A Lesson From CAP's AEX Middle School Earth & Science Book: Moon and Mars Rover Relay

Lesson Reference: This lesson is modified from NASA's Robots and Rovers: Rover Relay lesson located in the guide at www.nasa.gov/pdf/200173main_Lunar_Nautics_Guide.pdf.

Objectives:

- Students will simulate sending a signal/message from Earth to a lunar or Martian rover.
- Students will experience and understand time delays for sending a signal from Earth to Mars and from Earth to the Moon.
- Students will identify and define vocabulary associated the Moon and Mars.

National Science Standards:

- Earth and Space Science
  - Earth in the solar system
- Science and Technology
  - Abilities of technological design
- History and Nature of Science
  - Science as a human endeavor

Background Information:

Earth's nearby celestial neighbors, the Moon and Mars, have sparked human curiosity, imagination, and dreams of exploration for centuries. It was not until 1959 that two countries, the United States and the Soviet Union (Russia) had developed the technology to successfully send unmanned objects about 240,000 miles away to the Moon, and it became a race to see which rival country would be the first to land a man on the Moon.

On February 3, 1966, the Soviet Union's *Luna* 9 spacecraft became the first spacecraft to successfully land on the Moon. It was a rough landing, but it landed well enough for its camera to transmit the pictures directly from the Moon's surface to Earth. In December 1968, the crew of *Apollo* 8 became the first humans to orbit the Moon. (The first living specimens to go around the Moon - without going into orbit, similar to an *Apollo* 13 path - and return safely to Earth were turtles, wine flies, plants, and bacteria, among others, as part of the Soviet Union's *Zond* 5 mission in September 1968.) The historic moment of landing man on the Moon, however, occurred on July 20, 1969, by the United States. Neil Armstrong, the commander of the *Apollo* 11 mission, became the first human to walk on the Moon, followed by his fellow astronaut Edwin "Buzz" Aldrin, Jr. To date, the United States is the only country that landed men on the Moon, a total of 12 to be exact, with Eugene Cernan being the last to leave as part of the *Apollo* 17 mission in December 1972.

Source: http://spaceplace.nasa.gov/review/solar-system-scramble/images/moon2.jpg

While lunar missions subsided in the 1980s, they resumed in the 1990s. Not only did the United States and Russia continue lunar missions, but Japan (achieving a lunar flyby, orbit, and impact in the early 1990s along with another orbital mission in the late 2000s), Europe (launching an orbiter in 2003), China (launching a lunar orbiter in 2007 and 2010), and India (launching a lunar orbiter in 2008) have become active participants in lunar exploration.

Although the Soviets have not (to date) achieved manned lunar landings, they have other "first accomplishments" regarding lunar visits. *Luna* 16 was the first unmanned, robotic mission ever to return a sample, which consisted of more than 100 grams of lunar soil. Additionally, the Soviets landed the world's first unmanned rover, *Lunokhod* 1, on the Moon on November 17, 1970. As a NASA site explains, "The rover's operators had to contend with a 5-second delay between sending a command to the rover and seeing the results of the command, due to the round-trip travel time of radio signals at the speed of light."

Sojourner with rock, Yogi
Source: http://nssdc.gsfc.nasa.gov/planetary/image/marspath_yogi_rov.jpg

Along with exploration of the Moon, space scientists were and still are eager to learn more about one of our closer planet neighbors: Mars. The first rover to land on Mars was *Sojourner* in 1997, sent by the United States. (Read more about Martian exploration in Lesson 13: Payload Packaging.) Although the Soviet rover operators had to contend with a delay between sending signals to and receiving signals from a lunar rover, U.S. rover operators contend with an even longer delay between sending information to and receiving information from rovers on Mars, a one-way delay of 3-22 minutes!

The relay game in this lesson attempts to let the students experience the difficulty involved in communicating commands to a rover, waiting for the rover to perform the commands, and receiving confirmation. Additionally, this game allows students to learn or reinforce learning about the Moon and Mars.

Materials:

- Moon Team Cards
- Mars Team Cards
- Teacher: Card Information (one copy to use as a reference when discussing the connection between the word printed on each card and either the Moon or Mars)
- Laundry basket (or table or taped floor area) (one for each team)
- Two envelopes labeled Message (one envelope per team)
- Clipboard with a paper list of the words on the team's cards (one for each team that lists only the words on the cards pertaining to the specific team)
- Pen for each team
- Designated starting boundary for each team (such as a cone, chair, piece of tape, etc.)
- Timer (or watch with a second hand)
- (optional) Computer with Internet and projection system

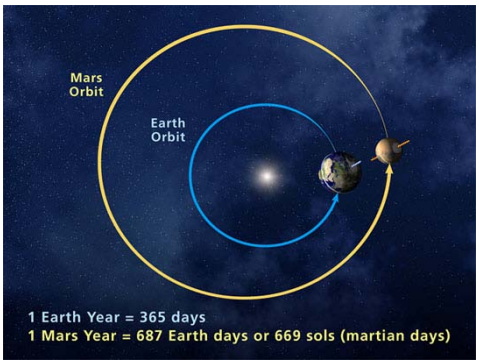
Advance Lesson Preparation:
Make a copy of the Moon Team Cards and the Mars Team Cards for each team and cut the cards out, resulting in 14 individual cards for each team. Consider using cardstock and/or laminating the cards for durability and easy re-use. Consider pre-determining team members for each of the two teams.

Lesson Presentation:

1. Engage the students by telling them that you want to try an experiment. Tell them that you would like to time the class to see how long it takes to send a message to the class, but only by relaying the message to one student at a time – like the old "telephone" game.

   Ensure the students are seated in rows or in a line. Think of a word or short phrase and whisper it in the ear of the student in the front row of the far side of the room (or in the front of a line). Instruct him/her to whisper the same word/phrase to the student behind him/her, and that process will continue until the message reaches the last student. Time the class to see how long it takes to complete the task. Hopefully, the message that reached the last person was correct.

2. Regardless of whether or not the message was correct when it reached the last student, explain to the class that they have essentially simulated how a message gets sent from Earth to the Moon or Mars. A signal is sent through space. The distance the Moon or Mars is from Earth as these objects orbit the Sun affects the amount of time it takes for a signal to get there.

   Source: http://mars.jpl.nasa.gov/images/mep/allaboutmars/EarthMarsOrbitTop.jpg

   Explain the following to students: The speed of light travels about 186,000 miles (300,000 km) per second. The Moon is about 240,000 miles (384,000 km) away; therefore, the delay of a one-way radio signal from the Earth to the Moon is about 1.28 seconds.

   The distance that the information has to travel is a factor in how long it takes for the communication to arrive at its destination. The distance a message must travel to get from the Earth to Mars is about 35,000,000 miles! That difference makes for longer time lapses on Mars reception than Moon reception. One-way radio transit between Mars and Earth can range from about 3 – 22 minutes, depending on where the planets are in relation to one another in their orbits around the Sun. To put this in prospective, that means that if you sent a message to a Mars rover and were waiting for it to respond, you would have to wait about 6 – 44 minutes from the time you sent your message to the time you received a confirmation message from the rover.

3. Explain to the students that they will be participating in a relay race and working with their team to collect cards related to either the Moon or Mars. The way the relay game is played will allow them to simulate a time delay between information sent from mission control on Earth to a rover robot on the Moon or Mars and then receiving signals from the rovers. Although transmitting information to a rover on Mars would certainly take more time than sending a message to a rover on the Moon, that specific detail will not be simulated in this game. The idea is to experience communication with a time delay and get an idea of how mission control and rovers communicate with one another. Tell the students that this game is also a fun way to help them learn or remember information about the Moon and Mars.
4. (optional) Tell the students that prior to playing the game, they will watch two short videos about the Moon and Mars.

   Moon:

   If you have a subscription to BrainPOP®, play their five-minute video about the Moon located at http://www.brainpop.com/science/space/moon/.

   Mars:

   http://www.neok12.com/php/watch.php?v=zX737f47445c5a5c0778526b&t=Solar-System (7.5 minutes)
5. Review the Moon Team Cards and the Mars Team Cards with the class. Discuss how the word printed on each card relates to the Moon or Mars. (Use the Teacher: Card Information page.)
6. Place each team's individual cards in a laundry basket (or other) with the print facing up and arranged so that all of the cards can be viewed. Place each team's basket an equal distance across the room from each team's starting point.
7. Designate a starting point for each team and one honest, responsible person to be the "communication officer" (referee) for each team (The teacher and a teacher assistant may wish to be the communication officers.) The communication officer is responsible for ensuring that he/she knows the correct message being sent from mission control and confirms that the rover returns the appropriate message. The communication officer will have a pen and a clipboard with a piece of paper that lists all of the words on the team's cards.
8. Divide the students evenly into two teams with one being named the Mars Team and the other the Moon Team. Have each team form a line behind the established starting boundary. State that the last student in the line represents mission control (where a team on Earth directs a space mission) and the first person in line represents a rover. Students between these two individuals represent the time delay caused by the long distances between the Earth and the Moon and Mars. Tell the students that if they were actually representing distances between Earth and the Moon and Mars in this game, there would be many more students on the Mars

Team because Mars is much farther away from Earth than the Moon. For this activity, however, the distances are not to scale.

9. Provide an overview of the game: Explain that the teams will whisper a word from a card from mission control to the rover (like playing telephone). Once the rover receives the word, he/she will race to the area where the team's cards are located and retrieve the card with that word on it. The first team to retrieve all their cards wins.

10. Provide the details of the game:
    - The mission control representative (last person in line) will identify a card for the robot rover to retrieve. In order to make sure there is evidence of which card the mission control representative has selected, he/she will circle the word on a piece of paper that a communication officer for each team will have. At that point, the communication officer is the only other person who knows the word about to be whispered up the line to the rover.
    - The mission control representative will then hand an empty envelope labeled Message to the person in front of him/her (or immediately next to him/her if students are forming a line standing shoulder to shoulder) and *whisper* the word in his/her ear.
    - That person passes the envelope and whispers the word to the person in front of/next to him/her, and the process continues until the envelope and message reaches the rover at the front of the line.
    - The rover runs (or walks quickly or crawls, as preferred by the teacher) and selects the card that displayed the word that was whispered to him/her and returns to the front of the line.
    - The rover places the card (message) in the envelope, and the students then pass it back one-by-one until the envelope reaches mission control.
    - The mission control representative then opens the envelope and looks at the card, along with the communication officer, to confirm that the robot obtained the correct message. In the event the robot did not obtain the correct card, the communication officer will return the card to the basket while the mission control representative starts the process again with the original word he/she whispered.
    - If the robot's returned message (card) is correct, then:
        - The communication officer keeps the card.
        - The mission control representative gives the empty envelope to the person directly in front of/beside him/her and then moves to the front of the line to become the next rover.
        - All of the other team members move back one space (toward mission control).
        - The process then begins again with the new mission control representative and rover.

11. Ask the students if they have any questions. If there are no questions, give the first mission control representative an empty envelope. Then, give the signal for the teams to begin. After the first team collects all of their cards (or the teacher-designated amount needed to win), the game is over.
12. Once the game is over, assemble the students together for a class discussion using the discussion question provided in the Summarization section.

Summarization:

Discuss the following:

- What are the similarities and differences of your relay game compared to that of real scientists communicating with rovers?
- What are things that scientists and engineers need to consider in order to best communicate with a rover on the Moon or Mars?
- What difficulties/disadvantages does a time delay create?
- How might a time delay affect a manned mission to Mars in the future?

Evaluation:

- Teacher observation

Lesson Enrichment/Extension:

- Play the game using a variety of objects (such as a golf ball, tennis shoe, helmet, etc.).
- Play the game using student spelling words.
- Have the students write an essay about the Moon or Mars that uses words from the game.

Associated Websites:

- Radio Waves and Speed of Light (discusses signals to/from the Moon and Mars, also has chart showing one-way time delays from Earth to other planets, the Sun, and other stars using distances in December 2005) http://www.aerospaceweb.org/question/astronomy/q0254.shtml
- Distance from Earth to Mars (includes info about signal delays) http://www.universetoday.com/14824/distance-from-earth-to-mars/
- Lunar Exploration Timeline (listed dates are launch dates) http://nssdc.gsfc.nasa.gov/planetary/lunar/lunartimeline.html
- Mars Exploration Timeline (listed dates are launch dates) http://nssdc.gsfc.nasa.gov/planetary/chronology_mars.html

- Moon videos
  - http://www.neok12.com/php/watch.php?v=zX027042720e5d4875587877&t=Solar-System (5.5 min.)
- Mars videos
  http://www.brainpop.com/science/space/mars/
  http://www.neok12.com/php/watch.php?v=zX737f47445c5a5c0778526b&t=Solar-System (7.5 min.)
- Challenges on the way to Mars (article)
  http://www.esa.int/Our_Activities/Human_Spaceflight/Mars500_diary_challenges_on_the_way_to_Mars

Source: http://mars.jpl.nasa.gov/images/msl20110602_PIA14175.jpg

Moon Team Cards

Lunar	Crescent
Waxing	Waning
Quarter	One-sixth
Moon buggy	Craters
Basalt	1969
Regolith	Month
Russia	United States

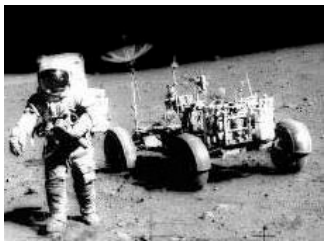
Mars Team Cards

Fourth	Red Planet
Spirit	Phoenix
Curiosity	Carbon Dioxide
Ice	Seasons
Canyons	Olympus Mons
Roman	Sojourner
Demos	One-third

TEACHER: CARD INFORMATION

Relevance of relay game cards to the Moon:

- Lunar – word that means of or relating to the Moon
- Month – the approximate amount of time it takes for the Moon to complete an orbit around Earth (about 27 days to orbit; 29 days to cycle through the phases of the Moon)
- Regolith - loose, fragmental material covering the lunar surface
- Craters – holes/indentions on the Moon's surface caused by meteoroid and/or asteroid strikes; These are preserved due to essentially no atmosphere and no active geological processes on the Moon. (There is no weather, wind, volcanic eruptions, erosion, etc.)
- 1/6 – gravity of the Moon compared to that of Earth's gravity (A person who weighed 120 pounds on Earth would weigh 20 pounds on the Moon.)
- 1969 – the year man first landed on the Moon; The first man to step foot on the Moon was Neil Armstrong on July 20, 1969. The last human to step foot on the Moon, to date, was Eugene Cernan in December 1972.)
- Waxing – moon is visibly getting larger
- Quarter – Half of the Moon is visible during the Quarter Moon phase.
- Crescent– The small sliver of the Moon visible during the month is called a Crescent Moon.
- Waning – moon is visibly getting smaller
- Moon buggy – vehicle (also called lunar rover) driven on the Moon by astronauts during the *Apollo* 15, 16, and 17 missions (The three lunar rovers are still on the Moon today.)
- Basalt – an igneous rock found on much of the Moon's surface
- Russia – Sent the world's first unmanned rover, *Lunokhod* 1, to the Moon. It landed in 1970 (when the country was still the Soviet Union).
- United States - To date, only this country has accomplished manned lunar landings.



Relevance of relay game cards to Mars:

- Fourth – Mars is the fourth planet from the sun.
- Red Planet – planet nickname due to the iron oxide (rust) on its surface
- *Spirit* – rover that launched from Earth in the summer of 2003 and landed on Mars in January 2004
- *Curiosity* – car-sized, 2,000-pound rover that landed in 2012
- *Phoenix* – Launched in 2007, the Phoenix lander (not a rover) landed in 2008. Its mission is to study the history of water and habitability potential of Mars.
- *Sojourner* – Launched Dec. 1996, this was the world's first successful rover to land and operate on Mars in 1997. It weighed about 23 pounds and was about the size of a microwave oven.
- Carbon Dioxide – gas that makes up most of the Martian atmosphere
- Seasons – Mars has 4 seasons.
- Ice – The polar ice caps are a surface feature of Mars. It has a north and south pole.
- Olympus Mons – largest volcano in our solar system; located on Mars
- Canyons – surface feature on Mars; Valles Marineris is largest canyon in solar system
- Roman – Mars is named for the Roman god of war, Ares.
- Demos – one of the two moons of Mars (The other moon's name is Phobos.)
- 1/3 – The gravity on Mars is about 1/3 that of the Earth's.

Moon Team: Communication Officer (for clipboard)

Moon buggy	Crescent	Waning	Waxing	One-sixth
Lunar	Quarter	Craters	Basalt	Month
Russia	1969	Regolith	United States	

Mars Team: Communication Officer (for clipboard)

Red Planet	Curiosity	Phoenix	Olympus Mons	One-third
Spirit	Seasons	Canyons	Roman	Demos
Fourth	Ice	Sojourner	Carbon Dioxide	