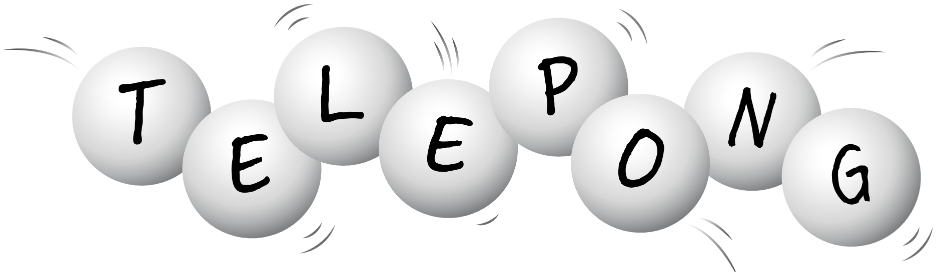
National Aeronautics and Space Administration



PART 2:

Communications Challenge: Save Critical NASA Mission Data

This kinetic activity illustrates the challenges of sending large volumes of data across the solar system. NASA's Space Communications and Navigation program needs a lot of special technology and testing to get data from space back to Earth. Students will learn more about transmitters and receivers, satellite networks or space relays, and the various challenges and benefits of laser communications in this collaborative exercise.

Refer to Telepong Part 1 and Telepong Part 3 for complete activity instructions.

GRADES:
5+

DURATION:
25-45 minutes

PREP TIME:
20 minutes

MATERIALS

- Lettered ping pong or other small balls, prepared as described in Telepong Part 1
- Assembled Receiver[1]
- Plastic egg cartons, cleaned and sterilized
- Paper and age-appropriate writing implements
- Measuring tape or yardstick
- Masking tape

OPTIONAL MATERIALS

- 26-30 sorting containers
- Tennis racket, paddle, etc. Can be made from cardboard.

ADDITIONAL RESOURCES

- Space Communications: 7 Things You Need to Know
- New Ground Station Brings Laser Communications Closer to Reality

Objective

Students investigate the delicate and challenging nature of space communications by composing messages with lettered balls and throwing them to an 'antenna' receiver. As students become more comfortable with the basics of data transmission, greater distances, participants, and obstacles will demonstrate the physical realities of sending information across the vast distances of space.

NGS Standards

Performance Expectations
MS-PS4-1, *-ETS1

Science and Engineering Practices

- Planning and Carrying Out Investigations
- Constructing Explanations and Designing Solution

Disciplinary Core Ideas

- Information Technologies and Instrumentation
- Defining and Delimiting Engineering Problems
- Developing Possible Solutions
- Optimizing the Design Solution

Cross-Cutting Concepts

- Patterns
- Cause and Effect: Mechanism and Prediction
- Structure and Function

[1] Instructions for students to design their own can be found in the first document. Teachers interested in skipping the first document may prefer this quick-start guide for making a simple receiver.

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VOCABULARY

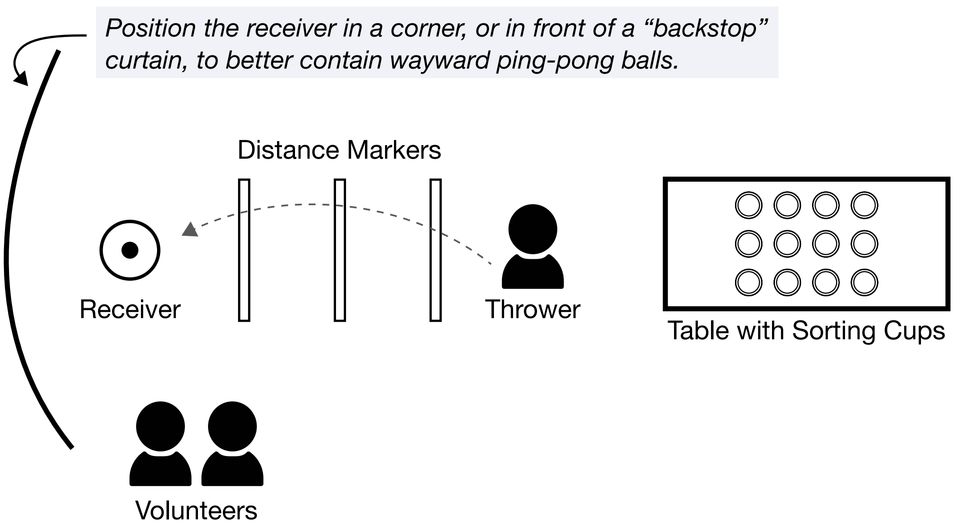
Antenna: a device which changes "free-space" electromagnetic energy (energy moving through the atmosphere or the vacuum of space) into electrical signals in a wire, or vice-versa
Data: facts or information
Electromagnetic Interference: external 'noise' which conflicts with the electromagnetic (see below) signal we are interested in receiving
Electromagnetic Spectrum: all the different colors and energies of light and radiation, even the ones humans cannot see
Ground Station: a facility on Earth designed to receive signals from space
Receive: to take in or 'catch' information
Satellite: anything that orbits a planet/moon. Can be artificial or natural (moons, comets)
Spacecraft: anything made by humans that leaves Earth's atmosphere and goes into space
Telescope: a device that gathers light and enable us to see things over larger distances; in space communications, telescopes can be used to receive or send information with laser light
Transmit: to send or 'throw' information

Teacher Preparation

1. Experiment with your setup before introducing it to students.
   - Ensure that the setup is physically stable.
   - Evaluate the difficulty of the activity. Ideally, learners should be able to 'receive' 50-75% (*but hopefully not 100%*) of balls thrown.
   - Choose a range of throwing distances according to the abilities of your students and mark lines on the floor with masking tape.

2. Assign volunteers to retrieve and re-sort any escaping ping pong balls.

3. Set out the sorted containers of alphabet balls.



Top-down diagram of setup.

Exploration

Student Activity

1. Introduce your students to ground stations, space relays, and laser communications with our two-minute Laser Communications Relay Demonstration (LCRD) Overview.

   a. **Discuss**: Can your students share examples in their lives when they had difficulty getting messages from one place to another? In their examples, challenge them to identify the specific factor(s) inhibiting their communication. For example:

Scenario	Challenge
Shouting across the house	Air is a poor conductor of sound
Using a cell phone in a remote area	Distant cell towers result in intermittent signal

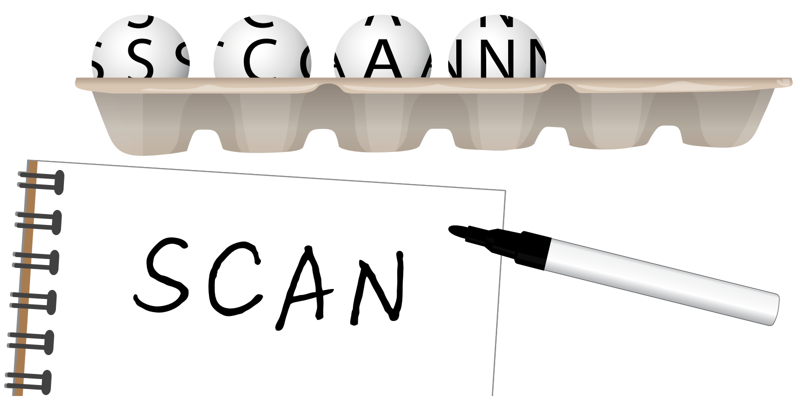
b. **Explain:** NASA's many science assets must send their information back to Earth for the data to be useful. Once launched, most space instruments will never be touched by human hands again.

c. **Challenge:** Ask students to think about ways in which errors can be obvious or sneaky. For example, a random-noise-generated 'X' in the middle of 'WATERMXELON' might be easily identified as anomalous, but missing a 'C' and 'F' from 'SPACECRAFT' would turn it into the radically different 'SPACERAT.'

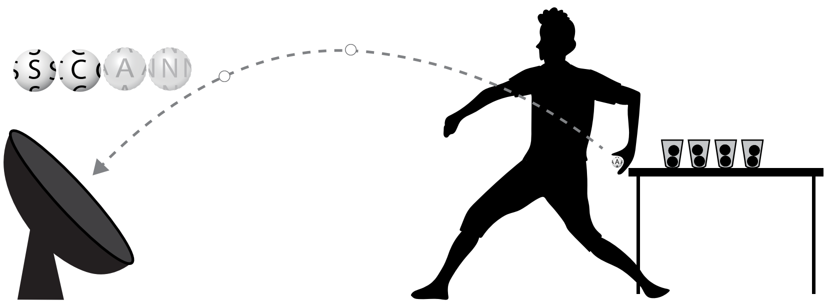
2. Students are now ready to experience their own space communications challenge! State the goal of this exercise. In this activity, students assume the role of a satellite's communications system by composing simple messages (via ping pong balls) and transmitting them to the ground station antenna or receiver (the cup/bowl/funnel). Teachers may prefer to tell students to use underhand rather than overhand throws, or allow them to discover the best technique on their own. Students will:

   a. Data composition phase: Compose a four- to eight-character message on paper. These should be kept brief to allow all learners an equal chance to play.

   b. Data encoding phase: One at a time, assemble their message with letter balls using the holder.



   c. Transmission phase: Toss the message into the receiver. Received balls should be stored in the tube in the sequence in which they were thrown.



Suggestion: Students have differing success with throwing challenges. You may consider implementing a rule where missed balls that roll towards the learner have "bounced off the ionosphere in a helpful way" and allow a re-try, while balls that roll away are "permanently lost" and returned to the pool of letters.

d. Message decoding phase: Slowly pour the balls into a holder once the data has been completely transmitted (all of their balls are thrown). **Be sure to preserve the sequence!**

e. If your learners find the transmission process too straightforward, increase the challenge by adding **interference.** Use a racket/paddle (labeled “INTERFERENCE”) to intentionally swat some balls out of the air or drop randomly-selected balls into the receiver in the middle of a transmission. How can your students ensure message integrity?
For example, a student ‘data checker’ can monitor and log interference. This log can then be incorporated into the message decoding phase. NASA uses slightly more complex techniques to deal with interference; students interested in computer science can explore “Correcting Bad Data Using Parity Bits”, and similar methods.

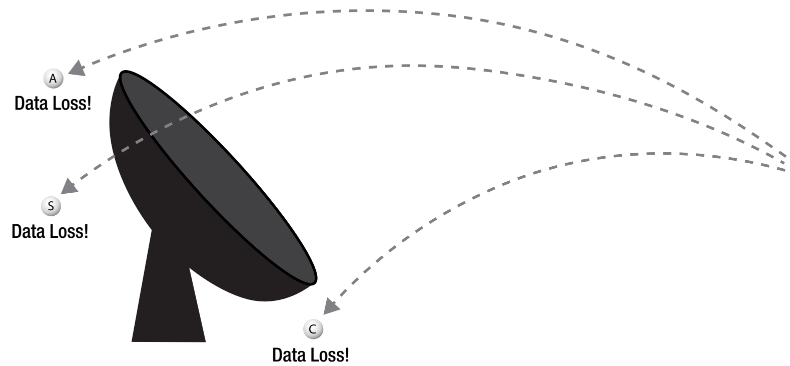
f. See **Expansion** below for additional ways to extend and differentiate this activity.

3. Ask your students about their messages. Are the messages still understandable? How did the ‘missing data’ change the message’s meaning? Ask them to identify what impacts their ability to receive the message accurately. When balls miss the mark, discuss the disruptive effects or transmitter calibrations that can cause real space data to be lost. Data might:

   a. Bounce off the ocean or get absorbed by nearby dirt & grass

   b. Take a different path to the transmitter and get garbled along the way

   c. Miss our planet completely



Evaluation and Assessment

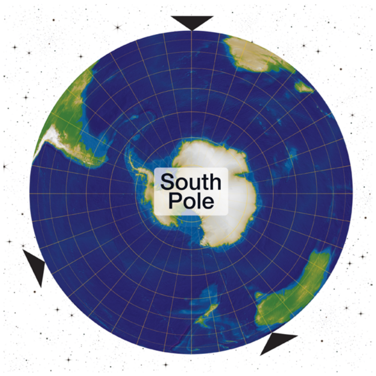
1. Quiz students on the core vocabulary; have them explain or illustrate the terms in their own words or pictures.

2. Ask users why they think it’s important to have satellites helping with communications.

3. What data might they want to send from space back to Earth? Why?

4. NASA's **Near Space Network,** which provides service for most spacecraft within 2,000,000 km of Earth, has ground stations and receivers dotted all over the globe. In contrast, NASA's **Deep Space Network** primarily uses ground stations at three locations: Madrid in Spain, Canberra in Australia, and Goldstone in the United States (California). Have your students look up these three locations on a globe or Google Earth. **Why do they think NASA selected those three sites?**

Suggestion: If learners are struggling to see the reason for picking those DSN sites, mark the three sites and then view the globe from one of the poles as shown here:



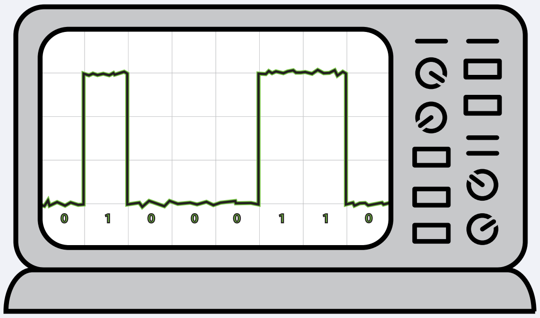
Those three sites are approximately 120° of longitude apart. This divides up the sky evenly and ensures that a Deep Space Network antenna will always be able to see (and, therefore, communicate with) satellites in deep space.

Our Digital World

Computers communicate with pulses of electricity (through copper wires) or light (through fiber optic cables). In this exercise, each ball represents a series of pulses comprising the letter written on it. In the real world, there are several ways to 'encode' a letter as a series of pulses.

Let's consider the capital letter 'F'. Using an encoding scheme called "ASCII", 'F' is represented either as the decimal number '070' or the binary number '01000110' (which is also '70', just in a different number base).

Electrical engineers monitoring cables carrying the signal for 'F' might see this represented as a series of 'high' (or 'on') and 'low' (or 'off') values:



If all this is required for just one letter, imagine how many 0's and 1's we need for high-resolution images of distant planets!

Expansion

Continue your exploration of space communications and the NASA design process by building on this activity! Further learning possibilities include:

1. Handling Interference: The universe is noisy. NASA puts a lot of effort into preserving the integrity of messages, protecting them from getting garbled or drowned out by other sources.

   a. Ask the learners to think of some other examples of noise interfering with communications: email spam, loud neighbors, microwaves disrupting wireless speakers, etc.

   b. Tune a radio to a frequency between two stations; the hiss you hear is the 'noise' of other electromagnetic interference (EMI):

- some EMI comes from the cosmic wash echoing from the Big Bang.
- some of it is generated by electronics around you.
- some is from our own sun.

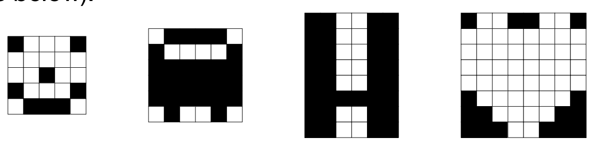
c. Tune the radio so two stations can be faintly heard over one frequency to show how two signals might "talk over" each other, overlapping.

2. **You Can Tell By The Pixels:** To broaden students' concepts of transmissible data as more than just letters and numbers, build and transmit a simple image:

a. Divide learners into two teams.

b. Both teams: Agree on a transmission protocol. Will the information be "encoded" left-to-right and then top-to-bottom? Another way?

c. Transmitting team: Design a simple pixel-based image on grid paper. (Examples below).

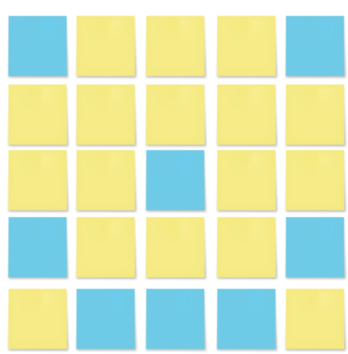


Face 5x5 | Car 6x6 | Exclamation 6x8 | Heart 8x8

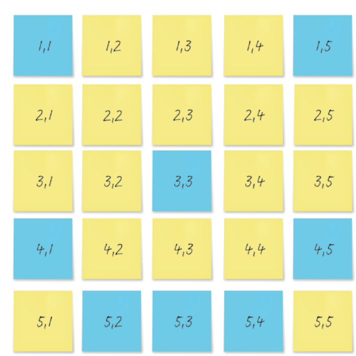
d. Transmitting team: Lay out sticky notes, colored index cards, or simple dark and light squares of paper to make the image. Prevent the receiver team from seeing the image. Consider taking a picture before transmitting.

e. Transmitting team: Crumple the papers up and transmit them in sequence, according to their agreed-on protocol.

f. Receiving team: Unfold the balls, then decode and reassemble the image. How do lost balls affect the image? Compare the image received with the one transmitted. How did the process change the image?



A simple 5x5 image, prior to being crumpled and transmitted.



The same image with an 'addressing' scheme; learners may find that giving each pixel a row-column "address" is critical to detecting missing pixels.

Suggestion: If you have a larger group, consider making two receivers and splitting learners into teams for a relay race. The activity can also be extended for larger groups with intermediate 'receivers' (pots/bowls/buckets) staffed by a 'repeater' learner who retrieves any balls from their receiver and throws it to the next receiver.

Explanation

As you reflect on this activity with your students, we offer the following “core takeaways” that informed our design:

- A satellite or rover experiment is worth far, far less if its data doesn’t get home.
- Data that misses the receiver is lost; this can scramble messages or ruin them entirely.
- Creating and managing an entire Internet on Earth is challenging; creating and sustaining a space-based Internet is immensely challenging.
- Accurate navigation, positioning, and timing is essential to maintaining solid communications

Crunching the Numbers

Fun Space Communications Facts

- Between 15 and 48 Terabytes – that’s between 120 and 384 TRILLION 0’s and 1’s – flow through NASA’s communication networks **every day**. Imagine what 380 trillion ping-pong balls[2] would look like!
- NASA ground stations range from small antennas that provide backup communications to the space station to a massive, 230-foot antenna that can communicate with far-off missions like the Voyager spacecraft (over 12 billion miles away).
- Communications don’t occur instantaneously. Just as there is a delay between releasing the ping pong ball from your hand and catching it in the receiver, the data NASA transmits and receives is also on a delay. They’re bound by a universal speed limit: the speed of light, about 186,000 miles per second. For spacecraft close to Earth, this time delay — or communications latency — is almost negligible. However, farther from Earth, latency can become a challenge. Depending on their orbit, astronauts on Mars would need to wait between four and 24 minutes for their messages to reach mission control, and another four to 24 minutes to receive a response. Thankfully, your ping pong ball data has a much closer destination!

FOR MORE SCAN ACTIVITIES, VISIT:

- Exploration and Space Communications Activities
- NASA Kahoot! Quizzes

Have feedback for us about any of these resources? Reach us at gsfc-scan-engagement@mail.nasa.gov. We especially love receiving pictures of your results in action!

[2] Learners may enjoy sketching or calculating how much volume this many balls, each 1.5” in diameter, might occupy.