The Cosmic Ray Telescope for the Effects of Radiation Educational Kit

Introduction

The Lunar Reconnaissance Orbiter (LRO) is a spacecraft orbiting the moon. Its mission has three main goals: (1) identifying safe landing sites for future human missions to the moon, (2) discovering potential resources on the moon, and (3) characterizing the radiation environment of the moon. This third goal is vital to protecting future astronauts journeying into deep space.

LRO carries onboard seven scientific instruments. The primary one for analyzing the moon's radiation environment is the Cosmic Ray Telescope for the Effects of Radiation (CRaTER). With it scientists study both the radiation itself and how it might affect the human body.

This booklet contains the background information needed to introduce middle school students to the nature of cosmic rays and how they affect humans. It also describes how CRaTER works. Throughout the booklet are various activities that make the esoteric concepts—even to us scientists sometimes!—real to the students.

The core of this educator's guide comprises four lessons that vary in length. Each lesson has five parts. The first is background information for the teacher. The second is a set of questions for the students. The third contains activities related to the lesson. The fourth is a common misconception associated with the content. Finally, an assessment activity helps the students review what they have learned.

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Lesson 3: How cosmic rays affect humans

Objectives: Students will be able to describe why cosmic rays are dangerous to astronauts.

3A. Background material for the teacher

[Ask Question 1 here.]

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 (remember the Motivation for Students at the beginning of this booklet). 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 space (see Lesson 1). 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.

[Do Activity 1 here.]

To test whether cosmic rays were causing the flashes, scientists created the detector shown in Figures 3a, 3b, and 3c. It is 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!

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 3d 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, then 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. See references in the Resources section.) 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.

[Do Activity 2 here.]

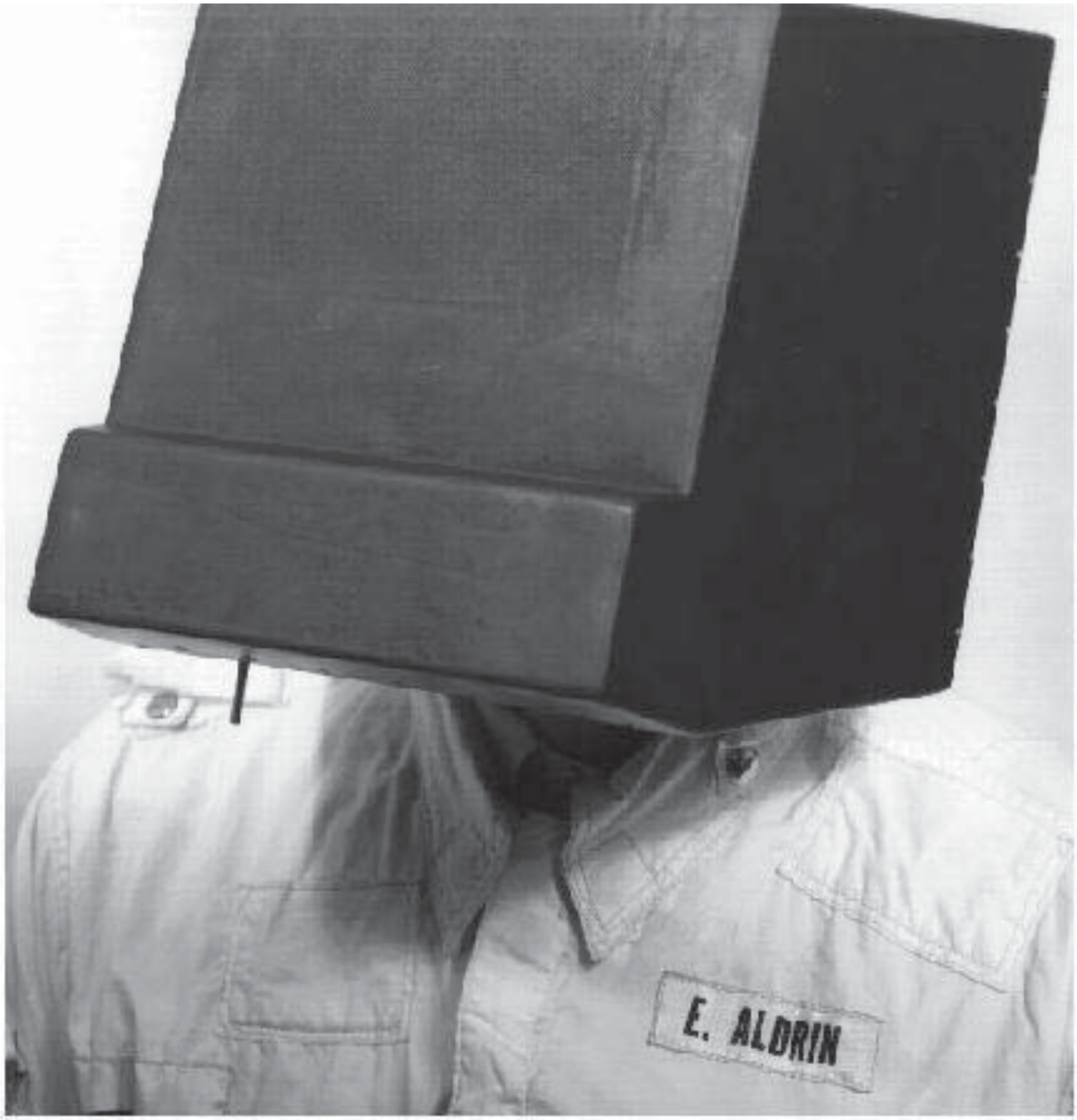

Figure 3a. Apollo 11 astronaut Buzz Aldrin (the second man on the moon), sports an attractive cosmic ray detector called ALFMED (Apollo Light Flash Moving Emulsion Detector). This picture was taken on Earth. Other astronauts wore it in space.

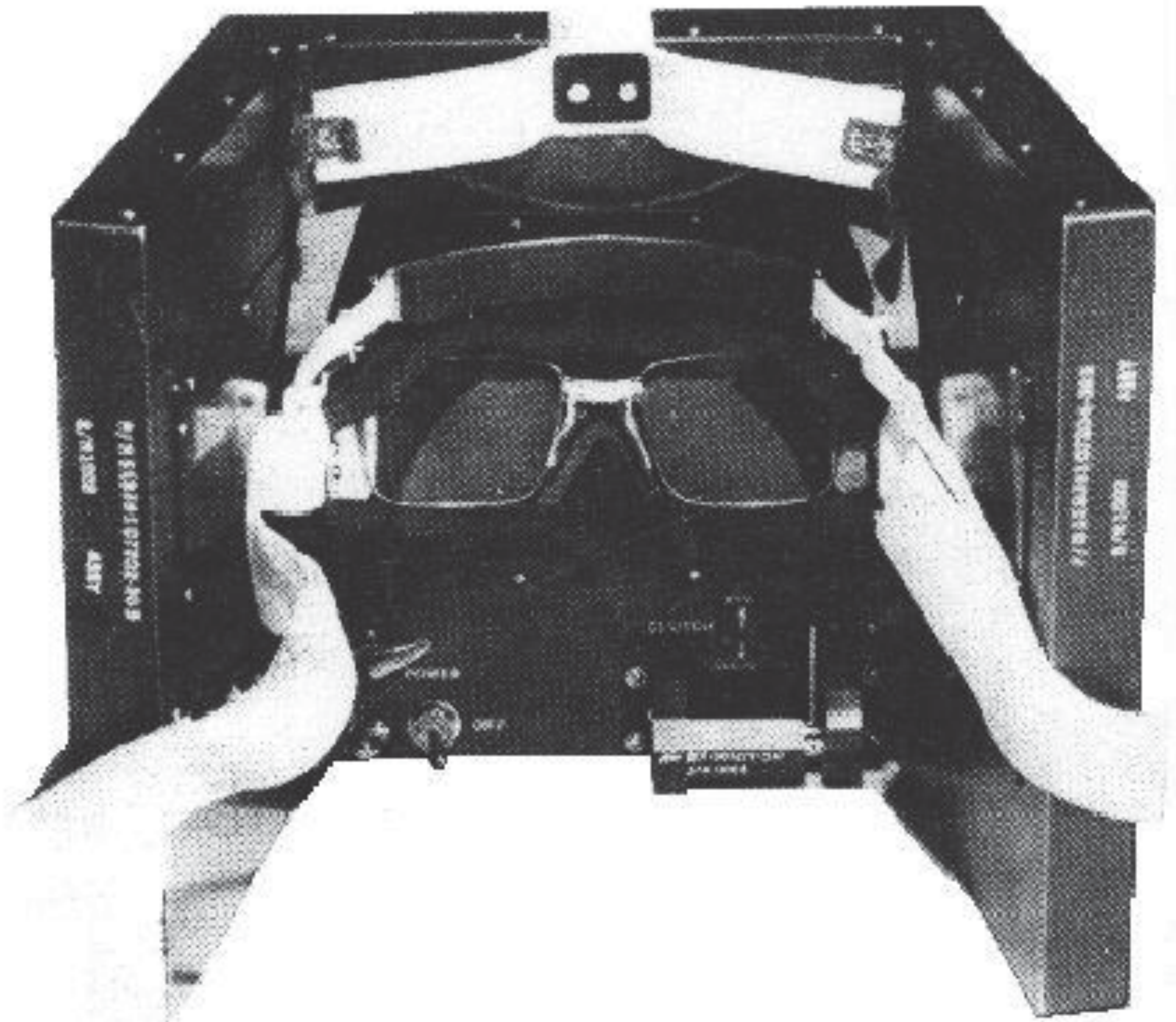

Figure 3b. This is the interior view of ALFMED. You can see the goggles to block out light (astronauts can only see the flashes in the dark) and the head strap.

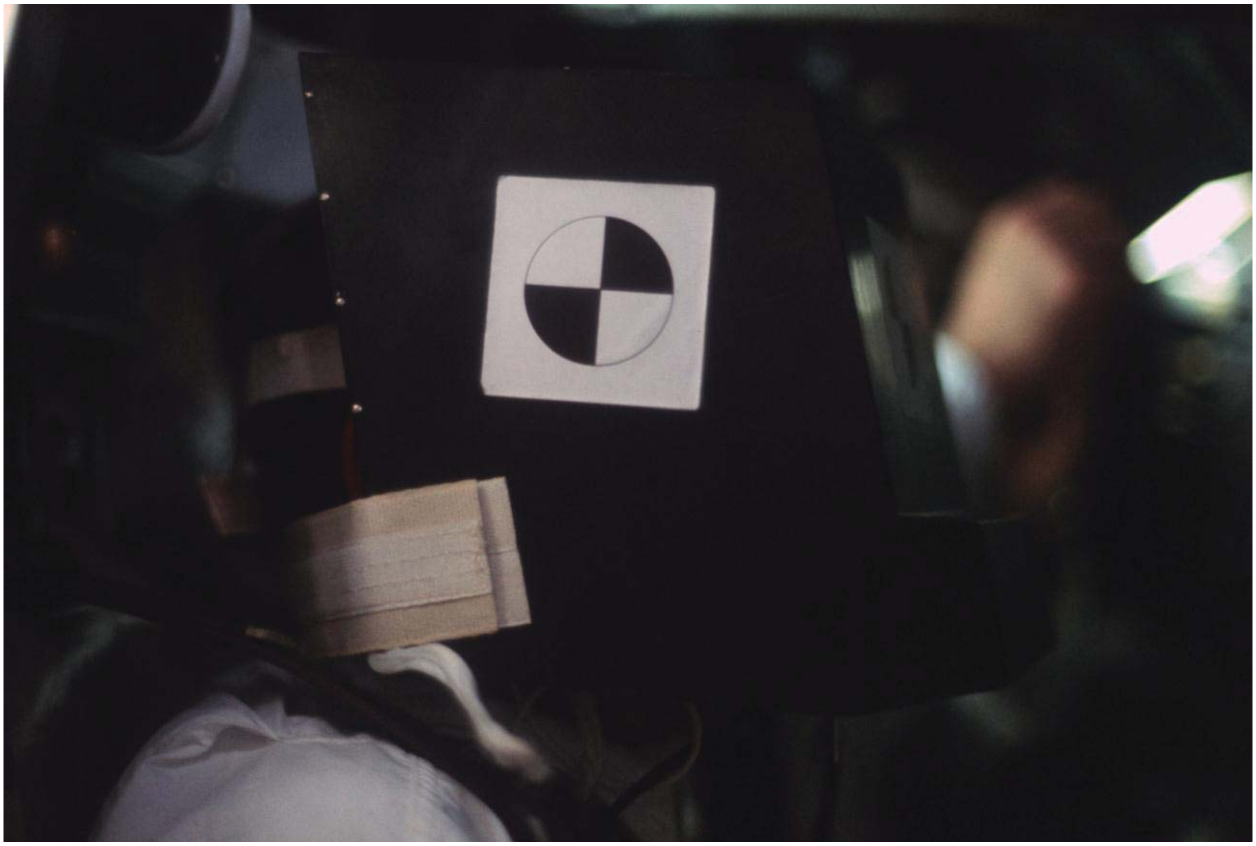

Figure 3c. Apollo 17 astronaut Ron Evans (facing right) wears ALFMED. You can see the back of his head and part of his ear on the left, just above the main head strap.

Figure 3d. 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.

3B. Questions

Question 1

How might cosmic rays affect astronauts in space? (This is a discussion question that the ensuing lesson will answer.)

3C. Activities

Activity 1: Match Wits with Scientists!
Time: 15 minutes
Objectives: Students will learn to design a scientific instrument.
Materials: Pencil and paper

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?

Activity 2
Time: At least 5 minutes
Objectives: Students will think critically about how to protect astronauts from cosmic rays.
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 in 3D). Trying a biological approach, such as repairing damaged DNA, is another possibility.

3D. 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.

3E. 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?