# Activity Three: Performance

## Educator Notes

### Learning Objectives

Students will

- Model how data (packets) can become degraded during deep space communications.
- Develop a protocol to diminish the amount of packet loss and degradation of data transmitted across networks.
- Explain Delay/Disruption Tolerant Networking (DTN), the protocol for packaging messages for delivery in the Deep Space Network (DSN).

### Challenge Overview

During the 3D (Delayed, Degraded, Delivered) Game, students will take on the roles of the NASA team developing the DSN by simulating how data transmitted across the DSN can be delayed, degraded, and delivered. This activity walks the educator and students through the ins and outs of DTN protocol by placing students in real-life DSN scenarios.

### Suggested Pacing

45 to 60 minutes

### National STEM Standards

| Science and Engineering (NGSS) | |
|---|---|
| • MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. (Grades 6–8)<br>*Disciplinary Core Ideas*<br>• A sound wave needs a medium through which it is transmitted. | *Science and Engineering Practices*<br>• Develop and use a model to describe phenomena. |
| **Technology (CSTA)** | |
| • 2-NI-04: Model the role of protocols in transmitting data across networks and the internet. | |
| **Mathematics (CCSS)** | |
| *Mathematical Practices*<br>• CSS.Math.Practice.MP3: Construct viable arguments and critique the reasoning of others. | |
| **Language Arts (CCSS)** | |
| *Language Arts Practices*<br>• CCSS.ELA-LITERACY.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). | *Language Arts Practices (continued)*<br>• CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. |

### Challenge Preparation

The Deep Space Network (DSN) is a worldwide system of sensitive antennas that communicates with interplanetary spacecraft. Signals to and from the spacecraft travel millions to billions of kilometers. To hear the spacecraft's faint signal, the antennas on Earth are equipped with amplifiers, but there are several problems. The signal becomes degraded by background radio noise (static) emitted naturally by nearly all objects in the universe, including the Sun and Earth. The background noise gets amplified along with the signal. The signal can also be degraded through absorption of the waves as a loss in sound energy. Also, the powerful electronic equipment amplifying the signal adds noise of its own. The Deep Space Network uses highly sophisticated technology, including cooling the amplifiers to a few degrees above absolute zero, and special coding techniques so the receiving system can distinguish the signal from the unwanted noise.

The educator should

- Read the introduction and background information, the Educator Notes, and the Student Handout to become familiar with the challenge.
- Print the Student Handout for each team.
- Copy the Cosmic Comic Game comic strip (one per team) at the end of the Educator Notes and cut it into individual images.

### Materials

- ☐ Cosmic Comic Game comic strip of NASA images, one set per team
- ☐ Dice or number cubes for each team
- ☐ Index cards
- ☐ Writing utensils
- ☐ Delayed, Degraded, Delivered worksheet, one per team

### Introduce the Challenge

Remind students to use school-appropriate language throughout this entire activity.

Come up with a space-themed sentence and jumble up the words. For example, "Don't turn on the thrusters until after you count to ten" could become "Turn on the ten to thrusters until after you don't count." Read the jumbled-up sentence to students and ask if they were able to understand it.

To activate prior knowledge, ask students the following questions:

- How does a text get from your phone to your friend's phone nearby?
- Why is Wi-Fi important to your everyday life?

Read the article "Space Communications: 7 Things You Need To Know" as a group, using strategies for reading comprehension (e.g., modeling by thinking aloud, using graphic organizers to assimilate information, and providing questions that require students to find evidence in the text). https://www.nasa.gov/feature/goddard/2020/space-communications-7-things-you-need-to-know

### Engage

- Share the video "7 Minutes of Terror." https://mars.nasa.gov/resources/20049/challenges-of-getting-to-mars-curiositys-seven-minutes-of-terror/?site=msl
- Ask students the following questions:
  - Why did the team who designed the entry, descent, and landing system feel "terror" during the landing of NASA's Mars Curiosity Rover?
  - Why is there a delay in communication with humans on the Moon and/or Mars?
  - How might that impact astronauts on the Moon and Mars?
  - What might be different if a human, instead of a robot, were landing on Mars?

### Facilitate the Challenge

### Explore

***Cosmic Comic Game***

This game is a paper-passing activity to simulate issues that can occur with data packets traveling across a network.

- Pre-cut the Cosmic Comic Game comic strip at the end of the Educator Notes and distribute the pieces (out of sequence) to small teams of no more than four students.

  Note: The educator may use other sources as long as the group of images depicts a clear sequence of events. Numerous NASA images can be found at https://www.nasa.gov/exploration/systems/sls/outreach/activities.html.
- Challenge students to work as a team to quickly organize the comic or picture pieces into the correct sequence.
- The team with the fastest time and correct order wins the round.
- After the Cosmic Comic Game, the educator will engage students with the following questions:
  - What does the model seem to be demonstrating?

  - How is this process similar to that of NASA's Deep Space Network?
  - What are some challenges NASA faces when trying to transmit and receive communications with spacecraft and satellites?
- Discuss with students how NASA communicates with spacecraft. The following videos are helpful resources to learn more.
  - For background on how the DSN operates, share the video "How Does a Spacecraft Take a Picture?" https://www.youtube.com/watch?v=5ueMGZTezfY (Video length 3:02)
  - Share the video "Mars in a Minute: Phoning Home—Communicating From Mars." https://www.jpl.nasa.gov/edu/learn/video/mars-in-a-minute-phoning-home-communicating-from-mars/ (Video length: 2:29)

### Explain

Have students select at least two of the following resources (one activity and one website) to learn more. After they have completed at least one activity and explored at least one website, have students create a graphic organizer or picture to demonstrate their mastery of how the DSN and DTN work. Students must include the following vocabulary: reflect, absorb, transmit, satellite, and signal. This will help students as they model how a signal travels in the 3D Game.

Activity resources:

- DSN Game UpLink–Downlink. https://spaceplace.nasa.gov/search/DSN/
- SCaN Coloring Page and "Color With NASA" video. https://www.nasa.gov/directorates/heo/scan/communications/outreach/students/create_with_scan
  - Optional: Educators can share their students' work on a social media platform with #NextGenSTEM.

Website resources:

- Deep Space Network *Now* website. https://eyes.nasa.gov/dsn/dsn.html
- "Building Interplanetary Internet With 'Disruption Tolerant Networking'" video. https://www.nasa.gov/feature/antarctic-selfie-s-journey-to-space-via-disruption-tolerant-networking
- DTN website. https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking

### Elaborate

***3D Game***

Students will play two rounds. Round 1 will demonstrate a signal from Earth to a spacecraft on the Moon (a distance of 382,500 kilometers, or 237,674 miles); this can be played with three to five students per team. Round 2 will demonstrate a signal from Earth to a spacecraft on Mars; the number of students per team can be doubled or tripled. The number of students per team is increased to represent the need for more relay stations to transmit a signal from Earth to Mars (a distance of 54.6 million kilometers, or 39,926,867 miles) and additional opportunities for that signal to experience degradation and delay.

Instructions:

- Divide the whole group into teams.
  - Round 1: Three to five students per team
  - Round 2: Six to ten students per team
- Give each team a Delayed, Degraded, Delivered worksheet, two dice or number cubes, and index cards.
- The first student in the team will be the DSN station sending a message to the spacecraft, which is the last student in the team. Everyone else acts as relay stations. The relay process is showing how a signal is transmitted from Earth to a spacecraft.
  - Round 1: The spacecraft is on the Moon.
  - Round 2: The spacecraft is on Mars.

- Instruct the DSN station (first student in the team) to select a physical location within the room and write a series of brief commands on index cards (one 3- to 5-word sentence/command per card) to direct the spacecraft (last student in the team) to the location.
  - For example: Walk 10 paces. Turn left at third desk. Continue straight for 2 paces. Stop at whiteboard.
- The DSN station will hand each command card in sequence to the relay team. As each relay student receives a command card, they will roll the dice, read the corresponding scenario from the Delayed, Degraded, Delivered sheet, make any instructed changes to the index card, and pass the card to the next team member. Each command card will cycle through this process until all relay students have had a turn with each command card and the command is received by the spacecraft.
- The last student (the spacecraft) will collect all the command cards and try to navigate to the location based on the revised command cards.

After both rounds have been completed, have each team examine their commands and discuss the following questions:

- How far off course was the person who followed the garbled message?
- Compare and contrast the Round 1 message to the Round 2 message. What trends did you notice?
- Why do you think that this trend occurred?
- At the end of Round 1, were you able to understand the message? At the end of Round 2, were you able to understand the message?
- Did some of the errors have a greater impact than others?

### ✓ Evaluate

- Have students develop a protocol that will allow them to overcome the various scenarios they encountered in the **Elaborate** section. The protocol must ensure that both the DSN station and the spacecraft can be confident the full message will be received.
- Guidelines for the protocol:
  - The full message must consist of a series of 3- to 5-word commands. Students may decide that as part of their protocol they want the data to arrive in packets; if so, they have the option to write each word on a different index card.
  - The location cannot be known beforehand. Only the DSN station can know the physical location within the room where the spacecraft is going.
- Some examples of protocols that students may implement:
  - Have data sent one packet at a time.
  - Double the message to ensure most of the message is delivered. For example, the message may be “Turn left at first desk,” and students may choose to double each sentence: “Turn left at first desk. Turn left at first desk.”
  - Student may decide to truncate commands as a protocol. For example, “Place tool on left side of capsule” would become “Place tool on left side.”
- Have students test their protocol at least once with a team of no more than five students.

### Share

Have students present their protocols. Engage students with the following discussion questions or prompts:

- Did your protocol work to ensure the message was delivered and not degraded?
- Why do you believe your protocol worked or did not work?
- If you could revise your protocol, what new revisions would you make?
- Compare and contrast your protocol to the DTN protocol. The DTN protocol can be found here: https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking

As students present, be sure to check that they have covered the following concepts:

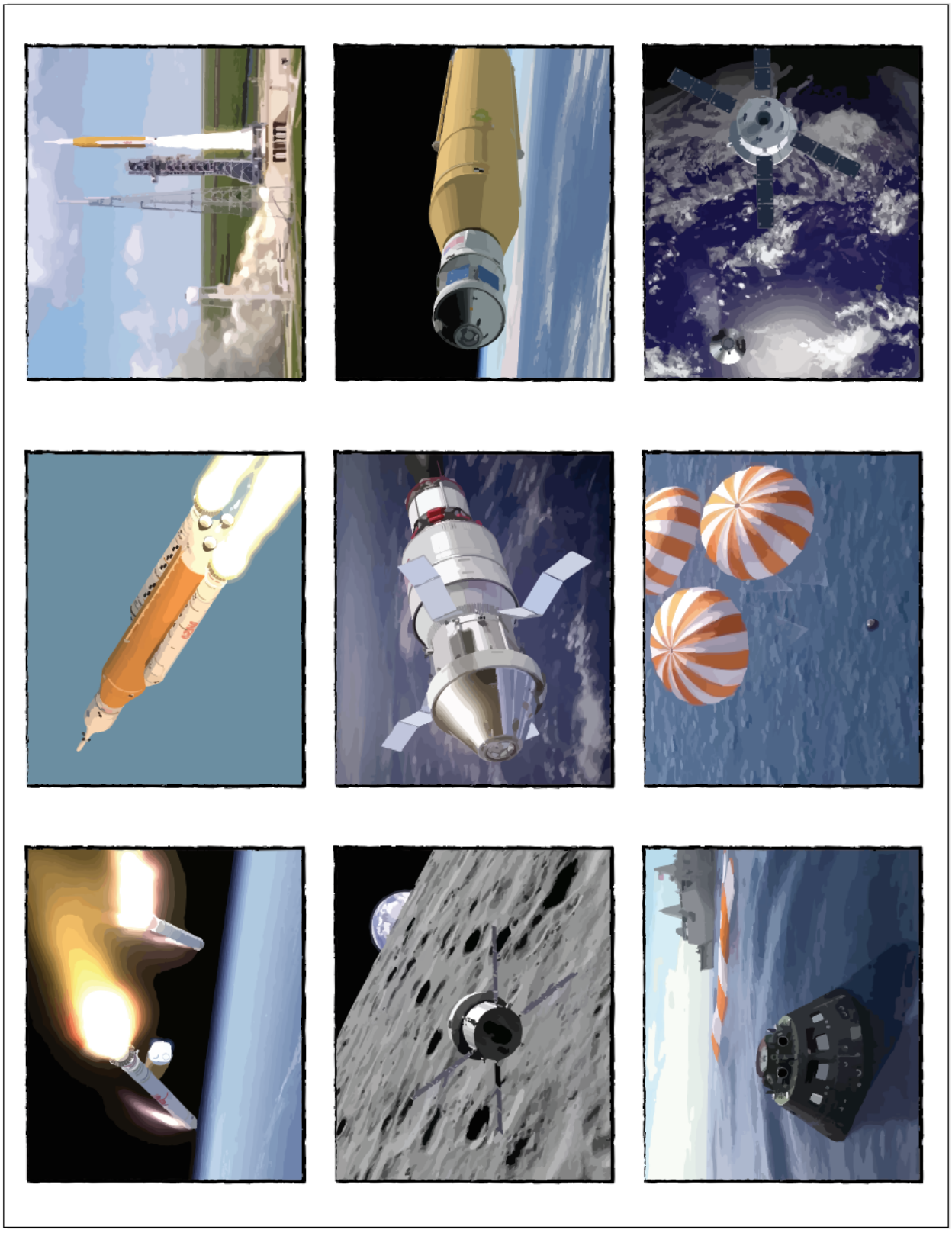
- ☐ Message was delivered.
- ☐ Students detailed the steps of their protocol.
- ☐ Students suggested improvements to their protocol.
- ☐ During the presentation, the students compared and contrasted their protocol to the DTN.

### Extensions

- Allow teams to test how many relay stations work best with their protocol to deliver the full message.
- Build Your Own Spacecraft! https://spaceplace.nasa.gov/build-a-spacecraft/en/
- Deep Space Network *Now*. https://eyes.nasa.gov/dsn/dsn.html

# Cosmic Comic Game Comic Strip

Educator: Pre-cut the Cosmic Comic Game comic strip (one set per team) and distribute the cut comic pieces sets (out of sequence) to small teams of no more than four students.



# Activity Three: Performance

## Student Handout

### Your Challenge

The Deep Space Network (DSN) is a worldwide system of sensitive antennas that communicates with interplanetary spacecraft. Signals to and from the spacecraft travel millions to billions of kilometers. That is a long journey, so you might be wondering, how does this work?

During the 3D (Delayed, Degraded, Delivered) Game, your team will take on the roles of a NASA team developing the DSN by simulating how data transmitted across a network can be delayed, degraded, and delivered. This activity walks you through the ins and outs of Delay/Disruption Tolerant Networking (DTN) protocol by placing you in real-life DSN scenarios.

### Engage

After watching "7 Minutes of Terror," discuss the following questions:

- Why did the team who designed the entry, descent, and landing system feel "terror" during the landing of NASA's Mars Curiosity Rover?
- Why is there a delay in communication with humans on the Moon and/or Mars?
- How might that impact astronauts on the Moon and Mars?
- What might be different if a human, instead of a robot, were landing on Mars?

### Explore

***Cosmic Comic Game***

This game is a paper-passing activity to simulate issues that can occur with data packets traveling across a network.

- You will be given pieces of a comic strip or an image.
- Your team will work quickly to organize those pieces into the correct sequence.

After organizing the images, think about the following questions:

- What does the model seem to be demonstrating?
- How is this process similar to that of NASA's Deep Space Network?
- What are some challenges NASA faces when trying to transmit and receive communications with spacecraft and satellites?

### Explain

How does NASA communicate with a spacecraft? Listed below are NASA resources for your team to explore. Select at least two of these resources (one activity and one website) to become familiar with the DSN, and create a graphic organizer or picture to demonstrate how the DSN and DTN work.

Activity resources:

- DSN Game UpLink–Downlink. https://spaceplace.nasa.gov/search/DSN/

### Fun Fact

In 1997, the Texas Legislature passed a bill that allowed NASA astronauts to vote from space.

In 2020, NASA astronaut Kate Rubins performed her civic duty from space on the International Space Station, 250 miles above the Earth's surface.

Learn more: https://www.nasa.gov/image-feature/goddard/2020/how-nasa-transmits-votes-from-the-space-station

### Career Corner

In the summer of 2020, a group of NASA Space Communications and Navigation (SCaN) interns helped develop network protocols that will extend internet-like services deep into the solar system.


Learn more: https://www.nasa.gov/feature/Goddard/2020/nasa-interns-extending-internetworking-off-world

- SCaN Coloring Page and "Color With NASA" video. https://www.nasa.gov/directorates/heo/scan/communications/outreach/students/create_with_scan

Website resources:

- Deep Space Network *Now* website. https://eyes.nasa.gov/dsn/dsn.html
- "Building Interplanetary Internet With 'Disruption Tolerant Networking'" video. https://www.nasa.gov/feature/antarctic-selfie-s-journey-to-space-via-disruption-tolerant-networking
- DTN website. https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking

## Elaborate

***3D Game***

Your teacher will assign teams to play two rounds of the 3D (Delayed, Degraded, Delivered) Game. Round 1 will demonstrate a signal from Earth to the Moon (a distance of 382,500 kilometers, or 237,674 miles). In Round 2, the number of students per team will be increased to represent the need for more relay stations to transmit a signal from Earth to Mars (a distance of 54.6 million kilometers, or 33,926,867 miles).

- Each team will receive a Delayed, Degraded, Delivered worksheet, two dice or number cubes, and index cards.
- The first student in the team will be the DSN station sending a message to the spacecraft, which is the last student in the team. Everyone else acts as relay stations. The relay process is showing how a signal is transmitted from Earth to a spacecraft.
  - Round 1: The spacecraft is on the Moon.
  - Round 2: The spacecraft is on Mars.
- The DSN station (first team member) will select a physical location in the room. Do not tell the spacecraft (the last team member) the location.
- The DSN station will write a series of brief commands on index cards (one 3- to 5-word sentence/command per card) to direct the spacecraft (last student in the team) to the location.
  - For example, if you want the spacecraft (last student) to get to the instructor's desk, you could write the following commands: Walk 10 paces. Turn left at third desk. Continue straight for 2 paces. Stop at whiteboard.
  - Remember: Each command will be on a different index card.
- The DSN station will hand each command card in sequence to the relay team. As each relay student receives a command card, they will roll the dice, read the corresponding scenario from the Delayed, Degraded, Delivered sheet, make any instructed changes to the index card, and pass the card to the next team member. Each command card will cycle through this process until all relay students have had a turn and the command is received by the spacecraft.
- The last student (the spacecraft) will collect all the command cards and try to navigate to the location based on the revised command cards.

As the team examines the original message and the message at the end of the activity, discuss the following questions:

- How far off course was the person who followed the garbled message?
- Compare and contrast the Round 1 message to the Round 2 message. What trends did you notice?
- Why do you think that this trend occurred?
- At the end of Round 1, were you able to understand the message? At the end of Round 2, were you able to understand the message?
- Did some of the errors have a greater impact than others?

## Evaluate

- Now that you have learned how a message can be delayed, degraded, or delivered, your team will develop a protocol that will allow you to overcome the various scenarios that were encountered in the 3D Game. The protocol must ensure that both the DSN station and the spacecraft can be confident the full message will be received.

- Guidelines for the protocol:
  - The full message must consist of a series of 3- to 5-word commands that allow the spacecraft to reach a destination.
  - The DSN station will create the full message. The rest of the team will not know the message ahead of time.
- You will be allowed time to test your protocol to see if the message was delivered.

**Share**

You will present your protocol. As you prepare your presentation, think about the following discussion questions or prompts:

- Did your protocol work to ensure the message was delivered and not degraded?
- Why do you believe your protocol worked or did not work?
- If you could revise your protocol, what new revisions would you make?
- Compare and contrast your protocol to the DTN protocol. The DTN protocol can be found here: https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking

# Delayed, Degraded, Delivered

This sheet is for use with the 3D Game.

Directions: After you receive your message from the Deep Space Network (DSN) station, roll your dice or number cubes and find the sum. Use the table below to see if your message is delayed, degraded, or delivered.

| Number rolled | Scenario | Action for index card |
|---|---|---|
| 2 | Delivered – Error detection has been completed, so there is no interference with the message. | **No change; deliver to next relay station** |
| 3 | Degraded – Transmission encounters ionized gas, which impairs the link between the spacecraft and the DSN station. | **Cross out the second word; deliver to next relay station** |
| 4 | Delayed – There is no direct line of view for the spacecraft to use the available antenna at the time of message delivery. | **Delay message for 60 seconds; after 60 seconds deliver to next relay station** |
| 5 | Delivered – Coding techniques successfully prevent interference with message. | **No change in the message; deliver to next relay station** |
| 6 | Degraded – Signal-to-noise ratio (signal power versus background noise) is low, so bit errors are excessive. | **Cross out every other word; deliver to next relay station** |
| 7 | Delivered – This relay station utilizes NASA's optical terminal (like the one that will be on Artemis II), which can send in 4K (resolution of approximately 4,000 pixels). | **No change; deliver to next relay station** |
| 8 | Delayed – A solar flare interferes with radio communications and causes a message delay. | **Delay message for 30 seconds; after 30 seconds deliver to next relay station** |
| 9 | Delivered – The single antenna is unable to capture the message, so an array is used to combine two or more antennas. | **No change; deliver to next relay station** |
| 10 | Degraded – The signal is degraded by background radio noise emitted naturally by objects in the universe. | **Tear out a word in the message; deliver to next relay station** |
| 11 | Degraded – There is a period of intense space weather (density of particles increased) disrupting radio frequencies. | **Cross out a part of the first, third, and fifth words; deliver to next relay station** |
| 12 | Degraded – The technology cooling the amplifiers is not working properly, which means additional noise is being added to the message. | **Add two additional words to the end of the message; deliver to the next relay station** |