Space Life Sciences Research Highlights

Space Radiation, Part 1: Understanding the Problem

The risks of exposure to space radiation are the most significant factor limiting humans' ability to participate in long-duration space missions. NASA-supported research focuses on improving our ability to quantify the risks of space radiation and on developing countermeasures to protect astronauts from those risks. Much of this research is conducted on the ground in facilities capable of simulating the space radiation environment.

The most critical risk to humans in space is radiation exposure. Space radiation is qualitatively different from the radiation humans encounter on Earth. It consists mainly of ionizing radiation in the form of charged atomic particles traveling at close to the speed of light. On Earth, the planet's magnetic field and thick atmosphere protect humans from this kind of ionizing radiation.

Highly charged, high-energy particles known as HZE particles pose the greatest risk to humans in space. Although not the most abundant form of ionizing radiation in space, HZE particles—because of their high energy and high charge—can do more damage to human tissue than other forms of space radiation.

The health risks from exposure to HZE particles are much less well defined than those posed by radiation exposure within Earth's atmosphere, says Francis A. Cucinotta, Ph.D., manager of the Space Radiation Health Project at NASA's Johnson Space Center in Houston, Texas.

"Radiation from HZE particles results in an entirely different pattern of damage to human cells and DNA than do x-rays and gamma rays, the most commonly encountered forms of radiation on Earth," says Cucinotta. "On Earth we know with a fair degree of certainty what the risk is from a given dose of radiation. For space radiation, however, we really don't know that."

Estimating Risk Is a Challenge

The potential "late effects" of radiation—effects that can show up many years after the exposure—are a major concern. Cancer is currently considered the most important of the known late effects. Some experimental data also suggest that exposure to HZE particles may cause damage to the central nervous system, although this risk remains poorly understood.

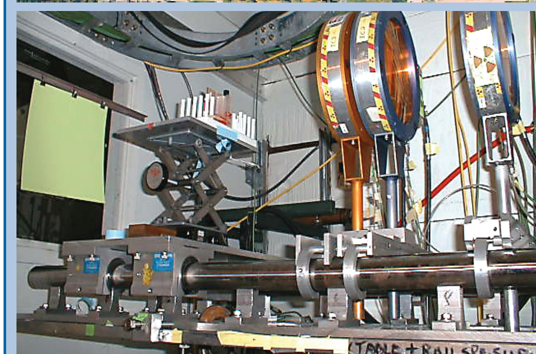
NASA currently bases its estimates of the risk of cancer from space radiation on the known rates of cancer in humans exposed to gamma rays on Earth. "But we estimate that the uncertainty in this method is about 500 percent—in other words, if we estimate that the risk of cancer is 1 percent, it might be as high as 5 percent or as low as 0.2 percent," explains Cucinotta.

Humans venturing into space are exposed to space radiation not only during extravehicular activity but also while living and working inside spacecraft. Space radiation must be better understood in order to safely conduct future long-duration space missions. (NASA photo STS-110-315-035.)

"On a 10-day space shuttle mission, the risk is so small that if I multiply it by 5 it's still small. On the other hand, for astronauts who might go on several missions to the International Space Station—or who might be involved in a future mission to Mars—if our estimates of cancer risk are wrong by a factor of 5, the risk to their health would be well above an acceptable level."

To further complicate the problem, some people face a higher risk from space radiation than others. "Younger people are more susceptible because they have more years of life left for radiation damage to develop," says Cucinotta. "Women are at greater risk because the breasts and ovaries are among the most radiation-sensitive human tissues and because their life expectancy is longer than men's."

Ground-Based Experiments Simulate Space Radiation



Left. Aerial view of Brookhaven National Laboratory where research on high energy radiation is being conducted. The Alternating Gradient Synchrotron (AGS) is in the lower middle part of the photograph.
Lower left. Hardware for AGS dosimetry for cell biology studies.
Lower right. Booster beam of the AGS.

Before scientists can develop countermeasures to adequately protect astronauts on future long-duration space missions from the hazards of space radiation, they must develop a much more detailed understanding of the effects of space radiation. It would be impractical as well as unacceptably risky to astronauts to conduct such research in space, says Walter Schimmerling, Ph.D., director of the Space Radiation Health Program at NASA Headquarters in Washington, DC. For this reason, much of this research is performed in ground-based laboratories capable of simulating the space radiation environment. Brookhaven National Laboratory in Long Island, New York is one of only three laboratories in the world that have this capability. This Department of Energy facility possesses several particle accelerators that accelerate beams of atomic nuclei to successively higher energies. NASA-supported researchers have used one of these particle accelerators, the Alternating Gradient Synchrotron (AGS), for the past 8 years to collect data on the effects of exposure to high-energy radiation beams on cells, tissues, and experimental animals.

Among the significant data acquired from these studies is the finding that high-energy particles cause patterns of DNA mutations that are different from those caused by common types of radiation, such as x-rays. This finding has led to the development of theoretical models of DNA structure that will be important to efforts to design drugs that can modify DNA damage, says Schimmerling.

Previous experimental studies produced a better understanding and accurate calculations of the behavior of high energy particle radiation when it penetrates radiation shielding materials. These results led to predictions that materials such as polyethylene—which are light and contain a lot of hydrogen—would be more effective shielding materials than an equal weight of commonly used metal, such as aluminum. This prediction has been successfully tested on the International Space Station, where polyethylene panels have been installed around the crew sleeping quarters to significantly reduce local radiation exposure.

The AGS can supply beams that cover only the upper one-third to one-half of the range of energies required to simulate space radiation. A new experimental facility at Brookhaven, the NASA Space Radiation Laboratory (NSRL)—funded by NASA, built to NASA's specifications, and scheduled to open in the summer of 2003—will enable NASA to conduct studies across the full range of particles and energy levels that are of significance for advancing understanding of the effects of space radiation exposure on humans, says Schimmerling.

"The NSRL will enable us to do experiments on many types of particles at different energy levels, reflecting the great variety of particles and energy levels that exist in space," he explains. "In addition, NASA will be the primary user of the new facility. We estimate that the rate of data gathering will increase by about a factor of 10."

References

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