Challenges of Space Travel

Engineers and scientists perform the difficult job of designing spacecraft that safely take humans to their celestial destinations and back (Figure 1). What challenges do you think spacecraft designers must overcome?

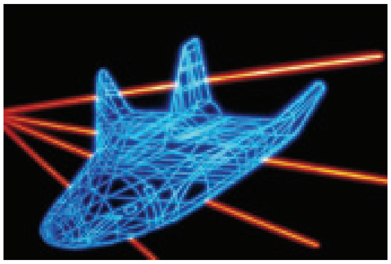

Figure 1 A wire frame computer graphic image of a spacecraft.

Getting into Space

Spacecraft must be equipped with powerful rockets that can reach a speed that will take the spacecraft beyond Earth's atmosphere and escape Earth's gravitational pull (Figure 2). To maintain its orbit, a spacecraft must travel at precisely the right speed. The acceleration of the rocket booster has to be carefully calculated based on the overall weight of the entire spacecraft. There cannot be too much vibration or gravitational pressure put on the spacecraft and its astronauts. Space shuttles, satellites, and other spacecraft require massive amounts of fuel to propel them into space. They may require additional fuel depending on their destination, trip time, and the mass of their cargo, or payload.

Figure 2 To escape Earth's atmosphere, rockets have to reach a speed of 7.7 km/s.

Traditional Fuel

Traditional launch vehicles are powered by a chemical reaction between fuel and oxygen. The fuel is heavy and most of it is used to overcome the pull of gravity during liftoff, so there is not much left over for the spacecraft to use for the remainder of the journey. Once the vehicle is in space, fuel is burned only in spurts for correcting or altering course. The spacecraft must coast between spurts in the desired direction. New space propulsion technologies using lightweight fuels are being developed to enable spacecraft to travel farther. However, traditional fuel is still the main way to launch spacecraft from Earth into orbit.

READING TIP

Drawing Conclusions

After reading a text, you might need to do some research to help you synthesize and draw conclusions. For example, if you wonder how much a space shuttle weighs, you might find the information and calculate the total weight to be 2050 metric tonnes. You might draw a conclusion that future spacecraft carrying humans to Mars will need to be launched from space.

Alternative Fuel

Instead of using traditional fuel, a number of small robotic planetary probes now fire atoms of xenon gas to provide the thrust they need to navigate through the Solar System. This new technology allows small spacecraft to travel great distances at relatively little cost.

DID YOU KNOW?

Powering Space Probes

Solar energy alone could not be used to provide all the electricity necessary for the instruments onboard *Cassini–Huygens*, a probe sent to Saturn in 2004. Because of the size of the probe and the weakness of solar radiation at Saturn's great distance from the Sun, scientists needed to use electricity generated by nuclear power. They were very concerned about the nuclear fuel at launch. If there had been a failure or malfunction in the launch systems, the radioactive fuel onboard the probe might have polluted the surface of Earth and the atmosphere around the launch site. Scientists conducted an environmental impact study that resulted in a number of recommendations aimed at preventing environmental damage.

Nuclear energy, which is energy released from the nucleus of radioactive atoms, can be used to power the instruments on space probes. The major advantage of this type of fuel is that a small mass produces enormous amounts of energy. By carrying a smaller mass of fuel, the space probe could carry more cargo and travel much faster. Using smaller masses of fuel also lowers the cost of space travel.

The next Mars rover, for NASA's Mars Science Laboratory mission, will use nuclear electrical energy to power scientific instruments. The compact car–sized rover will be able to conduct scientific experiments day and night and is expected to drive hundreds of kilometres on the Martian surface over many years (Figure 3).

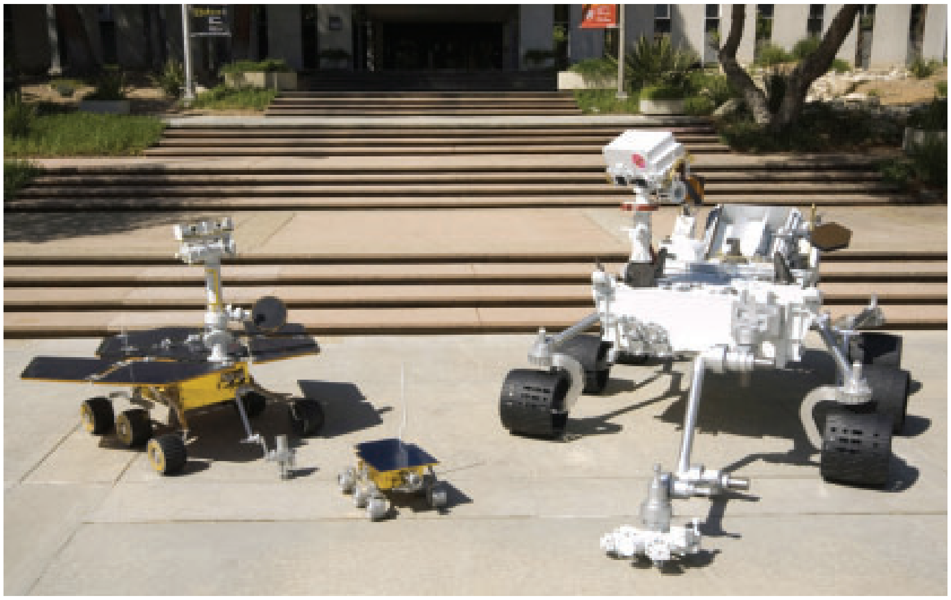

Figure 3 Three generations of Mars rovers: the two on the left used solar panels to generate power; the new, larger Mars rover uses a nuclear generator, giving it many times more power.

Space engineers estimate that nuclear propulsion may reduce the travel time to Mars from 8 months to as little as 4 months. New technologies that reduce travel times decrease the risks to astronauts during long-term space travel, such as weakening bone strength and other health issues. Using nuclear power also means that a spacecraft does not have to rely on solar energy. This is particularly important where the Sun's radiation is low, such as in the outer parts of the Solar System—Jupiter and beyond.

Nuclear fuel is not without risks. If an explosion occurred at a launch site, the surrounding environment would be contaminated with nuclear material. Today, jet propulsion technologists and design engineers are developing even safer nuclear power systems for human-occupied spacecraft. Other options that are being explored include solar and electrical propulsion systems.

To learn more about rocket engines and rocket fuel,
GO TO NELSON SCIENCE

To learn more about being a jet propulsion technologist or design engineer,
GO TO NELSON SCIENCE

A Feeling of "Weightlessness"

Another challenge of space travel is the apparent "weightlessness" of objects and people for the duration of a space voyage. Since the pull of gravity inside the orbiting ISS and space shuttle is only slightly less than it is at Earth's surface, why do astronauts and other objects appear to float inside these spacecraft?

When a spacecraft is placed into orbit, it rises to a predetermined height above the atmosphere and then turns and travels in a direction parallel to Earth's surface. If its forward speed is too slow, the spacecraft will collide with the ground. If its forward speed is too fast, the spacecraft may move away from Earth. When the pull of gravity and the forward speed are perfectly balanced, the spacecraft will fall toward Earth at the same time as it is trying to speed away from Earth. (Recall the cannonball diagrams from Chapter 8.)

The continuous falling motion, or free fall, gives the spacecraft and everything in it the feeling of weightlessness—the same feeling of weightlessness you experience in a plunging roller coaster. Although the force of gravity is still relatively strong, the continuous falling motion causes unsecured objects inside the spacecraft to appear to float (Figure 4). Sometimes this is called a **microgravity environment** because in this environment, unsecured objects behave as they would in an environment with very little gravity.

Figure 4 U.S. astronaut Mike Fincke with fresh fruit in microgravity conditions aboard the ISS.

microgravity environment an environment in which objects behave as though there is very little gravity affecting them

TRY THIS UNDERSTANDING FREE FALL

SKILLS: Controlling Variables, Performing, Observing, Communicating

SKILLS HANDBOOK 3.B.6.

When astronauts are in orbit around Earth, they appear to float because they are in free fall. Gravity accelerates all objects toward the centre of Earth at the same rate, which is why astronauts inside the ISS appear to float. In this activity, you will experiment with water inside a falling pop bottle to demonstrate the concept of free fall.

Equipment and Materials: geometry compass; empty 1 L pop bottle; pen; duct tape; water

1. Poke a small hole near the bottom of the pop bottle with the compass tip. Widen the hole with a pen, so the hole is as wide as the pen's body.

Compasses are very sharp! When pushing the compass tip into the pop bottle, be careful that it does not slip.

2. Cover the hole with a piece of duct tape and fill the pop bottle with water.
3. Holding it by the neck, position the bottle over a sink or take it outside. Pull off the tape and, without squeezing the bottle, watch the water stream out.
4. When the water has drained out, put tape over the hole and fill the bottle with water again.
5. Now raise the bottle as high as you can. As you peel the tape off the hole, drop the bottle and watch what happens to the water streaming out of the hole.

A. The first time you held the bottle up without squeezing it, the water flowed out. What was the force responsible for pushing the water out of the hole in the bottle? K/U T/I

B. When you dropped the bottle, what happened to the stream of water? T/I

C. Why did the water behave this way after you dropped the bottle? T/I

D. What do you think it would feel like if you were inside a giant container that was falling like this? T/I

E. Write a concluding statement about how this activity demonstrates the concept of free fall. T/I C

Health and Other Risks

The cells, tissues, and organ systems in your body rely on the force of gravity to assist in their function. In conditions of microgravity, astronauts may experience a range of health issues. About 50 % of astronauts experience dizziness, disorientation, and nausea during the first few days of exposure to microgravity. Researchers believe that this is caused by the balance organs in the inner ear being disoriented when there is little sensation of gravity.

Dr. Roberta Bondar was Canada's first woman in space. The experiments she conducted on an eight-day trip in 1992 revealed that exposure to microgravity can lead to some of the same symptoms as brain damage from strokes.

Figure 5 (a) Person on Earth (b) The same person under microgravity conditions. This effect is sometimes called the "puffy-face, bird-leg look."

Microgravity can also affect the appearance of the human body in space. For example, blood vessels in a person's legs have one-way valves to prevent blood from pooling in the feet due to the downward pull of gravity (Figure 5(a)). When astronauts are in space, blood pools in the upper part of their bodies (Figure 5(b)). This affects the body's ability to regulate water and can cause dehydration.

Blood cells have specific shapes required to carry out their functions (Figure 6(a)). In space, their shapes change, which affects their ability to function (Figure 6(b)). Because we are always working against it, the force of gravity helps keep our bones and muscles strong. Astronauts' bones and muscles weaken in space, where little force is needed to breathe, to move blood through the body, or to lift objects. As well, in space, the discs of the spinal column expand, making astronauts taller by about 2 to 4 cm while in orbit. This can lead to lower back pain in some taller astronauts.

To stay healthy and help avoid any permanent damage to their bones and muscles, astronauts spend time in space working their muscles with resistance devices and running on treadmills.

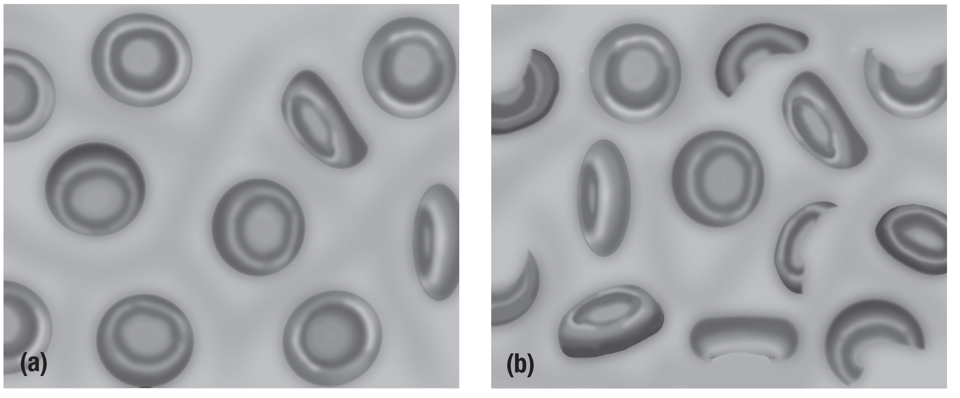

Figure 6 (a) Normal red blood cells (b) The shape of red blood cells in space

Bone Loss

Astronauts lose up to 2 % of their bone mass for each month they spend in microgravity conditions. Thus, a space environment offers the perfect conditions for researchers to study osteoporosis—an Earthly disease that causes a loss of bone mass. One in four women and one in eight men over the age of 50 suffer from osteoporosis. Treatment for osteoporosis costs Canadians more than $600 million annually. By focusing on the accelerated process of bone loss in space, scientists are able to conduct their studies more quickly and cheaply than on Earth.

Canada is a world leader in using space research to understand how bone loss happens in astronauts as well as in people here on Earth. Working with scientists in Ontario, the CSA has developed a unique mini-lab called OSTEO that has flown aboard the Space Shuttle and the ISS (Figure 7).

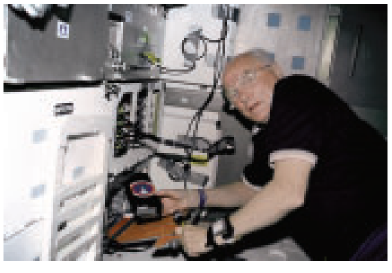

Figure 7 In 1998, 77-year-old astronaut John Glenn conducted the first OSTEO experiments to determine the rate of bone loss and help understand osteoporosis.

Medical Monitoring

When you are sick, you can go to a doctor and receive medicine to help you get better. Astronauts face routine illnesses and much more serious health issues without direct access to a doctor. For this reason, health care specialists on Earth use electronic communications to monitor an astronaut's heart and brain functions, body temperature, and respiration to anticipate and avoid serious health problems.

To learn more about being a health care technician or space physician,

GO TO NELSON SCIENCE

Radiation Alert

Earth's atmosphere and magnetic field help protect you from the Sun's radiation. In space, astronauts are not protected by the atmosphere. Protective shields on their space vehicle provide some safeguards from this harmful radiation. Their spacesuits are also specially designed to protect them from some of the incoming harmful radiation during their space walks. Astronauts on missions outside of Earth's magnetic field—such as those to the Moon or farther—have to take extra precautions. They must monitor the Sun's radiation and may have to consider aborting missions when radiation levels are too high.

To find out more about health problems that astronauts might experience while in space,

GO TO NELSON SCIENCE

Humans on Mars

Human-occupied spacecraft have landed on the Moon. The next step for future exploration of the Solar System is to safely land humans on the Moon to set up a permanent lunar base and then land on a nearby planet, such as Mars. A mission to Mars will require the cooperation of many governments, businesses, scientists, engineers, and health care professionals. All will work together to ensure the crew's protection from the Sun's radiation and other hazards of space (Figure 8).

Figure 8 This NASA image shows an artist's concept of a possible exploration program on Mars. Astronauts on Mars will probably live in a self-contained structure to protect them from harmful EM radiation and other hazards. Similar structures have already been tested in the Canadian Arctic.

The long trip to Mars will be one of the biggest challenges in space exploration and will be full of potential hazards. The spacecraft must carry enough fuel for the ship plus food and water for the crew during their interplanetary journey. A second robotic craft filled with all the supplies needed for a month-long stay would have to safely land on Mars before the astronauts arrive. The craft design has to be such that it could protect the astronauts from potentially hazardous amounts of solar radiation, especially during solar storms.

Before the astronauts leave Earth, scientists will need to determine how to keep them physically and mentally healthy, in spite of the long-term physical effects of microgravity, the lack of on-site medical care, and the psychological effects of being isolated from Earth while living in a confined area. Despite the many challenges of such a mission, the exploration of Mars will provide us with more clues to our understanding of the Universe, give us opportunities to develop new technologies, and satisfy our desire to explore.

Space Junk

Countries around the world have launched thousands of satellites, space probes, and telescopes into orbit since the 1950s. What happens when they no longer work or a new, improved model is developed? Some of this space technology becomes waste that stays in space.

Some satellites may remain in orbit for hundreds of years or more. As they deteriorate or collide with other objects, they create space debris or **space junk**. Space junk can also be tools or other materials that astronauts accidentally misplace as they work in space (Figure 9). For example, in November 2008, an astronaut working on the ISS let go of a backpack-sized toolbag. The orbiting toolbag can still be seen in the night sky.

space junk debris from artificial objects orbiting Earth

Figure 9 This artwork shows some of the many objects—from functioning satellites to old rocket parts—orbiting Earth. Some space junk or debris that circles Earth can cause re-entry problems for spacecraft.

Space junk travels at speeds up to 40 000 km/h and can damage the hundreds of functioning satellites or the ISS orbiting Earth. Scientists are trying to determine how to get rid of this space junk.

Astronomers use radar to monitor space junk. More than 100 objects have broken up in Earth's orbit, resulting in hundreds of thousands of pieces of debris in orbit, such as the upper stages of launch vehicles, nuclear reactor coolant, metal, nuts, bolts, and paint from deteriorating satellites, telescopes, and probes. Some of this debris lands on Earth. In early 2009, scientists were monitoring a Russian rocket that was entering Earth's atmosphere. Falling debris from the re-entry—10 square metres in size—appeared to be heading for southern Alberta. The city of Calgary was only minutes away from issuing an impact alert. Luckily, the trajectory shifted and the debris broke up over the ocean without incident.

Other space junk becomes dangerous when spacecraft such as the space shuttle are launched, as their trajectory must avoid hitting this floating junk. Astronomers, other scientists, and organizations such as NASA and the CSA are now studying the orbits and effects of space junk in space and on Earth.

DID YOU KNOW?

How Much Junk Is Too Much?
Astronomers are tracking any piece of space junk that is larger than a basketball. Currently, about 18 000 objects are being watched. Astronomers estimate that there may be more than 300 000 objects larger than 1 cm orbiting Earth at approximately 700 to 2000 km above the ground. That is a lot of junk!

To learn more about space debris sightings,
GO TO NELSON SCIENCE

RESEARCH THIS SPACE TRAVEL SAFETY

SKILLS: Defining the Issue, Researching, Defending a Decision, Communicating

SKILLS HANDBOOK 4.B., 4.C.4.

Nearly 500 humans have been in space, and space traveller numbers are growing rapidly. However, space travel is risky and is still considered experimental. It is not as safe as flying in an airplane. Thirty-two astronauts worldwide have lost their lives in space exploration accidents. Astronauts also experience serious health risks when exploring space.

In this activity, you will research the causes of a space shuttle accident. You will also research the safety requirements and considerations that are now in place for future space travel.

1. Using the Internet, research the missions of the *Challenger* in 1986 or the *Columbia* in 2003. What were the purposes of these missions?
2. Both of these missions ended in disaster. Research the causes of these disasters.
3. Research what safety measures were put in place by space safety engineers after the accident.

GO TO NELSON SCIENCE

A. How could space travel be made safer in the future? T/I

B. What is Canada's contribution to new safety measures for the space shuttle fleet? T/I

C. Could there have been other ways to achieve the goals of the *Challenger* and *Columbia* missions without putting human lives at risk? A

D. Write a paragraph or a list explaining why you think it is (or is not) worth risking people's lives to perform research in outer space. In a second paragraph or list, compare space travel with other explorations in history. C A

UNIT TASK Bookmark

You can apply what you have learned about Canadian space research in microgravity and the physical challenges of space travel when you work on the Unit Task described on page 446.

IN SUMMARY

- It takes an enormous amount of energy to travel in space, and various technologies have been developed to perform this task.
- Astronauts in a microgravity environment orbiting Earth appear to float because they and their spacecraft are in free fall around Earth.
- The microgravity environment causes serious health concerns for astronauts.
- Space debris orbiting Earth can create risks for further exploration.

CHECK YOUR LEARNING

1. Explain how spacecraft are launched into orbit. What are some of the challenges that must be overcome? K/U
2. Identify the type of probe that uses xenon gas for propulsive power. K/U
3. What are the potential dangers of nuclear power for spacecraft? What have scientists done to help reduce the possibility of a nuclear fuel accident? A
4. The next generation of Mars explorers, such as the Mars Science Laboratory, will be able to travel much farther on Mars than the current explorers. Explain why. K/U
5. Describe what scientists mean when they refer to a "microgravity" environment. How might you experience what a microgravity environment feels like? K/U
6. Describe three health problems astronauts experience when they are working aboard the ISS. K/U
7. Write a brief newspaper article (maximum 100 words) about Canada's contribution to osteoporosis research aboard the ISS. K/U C
8. How do astronauts protect themselves against radiation hazards when they are working outside the ISS? K/U
9. What are some of the challenges of sending people to Mars? Is sending humans to Mars necessary? How else could scientists explore the planet without actually going there? A
10. What is space junk, and why do scientists monitor its position in space? In your answer, give four examples of objects considered to be "space junk." K/U