times over a 10-year period. This system will provide 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.

Crewmembers and payloads for Spacelab will also be international in origin.



SPACE IN EVERYDAY LIVING



EARTHLY BENEFITS TODAY

Of what *EARTHLY* benefit is the space program?

In the early years of America's space program, men with vision forecast that multiple benefits would someday be derived from the research and development activities associated with this program. Those benefits are no longer a promise; they are realities.

And this is just the beginning. The versatility and flexibility of the Space Shuttle will open up opportunities for more and longer investigations.

Benefits from past space efforts have already worked their way into daily life, to a far greater extent than most people realize. We apply what we learn in space to improve the quality of life on Earth. Advances in medicine, environmental monitoring and control, meteorology, the study of oceans and Earth resources, communications, education, products and materials, and international peace are taken for granted. These benefits together with the acknowledged impetus given to our technical leadership in the world supply overwhelming evidence of value received.

Most of these benefits are available to mankind throughout the world and some are in current use in countries other than the United States.

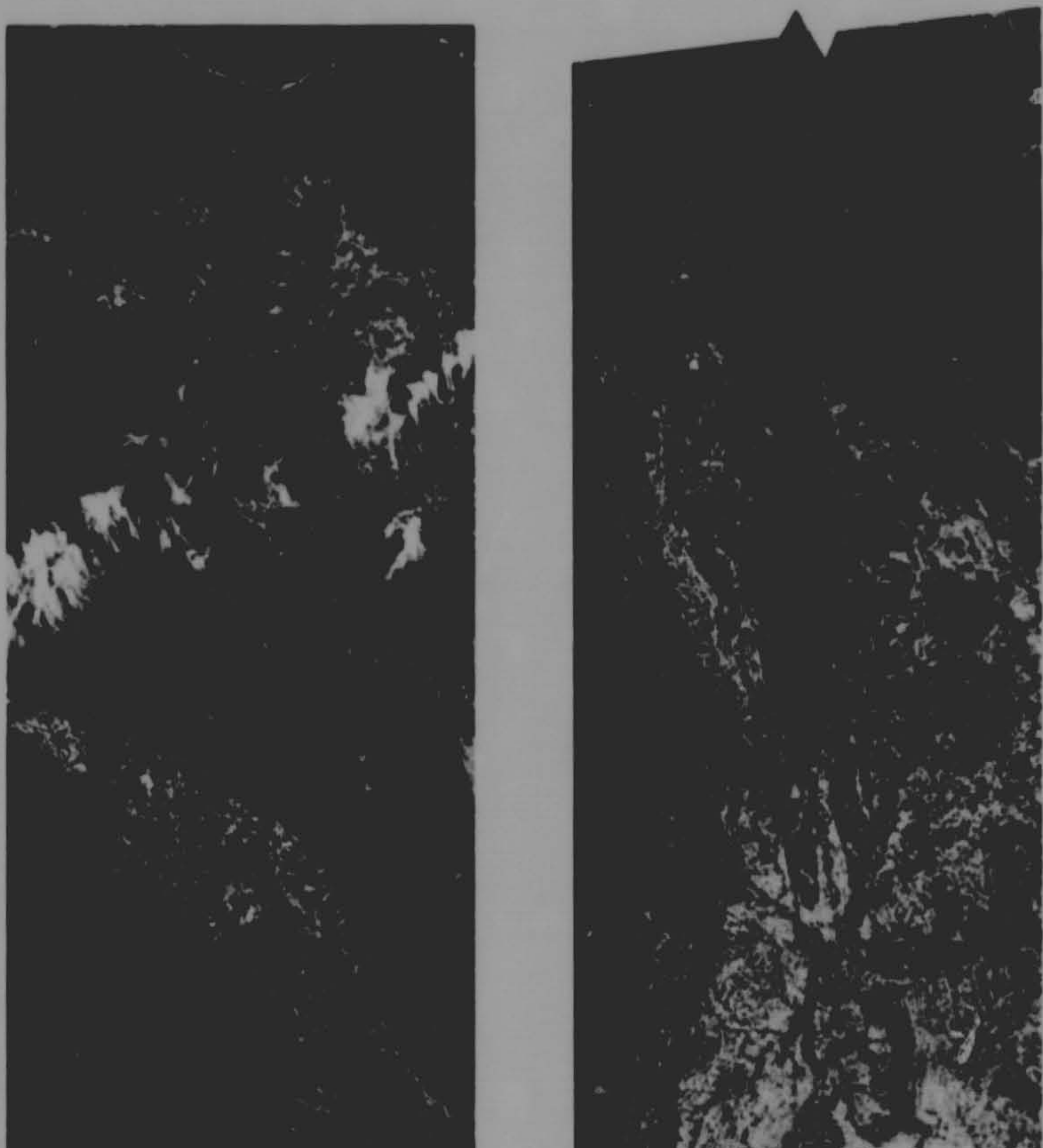
Some specific examples of these benefits follow. However, any list is obsolete as soon as it is written, because the applications of technology are constantly increasing.

The real extent of Earthly benefits from future space efforts can scarcely be predicted. The space program is an essential element in keeping our nation strong — scientifically, technologically, and economically — and thus it keeps us secure.

Photographs and other imagery from both manned and unmanned spacecraft have changed the ways we see our Earth.

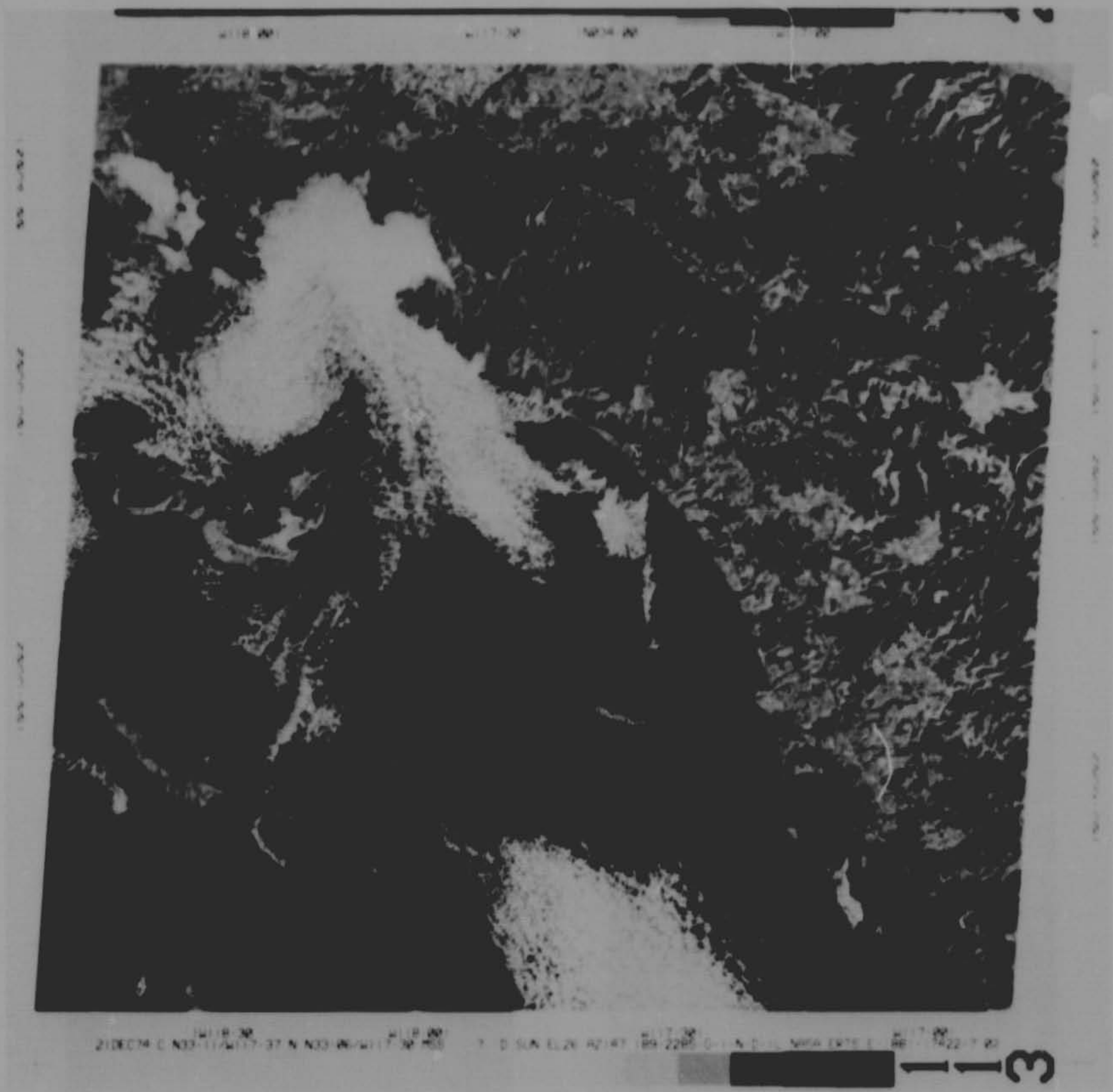
Weather

Weather satellite photographs are perhaps the best known applications that affect our daily lives. Since the first weather satellite was launched in 1960, meteorological spacecraft have returned to Earth more information about the atmosphere than had been learned since man first began to study weather. An estimated 100 000 American lives have been saved as a result of early warnings of hurricanes and other severe weather.



High-altitude photographs taken straight down can help mapmakers work efficiently and accurately. Because much larger areas can be covered by spacecraft than by aircraft in the same amount of time, maps can be changed frequently and accurately. The mosaic shown is part of one that was made from photographs taken of the East Coast from Skylab. Massachusetts is at the top (with Boston Harbor on the right edge of the photograph). The mosaic extends through the New York metropolitan area, New Jersey, and almost to Philadelphia. The Appalachian Mountains extend along the left side.

Land Use

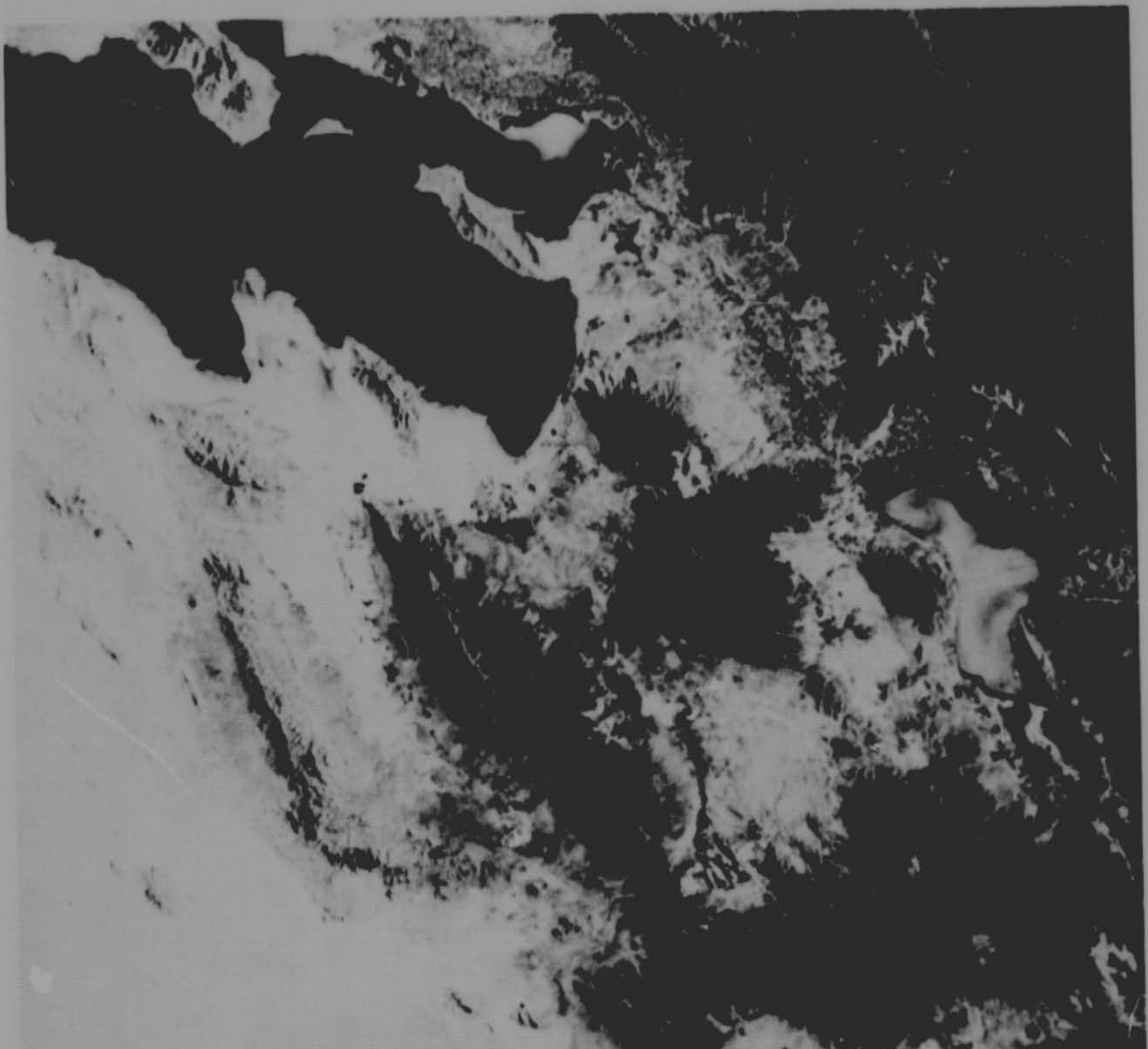


Images transmitted from the Earth Resources Technology Satellite (ERTS) are used for a variety of studies, including forecasting crop yields, determining land use patterns, and helping to find land and water resources in hard-to-reach areas. The area shown is the Southern California Coast extending from Long Beach to San Diego. San Clemente Island is visible in the lower left corner. Urban and suburban land use is heavy in coastal areas.

The Skylab view of the New York City area provides a clear view of land use patterns. Long Island is in the lower right corner and New Jersey in the lower left corner. The Hudson River is visible in the lower right side and the Catskill Mountains extend across the center portion of the photograph.

Pollution

The extent of water and air pollution and sometimes their sources can be established by space photography. Water pollution is visible as fuzziness along the southern shores of the Great Salt Lake. The sharp line across the lake near the top of the photograph represents a railroad bridge that impedes water circulation in the lake; the lighter area north of the bridge is much saltier than the darker area. On the right side of the photograph is Lake Utah, a fresh-water body. Salt Lake City lies between the two lakes. The white splotch in the highlands next to Salt Lake City is the world's largest open-pit copper mine.

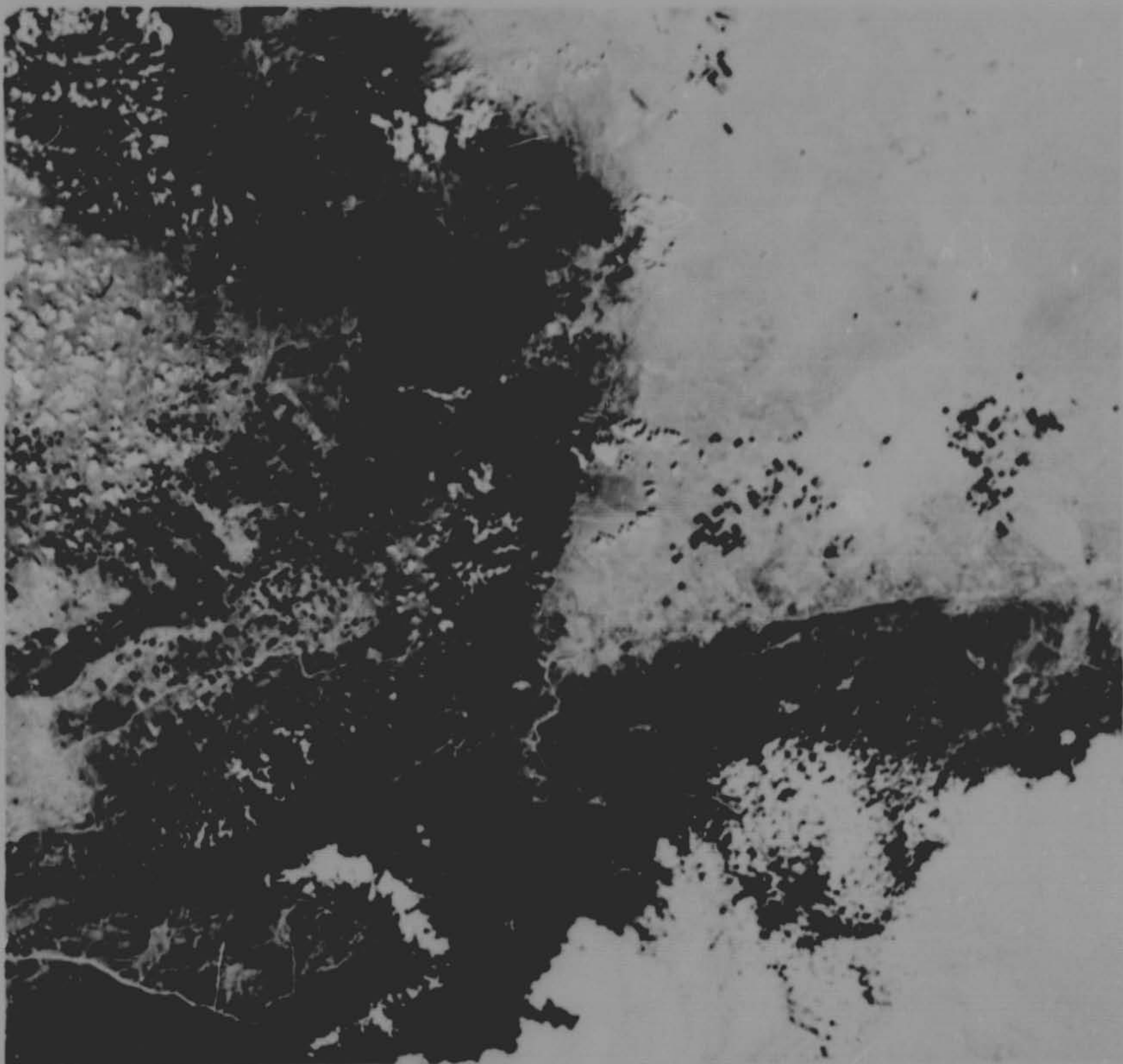


Water Resources

Water resources, especially in inaccessible areas, can be monitored from space. For example, a study of this photograph of snow along the Mogollon Rim in Arizona can lead to accurate prediction of how much water will be available after the thaw to irrigate the desert. Flagstaff is at the bottom center of the photograph and the Painted Desert is across the top. The Meteor Crater is visible slightly to the right of the center of the photograph.

Geology

Geological studies can be made from photographs such as this to support mineral exploration throughout the world. Geological faults often stand out in space imagery. The photograph of California just north of Los Angeles clearly defines where three faults meet in a populated area. If mankind can learn to monitor these faults from space, it might become possible to accurately predict the time, location, and intensity of earthquakes. The dark line across the lower third of the photograph is the San Andreas Fault. Angling into the lower right corner and partially hidden by clouds is the San Gabriel Fault. The Garlock Fault is the dark area extending up the middle of the photograph. Lake Isabella is in the upper right and the city of Bakersfield below it. On the right is Palmdale, where the Orbiter is being built.



ORIGINAL PAGE IS OF POOR QUALITY

Oceanography

Many features of the ocean can be studied from space more easily than any other way. The hazy, light areas in the photograph are areas of nutrients such as algae and plankton in the sea. This information is of importance to commercial fishermen because fish are likely to be concentrated in these areas.

Space imagery can also chart the movement of icebergs to indicate ocean currents and to aid routing of ships to safer areas. A computer using radiance data from a multispectral scanner aboard Skylab charted water depths; this method would simplify updating and correction of hydrographic charts.

Communications

Because of communications satellites, television viewers all over the world take for granted that they can watch sports and news events as they happen. The communications satellites in stationary orbit transmit a variety of other educational, governmental, and commercial data as well.

A new light beam voice communications device, called a retrometer, has been developed by NASA scientists because of space-oriented requirements. Communications by the retrometer are immune to interception and jamming and are completely private. Because the remote microphone requires no power, the system offers many possible applications in industry, at sea, and in air/sea rescue operations.

Many advances in health care have resulted from devices originally designed to monitor astronauts in space and send data back to Earth. For example, a lightweight battery-powered mobile unit that fits into an ambulance and links trained emergency medical technicians to a physician is already being used by some communities: the city of Houston, Texas, has equipped 28 rescue vehicles with these units. Especially important to cardiac patients, whose lives may be saved or lost within the first few minutes after an attack, the unit provides for constant treatment and monitoring both at the scene of the medical emergency and en route to the hospital. Two-way voice communication can be maintained between the technician and a doctor, while electrocardiogram data can be provided to a physician by telemetry. The unit is also equipped for oxygen administration, defibrillation, blood pressure measurement, fluids aspiration, respiratory resuscitation, and drug administration.

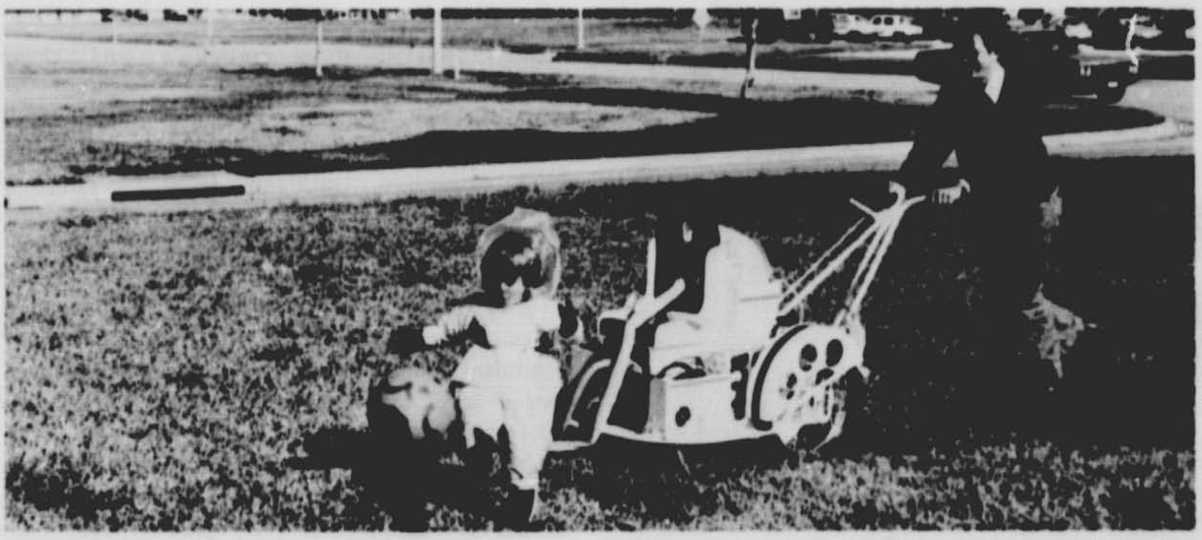
Inside hospitals, too, automatic monitoring systems similar to the ones used for Apollo astronauts can collect several channels of physiological data from as many as 64 patients and transmit the data in digital form to a central control station for processing by a computer. Palm Beach Community Hospital in Florida is one user of this type of system.

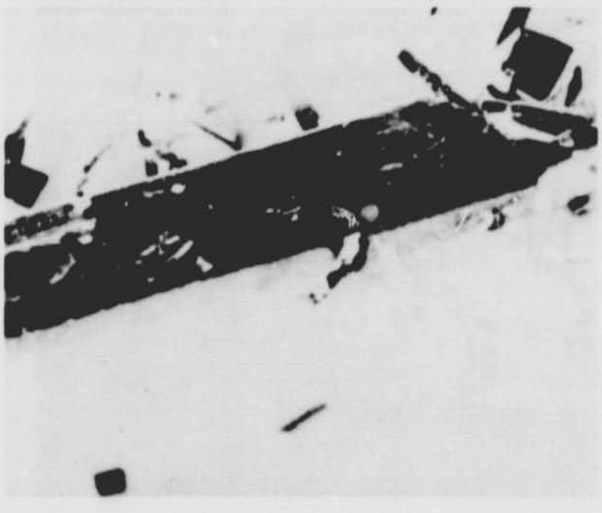
A cuff device perfected for Skylab crews and now in commercial use measures blood pressure automatically and displays a numerical reading, as shown in the photograph. This device can speed and simplify screening of large groups of people by paramedics. High blood pressure, a common and often unsuspected medical problem, can contribute to more serious problems such as heart attack and stroke; therefore, early detection has the potential to save many lives.

Spacesuits and portable life-support systems have inspired other medical advances. For example, the mobile biological isolation system in the photograph is being developed for patients with immune deficiency, those undergoing chemotherapy, or those whose natural immunity has been deliberately lowered for organ transplant. A suit such as this, which provides both mobility and protection, could also be used to protect doctors from communicable disease and to protect researchers working with dangerous viruses in laboratories.

Another application is a portable volume-controlled respirator that is lightweight and requires no external source of power or oxygen. The respirator weighs 75 percent less than common respirators and is much more precise. It has particular utility in disaster area field hospitals.

Computer terminals and software developed for the space program can simplify many health-related tasks and provide capabilities never before available. Individual medical records can be updated constantly. A laboratory technician or paramedic can enter various test data from a remote terminal and receive interpretations. Doctors can get clarified X-rays done by computer methods developed to clarify photographs transmitted from spacecraft.

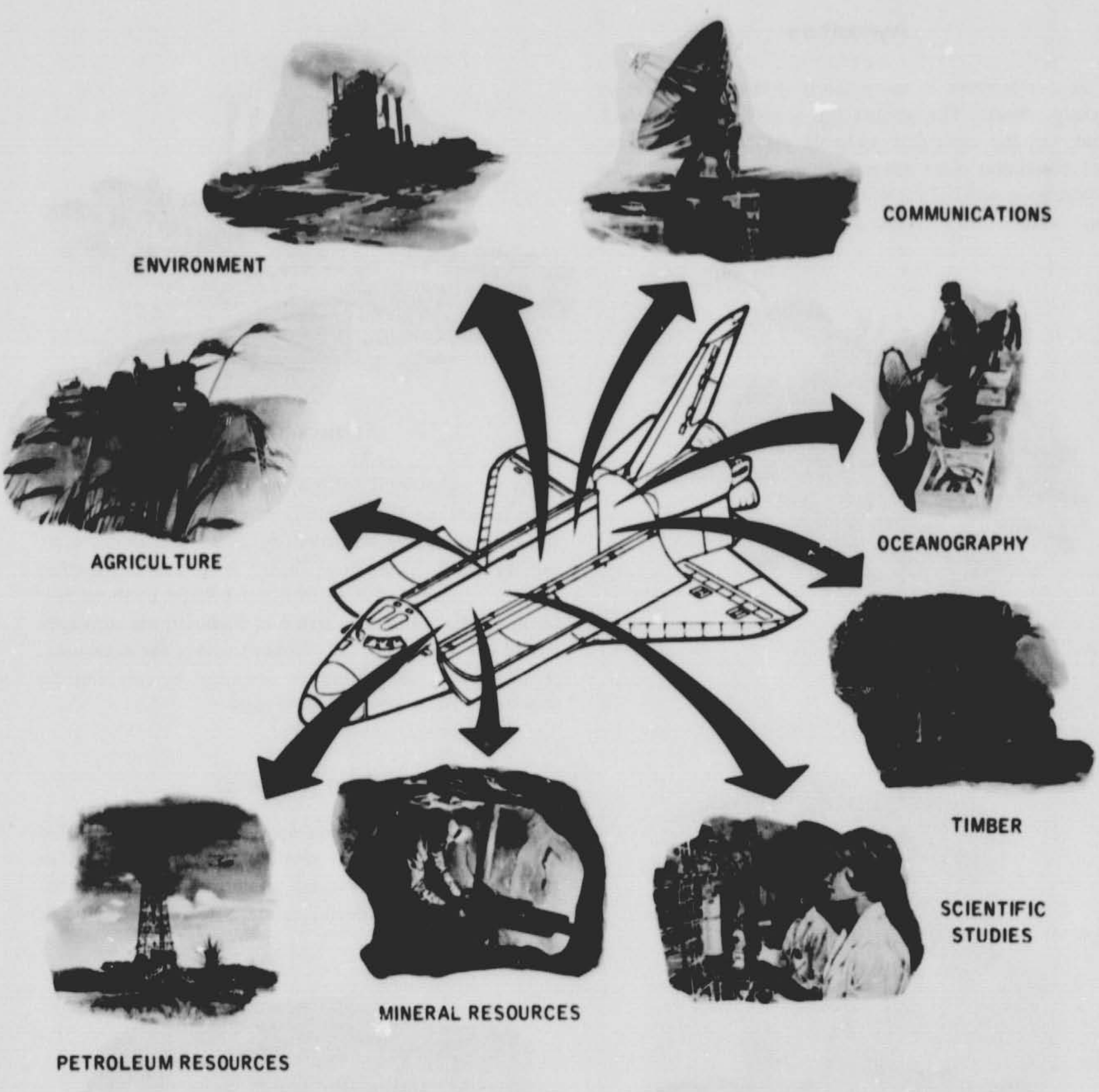




In industry, new materials and changed manufacturing processes have resulted from space-oriented research. Fireproof materials, for example, are constantly being improved to provide better protection (including facial covering) for firefighters.

Still in the experimental stage is the growing of crystals in space. The germanium selenide crystal shown was grown aboard Skylab and is about the size and shape needed for production of electronic devices. The experiment indicated that this type of production in space is feasible and provides data on the conditions under which products of this kind can be made.

These are just a few examples of the ways space research is affecting our daily lives in unexpected ways. And the list lengthens after every space venture.



EARTHLY PAYOFF TOMORROW

Man goes into space to explore the unknown – to increase our understanding of the past, present, and future of the universe and humanity's place in it. When the Space Shuttle becomes operational in 1980, it will be an important tool to provide mankind with information to help in managing and preserving our crowded Earth. Users of the versatile Shuttle system will include communication networks, research foundations, universities, observatories, federal departments and agencies, state agencies, county and city planners, public utilities, farm cooperatives, the medical profession, the fishing industry, the transportation industry, and power generation and water conservation planners.

Payloads launched by the Space Shuttle will provide practical data that will affect both the daily lives of people and the long-term future of mankind.

Agriculture

Sensor systems in space can help the world solve its food problems. The sensors can identify crops in each field, tell the vigor and probable yield of those crops, and determine plant diseases or insect infestation. This information will help agricultural specialists predict total food available on a worldwide basis.

Environment

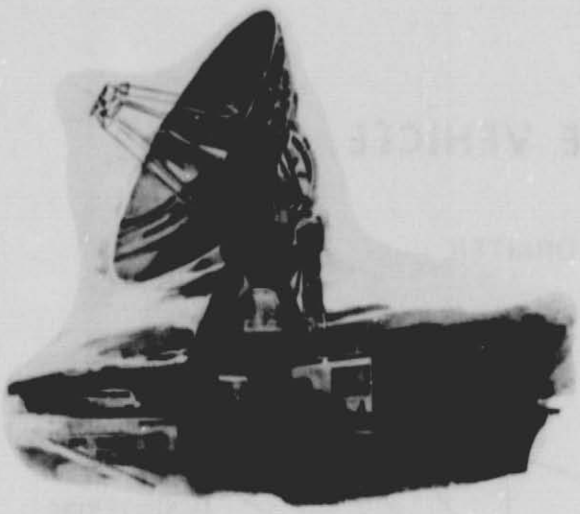
In environmental studies, satellites can send weather information to the ground, survey land use patterns, track air pollution and identify its source, monitor air quality, and locate oil slicks. A pollution-mapping satellite can cover the entire United States in about 500 photographs; cameras carried in high-altitude airplanes would use about 500 000 frames to cover the same area. What would take years to monitor by air can be monitored from space in a few days.

Petroleum Resources

Photographs of the Earth taken from space have already supported explorations of oil and natural gas around the world. The improved satellites of the Space Shuttle era will be able to locate new sources of fossil fuels.

Mineral Resources

Potentially large mineral deposits have been identified in many parts of the world as a result of Skylab photographs. The advanced satellites emplaced by the Space Shuttle are expected to make many more valuable mineral discoveries.

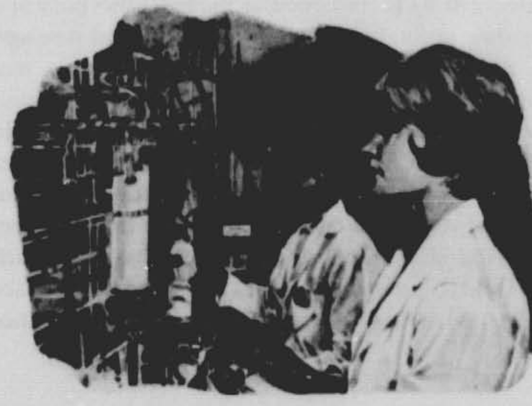


Communications

Communications satellites have made intercontinental television possible and are reducing the costs of transoceanic telephone calls. The costs will decrease again when the reusable Shuttle takes new and improved satellites into Earth orbit.

Scientific Studies

Shuttle is capable of taking into Earth orbit completely equipped scientific laboratories manned by scientists and technicians. In the weightless environment of space, researchers can perform many tasks that cannot be accomplished against the gravitational pull of Earth.



Oceanography

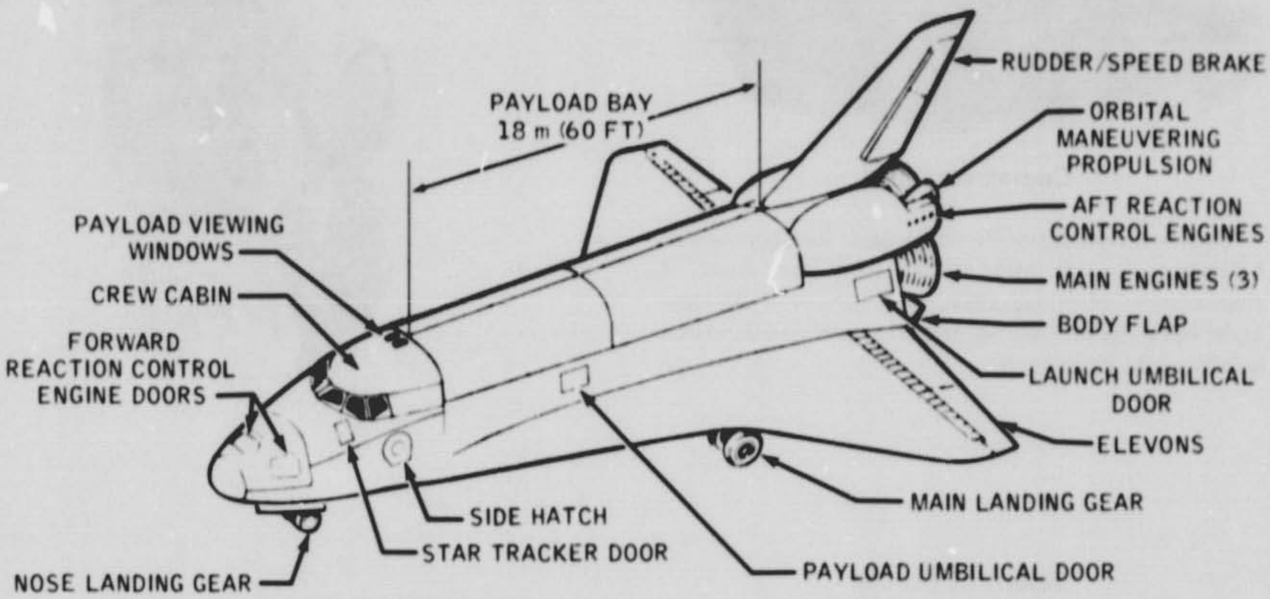
By mapping the ocean surface temperature, Earth resources satellites will help oceanographers understand current patterns. This, in turn, will enable fishing experts to predict the movements of schools of fish. Ice movements in the ocean can also be tracked from space.

Timber

Shuttle-launched satellites can help conserve our forest resources, especially in remote areas, by discovering fires, by detecting tree diseases and infestations of pests, and by providing accurate inventories of our timberlands.

SPACE SHUTTLE VEHICLE

SPACE SHUTTLE ORBITER

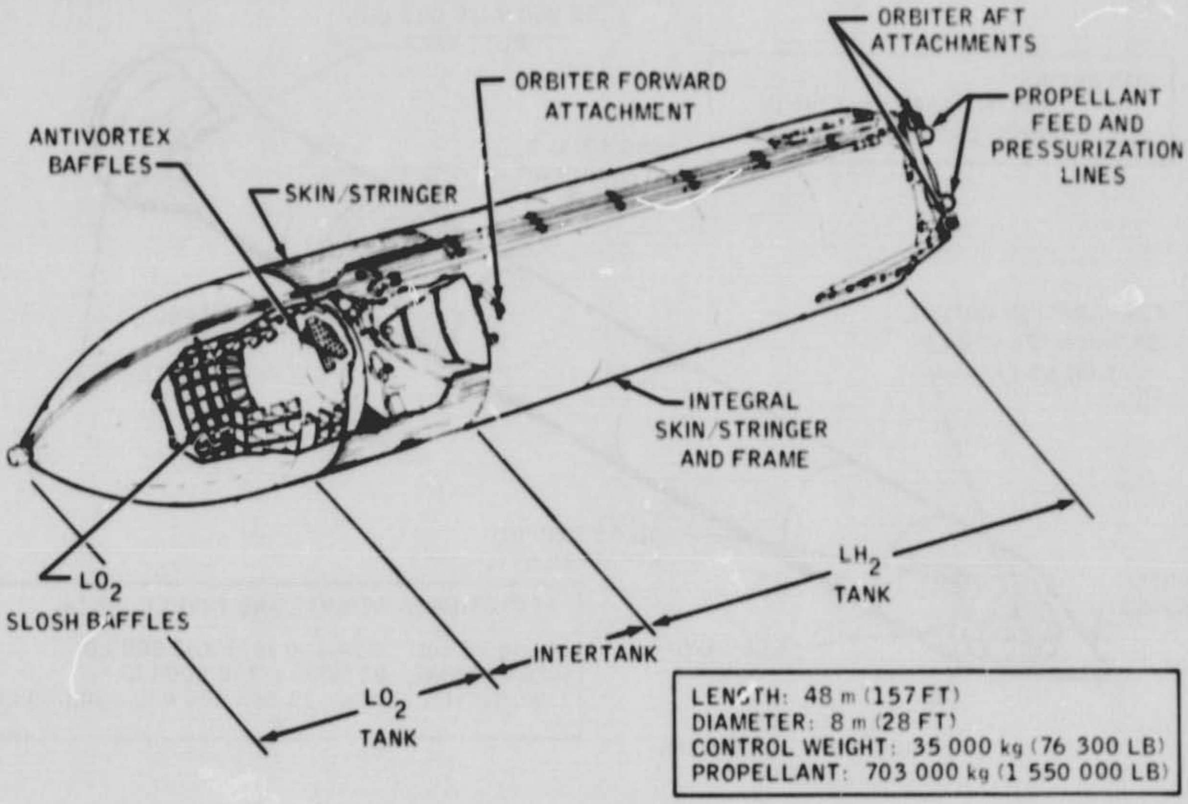


The Orbiter spacecraft contains the crew and payload for the Space Shuttle system. The Orbiter can deliver to orbit payloads of 29 500 kilograms (65 000 pounds) with lengths to 18 meters (60 feet) and diameters of 5 meters (15 feet). The Orbiter is comparable in size and weight to modern transport aircraft; it has a dry weight of approximately 68 000 kilograms (150 000 pounds), a length of 37 meters (122 feet), and a wingspan of 24 meters (78 feet).

The crew compartment can accommodate seven crewmembers and passengers for some missions (four is the baseline) but will hold as many as 10 persons in emergency operations.

The three main propulsion rocket engines used during launch are contained in the aft fuselage. The rocket engine propellant is contained in the external tank (ET), which is jettisoned before initial orbit insertion. The orbital maneuvering subsystem (OMS) is contained in two external pods on the aft fuselage. These units provide thrust for orbit insertion, orbit change, rendezvous, and return to Earth. 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 modification. In addition, the RCS, in conjunction with the Orbiter aerodynamic control surfaces, provides attitude control during reentry. The aerodynamic control surfaces provide control of the Orbiter at speeds less than Mach 5. The Orbiter is designed to land at a speed of 95 m/sec (185 knots), similar to current high-performance aircraft.

EXTERNAL TANK



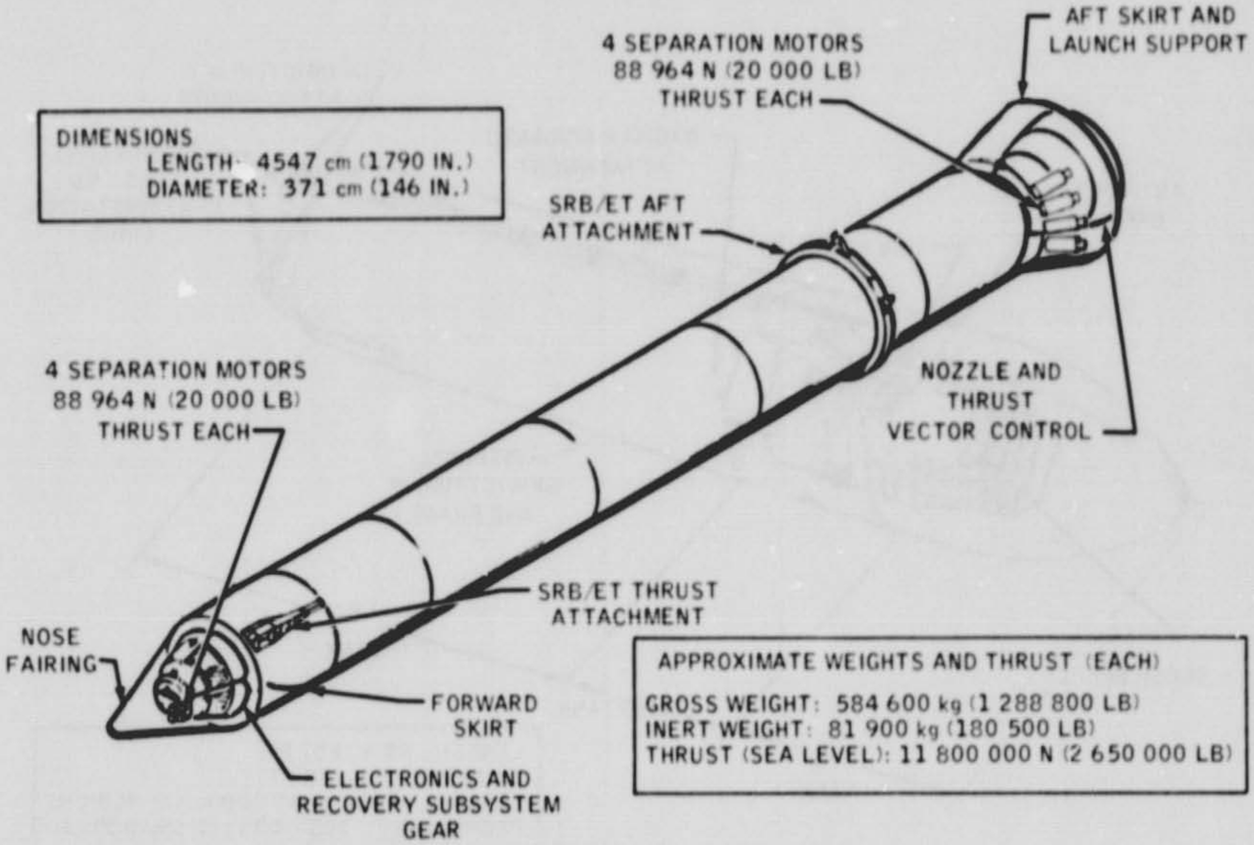
The external tank contains the propellants for the Orbiter main engines: liquid hydrogen (LH_2) fuel and liquid oxygen (LO_2) oxidizer. All fluid controls and valves (except the vent valves) for operation of the main propulsion system are located in the Orbiter to minimize throwaway costs. Antivortex and slosh baffles are mounted in the oxidizer tank to minimize liquid residuals and to damp fluid motion. Five lines (three for fuel and two for oxidizer) interface between the external tank and the Orbiter. All are insulated except the oxidizer pressurization line. An antigeyser line on the external tank provides LO_2 geyser suppression. Liquid-level point sensors are used in both tanks for loading control.

At lift-off, the external tank contains 703 000 kilograms (1 550 000 pounds) of usable propellant. The LH_2 tank volume is 1523 m^3 (53 800 ft^3) and the LO_2 tank volume is 552 m^3 (19 500 ft^3). These volumes include a 3-percent ullage provision. The hydrogen tank is pressurized to a range of 220 600 to 234 400 N/m^2 (32 to 34 psia) and the oxygen tank to 137 900 to 151 700 N/m^2 (20 to 22 psia).

Both tanks are constructed of aluminum alloy skins with support or stability frames as required. The sidewalls and end bulkheads use the largest available width of plate stock. The skins are butt-fusion-welded together to provide reliable sealed joints. The skirt aluminum structure uses skin/stringers with stabilizing frames. The primary structural attachment to the Orbiter consists of one forward and two rear connections.

Spray-on foam insulation (SOFI) is applied to the complete outer surface of the external tank, including the sidewalls and the forward bulkheads. SLA-561 spray-on ablator is applied to all protuberances, such as attachment structures, because shock impingement causes increased heating to these areas. The thermal protection system (TPS) coverage is minimized by using the heat-sink approach provided by the sidewalls and propellants.

SOLID ROCKET BOOSTERS



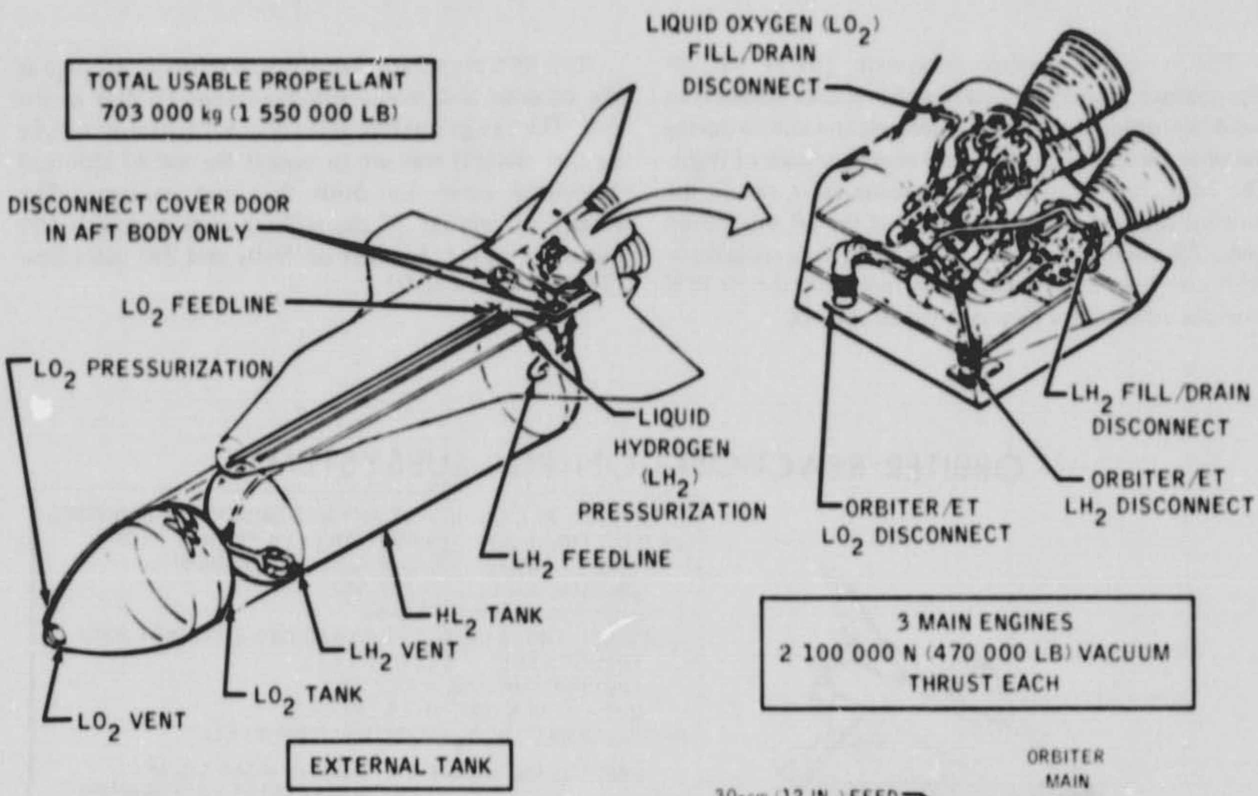
Two solid rocket boosters (SRB's) burn in parallel with the main propulsion system of the Orbiter to provide initial ascent thrust. Primary elements of the booster are the motor, including case, propellant, igniter, and nozzle; forward and aft structures; separation and recovery avionics; and thrust vector control subsystems. Each SRB weighs approximately 584 600 kilograms (1 288 800 pounds) and produces 11 800 000 newtons (2 650 000 pounds) of thrust at sea level. The propellant grain is shaped to reduce thrust approximately one-third 55 seconds after lift-off to prevent overstressing the vehicle during the period of maximum dynamic pressure. The grain is of conventional design, with a star-configured perforation in the forward casting segment and a truncated cone perforation in each of the segments and the aft closure. The contoured nozzle expansion ratio (area of exit to area of throat) is 7.16:1. The thrust vector control subsystem has a maximum omniaxial gimbal capability of slightly over 7° which, in conjunction with the Orbiter main engines, provides flight control during the Shuttle boost phase.

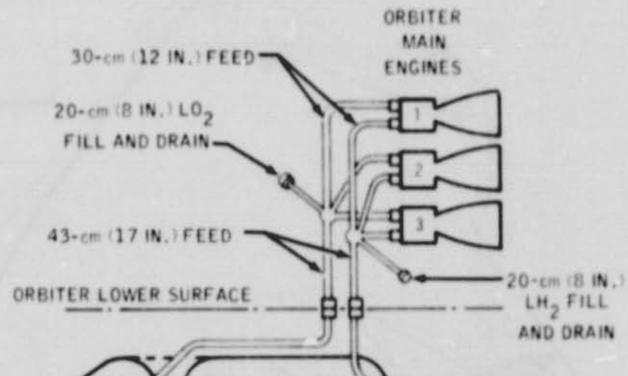
Maximum flexibility in fabrication and ease of transportation and handling are made possible by a segmented case design. Two lateral sway braces and a slide attachment at the aft frame provide the structural attachment between the SRB and the tank. The SRB is attached to the tank at the forward end of the forward skirt by a single thrust attachment. The pilot, drogue, and main parachute risers of the recovery subsystem are attached to the same thrust structure.

The SRB's are released by pyrotechnic separation devices at the forward thrust attachment and the aft sway braces. Eight separation rockets on each SRB (four aft and four forward) separate the SRB from the Orbiter and external tank.

The forward section provides installation space for the SRB electronics and recovery gear and for the forward separation rockets.

ORBITER MAIN PROPULSION





The Orbiter main propulsion engines burn for approximately 8 minutes. These two systems provide the velocity increment necessary to almost achieve the initial mission orbit. The final boost into the desired orbit is provided by the orbital maneuvering system.

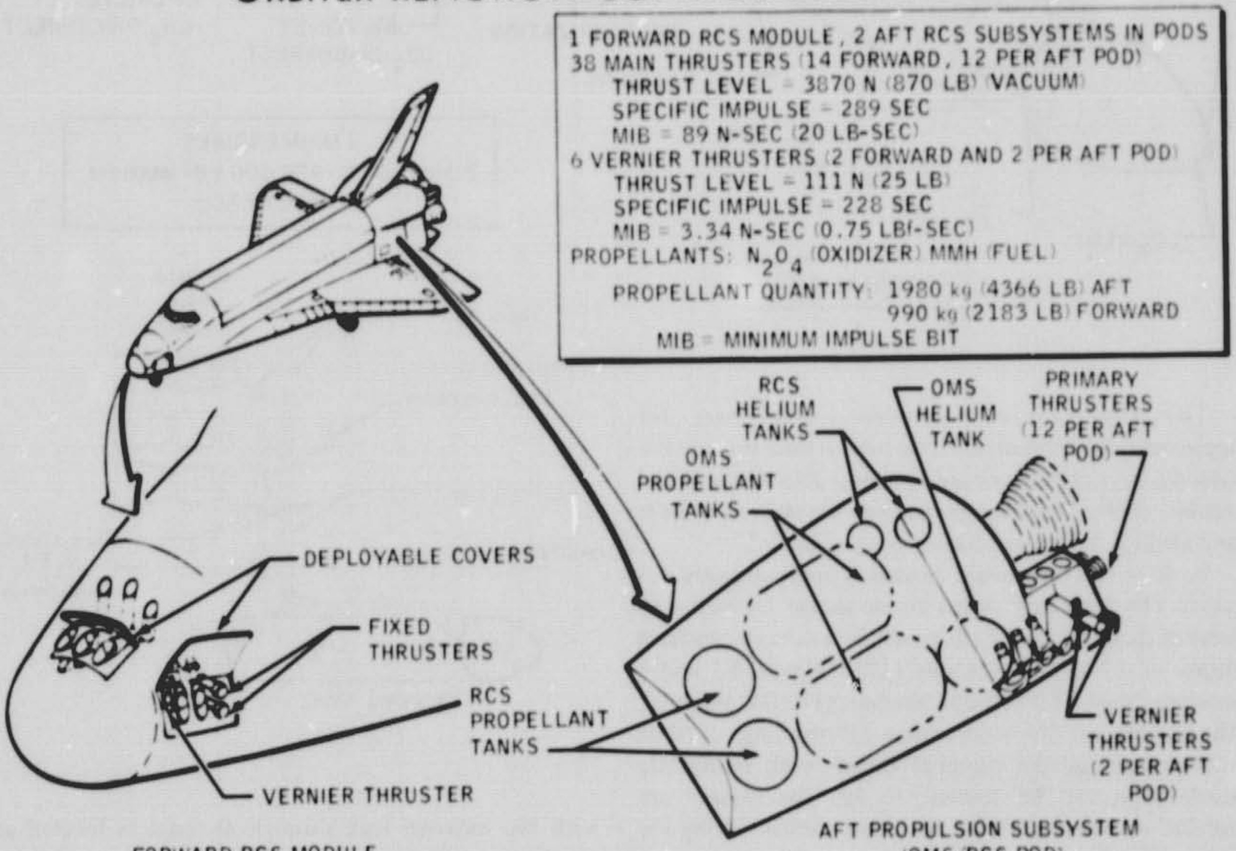
Each of the three main engines is approximately 4.3 meters (14 feet) long with a nozzle almost 2.4 meters (8 feet) in diameter, and each produces a nominal sea-level thrust of 1 668 100 newtons (375 000 pounds) and a vacuum thrust of 2 100 000 newtons (470 000 pounds). The engines are throttleable over a thrust range of 50 to 109 percent of the nominal thrust level, so Shuttle acceleration can be limited to 3g. The engines are capable of being gimbaled for flight control during the Orbiter boost phase.

The 603 300 kilograms (1 330 000 pounds) of liquid oxygen and 99 800 kilograms (220 000 pounds) of liquid hydrogen used during ascent are stored in the external tank. The propellant is expended before achieving orbit and the tank falls to the ocean after separating from the Orbiter. The fluid lines interface with the external tank through disconnects located at the bottom of the Orbiter aft fuselage. The hydrogen disconnects are mounted on a carrier plate on the left side of the Orbiter and the oxygen disconnects on the right side. These disconnect openings are covered by large doors immediately after tank separation from the Orbiter. Ground servicing is done through umbilicals on both sides of the aft fuselage.

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

The RCS propellants are nitrogen tetroxide (N_2O_4) as the oxidizer and monomethylhydrazine (MMH) as the fuel. The design mixture ratio of 1.6:1 (oxidizer weight to fuel weight) was set to permit the use of identical propellant tanks for both fuel and oxidizer. The propellant capacity of the tanks in each module is 609 kilograms (1343 pounds) of N_2O_4 and 381 kilograms (840 pounds) of MMH.

ORBITER REACTION CONTROL SUBSYSTEM

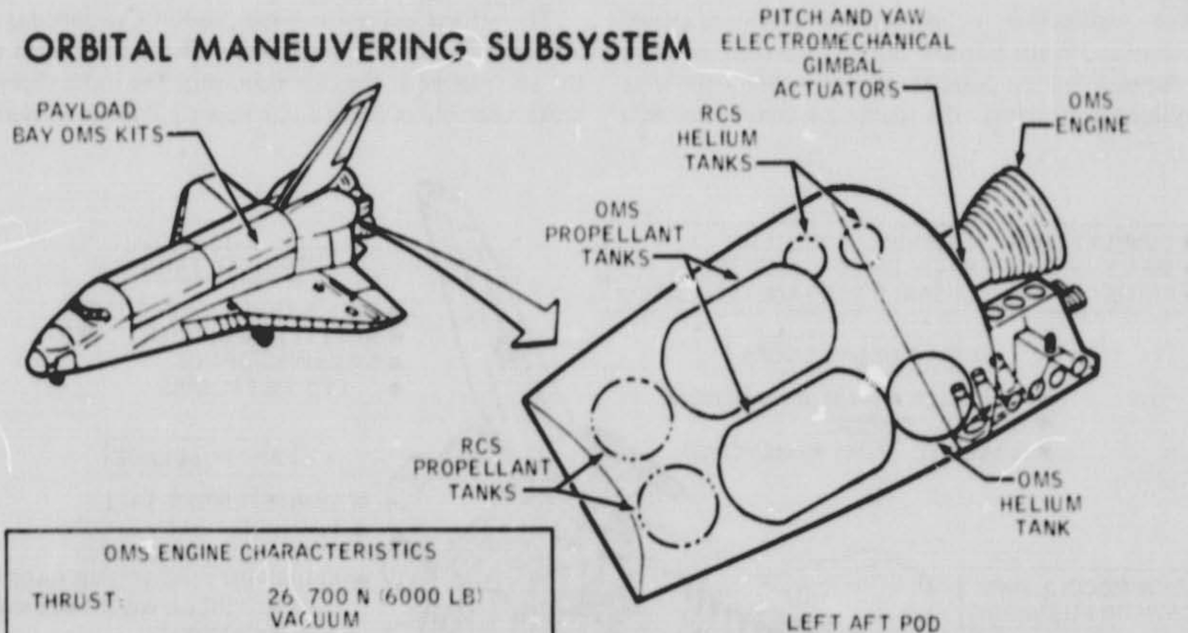


ORBITAL MANEUVERING SUBSYSTEMS

The orbital maneuvering 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 change in velocity of 305 m/sec (1000 ft/sec) when the vehicle carries a payload of 29 500 kilograms (65 000 pounds). A portion of this velocity change capacity is used during ascent. The 10 830 kilograms (23 900 pounds) of usable propellant, plus 420 kilograms (925 pounds) of residuals and losses, is contained in two pods, one on each side of the aft fuselage. Each pod contains a high-pressure helium storage bottle; tank pressurization regulators and controls; a fuel tank; an oxidizer tank; and a pressure-fed regeneratively cooled rocket engine. Each engine produces a vacuum thrust of 26 700 newtons (6000 pounds) at a chamber pressure of 861 850 N/m^2 (125 psia) and a specific impulse of 313 seconds.

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 RCS systems. In addition, propellant lines from the auxiliary OMS tanks in the Orbiter cargo bay (if carried as a mission kit) interconnect with the OMS propellant lines in each pod.

ORBITAL MANEUVERING SUBSYSTEM



OMS ENGINE CHARACTERISTICS	
THRUST:	26 700 N (6000 LB) VACUUM
SPECIFIC IMPULSE:	313 SEC
CHAMBER PRESSURE:	861 850 N/m^2 (125 PSIA)
MIXTURE RATIO:	1.65:1
GIMBAL CAPABILITY:	± 4° PITCH ± 8° YAW

OMS TANKAGE CAPACITY FOR 305 m/SEC (1000 FT/SEC) VELOCITY CHANGE -		
FUEL (MMH) WEIGHT:	4087 kg (9010 LB)	USABLE
OXIDIZER (N_2O_4) WEIGHT:	6743 kg (14 866 LB)	USABLE

ORBITER STRUCTURE SUBSYSTEM

The Orbiter structure is constructed primarily of aluminum protected by reusable surface insulation. The primary structural subassemblies are the crew module and forward fuselage, midfuselage and payload bay doors, aft fuselage and engine thrust structure, wing, and vertical tail.

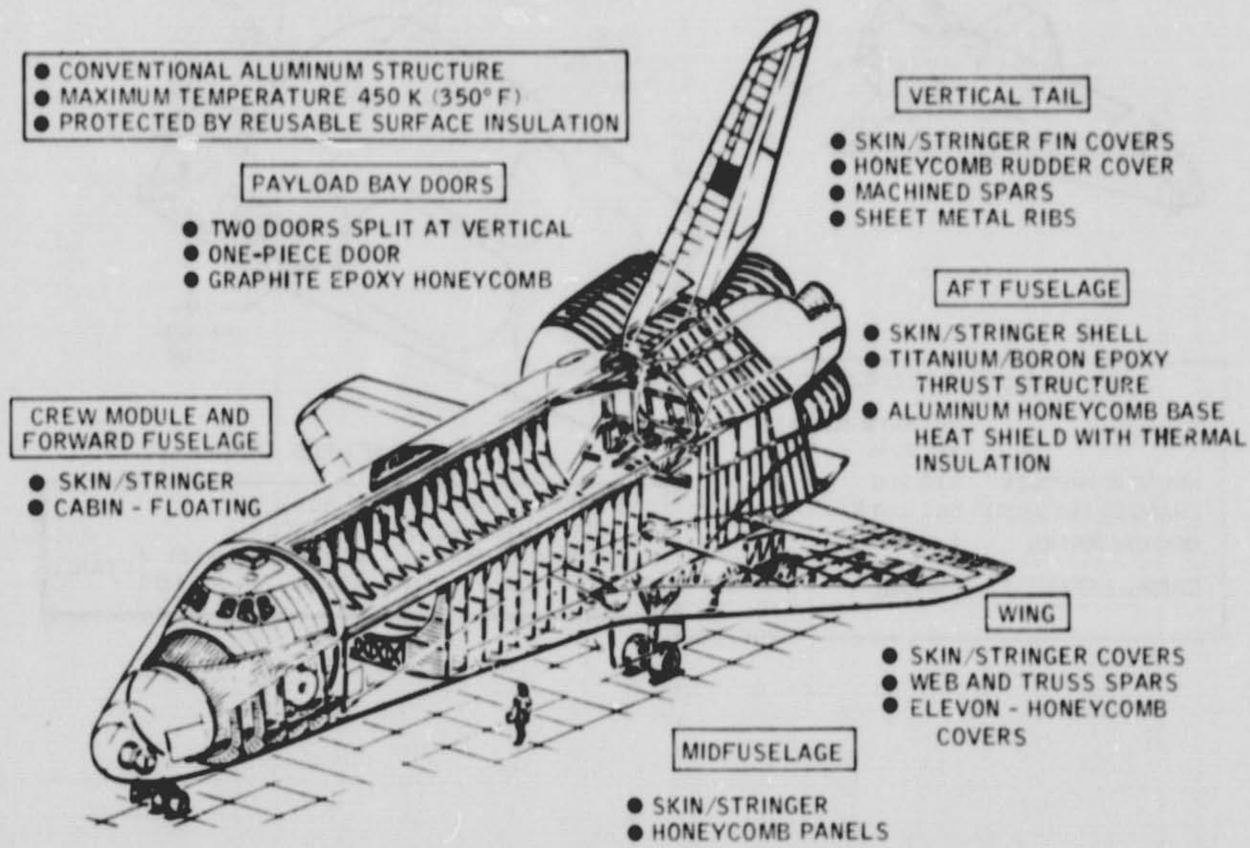
The crew module is machined aluminum alloy plate with integral stiffening stringers and internal framing and is welded to create a pressure-tight vessel. The module has a side hatch for normal ingress and egress, a hatch into the airlock from the crew living deck, and a hatch from the airlock into the payload bay. The forward fuselage structure is aluminum alloy skin/stringer panels, frames, and bulkheads. The window frames are machined parts attached to the structural panels and frames.

The midfuselage is an integral machined panel structure and is the primary carrying structure between the forward and aft fuselage; it also includes the wing carrythrough structure. 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 midfuselage consists of structural payload bay doors, hinged along the side and split at the top centerline.

The main engine thrust loads to the midfuselage and external tank are carried by the aft fuselage structure. This structure is an aluminum integral machined panel and includes a truss-type internal titanium structure reinforced with boron epoxy. A honeycomb-base aluminum heat shield with insulation at the rear protects the main engine systems.

The wing is constructed with corrugated spar web, truss-type ribs, and riveted skin/stringer covers of aluminum alloy. The elevons are constructed of aluminum honeycomb.

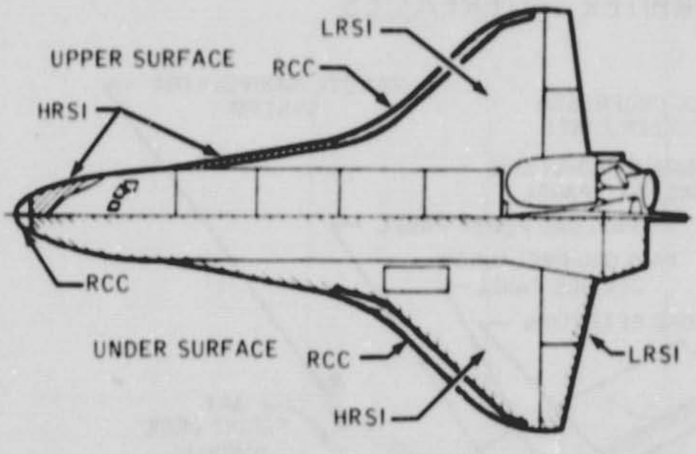
The vertical tail is a two-spar, multirib, stiffened-skin box assembly of aluminum alloy. The tail is bolted to the aft fuselage at the two main spars. The rudder/speed brake assembly is divided into upper and lower sections.



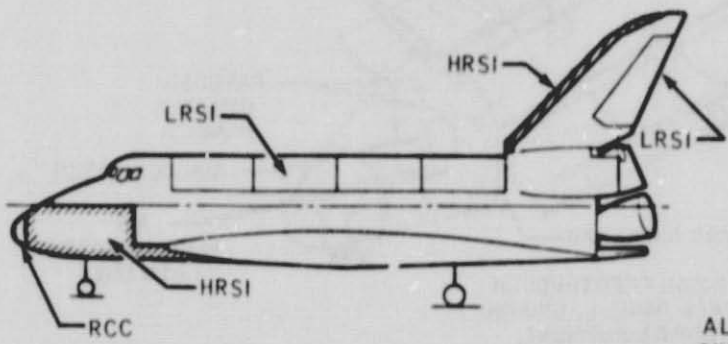
ORBITER THERMAL PROTECTION SYSTEM

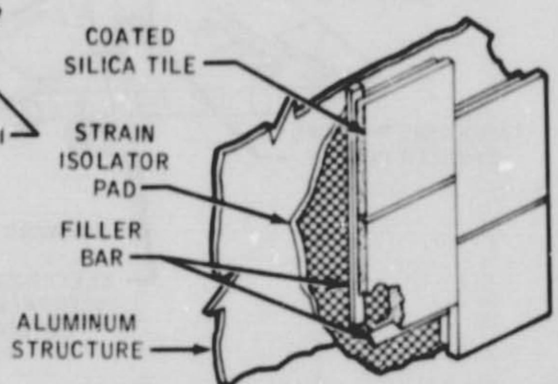
The thermal protection subsystem (TPS) consists of materials applied externally to the primary structural shell of the Orbiter vehicle to maintain the airframe within acceptable temperature limits. The TPS is composed of two types of reusable surface insulation (RSI), a high-temperature structure coupled with internal insulation, thermal window panes, and thermal seals to protect against aerodynamic heating.

The Orbiter is predominantly covered by RSI made of coated silica tile. The two types of RSI differ only physically to provide protection for different temperature regimes. The low-temperature reusable surface insulation (LRSI) is 20-centimeter (8 inch) square silica tiles and covers the top of the vehicle where temperatures are less than 925 K (1200° F). The high-temperature reusable surface insulation (HRSI) is 15-centimeter (6 inch) square silica tiles and covers the bottom and some leading edges of the Orbiter where temperatures are below 1500 K (2300° F). A high-temperature structure of reinforced carbon-carbon (RCC) is used with internal insulation for the nose cap and wing leading edges where temperatures are greater than 1500 K (2300° F).



INSULATION	AREA	MAXIMUM DESIGN TEMPERATURE
LRSI	603 m^2 (6488 FT^2)	900 K (1200° F)
HRSI	434 m^2 (4670 FT^2)	1300 K (2300° F)
RCC	38 m^2 (409 FT^2)	1800 K (2800° F)
TOTAL	1075 m^2 (11 567 FT^2)	---





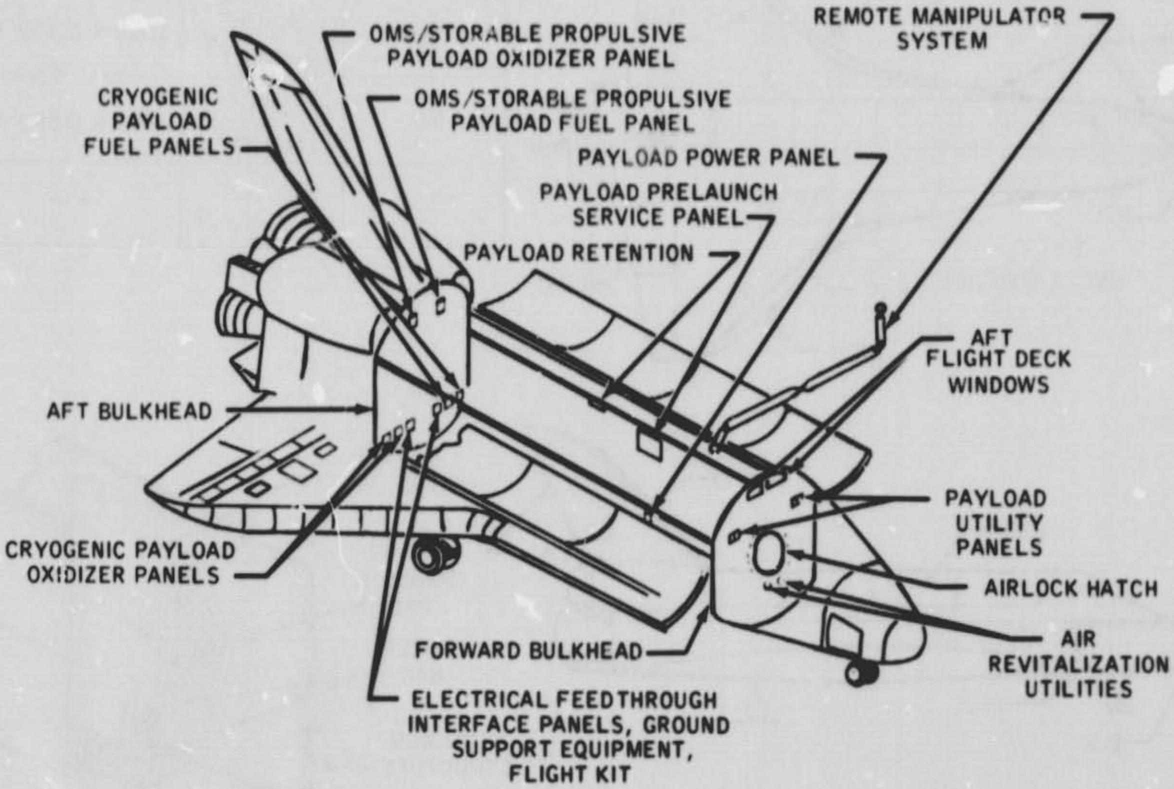
TYPICAL TILE INSTALLATION

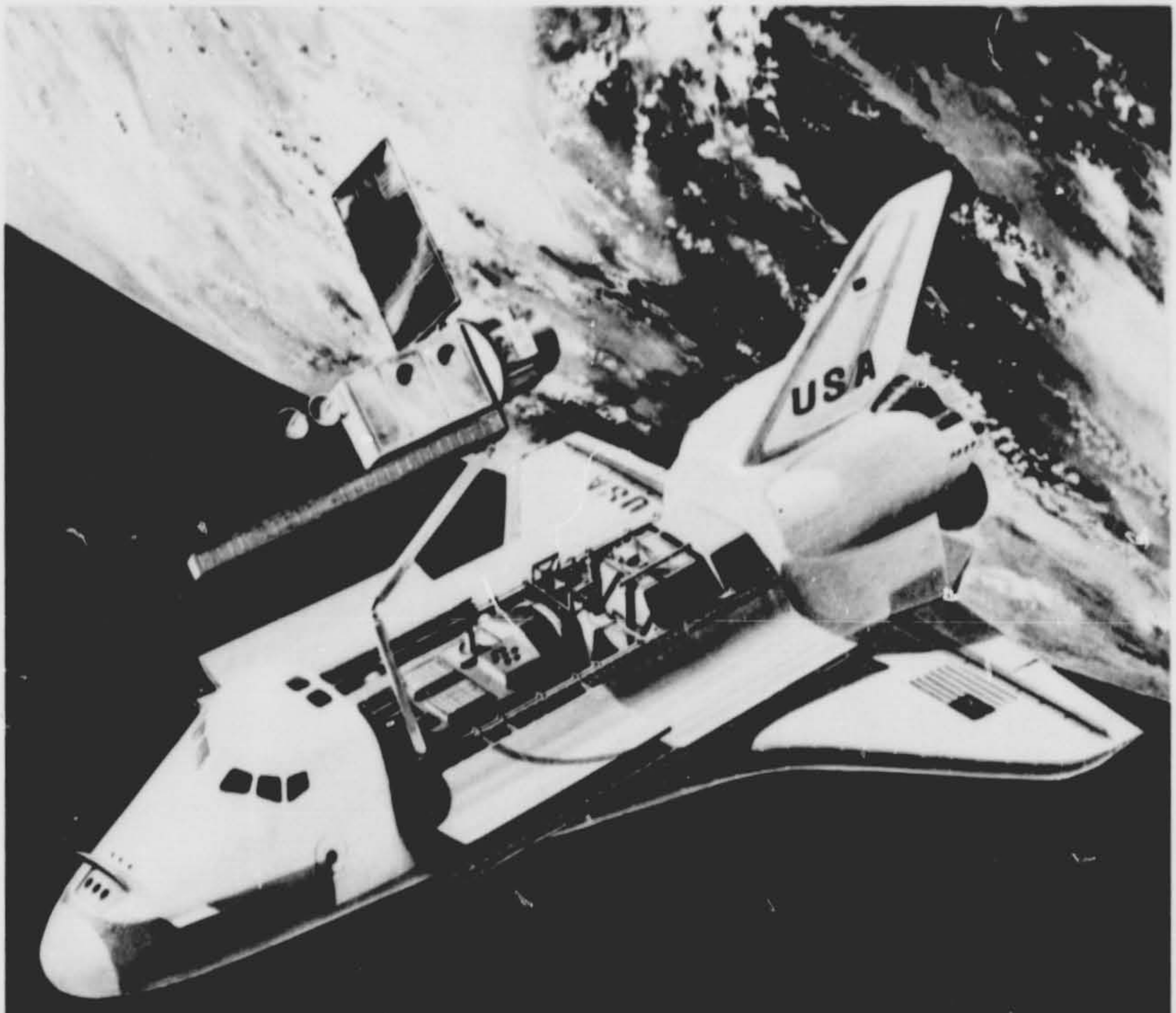
PAYLOAD ACCOMMODATIONS

The Orbiter systems are being designed to handle various payloads and to support a variety of payload functions. The payload and mission specialist stations on the flight deck provide command and control facilities for payload operations required by the cognizant scientist (the user). Remote-control techniques can be employed from the ground when desirable. The Spacelab payload provides additional command and data management capability plus a work area in the payload bay for the payload specialists. The crew will be able to use a manipulator to handle complete payloads or selected packages.

The manipulator arm, complemented by the television display system, allows the payload operator to transfer experiment packages and cargo in and out of the Orbiter bay, to place into orbit spacecraft carried up by the Shuttle, and to inspect retrieved orbital spacecraft. The system can also aid in inspection of critical areas on the vehicle exterior, such as the heat shield.

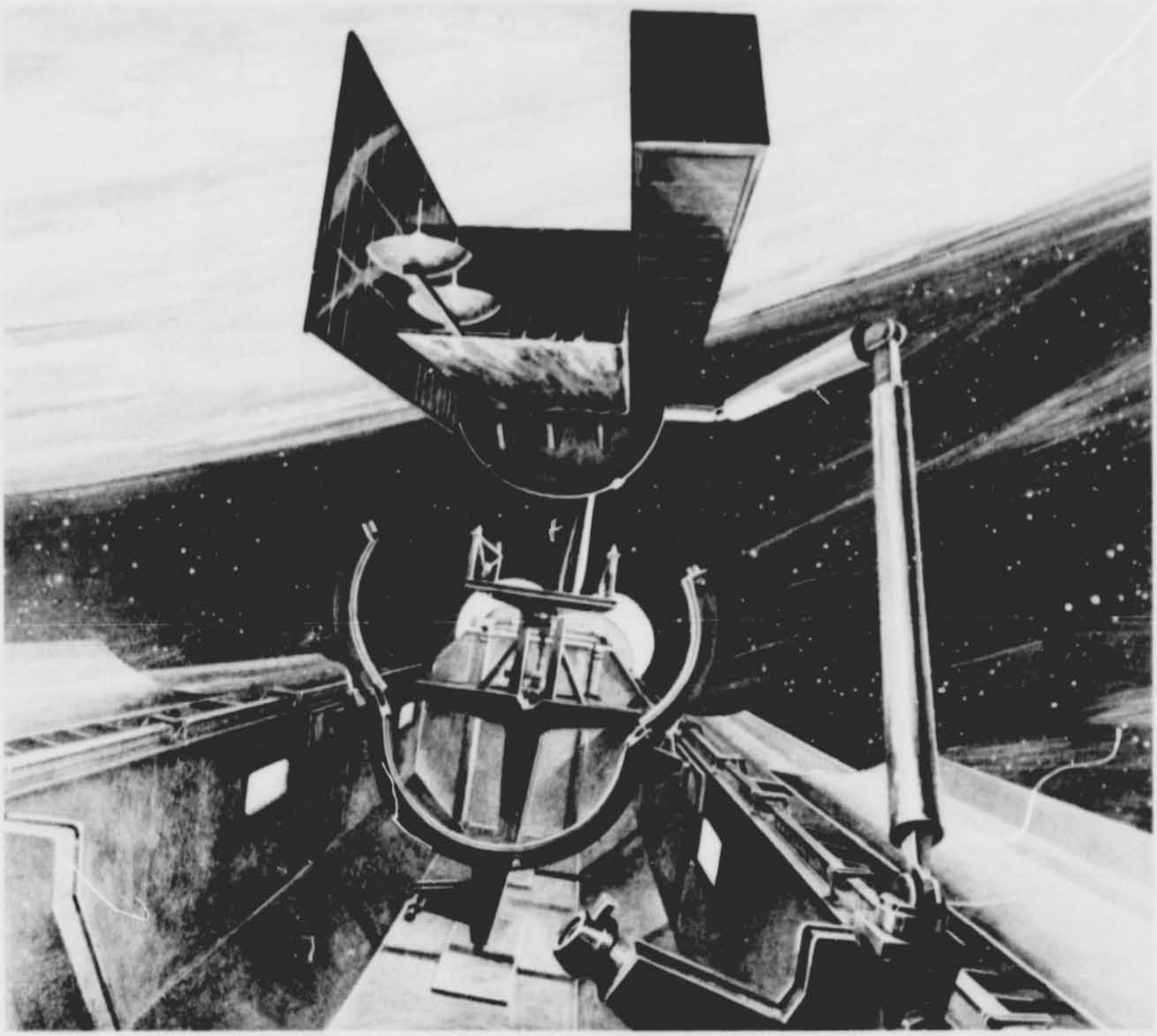
PAYLOAD/ORBITER INTERFACES





SUPPORTING SUBSYSTEMS FOR PAYLOADS

- PAYLOAD ATTACHMENTS
- REMOTE MANIPULATOR HANDLING SYSTEM
- ELECTRICAL POWER/FLUID/GAS UTILITIES
- ENVIRONMENTAL CONTROL
- COMMUNICATIONS, DATA HANDLING, AND DISPLAYS
- GUIDANCE AND NAVIGATION
- MISSION KITS



PAYLOAD HANDLING

The deployment and retrieval of payloads are accomplished by using the general-purpose remote manipulator system. Payload retrieval involves the combined operations of rendezvous, stationkeeping, and manipulator arm control. One manipulator arm is standard equipment on the Orbiter and may be mounted on either the left or right longeron. A second arm can be installed and controlled separately for payloads requiring handling with two manipulators. Each arm has remotely controlled television and lights to provide side viewing and depth perception. Lights on booms and side bulkheads provide appropriate illumination levels for any task that must be performed in the payload bay.

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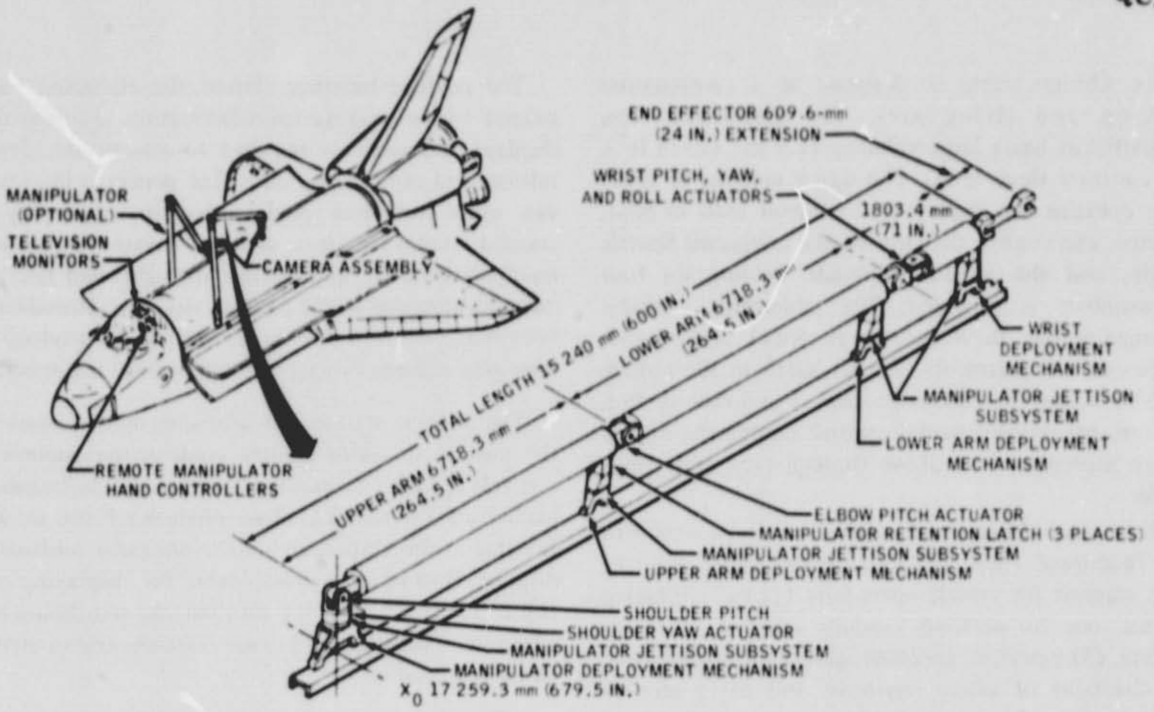
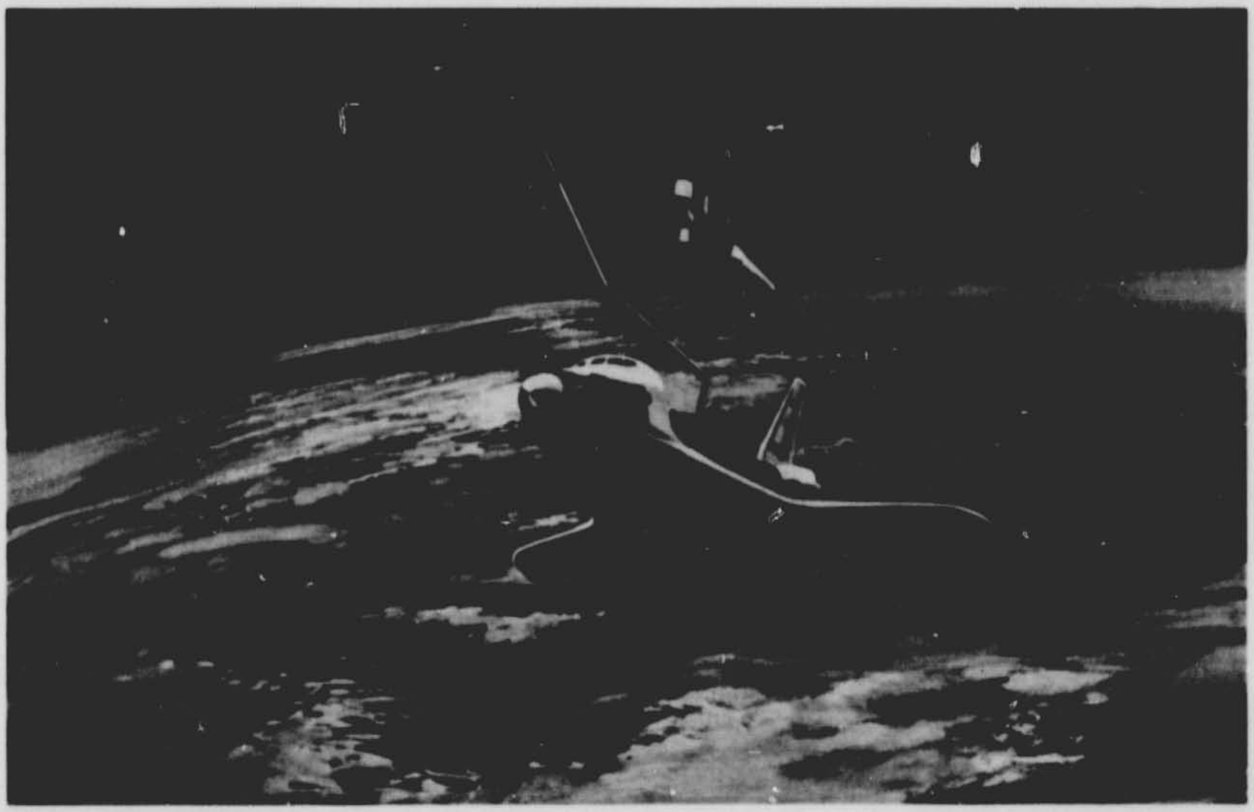
PAYLOAD DEPLOYMENT/RETRIEVAL MECHANISM





CREW CABIN AND CREW ACCOMMODATIONS

The Orbiter cabin is designed as a combination working and living area. The pressurized crew compartment has a large volume, 71.5 m^3 (2525 ft^3), and contains three levels. The upper section, or flight deck, contains the displays and controls used to pilot, monitor, and control the Orbiter, the integrated Shuttle vehicle, and the mission payloads. Seating for four crewmembers is provided. The midsection contains passenger seating, the living area, an airlock, and avionics equipment compartments. An aft hatch in the airlock provides access to the cargo bay. The lower section contains the environmental control equipment and is readily accessible from above through removable floor panels.

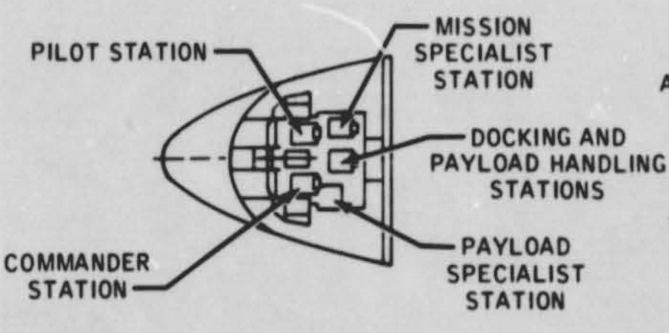
Flight deck displays and controls are organized into four functional areas: (1) two forward-facing primary flight stations for vehicle operations, (2) two aft-facing stations, one for payload handling and the other for docking, (3) a payload specialist station for management and checkout of active payloads, and (4) a mission specialist station for Orbiter subsystem/payload interface, power, and communications control in the remaining flight deck area.

The forward-facing primary flight stations are organized in the usual pilot-copilot relationship, with duplicated controls that permit the vehicle to be piloted from either seat or returned to Earth by one crewmember in an emergency. Manual flight controls include rotation and translation hand controllers, rudder pedals, and speed brake controllers at each station.

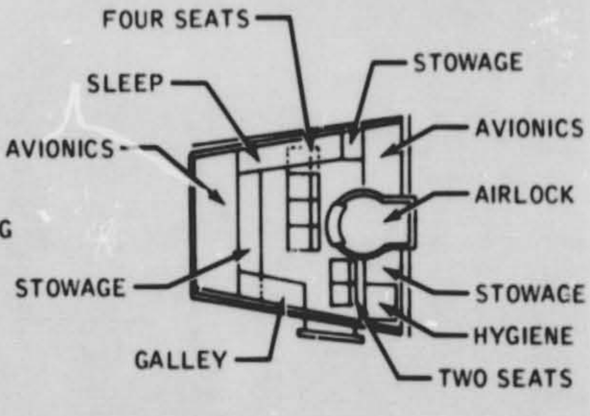
The payload handling station, the aft-facing station nearest to the payload specialist station, contains those displays and controls required to manipulate, deploy, release, and capture payloads. The person at this station can open and close payload bay doors; deploy the coolant system radiators; deploy, operate, and stow the manipulator arms; and operate the lights and television cameras mounted in the payload bay. Two closed-circuit television monitors display video from the payload bay television cameras for monitoring payload manipulation.

The docking station, the aft-facing station nearest to the mission specialist station, contains the displays and controls required to execute Orbiter attitude/translation maneuvers for terminal-phase rendezvous and docking. Located at this station are rendezvous radar controls and displays (including a crosspointer for displaying pitch and roll angles and rates), rotation and translation hand controllers, flight control mode switches, and an attitude director indicator.

The payload specialist station, just aft and to the left of the commander's station, includes a 2-square-meter (20 square foot) surface area for installing displays and controls unique to a specific payload. A cathode ray tube (CRT) display and keyboard may be added for communication with payloads through the Orbiter data processing subsystem. Standardized electrical interfaces are provided for payload power, monitoring, command, and control. Forced-air cooling can be provided for equipment requiring heat removal.

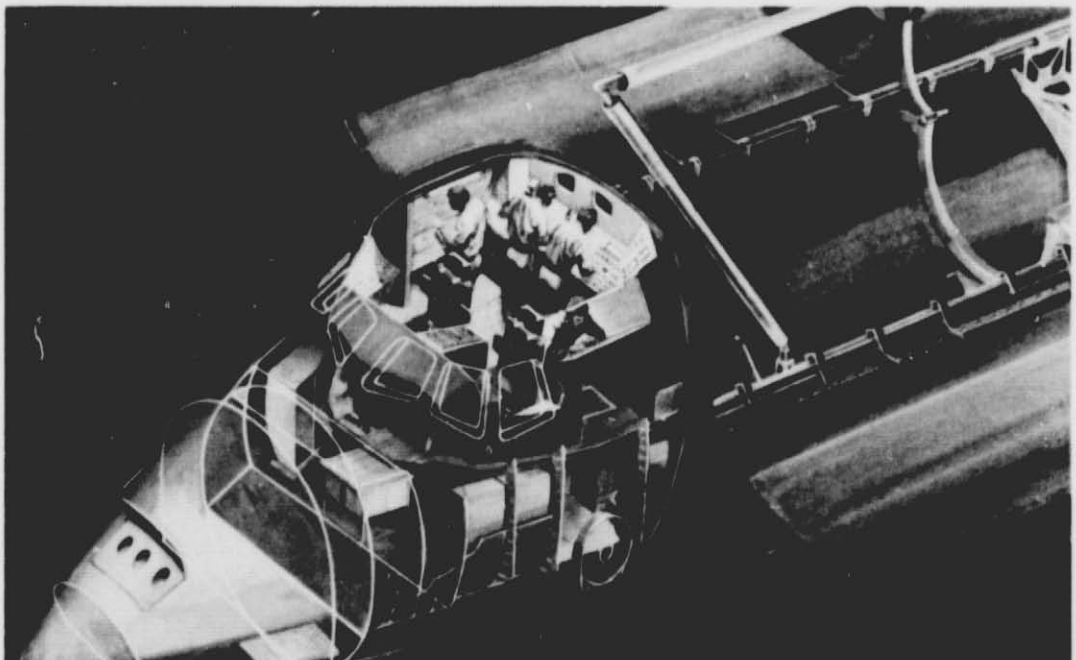


FLIGHT SECTION

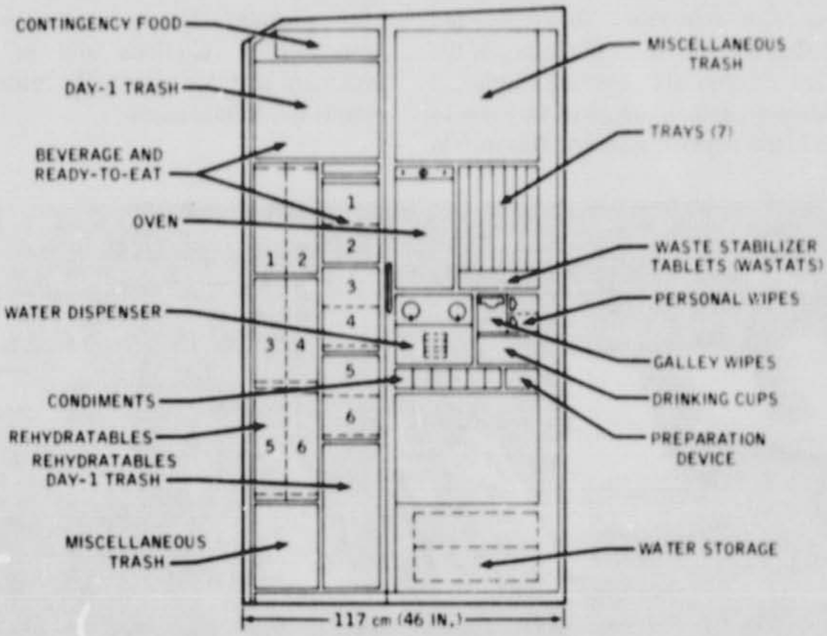


MIDSECTION

The mission specialist station, just aft and to the right of the pilot's station, contains the displays and controls required to manage Orbiter/payload interfaces and payload subsystems that are critical to the safety of the Orbiter. An auxiliary caution and warning display is provided at this station to detect and alert the crew to critical malfunctions in the payload systems. This station is equipped to monitor, command, control, and communicate with attached or detached payloads. It also provides for the management of on-orbit housekeeping functions and of Orbiter subsystem functions that are not flight critical and that do not require immediate access.



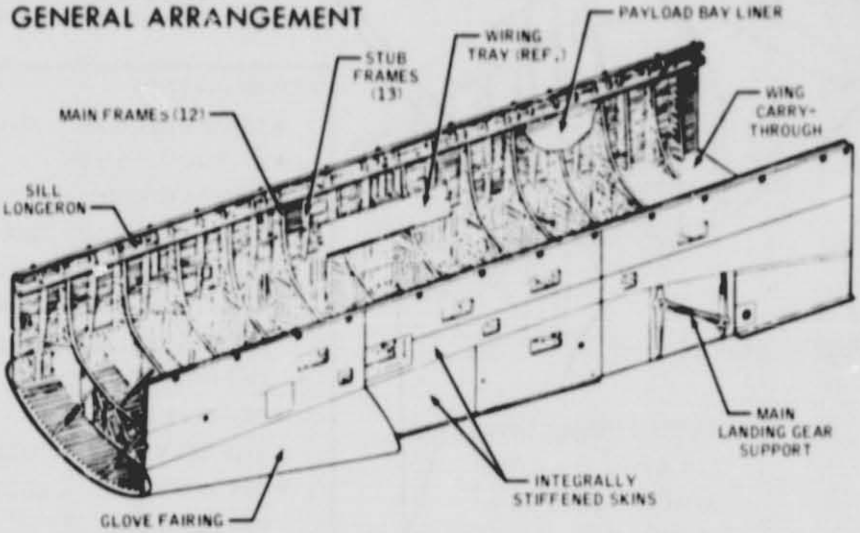
GALLEY DETAILS



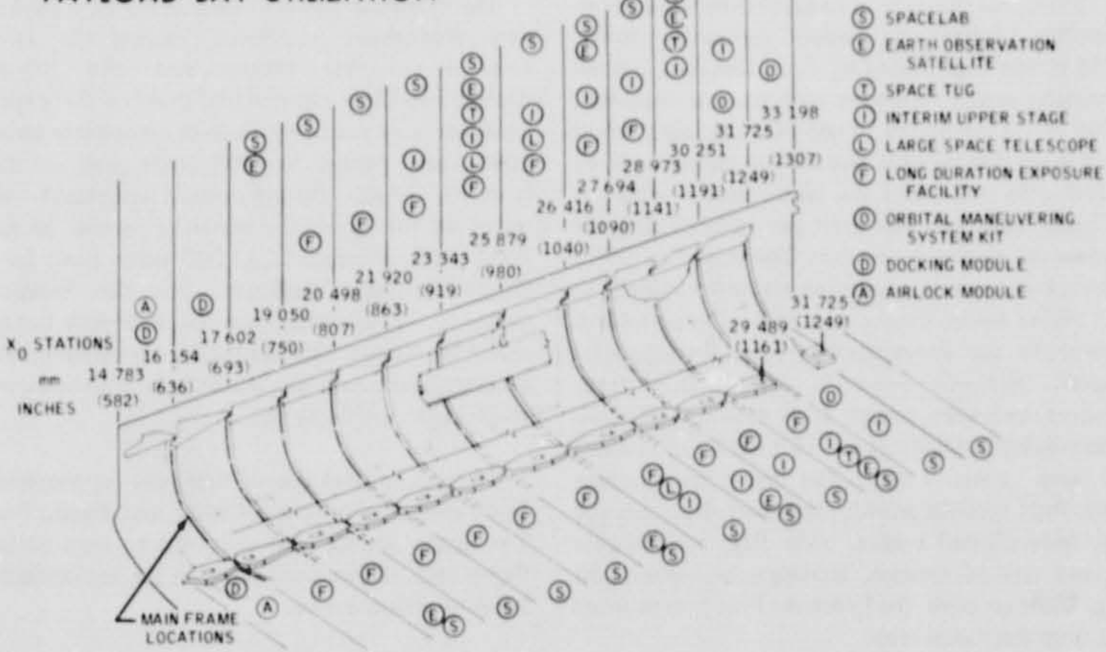
PAYLOAD ATTACHMENTS

Numerous attachment points along the sides and bottom of the 18-meter (60 foot) payload bay provide places for the many payloads to be accommodated. Thirteen primary attachment points along the sides accept longitudinal and vertical loads. There are twelve positions along the keel that take lateral loads. The proposed design of the standard attachment fitting includes adjustment capability to adapt to specific payload weight distributions in the bay.

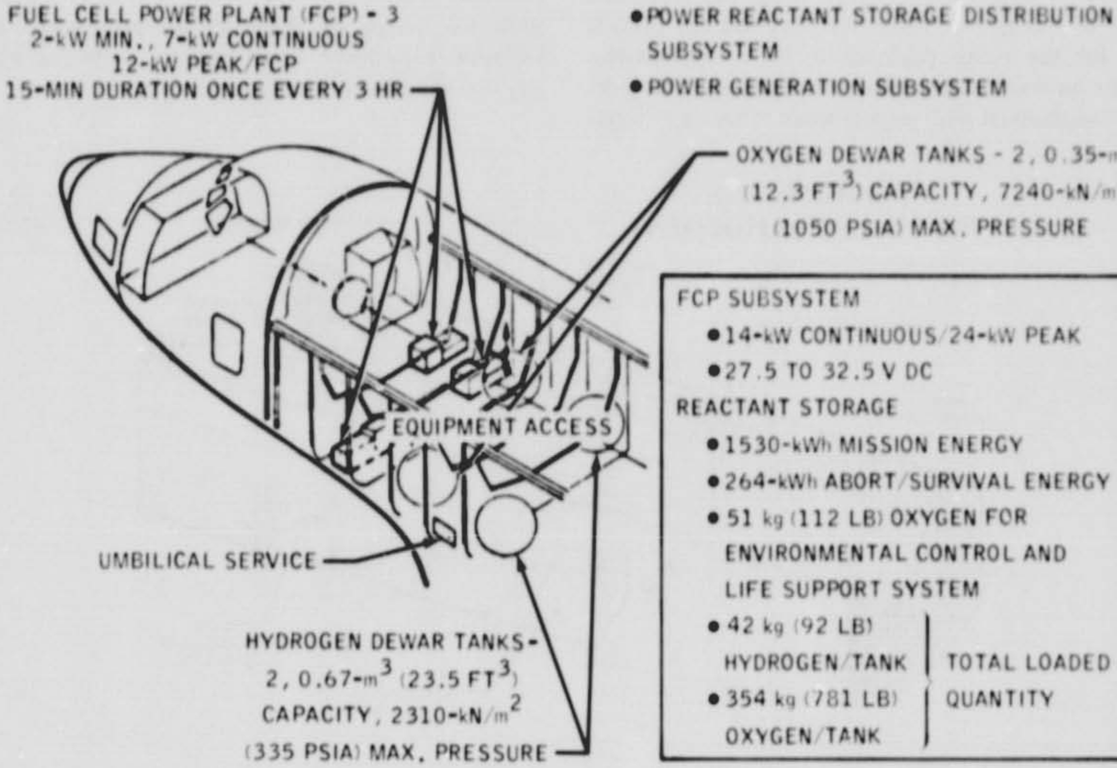
MIDFUSELAGE GENERAL ARRANGEMENT



PAYLOAD BAY UTILIZATION



POWER SYSTEMS

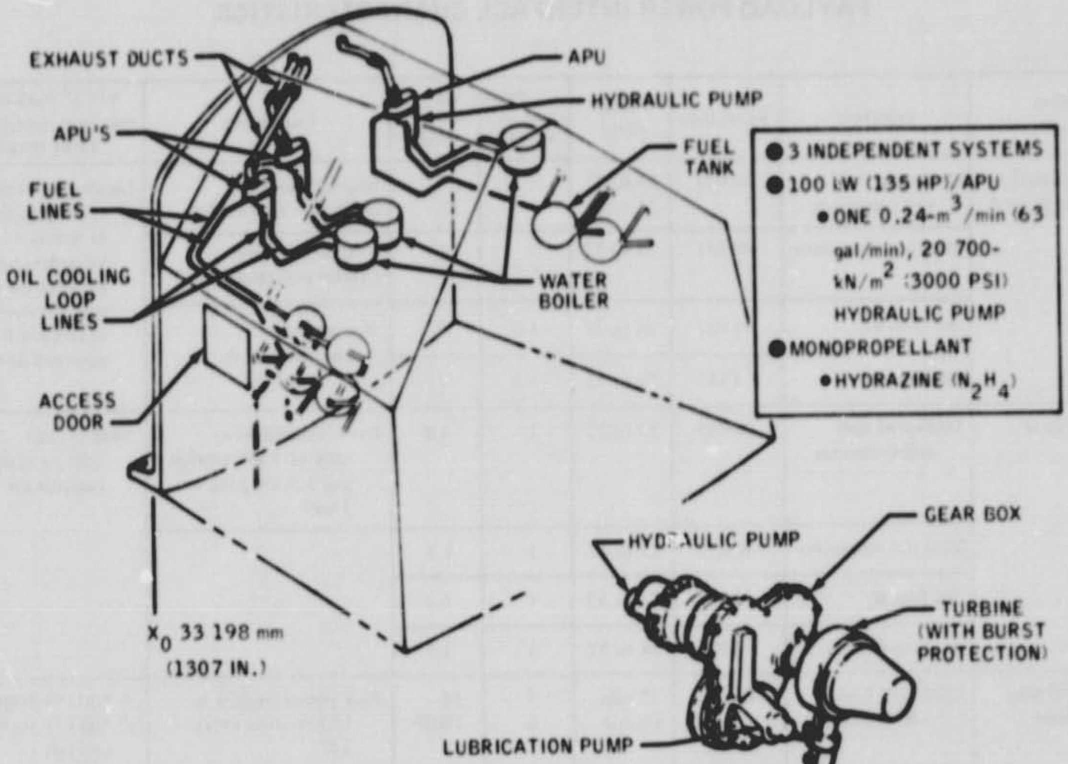


The Orbiter has one system to supply electrical power and another system to supply hydraulic power. Electrical power is generated by three fuel cells that use cryogenically stored hydrogen and oxygen reactants. Each fuel cell is connected to one of three independent electrical buses. During peak and average power loads, all three fuel cells and buses are used; during minimum power loads, only two fuel cells are used but they are interconnected to the three buses. The third fuel cell is shut down but can be reconnected within 15 minutes to support higher loads. Excess heat from the fuel cells is transferred to the Freon cooling loop through heat exchangers. Hydraulic power is derived from three independent hydraulic pumps, each driven by its own hydrazine-fueled auxiliary power unit (APU) and cooled by its own water boiler. The three independent hydraulic fluid systems provide the power to actuate the elevons, rudder/speed brakes, body flap, main engine gimbal and control systems, landing gear brakes, and steering. While on orbit, the hydraulic fluid is kept warm by heat from the Freon loop.

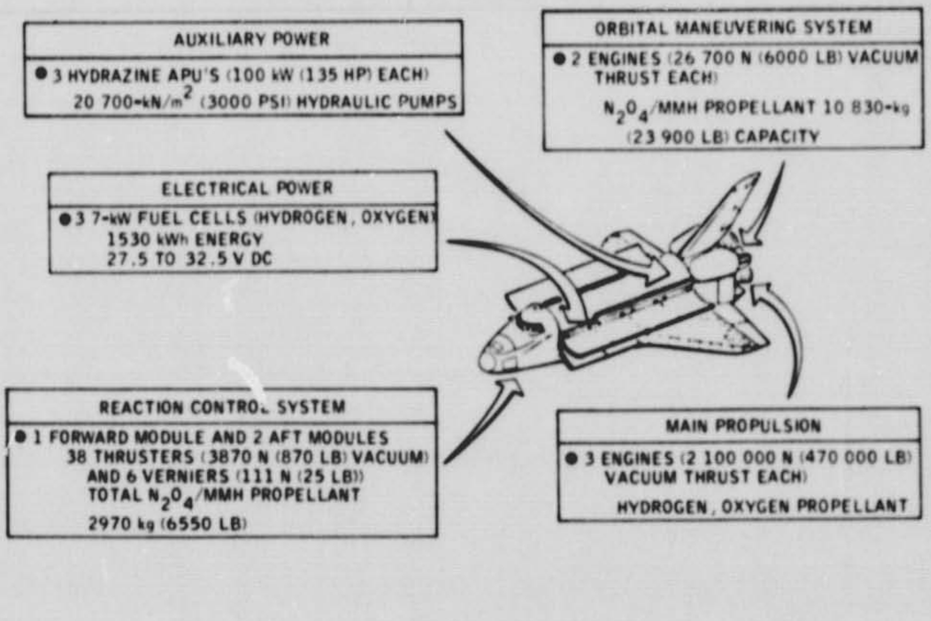
The electrical power requirements of a payload will vary throughout a mission. During the 10-minute launch-to-orbit phase and the 30-minute deorbit-to-landing phase when most of the experiment hardware is in a standby mode or completely turned off, 1000 watts average to 1500 watts peak are available from the Orbiter. During payload equipment operation on orbit, the capability exists to provide as much as 7000 watts 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. Mission kits containing consumables for 840 kilowatt-hours each are available in quantities required according to the flight plan.

The operational use of fuel cells for manned space flight evolved during the Gemini and Apollo Programs. The Space Shuttle fuel cells will be serviced between flights and reflown until each one has accumulated 5000 hours of online service.

AUXILIARY POWER UNIT SUBSYSTEM



ORBITER SUBSYSTEM SUMMARY PROPULSION AND POWER



PAYLOAD POWER INTERFACE CHARACTERISTICS

Mission phase	Interface	X_0 station	Voltage range	Power, kW		Comments	ATCS[a] payload heat rejection configuration, kJ/hr (Btu/hr)
				Average	Peak		
Ground operation (ground power)	Dedicated fuel cell connector	≈695	24 to 32 27 to 32	3 7	4 12	Normal checkout Orbiter powered down	Limited to 5486 kJ/hr (5200 Btu/hr) with or without radiator kit unless payload has GSE connection for cooling or Orbiter is powered down
	Main bus connector	≈695	24 to 32	3 5	4 8	Normal checkout Orbiter powered down	
	Aft (bus B)	1307	24 to 32	1.5	2	May be used simultaneously	
	Aft (bus C)	1307	24 to 32	1.5	2		
Ascent/descent	Dedicated fuel cell connector	≈695	27 to 32	1	1.5	Power limited to a total of 1 kW average and 1.5 kW peak for 2 min	5486 (5200) with or without radiator kit
	Main bus connector	≈695	27 to 32	1	1.5		
	Aft (bus B)	1307	24 to 32	1	1.5		
	Aft (bus C)	1307	24 to 32	1	1.5		
On-orbit payload operations	Dedicated fuel cell connector	≈695	27 min. (max.)	7 6	12 TBD[b]	Peak power limited to 15 min once every 3 hr	31 100 (29 500) (kit) 22 700 (21 500) (no kit)
	Main bus connector	≈695	27 to 32	5	8		
	Aft (bus B)	1307	24 to 32	1.5	2	Power may be utilized from both interfaces simultaneously; buses must be isolated on the payload side of the interface	22 700 or 31 100 (21 500 or 29 500)
	Aft (bus C)	1307	24 to 32	1.5	2		

[a]Active thermal control subsystem.

[b]To be determined.

ENVIRONMENTAL CONTROL

Cooling services are provided to payloads by the Space Shuttle. Ground support equipment provides a selectable temperature range during prelaunch activities. After the Orbiter lands, ground support equipment similar to airline support hardware is connected to the cabin and payload bay to control temperature levels.

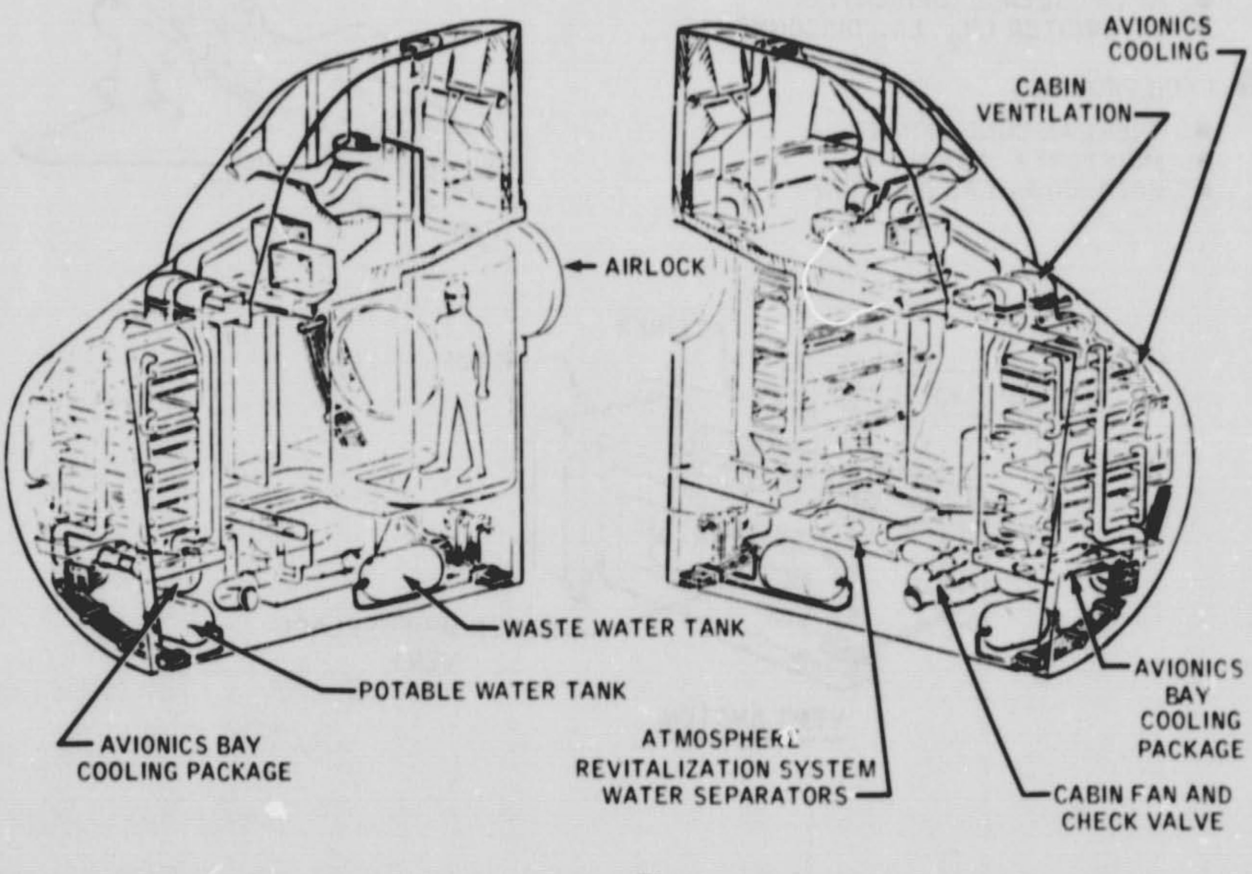
The payload bay is purged with conditioned air at the launch pad until 30 minutes before the start of propellant loading; then dry nitrogen gas is supplied until lift-off. The payload bay is vented during the launch and entry phases and is unpressurized during the orbital phase of the mission. The pressure difference between the payload bay and outside air is minimized to allow a lightweight structure and thus an economical design for the payload bay.

The cabin atmosphere (temperature, pressure, humidity, carbon dioxide level, and odor) is controlled by the cabin heat exchanger and associated equipment. The temperature is maintained between 289 and 305 K (61° and 90° F). An oxygen partial pressure of

ATMOSPHERIC REVITALIZATION SUBSYSTEM

- FUNCTIONS
  - CARBON DIOXIDE, ODOR, AND WATER VAPOR CONTROL IN PRESSURIZED CABIN
  - CABIN PRESSURE MAINTENANCE AND CONTROL
  - CABIN ATMOSPHERE THERMAL CONTROL
  - CABIN AND AFT SECTION AVIONICS THERMAL CONTROL
  - ATMOSPHERIC REVITALIZATION FOR HABITABLE PAYLOADS (WHEN REQUIRED)
- DESIGN/PERFORMANCE REQUIREMENTS
  - MISSION
    - NOMINAL: 42 MAN-DAYS
    - EXTRAVEHICULAR ACTIVITY: 3 TWO-MAN PERIODS
    - CONTINGENCIES: 16 MAN-DAYS OR 1 CABIN REPRESSURIZATION OR MAINTAIN PRESSURE WITH CABIN LEAK
  - PERSONNEL (CREW/PASSENGERS)
    - CABIN: DESIGN OPERATION, 3 TO 10; NORMAL, 3 TO 7; RESCUE, 6 TO 10
    - CABIN PRESSURE: 101 354 N/m^2 (14.7 PSIA)
    - ATMOSPHERIC COMPOSITION: 21 374 N/m^2 (3.1 PSIA) OXYGEN; 79 980 N/m^2 (11.6 PSIA) NITROGEN

22 065 ± 1725 N/m^2 (3.2 ± 0.25 psia) is maintained, and nitrogen is added to achieve a total pressure of 101 355 N/m^2 (14.7 psi). The oxygen is supplied from



the same cryogenic tanks that supply the fuel cells. Nitrogen for normal operation and emergency oxygen is supplied from 20 700-kN/m^2 (3000 psi) pressure vessels mounted in the midfuselage. The cabin atmosphere and part of the avionic equipment cooling is controlled by air that is ducted through the cabin heat exchanger.

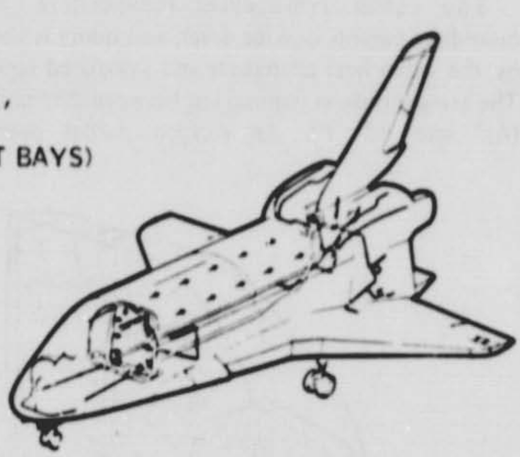
The radiator system located on the inside of the payload bay doors is the primary on-orbit heat rejection system. A water loop transports the excess heat from the cabin heat exchanger and remaining avionic equipment (through cold plates) to the Freon cooling loop by way of the cabin heat interchanger. The Freon cooling loop delivers this heat, together with heat from the fuel cells, payloads, and cold plates of the aft avionic equipment, to the 111-square-meter (1195 square foot) (effective area) baseline radiators, where the heat is radiated into space. The water flash evaporator is used to supplement the radiator cooling capacity. Extra radiator panels can be added to accommodate payloads with high heat loads.

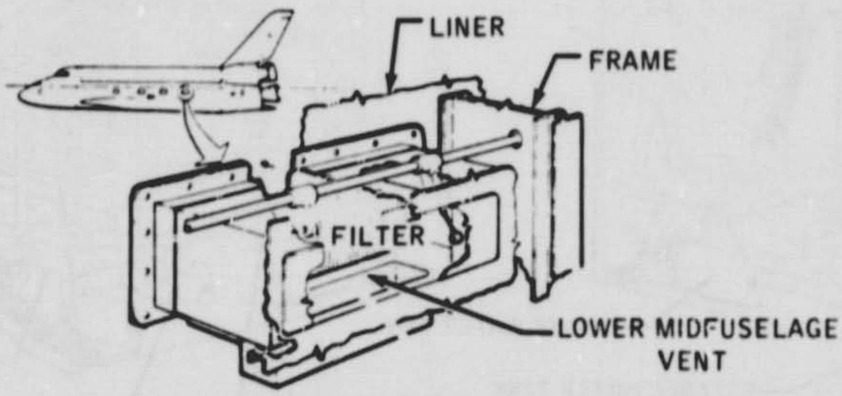
During the ascent and descent (down to an altitude of 30 500 meters (100 000 feet), when the cargo bay doors are closed and the radiators are ineffective), cooling is provided by the cabin heat sublimators. From the altitude of 30 500 meters (100 000 feet) to landing and connection with the ground support equipment, the ammonia boiler provides the required cooling.

ORBITER PURGE AND VENT SYSTEM

PURGE DUCT SYSTEM

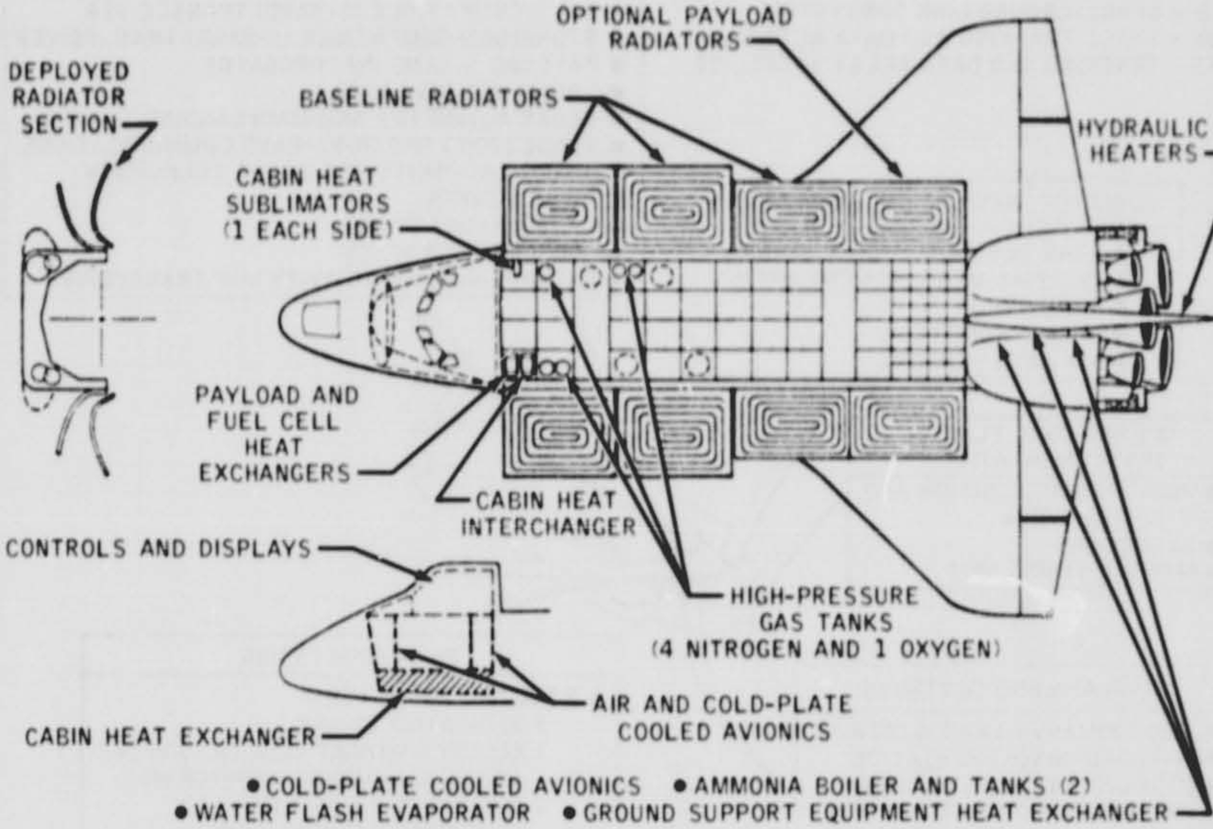
- CONSISTS OF 4 SEPARATE/DEDICATED SYSTEMS
  - FORWARD FUSELAGE, FORWARD RCS, OMS PODS, WING, VERTICAL STABILIZER
  - MIDFUSELAGE (PAYLOAD AND LOWER EQUIPMENT BAYS)
  - AFT FUSELAGE (DEDICATED)
  - ET/ORBITER LH_2, LO_2 DISCONNECTS
- EACH PROVIDES
  - THERMAL CONDITIONING
  - MOISTURE CONTROL
  - HAZARDOUS-GAS DILUTION





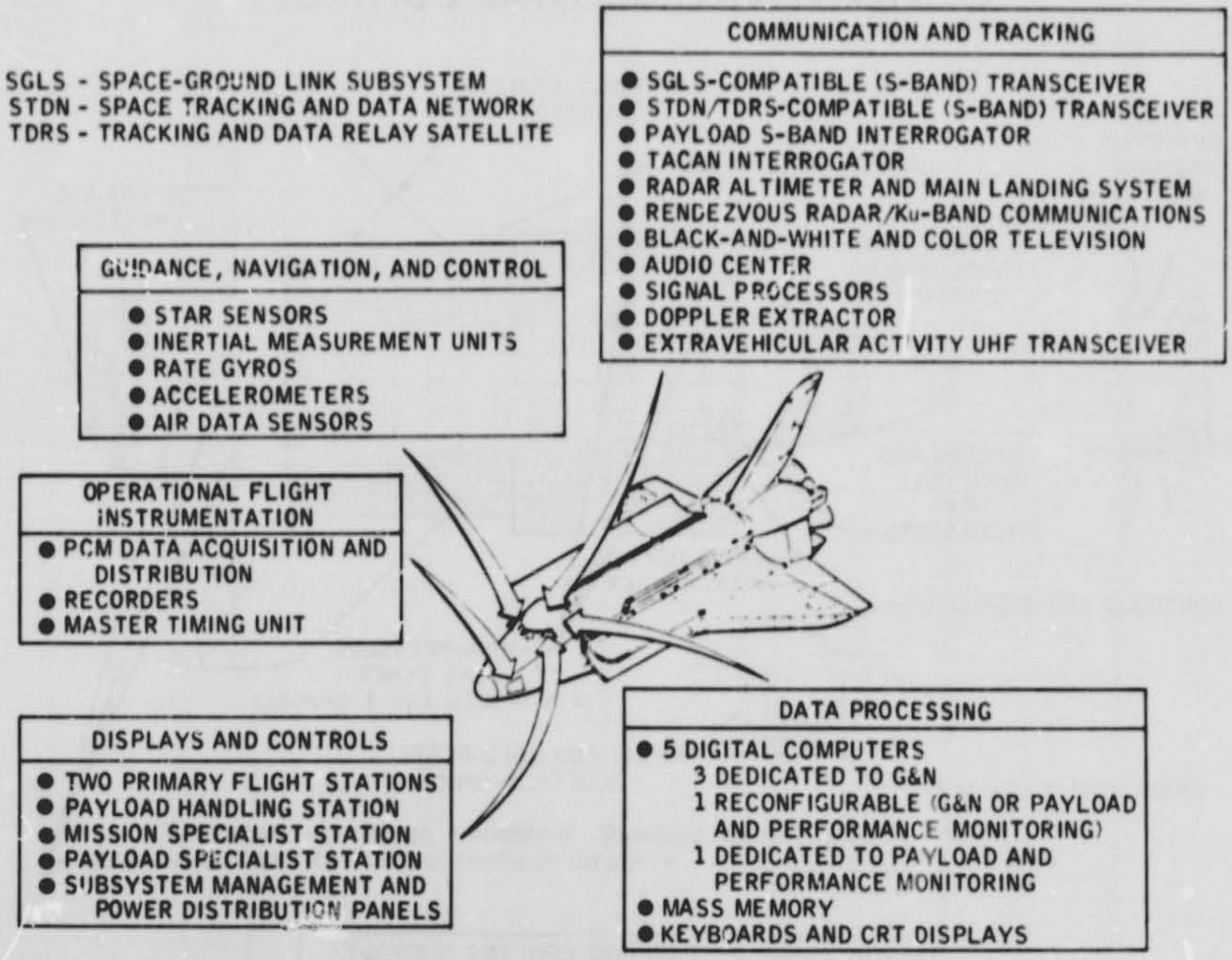
VENT SYSTEM

ORBITER ENVIRONMENTAL CONTROL



FLIGHT PHASE	PAYLOAD COOLING SUPPORT
PRELAUNCH	SELECTABLE RANGE USING GROUND SUPPORT EQUIPMENT
LAUNCH	1.5 kW THERMAL
ON ORBIT	6.3 kW THERMAL 8.5 kW THERMAL WITH MISSION KIT
ENTRY	1.5 kW THERMAL
POSTLANDING	COOLING SUPPLIED FROM GROUND SUPPORT EQUIPMENT

ORBITER SUBSYSTEM SUMMARY



AVIONICS

The Shuttle avionics subsystem provides commands; guidance and navigation (G&N) and control; communications; computations; displays and controls; instrumentation; and electrical power distribution and control for the Orbiter, the external tank, and the SRB. The avionics equipment is arranged to facilitate checkout, access, and replacement with minimal disturbance to other subsystems. Almost all electrical and electronic equipment is installed in three areas of the Orbiter: the flight deck, the forward avionic equipment bays, and the aft avionic equipment bays.

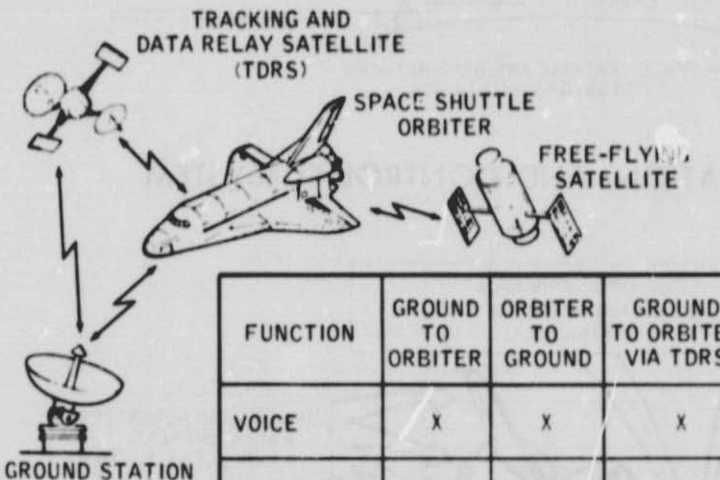
The Orbiter flight deck is the center of both in-flight and ground activities except during hazardous servicing. Automatic vehicle flight control is provided for all mission phases except docking; manual control options are available at all times. Side-stick rotation controllers, rudder pedals, and trim controls allow manual control, and a computer provides commands for automatic flight control to the aerosurfaces or propulsive elements as required. Attitude information is obtained from the inertial measuring unit. Air data are provided by redundant probes deployed at lower altitudes. Gimbaled inertial measuring units provide the navigation reference with star sensors for autonomous alinement and state vector update. During active rendezvous, a rendezvous radar is used to obtain range and bearing information. Orbiter-to-ground communication is by radiofrequency transmission in both frequency modulation and pulse code modulation (PCM) modes.

COMMUNICATIONS, TRACKING, AND DATA MANAGEMENT

The payload communications, tracking, and data management baseline configuration has sufficient flexibility to accommodate most payloads so that between-flight changes will be required only infrequently for special missions. Voice, television, and data-handling capabilities support onboard control or remote control from the ground when desirable. The on-orbit and ground facility handling system must be very efficient to support the many payloads to be flown.

The communications and tracking subsystem in the Orbiter supports Orbiter-to-payload communications as well as the transfer of payload telemetry, uplink data commands, and voice signals to and from the space networks.

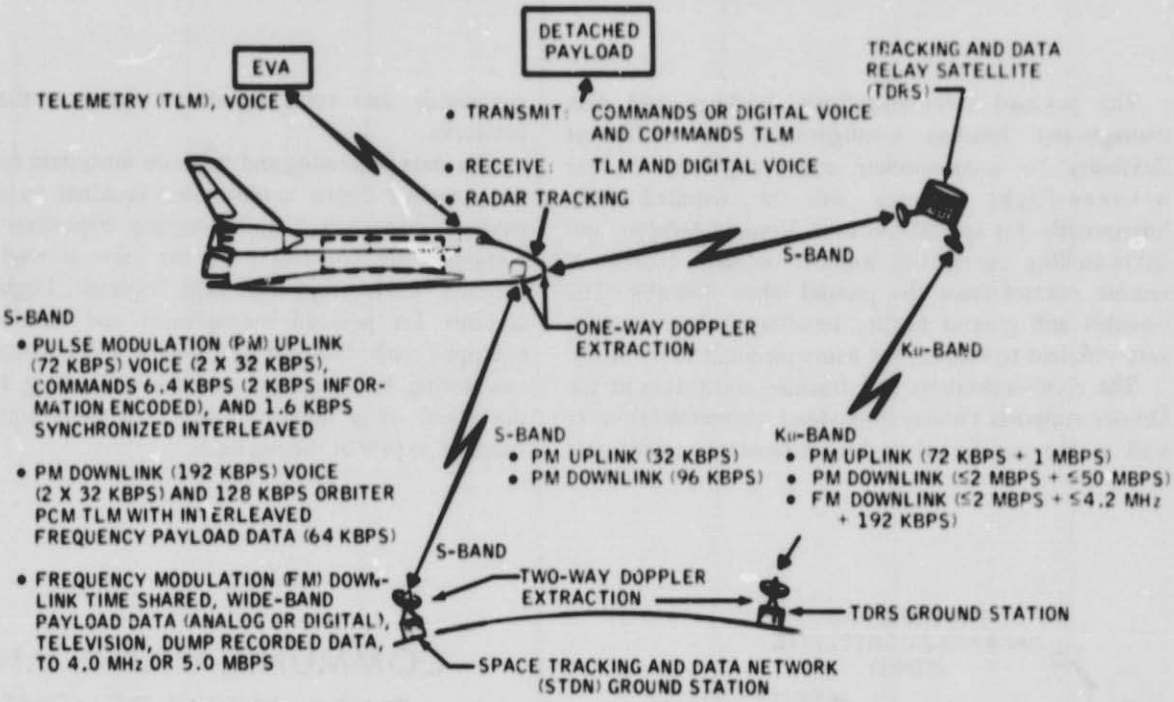
The data processing and software subsystem furnishes the onboard digital computation required to support payload management and handling. Functions in the computer are controlled by the crew through main memory loads from the tape memory. Flight deck stations for payload management and handling are equipped with data displays, CRT's, and keyboards for monitoring by the crew and for controlling payload operations on a flight-by-flight basis using equipment supplied as part of the payload.



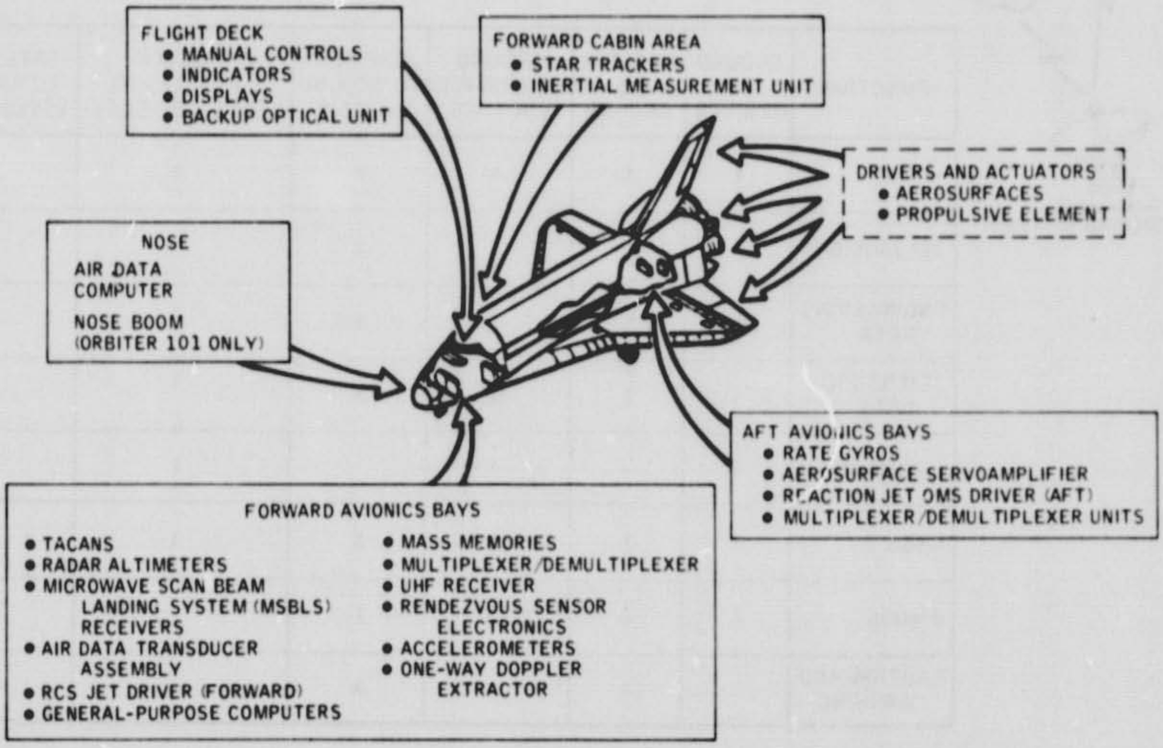
COMMUNICATIONS AND DATA MANAGEMENT

FUNCTION	GROUND TO ORBITER	ORBITER TO GROUND	GROUND TO ORBITER VIA TDRS	ORBITER TO GROUND VIA TDRS	ORBITER TO SATELLITE (PRIME OR RELAY)	SATELLITE TO GROUND VIA ORBITER
VOICE	X	X	X	X	X	X
TELEVISION		X		X		
ENGINEERING DATA	X	X	X	X		X
SCIENTIFIC DATA		X	X	X		X
COMMANDS	X		X		X	
GN&C	X	X	X	X	X	
TIMING	X	X	X	X		X
CAUTION AND WARNING		X		X		X

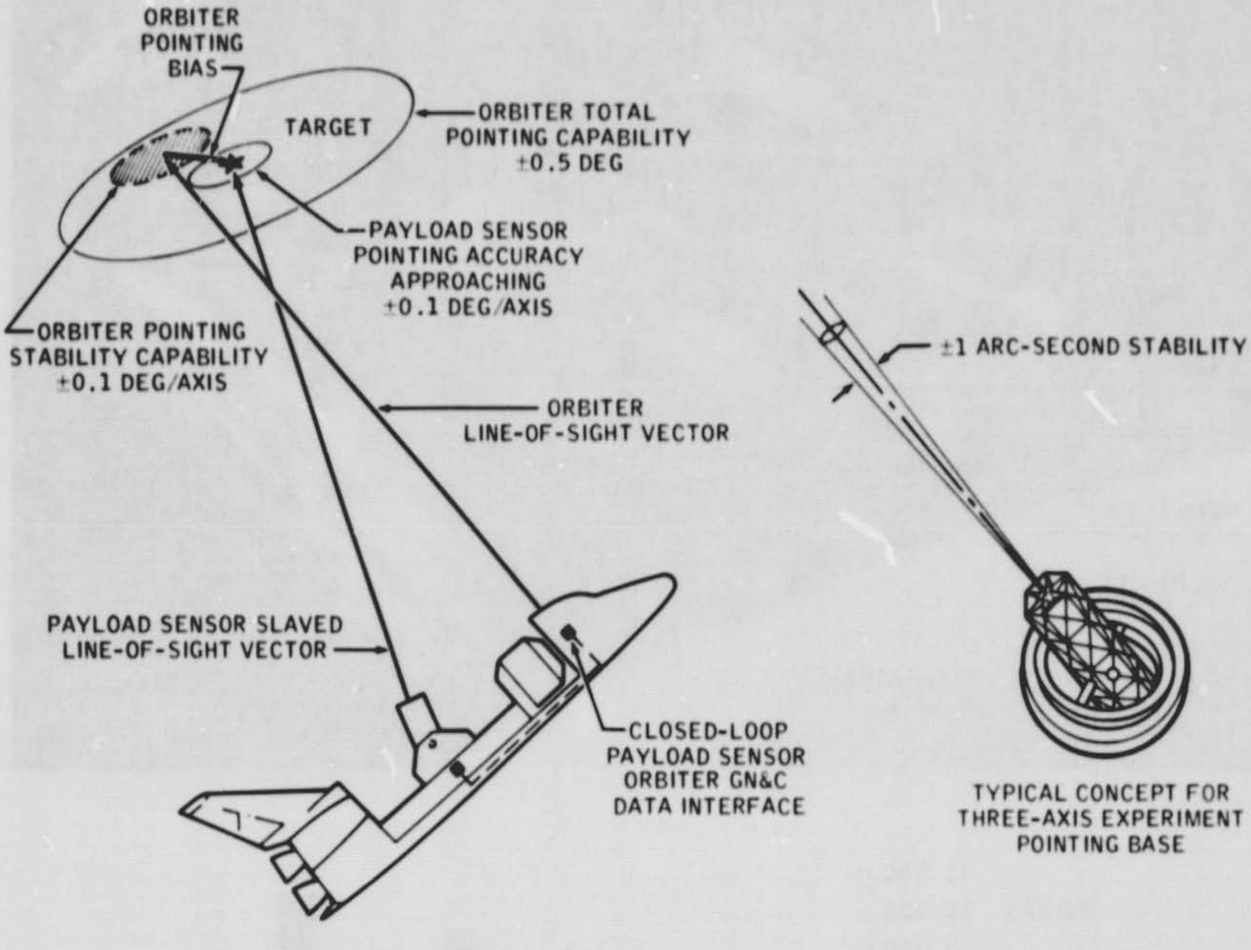
ORBITAL COMMUNICATIONS AND TRACKING LINKS



GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM



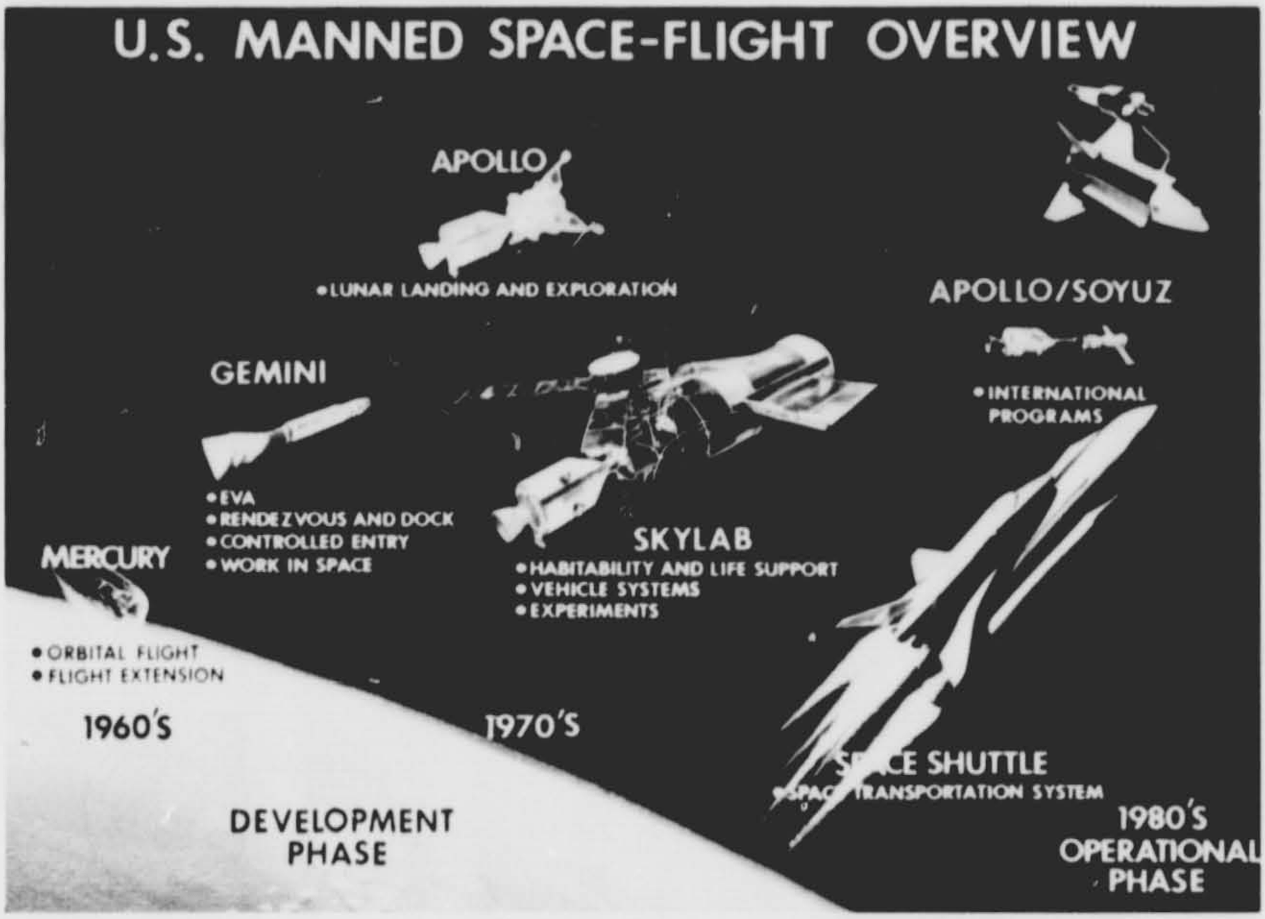
PAYLOAD POINTING AND STABILIZATION SUPPORT



ORBITER PROVIDED

PAYLOAD PROVIDED

The Orbiter 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°. Pointing vector accuracies with respect to an open loop payload sensor-fixed axis system are not as exact as the vehicle pointing accuracies because large misalinement and structural deformation error sources exist between the sensors. However, when the Orbiter guidance, navigation, and control system and a more accurate payload-mounted sensor are operated in a closed loop, payload pointing accuracies approaching ±0.1 deg/axis are possible. In either case, the Orbiter can be stabilized at a rate as low as ±0.01 deg/sec. Payloads requiring more stringent pointing and stability accuracies must provide their own stabilization and control system for that particular experiment. Orbiter guidance, navigation, and control system data interfaces are also provided to accommodate these types of payload requirements.



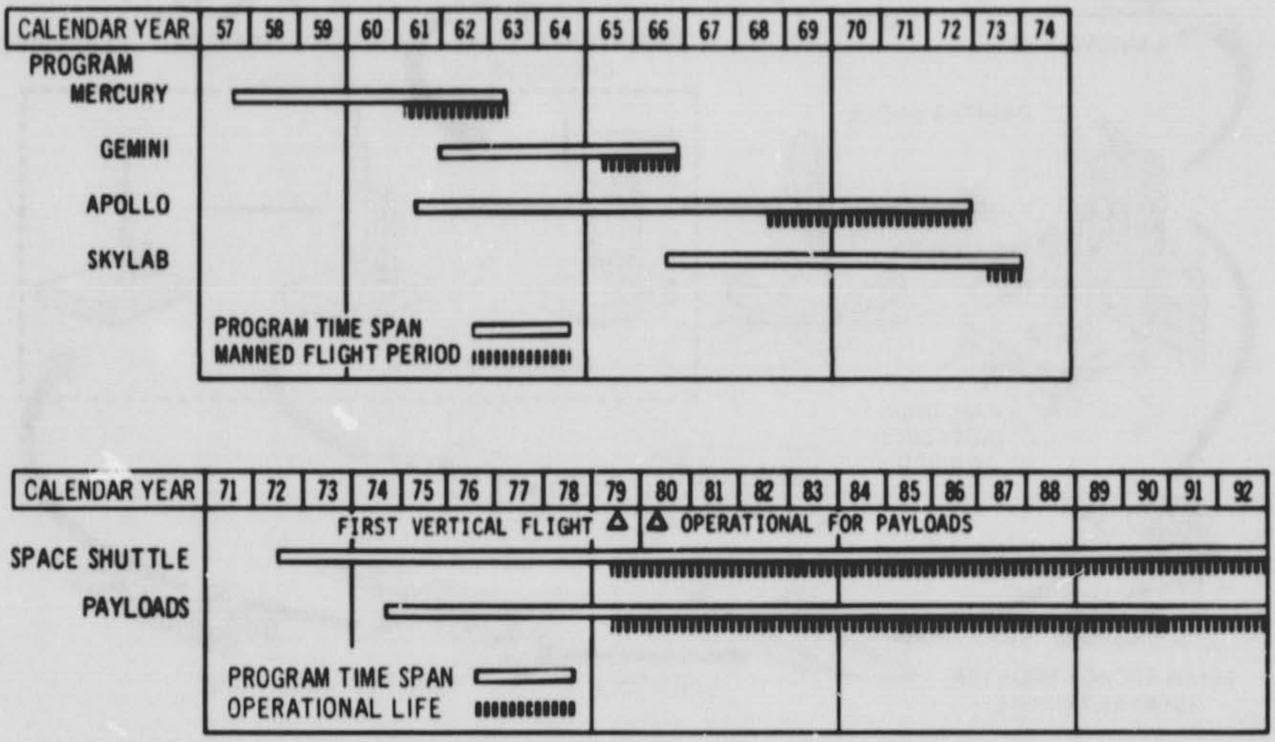
PROGRAM	MERCURY	GEMINI	APOLLO	SKYLAB
PROGRAM MAN-HOURS IN SPACE	54	1 940	7 506	12 351
NUMBER OF MANNED FLIGHTS	6	10	11	3
CREW SIZE	1	2	3	3

CUMULATIVE MAN HOURS IN SPACE
21 851 HOURS 24 MINUTES 41 SECONDS

REUSABLE SPACE HARDWARE

The Space Shuttle era will emphasize operational reuse of flight hardware, which will result in low cost per flight to the users. Low cost was and continues to be the basic concept on which the total space transportation system is being developed. In addition, the Space Shuttle operational phase will last much longer than the developmental phase, as illustrated in the following figure. Multiuse mission support equipment, like the Space Shuttle Orbiter, is being readied and will also be reflown in support of a wide variety of payloads.

MANNED SPACE FLIGHT PROGRAMS

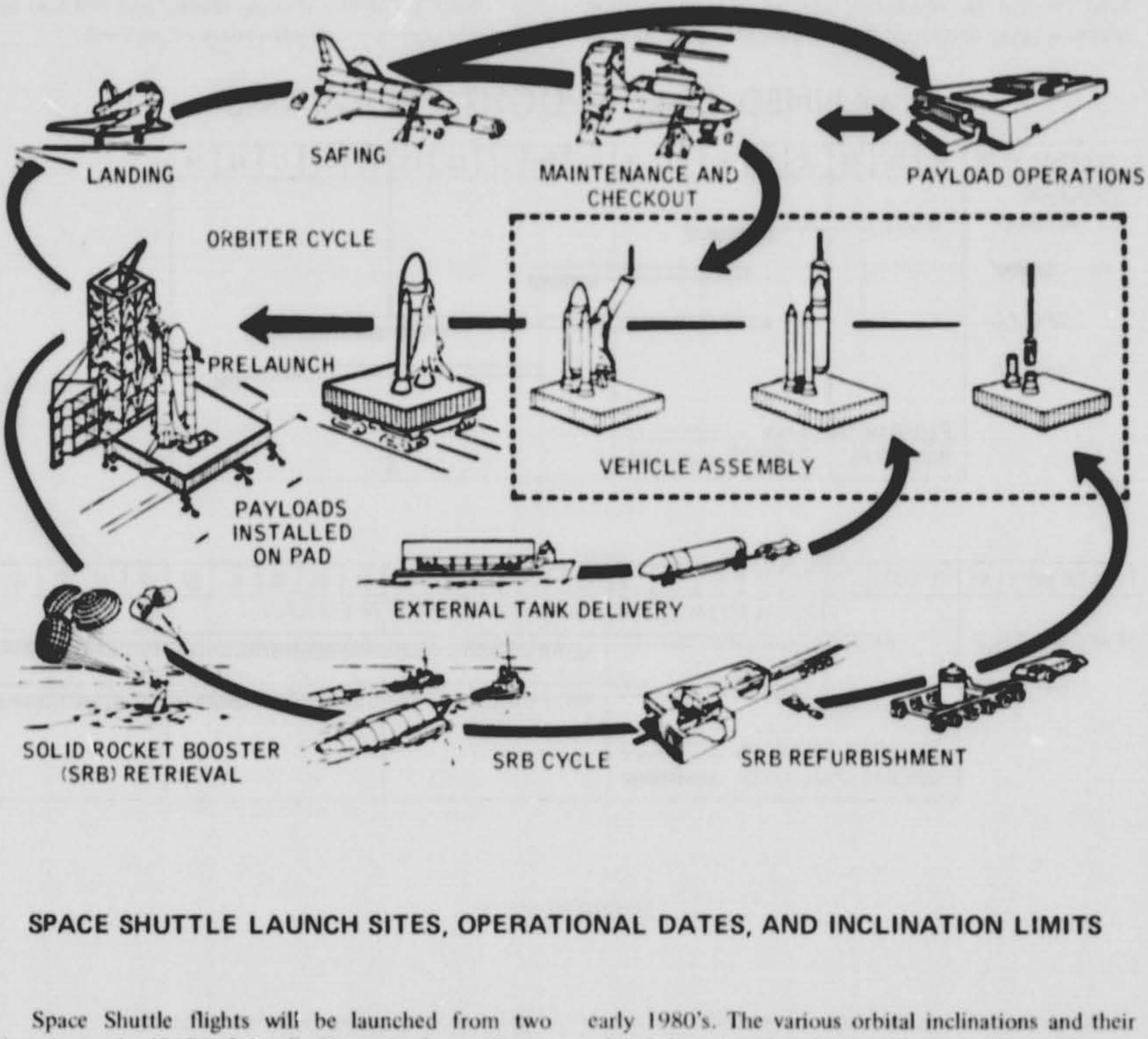


MISSION KITS

A group of 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 and to generate electrical energy
- Life support for extended missions
- Added propellant tanks for special on-orbit mission maneuvers
- Extra or specialized attachment fittings
- Transfer tunnels and docking modules
- A second remote manipulator arm and an extra high-gain antenna
- Fill, vent, drain, purge, and dump lines
- Additional radiator panels for increased heat rejection
- Additional storage tanks
- Electrical harnesses

KSC SHUTTLE SYSTEM GROUND FLOW

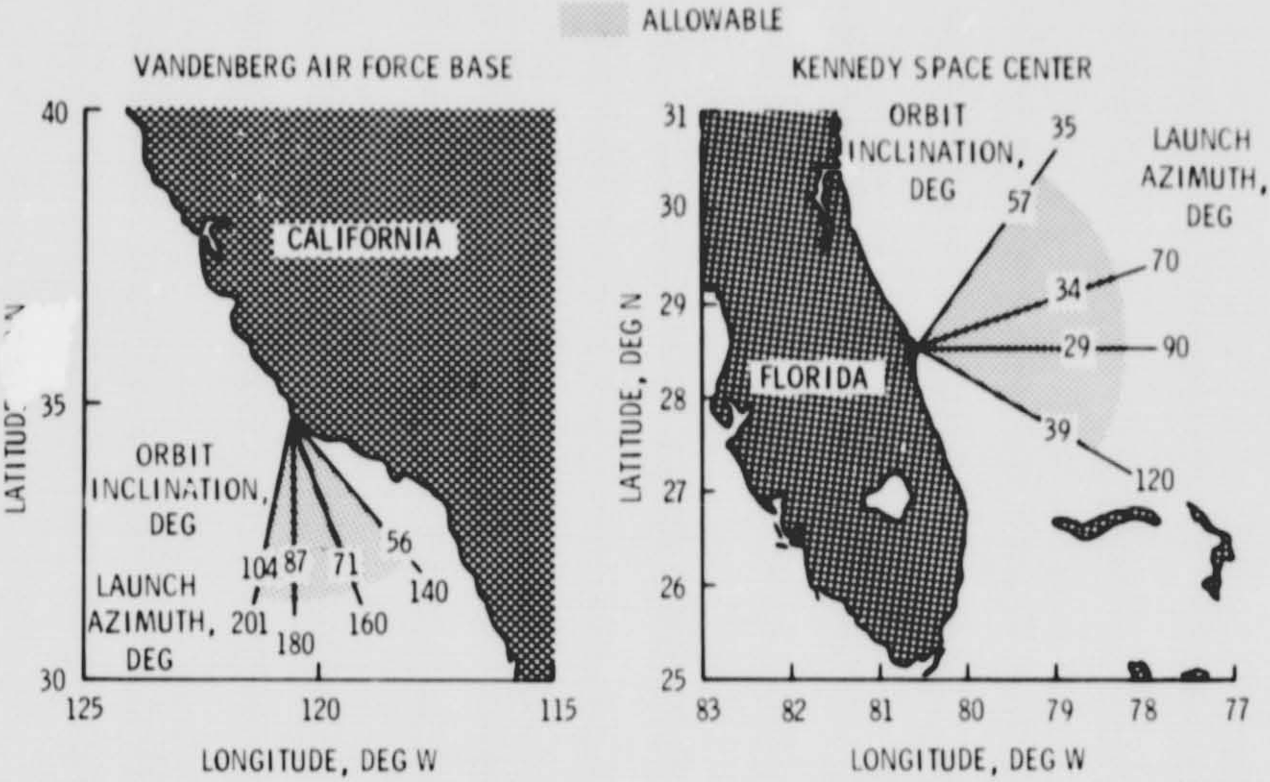


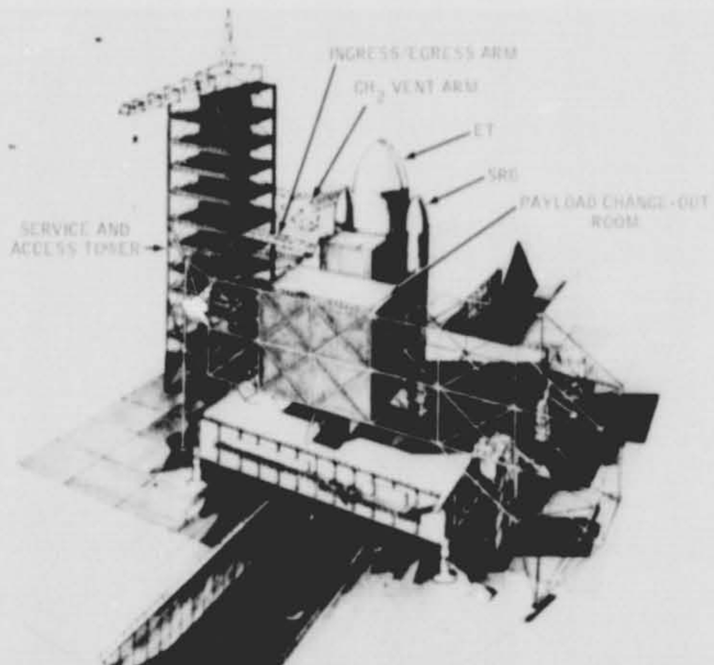
SPACE SHUTTLE LAUNCH SITES, OPERATIONAL DATES, AND INCLINATION LIMITS

Space Shuttle flights will be launched from two locations, the NASA John F. Kennedy Space Center (KSC) in Florida and the Vandenberg Air Force Base (VAFB) in California. Present program planning calls for a gradual buildup of 40 to 60 total flights per year into many varying orbits and inclinations.

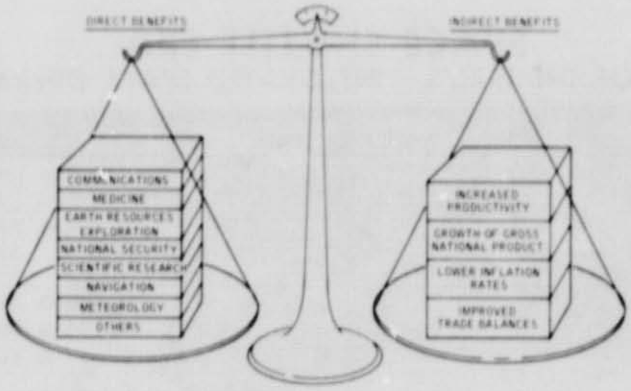
To attain operational status by 1980, Space Shuttle orbital test flights are scheduled to begin from KSC during 1979; VAFB is planned to be available in the early 1980's. The various orbital inclinations and their related launch azimuths are illustrated for each site. Together, these capabilities satisfy all known future requirements. Payloads as large as 29 500 kilograms (65 000 pounds) can be launched due east from KSC into an orbit of 28.5° inclination. Payloads of 14 500 kilograms (32 000 pounds) can be launched from VAFB into the highest inclination orbit of 104°. Polar orbiting capabilities up to 18 000 kilograms (40 000 pounds) can be achieved from VAFB.

ORBIT INCLINATIONS AND LAUNCH AZIMUTHS FROM VAFB AND KSC





LAUNCH PAD SERVICE AND ACCESS TOWER



ECONOMIC IMPACT OF SPACE SHUTTLE

There is abundant and well-documented evidence of the widespread benefits flowing from the space program to the nation and, indeed, to the world. The fields of medicine, communications, navigation, meteorology, Earth resources exploitation, and many others have been enriched. The Shuttle will increase these benefits and bring others in the future. However, the space program also spawns many less apparent economic benefits that are potentially as significant as the direct contributions. These indirect economic effects are not widely recognized, nor do they constitute the primary justification for the space program. Yet several recent studies have shown that they strengthen the nation's economy by making important contributions in our efforts to solve our basic economic problems.

Economists have long known that technological advance is the primary source of higher productivity and economic growth, and that research and development (R&D) is the chief contributor to technology. What is new is the preponderance of recent evidence that high-technology efforts such as the Shuttle and other space programs have a more potent effect on the economy than most other forms of R&D activity.

The reasons for the high technological leverage of the space program are straightforward. One is that the government-industry space team has consciously developed and implemented highly effective mechanisms for identifying and transferring space technology to other sectors of the economy for subsequent nonspace applications. Another reason is that industries performing space research are among the most technology-intensive and -innovative in the economy; they generate the all-important technology stimulus the U.S. economy must have for improved productivity rates and expanded output.

These same industries are the ones the United States relies on in its efforts to maintain favorable trade balances. Expanded exports of high-technology products will offset the traditional negative balances in minerals, raw materials, fuels, and low-technology manufactured goods. In this regard, the Space Shuttle Program will contribute favorably to the U.S. trade posture in two ways. It will help speed the pace of technology because of its highly stimulative effects on those technology-intensive industries that are depended on for a high dollar volume of exports. And it will contribute directly by launching and servicing the satellites of other nations. The ability of the Shuttle to provide launch services at lower costs and to offer orbital maintenance services never before available should markedly increase foreign participation in U.S. space exploration and exploitation.

The U.S. accomplishments in science, technology, exploration, and Earth applications attest to our success in meeting the goals of the National Aeronautics and Space Act during the past 16 years. The ancillary benefits of the space program – its ability to stimulate the economy; its applications to the solutions of earthbound problems; its contributions to international cooperation; and its creation of tens of thousands of jobs for our highly skilled scientists, engineers, and technicians – provide further proof of this success. These accomplishments and benefits should weigh heavily in the deliberations of policymakers as they determine the level of resources to be allocated to the Space Shuttle and the payloads in this and coming decades.

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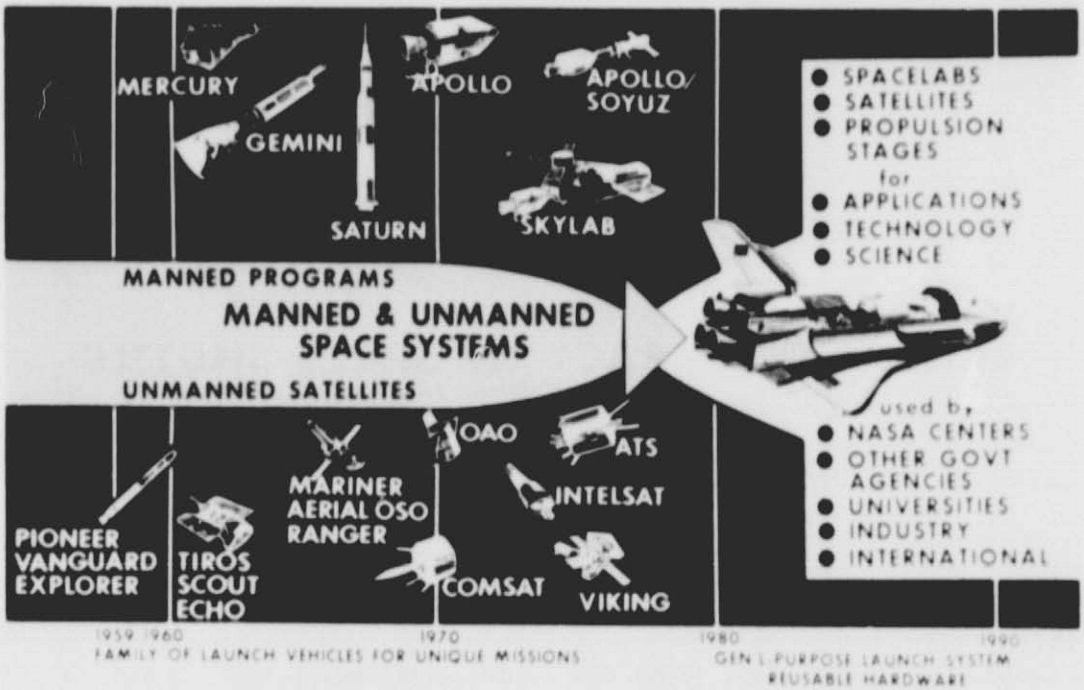
SPACE SHUTTLE ERA
TRENDS OF THE 1980'S - INTEGRATED SPACE OPERATIONS



TO ESTABLISH A NATIONAL SPACE TRANSPORTATION CAPABILITY THAT WILL

- SUBSTANTIALLY REDUCE THE COST OF SPACE OPERATIONS AND
- PROVIDE A CAPABILITY DESIGNED TO SUPPORT A WIDE RANGE OF SCIENTIFIC, APPLICATIONS, DEFENSE, COMMERCIAL AND INTERNATIONAL USES

SPACE SHUTTLE PARTICIPANTS

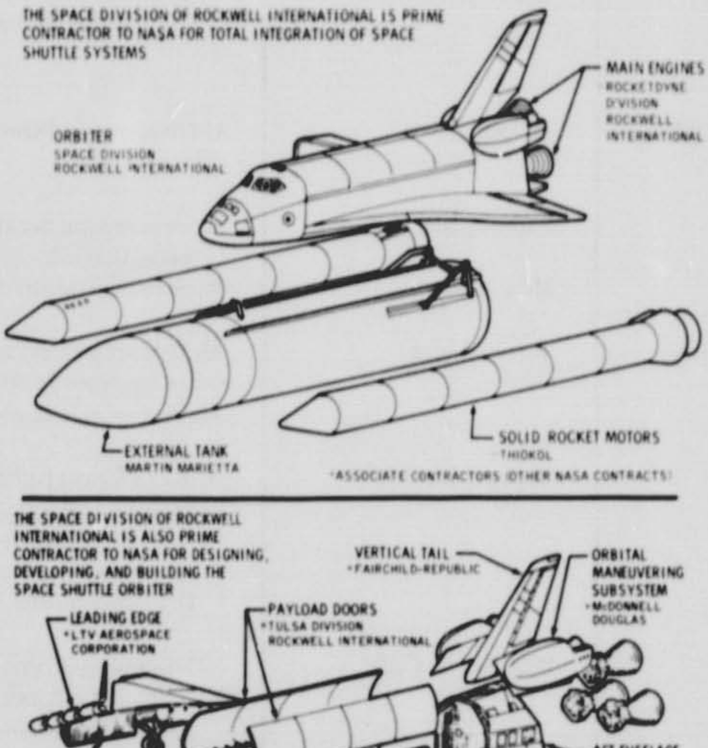
Overall direction of the Shuttle is in the Space Shuttle Program Office of Manned Space Flight at NASA Headquarters in Washington, D.C. This office is responsible for the detailed assignment of responsibilities, basic performance requirements, control of major milestones, and funding allocations to the various NASA field centers.

The Lyndon B. Johnson Space Center (JSC) in Texas is the lead Center and as such has program management responsibility for program control, overall systems engineering and systems integration, and overall responsibility and authority for definition of those elements of the total system that interact with other elements, such as total configuration and combined aerodynamic loads. JSC also is responsible for development, production, and delivery of the Shuttle Orbiter and manages the contract with Rockwell International Space Division.

The John F. Kennedy Space Center (KSC) in Florida is responsible for the design of launch and recovery facilities and will serve as the launch and landing site for the Space Shuttle development flight and for operational missions requiring launches in an easterly direction.

The George C. Marshall Space Flight Center (MSFC) in Alabama is responsible for the development, production, and delivery of the Orbiter main engine, the solid rocket booster, and the hydrogen/oxygen propellant tank.

The contractor team is still growing as the initial manufactured hardware takes form. All prime contractors and subcontractors involved to date are listed on the following pages.



Contractor	Location	System/subsystem
Abex Corporation, Aerospace Division	Oxnard, Calif.	Variable-delivery hydraulic pump
Aerodyne Controls Corporation	Farmingdale, N.Y.	Oxygen, hydrogen check valve (fuel cell and environmental control life support system) Pressure relief valve (water)
Aerojet General, Aerojet Liquid Rocket Company	Sacramento, Calif.	Orbital maneuvering system engines
Aerospace Avionics	Bohemia, N.Y.	Annunciator assembly, caution/warning Annunciator display general requirements Annunciator, performance monitoring Annunciator, special
Aeroquip Corporation, Aerospace Division, Marman Division	Los Angeles, Calif.	Couplings for environmental control and life support system
Aiken Industries, Mechanical Product Division	Jackson, Mich.	Thermal circuit breakers
AIL, Cutler Hammer	Farmingdale, N.Y. Milwaukee, Wis.	Microwave scan beam landing system, navigation set Remote-control circuit breaker
AiResearch Manufacturing Company, Garrett Corporation	Torrance, Calif.	Air data transducer assembly Cabin air pressure safety valve Air shutoff solenoid valve
Airite Division, Sargent Industries	El Segundo, Calif.	Helium receiver (spherical), surge pressure main propulsion system (MPS); relief of gaseous helium during MPS actuation of valves and external tank (ET) disconnects
Ametek Calmec	Pico Rivera, Calif.	MPS liquid hydrogen shutoff valve MPS liquid hydrogen disconnect; Orbiter-to-tank recirculation and replenishment system MPS gaseous hydrogen/gaseous oxygen disconnect, Orbiter-to-tank pressurization system

Contractor	Location	System/subsystem
Ametek Straza	El Cajon, Calif.	MPS liquid hydrogen and liquid oxygen fill and drain assembly MPS liquid hydrogen recirculation and replenishment line assembly
Amex System	Lawndale, Calif.	High-temperature, flight-instrumentation coaxial cable
Applied Resources	Fairfield, N.J.	Rotary switch
Arkwin Industries	Westbury, N.Y.	Hydraulic reservoir, bootstrap Six-way, two-position hydraulic control valve Three-way, two-position hydraulic control valve
Arrowhead Products, Division of Federal Mogul	Los Alamitos, Calif.	Space Shuttle main engine liquid oxygen and liquid hydrogen feedlines Coupling sleeve and flexible ducting for environmental control and life support system
Avco	Wilmington, Mass.	Ku-band antenna, microwave scan beam landing system
Aydin, Vector Division	Newton, Pa.	Wideband frequency division multiplexing unit
Ball Brothers Research	Boulder, Colo.	Star tracker
Beech Aircraft Corporation, Boulder Division	Boulder, Colo.	Power reactant storage assembly
B. F. Goodrich Company	Troy, Ohio Akron, Ohio	Main and nose landing gear wheel and main landing gear brake assembly Main and nose gear tires
Bell Industries	Gardena, Calif.	Modular terminal boards
Bendix Corporation	Sydney, N.Y.	High-density connector, data processing software

Contractor	Location	System/subsystem
Bendix Corporation (continued)	Teterboro, N.J.	Surface position, alpha Mach, and altitude/vertical velocity indicators
	Franklin, Ind.	Triaxial connector (93-ohm), electrical power distribution system
	Davenport, Iowa	Accelerometer
Bertea Corporation	Irvine, Calif.	Main landing gear hydraulic uplock actuator Main landing gear strut actuator Nose landing gear uplock actuator
Boeing	Houston, Tex. Seattle, Wash.	Sneak circuit analysis Carrier aircraft modification Tooling
Bomar/TIC	Newbury Park, Calif.	Variable transformer, displays and controls
Bussman Division of McGraw	St. Louis, Mo.	General fuse Seal for bulkhead window conditioning system
Brunswick	Lincoln, Neb.	Filament wound tank (developmental program)
Carleton Controls	East Aurora, N.Y.	Atmospheric pressure control system
Celesco Industries	Costa Mesa, Calif.	Smoke detection Fire suppression system
Chem Tric	Rosemont, Ill.	Silver ion generator, environmental control life support system
Circle Seal	Anaheim, Calif.	Purge, vent, and drain check valve
Columbus Aircraft Division, Rockwell International Corporation	Columbus, Ohio	Body flap structure
Conrac Corporation	West Caldwell, N.J.	MPS engine interface unit Mission timer Event timer

Contractor	Location	System/subsystem
Consolidated Controls	El Segundo, Calif.	Fuel isolation valve auxiliary power unit Unidirectional/bidirectional shutoff valve for fuel cell power plant and environmental control life support system
Convair Aerospace Division of General Dynamics	San Diego, Calif.	Midfuselage (includes midfuselage glove fairing)
Corning Glass	Corning, N.Y.	Windshield and windows
Crane Company-Hydro Aire	Burbank, Calif.	Main landing gear brake antiskid
Crissair Incorporated	El Segundo, Calif.	Hydraulic check valve Hydraulic flow restrictor
Datum Incorporated	Anaheim, Calif.	Multichannel closed-loop structural test
Deutsch	Banning, Calif.	General-purpose electrical connector
Edison Electronics, Division of McGraw Edison	Manchester, N.H.	Digital select thumbwheel switch Toggle switches
Edcliff Instruments	Monrovia, Calif.	Position transducer, landing gear and rudder, Orbiter 101 approach and landing flight test
Eldec Corporation	Lynnwood, Wash.	Dedicated signal conditioner (subsystem pressure, temperature, etc., to multiplexer, demultiplexer Tape meter Proximity switch (landing gear operation)
Electronics Associated	West Long Branch, N.J.	Analog computer system (Space Division simulator)
Electronic Resources Incorporated	Los Angeles, Calif.	Coaxial cable (special external-temperature cable for communication tie, links)
Ellneff	Corona, N.Y.	Hatch latch actuator

Contractor	Location	System/subsystem
EnJevco	San Juan Capistrano, Calif.	Piezo electric accel.rometer (flight instrumentation vibration-acoustic data) Acoustic pickup piezo electric (development flight instrumentation acoustic data Orbiter 101)
Explosive Technology	Fairfield, Calif.	Pyrotechnic crew escape interseat energy, transfer and sequencer
Fairchild Republic	Farmingdale, N.Y.	Vertical tail
Fairchild Stratos	Manhattan Beach, Calif.	MPS shutoff propellant prevalves MPS liquid oxygen overboard bleed disconnect MPS fill and drain valve propellant Ammonia boiler subsystem (rejects heat during reentry) MPS helium and gaseous nitrogen pneumatic disconnect MPS liquid oxygen and liquid hydrogen relief shutoff valve Forward and aft reaction control system (RCS) helium pressure regulator Cryogenic fluid and gas supply disconnects to connect Orbiter power reactant storage and distribution system fill, drain, and vent lines to their respective ground support equipment
General Electric	Valley Forge, Pa.	Waste collector subsystem
Gulton Industries	Costa Mesa, Calif.	Linear low-frequency acceleroneter (flight instrumentation vibration-acoustic data) Differential pressure transducer, hydraulic actuators
Grumman Corporation	Bethpage, N.Y.	Wing (includes main landing gear doors, elevons, and wing box glove) Shuttle training aircraft (prime contract)

Contractor	Location	System/subsystem
Hamilton Standard, Division of United Aircraft Corporation	Windsor Locks, Conn.	Atmospheric revitalization subsystem Freon coolant loop Water boiler, hydraulic thermal control unit Ground support equipment hydraulic cart
Harris Corporation, Electronics Systems Division	Melbourne, Fla.	Pulse code modulation master unit
Haveg Industries Incorporated	Winooski, Vt.	General-purpose wire
Hoffman Electronics Corporation, Navcom Systems Division	El Monte, Calif.	TACAN (tactical air navigation)
Honeywell Inc., Aerospace Division	St. Petersburg, Fla. Minneapolis, Minn.	Flight control system displays and controls Radar altimeter; main engine controller
Hydraulic Research & Manufacturing	Valencia, Calif.	Servoactuator elevon-electro command hydraulics Four-way hydraulic system flow control pressure valve
IBM Corporation, Federal Systems Division, Electronics Systems Center	Oswego, N.Y.	Mass memory/multifunction cathode ray tube (CRT) display subsystem General-purpose computer and input-output processor
ILC Technology	Sunnyvale, Calif.	Cabin interior lighting
Intermetrics Incorporated	Cambridge, Mass.	Advance computer programing language, HAL/S (high-order assembly language/Shuttle)
ITT Cannon	Santa Ana, Calif.	Power, high-density, rectangular, and coaxial connectors
J.L. Products	Gardena, Calif.	Crew compartment failure warning and corrective control Arming fire switch, pushbutton Pushbutton switch

Contractor	Location	System/subsystem
Kelly Hayes Company	Lake Orion, Mich.	Hydraulic switching and isolation valve
K-West	Westminster, Calif.	Wideband signal conditioner, accelerometer/acoustic Strain gage signal conditioner, stresses Ullage pressure signal conditioner for external tank (monitors and controls external tank liquid oxygen and liquid hydrogen ullage pressure) Differential pressure transducer and electronics MPS propellant head pressure in main feed and fill lines
Labarge	Santa Ana, Calif.	General-purpose wire
Leach Relay	Los Angeles, Calif.	General-purpose latching relay
Lear Siegler	Grand Rapids, Mich. Elyria, Ohio	Attitude direction indicator Hydraulic disconnect supply
Lockheed Missiles & Space Company, Inc.	Sunnyvale, Calif.	High- and low-temperature reusable surface insulation
Lockheed-California Company	Burbank, Calif.	Crew escape system ejection seats (Orbiters 101 and 102) Orbiter structural static and fatigue testing
LTV Aerospace Corporation, Vought Systems Division	Dallas, Tex.	Leading edge structural subsystem and nose cap, RCC (reinforced carbon-carbon) Radiator and flow control assembly system (study only)
Marquardt Company, CCI Corporation	Van Nuys, Calif.	Reaction control system thrusters
Martin Marietta	Denver, Colo.	Caution and warning electronics Pyro initiator controller Reaction control system tanks (forward and aft) S-band quad, hemi, and payload antennas
	New Orleans, La.	External tank (prime contract)

Contractor	Location	System/subsystem
McDonnell Douglas Astronautics Company	East St. Louis, Mo.	Orbital maneuvering system/reaction control system aft propulsion pod
Megatek	Van Nuys, Calif.	MPS cryogenic seals, line flange
Menasco Manufacturing Company	Burbank, Calif.	Main/nose landing gear shock struts and brace assembly
Metal Bellows Company	Chatsworth, Calif.	Potable and waste water tanks
Micro Measurements	Romulus, Mich.	Strain gage
Modular Computer Systems	Fort Lauderdale, Fla.	Data acquisition system (Space Division laboratories)
Moog, Incorporated, Controls Division	East Aurora, N.Y.	Main engine gimbal servoactuator
Networks Electronics Corporation, U.S. Bearings Division	Chatsworth, Calif.	Hatch latch links, main ingress/egress hatch
Northrop Corporation, Electronics Division	Norwood, Mass.	Rate gyro assembly
OEA	Des Plaines, Ill.	Pyrotechnic thruster assembly, nose gear uplock release
Parker Hannifin Corporation	Irvine, Calif.	MPS liquid hydrogen Orbiter-to-tank feed system disconnects MPS liquid hydrogen and liquid oxygen Orbiter-to-ground fill and drain disconnects Hydraulic accumulator
Pneu Devices	Goleta, Calif.	Hydraulic shutoff valve, emergency thermal control Electri notor-driven hydraulic circulation pump
Pneu Draulics	Montclair, Calif.	Hydraulic priority valve reservoir primary
Pratt & Whitney, Division of United Aircraft	East Hartford, Conn.	Fuel cell power plant

Contractor	Location	System/subsystem
Purolator Incorporated	Newbury Park, Calif.	Hydraulic filter module assembly
RDF Corporation	Hudson, N.H.	Temperature senso /transducer (general) Temperature resistance transducer (probe-type) Cryogenic temperature transducer
Rocketdyne Division, Rockwell International Corporation	Canoga Pa k, Calif.	Space Shuttle main engines (prime contra t)
ROHR	Chula Vista, Calif.	Solid rocket booster case
Rosemount Incorporated	Eden Prairie, Minn.	Air data sensor probe system Air data sensor flight-boom probe Sensor temperature probe Sensor temperature surface (general)
R. V. Weatherford	Glendale, Calif.	Shunt
Simmonds Precision Instruments	Vergennes, Vt.	MPS liquid oxygen and liquid hydrogen point-level sensors and electronics
Singer Kearfott	Little Falls, N.J.	Inertial measurement unit Multiplexer interface adapter Data bus coupler Data bus isolation
Skipper and Company	Cerritos, Calif.	Chemical processing (Downey facility)
Space Division, Rockwell International Corporation	Downey, Calif.	Space Shuttle Orbiter and integration
Space Ordnance Systems	Saugus, Calif.	Cartridge assembl detonator (frangible nut, tail cone separation, Orbiter carrier aircraft separation and Orbiter external tank separation)
Sperry Rand Corporation, Flight Systems Division	Phoenix, Ariz.	Multiplexer/demultiplexer Automatic landing
Statham Instruments	Oxnard, Calif.	Pressure transducer (low, medium, high, general systems)

Contractor	Location	System/subsystem
Sterer Engineering & Manufacturing	Los Angeles, Calif.	Nose gear steering and damping system Selector three-way, solenoid-operated landing gear uplock and control valves Solenoid-operated, Space Shuttle main engine hydraulic and hydraulic landing gear shutoff valve
Sterling Transformer Corporation	Brooklyn, N.Y.	Transformer (power displays and controls, 115/26 volt)
SSP Products Incorporated	Burbank, Calif.	Auxiliary power unit exhaust duct assembly
Sundstrand	Rockford, Ill.	Auxiliary power unit Rudder speed brake actuation unit Body flap actuation unit MPS hydrogen recirculation pump assembly
Symetrics	Canoga Park, Calif.	Hydraulic quick disconnects Quick disconnects (water boiler fill vent) Fluid disconnect
Systron-Donner	Concord, Calif.	Angular three-axis accelerometer (development flight instrumentation)
Tech Systems Corporation	Thomaston, Conn.	Ku-band wave guide assembly (part of interconnecting link between microwave scan beam landing system antenna and navigation set)
Teledynamics, Division of Ambac Industries	Fort Washington, Pa.	S-band transmitter (development flight instrumentation) frequency modulation
Teledyne Kinetics	Solano Beach, Calif.	Direct-current power contractor
Teledyne Thermatics	Pasadena, Calif. Elm City, N.C.	Coaxial prototype cable General-purpose wire Special-purpose wire
Teledyne McCormack	Hollister, Calif.	Crew escape system pyrotechnic initiator assembly
Thiokol Chemical Corporation, Wastach Division	Brigham City, Utah	Solid rocket motors

Contractor	Location	System/subsystem
Times Wire and Cable	Wallingford, Conn.	Coaxial cable
Titeflex Division	Springfield, Mass.	Flex hose, low-pressure, windshield purge Flex line coolant loop (water coolant) High/low pressure hydraulic system hose Swivel assembly, hydraulic system hose
Tulsa Division, Rockwell International Corporation	Tulsa, Okla.	Cargo-bay doors
Valcor Engineering Corporation	Kenilworth, N.J.	Hydrogen and oxygen pressurant flow control valve (controls flow from Orbiter main engines for external tank pressurization, main propulsion system)
Waltham Precision Instruments	Waltham, Mass.	Eight-day windup clock
Watkins Johnson	Palo Alto, Calif.	C-band radar altimeter antenna UHF air traffic control voice antenna L-band TACAN antenna
Wavecom	Northridge, Calif.	S-band multiplexer development flight instrumentation
Westinghouse Electric Corporation, Systems Development Division	Baltimore, Md.	Master timing unit
Westinghouse Electric Corporation, Aerospace Electrical Division	Lima, Ohio	Remote power controller Electrical system inverters (dc-ac)
Weston Instruments	Newark, N.J.	Event indicator Electrical indicator meter
Whittaker Corporation	North Hollywood, Calif.	Dump valve manually operated, hydraulic accumulator (ground) MPS helium pressure regulator MPS helium regulator

Contractor	Location	System/subsystem
Wintek	El Segundo, Calif.	Auxiliary power unit fuel line filter Purge, vent and drain filter (windshield) Coolant return filter Cryogenic filter assembly
Wright Components, Inc.	Clifton Springs, N.Y.	MPS two-way pneumatic solenoid valve MPS three-way helium solenoid valve
Xebec Corporation	Kansas City, Mo.	Automated circuit
Xe-Cell-O Corporation, Division of Cadillac Controls	Costa Mesa, Calif.	Main ingress/egress hatch attenuator
Xerox Corporation	El Segundo, Calif.	Digital computer (Space Division simulator)

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