National Aeronautics and Space Administration

Information Summary

Living and Working on the New Frontier

The idea that people other than highly trained astronauts would someday live and work in space has long fascinated science fiction fans.

Today it interests professional space scientists and engineers as well.

The space shuttle, in which anyone in ordinary good health can ride into orbit, was the first step in turning this dream into reality.

The International Space Station, on which assembly in space began in 1998 with the launch of the Russian module Zarya, provides a permanent facility in orbit for continuing technical and scientific work.

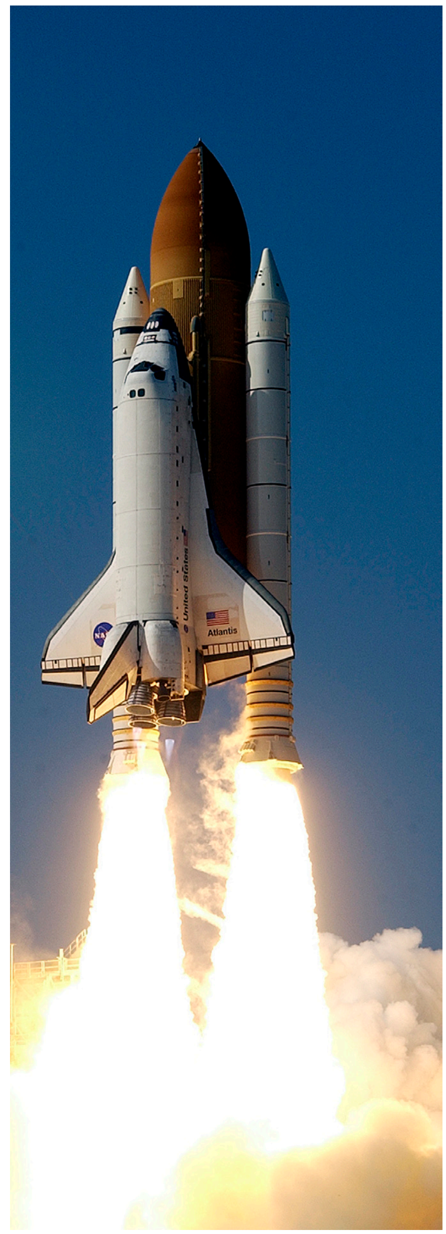
It is operated by rotating crews from Earth, including personnel who are not career astronauts.

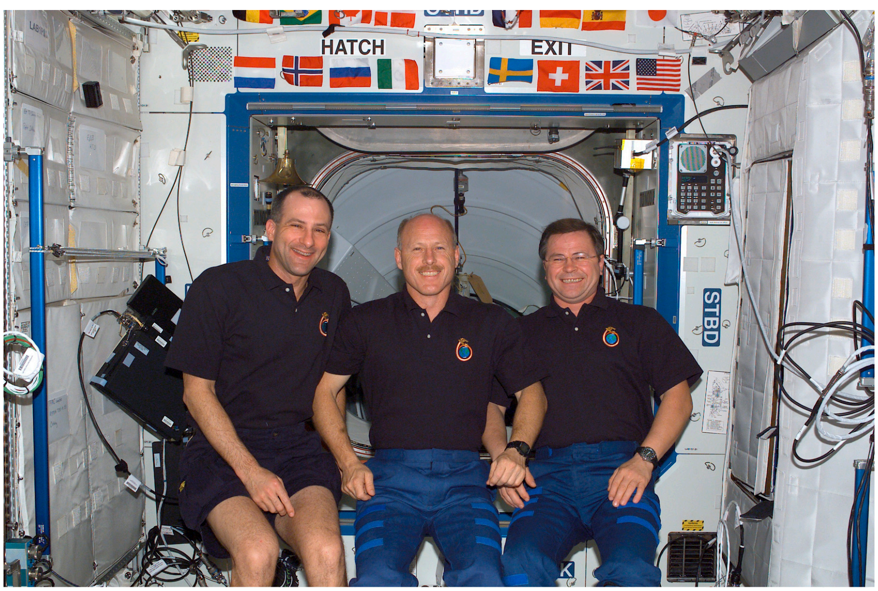
Before the International Space Station, Skylab, an early type of space station, was launched in May 1973. Three crews of three astronauts lived and worked aboard Skylab, occupying it until early February 1974. Skylab could not be resupplied with consumables, had no on-board propulsion system to keep itself in orbit, and was never intended for permanent occupation. But operating

During STS-106, Sept. 11, 2000, cosmonaut Yuri I. Malenchenko, mission specialist, was captured on film by his spacewalking colleague, astronaut Edward T. Lu, during the six-hour-plus spacewalk the two performed on the exterior of the International Space Station.

The International Space Station in 2001.

Space Shuttle Atlantis carries the S1 integrated truss structure and the crew and equipment translation aid (CETA) cart A to the International Space Station on mission STS-102 in October 2002.





The Expedition Six crew members pose for a crew photo in the Destiny laboratory on the International Space Station. From the left are astronauts Donald R. Pettit, NASA space station science officer; Kenneth D. Bowersox, mission commander; and cosmonaut Nikolai M. Budarin, flight engineer representing Rosaviakosmos, the Russian space agency.

it provided valuable data needed by the engineers then planning the human support systems on the space shuttle orbiter. That data is still of value to the engineers working on the manned space station today.

The Versatile Space Shuttle: Workhorse of the New Frontier

The space shuttle is the first reusable aerospace vehicle, taking off vertically like a rocket, maneuvering in orbit like a spaceship, and at the end of the mission, landing on a runway like an unpowered glider. The delta-winged orbiter is about the size and general shape of a DC-9 jetliner.

The space shuttle takes much larger crews into orbit than any prior launch vehicle. The work these crews perform varies greatly, according to the particular mission. Some tasks are similar to those done every day on Earth, but most are unique to the requirements of space flight.

Early missions were devoted primarily to verifying the performance of the space shuttle and its associated equipment. Crews on later flights have operated instruments to perform extensive observations of the Earth, studied objects of interest in astronomy, processed materials in microgravity, and performed biological experiments with seeds, plants, insects and small animals.

A very important part of the work has been launching satellites for scientific and commercial use, such as the Hubble Space Telescope, and repairing spacecraft in orbit. Some satellites have been recovered from orbit and returned to the ground, refurbished and launched again. Since its debut on April 12, 1981, the space shuttle has made more than 113 flights, far more than any other American manned vehicle.

The space shuttle is now being utilized nearly exclusviely for construction and maintenance of the space station. In the past, the shuttle orbiter was used as an observation platform, from which instruments were focused on the ground passing below, or on objects in space of strong interest to astronomers. The orbiter also carried a small but fully equipped manned laboratory, called Spacelab, for medical, scientific, engineering and industrial experiments. Spacelabs were flown on numerous successful missions. The pressurized modules remained in the cargo bay of the orbiter throughout the mission. Spacelab is one of NASA's most successful in-orbit scientific research programs.

One of the key attributes of the space shuttle is the relatively low acceleration and deceleration forces exerted on crew and passengers during launch and reentry. These forces reach a peak of 3 Gs — three times the force of gravity on the Earth's surface — for a few minutes at a time. The strain is well within the limits that can be tolerated by healthy people.

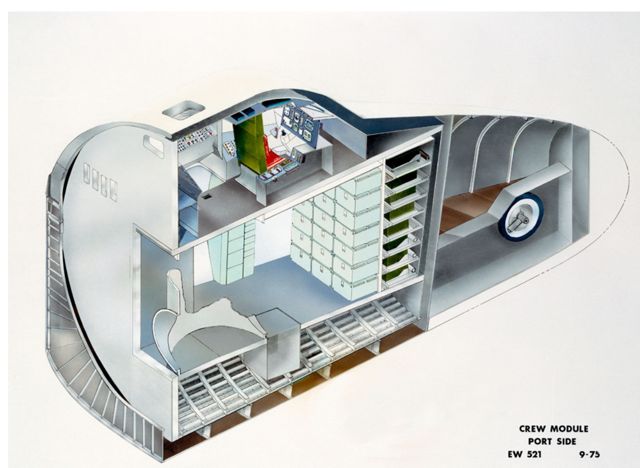
The Orbiter Crew Compartment

The living space aboard an orbiter is relatively roomy and comfortable, compared to that in early manned spacecraft. There are two floors in the pressurized cabin located in the nose section (see illustration). Together they provide 2,325 cubic feet (65.8 cubic meters) of space. The temperature can be regulated to stay between 61 and 90 degrees Fahrenheit (16 and 32 degrees Celsius).

The top level of the cabin is the flight deck. Here the commander and pilot monitor and operate a sophisticated array of controls that are far more complicated than those of a giant jetliner. Behind their seats is a work area for mission and payload specialists. There crew members operate experiment controls, and check out and deploy spacecraft carried inside the large, unpressurized cargo bay.

The bottom level of the cabin is the mid-deck. This is the living quarters for the crew, although experiments that require air, such as plants and small animals, can also be carried there. The mid-deck contains lockers for stowing crew equipment, and facilities for sleeping, eating, personal hygiene, and waste disposal.

Air pressure inside the crew compartment is the same as Earth's at sea level: 14.7 pounds per square inch (1,033 grams per square centimeter). This atmosphere is made up of 80 percent nitrogen and 20 percent oxygen. Earth's atmosphere is 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases, such as argon and neon. The crew members wear



The orbiter's two-story crew cabin contains a flight deck on the top level and living quarters underneath.
This cut-a-way view shows the left side of both stories.

ordinary clothing. They don the bulky spacesuits only for extravehicular activities outside the cabin.

Fans circulate the cabin air through cleansing filters, which are changed regularly. These filters contain activated charcoal to remove odor, and lithium hydroxide to remove carbon dioxide. Excess moisture is also removed, keeping the humidity at comfortable levels. The air in an orbiter is cleaner than that on Earth. Hay fever sufferers would welcome such a pollen-free atmosphere.

What Space Travelers Eat*

The one-, two- and three-person crews in earlier programs ate their meals out of containers or pouches, most commonly prepared by adding water and kneading the mixture by hand. The food was nutritious, but not very appetizing. The space shuttle carried eight people on one mission, and seven has been a common number. For these large crews, or missions planned to last for a week or more, a galley "mission kit" can be loaded in the orbiter mid-deck.

The mid-deck galley includes special serving trays that hold the different food containers in place in microgravity. It also has a convection-type oven where packages of food are warmed before going into the trays. A small dining area, consisting of a table and several foot loops, is optional on each mission. The foot loops are floor restraints that help the astronauts steady themselves and remain in place while eating.

If no galley is loaded aboard, the astronauts eat virtually the same meals, but they are heated inside a food warmer the size of a suitcase. Earthbound chefs might envy meal preparation on the orbiter. One crew member can prepare meals for four people in about five minutes (excluding heating time).

During off-duty time on mission STS-85, astronauts N. Jan Davis, payload commander, and Stephen K. Robinson, mission specialist, try their hands at chopsticks while having a meal of Japanese rice on Space Shuttle Discovery's mid-deck.

The orbiter does not normally carry a refrigerator because of the weight. If one is needed for biomedical experiments, and extra room is available, foods such as ice cream and frozen steaks may be added to the astronaut menu.

About half the shuttle foods and beverages are preserved by dehydration, which saves both weight and storage space. There is ample water for rehydration, since the fuel cells that power the orbiter produce it as a byproduct when generating electricity. (Both hot and cool water are available.) Some foods are thermostabilized — that is, heat-sterilized and then sealed in conventional cans or plastic pouches. A few, such as cookies and nuts, are available in a ready-to-eat form.

Meals in orbit are both tasty and nutritious. The menu includes more than 70 food items and 20 beverages. With so many different choices available, astronaut crews can have a varied menu every day for four days.

About three weeks before a launch, food lockers are shipped to Kennedy Space Center. They are refrigerated until installation in the shuttle two to three days before liftoff. Besides the meal and pantry food lockers, a fresh food locker is placed at Kennedy and installed on the shuttle 24 to 36 hours before launch. The fresh food comprises items such as tortillas, bread, breakfast rolls, and fruits and vegetables (apples, bananas, oranges, carrots and celery sticks). Unless refrigeration is available, such fresh foods must be eaten within the first few days of flight or they will spoil.

Astronauts are supplied with three balanced meals, plus snacks, per day. The menu for a typical day might start with an orange drink, peaches, scrambled eggs, sausage, cocoa and a sweet roll for breakfast; cream of mushroom soup, a ham and cheese sandwich, stewed tomatoes, a banana and cookies for lunch; and shrimp cocktail, beefsteak, broccoli au gratin, strawberries, pudding and cocoa for dinner. The carefully selected menus provide about 3,000 calories per person daily, although crew members are not required to eat that much. Previous space missions demonstrated that astronauts need at least as many calories in space as they do on Earth.

Meals served on the space station resemble those available on the space shuttle. Crews have a menu cycle of eight days. Half of the food system is U.S. and half is Russian. Plans call for adding foods of other space station partner countries in the future. Fresh food is delivered to station crews when either a shuttle or a Progress spacecraft docks.

Sanitation in Orbit

Sanitation is more important within the confines of a spaceship or space station than on Earth. Studies have shown that the population of some microbes can increase extraordinarily in microgravity and confined spaces. This means many infectious illnesses could easily spread to everyone aboard.

The eating equipment, dining area, toilet and sleeping facilities in an orbiter are regularly cleaned to prevent the growth of microorganisms. Since there is no washing machine aboard, trousers (changed weekly), socks, shirts and underwear (changed every two days) are sealed in airtight plastic bags after being worn. Garbage and trash are also sealed in plastic bags.

Shuttle travelers don't have to do many dishes. Following a meal, food containers are discarded in the trash compartment below the mid-deck floor. Eating utensils and trays are cleaned with premoistened, sanitizing towelettes.

A favorite early question of people interested in space flight was how the astronauts took care of digestive elimination. The orbiter travelers use a toilet that operates very much like one on Earth. A steady flow of air moves through the unit when it is in use, carrying wastes to a special container or into plastic bags. The container can be opened to vacuum, which exhausts the water and dries the solids, and the plastic bags, when used, can be sealed.

Some of the wastes may be returned to Earth for post-flight laboratory analysis. In the past, such analyses have helped doctors understand how the body functions in microgravity, including data about what minerals the body loses in unusual amounts.

Unlike Skylab, which had an enclosed shower, shuttle travelers can only take sponge baths in space. Water droplets float about in weightlessness, creating a potential hazard for electrical equipment. Water is obtained from a handgun, where the temperature can be set at any comfortable level from 65 to 95 degrees F (18 to 35 degrees C). Dirty water from the sponge is squeezed into an airflow system which conveys it to the orbiter's waste collection tank.

Whiskers cut off in shaving could also become a nuisance if they floated about, with a potential to damage equipment. Male astronauts can avoid this problem by using conventional shaving cream and a safety razor, then cleaning off the face with a disposable towel.

Engineers drew on the experience gained in earlier manned space flight programs to plan sleeping and sanitary arrangements for the space station that are more like those on Earth. A visitor to the space station should be able to eat a meal or use the sanitary facilities without special instructions.

Spacesuits and Rescue Equipment

In earlier programs, spacesuits were tailor-made for each astronaut, a time-consuming and expensive process. Now only the gloves are custom-fitted. The shuttle spacesuit is made in small, medium and large sizes, and can be worn by either men or women. The suit comes with an upper and lower torso, equivalent to a shirt and trousers, and the two pieces snap together with seal rings. A life-support system comes built into the upper torso. All earlier versions had separate support systems that had to be connected to the suits.

In addition to new spacewalking tools and philosophies for assembly of the International Space Station, spacewalkers have an enhanced spacesuit. The shuttle spacesuit, or

Astronauts and cosmonauts representing three different crews are just about to share a meal in the Zvezda Service Module on the International Space Station. Scott J. Horowitz, STS-105 mission commander, opens a can of food as he floats near the ceiling. Others from the left are astronaut Susan J. Helms, Expedition Two flight engineer; Frank L. Culbertson Jr., Expedition Three commander; Yury V. Usachev, Expedition Two commander; James S. Voss, Expedition Two flight engineer; and Vladimimr N. Dezhurov, Expedition Three flight engineer.

extravehicular mobility unit as it is technically called, was originally designed for sizing and maintenance between flights by skilled specialists on Earth. This would be a difficult if not impossible requirement for astronauts aboard the station.

The shuttle spacesuit is lighter, more durable and easier to move about in than its predecessors. It is only used for an extravehicular activity (EVA) outside the crew cabin. The astronauts wear pressure suits, the familiar orange launch and entry suits, during launches and landings. They wear regular clothing while in orbit.

That same suit has been improved for the International Space Station. The spacesuit can be stored in orbit and is certified for up to 25 spacewalks before it must be returned to Earth for refurbishment. It can be adjusted in flight to fit different astronauts and be easily cleaned and refurbished between spacewalks onboard the station. In addition, assembly work on the station is done in much colder temperatures than most space shuttle spacewalks. Unlike the shuttle, the station cannot be turned to provide the most optimum sunlight to moderate temperatures during a spacewalk.

Enhancements to the suit to better prepare it for assembly and use aboard the station include: easily replaceable internal parts; reusable carbon dioxide removal cartridges; metal sizing rings that allow in-flight suit adjustments to fit different crew members; new gloves with enhanced dexterity; a new radio with more channels to allow up to five people to talk at one time; warmth enhancements such as fingertip heaters and a cooling system shutoff; new helmet-mounted flood and spot lights; and a jet-pack "life jacket" called SAFER to allow an accidentally untethered astronaut to fly back to the station in an emergency.

On mission STS-112, Astronaut Sandra H. Magnus, mission specialist, washes her hair near a bicycle ergometer on the mid-deck of the Space Shuttle Atlantis.

February 2001, STS-98 Pilot Mark L. Polansky (left) and Commander Kenneth D. Cockrell share a mirror shaving their faces on the mid-deck of the Space Shuttle Atlantis.

Recreation and Sleeping*

Just as on Earth, recreation and sleep are important to good health when working in space. Astronauts perform a scientifically planned exercise program, largely to counter the atrophy some muscles experience in a weightless environment. Cards and other games, books, CDs and CD players can be taken aboard.

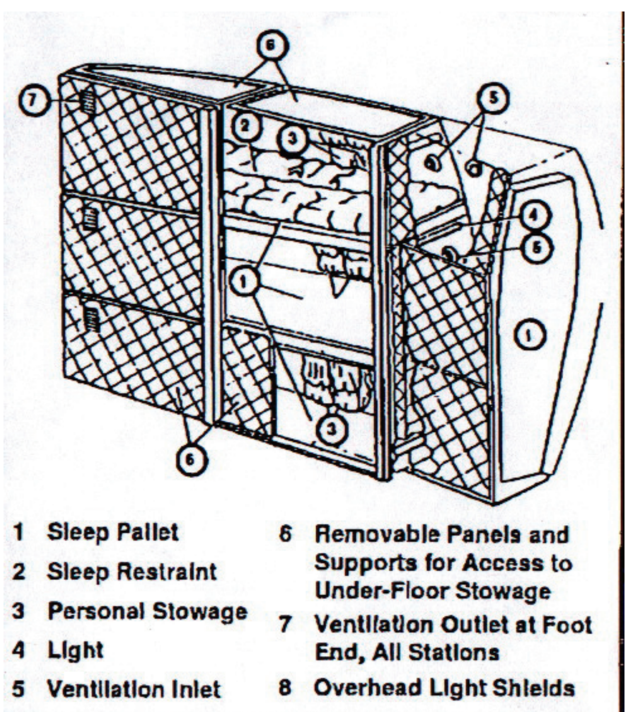
Sleeping accommodations aboard the shuttle vary, depending on the requirements of the particular mission. On the first flight, astronauts Young and Crippen slept in the commander and pilot seats. They wanted to be instantly available if needed. Later crews slept in their seats, in sleeping bags, in bunks, or by simply tethering themselves to the orbiter walls.

The sleeping bags are cocoon-like restraints attached to the lockers where crew provisions are stored. In microgravity there is no "up," and the astronauts can sleep as comfortably in the vertical position as the horizontal.

There is one sleeping bag for each crew member. The sleeping bag itself is attached to a flexible support pad by two zippers. Two adjustable elastic straps are used to restrain the body in the bag. The straps pull the astronaut against the support pad and the shuttle's wall, which applies a pressure to the back similar to sleeping on a mattress. A removable pillow is attached to the upper end of the support pad and a head restraint is available to pull the head into the pillow. This is done to simulate gravity, and many astronauts use the head restraint in the first few days on orbit until they adapt to sleeping in microgravity.

During mission STS-85, payload specialist Bjarni V. Tryggvason, representing the Canadian Space Agency, sleeps on the Space Shuttle Discovery's mid-deck floor with his arms free-floating. Tryggvason elected to not use a pillow, allowing his head to float freely in the microgravity environment.

A bunk bed kit (seen below) was available by the time of the STS-9 mission. Crew members could sleep in three horizontal bunks when these were installed, and an extra vertical bunk was available if needed. Each bunk comes complete with an individual light, communications station, fan, sound suppression blanket, and sheets with microgravity restraints. The bunks even have pillows.



The shuttle orbiter can be outfitted with up to four bunks, three horizontal and one vertical.

When the bunks must be removed to allow room in the mid-deck for experiments or extra equipment, up to four optional sleeping bags can be used instead.

The Continuing Challenge of Microgravity

Many of the problems that arise from living and working in space have been resolved. However, the physiological effects of weightlessness are still not completely understood. Among these are the leaching of certain minerals from bones; atrophy of muscles when not exercised; and space adaptation syndrome, a form of motion sickness found only in space flight.

All the deleterious effects of living in microgravity disappear after an astronaut returns to the ground. Some can be countered while in orbit by special diet and exercise. But even a vigorous exercise program does not appear to stop bone loss, or the decrease in the rate of normal bone formation.

NASA is engaged in a long-term program to understand the causes underlying these changes, in order to develop ways to prevent them. This is particularly important for the longer tours of duty on the space station, where crew members are in orbit for three months or more at a time.

Living and Working Aboard a Permanent Space Station

The United States and its partners, Japan, Canada, Russia and members of ESA, the European Space Agency — Italy, Belgium, Netherlands, Denmark, Norway, Sweden, Switzerland, France, Spain, Germany and the United Kingdom — are engaged in the largest cooperative scientific program in history, building and operating the International Space Station.

The launch of the first element was in 1998, the Russian module Zarya. The first launch of an American module was mission STS-88, delivering the Unity connecting module, on Dec. 4, 1998. Other modules or components have been provided by Canada and the ESA. Other components still to be added will come from Japan and the ESA. Assembly of the components (more than 100 when complete) requires a combination of human spacewalks and robot technologies. To aid in the assembly, the Canadian-built 55-foot robot arm assembly can lift 220,000 pounds, the weight of a space shuttle.

Astronaut Kenneth D. Bowersox, Expedition Six mission commander, works with an experiment cartridge for the Zeolite Crystal Growth experiment in the Destiny laboratory on the International Space Station, Dec. 17, 2002.

By 2003, there had been 16 space shuttle flights to the space station and 14 American, Canadian and Russian modules attached to the space station 250 miles in space. The first resident crew, named Expedition One, was launched Oct. 31, 2000, from Baikonur Cosmodrome, Kazakhstan, on a Russian Soyuz rocket. Two Russian cosmonauts, Yuri Pavlovich Gidzenko and Sergei K. Krikalev, were joined by astronaut William B. Shepherd. Within five years, 12 crews had provided continuous occupancy of the space station.

Five times as large as the Skylab and four times as large as the Russian space station Mir, the space station, when complete, will measure 361 feet (110 meters) end to end (the length of a football field including the end zones).

The 110 kilowatts of power for the space station will be supplied by an acre of solar panels. The solar array wingspan (240 feet/73.2 meters) will be longer than that of a Boeing 777 model, which is just 212 feet (64.6 meters), and large enough to cover the U.S. Senate Chamber more than three times.

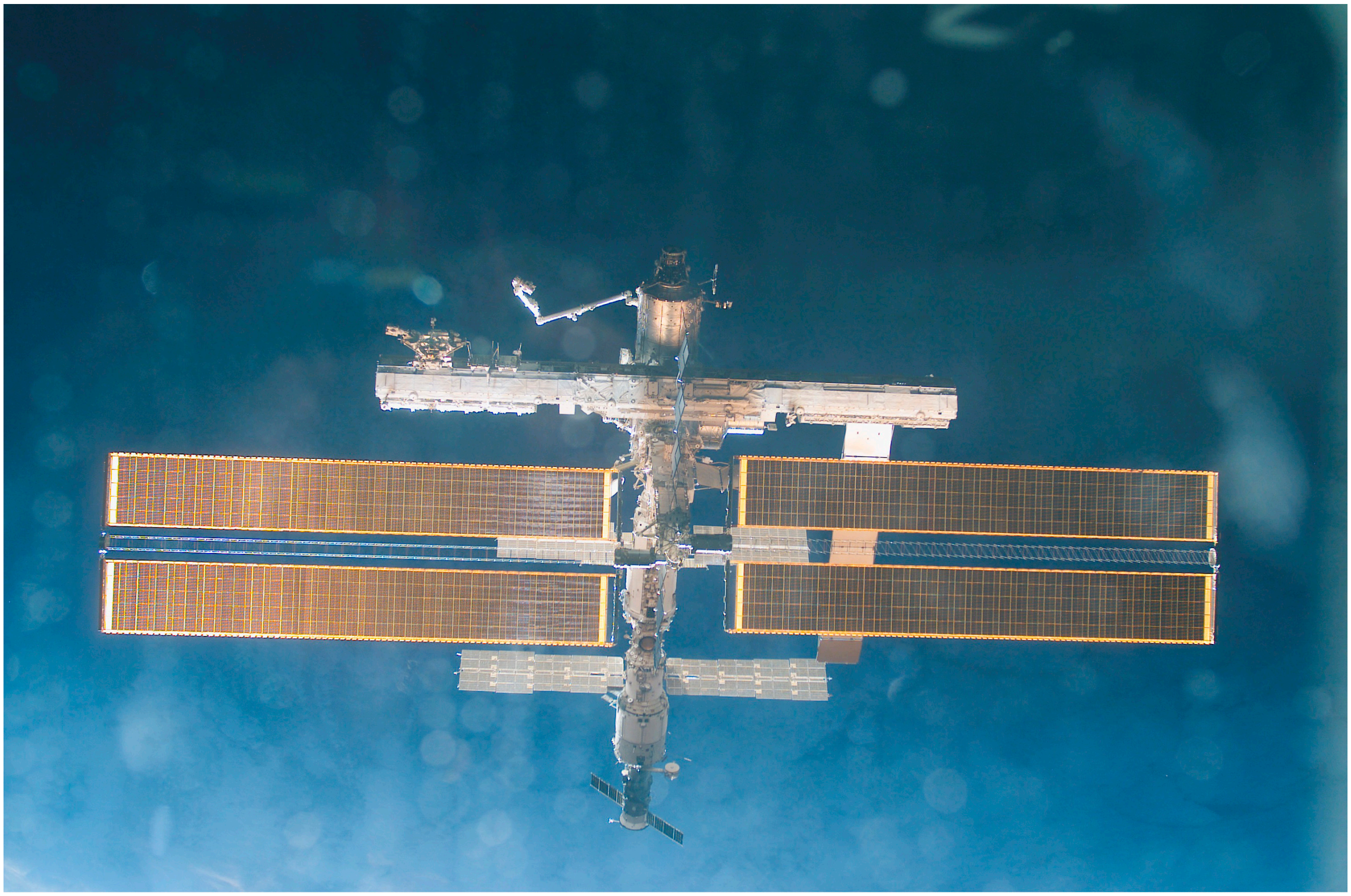
Larger than a five-bedroom house, the internal pressurized volume will be 46,000 cubic feet (or about 1.5 Boeing 747s). The final mass in orbit will be almost one million pounds (453,593 kilograms), or the equivalent of more than 330 automobiles.

The station's assigned operating altitude is 250 miles (354 kilometers) above mean sea level, with an inclination to the equator of 51.6 degrees.

The race to be first on the moon required great advances in engineering and technology that still fuel our economy today. The International Space Station is also a test bed for technologies of the future, taking advantage of the unique research opportunities available in microgravity.

Researchers study materials that could not be produced, and processes that could not take place, in the normal gravity of Earth. This research is leading to increased applications in many fields, including telepresence, telescience, expert systems, superalloys, recycling systems, and communications and data integration, among others.

As with material science and physics, research in the health sciences on the space station build on the proven work



Backdropped by the blackness of space, this full view of the International Space Station was photographed by a crew member on board the Space Shuttle Endeavour following the undocking of the two spacecraft. Endeavour pulled away from the complex Dec. 2, 2002, as the two spacecraft flew over northwestern Australia. The newly installed Port One (P1) truss now complements the Starboard One (S1) truss in center frame.

already performed on other manned programs. But where experiments on the space shuttle are limited to the roughly two-week length of a mission, work on the station can continue as long as needed for a good result.

For example, growing large protein crystals is a slow process, and on Earth the final size is limited by gravity. Very large ones can be grown in the microgravity environment of the station. These larger crystals are much easier to study and understand, providing new and very valuable information on the structure and function of proteins, one of the building blocks of life. A better understanding of protein structure may provide new insights into cancer research, diabetes, emphysema, and immune system disorders, among many others.

NASA considers the International Space Station to be the next logical step in the continuing scientific exploration and utilization of space, making vast resources and new knowledge available to humanity. The conquest of space offers benefits and possibilities whose potentials are only dimly visible today.

Statistics

- 52 computers will control the systems on the International Space Station.
- 2.6 million lines of software code on the ground will support 1.5 million lines of light software code. In the U.S. segment, the lines will run on 44 computers via 100 data networks transferring 400,000 signals (e.g., pressure or temperature measurements, valve positions, etc.).
- 8 miles of wire will connect the electrical power system.
- The station will manage 20 times as many signals as the space shuttle.

NASA's Future in Space: the Moon, Mars and Beyond

As the world enters the second century of powered flight, a new vision is defining and guiding U.S. space exploration activities for the next several decades. The vision for space exploration will take Americans back to the moon, look to Mars and even beyond.

The vision was presented by President George W. Bush in January 2004 with the fundamental goal to advance U.S. scientific, security and economic interests through a robust space exploration program.

The vision stated that in support of this goal, the U.S. will:

- Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
- Extend human presence across the solar system, starting with a human return to the moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- Develop the innovative technologies, knowledge and infrastructures both to explore and to support decisions about the destinations for human exploration; and
- Promote international and commercial participation in exploration to further U.S. scientific, security and economic interests.

In the meantime, the Space Shuttle Program will continue to function in order to complete the assembly of the International Space Station. At that point, approximately 2010, the shuttle progam will be discontinued in favor of a more efficient, less costly space vehicle.

The new crew exploration vehicle will provide crew transportation for missions beyond low-Earth orbit. The goal is to conduct the initial test flight before the end of this decade in order to provide an operational capability to support human exploration missions no later than 2014.

NASA will undertake lunar exploration activities to enable sustained human and robotic exploration of Mars and more distant destinations in the solar system. A series of robotic missions to the moon are proposed to prepare for and support future human exploration activities.

Goals are to conduct the first extended human expedition to the lunar surface no later than the year 2020; and use lunar exploration activities to further science, and to develop and test new approaches, technologies and systems, including use of lunar and other space resources, to support sustained human space exploration to Mars and other destinations.

Why set such goals for humans in space? Direct human experience in space has fundamentally altered our perspective of humanity and our place in the universe. Humans have the ability to respond to the unexpected developments inherent in space travel and possess unique skills that enhance discoveries.

NASA's chief historian, Steven J. Dick, states in an essay on exploration:

> "Even though science may be a motivation for exploration and a product of it, human exploration is more than the sum of all science. It is individually a primordial human urge, and in a larger sense the mark of a creative society."

Oct. 12, 2002, astronauts David A. Wolf (left) and Piers J. Sellers, both STS-112 mission specialists, participate in the mission's second session of extravehicular activity (EVA). Wolf is anchored to a foot restraint on the International Space Station's (ISS) Canadarm2 while Sellers traverses along the airlock spur, a route used by spacewalkers to get from the Quest airlock on the station to the outpost's truss.

*OTHER SOURCES OF INFORMATION

For more about the food system for space travelers, read the Johnson Space Center fact sheet "Space Food" on the Web at
http://spaceflight.nasa.gov/spacenews/factsheets/.

For more about sleeping in space, go to
http://lsda.jsc.nasa.gov/kids/L&W/sleep.htm.

For others, go to
http://spaceflight.nasa.gov/living/index.html.

More fact sheets on the Web can be found at
http://www-pao.ksc.nasa.gov/kscpao/educate/docs.htm.

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