NASA Facts

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Lyndon B. Johnson Space Center

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Understanding Space Radiation

Outside the protective cocoon of the Earth's atmosphere is a universe full of radiation – it is all around us.

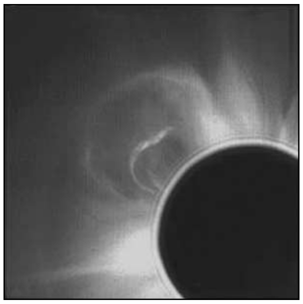
Space radiation is different from the kinds of radiation we experience here on Earth, such as x rays or gamma rays. Space radiation is comprised of atoms in which electrons have been stripped away as the atom accelerated in interstellar space to speeds approaching the speed of light – eventually, only the nucleus of the atom remains.

Space radiation also has very different effects on human DNA, cells and tissues. This is due largely to the increased ***ionization*** that takes place near the track a particle of space radiation takes through a material. ***Ionizing radiation*** has so much energy it can literally knock the electrons out of any atom it strikes – ***ionizing*** the atom. This effect can damage the atoms in human cells, leading to future health problems such as cataracts, cancer and damage to the central nervous system.

It is very difficult to predict the long-term effects of space radiation on the human body, especially on our astronauts, who may spend many months in space. Because of this uncertainty, NASA is funding research to determine how much radiation is in space and how much damage it may cause – research that will help us to understand the risks astronauts face when they spend long periods of time in space, as well as to develop methods to mitigate those risks.

What is Space Radiation?

Space radiation is made up of three kinds of radiation: particles trapped in the Earth's magnetic field; particles shot into space during solar flares (solar particle events); and galactic cosmic rays, which are high-energy protons and heavy ions from outside our solar system. All of these kinds of space radiation represent ionizing radiation.



Flares and Coronal Mass Ejections

When a solar flare or a coronal mass ejection occurs (the two often occur at the same time, but not always), large amounts of high-energy protons are released, often in the direction of the Earth. These high-energy protons can easily reach the Earth's poles and high-altitude orbits in less than 30 minutes. Because such events are very difficult to predict, there is often little time to prepare for their arrival.

Galactic Cosmic Rays

Galactic cosmic rays include heavy, high-energy ***ions*** of elements that have had all their electrons stripped away as they journeyed through the galaxy at nearly the speed of light. Cosmic rays, which can cause the ionization of atoms as they pass through matter, can pass practically unimpeded through a typical spacecraft or the skin of an astronaut. Galactic cosmic rays are the dominant source of radiation that must be dealt with aboard the International Space Station, as well as on future space missions within our solar system. Because these particles are affected by the Sun's magnetic field, their average intensity is highest during the period of minimum sunspots when the Sun's magnetic field is weakest and less able to deflect them. Also, because cosmic rays are difficult to shield against and occur on each space mission, they are often more hazardous than occasional solar particle events. They are, however, easier to predict than solar particle events.

What Are the Effects of Space Radiation?

The energy that ionizing radiation loses as it travels through a material or living tissue is absorbed by that material or living tissue. The ionization of water and other cell components can damage DNA molecules near the path the particle takes – a ***direct effect*** of which is breaks in DNA strands including clusters of breaks near one another; breaks that are not easily repaired by cells. Such DNA break clusters are much less frequent, or do not occur at all, when cells are exposed to the types of radiation found on Earth. Because it can disrupt an atom, space radiation also can produce more particles, including neutrons, when it strikes a spacecraft or an astronaut inside a spacecraft – this is called a ***secondary effect***.

Future research will develop the knowledge to understand how initial damage to DNA and cells from heavy ions relates to increased risks for cancer or other health effects, and how biological countermeasures to such risks can be developed.

How Much Space Radiation Do Astronauts Receive?

The amount of space radiation an astronaut may be exposed to while orbiting the Earth depends on a number of factors:

- **Orbital inclination** – the closer a spacecraft's orbit takes it to the Earth's poles (where the Earth's magnetic field concentrates ionizing particles), the higher the radiation levels will be.

- **Altitude above the Earth** – at higher altitudes the Earth's magnetic field is weaker, so there is less protection against ionizing particles, and spacecraft pass through the trapped radiation belts more often.
- **Solar cycle** – the Sun has an 11-year cycle, which culminates in a dramatic increase in the number and intensity of solar flares, especially during periods when there are numerous sunspots.
- **Individual's susceptibility** – researchers are still working to determine what makes one person more susceptible to the effects of space radiation than another person.

Measuring Radiation

The **absorbed dose of radiation** is the amount of energy deposited by radiation per unit mass of material. It is measured in units of rad (radiation absorbed dose) or in the international unit of Grays (1 Gray = 1 Gy = 1 Joule of energy per kilogram of material = 100 rad). The **mGy** (milliGray = 1/1000 Gray) is the unit usually used to measure how much radiation the body absorbs. However, because different types of radiation deposit energy in unique ways, an **equivalent biological dose** is used to estimate the effects of different types of radiation. Equivalent dose is measured in ***milliSieverts (mSv)***. The mSv, therefore, takes into account not only how much radiation a person receives, but how much damage that particular type of radiation can do – the greater the possibility of damage for the same dose of radiation, the higher the mSv value.

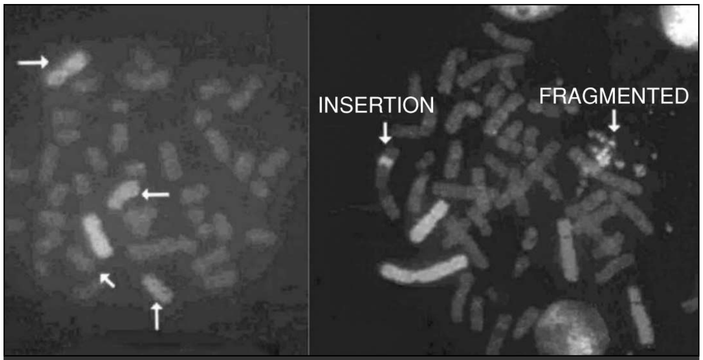
Crews aboard the space station receive an average of 80 mSv for a six-month stay at solar maximum (the time period with the maximum number of sunspots and a maximum solar magnetic field to deflect the particles) and an average of 160 mSv for a six-month stay at solar minimum (the period with the minimum number of sunspots and a minimum solar magnetic field). Although the type of radiation is different, one mSv of space radiation is approximately equivalent to receiving three chest x rays. On Earth, we receive an average of two mSv every year from background radiation alone.

Crew members could receive higher doses of space radiation during space walks while outside the protective confines of the space station; however, NASA plans space walks to avoid the trapped radiation belts around the Earth, and doses on previous space walks have been kept very small.

Protecting Current and Future Space Station Crews

To determine acceptable levels of risk for astronauts, NASA follows the standard radiation protection practices recommended by the U.S. National Academy of Sciences Space Science Board and the U.S. National Council on Radiation Protection and Measurements.

Aboard the space station, improving the amounts and types of shielding in the most frequently occupied locations, such as the sleeping quarters and the galley, has reduced the crew's exposure to space radiation. Materials that have high hydrogen contents, such as polyethylene, can reduce primary and secondary radiation to a greater extent than metals, such as aluminum.



Normal chromosome No. 2 and No. 4 in a postflight metaphase sample

Damaged chromosome No. 2 in a postflight metaphase sample

Space station crew members each wear physical dosimeters, and also undergo a biodosimtery evaluation measuring radiation damage to chromosomes in blood cells (see figure above).

Active monitoring of space radiation levels also can help reduce the levels of radiation an astronaut receives by helping the astronauts locate the best-shielded locations on the station. The monitoring also serves as a warning should radiation levels increase due to solar disturbances. Following a healthy diet and lifestyle, including the use of antioxidants following radiation exposure, should also reduce risks.

Radiation Measurements Aboard the International Space Station

Below, in alphabetical order, are the many radiation measurement devices and experiments that have flown to the International Space Station.

Bonner Ball Neutron Detector
March – December 2001
A Japanese Space Agency experiment that measured the amount of neutron radiation that entered the space station. Neutron radiation can affect the blood-forming marrow in bones.

Charged Particle Directional Spectrometers – CPDS
2001 – present
There are three units mounted outside on the station's S0 truss that are designed to record the direction from which radiation strikes. There is another unit inside the station.

Dosimetric Mapping – DOSMAP
March – August 2001
A German Space Agency/European Space Agency experiment that consisted of four different types of radiation detectors located throughout the space station, These measured the amounts and types of radiation that entered the ISS.

Study of Radiation Doses Experienced by Astronauts in EVA – EVARM
February 2002 – present
These sensors are being used to determine the levels of radiation space walkers receive in their skin, eyes and blood-forming organs. EVARM consists of three active dosimeters (placed on

the leg, torso and near the eye) that are read before and after a space walk. The EVARM data could be used to devise methods of reducing the amount of radiation astronauts are exposed to during space walks.

Passive Dosimetry

1999 – present

There are several types of radiation detectors aboard the space station. The radiation area monitor (RAM) is a small set of thermoluminescent detectors encased in Lexan plastic that respond to radiation – the amount of radiation they absorb can be revealed by applying heat and measuring the amount of visible light released. RAM units are scattered inside the space station and are returned to Earth for measurement after periodic space shuttle visits. The crew passive dosimeter is very similar to the RAM and is carried by each member of the crew. The AN/UDR-13 radiac Set (a high-rate dosimeter) is a compact, handheld or pocket-carried device capable of quickly measuring doses of gamma or neutron radiation. Data readout and warning messages are provided by a liquid crystal display on the set.

Phantom Torso

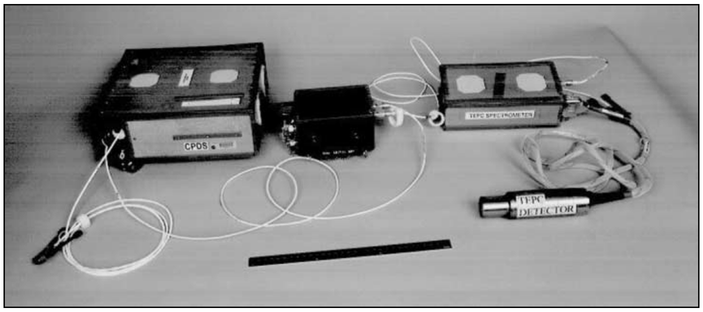
March – August 2001

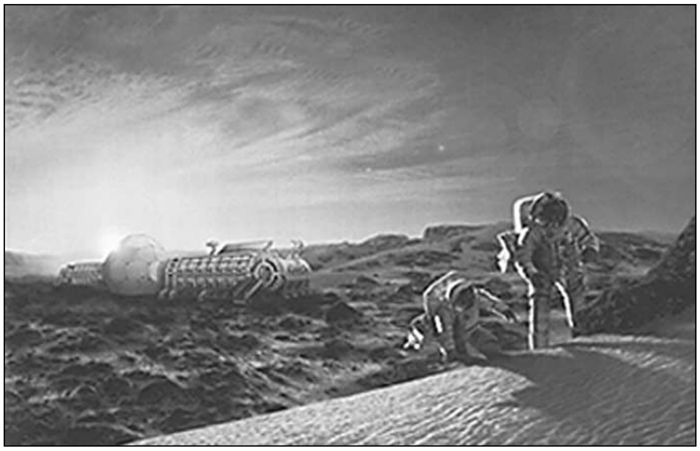
This unique experiment measured the effects of radiation on organs inside the human body by using a torso equivalent in height and weight to an average adult male. The torso contained radiation detectors that measured how much radiation the brain, thyroid, stomach, colon, and heart and lung area received on a daily basis. The data are still being analyzed to determine how the body reacts to and shields its internal organs from radiation, information that will be very important during longer-duration space flights.

Tissue Equivalent Proportional Counter – TEPC

2000 – present

This radiation detector consists of a 2″-diameter by 2″-long cylindrical cell that is filled with low-pressure propane gas. The gas is used to simulate the hydrocarbon content of a human cell that is two microns in diameter. A plastic jacket covering the cell simulates the properties of adjacent tissue cells. Particles passing through the gas release electrons, which are collected, helping to identify the energy of the particles.





Measuring Space Radiation Between the Earth and Mars

As the Mars Odyssey spacecraft made its way to Mars between April and October 2001, the Mars radiation environment experiment (MARIE) measured the amounts and kinds of space radiation the spacecraft encountered along the way. These data are essential to understanding how much and what kinds of radiation future space travelers might encounter on a long trip to explore the red planet.

Now in orbit around Mars, MARIE continues to measure the amount of harmful radiation at the planet itself. Unlike Earth, Mars does not have a global magnetic field to shield it from solar flares and cosmic rays. Mars' atmosphere is also less than one percent as thick as the Earth's. These two factors make Mars very vulnerable to space radiation.

Aboard the International Space Station and in our own solar system, NASA researchers continue to quantify the amounts of space radiation our explorers face every day and will face in the future. Understanding space radiation will not only protect the crew currently aboard the International Space Station, but those first humans who will continue the exploration of our solar system.

Related Web Sites

http://srhp.jsc.nasa.gov/

http://spaceresearch.nasa.gov/research_projects/radiation.html

http://www.spaceflight.nasa.gov/station/science/bioastronautics/

http://marie.jsc.nasa.gov/main.html