FUTURE U.

Long Endurance Space Flight

Objectives

Students will be able to:

- **Compare** and **contrast** how distance is measured and scales are created
- **Explain** the effects of space travel on the human body
- **Analyze** lessons learned from a simulation to consider space's effects on communication
- **Develop** a personal statement regarding long endurance space flights that **integrates** information learned from past mistakes, as well as current risks and complications

Overview

As in-training members of NASA's mission control staff, students will explore the principles of scale, proportion, time and distance to gain an understanding of the problems that could arise on a long endurance space flight or when rovers need to communicate issues back to mission control. To accomplish this, students will first engage in a series of questions related to scale, proportion and quantity to activate prior knowledge before watching a video that takes them on a journey from the subatomic level to the edge of the universe. They will then explore several maps as they discuss how the scales vary, which will lead them to learn about the units of distance used by astronomers. Next, students will research the ways long endurance space flights put stress on space travelers' bodies and how these effects can be tempered and monitored. In a final exploration of the effects of long-distance flights, students will participate in a simulation of communication delays that occur during such journeys and will evaluate other lessons that mission control staff have learned in the past. Students will ultimately apply what they have learned as they write a personal statement that outlines how they believe NASA should approach these perilous but important voyages.

This lesson focuses on

Engineering Design Process

- *Defining the Problem*
- *Designing Solutions*
- *Communicating Results*

21st Century Skills

- *Collaboration*
- *Communication*
- *Critical thinking*

Timing

Three 45–60-minute class periods

Materials

- Computer or device with the ability to project
- Path to Mars video, to project
- Scale of the Universe video, to project
- One ruler
- Graph paper, one per student
- Calculator, at least one for the class
- Space Effects article, one per student
- Effects of Space Travel Graphic Organizer, one per student
- SLAMMD video, to project
- Lunar Rover Vehicle Image, eight copies
- Simulation Scenario, one teacher copy
- Reply Message #1 handout, eight copies
- Reply Message #2 handout, eight copies
- Challenger article, one per student
- Personal Statement, one per student

Have you ever wondered…

What is the farthest distance a human has ever traveled in space?
In April 1970, NASA's Apollo 13 mission traveled the greatest distance from Earth that man has ever gone. This trip went around the far side of the Moon and traveled 248,655 miles away from Earth. Though it's been close to 50 years since this occurred, no human has broken this record![1]

What is the longest amount of time someone has been in space?
Cosmonaut (Russian astronaut) Gennady Padalka holds the record for most time spent in space over the course of a lifetime. Over five different spaceflights, he accumulated more than 878 days in space…which is almost two and a half years! The longest time spent consecutively in space was achieved by Cosmonaut Valery Polyakov who was in space for 438 days from January 1994 to March 1995. The longest consecutive amount of time that an American has spent in space is 340 days, an accomplishment held by Scott Kelly during his mission to the International Space Station.[1]

MAKE CONNECTIONS!

How does this connect to students?

During the students' lifetime, travel is likely to occur not only back to the Moon, but to Mars and beyond. The President's 2017 space directive stated that "Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."[2] As NASA and private companies work to make this a reality, long duration space flights will likely become more frequent in the future. Students may even live to see tourists aboard these flights!

How does this connect to careers?

Astronaut: An astronaut has many jobs, and they often depend on where the astronaut travels. At the International Space Station, astronauts spend their days experimenting and conducting research, as well as maintaining the space center itself.

Flight Controllers: Flight controllers work on Earth in a mission control center. People in this job support missions, including the International Space Center. They monitor the space center constantly and send messages that help the crew with both daily routines and any issues that arise.

Aerospace Physician: As their name implies, these physicians specialize in the health and wellbeing of astronauts, pilots and aircrews. They practice preventative and occupational medicine, helping those who fly before, during and after their trips.

How does this connect to our world?

Similar to lunar travel, long endurance space fights and voyages to Mars and beyond will be an international endeavor. NASA states that one of their goals for this year is to "offer to expand the International Space Station partnerships to new nations, including new international astronaut visits" as well as "seek and develop substantial new international, commercial, and inter-agency partnerships, leveraging current International Space Station (ISS) partnerships and building new cooperative ventures for exploration."[2]

In other words, NASA is seeking opportunities to create international partnerships that strengthen and further space exploration!

Sources

[1] Wall, Mike. "The Most Extreme Human Spaceflight Records." space.com/11337-human-spaceflight-records-50th-anniversary.html.

[2] "Moon to Mars Overview. NASA. nasa.gov/topics/moon-to-mars/overview.

Blueprint for Discovery

DAY 1

1. Begin with playing this Path to Mars video up until 1:01. Then welcome students to the first day of NASA Mission Control Training. Explain that they are among an elite group who will eventually be responsible for guiding astronauts as they travel deeper and deeper into outer space. Before they receive on-the-job training, they will gain a basic understanding of what space travel entails.
2. Tell students that first they will answer a series of questions in which they must decide which of two objects is larger. If they don't know, they should take an educated guess. For each question, they will demonstrate their opinion by going to one side of the classroom. Ask:
    a. Which is larger: a piece of DNA or an ant?
    [Direct students who believe DNA is larger to go to one side of the classroom, and those who believe an ant is larger to go to the opposite side of the classroom. Continue these directions for each of the questions below.]
    b. Which is larger: Mount Everest or the Empire State Building?
    c. Which is larger: Mercury or Jupiter?
    d. Which is larger: the distance between the Earth and the Moon or the diameter of the Sun?
    e. Which is larger: 9,460,000,000,000 kilometers (about 6 trillion miles) or 1 light-year?
3. Play this The Scale of the Universe video and instruct students to listen for answers to these questions…especially the light-year one!
4. When the video is complete, discuss: Are 9,460,000,000,000 (nine trillion four hundred sixty billion) kilometers equal to 1 light-year? Explain that a light-year is the distance that light travels in one year… and yes, it is equal to about 9.5 trillion kilometers!

    Note: If needed, quickly review the concept of kilometers. Explain that one mile is about 1.6 kilometers. While the United States commonly measures distances in miles, scientists generally use kilometers because the metric system is used widely by the rest of the world.
5. Project maps.google.com and input the address of your school. Direct students' attention to the map scale in the bottom right corner of the screen, which will usually begin with a scale of 1 inch = 1000 feet. Explain that a map scale shows the ratio between the distance on a map (one inch) and the distance in real life (1000 feet). Click the "—" button a couple times to zoom out until the scale says "1 mile" then "2 miles" then "5 miles". Discuss:
    a. What happened to the map at each of these scales?
    b. What are the advantages and disadvantages of each scale?
    c. Why does the concept of a map scale exist?
6. Zoom back in to the 1-mile map scale. Remind students that one light-year equals about 9.5 trillion kilometers or 6 trillion miles. Ask: If want to create an image on the board that illustrates one light-year, what kind of scale could we use?
    a. Accept any answers that will work: For example, one inch = 1 trillion miles; one inch = 500 billion miles, or even one inch = 250 billion miles.
    b. Choose one of the scales and then challenge the class to use a ratio to figure out the distance of one light-year. For instance:

i. 1 intch / 500 billion miles = x inches / 6 trillion miles. Cross multiply and divide to show students how to calculate the distance for x. In this case, x = 12 inches.

ii. Draw this distance on the board, along with the scale.

7. Pass out a piece of graph paper to each student and remind them that they can incorporate graph paper squares into their scale. For instance, one graph paper square may equal one foot, or five feet, or one mile, or 500 kilometers. The scale is entirely up to the creator!

8. Write the number "150,000,000" on the board, and explain that this is the approximate distance—in kilometers—of the Earth from the Sun.

9. In pairs, challenge students to create a drawing on their graph paper that would show this distance to scale. For instance, one square could equal 100,000,00 kilometers. At this scale, the Earth would be 15 squares away from the Sun.

10. Once students have developed their drawing with a scale that uses kilometers, introduce the following measurement units and explain that these are commonly used to measure distances in outer space:

    a. Astronomical unit: An astronomical unit (A.U) is the distance between the Earth and the Sun. For instance: Mars is about 1.5 A.U. from the Sun, while Mercury is a little over one-third of an A.U. from the Sun. Instruct students to add A.U. to their map scale. Based on their scale, how many graph squares is 1 A.U. equal to?

    b. Light-years: Students have already learned that a light-year equals 6 trillion miles or about 9.5 trillion kilometers. Ask: Would it make sense to use a scale of light-years for this map? Arrive at an understanding that it would not make sense because one light-year is much longer than 150 million kilometers. Using this scale, their drawing would have to be miniscule!

    c. Even bigger than light-years are parsecs. A parsec is equal to 3.26 light-years. Ask: Would it make sense to include parsecs on this map? Why not?

11. Probe students to share the farthest distances they have ever traveled, estimated in kilometers. It may be helpful to explain that the distance from New York City to Los Angeles is about 5,633 kilometers, and the distance from New York City to Tokyo is 10,842 kilometers! Taking these figures into consideration, ask: Can anyone imagine traveling 384,400 kilometers to the Moon? What about 4.2 astronomical units to Jupiter?

12. Segue to the idea that traveling such a long distance—and so far from Earth—takes a toll on the human body. Distribute one Effect of Space article to each student. Direct students to read the article once themselves to get the gist of the text. As they read, they should annotate (highlight or underline) for the effects of space travel on the human body.

13. Once students have read the article, pass out one Effects of Space graphic organizer to each student. Put students into pairs, and direct them to work together until the end of class to fill in the chart. Pairs that finish early may answer the question at the bottom of the handout.

DAY 2

1. If needed, allow student pairs a few minutes to complete their graphic organizers. Once complete, pose the question at the bottom of the sheet: Based on the information above, what are the biggest effects of long-distance space travel on the human body? Allow a variety of answers as long as students can justify their response with text evidence.

2. Introduce the idea that body mass is important when considering the stress of long endurance space travel. If needed, briefly review the difference between mass and weight: Weight changes when you leave Earth because weight is the measured by gravity's pull, and gravity fluctuates throughout the solar system. Mass, however, is the measurement of matter something contains so it does not automatically change when you leave Earth.
3. Project and play this video. As students watch, urge them to think about *why* this device is important, especially when thinking about the effects of space on the human body.
4. When the video is complete, allow students a couple minutes to discuss their ideas with a partner and then share their thoughts with the class. Make sure students understand that body mass is a large indicator of health because muscles, fat and bone density all contribute to the amount of mass a body contains. Because of this body mass device, astronauts are able to better track and regulate their overall health.
5. Ask: What might an astronaut need to do onboard a spacecraft and/or what might a spaceship need to contain to make sure astronauts maintain their body mass? Answers may include: Consistent exercise and weight lifting, eating a healthy diet that meets their caloric needs (often this means eating even when full because food settles in astronauts' stomachs differently!), and taking supplements/ medicine to lessen the loss of bone density.
6. Move on and explain that traveling far from Earth comes with other obstacles too. One obstacle that becomes harder and harder the farther away you go is communication.
7. To participate in a simulation related to this obstacle, divide students into groups of four or five. One student from each group will be stationed at a command center on Earth and the remaining students will be astronauts exploring new planets.
8. Instruct the command center crew to stand together on one end of the classroom. The other groups of astronauts should each be on their own "planet" in different sections of the room. Each group should be at varying distances from the Command Center but several feet away at minimum.
9. Once the groups are situated, follow the directions on the Simulation Scenario handout to lead the class through the simulation.
10. When the simulation is complete, discuss the following questions as a class:
    a. What challenges did you experience?
    b. Why did some emails take longer than others to arrive?
    c. If Mars is currently 225 million kilometers away from Earth, and information travels at the speed of light, what is the shortest amount of time it would take for a message to reach Earth? Remind students that in a year, light can move about 9.5 trillion kilometers.
        i. Lead students to understand that if light travels 9.5 trillion kilometers in a year, it travels about 300,000 kilometers per second. At this distance, it would take about 12.5 minutes for communication to be transmitted. Explain that the distance between Mars and Earth varies because both planets have different orbits. Therefore, the transfer would normally take between three and twenty-three minutes for each exchange.

d. Explain that this experience *actually* happened to astronauts during the Apollo 13 Moon mission. However, their communication was slightly different, because the delay in communication between the Moon and the Earth is only just over a second!

e. To wrap up your discussion, ask: What effects could this communication delay have on travel to Mars and beyond?

DAY 3

1. Tell students that they now have one last important learning opportunity as in-training members of NASA's mission control staff: They need to be able to learn from past mistakes.
2. Distribute one Challenger article to each student. Individually or in pairs, instruct students to read and annotate for lessons that should be learned from this space flight. When students have finished reading and annotating, briefly discuss the lessons as a class.
3. Finally, tell students that in order to graduate from training, they must apply what they have learned and write their own personal statement that summarizes their viewpoint on long endurance space flights and deep space exploration. Distribute the Personal Statement handout, review the instructions and then allow them to get to work!
4. Conclude the lesson by showing the rest of the video that kicked off Day 1 (from 1:01 to the end) to show what Boeing is doing to prepare for long endurance space travel. Encourage students to consider one of the diverse careers that would help further space exploration!

EXTEND

To guide students in a more thorough reflection of what they have learned over the course of these three class periods, encourage them to keep a reflection journal. Within their journal, they can maintain the role of NASA Mission Control trainee. Their journal can be used to capture what they have learned through each step of the training as well as reflect on their learning's implications for long endurance space travel. Students may then use this journal as they complete their Personal Statement final assessment.

National Standards

Next Generation Science Standards

Space Systems

- MS-ESS1-3. Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- Motion and Stability: Forces and Interaction
- MS-PS2-3. Cause and effect relationships are routinely identified, tested, and used to explain change

Common Core English Language Arts Standards

Science & Technical Subjects, Grades 6–8

- RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
- RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Common Core Mathematics Standards

Science & Technical Subjects, Grades 6–8

- 7.RP.A.2. Recognize and represent proportional relationships between quantities.

Effects of Space Travel Graphic Organizer

Directions: Read the article once to get the gist of the text. As you read, annotate for effects of space travel on the human body. Then read the text a second time, and pause to fill in the chart below.

How and why does space travel affect your…? Include the effects of space travel as well as why these effects seem to occur:	Is the effect temporary or long-term?
Genes	
Eyes	
Mind	
Physical Body	

Based on the information above, what are the biggest effects of long-distance space travel on the human body?

Simulation Scenario

Step 1

Once you have astronaut teams spread out on "planets" around the classroom, as well as one command center crew, read the following aloud:

"Astronauts, you have recently arrived on a new planet as part of an exciting and expensive research expedition. To aid in your investigation, your crew has a vehicle that you have nicknamed "the Buggy". The Buggy makes it easier to traverse long distances on this planet and explore diverse geological landscapes. It's really the only way you can complete the research you've come this far to do!

However, near the beginning of your first of several extravehicular activities in which you collect and measure invaluable data using your Buggy, trouble arises that puts your mission in serious jeopardy.

"Ohh you won't believe it," you hear your colleague say. "Ohhh there goes a fender. Oh no." [Pass out the Lunar Rover Vehicle Image to each group so they can see what the fender used to look like.]

You realize that the hammer in your colleague's suit pocket had caught the edge of the back-right tire's fender extension, and it popped right off. This accident could have totaled your entire rover vehicle. It thankfully didn't, but you have other serious problems.

Without the fender extension protecting you and the Buggy from planetary dust, driving the Buggy becomes a serious hazard. When dirt is picked up by the woven wire wheels in the airless near-vacuum of the planet's surface, the dust travels much farther than it would on Earth. Much more abrasive than any sand found on Earth because the grains are not worn down by wind and water, the dust that is lifted off the surface by the wheel is capable of catastrophic consequences.

Riding without the fender extension begins to cause massive rooster tails, which are clouds of dust that travel up and over the Buggy. These rooster tails spread dust into every nook and cranny of your instruments. If the darker colored dust stays on any instrument for too long, the dust will absorb heat from the sun. This will then heat the instruments to very high temperatures, potentially causing them to fail. And not only is the dust covering your instruments, but it is also beginning to cover your suits more and more, which makes them heavy and harder to move. "

[Modified and adapted from airandspace.si.edu/stories/editorial/duct-tape-auto-repair-moon for this scenario.]

Step 2

Say: "You know you must notify your command center to aware them of this situation and ask for help.
If you can't fix this, your entire mission was for nothing! Thankfully, you are able to email the command crew on the ground."

Distribute a blank piece of paper to each group.
Say: "Think carefully about what you want to ask and tell the command crew and write your email."

Step 3

When the email is written, instruct each team to designate one astronaut to communicate with the control center. This person will carry the written message to simulate an email being sent, but they will only be allowed to take one step toward the command center every 30 seconds. (Note: this distance and time can be modified based on the size of your classroom and the time available, but the delivery should take at least 3 minutes. Every email should move at the same pace, no matter the distance it has to travel.

Simulation Scenario, continued

Step 4

As the team of astronauts waits for a reply, urge them to work together to brainstorm their own solutions. Say: “Unfortunately, the dust is getting worse. If you don’t think of a solution soon, you may never be able to resurrect your vehicle.”

Step 5

Once the message reaches the command center, instruct the mission control team member on the receiving end to read the email, and then give Reply Message Handout 1 to the astronaut. This astronaut should then slowly make their way back to their team, moving at the same pace as before.

Step 6

After each team reads Reply Message Handout 1, they should work together to add information about their situation. Tell the class, if necessary, that they may use their imaginations to make up additional plausible information.

Step 7

The astronaut should slowly again simulate an email exchange and move at the same pace back to the command center.

Step 8

Once this second message reaches the command center, instruct the mission control commander on the receiving end to read the email, think for a moment, and then give Reply Message Handout 2 to the astronaut. This astronaut should then slowly make their way back to their team, moving at the same pace as before.

Step 9

Once the first astronaut has returned to their group and shared the Reply Message #2, pause all movement and say: “Thankfully communication to and from Earth was able to save this planet’s Buggy. These astronauts now have the information they need to repair their vehicle. The communication came back just in time. Unfortunately, the rovers on every other planet have withstood too much damage and they are now beyond repair. You must return home without the research and data you were hoping to collect.”

Reply Message 1

Subject: RE: Fender Issue

From: Ground Mission Control

To: Planet Explorers

Can you please provide more details? We do not fully understand what has occurred.

Thank you.
Mission Control

Reply Message 2

Subject: RE: RE: Fender Issue

From: Ground Mission Control

To: Planet Explorers

Use the materials you have on board! Combine several of your paper maps with duct tape to create a replacement fender. You should then be able to attach this back to the rover with clamps from your telescope. We created a model for you.

Good luck.
Mission Control

Attachment: NASA AS17-137-20979

Personal Statement Mission Control

Directions: You are about to be a graduate of NASA's Mission Control Training Program in a crucial time for space exploration. With more and more emphasis on traveling to Mars and beyond, long endurance space flights will become your reality. It is therefore of the utmost importance that you have thoroughly considered the both the opportunities and potential consequences of long-distance space flights in order to provide the best possible support for astronauts on these missions.

Given what you know about the effects of lunar travel on the human body, space's communication complications, and lessons learned from the Challenger decision, how do you believe your team and NASA as a whole should approach long endurance flights? In your personal statement, include any steps and/or precautions that you believe need to be taken before astronauts travel to Mars and beyond.