Space Radiation, Part 2: Learning from Experiments in Space

Developing a better understanding of the effects of space radiation on humans is an important focus of NASA-supported research. Knowledge gained from experiments conducted aboard the Space Shuttle has helped to improve radiation shielding on the International Space Station and is helping to produce more accurate estimates of the health risks astronauts face from space radiation.

The risks of exposure to space radiation—described in *Space Radiation, Part 1: Understanding the Problem*—are the most significant factor limiting humans' ability to participate in long-duration space missions.

Before scientists can develop countermeasures to adequately protect astronauts from the hazards of space radiation, they must first devise ways to quantify more precisely the risks that space radiation poses. Thus, the development of technology to more accurately measure the space radiation environment—especially those characteristics that are correlated with effects of space radiation on humans (i.e., radiation dosimetry)—has been a focus of NASA-supported research for many years. Developing the most effective radiation shielding materials has been another focus.

Currently, astronauts' exposure to radiation is reduced in two ways:

- Space activities can be carefully scheduled to coincide with periods of less intense space radiation. For example, space walks are timed to avoid passages through the South Atlantic Anomaly, a low-altitude portion of the Van Allen Radiation Belts (doughnut-shaped rings of charged particles that surround the Earth).
- Materials inside a spacecraft and in its structure can be used as shielding to reduce the intensity of radiation exposure. Shielding is particularly important in areas of the spacecraft where crew members spend a lot of time, such as the sleeping quarters, the galley, and the exercise area. However, it would be impractical for any spacecraft to carry the thickness of shielding necessary to block all incoming radiation.

Finding the Most Effective Shielding Materials

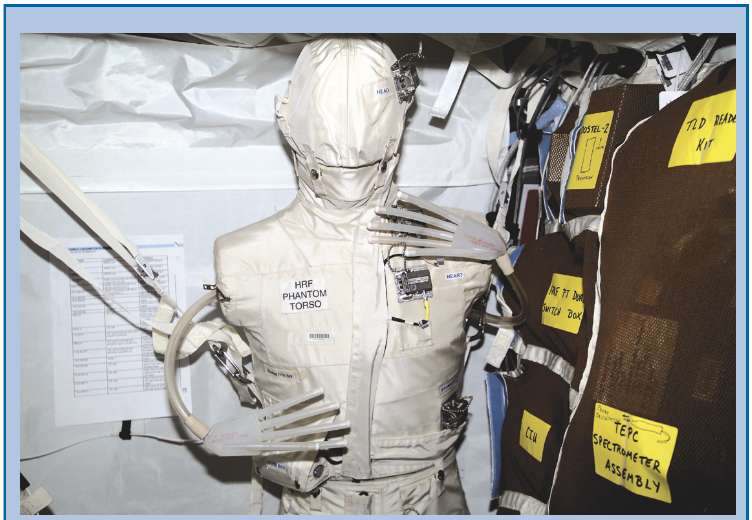
Aluminum, which is both lightweight and dense, is the most commonly used shielding material. However, research conducted at NASA's Langley Research Center and by NASA scientists at the Lawrence Berkeley National Laboratory in the late 1980s showed that materials that contain a lot of hydrogen provide the most effective shielding against radiation from HZE particles. One of the most practical materials is polyethylene—the stuff plastic grocery bags and kitchen cutting boards are made of. Chemically, polyethylene consists of a chain of carbon atoms, each of which is connected to two hydrogen atoms.

On the STS-81 and STS-89 missions, data were collected to compare the shielding properties of aluminum and polyethylene. This experiment used an instrument known as a tissue-equivalent proportional counter (TEPC), which is widely used on space shuttle missions and on the International Space Station to measure external radiation.

Temporary sleep station in the International Space Station, outfitted with polyethylene shielding and water to improve radiation shielding for astronauts. The thin flat panels are polyethylene shielding, while stowage water packaging is located above the sleep station.

The TEPC detector is a 2-inch by 2-inch cylindrical cell filled with low-pressure propane gas. At low pressure, the quantity of gas in the TEPC is similar to the amount of material in the nucleus of a human cell. A plastic jacket covering the cylinder simulates the properties of adjacent tissue. Atomic particles that pass through the gas release electrons, which are collected as pulses. The amount of energy (ionizing radiation) deposited in the gas can be calculated by analyzing the characteristics of these pulses. This measurement provides information about the effectiveness of radiation at the cell level, as well as a value for the radiation dosage.

This experiment showed that polyethylene was approximately 30 percent more effective than a comparable thickness of aluminum as an absorber of radiation from HZE particles. Beyond that point, however, the law of diminishing returns sets in: increasing the thickness of the shielding by another three inches provides only about half as much added protection as the first three inches, and so on.



The Phantom Torso, seen in the Destiny laboratory on the International Space Station. The torso is designed to measure radiation dose throughout the human body. It was delivered to ISS by the STS-100 crew in April 2001. (NASA photo ISS002-E-5952.)

Measuring Radiation Dose in Space with a Phantom Human Torso

Radiation is absorbed by the skin and organs of the human body, just like any other shielding material. To measure how radiation dose is distributed throughout the human body in detail, NASA-supported investigators flew a "phantom torso"—an anatomical model of a male head and torso—on STS-91. Similar to models used on Earth to train radiologists, the torso is equivalent in height and weight to an average adult male.

The torso is covered in a heat-resistant fiber "skin" that holds together the simulated bones, muscles, and other body tissues. The torso's interior is horizontally sliced into 34 sections, each about 1 inch thick. Each section is embedded with radiation detectors. Five custom-designed, battery-powered "active" detectors measured the radiation dose to the brain, thyroid gland, heart and lung area, stomach, and colon, transmitting data at 1-minute intervals.

In addition, "passive" detectors (which were read only after the torso returned to Earth) measured radiation exposure to body tissues including the stomach, liver, bone surfaces and bone marrow, and sexual organs. Two passive detectors placed on the torso's chest and abdomen measured the radiation dose to the skin. Radiation in the environment around the phantom torso was measured by a TEPC, which recorded the external radiation dose, and a spectrometer, which recorded the energy and direction of the radiation particles.

Among other findings, this experiment showed that the internal organs absorbed about 80 percent of the radiation dose absorbed by the skin. By contrast, when the human body is exposed to x-rays, the radiation dose is significantly weakened within a few millimeters of the skin and the dose absorbed by the organs is minimal.

"This is the first experimental confirmation of a relationship between skin doses and organ doses that is different in space," says Francis A. Cucinotta, Ph.D., manager of the Space Radiation Health Project at NASA's Johnson Space Center in Houston, Texas.

"This experiment has also provided a comprehensive set of data on the distribution of space radiation within a model of the human body," adds Cucinotta. "These data will help us to more accurately assess the risks astronauts face from space radiation."

References
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