Chapter 27

MANNED SPACE EXPLORATIONS

The space race between the United States and the Soviet Union, and the early satellite launches paved the way for the continuing exploration of space. It was only a matter of time before manned exploration became a reality. The United States and the Soviet Union both had manned space exploration programs.

Objectives

Identify the contributions of the US manned space flights and their missions.
Describe the Soviet manned space flights and their missions.
Identify the American and Soviet joint manned spacecraft mission.
Describe astronaut and cosmonaut individual accomplishments.
Identify the three major parts of the Space Shuttle.
Describe *Spacelab*, *Long-Duration Exposure Facility,* and the *International Space Station*.
Describe the living and working conditions in space.
Describe the different space suits.
Define the X-Prize.

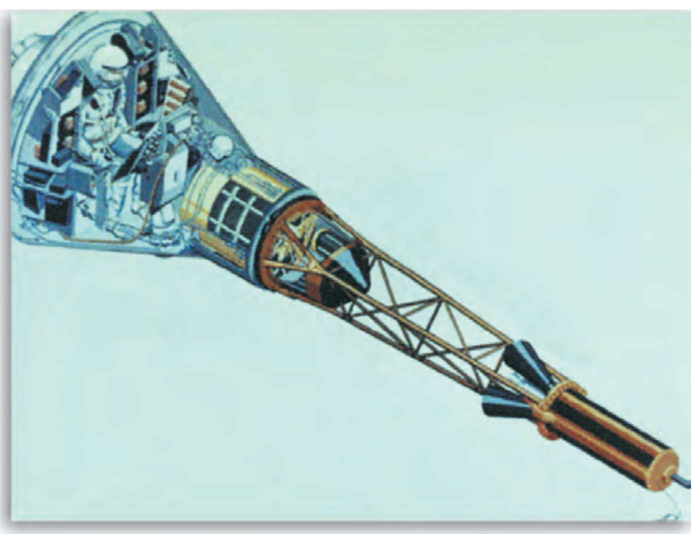
US Manned Space Program

The United States, through NASA, developed a systematic manned space flight program. Five programs were successfully developed from 1961 through 1975.

Project Mercury

The United States launched its first satellite in 1958, and by 1961, the United States was ready to attempt manned space flight. America's first manned space flight program was called Project Mercury.

Seven U.S. pilots were chosen as the original astronauts: Scott Carpenter, Gordon Cooper, John Glenn, Virgil Grissom, Walter Schirra, Alan Shepard and Donald Slayton. *Mercury's* mission was to find out if a human could survive space travel and what, if any, effects would space travel have on the human body.



A Cutaway of the *Mercury* Capsule

The Seven Original NASA Astronauts Selected in 1959 for the Mercury Program

Alan Shepherd Suiting-up before the First Manned Space Flight

Project Mercury lasted 2 years and consisted of six manned flights. *Mercury* also conducted 19 test flights before the capsule was ready for manned space flight. The first flight involved sending one astronaut into space. This first flight was suborbital and lasted for only 15 minutes. May 5, 1961, astronaut Alan Shepard became the first American in space.

Project Mercury's third flight was also its first orbital flight. During this flight, astronaut John Glenn became the first American to orbit the earth. He remained in orbit for 4 hours and 55 minutes, while orbiting the Earth three times.

John Glenn enters his capsule, *Friendship* 7

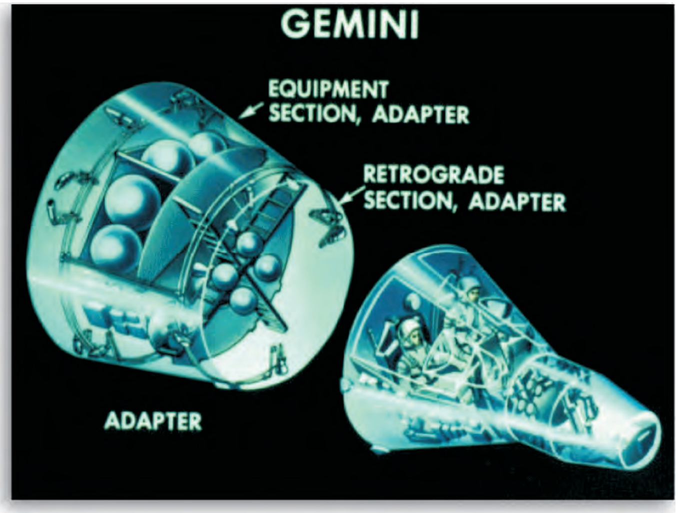
On the final Mercury flight, astronaut Gordon Cooper orbited the earth 22 times and stayed in space for about 34 hours. Project Mercury answered the basic questions about survival in space. Project Mercury accomplished its mission.

While the original goal of Project Mercury had been to put someone into orbit for a day's flight, the six flights of the program proved that the basic flight sequences that had been developed were sound and that a pilot had a place in orbital flight. Even though astronauts could not maneuver the capsule, they had proven they could take over controls to keep the capsule steady in flight and to direct it to its splashdown point. It was time to move on.

Project Gemini

The next manned space flight project was Project Gemini. Gemini's objectives were to improve techniques needed for a lunar mission, put two persons in space, rendezvous and dock with another spacecraft, and achieve the first walk in space.

In 1961, President John F. Kennedy committed America to putting an astronaut on the moon before the end of the decade. Accomplishing the objectives of Gemini would determine if America would meet that commitment.



The Two-Man *Gemini* Capsule

There were a total of 10 Gemini flights. Gemini was the first two-man capsule and it did achieve the first American walk in space. The Gemini flights also gathered additional information about the effect of space flight on the human body. The astronauts studied the effects of weightlessness and were involved in an exercise program. At times, they removed their space suits and relaxed in short-sleeve shirts.

Because the flights lasted for several days, the astronauts were able to establish routines for sleeping and eating. Enough information was gathered to convince scientists that a space flight could safely last for several weeks or even months. These Gemini flights were very valuable in America's plan of placing a man on the moon.


***Gemini* IV's astronaut, Ed White, made a 22-minute space walk.**

Project Gemini had been designed with two primary goals: a flight duration of 2 weeks and the development of techniques for a rendezvous in space. Both of the objectives were of paramount importance if a lunar landing were to be made. Project Apollo was already in the planning stages when the Gemini missions were begun. By the time its missions were completed, the astronauts had the skills necessary to make a moon landing and to meet the national goal set by President Kennedy more than 5 years earilier.

Project Apollo

After the Gemini missions were completed, Project Apollo took center stage in America's space program. From the early 1960s, it was known that Apollo's mission would be to put a man on the moon. So, the Apollo flights were conducted with that overall goal in mind. Several of the early Apollo flights traveled to the moon, orbited it and returned to earth. It was not until *Apollo* 11 that the mission was accomplished. *Apollo* 11 landed on the moon, and on July 20, 1969, Neil Armstrong was the first man to walk on the moon.

A few minutes later, Edwin "Buzz" Aldrin also stepped off the ladder of the *Lunar Module* and joined Armstrong on the moon. Many have called that landing the greatest scientific and engineering accomplishment in history.

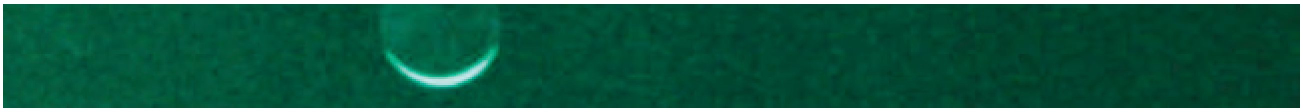
After *Apollo* 11, there were six more Apollo flights to the moon. Five of them resulted in successful moon landings. The only flight of the six that didn't land on the Moon was *Apollo* 13. *Apollo* 13 had to be aborted due to an explosion in the spacecraft. However, *Apollo* 13 did make a successful emergency landing back on earth.

Neil Armstrrong was the first man to walk on the moon.

Aldrin joins Armstrong on the surface of the moon.

The *Apollo* 11 astronauts were Michael Collins, Edwin E. "Buzz" Aldrin and Neil A. Armstrong.

Early in the space program, six unmanned flights were made for equipment testing. Plans progressed to send astronauts into space to continue testing, but the program was halted for almost 2 years when astronauts Gus Grissom, Ed White and Roger Chaffee were killed in a launch pad fire as they were testing the command module on the *Atlas* booster. The January 27, 1967, tragedy stunned the nation.

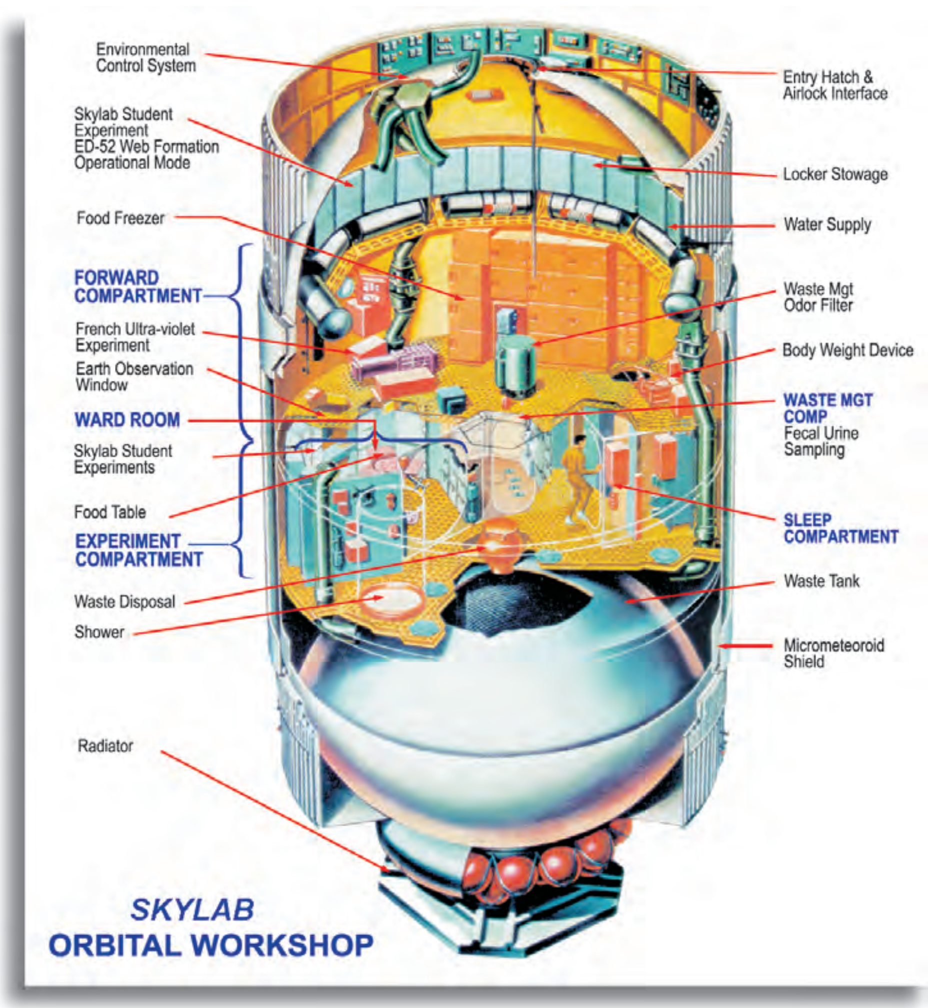


In order to eliminate the fire threat that had killed the astronauts, NASA modified both the command module and the astronauts' space suits. These changes and new flight suits were all tested. Finally, in October 1968, the manned Apollo flights resumed and the nation was poised to meet the national goal of a man on the moon before the end of the decade.

Project Skylab

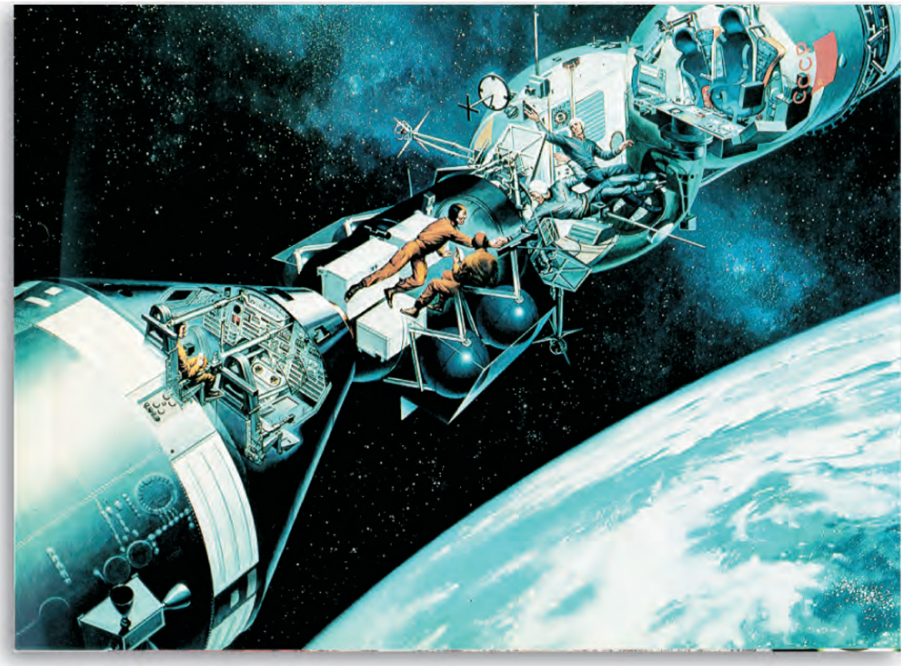
Project Skylab, the next space flight project, used a lot of left over equipment from the Apollo missions. Skylab's mission was to put a laboratory into space. Scientists had been interested in continuing their studies of the effects of long-duration space flights using a manned orbiting laboratory. This was accomplished when *Skylab* was launched in May 1973.

Skylab had about the same amount of room as a three-bedroom house. It also contained all of the food, water and oxygen needed to support the entire mission. A close look at the picture at the left will show what the living conditions were like. The astronauts slept standing up in restraints that resembled vertical sleeping bags. For eating, knives and forks were secured with magnets. To move around, the astronauts could walk with special cleats. For breathing, the air was a combination of oxygen and nitrogen, so the astronauts could move around without their space suits.



Three different crews spent time in the lab. The first crew manned *Skylab* for 28 days. The second crew spent 58 days aboard the laboratory. The final crew spent 84 days in space. The main lesson that came from *Skylab* was that people could live and work in space for at least 3 months with no ill effects.

Project Apollo-Soyuz



The Apollo-Soyuz project is depicted in this illustration.

After the Apollo flights, the last manned space launch before the Space Shuttle was the Apollo-Soyuz Test Project. This occurred in July 1975, and involved a linkup in space of an American and a Soviet manned spacecraft. As depicted in the illustration to the right, this was a unique moment in history. These two superpowers, that had been involved in a well-publicized space race for 15 years, meeting and shaking hands in space was indeed a special moment.

The two crews docked together and spent 2 days moving between the capsules helping each other with scientific experiments. Among the American crew were former *Mercury* and *Gemini* astronauts. Among the Soviet crew was Aleksei Leonov, the first man to walk in space. Back in 1965, Leonov walked in space 2 months prior to the American walk in space. This joint venture truly was an historic event.

Apollo-Soyuz marked the end of an era. It marked the end of the expendable spacecraft. A new era was being ushered in, the era of the reusable space vehicle, the space shuttle.

US Second Era

Space Shuttle

From 1975 until 1981, the U.S. didn't have any astronauts in space, but that changed with the space shuttle. In April 1981, the Space Transportation System (STS), commonly called the space shuttle, was launched. The space shuttle provided a system for transportation into space and a return back to earth. This has been a major advantage of the shuttle since it can be used again and again.

The space shuttle consists of three main parts: the orbiter, the solid rocket boosters and the external tank. The orbiter looks like an airplane and is about the same size as a DC-9 jet. The orbiter carries the crew and the payload. The other two parts are required to launch the shuttle into space. The boosters burn away and the tank separates early into the flight.

When the shuttle was first built, it could remain in space for 14 days. That time has increased to 30 days now. When it is time for the shuttle to return to earth, the astronauts fire the two orbital maneuvering engines, which slows down the shuttle. The shuttle then reenters the earth's atmosphere.

The first space shuttle was actually the *Enterprise,* but it was only used for flight tests. It was not designed for going into space. The other five space shuttle spacecraft have all gone into space and have been used for a variety of missions. They are the *Columbia*, *Challenger*, *Discovery*, *Atlantis* and *Endeavour*.

The first four flights of the *Columbia* were mainly tests. Most of the concern centered around how the *Columbia* would handle reentry into the earth's atmosphere and how its protective shields would perform. STS-5 was the first real operational flight, and it occurred in November 1982.

The Liftoff of the Space Shuttle Disc*overy*

From orbit, the *STS-5* launched 2 satellites.

Over the years, the space shuttle has been used in many ways to further our knowledge of space. The first American woman in space, Dr. Sally Ride, was aboard the *Challenger* for STS-7. STS-9 delivered the first European Space Agency Spacelab into space. STS-13 placed the *Long-Duration Exposure Facility (LDEF)* into space to conduct experiments. A few years later, the *LDEF* was retrieved and the many experiments analyzed.

On January 28, 1986, less than 2 minutes after takeoff, the *Challenger* (STS-25) exploded. The entire crew of seven died. A leak in one of the solid rocket boosters was the cause. After the *Challenger* accident, the shuttle program was suspended for over 2 years. After design changes were made, and safety procedures and precautions taken, on September 29, 1988, the space shuttle flights resumed.

The *Hubble Space Telescope*

In April 1990, the shuttle *Discovery* deployed the *Hubble Space Telescope.* The *Hubble Space Telescope* is operating at over 300 miles above the earth and is free of any atmospheric interference. Therefore, the objects are seen much more clearly than from ground observations.

The telescope is expected to operate until 2013. However, the space shuttle can retrieve it, repair it and return it to orbit for continued use.

Atlantis, with mission STS-34, placed the *Galileo* probe into space. The *Galileo* probe is investigating Jupiter for 6 years. In 1993, STS-55 carried the European developed *Spacelab* into orbit. Many useful experiments were conducted from the *Spacelab*.

As you can tell from the few examples that have been mentioned, the space shuttle was designed to be the workhorse of our space program, and indeed it has been. The space shuttle has had about 100 missions so far, and it has served our nation well. Our knowledge of space has increased tremendously with the help of the space shuttle.

The Crew

The crew of the *Challenger* mission STS-7 included the first woman in space, Dr. Sally Ride.

Prior to the Space Shuttle Program, all US astronauts were highly qualified pilots, and many were specialists in other fields as well. The shuttle has numerous diversified missions that require the knowledge and skills of several scientific fields. Hence, the pool of astronauts contains individuals with special skills, but not necessarily those of a pilot.

When NASA asked for volunteers in 1976, over 8,000 applications were received. From this number, 208 were selected as finalists. The finalists were interviewed and given medical examinations at the Johnson Space Center in Houston, Texas. Thirty-five of the finalists were chosen to undergo a 2-year training program, after which they would join the existing pool of "older" astronauts.

The "new" astronaut candidates included women and men, pilots and non-pilots, and civilian and military personnel. There were 21 military officers and 14 civilians. All were grouped for assignment as either mission pilots or mission specialists. The pilots were trained to fly the space shuttle orbiter while the mission specialists were trained according to the needs of programmed missions. However, with systems as complex as the orbiter's, there has to be a certain amount of cross training.

Imagine the amount of training astronaut candidates must experience to qualify as a full-fledged astronaut. They have to understand the organization and structure of their employer, NASA. They certainly must be familiar with the systems and structural aspects of the spacecraft. They have to keep physically fit. They have to understand the aerospace technology associated with the space shuttle in order to support technical or scientific assignments. They also must be taught what to expect physiologically and psychologically while in orbital flight.

Mission pilot astronauts keep their flying skills sharpened with lots of flight time in jet aircraft. Mission specialist astronauts are trained in navigation, communications and other subjects related to

The seven members of the *Challenger* *Space Shuttle* 51-L mission are: (back row, left to right) Mission Specialist El Onizuka, Teacher in Space participant S. Christa McAuliffe, Payload Specialist Greg Jarvis and Mission Specialist Judy Resnik; (front row, left to right) Pilot Mike Smith, Commander Dick Scobee, and Mission Specialist Ron McNair.

aircraft flight. They also get flight time. Their flights in the jet aircraft are as "rear seaters" to help the pilots with planning navigation and communications. Mission specialists with little flight experience become accustomed to high altitude and the unusual sensations of various flight attitudes. Rides in NASA's *"Vomit Comet"* are essential to their learning to adjust to free-fall.

Once they are fully qualified, the astronauts continue training according to need. For example, after an astronaut team is selected for a flight, each person receives intensified training for the flight's mission. The missions differ for every flight and there are numerous sub-missions to be accomplished. Thus, learning occupies a large segment of an astronaut's time.

The crew of the *Discovery* Space Shuttle Mission STS-95 included the 77-year-old Payload Specialist, Senator John H. Glenn, Jr. Glenn was the first American to orbit the earth in his *Mercury* capsule *Friendship 7* in 1962.

The other crew members are: (back row, left to right) Mission Specialist Scott E. Parazynski, M.D.; Payload Commander Mission Specialist Stephen K. Robinson, PhD.; Mission Specialist Pedro Duque; Payload Specialist John H. Glenn, Jr.; (front row, left to right) Pilot Steve Lindsey, Lt Col, USAF; Payload Specialist Chiaki Mukai, M.D., PhD.; and Commander Curt Brown, Lt Col, USAF.

Astronauts not on flight status for a mission have other duties to perform. These duties may include assignments in mission control or other support functions. Some of the astronauts assist with public understanding of the space shuttle flight missions by appearing with news media personnel and providing expert commentary.

When missions are not being flown, it is also the astronauts' duty to respond to requests for public appearances. Their knowledge of present systems and plans for future manned space flights is in considerable demand by various organizations. These public appearances are a key part to increasing public awareness of the space program. Astronauts provide the public with insights into space exploration and the value of spending billions on the space program.

The payload specialist is a specially trained person who is the expert for a particular payload. Most of the payload specialist's training is received from the payload developer and pertains to a highly technical or scientific project. However, every payload specialist does get some training from NASA. This training is conducted at the Johnson Space Center and involves about 150 hours of classroom time. The training is sufficient to familiarize the payload specialist with the spacecraft and payload support equipment, crew operations and emergency procedures.

The Craft

The orbiter is the most sophisticated truck ever devised. And it is large! It has a wingspan of 78.06 feet. Its total fuselage length, to include its engines and vertical stabilizer, is 122.2 feet. The orbiter's payloads can weigh a total of 65,000 pounds on a single flight. With lighter-weight payloads, the craft can reach an orbital altitude of 690 miles.

The Space Shuttle Orbiter *Endeavor*

The orbiter carries the crew and payload to and from space. Like a conventional aircraft, the orbiter's fuselage is constructed in three major sections: the forward fuselage, the mid-fuselage and the aft-fuselage.

Astronauts and payload specialists occupy the forward fuselage. While the forward fuselage is further subdivided into smaller units, two decks form the cabin of working and living quarters. The flight deck is where control of the craft and manipulation of most payloads occur. Below the flight deck is the mid deck. Here we find the astronauts' living quarters.

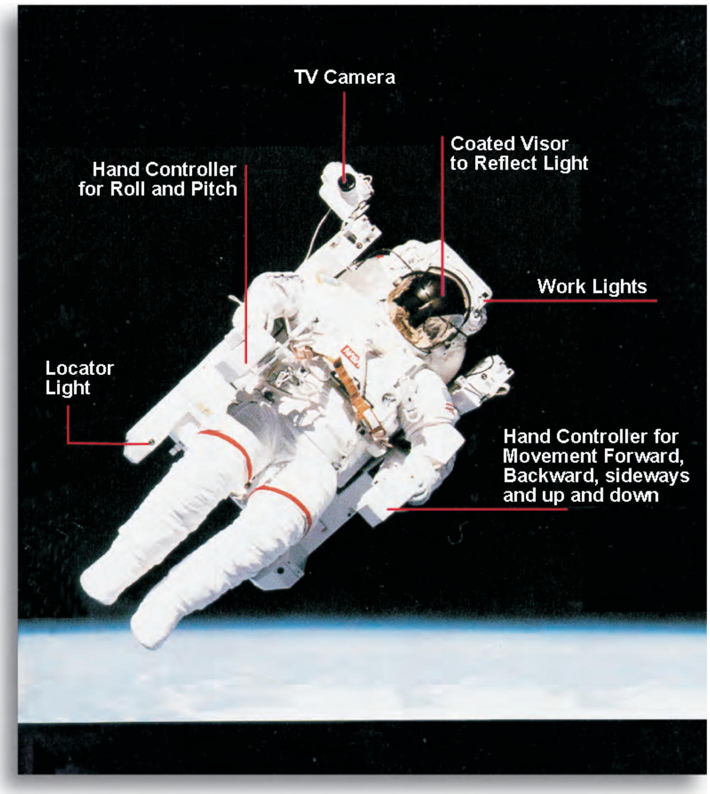
The mid-deck has storage space for food, a galley where the food is prepared for consumption, sleeping stations for four crew members at one time, multiple storage lockers, a toilet, wet trash storage and an air lock. The air lock is used to transfer from mid deck into the payload bay area when required. The air lock is where extra-vehicular activity (EVA) suits are stored. It is a cylinder that is about 7 feet high and slightly more than 5 feet wide.

An astronaut going for EVA enters the air lock and puts on the very complex suit, which contains its own life-support system. Once the suit is checked out, pressure inside the air lock is reduced slowly until a space environment is achieved. The hatch leading


***Endeavor* crew members capture the *INTELSAT* VI communications satellite.**

into the payload bay is then opened for EVA. Astronauts completing an EVA return to mid deck in reverse manner, storing their EVA suits within the air lock. Astronauts participating in EVA can now use the Manned Maneuvering Unit (MMU). The MMU is a nitrogen-propelled, hand-controlled device that allows the astronauts more mobility than that afforded those who used restrictive tethers.

The center-fuselage section contains the purpose of each flight mission because this section consists mostly of the payload bay. The payload bay is about 60 feet long and has a diameter of about 15 feet. Its doors are opened and closed by a mission specialist working on the flight deck.



Manned Maneuvering Unit

A most important unit located within the payload bay area is the remote manipulator system's manipulator arm. This arm also is controlled from the flight deck, and it is the action portion of a very complex system. It can deploy, retrieve or otherwise affect a payload without the need of an EVA. The arm has a special light and television camera so that its human operator can see the detail of what is taking place as the system is operated. It is possible for two manipulator arms to be located in the payload bay if required by a mission. However, only one arm can be operated at a time.

The orbiter's aft-fuselage primarily contains, or has attached to it, units for orbital propulsion and aerodynamic flight control. The craft's main propulsion system engines, orbital maneuvering system engines, and aft reaction control system engines are found within the aft- fuselage. The vertical stabilizer is attached to the topside of the aft fuselage, and the body flap is attached to the bottom side of the aft-fuselage. The vertical stabilizer's attached rudder is sectioned so that it can be "spread" and serve as a speed brake in atmospheric flight. The body flap also serves as a speed brake during the return flight to earth.

The craft's wings are attached to the center- and aft-fuselages, with the major portions joined to the center-fuselage. The wings' function does not begin until the upper atmosphere is encountered upon reentry. The primary function of the wings, of course, is to provide aerodynamic lift for the craft. Recall from earlier discussions of space definitions that this occurs at approximately 62 miles above the earth. However, they first serve as a brake and energy dissipater to slow the craft to aerodynamic flight speed.

In addition to acting as speed brake and lift producers, the wings house the craft's main landing gear. To provide the craft a means of aerodynamic control, the wings are fitted with elevons. These elevons are located along the wings' trailing edges and function as either elevators or ailerons, according to how they are moved.

Payloads

The shuttle can carry a variety of payloads into space. At one time, it was thought satellites could be deployed from the shuttle more efficiently than from expendable launch vehicles. The shear number of new satellites being launched all the time makes that impossible. Most shuttle missions are geared toward those that need onboard specialists. Two notable ones are the Spacelab and Long-Duration Exposure Facility missions.

Soviet Manned Space Program

The Soviet Union's space flight programs developed along the same lines as the American programs and occurred at approximately the same times. However, the Soviets had several firsts in the space race.

Vostok

As mentioned earlier, the Soviets launched the first satellite into space. After *Sputnik,* the Soviets launched nine more Sputniks in about 31/2 years. The last two were accomplished in preparation for their first manned space flight.

With the initial advantage of having large rockets, the Soviets put the first man in space on April 12, 1961. Major Yuri Gagarin, aboard *Vostok* 1, was the first man to escape from earth's atmosphere into space. Although he only stayed up for one orbit (108 minutes), he described sights no human eyes had ever seen before.

Yuri Gagarin of the Soviet Union is the first human in space.

In June 1963, *Vostok* 6 had the distinction of carrying Valentina Tereshkova, the first woman, into space. She completed 48 orbits and was in space for 3 days before returning safely to earth. This was the last *Vostok* flight.

Voskhod

The success of *Vostok* led to the Voskhod series. The first *Voskhod* was launched in October of 1964, and was a three-man capsule.

On March 18, 1965, aboard the *Voskhod 2* spacecraft, Cosmonaut Alexei Leonov became the first person to "walk in space." He spent 20 minutes outside of his spacecraft. This space walk occurred about two months before the Americans walked in space.

Soyuz

The Launch of the *Soyuz*

Soyuz means "union," and the spacecraft were designed for docking in space. *Soyuz* consisted of three modules: an instrument module with the rocket engines, an orbital module and a descent module.

The cosmonauts would begin in the instrument section, and then after reaching orbit they would move into the orbiter module and conduct experiments. When they started the flight back to earth, they would move into the descent module.

Upon reentry into the earth's atmosphere, the three modules would separate. Only the descent module reentered the earth's atmosphere intact. Forty Soyuz spacecraft were launched between 1967 and 1981.

In April 1967, *Soyuz* 1 was launched. It was designed to rendezvous with *Soyuz 2,* but there were problems and cosmonaut Vladimir Komarov died when *Soyuz* 1 crashed.

The Soviets did not resume their flights until October 1968. It was not until January 1969 that *Soyuzs* 4 and 5 fulfilled the mission of docking and transferring crew members in space. The remaining Soyuz missions continued docking techniques and conducting experiments. They also prepared for and worked in conjunction with their first space stations.

Space Stations

The basic objective of both the Soviet and American space stations was the physiological study of long-term manned flight. Again, the Soviets were the first to launch a space station. So, let us take a look at their program, and then we will discuss the American space stations.

Soviet Space Stations

Salyut

The Soviets launched their *Salyut* 1 space station on April 19, 1971, and on April 22, 1971, *Soyuz* 10 docked with the world's first space laboratory, although the crew of the *Soyuz* did not board the

Salyut. In June of 1971, *Soyuz* 11 docked with *Salyut* 1 for 22 days. Unfortunately, the crew died as they returned to earth when a faulty valve allowed air to escape from the cabin.

By the end of 1976, the Soviet Union had put up six Salyut space stations. These stations were experimental laboratories and were the basis of the Soviet Union's long-term manned program. Despite setbacks in the program, they continued to pursue the Salyut Project. By the time *Soyuz* 23 failed to dock with *Salyut* 5 and had to make a quick trip home, there had been 7 failures in 11 attempts to complete space station missions.

For *Salyut* 6, the Soviets made a few changes, most notably a second docking port and a new propulsion system. These two changes made it possible to resupply, repair and refuel missions much easier. *Salyut* 6 was launched in September 1977, and it stayed in space for about 4 years.

Salyut 7, launched in 1982, had many more modifications. In 1984, Svetlana Savitskaya visited *Salyut* 7 and became the first woman to space walk. Also in 1984, a Soviet crew set an endurance record of 234 days in space. *Salyut* 7 fell back to earth in 1991.

Mir

The next Soviet space station model was the *Mir*. *Mir* (means "peace") was launched in February 1986, so it was in space before *Salyut* 7 fell to earth. *Mir* weighs about the same as *Salyut*, but it doesn't carry as much scientific equipment, so there is more room and comfort for the cosmonauts.

Mir conducts experiments, but is mainly used for the cosmonauts as they come and go from space. It has 6 docking ports and has living quarters for up to six cosmonauts. It can also dock with the space shuttle. In fact, in 1998, the United States sent the space shuttle to *Mir* several times to help with repairs. American astronauts have spent over 2 years aboard *Mir* on different missions.

The *Mir* space station was originally planned to be followed by a *Mir 2,* but only the core module, *Zvezda,* became an integral part of the *International* Space Station. *Mir* went through de-orbit and broke up in the earth's atmosphere over the South Pacific in March of 2001.

Mir

American Space Station

Skylab

As early as 1970, the United States had made plans to establish a space laboratory program. This program was originally called the Apollo Applications Program, but was later renamed the Skylab. The original intent of the program was to make some practical use of leftover hardware from the Apollo moon landings. Instead, it gradually grew into a vital step in our mastery of the space environment.

On May 14, 1973, the *Skylab* 1 unmanned orbital workshop was placed into orbit, 2 years after *Salyut*. There was a failure in the powered phase of the launch, which ripped off one of the solar array wings from the workshop. Stopgap measures were taken to control the solar radiation and prepare a repair kit for the astronauts who would go up and dock with *Skylab* 1.

Skylab was constructed partly from off-the-shelf hardware. Its main compartment, called the orbital workshop module, was constructed from a *Saturn* V rocket section. Within this section were the astronaut's living quarters, a work area and many of the vehicle's scientific experiments.

Skylab

A second special module was an air-lock device used to exit and enter the spacecraft when necessary to perform work outside the craft. This particular module proved very necessary when the astronauts had to erect a sunshade at the location of a micrometeoroid shield that had been torn off during the launch phase. A secondary function to the micrometeoroid shield was to serve as a sunshade to keep the laboratory/living quarters from overheating.

A third module was the multiple docking adapter. This portion was especially designed to accept the *Apollo* command module in airtight linkup so that the astronauts could transfer safely into the laboratory and back to the command module for return to earth.

Skylab was NASA's only orbited space station. Three different crews lived at different times in the *Skylab*. The last crew stayed for 84 days, which was the longest of the crews. During their stays, the crews conducted many experiments. They demonstrated that people could live and work in space. No other crews visited *Skylab*, but it remained in space for 6 years before reentering the earth's atmosphere and falling back to earth. Most of *Skylab* burned up on reentry, but some pieces landed in the Indian Ocean and were recovered.

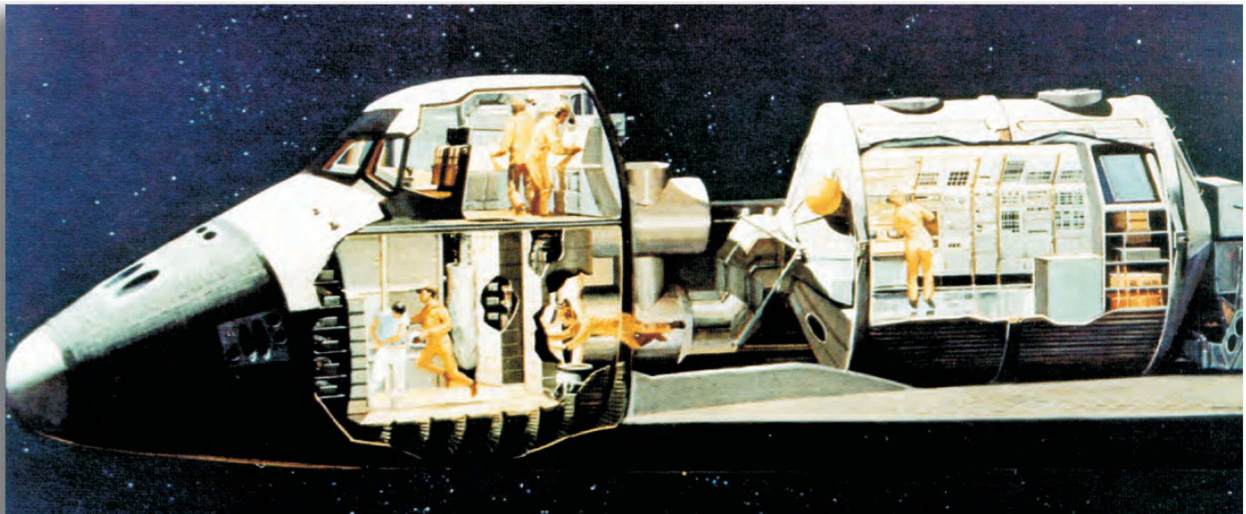
European Space Station

Spacelab

Spacelab was an orbiting laboratory designed by the European Space Agency to be flown in the space shuttle's cargo bay. Designed on a modular principle, the *Spacelab* was comprised of a long or short pressurized cabin inside which astronauts could work on experiments. Between one and three U-shaped pallets could be added to the laboratory, allowing experiments to be exposed directly to the vacuum of space.

These pallets were special modular containers in which the experiments could be placed. *Spacelab's* environment provided payload specialists with a "short-sleeve-shirt environment" that allowed them to work on experiments without a space suit. To facilitate entry to the *Spacelab*, a tunnel was attached to the airlock; entry to the module was through the orbiter's airlock and this tunnel.

Spacelab missions addressed a wide variety of scientific topics including astronomy, microgravity, life sciences, biomedicine and industrial technology. The flights were discontinued in 1997 as preparations were made for the Space Station Project.

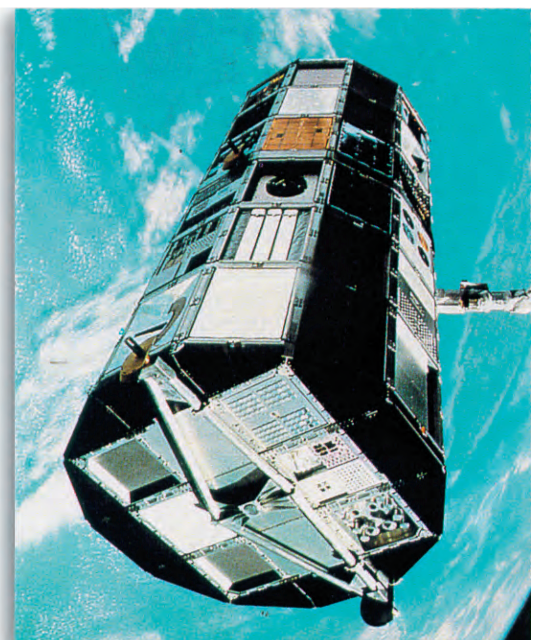


Spacelab* on board the Space Shuttle *Columbia

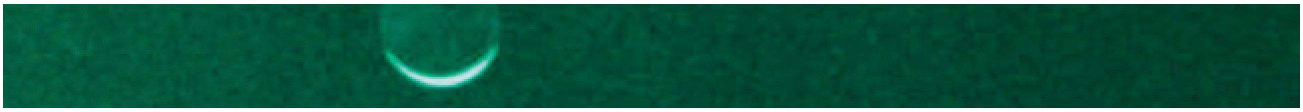
Long-Duration Exposure Facility (LDEF)

The *Long Duration Exposure Facility* was designed to provide long-term data on the space environment and its effects on space systems and operations. Constructed of aluminum, *LDEF* was a nearly cylindrical 12-sided regular polygon 30 feet long and just over 14 feet in diameter. Fifty-two experiments were mounted in 86 trays around the periphery and on both ends.

One of the largest payloads ever deployed by the shuttle, *LDEF* was placed into orbit by Space Shuttle *Challenger* on April 7, 1984. The facility remained in space for 69 months, completing 32,422 orbits of earth before it was retrieved by Space Shuttle *Columbia* on January 11, 1990. The retrieval of *LDEF* and its experiments was accomplished about 1month before the



***Long-Duration Exposure Facility (LDEF)* during deployment from shuttle.**



facility would have reentered earth's atmosphere and been destroyed.

The 5-plus-year flight of the facility was a direct result of the suspension of all shuttle operations following the loss of *Challenger* in 1986. The result was that the facility, having been launched during a solar minimum and retrieved at a solar maximum, remained in orbit through half of a solar cycle. This lengthened stay increased the scientific and technological value toward our understanding of the space environment and its effects.

The experiments carried by *LDEF* involved the participation of more than 200 principal investigators representing 33 private companies, 21 universities, seven NASA centers, nine Department of Defense laboratories and eight foreign countries. Following the de-integration of each experiment from *LDEF*, research activities included a radiation survey, infrared-video survey, meteoroid and debris survey, contamination inspection and extensive photographic documentation. After these activities were completed, the experiment trays were returned to the laboratories of each principal investigator. Post-flight special investigations and continued principal investigator research resulted in a total number of investigators of between 300 and 400, and provided a broad and detailed collection of space environment data.

The International Space Stations

In its current operational state, the *International* Space Station weighs 471,444 pounds. It has a habitable volume of 15,000 cubic feet and the length of its solar panel array is 240 feet. From the *Destiny Lab* to *Zvedzda,* it is 146 feet long and the height is 90 feet.

To date, 90 scientific investigations have been conducted on the space station and much more scientific data is to come. Results from space station research, is available on the internet from NASA.

"One of the primary goals of the Space Station scientists is to develop technologies and capabilities that will allow humans to go places far away from Planet Earth. If we don't have these capabilities, we are pretty much destined to stay close to the earth — and I don't think that's what humans are all about." (quote from *Expedition* 1 Commander Bill Shepherd)

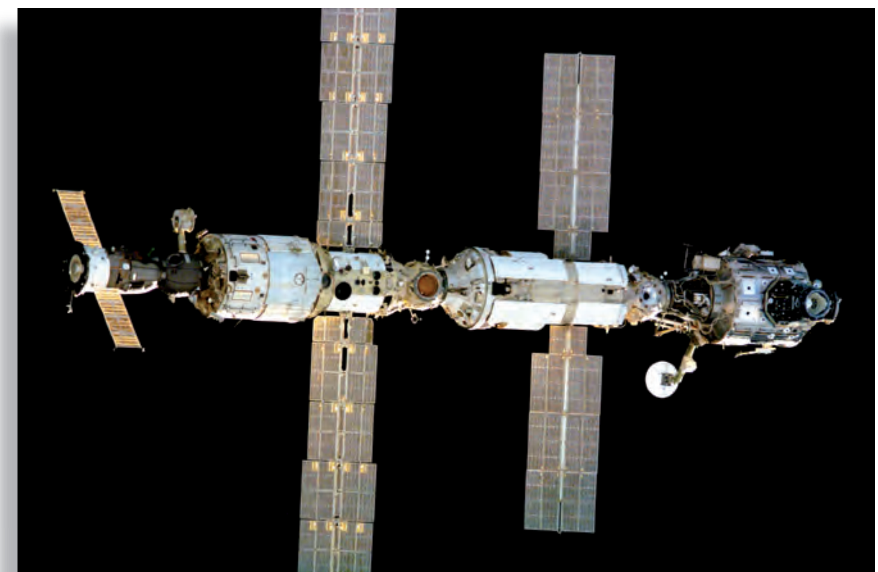
"The *International* Space Station is a perfect stepping-stone for us to perfect the

STS096-042-715 (3 June 1999)---A STS-96 crew member aboard Discovery recorded this image of the ISS during a fly-around to follow separation of the two crafts. Lake Hulun Nur in the China is visible in the lower left portion of the frame. A portion of the work performed on the May 30 space walk by astronauts Tamara Jernigan and Dan Barry is evident at various points on the ISS, including the installation of the Russian-built crane (called Strela) and the U.S. built crane. *(Courtesy of NASA)*

S106-E-5318 (18 September 2000) backdropped against the earth's horizon, the International Space Station (ISS) is seen following it undocking with the space shuttle *Atlantis*. After accomplishing all mission objectives in outfitting the station for the first resident crew, the seven astronauts and cosmonauts undocked at 3:46 GMT on Sept. 18, over Russia near the northeastern portion of the Ukrain. When Atlantis was at a safe distance from the station, about 450 feet, astronaut Scot Altman, pilot, performed a 90 minute, double-loop fly around to enable the crew to document the station's exterior. He fired Atlantis' jets one final time to separate from the station at 5:35 GMT. *(Courtesy NASA)*

technology, to perfect the operational tempo, and operational parameters needed in order to make long duration missions successful." (quoted from Expedition 9 by Flight Engineer Mike Fincke).

The *International* Space Station continues to be the focal point for the advancement of technology in a realm with gravity. Over the years to come, this space-based laboratory will provide new and wonderful scientific information that will benefit all mankind and hopefully extend life beyond our home planet, Space Ship Earth!



S97-E-5010 (2 December 2000) ISS against the darkness of space. This shows the progress of development in just a four month period. *(Courtesy NASA)*

S114-E-7200 (6 August 2005) – The International Space Station is backdropped against a heavily cloud-covered part of earth as the orbital outpost moves away from the space shuttle *Discovery*. Earlier, the crews of the two spacecraft concluded nine days of cooperative work. As the shuttle moved away to a distance of 400 feet, astronaut and pilot, James Kelly, initiated a slow fly-around of the station, while cameras on each space craft captured video and still images of the other. Undocking occurred at 2:24 a.m. (CDT) August 6, 2005.)
(Courtesy NASA)

Living and Working in Space Stations

The space station has been a part of the manned space program for many years. The creation and assembly of the *International Space Station* provides a permanent laboratory where gravity, temperature and pressure can be manipulated to achieve a variety of scientific and engineering pursuits that are impossible in ground-based laboratories. It is a test bed for technologies of the future as well as a laboratory for research on new, advanced industrial materials, communications technology, medical research and more. On-orbit assembly of the station began as a cooperative effort between nations of earth's global community and its completion will be one of the largest international scientific and technological endeavors ever undertaken.

What is it like to live and work on the space station? Working in space presents its own unique challenges, not the least of which is microgravity. The force of gravity in low-earth orbit is almost as strong as it is on the ground. However, the outward force on the station as it orbits earth counterbalances the downward pull of gravity and this free-fall state creates an environment known as microgravity. The pull of microgravity is approximately one-millionth the gravity on earth, but since all unsecured objects (including people) fall together within the station,

Weightless in Space

Foot restraints hold astronaut in place.

they appear to be weightless and they float. Astronauts have learned how to function effectively in this apparent weightlessness and have adapted to working in a microgravity environment.

The atmosphere inside the space station is a mixture of nitrogen and oxygen, a better system than one using pure oxygen since earth's atmosphere is a similar mixture. The air pressure and temperature is also regulated and astronauts wear comfortable clothing such as T-shirts and shorts, or sports shirts and pants.

Astronauts eat their food strapped to their laps or to the cabin ceiling.

Much of the food aboard the station is dehydrated, saving both weight and storage space. A variety of tasty, nutritious foods and beverages are available; some foods may be eaten as is, while others can be heated before serving. Since the electrical power for the *ISS* is generated from solar panels rather than from fuel cells, there is no extra water generated aboard the station. Water is recycled from cabin air, but not enough for significant use in the food system. Hence the percentage of rehydratable foods will decrease and the percentage of thermostabilized foods will increase over time. Water is plentiful as it is a byproduct of the fuel cells when generating electricity; therefore, re-hydration of foods or beverages can be easily accomplished. Astronauts are able to anchor themselves in place for eating through the use of special floor restraints known as foot loops.

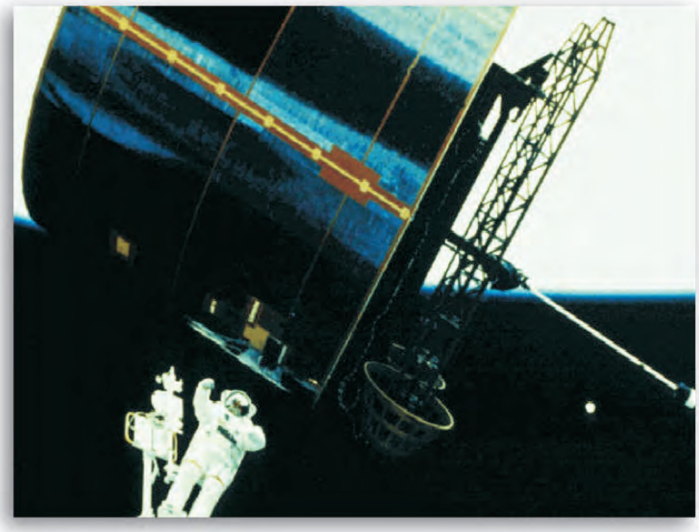
Astronaut Sally Ride in Sleep Restraint

A wide variety of choices in sleeping accommodations are available to the astronauts, including such options as sleeping in their seats, restrained in bunks, in sleeping bags or simply by tethering themselves to the wall. Sleeping bags would most likely be cocoon-like restraints that could be attached to lockers or walls, much like current shuttle systems. In microgravity, there is no "up," and astronauts can comfortably sleep either vertically or horizontally.

Recreation is an important factor in space station living. Along with regular exercise necessary to counter muscle atrophy that occurs in the microgravity environment, cards, games, books, taped music and videos are available to crew members.

Sanitation is vitally important within the confines of the space station. Since the population of some microbes can increase extraordinarily in microgravity, infectious illnesses could be easily spread. Eating equipment, dining areas, toilets, and sleeping facilities need to be cleaned regularly to prevent micro-organism growth.

Work done by astronauts aboard the space station varies according to needs and missions, but, in addition to regular housekeeping chores, work involves developing and processing new materials, performing fundamental medical research, performing long-duration research, and repairing satellites and spacecraft in orbit.



Taking a Look at the *Hubble Space Telescope*

Any activity outside the space station requires astronauts to wear space suits. The first space walk, or extra-vehicular activity (EVA), was accomplished by Aleksei Leonov in March 1965, when he went outside his *Voskhod* II spacecraft for about 20 minutes. In June of that same year, astronaut Ed White spent 22 minutes outside his *Gemini* IV capsule. By 1973, *Skylab* astronauts were setting duration records for EVAs with outside missions lasting more than 7 hours. Extra-vehicular activity allowed astronauts to retrieve satellites or to repair them while they remain in orbit. Missions such as the repair of the *Hubble Space Telescope* allowed earthbound scientists to continue making astounding new discoveries as they use orbiting satellites and telescopes to help them understand the universe.

In the 1930s, high-altitude flyers wore pressure suits; all of the Mercury astronauts wore a modified version of a US Navy high-altitude jet aircraft pressure suit. Mobility was quite limited in these suits. Later designs provided greater suit mobility. During the Gemini missions, a lighter weight, easily

Pressure suits worn by the seven Mercury astronauts.

Gemini Astronauts wore light-weight space suits.

Apollo astronauts wore a more advanced suit for moon walking.

removable suit was developed and for the first time astronauts removed their spacesuits while in orbit. Up through the Apollo missions, all space suits had a separate backpack-type life support system that had to be connected to the suit. The suit was also tailor-made for each astronaut, a time-consuming and expensive process. With the advent of the Space Shuttle Program, suits became lighter, more durable and easier to move around in. Manufactured in small, medium and large sizes, today's suits may be worn interchangeably by men or women. Life support systems are built into the torso of the suit; only the gloves continue to be custom-fitted for each astronaut.

The X-Prize

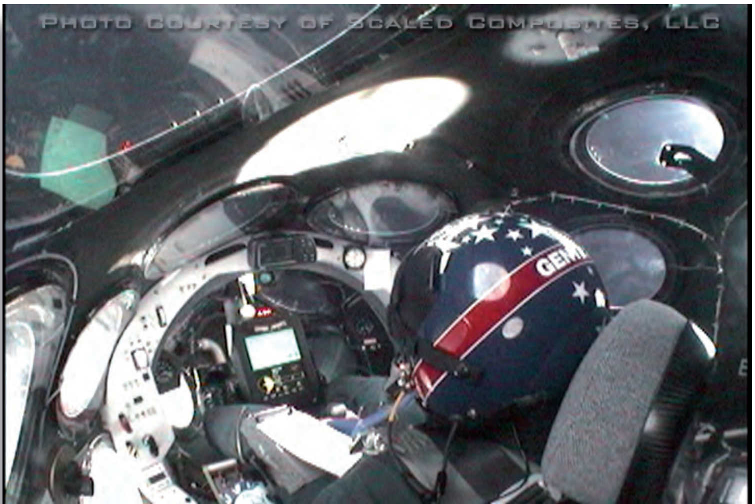
THE X PRIZE- PRIVATE ENTERPRISE FLIES INTO SPACE

The X-Prize Heritage — From the very beginning of aviation's rich history, prizes have been offered for numerous achievements. One of the most notable was the Orteig Prize and it was offered by a wealthy entrepreneur, Raymond Orteig, in 1919. He offered a $25,000 award to the first person who could fly from New York to Paris, non-stop. This was 1927 and the winner was Charles A. Lindbergh. Since it was a private venture, not one but nine different entries were involved. At the time, no one had any idea of how important Lindbergh's flight was to the development of aviation, but his flight is considered to be the beginning of the world's huge aerospace industry of today.

The Requirements — The 21st Century X-Prize took the Orteig Prize one step further by offering $10,000,000 to the first non-government organization to launch a reusable manned spacecraft that could fly into space (defined as 100 Km or 62 miles above the surface of the earth) and return within a period of two weeks. It also required that the vehicle carry the weight of three adult humans on each flight.

The People and Funding — The X-Prize was the brainchild of Dr. Peter H. Diamandis. He believed that a privately-funded flight into space could change the world. He was influenced by a gift, Charles Lindbergh's book *The Spirit of St. Louis*. In 1995, Diamandis established the X-Prize Foundation and his team set about getting

The *White Knight* "mother ship." *SpaceShipOne* is released at 50,000 and the *White Knight* then returns to the airport.
(Permission granted to Civil Air Patrol by Mojave Aerospace Ventures LLC, photo by Scaled Composites. SpaceShipOne is a Paul G. Allen Project.)

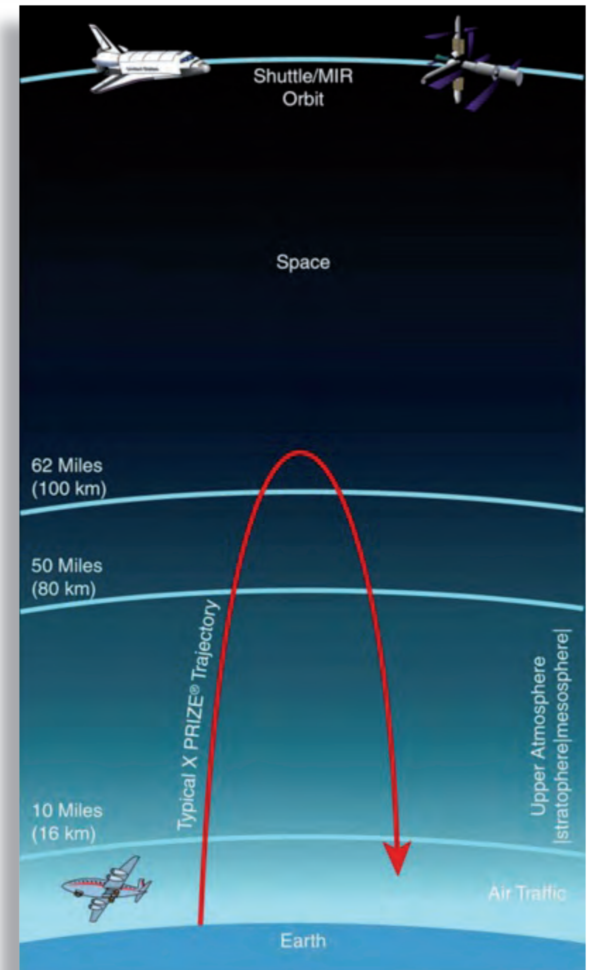


Inside *SpaceShipOne* during flight. *(Permission granted to Civil Air Patrol by Mojave Aerospace Ventures LLC, photography by Scaled Composites. SpaceShipOne is a Paul G. Allen Project)*

financial support for the prize money. Several corporations and individuals contributed to the Foundation. This organization also included Erik and Morgan Lindbergh, the grandchildren of Charles A. Lindbergh. A substantial contribution made by the Ansari family helped make the prize a reality. As a result the original X-Prize was renamed the Ansari X-Prize.

The Winning Team — Several flight attempts were made, but on November 6, 2004, the $10M prize was officially awarded to Mojave Aerospace Ventures for meeting all of the requirements in an aerospace craft they called *SpaceShipOne*. Earlier, on June 21, 2004, test pilot Mike Melville flew *SpaceShipOne* to a record-breaking altitude of 328,491 feet, making him the first private pilot to earn NASA's coveted astronaut wings. The X-Prize set a parameter of 62 miles, or 100 kilometers, as the line defining space. On the final flight of *SpaceShipOne,* test pilot Brian Binnie, flew the vehicle to another record-breaking altitude of 367,442 feet, or 69.6 miles, above the earth's surface. With the necessary payload, this flight met all of the requirements to win the $10,000,000 Ansari X-Prize. It was made on October 4th, the 47th anniversary of the Soviet Union's launch of *Sputnik*.

"This flight begins an exciting new era in space travel," said Paul G. Allen, sponsor of the SpaceShipOne program. He continued, " Burt Rutan and his team at Scaled Composites are part of a new generation of explorers who are sparking the imagination of a huge number of people worldwide and ushering in the birth of a new industry of privately-funded, manned space flight." Burt Rutan commented to the press, "Today's flight marks a critical turning point in the



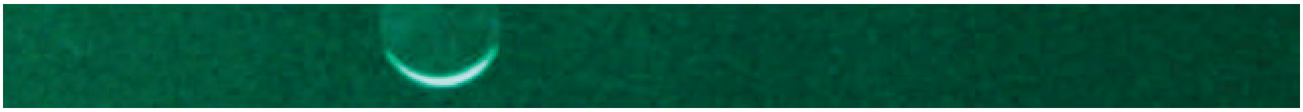
This artist illustration shows a typical X-prize flight trajectory as it enters space 62.14 miles above the earth.

history of aerospace…we have redefined space travel as we know it." In fulfillment of his dream, Dr. Peter Diamandis said, "Today we have made history. Today we go to the stars."

The Flight Crew of *SpaceShipOne*. From left to right, top to bottom, Brian Binnie, Pete Siebold, Mike Melvill, and Doug Shane. They are pilots whose fame is right up there with Charles A. Lindbergh. Godspeed Gentlemen. (*Permission granted to Civil Air Patrol by Scaled Composites.* SpaceShipOne *is a Paul G. Allen Project)*

***SpaceShipOne* returns from one of several test flights.** *(Permission given to Civil Air Patrol by Mojave Aerospace Ventures LLC, photographs by Scaled Composites.* SpaceShipOne *is a Paul G. Allen Project.)*

Legendary Aerospace pioneer, Burt Rutan (right) discusses the program with fiancier, Paul G. Allen (left). *(Permission given to Civil Air Patrol by Mojave Aerospace Ventures LLC. Photographs by Scaled Composites.* SpaceShipOne *is a Paul G. Allen Project.)*



Future Manned Spacecraft

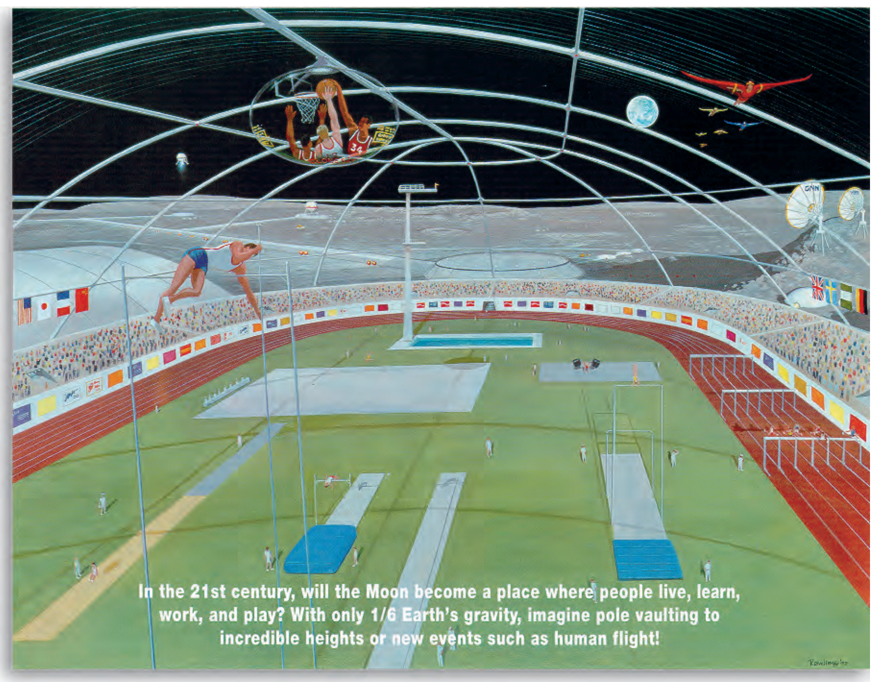
The future is now–at least part of it. The commercial satellite industry is booming. Hundreds of new satellites are scheduled for launch in the next few years. We are in the middle of a communications revolution that may continue for a decade or more. While the United States may now be considered the leading information society, soon the whole world will have access. The United States continues to aggressively pursue the construction of the *International Space Station*.

In November 1998, the first of several launches that will construct *Space Station Alpha* began. It will take about 15 shuttle flights to complete *Alpha*. This is a joint venture between the United States, Europe, Canada, Japan and Russia. It is to be the permanent space station of the near future. As of 2007, the assembly of the ISS is still on-going. Each of the countries is responsible for various parts of the project.

The space station will be a permanently manned laboratory in space where men and women will be aboard full-time, 24 hours a day, 365 days a year. The space station's microgravity environment, high levels of power and extended time in orbit will enable scientists to make new discoveries in materials, research and life sciences. NASA's current focus is to move beyond Earth's orbit for human exploration and scientific discovery. As NASA Administrator Michael Griffin says, "the International Space Station is a stepping stone along the way." Astronaut crews will continue to learn how to live and work in space and also build hardware that will help the astronauts on a voyage from Earth to Mars.

Space Colonies

Far beyond the concept of space stations is that of permanent colonies for some of earth's people. It will be a long, cautious road to the eventual construction of space colonies, and there seems to be no reason to doubt that the colonies will become a reality. Why should they be built? One of the primary reasons is that extensive materials processing and manufacturing can take place without polluting the earth's environment. Another reason is that more unique and better products can be developed in space. Still another more far-reaching promise is



***Lunar* Outpost**

that the space colony approach could lead to people's existence in other solar systems that do not have habitable planets. However, the overpowering reason probably is that space is indeed a new and different frontier, and history has shown that new frontiers have always attracted explorers and settlers.

Serious work continues in an effort to define the best locations and missions for space colonies. As early as 1975, in summer workshops, scientists, engineers and others concluded that colonies in space are feasible and could be a great boom to human life.

There are two points in space which seem to be the best locations for eventual, sophisticated space colonies. These points are designated L4 and L5. The L of the designation signifies Lagrange, after Joseph Louis Lagrange. In 1772, Lagrange pointed out that there are points in relation to two large planetary masses where a body will be in gravitational equilibrium. The Lagrangian points would be a precise location around which space colony structures could orbit. This orbit within an orbit is necessary because of the gravitational influence of the sun.

When exactly will space colonies be in orbit at L5? No one really knows. But the 1990s television series Babylon 5 is based on the prospect. Just knowing that advances in space construction techniques and propulsion systems could eventually lead to the colonization of space should reinforce our hopes for the future.

Currently, NASA is researching the feasibillity of a single-stage-to-orbit reusable launch vehicle that lifts off into space and returns to earth intact. The X-34 will demonstrate key vehicles and operational technologies applicable to future low-cost reusable launch vehicles.

The Experimental *DC-X Delta Clipper* takesoff and lands vertically, and will be a breakthrough in low-earth orbit.

Key Terms and Concepts

- manned spacecraft
- National Aeronautics and Space Administration (NASA)
- Apollo Space Program
- Project Mercury
- Project Gemini
- Space Shuttle
- *Hubble Space Telescope*
- *Skylab*
- Apollo-Soyuz Test Project
- Space Transportation System (STS)
- extra-vehicular activity (EVA) suit
- Manned Maneuvering Unit (MMU)
- *Spacelab*
- *Long-Duration Exposure Facility (LDEF)*
- *Soyuz*
- *Salyut*
- *Mir*
- *Vostok*
- *Voskhod*

? Test Your Knowledge ?

SELECT THE CORRECT ANSWER

1. *The* **(Mercury/Gemini/Apollo)** *Program landed a man on the moon.*
2. *The* **(Mercury/Gemini/Apollo)** *was the first US manned space flight.*
3. *The* **(Mercury/Gemini/Apollo)** *was the first US space flight to place two persons in space.*

MATCHING

4. **Match the following:**

a. Mir	**1) Transports up to three cosmonauts to and from space**
b. Gagarin	**2) First space station intended for prolonged occupancy**
c. Salyut	**3) First man into space**
d. Soyuz	**4) Later version of space station that has docked with the shuttle**

FILL IN THE BLANKS

5. _____ ________ *was the first American to orbit the earth.*
6. _________ __________ *was the first Russian to walk in space.*
7. *On July 20, 1969,* _______ __ *landed on the moon and* _____ _________*was the first man to walk on the moon.*

8. ______-_________ involved a linkup in space between an American and a Russian manned spacecraft.
9. The ______ ____________ ________ is commonly called the space shuttle.
10. The ____________ was the first space shuttle, but it was only used for flight tests.
11. Name the other five space shuttles: _________, _________, __________, __________ and ____________.
12. The ________ ________ _________ is operating at 300 miles above the earth and is free of any atmospheric interference.

TRUE OR FALSE

13. A space walk is also referred to as an extravehicular activity.
14. The Long-Duration Exposure Facility is used for experiments up to 30 days.
15. The first space walk lasted for 60 minutes.
16. The Spacelab was built by the European Space Agency.
17. The air inside of space stations is a mixture of oxygen and nitrogen.
18. Astronauts inside the space shuttle must leave their space suits on at all times.
19. Skylab used a lot of left over parts from the Apollo missions.
20. Alan Shepard was the first American in space.
21. The X-Prize was awarded to Mojave Aerospace Ventures.
22. The aerospace craft that won the X-Prize was called the Sputnik.