4.8 Space Research and Exploration

Getting Into Space

Astronauts are pioneers venturing into uncharted territory. The vehicles used to get them into space are complex and use powerful rockets. Space vehicles need to be durable as they leave and then re-enter Earth's atmosphere. Also, space vehicles have limited space. During space missions, astronauts have to take with them everything they will need.

Space Exploration

Technological developments in the past five decades have helped humans in their quest to explore outer space. We have expanded our presence from Earth to the edge of the Solar System, and beyond. We have built scientific laboratories in space. Vehicles designed for space travel, called spacecraft, have landed on planets, moons, and asteroids. We have also sent instruments, such as the Hubble Space Telescope, into space to gather information we cannot get from Earth. We have sent probes to planets that are not yet fit to live on, or too far away for humans to safely make the trip. Future missions are planned to send even more technologically advanced spacecraft into space.

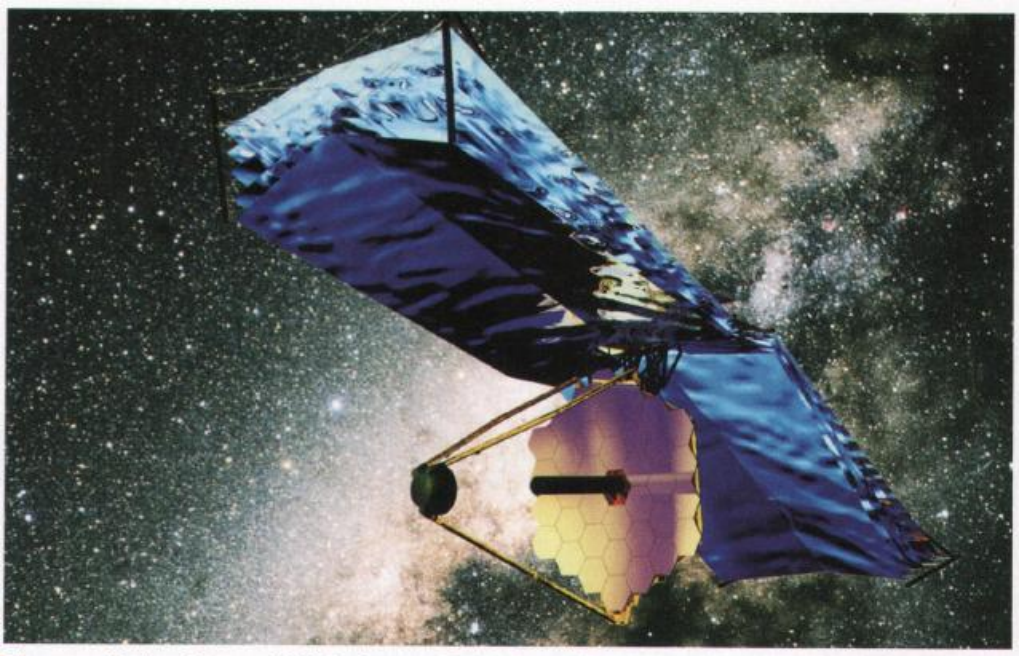


Figure 1 The James Webb Space Telescope (JWST), an international collaboration, will be a large infrared telescope with a 6.5 m mirror. The JWST will replace the Hubble Space Telescope when it is launched in 2014.

Types of Spacecraft

There are different types of spacecraft that serve different purposes in space exploration. Some spacecraft, such as the space shuttle in Figure 2, travel in low orbits around Earth on short-term missions. Other spacecraft, such as weather and communications satellites, are in long-term orbits around Earth. The International Space Station (ISS) is a space research laboratory that has been in low orbit around Earth since 1998 (Figure 3).

All spacecraft have similar components. A launch vehicle is a rocket that carries the spacecraft from Earth's surface into outer space. On most human-occupied missions, astronauts sit in one section of the launch vehicle to control the spacecraft. Another section of a spacecraft, called a payload, carries cargo. Cargo can include scientific equipment and supplies. Cargo can also be other spacecraft, such as planetary land rovers (Figure 4). Specialized satellites may also be carried as cargo and released into space once the spacecraft is beyond Earth's atmosphere (Figure 5).

Figure 2 The Space Shuttle *Endeavour* lands after a mission to the International Space Station.

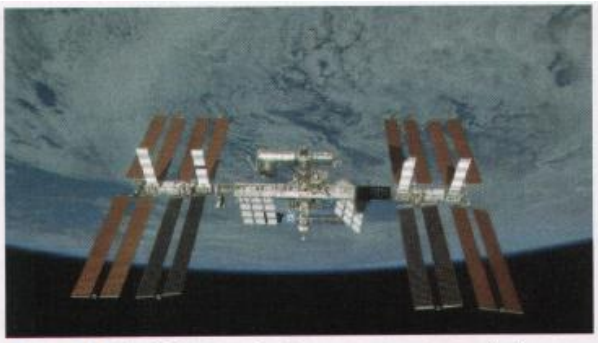


Figure 3 The ISS travels at an average speed of 27 700 km/h. It orbits Earth 15.7 times each day.

Figure 4 The Apollo 17 mission in 1972 carried the lunar roving vehicle to the Moon.

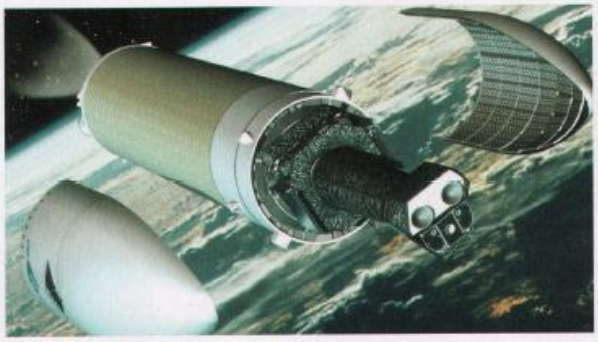


Figure 5 The XMM-Newton is an orbiting X-ray observatory belonging to the European Space Agency.

Space Travel

One of the biggest challenges of space travel is the very first step getting up and out of Earth's atmosphere. Earth's atmosphere exerts air resistance that works opposite the

direction of the motion of the spacecraft. This reduces the speed of the spacecraft. A spacecraft needs a lot of force, or thrust, to lift off from Earth's surface and overcome this air resistance. To attain orbit, a spacecraft must be able to travel about 7.5 km/s. That means a spacecraft could travel the distance from London, Ontario, to Kingston, Ontario, in just under one minute!

It is essential for spacecraft to travel a gravitational orbit (usually around Earth). Spacecraft must be equipped with powerful engines that will allow them to reach the speed required to place them into Earth's orbit. Only a small amount of fuel can be brought into space with the craft, and the fuel needs to be used wisely. Once in orbit, the gravitational pull of Earth keeps the spacecraft in motion. Spacecraft must also be constructed to withstand travel in space and to safely transport humans into space and then back to Earth again.

Liftoff

Many spacecraft use rocket boosters for liftoff. A rocket booster is a large powerful rocket engine containing fuel that attaches to a spacecraft. Rocket boosters provide most of the liftoff thrust for a spacecraft. Once the spacecraft has gained a certain altitude, the empty rocket boosters break away from the spacecraft and fall. This reduces the mass of the spacecraft and allows the spacecraft to use less fuel for the rest of its journey.

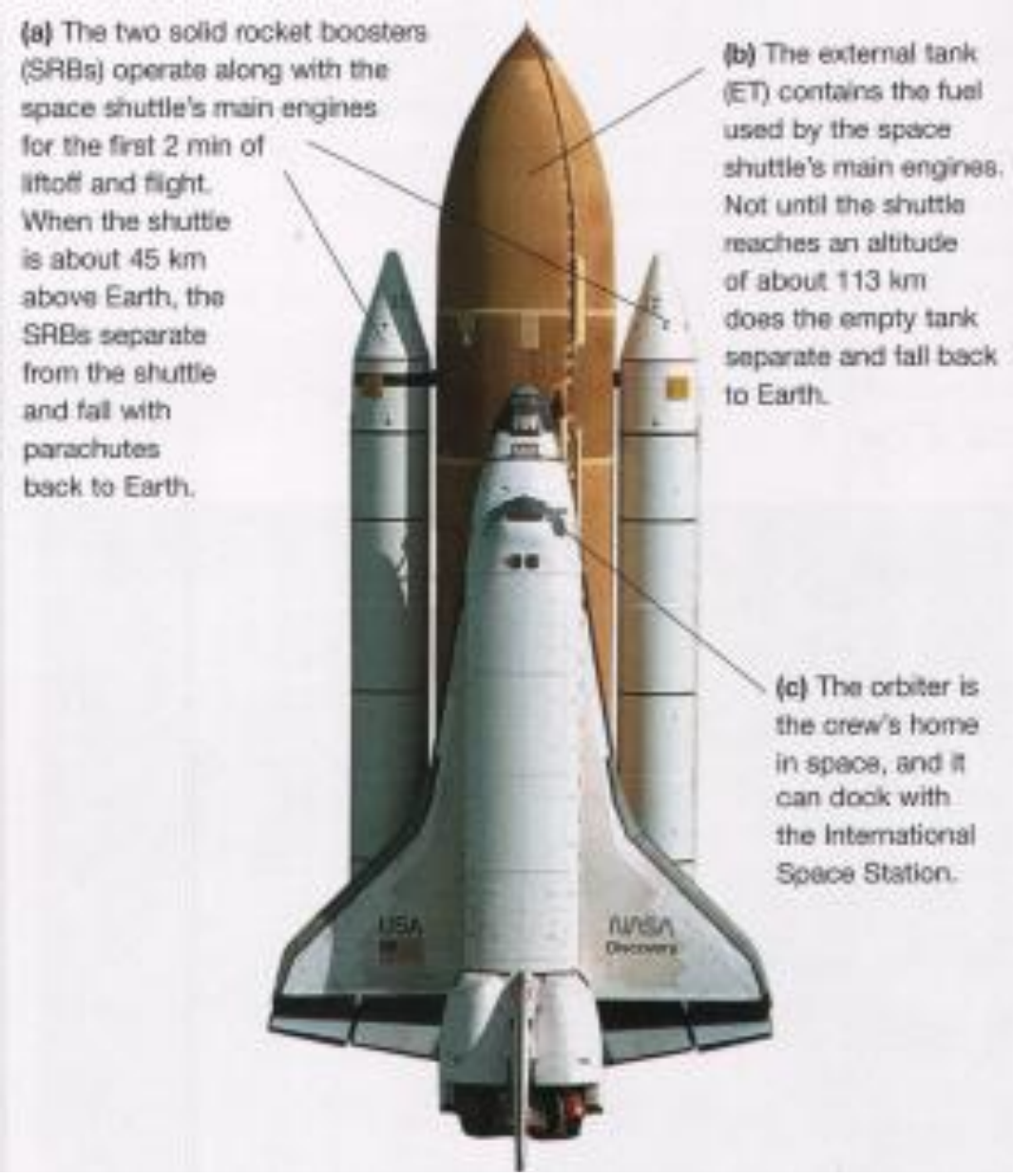
A Model of Liftoff

Think about a balloon model of a rocket. If you inflate a balloon and then release it, the escaping air propels the balloon upward. It is this same principle that launches a rocket at liftoff. In a rocket, a chemical change occurs that produces hot gases. The gases are expelled through the bottom of the rocket at great speed, causing the rocket to move in the opposite direction.

The acceleration and speed provided by a rocket booster have to be carefully calculated based on the overall mass of the spacecraft, including the fuel. The greater the mass, the more thrust needed for liftoff. Once in orbit, a spacecraft coasts along, conserving energy. The spacecraft can do this because it is above the atmosphere and there is no air to slow it down.

Fuel Supplies

A spacecraft requires massive amounts of fuel to launch it into space. The fuel is heavy, and enormous amounts of it are burned to overcome the pull of gravity during liftoff. Once the vehicle is in space, there is not much fuel left over for the rest of the journey. Small amounts of fuel are burned in bursts for correcting or changing direction. The spacecraft coasts for long periods between bursts in the desired direction. Below is an image that shows the components of a Space Shuttle.

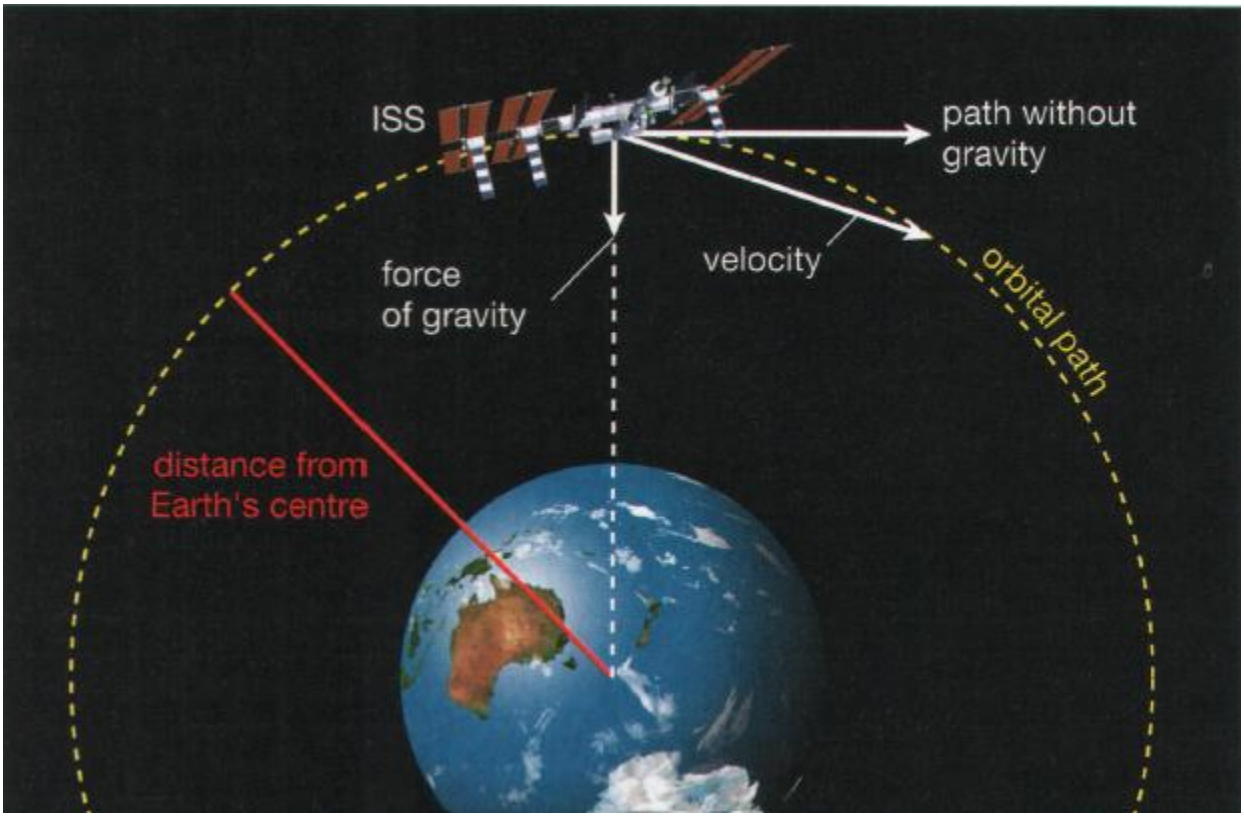


Orbiting Earth

A satellite in orbit moves faster when it is closer to the celestial object it is orbiting. Similarly, it moves slower when it is farther away. For example, the International Space Station orbits 380 km above Earth and travels at a speed of about 8 km/s. Global positioning satellites, on the other hand, orbit 20 000 km above Earth and travel at a speed of about 4 km/s-much more slowly. Earth's Moon is also a satellite. It is about 385 000 km from Earth and orbits at a speed of about 1 km/s. Once in orbit, a satellite moves at a constant speed.

Staying in Orbit

An object in space travels forward in a straight line unless a force acts on it. Objects launched into space from Earth are pulled back toward Earth by the force of gravity. If an object does not have enough travelling speed when it is launched, it will be pulled back to Earth's surface. lf an object is travelling too fast, it will continue to move away from Earth. The combination of the forward motion of a spacecraft and the pull of Earth's gravity keeps the spacecraft in orbit.



The Future of Space Exploration

Humans have landed on the Moon, sent robotic probes to distant planets, and have lived and worked in orbit aboard space stations. What do you think will be the next steps for space exploration?

Limitations of Space Travel

Over the last 50 years, engineers and scientists have overcome many of the challenges of space travel. What are some of these challenges and how have they been overcome?

Human Survival

One of the main concerns of long-term space travel is keeping the crew alive. There are many physical and mental challenges that astronauts must overcome on their missions. The following list outlines some of these challenges:

- **Basic Needs**: Some of the problems with long-term space travel include how to bring along enough air, food, and water, and what to do with waste.
- **Emotional and Mental Well-Being**: The mental health of the crew is also an issue. Crew members might get home-sick -they might miss family and Earth. They might suffer from claustrophobia-a fear of being in an enclosed space.
- **Physical Well-Being**: Physical problems, such as weakened bones and muscles due to prolonged periods in space, are another concern.
- **Boredom**: Long space voyages can be boring for astronauts.

A space mission to the Moon was possible because spacecraft can reach the Moon in less than four days. Travelling to a planet such as Mars would take seven to ten months. Sending equipment and people to Mars is far more time-consuming, expensive, and risky than to the Moon

Low Orbit Missions in Space

There are two basic locations in space where humans have lived and worked. One is in the spacecraft of the Apollo as it voyaged to the Moon. The other is in low Earth orbit, between 200 km and 2000 km above Earth's surface. Both the space shuttle missions and the International Space Station are examples of low orbit missions.

To the Moon and Back

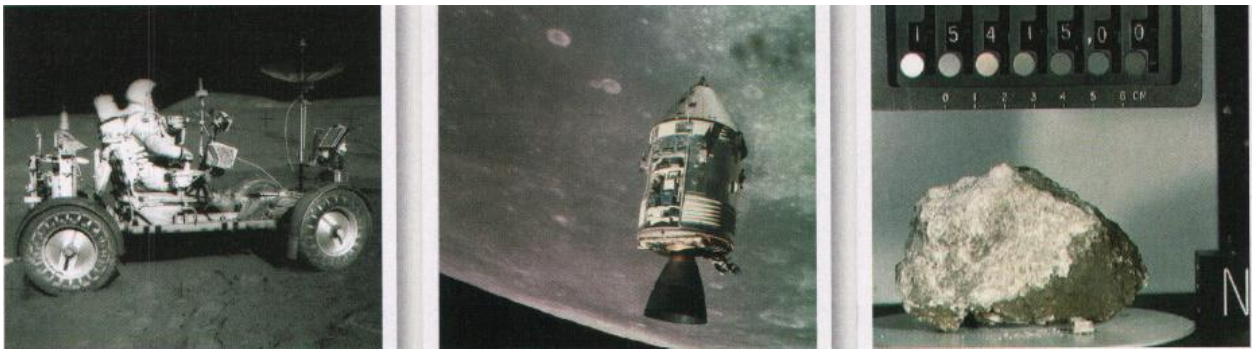
The Apollo missions that sent humans to the Moon used a Saturn V launch rocket. These rockets carried the human crew, the lunar lander, and the command module, the section of the spacecraft that carried the crew, toward the Moon. In all, there were 11 Apollo missions.

Apollo 13's planned Moon landing was aborted due to an oxygen tank explosion. There were six Moon landings. Of these, Apollo 15 was the first of the missions in which astronauts spent long periods of time on the Moon's surface.

Apollo 15

Apollo 15 was the fourth mission to land on the Moon. In the lunar module Falcon, astronauts David Scott and James Irwin spent 67 hours on the Moon's surface and explored the surface of the Moon for a total of 18.5 hours. It was the first time astronauts used a motorized lunar roving vehicle (LRV) to drive around on the Moon's surface. The mission lasted a little over 12 days before the astronauts returned to Earth in the command module. On this mission, astronauts found a rock called the "Genesis

Rock." It is thought that this rock is part of the original lunar crust when the Moon was formed about 4.6 billion years ago.



The Space Shuttle Program

In the early 1970s, after the Apollo program ended, the United States built a mostly reusable spacecraft called a space shuttle. The Space Transportation System (STS), also called the Space Shuttle program, launched with the Space Shuttle Columbia (STS-1) in April 1981 . Shuttles launch from Cape Canaveral, on Florida's east coast.

The International Space Station

The International Space Station (ISS) is the ninth space research facility to be built in orbit. Since its launch in 1998, more than 16 countries have participated in its construction and use. The ISS weighs 245 735 kg, and it is the largest human-made object to orbit Earth.

Future Space Missions

Presently, human space exploration is limited to low orbit missions. Future space missions may include further trips to the Moon, as well as building lunar bases.

Mission planners are also discussing a long-term mission to Mars. This mission would be one of the greatest challenges in space exploration and full of potential hazards. Despite the challenges, the exploration of Mars will provide us with more clues to further our understanding of the Universe, as it is believed that Mars is the most Earth-like planet. It will also give us opportunities to develop new technologies and satisfy our desire to explore. Canada's plans include designing and producing new lunar and Martian rovers for use in these upcoming missions.

Worksheet 4.8

1. (a) Explain how spacecraft are launched into orbit.
   (b) What are some of the challenges that must be overcome?
2. What must a rocket be able to do to lift off and escape Earth's atmosphere?
3. Why do the empty rocket boosters separate from the space shuttle soon after launch?
4. Draw a diagram to describe what happens to rocket fuel as a spacecraft lifts off and leaves Earth's atmosphere. Label your diagram.
5. Describe how a spacecraft is able to stay in orbit around Earth.
6. What will happen when a girl releases a blown-up balloon? What does this balloon have in common with rocket boosters?
7. Explain how the distance of a celestial object affects the ability of a human to travel to that celestial object.
8. How might a future mission to Mars better explain our understanding of our own planet? Explain your reasoning.
9. Why do you think low orbit missions are the most common type of space missions? Provide at least two reasons for your thinking.
10. List some benefits of future human missions to space.
11. There are many challenges to space exploration. Rank the following criteria from most important (1) to least important (6). Explain your reasoning.
    - constant supply of water
    - protection from harsh conditions
    - constant supply of oxygen
    - constant supply of food
    - dealing with feelings of claustrophobia
    - dealing with feelings of isolation
12. a) Would you like to become an astronaut? Explain why or why not.
    (b) What do you think an astronaut's training is like?