Lunar Reconnaissance Orbiter: (CRaTER)

Audience
Grades 6-8

Time Recommended
30-45 minutes

AAAS STANDARDS
- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

NSES STANDARDS
Content Standard A (5-8): Abilities necessary to do scientific inquiry:

c. Use appropriate tools to gather, analyze and interpret data.

d. Develop descriptions and explanations using evidence.

e. Think critically and logically to make relationships between evidence and explanations

Content Standard E (5-8): Science and Technology:

b. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

MATERIALS
- Pencil and paper
- Activity Worksheets (included)

CRaTER: How Cosmic Rays Affect Humans

Learning Objectives:
- Students will be able to describe why cosmic rays are dangerous to astronauts.
- Students will learn to design a scientific instrument.
- Students will think critically about how to protect astronauts from cosmic rays.

Preparation:
None

Background Information:
On their trips to and from the Moon, Apollo astronauts saw small white flashes of light while in the dark—even with their eyes closed. They usually saw no more than a couple each minute, although at least one astronaut saw so many he had trouble sleeping. What caused these flashes?

The answer is cosmic rays. Because of their high speeds, thousands of these cosmic rays were passing through the bodies of the Apollo astronauts every second. Most went straight through because atoms are mostly empty space. Some cosmic rays, however, hit atoms in the astronauts' bodies. The ones hitting atoms in the astronauts' eyeballs released a small amount of energy in the form of small flashes.

Procedure:
1. Ask the main question of the entire lesson: how might cosmic rays affect astronauts in space?

2. Do activity 1:

   Time: 15-20 minutes

   Materials: Pencil and paper

   Ask what experiment would you design to see whether cosmic rays hitting the eyeballs really do cause the flashes? Figure out what questions you need to answer. (Examples: are there cosmic rays in the spacecraft; do they go through the astronauts' eyeballs; do they go through their eyeballs when the astronauts see flashes? The experiment also requires timing of cosmic rays and timing of when the astronauts see flashes.) How does your design compare with what they actually did?

3. Discuss the following: To test whether cosmic rays were causing the flashes, scientists created the detector shown in **Figures 1, 2, and 3** (located in worksheets section; show them to students). It was the Apollo Light Flash Moving Emulsion Detector, or ALFMED. The emulsion was a gel-like chemical sensitive to cosmic rays. The astronauts would wear ALFMED over their heads for an hour and then time when they saw light flashes. The detector would keep track of when cosmic rays passed through itself and the astronauts' heads. It could also tell whether a cosmic ray had gone through the eye. On the ground, scientists found that when an astronaut saw a flash, a cosmic ray had passed through his eyeball!

   Background: more recently, the Italian Space Agency created a similar cosmic ray detector for the International Space Station (ISS); it is the Anomalous Long Term Effects in Astronauts' Central Nervous System, or ALTEA. It was on the ISS for much of 2006 and 2007. Figure 4 (see worksheets section) shows an astronaut performing an experiment with it. Although it looks similar to ALFMED, it is more complex. The helmet portion contains cosmic ray detectors that can tell whether a cosmic ray has passed through the brain. A device called an electroencephalograph (EEG) simultaneously measures the astronaut's brain activity. The results from this experiment will help determine how cosmic rays can affect the brain. The data are still being analyzed (for more information, see www.nasa.gov/mission_pages/station/research/experiments/ALTEA.html).

   Cosmic ray collisions in the body can be harmful because they can damage the DNA in cells. Remember, a single cosmic ray has a large amount of energy. If it collides with DNA, it will destroy part of that DNA strand. DNA contains instructions for the cell to function properly. When the DNA is damaged, the cell will malfunction. Usually the cell will then die, but sometimes it can reproduce itself. If that happens on a large enough scale, the person may develop cancer.

   Cosmic rays tend not to be a problem for a short mission. For example, the Apollo missions lasted no more than about a week. (A 2001 study, however, does indicate that even such a short mission increased the astronauts' likelihood of developing cataracts.) Long-term missions (at least six months) to the Moon, Mars, or deep space, however, will increase the radiation risk. Therefore we must understand how this particle radiation affects the body.

   We also need to learn how to best shield astronauts from cosmic rays. Unfortunately, shields require much mass to be effective. The more mass a shield has, the more likely it is for a cosmic ray to deposit energy in the shielding and not in the astronauts. Increasing the mass of a spacecraft, however, makes it more difficult and expensive to launch into space and to land. Current and future engineers have an important task ahead: to keep astronauts as safe as possible on such missions.

4. Do activity 2:

   Time: 10 minutes

   Materials: Pencil and paper

   Imagine that you are an astronaut setting up a base on the Moon. What are some of the ways to protect you and your fellow crew members from the effects of cosmic radiation? What might make a good shield?

   Possible ideas include creating an underground station or using a cave. Water is a good shield against cosmic rays, so students might decide to build a station near water ice. On the other hand, lead shielding is a dangerous idea (see the misconception section below). Trying a biological approach, such as repairing damaged DNA, is another possibility.

Note: Misconception

An important misconception is that lead can protect astronauts from cosmic rays. This is incorrect. Lead can actually be more dangerous than having no shielding at all! The reason is that when cosmic rays collide with the lead nuclei, they split the nuclei. These new nuclei are energetic enough to collide with and split even more nuclei. An astronaut on the other side of the lead shield will thus be bombarded by many more particles than just the original cosmic ray. Unless the shield is very thick, the radiation dose is higher with the lead shielding.

This is true of all materials, except hydrogen. Because hydrogen has only one proton in its nucleus, its nucleus cannot split into smaller parts. Therefore materials with a large amount of hydrogen in them, such as water and some plastics, make good shields.

worksheet

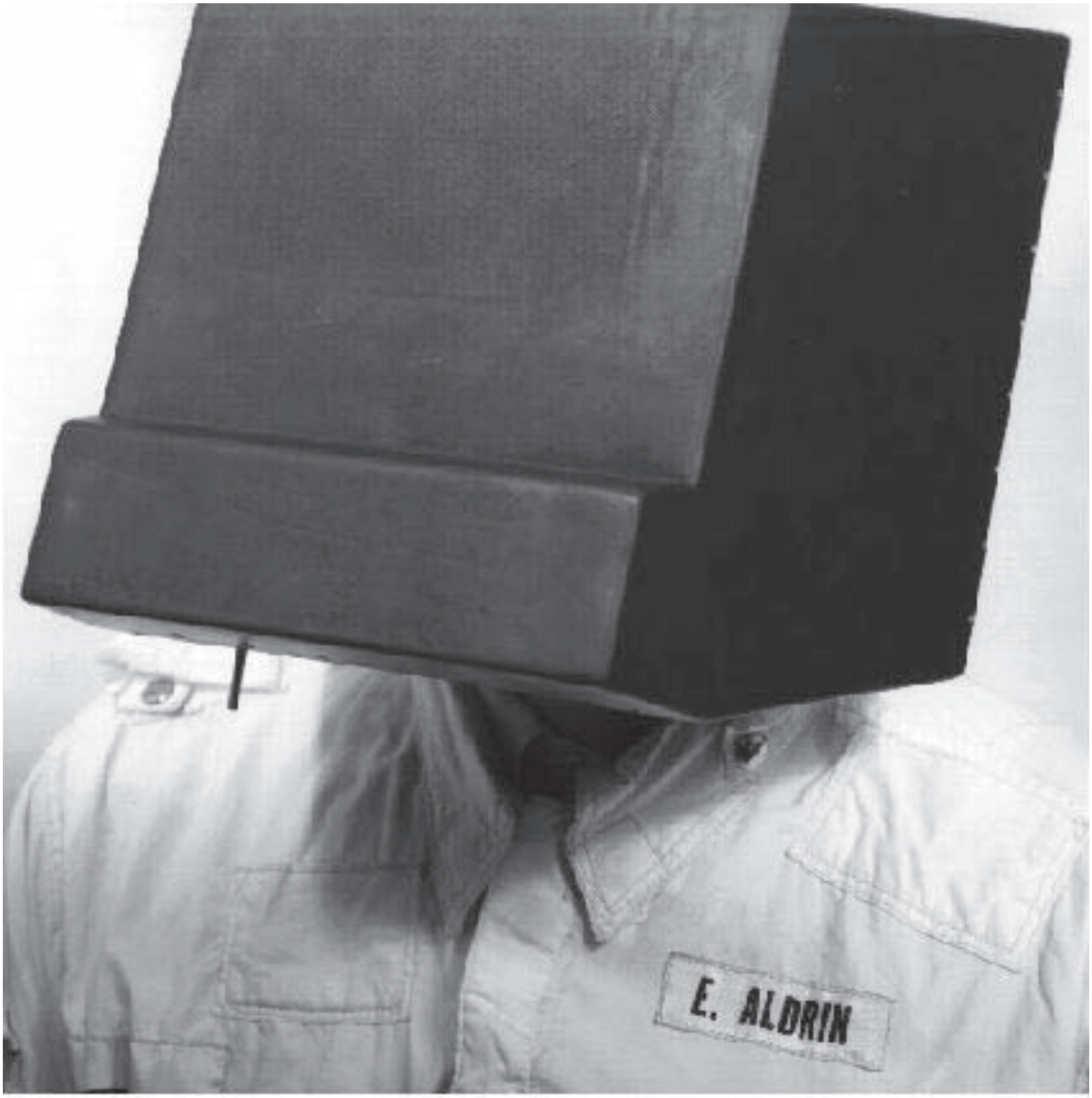

Figure 1. Apollo 11 astronaut Buzz Aldrin (the second man on the moon), sports an attractive cosmic ray detector called ALFMED (Apollo Light Flash Moving Emulsion Detector). This picture was taken on Earth. Other astronauts wore it in space.

worksheet

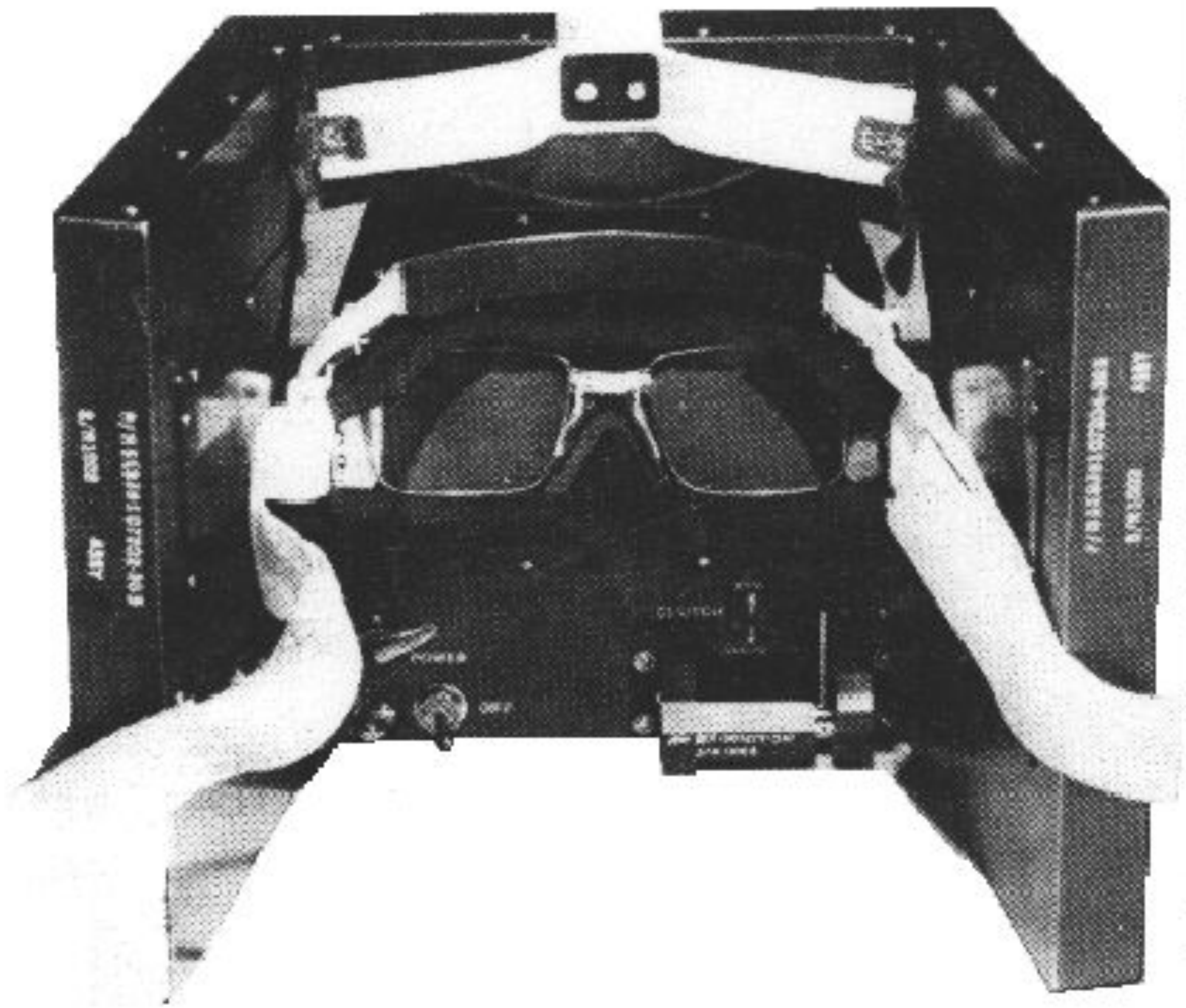

Figure 2. Apollo 17 astronaut Ron Evans (facing right) wears ALFMED. You can see the back of his head and part of his ear on the left, just above the main head strap.

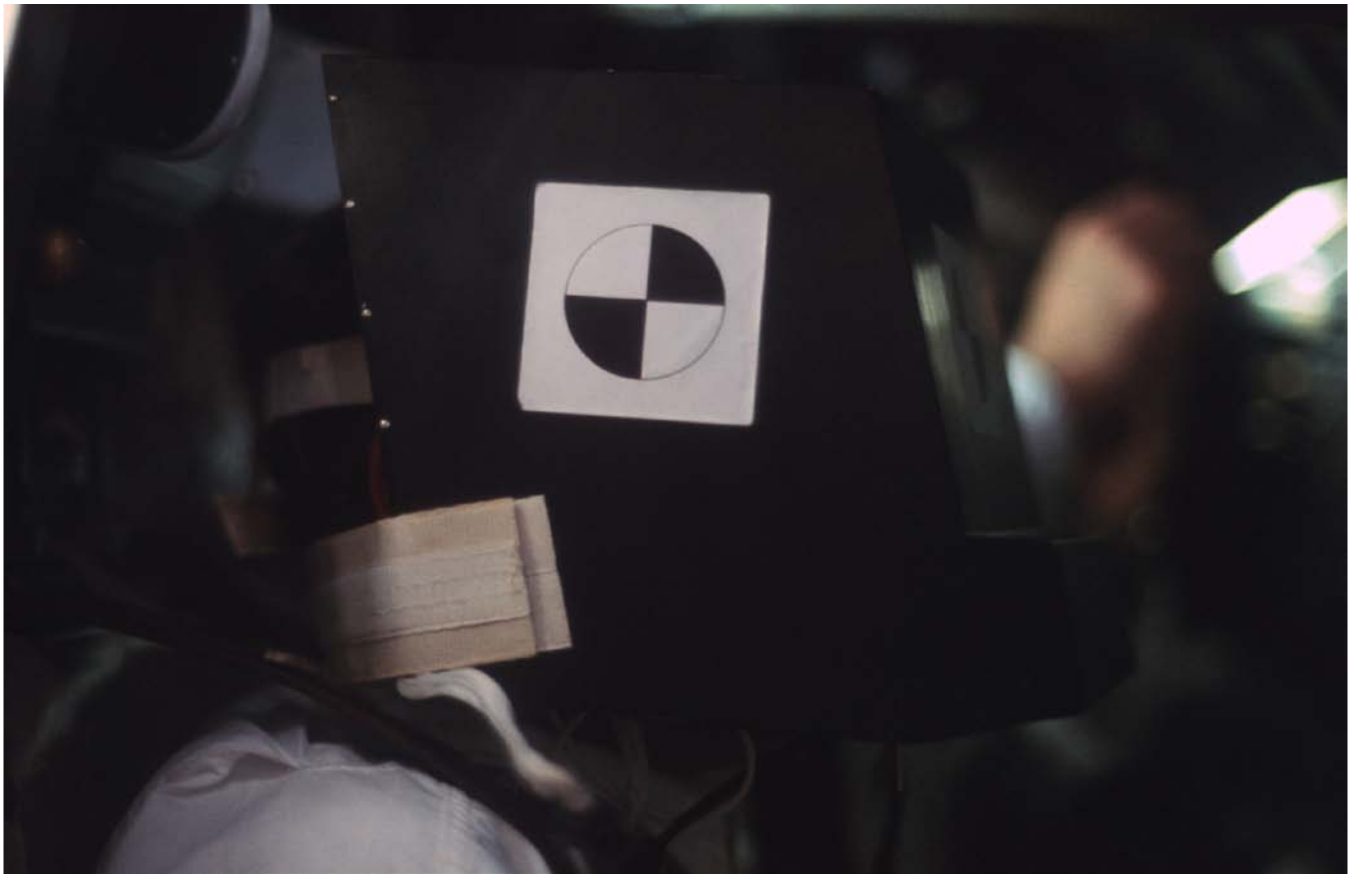

Figure 3. Apollo 17 astronaut Ron Evans (facing right) wears ALFMED. You can see the back of his head and part of his ear on the left, just above the main head strap.

worksheet

Figure 4. Expedition 13 ISS (International Space Station) Science Officer Jeff Williams shows off Italian cosmic ray detecting headgear. He stayed in the ALTEA helmet for 90 minutes.

Assessment:

Homework Assignment: Find a book at home or in the library that describes building a station in space, on the Moon, on Mars, etc. Does it describe how to protect the astronauts from cosmic rays? If so, what is the method? Is it a good idea? Why or why not? If the book does not talk about cosmic rays, do you think that the astronauts would be in danger in that station? Why or why not?

SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

Resources:

Information about CRaTER and LRO

LRO site:
lunar.gsfc.nasa.gov

CRaTER's website:
crater.unh.edu

A video in which the man responsible for CRaTER describes cosmic rays and the instrument:
www.nasa.gov/multimedia/nasatv/on_demand_video.html?param=http://anon.nasa-global.edgesuite.net/anon.nasa-global/ccvideos/GSFC_20090416_LRO_CRaTERvideo.asx

General information about cosmic rays

A Thin Cosmic Rain: Particles from Outer Space (previously published as Cosmic Rays), Cambridge, MA: Harvard, 2000.

Cosmicopia: An Abundance of Cosmic Rays (a NASA Goddard website about cosmic rays):
helios.gsfc.nasa.gov/cosmic.html

Cosmic ray comic book:
www.scostep.ucar.edu/comics/books, then click on the file labeled cosmicrays_e.pdf.

Air shower movies generated from the ARIES (Air shower Extended Simulations):
http://astro.uchicago.edu/cosmus/projects/aires

Space Radiation

Space Radiation Analysis Group at Johnson Space Center:
http://srag-nt.jsc.nasa.gov

Eugene N. Parker, "Shielding Space Travelers," *Scientific American,* March 2006.

M.G. Lord, "Are We Trapped On Earth?" *Discover,* June 2006.

Cosmic rays and cataracts:
http://science.nasa.gov/science-news/science-at-nasa/2004/22oct_cataracts

A NASA 6-12 educators guide to radiation math, with worksheets for students:
www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Radiation_Math.htm

Glossary:

ALFMED: Apollo Light Flash Moving Emulsion Detector, designed to detect whether cosmic rays create small flashes in astronauts' vision

ALTEA: Anomalous Long Term Effects in Astronauts' Central Nervous System; a device onboard the ISS to determine how cosmic rays affect the human brain

Atom: the smallest particle that still has the chemical qualities of an element; composed of a nucleus and electrons

Cosmic ray: an ion or electron in space that travels at a speed similar to that of light

CRaTER: Cosmic Ray Telescope for the Effects of Radiation; an instrument on the Lunar Reconnaissance Orbiter designed to study particle radiation near the moon

Electroencephalograph: an instrument that records the brain's electrical activity

Electromagnetic radiation: energy emitted in the form of electric and magnetic waves

Electron: a negatively charge subatomic particle; one of three particles to comprise atoms

Electroscope: a scientific tool used to store electric charge

Emulsion: a gel-like substance used to detect electromagnetic or particle radiation

ISS: International Space Station

LRO: Lunar Reconnaissance Orbiter; a spacecraft designed to study the moon's resources and radiation environment

NASA: National Aeronautics and Space Administration

Nucleus: the core of an atom, consisting of at least a proton (in hydrogen), or protons and neutrons

Particle radiation: energy emitted in the form of subatomic particles

Phosphor: a material that, when stimulated, emits electromagnetic radiation

Proton: a positively charged subatomic particle; one of two particles to comprise atomic nuclei

TEP: tissue-equivalent plastic, which has radiation-absorbing properties similar to human tissue

Radioactivity: the condition of a substance to emit ionizing particles or electromagnetic radiation