LESSON 3

The Hazards for Spacecraft

Quick Write

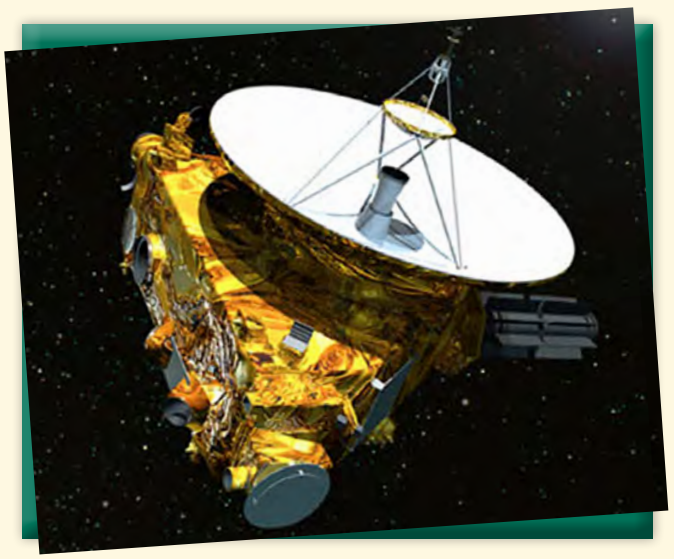
The New Horizons probe accomplished an impossible mission and provided an immense amount of data for scientists. What challenges do you think a probe would face to travel outside our solar system?

Learn About

- radiation hazards
- the hazard of impact damage
- threats associated with surface landings
- fire hazards in space

On January 19, 2006, NASA launched the New Horizons space probe. The mission of New Horizons was ambitious. The probe would travel past the planets in our solar system and send data back to Earth, taking nine years to reach the last planet, Pluto. It's a long journey, and the New Horizons spacecraft faced many challenges and hazards that could be detrimental to the mission.

Even before launch, the New Horizons probe faced challenges. It survived the torrential rain and winds of Hurricane Wilma, the coordination of many teams and components, and a successful launch schedule. New Horizons had a launch window of January 11 to February 14, 2006. However, if it was launched within the first 23 days of that window, New Horizons would receive a boost from the gravity on Jupiter. If the launch window was missed, the probe would have reached Pluto up to six years later.



A rendering of the New Horizons probe in space.
Courtesy of NASA

Once airborne, New Horizons had a new challenge: how to power the batteries. Pluto is three billion miles away from Earth, and the Sun's rays are not powerful enough to reach Pluto with enough strength to power the batteries. So, New Horizons is powered by nuclear power that can withstand the radiation hazards and longevity of its mission in space. In addition, multiple backup systems are on board in case of failure or radiation damage to any of the probe's components.

Before New Horizons reached Pluto, several new moons were discovered around the dwarf planet, posing an impact hazard to the spacecraft.

New Horizons successfully reached Pluto in July 2015, sending magnificent images of the dwarf planet's icy surface and its largest moon, Charon. New Horizons did not stop at Pluto, however. Instead, it is continuing into deep space to the Kuiper Belt, which it will reach in July 2019.

Vocabulary

- space radiation
- galactic cosmic rays
- space debris
- orbital debris
- micrometeoroids
- molecular diffusion

Images from New Horizons Long Range Reconnaissance Imager LORRI were combined with data from the spacecraft Ralph instrument to create this enhanced view of Pluto.

Courtesy of NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

Your mission is planned, and it's time to travel into space. Unfortunately, many dangers lie ahead. Space travel is a risky business and has many hazards. In this lesson, we will explore the risks that a spacecraft faces during its journey.

Radiation Hazards

What is radiation? Radiation is a form of energy that is emitted in particles or waves. Radiation can occur in many different forms. It is all around us on Earth, but our atmosphere protects us from the harsh radiation that exists in space.

Space radiation *contains atoms that have been stripped of their electrons as they accelerate through space at speeds close to the speed of light*. As the atoms speed up, they will lose all of their electrons and be left with only the nucleus. There are three kinds of space radiation:

- Particles trapped in the magnetic field of Earth
- Particles sent flying into space during a solar flare
- Galactic cosmic rays, which are *high-energy protons and heavy ions that originate outside our solar system*

Radiation can be extremely dangerous to the human body, and astronauts are exposed to a large amount of radiation in space. Spacecraft must be designed to simulate Earth's atmosphere to try to protect astronauts from being exposed to large amounts of radiation. We'll learn more about the hazards of radiation to astronauts in a later chapter.

A 3D illustration of the Sun's surface with solar flares.

Pixus/Shutterstock

Radiation's Effect on Electronic Systems

Another concern about radiation in space is the danger to the electronics that protect both the spacecraft and astronauts. Radiation can energize the circuits in computers, which can erase the data on the computers and cause glitches that affect the spacecraft's operability. Most space-based computer failures are a result of single events of high-energized particles traveling through space.

There are two ways radiation affects electronics. Short bursts of high-energy can disrupt electrical charges and penetrate integrated circuits. All programming is a series of bits and bytes–0's and 1's; radiation can actually flip those bits, causing a change in the programming. One small change in programming can have devastating effects on a spacecraft. In addition, radiation can affect microprocessors by causing them to execute a program incorrectly. For example, radiation could cause a program to believe that 2+2 = 5.

Astronaut on a spacewalk to perform maintenance, with Earth in the background. Elements of this image furnished by NASA.

Castleski/Shutterstock

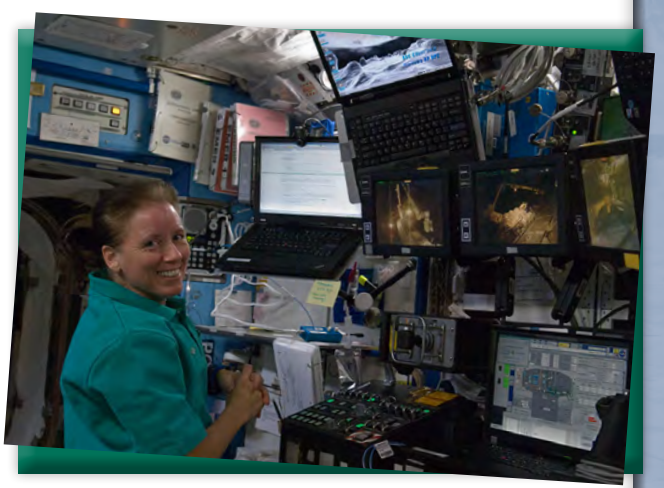
The second effect of radiation is the long-term threat to circuits. Over time, if circuits are continually exposed to harmful radiation, they become less effective at storing information and making calculations,

The risk of radiation hazards to spacecrafts varies, depending on the location of the craft. For example, radiation around Jupiter is extremely high, and disasters can occur each minute a satellite or spacecraft passes Jupiter. NASA reduces the risk of radiation hazards to some spacecraft, such as the Hubble Space Telescope, by shutting them down entirely when they pass through high radiation zones, such as the Van Allen belt.

So how do we shield electronic equipment from radiation? Radiation shielding is possible, but the shields are heavy and very costly, which does not make them an ideal solution for satellites. Engineers designing the chips and circuits in the electronic systems in space are working to build components that are less susceptible to radiation. Again, this technology is expensive, so it's not an option for many spacecrafts.

The International Space Station (ISS) currently is testing the Radiation Tolerant Computer Mission (RTcMISS), which is a computer system designed to handle the negative effects of space radiation.

The most common option for fighting radiation hazards to protect electronics is Triple Modular Redundancy (TMR). TMR uses readily available electronic components, but in triplicate. Therefore, if one system has an error, the other two can correct it.



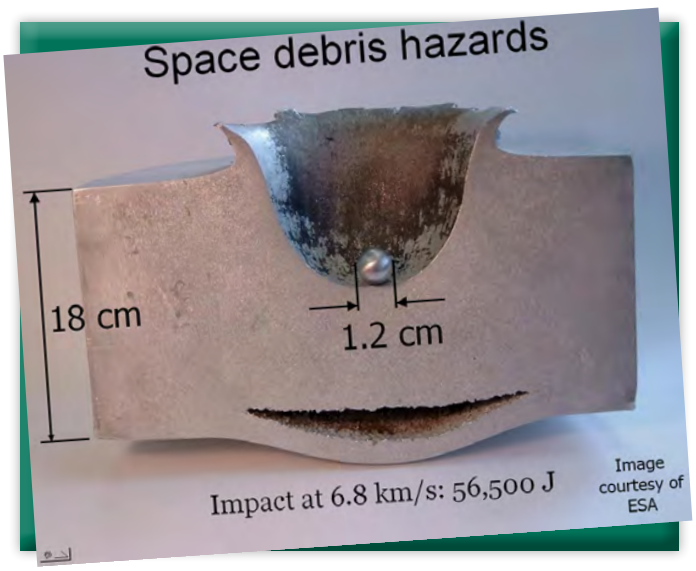
NASA astronaut Shannon Walker, Expedition 24 flight engineer, is pictured near a robotic workstation in the Destiny laboratory of the International Space Station.

Courtesy of NASA

Did You Know?

Computer systems are more susceptible to radiation today than when the Apollo mission went to the Moon. As computer systems advance, they become smaller and more complex. This actually allows more interference from radiation.

The Hazard of Impact Damage



Space mission operators may have to maneuver spacecraft to avoid collisions. 1.2 cm is the size of a pea, 18 cm equates to just over 7 inches. In some cases, no maneuvers are possible.

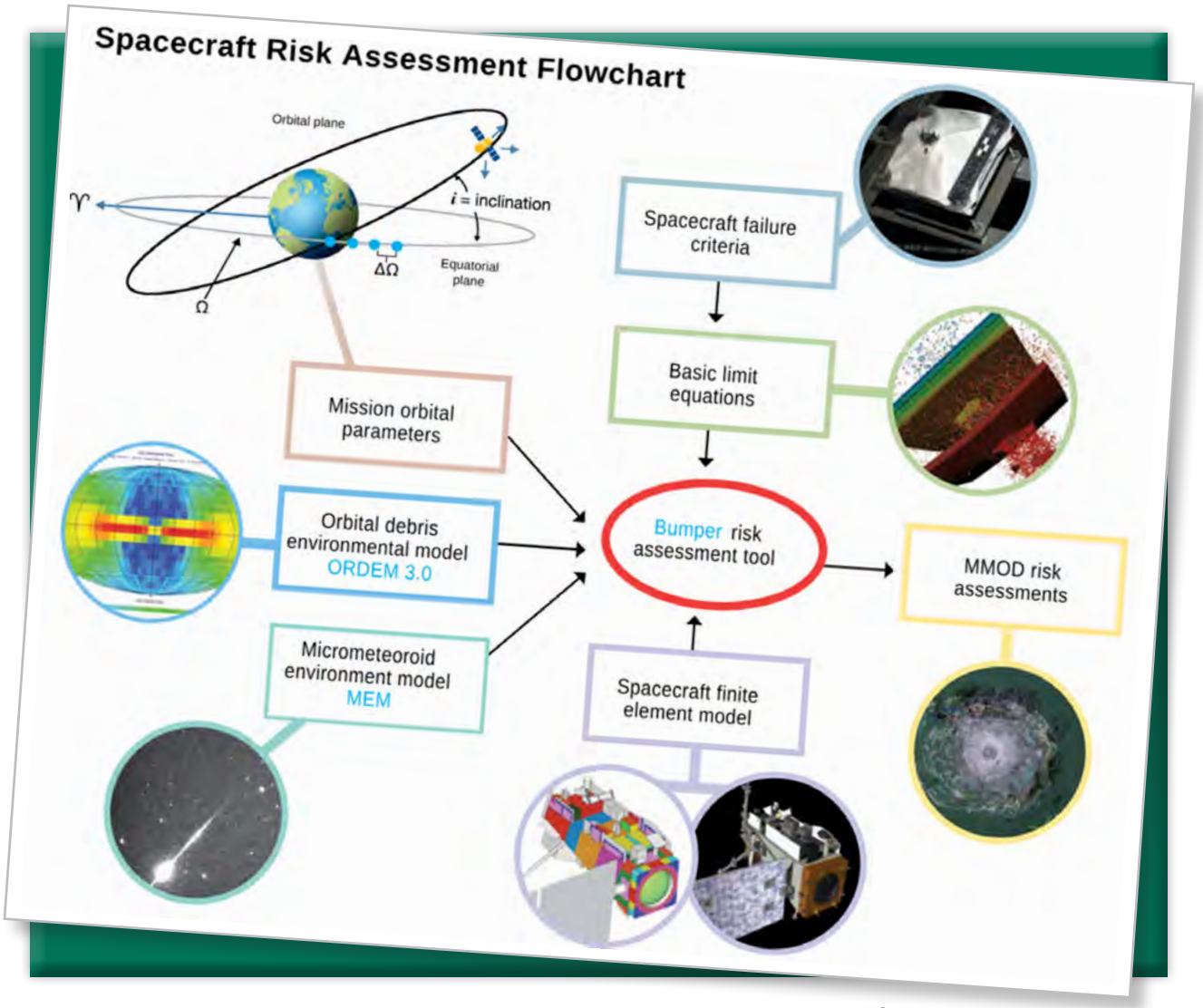
Courtesy of ESA

Space debris refers to *natural and man-made particles in space*. The definition includes orbital debris, which is *man-made particles in space, like trash from spent rockets and broken satellites*. Orbital debris, which orbits the Earth, is also referred to as "space junk."

There currently are more than 500,000 pieces of orbital debris orbiting the Earth. Orbital debris orbits at a speed of 17,500 mph. This causes a collision hazard for spacecraft, satellites, and the ISS. A collision with orbital debris could be catastrophic in space. As a result, NASA has invested in the detection and prevention of collisions with space debris.

Meteoroids, which orbit the Sun, are another hazard to spacecraft and travel at twice the speed of space junk. However, the majority of meteoroids are very small micrometeoroids. Micrometeoroids are *small pieces of asteroids and comets that cannot be tracked*.

Micrometeoroids and orbital debris (MMOD) are the biggest risk for NASA's flight programs. About 20,000 pieces of orbital debris are larger than a softball. About 500,000 pieces of orbital debris are the size of a marble or larger. Larger orbital debris can be tracked and avoided by spacecraft, but there are millions of pieces of small orbital debris that cannot be tracked. NASA uses computer modeling to mitigate the risks of MMOD to spacecraft. The primary tool used by NASA is a computer program named Bumper. Bumper analyzes the probability of spacecraft being damaged by MMOD.



The Bumper risk assessment tool evaluates many areas to determine the risk of impact to a spacecraft.

Courtesy of NASA

Let's think about at a small fleck of paint orbiting Earth at about 17,500 mph. If that small fleck of paint collides with a spacecraft entering space, the velocities of each of these objects can create a surprising amount of damage to a spacecraft. NASA has had to replace many windows in space shuttles due to debris collision with flecks of paint. Thus, the greatest risk to spacecraft is the undetectable space debris.

The Right Stuff

Space Debris Collisions

With the large amount of space debris in orbit, one might expect a high number of disastrous collisions. However, NASA and the Department of Defense (DoD) actively track space debris to try to avoid collisions. DoD's Space Surveillance Network tracks objects as small as two inches in diameter in low earth orbit, and about three feet in diameter in higher orbits. Just one collision could add thousands of pieces to the current space debris problem.

1996

A French satellite was hit by debris from a French rocket that exploded more than 10 years earlier. The satellite was damaged by the impact.

2007

China used a missile to destroy an old weather satellite, creating more than 3,000 pieces of space debris.

2009

The US commercial satellite Iridium collided with an inoperable Russian satellite. Iridium was destroyed in the collision and added about 2,000 pieces of trackable debris to the amount of space junk..

Avoiding a Collision with Space Debris

So how do spacecrafts avoid a collision with so much space debris in orbit? NASA has a standard set of guidelines to assess the risk of impact with space debris. The guidelines create an imaginary box, known as the "pizza box," around a spacecraft. The pizza box is a mile deep and 30 miles across and long. If an assessment determines that debris will pass within the pizza box, Mission Control centers work to determine a course of action. The launch path and/or date may be altered to avoid collision or the spacecraft may need to engage in avoidance maneuvers. These maneuvers are typically small and occur at least an hour before a collision may occur.

Cleaning Up Space

Although NASA and the DoD have effective methods for avoiding impacts with space debris, the ultimate solution is to clean up the space junk. As more junk is created, the risk of collision increases exponentially. International guidelines exist that require the removal of space debris and spacecraft within 25 years of the end of the mission for the spacecraft. That's a long time for, say, an inoperable satellite to be orbiting Earth. And not surprisingly, only 60% of operators actually follow through with the removal of their spacecrafts.

Several plans for space debris cleanup are in the works. In June 2018, astronauts in the ISS deployed the RemoveDebris (RemDeb) spacecraft for its first mission: an experimental phase that began in September 2018. To do its job, RemDeb launches a cube that travels 16 to 23 feet away from the main spacecraft. RemDeb then launches a net to capture the cube and any space debris in the vicinity. Next, it launches a sail to assist with deorbiting, which returns the debris to Earth in about 10 weeks.

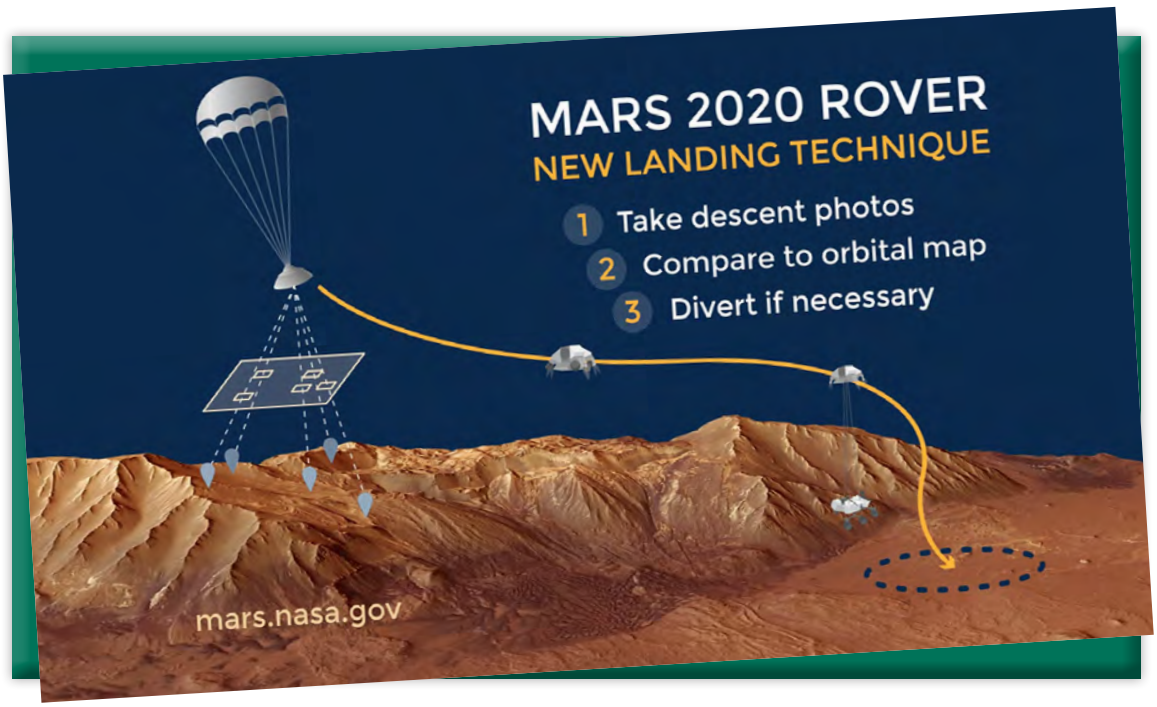
Threats Associated with Surface Landings

Your spacecraft has made it to space, but now what? You may be landing back on Earth, the Moon, or Mars! There are hazards to a spacecraft associated with landings.

NASA's shuttle program used Kennedy Space Center's runway as its landing point. The runway is longer and wider than most commercial runways. It was kept clean and free of debris to offer perfect landing conditions to arriving shuttle astronauts. But what about landing on the Moon or Mars? There are no runways available for a smooth landing. The surfaces of the Moon and other planets are rocky, unwelcoming locations. So how do we prevent damage to a spacecraft from landing in these areas?

NASA's Autonomous Landing and Hazard Avoidance Technology (ALHAT) project successfully concluded in 2014. The program's mission was to design and develop advanced technologies that use surface-tracking sensors to identify a landing area. The ALHAT navigation system can successfully navigate a spacecraft to a safe landing area and bring the spacecraft to a landing without human interaction.

The Mars 2020 Rover has a new landing technique that will allow it to land closer to its target. In previous Rover missions, weeks and months were spent travelling to the perfect target location. With the new landing technique, the Rover will take descent photos, compare them to the orbital map, and then divert the landing, if necessary. The landing area will also require 50% less space than previous missions. This is called Terrain-Relative Navigation (TRN). Terrain-Relative Navigation is critical for the exploration of Mars. As discussed in Chapter 2, Mars is a very rocky planet and has a tricky terrain. Of course, these rocky areas are also the most interesting parts of Mars to explore. However, they have been off-limits as potential landing sites because 99% of a landing area has to be free of hazardous slopes and rocks.



The Mars 2020 Rover will use a new landing technique to allow the Rover to land in previously off-limits areas.

Courtesy of NASA

Fire Hazards in Space

Fire is another hazard to spacecraft. Fire burns very differently in space. When a fire burns on Earth, oxygen is pulled into the flames and combustion products are pushed out. Heat and hot gases rise from the flames on Earth. In space, there is no gravity, so heat does not rise. A process called "molecular diffusion" controls a flame's behavior in space. Molecular diffusion is *the thermal motion of all particles at temperatures above absolute zero*. What this means is that, in space, fire draws in oxygen and releases combustion products 100 times slower than on Earth. Flames in space also burn at a lower temperature and need less oxygen to burn. For this reason, the material used to extinguish space flames must be more concentrated.

Fire needs oxygen and airflow to survive. On the ISS, the ventilation system supplies the airflow needed for a fire to survive. This means that if a fire were to ignite on the ISS, it could spread in any direction. On Earth, flames would only burn upward because of the effects of gravity. Because smoke and fire don't rise in the zero gravity of space, the smoke detectors on the ISS are installed in the ventilation system.

Two candle flame images showing air flow from bottom to top, as compared with how a flame appears on Earth.
Courtesy of NASA

So how do we protect spacecraft from fires in space? The best way to fight a fire in space is prevention. All spacecraft and space components must complete a flammability test before launch to help prevent space fires.

If a fire did occur on the ISS, the astronauts would follow a three-step plan:

1. Turn off the ventilation system.
2. Shut off power to the affected area.
3. Use extinguishers to put out the flames.

As you have read, there are many hazards to both space travel and to a spacecraft itself. NASA and commercial space organizations are constantly researching methods to prevent these hazards from occurring. In later chapters, you'll read about the hazards to astronauts in space.

Did You Know?

The ISS is experimenting with fire in space as part of the Flame Extinguishment Experiment (FLEX). Scientists ignite a fire in a special experiment rack and record the burning process. These experiments have demonstrated that fire is less predictable in space and can be deadlier than on Earth.

CHECKPOINTS

Lesson 3 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What are the three kinds of space radiation?
2. What is the most common option for fighting radiation?
3. What are micrometeoroids?
4. What is the "pizza box" around a spacecraft?
5. How does the RemoveDebris spacecraft work?
6. Why is it so hard to land on the Moon or other planets?
7. How does the Mars 2020 Rover's landing technique work?
8. How is fire different in space?
9. How would astronauts on the ISS handle a fire?

APPLYING YOUR LEARNING

10. Many organizations have proposed solutions for the orbital debris problem. Based what you have read in this lesson, what possible solution would you offer for removing orbital debris from space?