The Phantom Torso

An unusual space traveler named Fred is orbiting Earth aboard the International Space Station. His job? To keep astronauts safe from space radiation.

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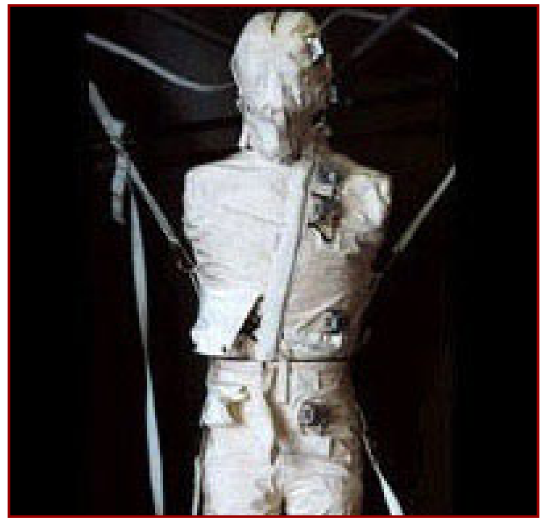
May 4, 2001 -- Fred has no arms. He has no legs. His job is keeping astronauts safe.



Fred is the Phantom Torso, an approximately 95-pound, 3 foot high mockup of a human upper body. Beneath Fred's artificial skin are real bones. Fred's organs -- the heart, brain, thyroid, colon and so on -- are made of a special plastic that matches as closely as possible the density of human tissue.

Right: The Phantom Torso, also known as "Fred," is an anatomical model of a human torso and head. Fred contains hundreds of radiation monitoring devices. [more information]

Fred, who's spending the next four months on board the International Space Station (ISS), will measure the amount of radiation to which astronauts are exposed. High-energy particles that pass through the human body can disrupt the way cells function. Although no astronaut has ever been diagnosed with space radiation sickness, excessive exposure could lead to health problems.

"We believe the current dose [of radiation to the crew of the ISS] is too small to be of concern," says Dr. Gautam Badhwar, the study's principal investigator at the Johnson Space Center. "The one possibility for radiation sickness might be an EVA situation during a solar event, if perhaps a crew member couldn't be brought back inside safely." But there's still lots to learn, he added, and that's where Fred can help.

The Phantom Torso is designed to do three things, explains Badhwar. First, it will determine the distribution of radiation doses inside the human body at various tissues and organs. Second, it will provide a way to correlate these doses to measurements made on the skin. "In the past we've typically recorded doses *only* on the skin," explains Badhwar, "whereas the risk to crew members is established by exposure to internal organs." Finally, the Phantom will help check the accuracy of models that predict how radiation moves through the body.

Three types of radiation can endanger astronauts in space.

The most energetic are Galactic Cosmic Rays (GCRs) -- the nuclei of atoms accelerated by supernova explosions outside our solar system. Cosmic ray nuclei can be as light as hydrogen, as heavy as iron, or almost anything in between. Because they lack their surrounding coat of negatively-charged electrons, GCRs are positively charged. The heavier nuclei carry the greatest charge, explains Badhwar. "As the charge increases, the amount of energy that the particle can deposit in tissue increases as well."

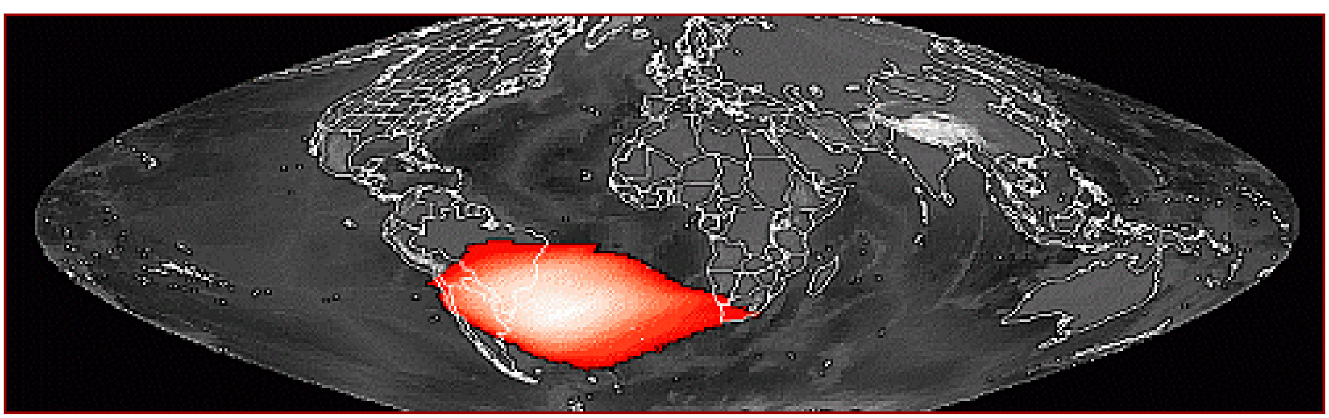
Left: Supernova explosions like this one accelerate atomic nuclei to nearly light speed. The resulting "cosmic rays" pose a potential hazard to astronauts. [more information]

The other forms of particulate radiation consist mostly of protons. Most high-energy protons in the solar system come from the Sun. Although their charge is not great and they are less energetic than GCRs, solar protons can still be dangerous when they come in intense bursts known as solar flares.

The third kind of radiation, which surrounds Earth in areas known as Van Allen belts, consist mostly of decayed products from galactic cosmic ray interactions that have been trapped by Earth's magnetic field.

Some of this trapped radiation is confined to a region above the coast of Brazil, known as the South Atlantic Anomaly. "The Space Station goes through that Anomaly roughly five times a day," says Badhwar. The passage takes, at most, 22 or 23 minutes. That's good, he says.

"If you go through the trapped radiation belt in less than twenty minutes or so, then for the next seventy minutes the body has time to do some repair to the damage done by the radiation." The radiation from solar flares can actually do more harm, he says, simply because it comes at a rate that doesn't give the body time to recover.

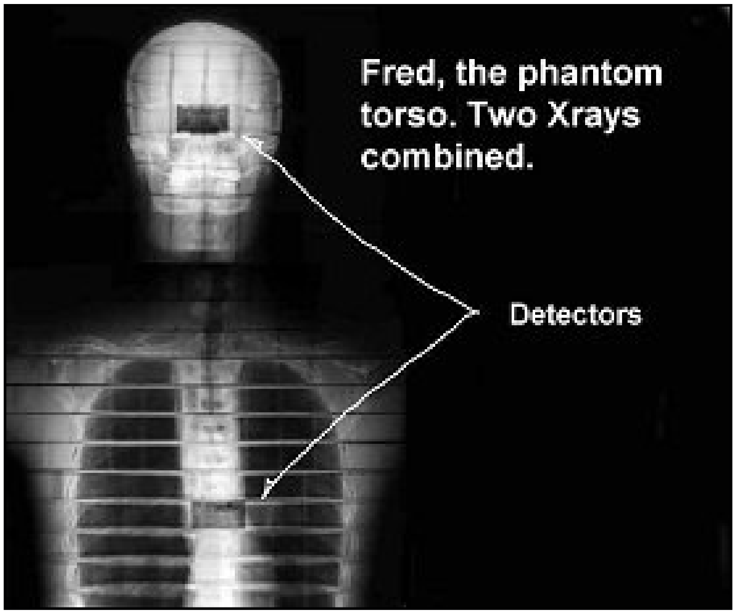


Above: The "South Atlantic Anomaly" is an area of trapped radiation located over the east coast of Brazil. [more information]

In order to measure space radiation as it propagates through Fred's body, Badhwar and his team have sliced Fred horizontally into 35 one-inch layers. In each section they've made holes for radiation detectors called dosimeters. The torso carries 416 lithium-crystal based passive dosimeters, which simply record the total radiation dose received throughout the mission. Fred is also equipped with 5 active detectors. These, placed at the Phantom's brain, thyroid, heart, colon, and stomach, can track the times that the radiation exposures took place.

"With the active detectors, we can correlate the time the radiation was received with the position of the spacecraft," explains Badhwar. "We can separate out quite reliably when we were in the Anomaly and when we were in the Galactic Cosmic Ray region." This kind of split makes radiation models derived from such data applicable to interplanetary missions, too. To assess astronaut exposure on a trip to Mars, for example, "we'll just switch off the Van Allen Belt particles," says Badhwar.

Radiation models devised by Badhwar and colleagues will be able to estimate how much radiation reaches an astronaut's internal organs simply by looking at the dose on his or her skin. That's important, because while the permissible radiation limits are based on internal exposures, practically speaking, all that can be measured is what occurs on the skin.



Right: The Phantom Torso consists of 35 sliced "sections" housed in a Nomex suit. [more information]

Such models are also scalable. Rather than giving a blanket risk assessment for all crew members, they can be customized to each individual in terms of height, weight, and even personal histories: how the astronaut flies an aircraft, or what medical tests he or she might have taken. All this contributes, says Badhwar, to total radiation exposure.

Even our internal bacteria rate a careful look: If a crew member gets too much radiation, it could kill the digestive bacteria essential for breaking down food.

Space station crew members will be sending data from the Phantom's five active dosimeters back to Earth about every ten days. When the device returns to Earth next fall, Badhwar and his team will be able to examine results from Fred's passive detectors as well.

"The thing that we're really going after is to get as good a handle as we can on what the organ exposures really are." he says. The goal is to make sure that the crew is exposed to the least amount of radiation possible.

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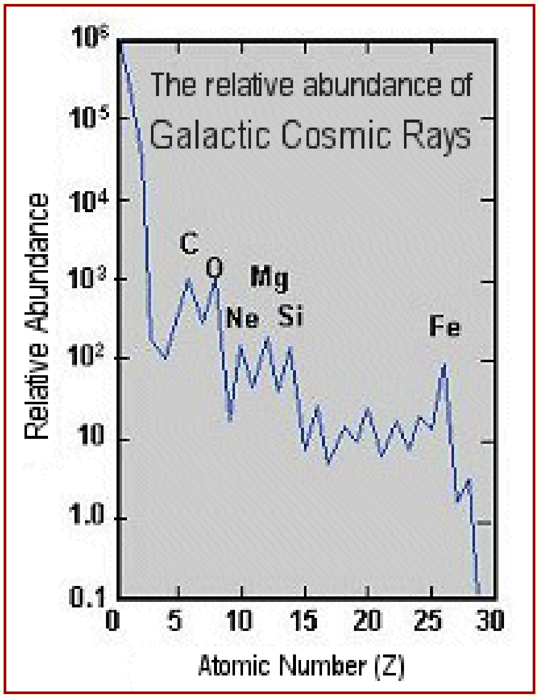

Space Radiation: Effects on Humans -- from the National Space Biomedical Research Institute

Ionizing Radiation in Space -- the basics, from the NASA/MSFC Space Environment & Effects Group

The Phantom Torso Fact Sheet -- from the NASA Marshall Space Flight Center newsroom

Galactic Cosmic Rays -- Galactic cosmic rays (GCRs) come from outside the solar system but generally from within our Milky Way galaxy. Find out more at this site from NASA/Goddard.

ISS Radiation Experiments -- Three radiation experiments are underway on the International Space Station.

Right: Galactic Cosmic Rays consist of many elements, but the lighter nuclei dominate. Heavier nuclei carry a greater charge and are more damaging to human tissue. [more information]

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African Dust Leads to Toxic Algae Blooms

Saharan dust clouds travel thousands of miles and fertilize the water off the West Florida coast with iron, which kicks off blooms of toxic algae, according to a new study. Storm activity in the Sahara Desert region generates clouds of dust that originate from fine particles in the arid topsoil. Easterly trade winds carry the dust across the Atlantic Ocean and into the Gulf of Mexico.Toxic algal blooms, sometimes called red tides, have in the past killed huge numbers of fish, shellfish, marine mammals, birds, and can cause skin and respiratory problems in humans. The research was partially funded by a NASA grant as part of ECOHAB: Florida (Ecology and Oceanography of Harmful Algal Blooms), a multi-disciplinary research project designed to study harmful algae. (Full Story)

(08/28/2001)

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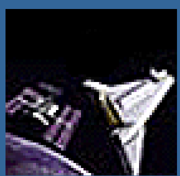

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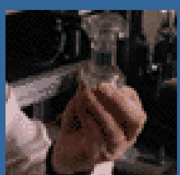

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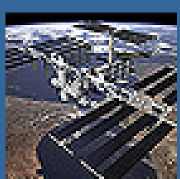

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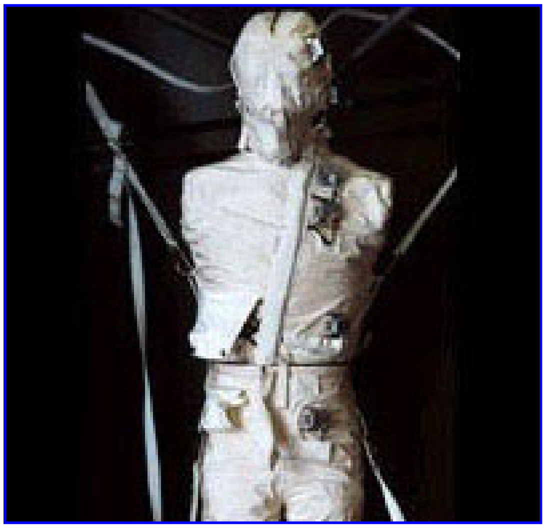
FS-2001-02-42-MSFC

Feb. 28, 2001

Phantom Torso



The Phantom Torso is a tissue-muscle plastic anatomical model of a torso and head. It contains over 350 radiation measuring devices to calculate the radiation that penetrates internal organs in space travel. The Phantom Torso is one of three radiation experiments in Expedition Two including the Bonner Ball Neutron Detector and Dosimetric Mapping. (NASA/JSC)

Missions: Expedition Two Mission 6A, STS-100 Space Shuttle Flight, return 7A.1, STS-105

Experiment Location on ISS: U.S. Laboratory

Principal Investigator: Dr. Gautam Badhwar, Johnson Space Center, Houston, Texas

Project Manager: Frank Gibbons, Lockheed-Martin

Overview

Traveling in space can be dangerous for human beings because of the large amounts of radiation, especially during times of extreme solar flare activity and eventual crewed missions to Mars or other planets. High doses of radiation can kill cells and damage tissue, leading to cancer, cataracts, and even cause injury to the central nervous system.

To learn more about how to protect astronauts from the effects of radiation, monitoring devices have flown on several Space Shuttle missions and the Russian space station Mir. The measurements yielded valuable information, but were limited to radiation doses on the external part of the body.

The Phantom Torso experiment is the first aboard Space Station to estimate the effects of radiation on organs inside the body, especially blood-forming organs. The Torso is a "phantom" because it is not human, but closely mimics human tissues and organs.

Experiment Operations

The Phantom Torso is similar to torsos used to train radiologists on Earth, and is equivalent in height and weight to an average adult male.

The Phantom is covered in a Nomex "skin" —a safe, non-flammable material. The skin holds together and covers an interior of complete bone structure and plastic tissue-muscle components. The interior is horizontally sliced into 34 sections 1-inch (2.3 centimeters) thick. Each slice is embedded with two kinds of detectors: passive detectors, which use no power and will be read after the torso returns to Earth; and active detectors that will measure real-time radiation doses on the brain, thyroid, heart and lung area, stomach and colon. Data collected from the active detectors is transmitted by the crew on board the International Space Station to scientists on Earth every 10 days.

Two passive detectors are mounted in the pocket of the Nomex for radiation dose measurements to the skin. Scientists on Earth will compare the radiation doses of the Nomex "skin" to the radiation doses of the phantom internal organs —for the first time comparing recordings taken in the same place, at the same time, for the same length of time. Past radiation space flight experiments recorded only radiation doses on the skin.

Also, radiation measurements on the Phantom Torso are recorded by the Tissue Equivalent Proportional Counter (TEPC) and the Charged Particle Direction Spectrometer (CPDS) for comparison with those recorded by the detectors. The TEPC measures external radiation doses, and the CPDS measures particle energy and direction.

Data collection occurs without assistance from crew members on board the International Space Station. However, a Station crew member downloads data every 10 days from the Phantom Torso, TEPC and CPDS using the Human Research Facility Portable Computer. Data are sent from the computer to the Telescience Center at NASA's Johnson Space Flight Center in Houston, Texas, where investigators receive the information for study.

Station crew involvement with the Phantom Torso experiment includes equipment set-up and activation, equipment status checks every seven-to-10 days, data downlink every 10 days, battery recharge or change out every 20 days, and deactivation and stowing of the equipment for the return Space Shuttle flight to Earth.

Flight History/Background

Since balloon launches in the 1940s, scientists have been measuring radiation in Earth's upper atmosphere and beyond. Radiation experiments have been part of many human space missions including the space station Mir, measuring radiation exposure to spacecraft and space travelers.

Benefits

The Phantom Torso will help scientists more accurately predict the radiation exposure astronauts will experience inside their bodies —especially to critical blood-forming organs. By performing this experiment on board the International Space Station, scientists also will learn how long human beings can remain in space before dangerous levels of radiation are absorbed by the body. The experiment may lead to countermeasures to safely prolong human exposure to radiation.

There are benefits on Earth, as well. This experiment is teaching scientists more about the use of embedded devices for data collection and how to monitor real-time data. This could prove beneficial to radiation monitoring of commercial airline crews and military flight crews.

The Phantom Torso is one of three radiation measuring devices which will fly on board the International Space Station during Expedition Two. For more about these radiation experiments and all Expedition Two science experiments, visit:

www.nsbri.org/Radiation

www.scipoc.msfc.nasa.gov

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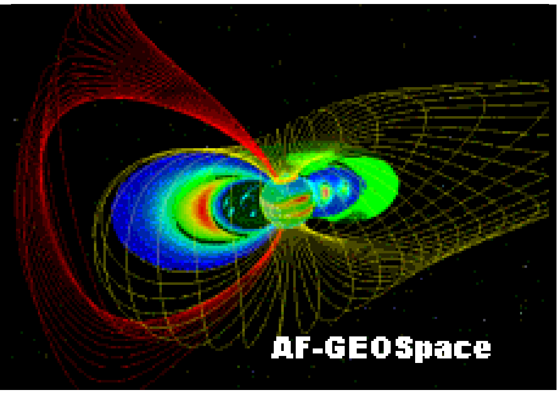
Radiation and Long-Term Space Flight



- **How are humans affected by ionizing radiation?**
- **Is it known how much radiation a human can take?**

The biological effects of heavy particle ionizing radiation are approximately proportional to what is called Absorbed Dose (or simply dose). This is measured with instruments which detect the average energy deposited inside a small test volume.

Louis Gray (1905-65)

The unit of dose is the gray (abbreviated Gy) which represents the absorbtion of an average of one joule of energy per kilogram of mass in the target material. This new unit has officially replaced the rad, an older unit (but still seen a lot in the radiation literature). One gray equals 100 rads. Absorbed Dose was originally measured for x-rays and gamma radiation but has been extended to describe protons and HZE particles. When used in predicting biological damage, a further distinction must be made as to the "quality" of the radiation. >More on definitions

Although the Absorbed Dose of of some radiation may be measured, another level of consideration must be made before the biological effects of this radiation can be predicted. The problem is that although two different types of heavy charged particle may deposit the same average energy in a test sample, living cells and tissues do not necessarily respond in the same way to these two radiations. This distinction is made via the concept of Relative Biological

Effectiveness (RBE) which is a measure of how damaging a given type of particle is when compared to an equivalent dose of x-rays. The Quality Factor of a given type of radiation is determined in the following way: A group of RBE measurements are made using a variety of cells and/or tissue (these experiments aren't cheap to perform and the number that are done is driven by the overall interest in the radiation being studied). Basically, the RBE is determined by comparing the damage of the radiation to the cells/tissue of interest to that with an equal dose of gammas or xrays.   Once the RBE data are in hand, a commitee of radiation experts meets and considers all the available data and then assigns a Quality Factor to the radiation. This may seem a bit unusual to those used to hard formulas or well-defined procedures.

For example, the RBE of alpha particles has been determined (by committee) to be 20 (apparently not very dependent on the energy of these particles). This means that 1 Gy of alphas is equivalent to 20 Gy of gammas/xrays. Another way to say this is to use a new unit, the sievert (Sv) which measures Dose Equivalent (the old unit is the rem; 1 sievert = 100 rem). Click here for info on Mr. Sievert. Thus 1 Gy absorbed dose of alpha particles is 20 Sv dose equivalent. The sievert is the unit used in NASA's radiation limits for humans in Low Earth Orbit:

Dose Limits for STS and ISS

NCRP Report 98 (1989)[a,b]

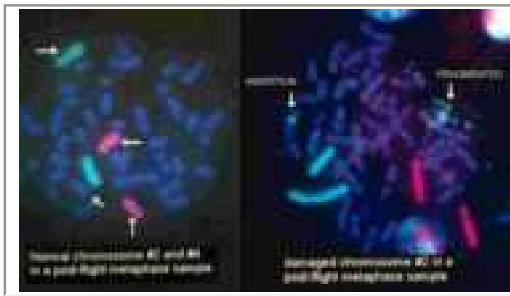
	BFO[c] (5 cm)	Eye (0.3 cm)	Skin (0.01 cm)
30 Day	0.25	1.0	1.5
Annual	0.5	2.0	3.0
Career[d]	1.0 - 4.0	4.0	6.0

a) Units are 1 Sievert (Sv) = 100 rem at the depth indicated in parenthesis
b) These limits do not apply to missions outside low Earth orbit
c) BFO = blood-forming organs
d) The career limits depend on gender and on age at beginning of exposure, according to

$$2.0 + 0.075 \times \begin{cases} (\text{age} - 30) \text{ for males} \\ \text{and} \\ (\text{age} - 38) \text{ for females} \end{cases}$$

So far, no American astronaut has received doses anywhere near these limits (although details of each astronaut's exposure are private medical data and cannot, by law, be revealed to the public). But, the longest stay in orbit has been measured only in months. The possibility of long-term spaceflight makes this issue much more important than it has been in the past.

Here is a description of a typical procedure to determine the RBE (or equivalently, the absorbed dose) of an astronaut during a given exposure in space (thanks to Neal Zapp/NASA/JSC): First, before the flight, a sample of his/her blood is taken and divided into 4 parts. At a professional lab, these parts are exposed to 4 different dose levels of gamma radiation. Later, this blood is processed and photographs are made of the chromosomes from these cells. These photos are viewed by experts and counts of identifiable damage are recorded. These data are used to make a simple (roughly linear) graph relating measured chromosomal damage to dose (the Damage/Dose relationship). Next, the astronaut goes off on her spaceflight mission. On return, another blood sample is taken and chromosome damage counts are made once again. Finally, the Damage/Dose curve is used to determine the equivalent dose due of radiation received while in space.

	Photo set of damaged and undamaged chromosomes used in these studies. (click to enlarge)

In the image above, note in the upper right a chromosome has been broken up and at upper left (on the right photo) a repair process has put one back together using some bits from the wrong chromosome. Statistics limit the use of these data, especially for short Shuttle missions. Better statistics have been obtained from US astronauts who spent months aboard the Russian MIR spacecraft.

The effects of a given dose of ionizing radiation on humans can be separated into two broad categories: Acute and Long-Term effects.

ACUTE EFFECTS
The acute, or more immediately-seen effects of radiation can affect the performance astronauts. These effects include skin-reddening, vomiting/nausea and dehydration. Other tissue and organ effects are possible. Another term: Acute Radiation Syndrome.

LONG TERM EFFECTS.
Given that only moderate doses of radiation are encountered (and thus acute effects are not seen) the long-term effects of radiation become the most important to consider. The passage of an energetic charged particle through a cell produces a region of dense ionization along its track. The ionization of water and other cell components can damage DNA molecules near the particle path but a "direct" effect is breaks in DNA strands. Single strand breaks (SSB) are quite common and Double Strand Breaks (DSB) are less common but both can be repaired by built-in cell mechanisms. "Clustered" DNA damage, areas where both SSB and DSB occur can lead to cell death. Although "endogenous

processes" can lead to DSB, its occurance due to ionizing radiation (especially the high LET radiation found in space) is an important component of long-term risk . For most cell types, the death of a single cell is no big deal -- cells continually die and are replaced by normal processes. A more dangerous event may be the non-lethal change of DNA molecules which may lead to cell proliferation, a form of cancer. Research topic: The RBE of alpha particles on stem cells. These single and double strand breaks, or lesions, can be studied with the scanning tunneling microscope.

Is there any level of exposure to ionizing radiation which does not produce the risk of long term effects? This question is controversial and was a topic discussed in an August, 1999 scientific meeting in Ireland. Read a newspaper report on the meeting.

A related topic of practical importance is the question of how other critical items in space manage under the constant bombardment of ionizating radiation. It has long been known that electronics equipment can fail due to "short circuits" caused by the passage of cosmic rays through crucial parts. Other significant problems exist even when no permanent damage is caused. Errors due to Single Event Upsets in memory locations caused by particles are a constant problem and critical computer systems must therefore have error detection and correction capability. For example, the Shuttle has 4 computers which vote on each action before making a decision. This is because at any time one or more of these computers could have made a mistake due to a radiation-caused memory error. Currently, an Air Force satellite called APEX has on-board experiments to gather data on the radiation menace to electronics packages in space. Most of the radiation hits are in the SAA but some are direct GCR particles.

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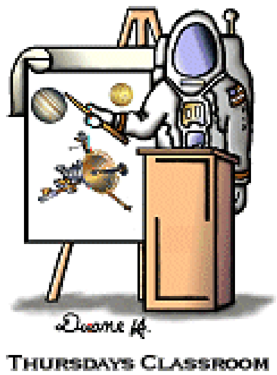
☐		Lesson plans and classroom activities centered on a NASA science topic for Educators and home schoolers. Announcements come out not quite weekly.

Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2001 March 25

The Crab Nebula from VLT
Credit: FORS Team, 8.2-meter VLT, ESO

Explanation: The Crab Nebula, filled with mysterious filaments, is the result of a star that was seen to explode in 1054 AD. This spectacular supernova explosion was recorded by Chinese and (quite probably) Anasazi Indian astronomers. The filaments are mysterious because they appear to have less mass than expelled in the original supernova and higher speed than expected from a free explosion. In the above picture taken recently from a Very Large Telescope, the color indicates what is happening to the electrons in different parts of the Crab Nebula. Red indicates the electrons are recombining with protons to form neutral hydrogen, while blue indicates the electrons are whirling around the magnetic field of the inner nebula. In the nebula's very center lies a pulsar: a neutron star rotating, in this case, 30 times a second.

Tomorrow's picture: Still Hale-Bopping

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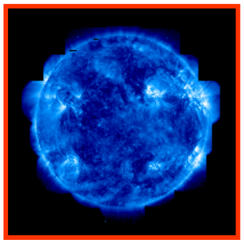
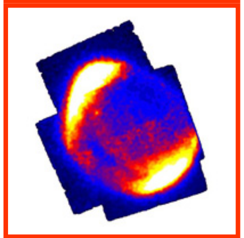
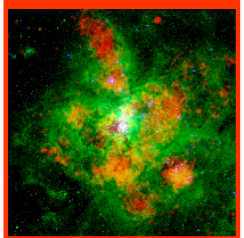
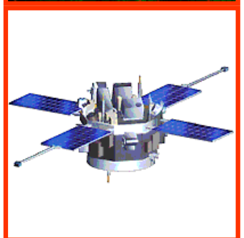
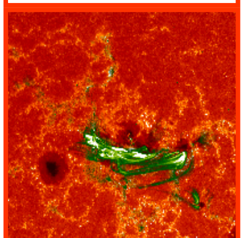
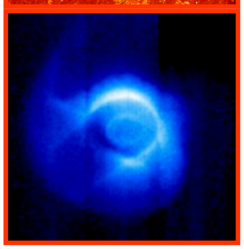

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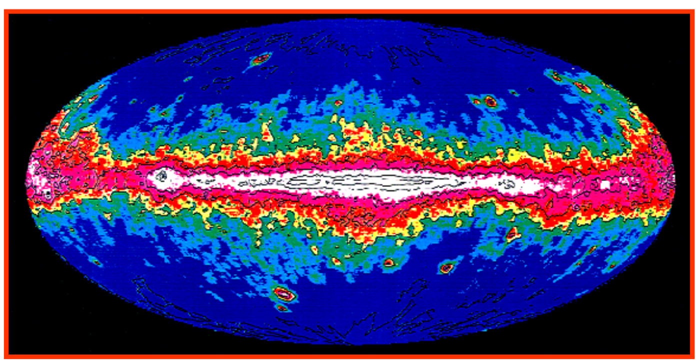
Galactic Cosmic Rays

Galactic Cosmic Rays in the News

Galactic cosmic rays (GCRs) come from outside the solar system but generally from within our Milky Way galaxy. GCRs are atomic nuclei from which all of the surrounding electrons have been stripped away during their high-speed passage through the galaxy. They have probably been accelerated within the last few million years, and have traveled many times across the galaxy, trapped by the galactic magnetic field. GCRs have been accelerated to nearly the speed of light, probably by supernova remnants. As they travel through the very thin gas of interstellar space, some of the GCRs interact and emit gamma rays, which is how we know that they pass through the Milky Way and other galaxies.

The *elemental* makeup of GCRs has been studied in detail , and is very similar to the composition of the Earth and solar system. but studies of the composition of the *isotopes* in GCRs may indicate the that the seed population for GCRs is neither the interstellar gas nor the shards of giant stars that went supernova. This is an area of current study.



The image on the right is the EGRET gamma ray all-sky survey, courtesy of Dr. Carl Fichtel and the EGRET Instrument Science Team. Some GCRs interact with the interstellar medium and produce gamma rays. More about the interstellar medium...

Included in the cosmic rays are a number of radioactive nuclei whose numbers decrease over time. As in the carbon-14 dating technique, measurements of these nuclei can be used to determine how long it has been since cosmic ray material was synthesized in the galactic magnetic field before leaking out into the vast void between the galaxies. These nuclei are called **"cosmic ray clocks"**.

Back to cosmic rays

Galactic Cosmic Rays in the News:

June 1, 2001: World's largest cosmic-ray detector -- Sky & Telescope
May 25, 2001: Massive cosmic ray observatory planned for Tibet -- Ananova
May 14, 2001: Moon helps hunt for mystery particles -- Space.com **March 27, 2001:** Going to the ends of the Earth for cosmic rays: LSU researchers survive Antarctica -- LSU
March 20, 2001: The Grand ASCA Mission: 1993-2001 -- NASA GSFC Imagine the Universe!
February 28, 2001: Moonstruck -- New Scientist
February 1, 2001: The heavenly union of inner and outer space -- L.A. Times
January 18, 2001: 11 key questions about the universe -- PhysicsWeb
January 12, 2001: Ballooning for cosmic rays -- Science@NASA
January 7, 2001: Top 10 weirdest things in space - Number 8 is high-energy cosmic rays -- Space.com
January 1, 2001: High energies and high altitudes -- CERN Courier
December 28, 2000: Launch of the Advanced Thin Ionization Calorimeter (ATIC scientific balloon experiment -- LSU
December 2, 2000: SN 1006: Pieces of the cosmic ray puzzle -- NASA GSFC APOD
November 22, 2000: Cosmic rays and cloud cover -- Physics News Update
September 20, 2000: Climate change: new impressions from space -- ESA
September 8, 2000: Researchers developing bricks to block radiation on Mars -- CNN.com
September 4, 2000: Meteorite gives clues to solar system's early radioactivity -- Spaceflight Now
July 18, 2000: ACE NEWS -- Energy-dependent electron-capture decay observed in galactic cosmic rays
July 9, 2000: Science takes balloon ride -- Spaceflight Now
June 7, 2000: Catching a very rare ray -- ABC News
April 11, 2000: The local interstellar cloud -- NASA GSFC APOD
March 15, 2000: A glowing discovery at the forefront of our plunge through space -- explorezone.com

February 28, 2000: Astronomers find supernova remnant being created -- Spaceflight Now
February 21, 2000: Astronomer uses computers to simulate supernova explosions -- ScienceDaily
December 23, 1999: Supernova's heart and soul seen streaming into space -- explorezone.com
December 21, 1999: Going prospecting inside a supernova -- NASA MSFC
December 17, 1999: Balloon flight will help scientists understand how to shield Mars crews -- NASA MSFC
October 11, 1999: Floating in space -- Scientific American
June 1, 1999: Cosmic ray history encoded in abundances of light elements -- UIUC
May 31, 1999: New findings narrow theories on cosmic ray origin -- NASA GSFC
December 21, 1998: Copper and zinc isotopes resolved in CRIS -- ACE News
June 11, 1998: New cosmic ray theory sheds light on galactic evolutionar mystery -- NASA GSFC
February 13, 1998: Radioactive clock isotopes observed with CRIS -- ACE News

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This file was last modified: June 11, 2001

The Radiation Environment

Radiation in the space environment comes from the trapped particle belts, solar particle events and cosmic rays.

Trapped Particle Belts

The radiation belts consist principally of electrons of up to a few MeV energy and protons of up to several hundred MeV energy. These are trapped in the Earth's magnetic field; their motions in the field consist of a gyration about field lines, a bouncing motion between the magnetic mirrors found near the Earth's poles, and a drift motion around the Earth [Hess] (Fig. 1).

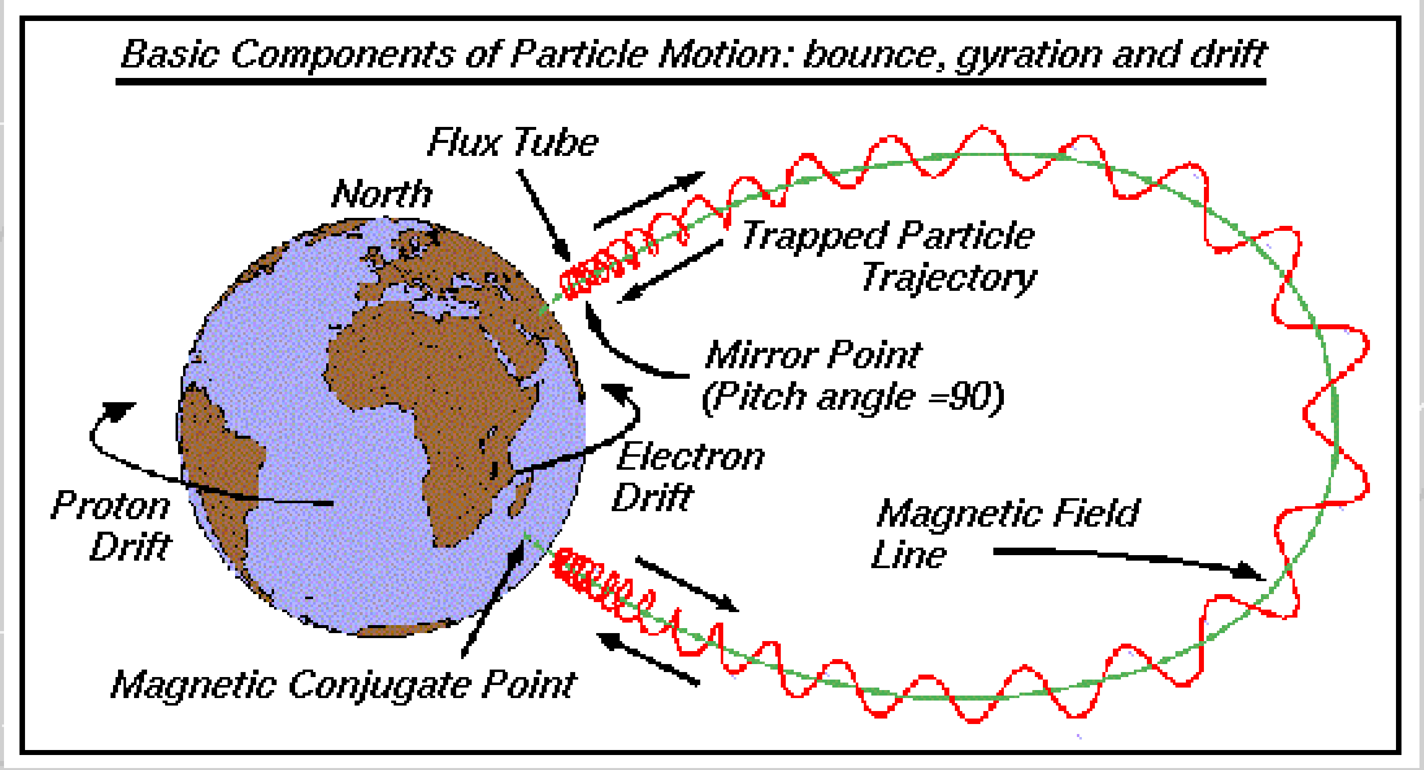

Figure 1: The Basic Motions of Trapped Particles in the Earth's Magnetic Field.

Radiation is an obvious concern for manned missions. In the near-term, manned activities are limited to low altitude, and mainly low-inclination missions. The International Space Station, Space Shuttle, ERS-2, EnviSat and other low altitude missions will therefore encounter the inner edge of the radiation belt. This region is dominated by the "**South Atlantic Anomaly**" - an area of enhanced radiation (Fig. 2) caused by the offset and tilt of the geomagnetic axis with respect to the earth's rotation axis.

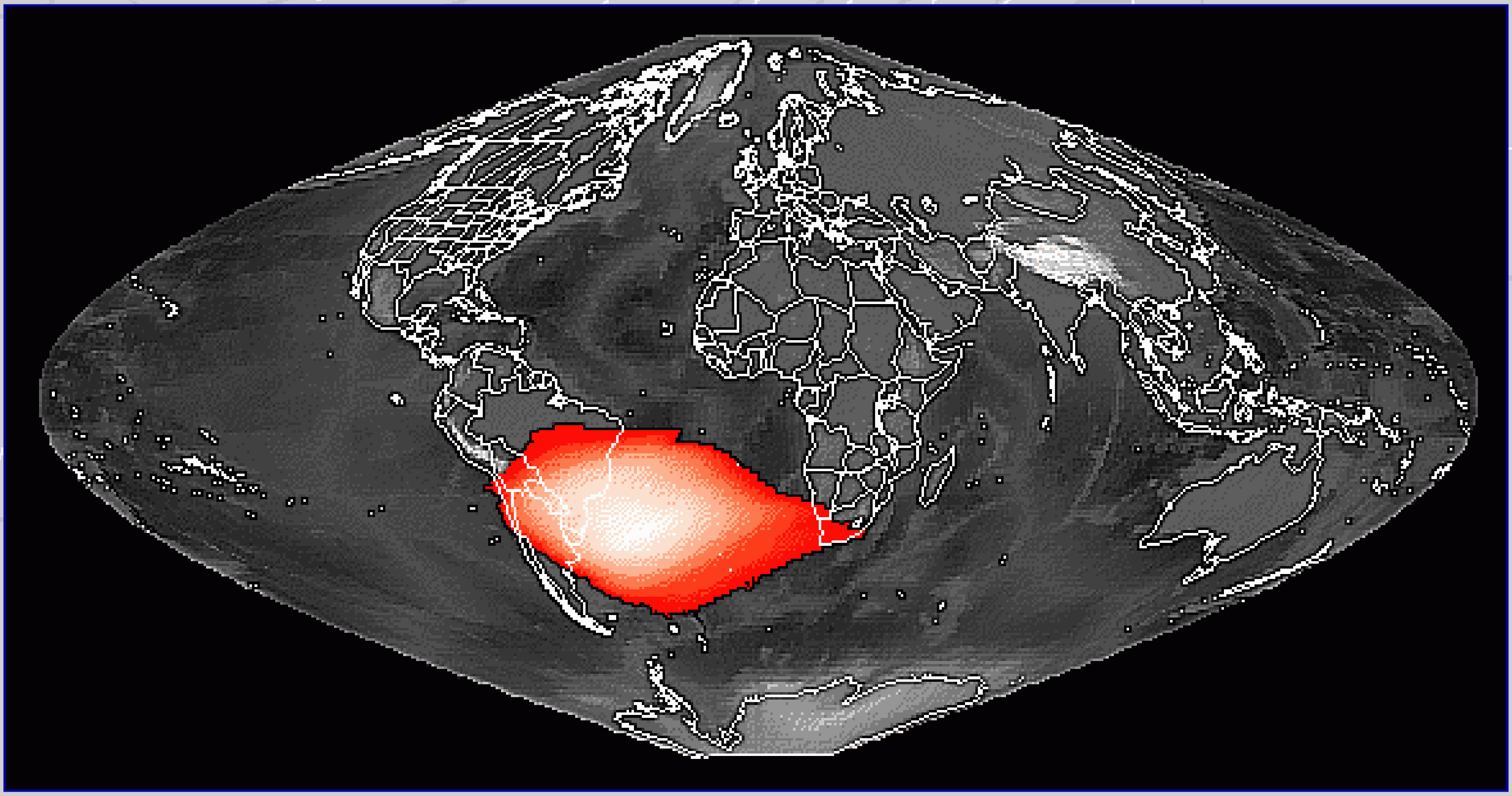

Figure 2: The South Atlantic Anomaly

This brings part of the radiation belt to lower altitudes (Fig 3). Note how the inner edge of the proton radiation belt dips below the line drawn at 500km altitude. At these altitudes, there are important interactions between the trapped radiation belts and the atmosphere, giving rise to a strong asymmetry in fluxes from East and West [Daly]. This is important for oriented spacecraft such as the International Space Station.

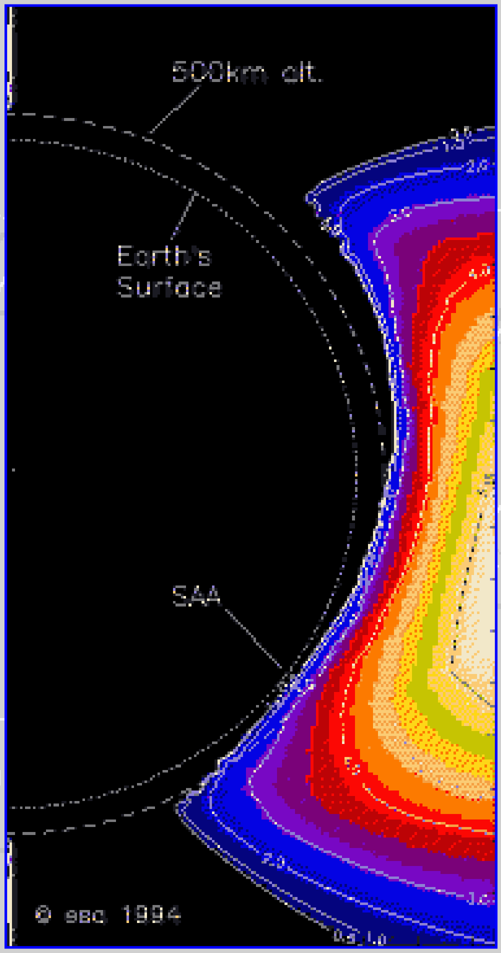

Figure 3: Energetic proton fluxes in a slice through the Earth at longitude 325.

If we look at a contour plot of particle fluxes at 500km (Fig. 4), the South Atlantic Anomaly is clear.

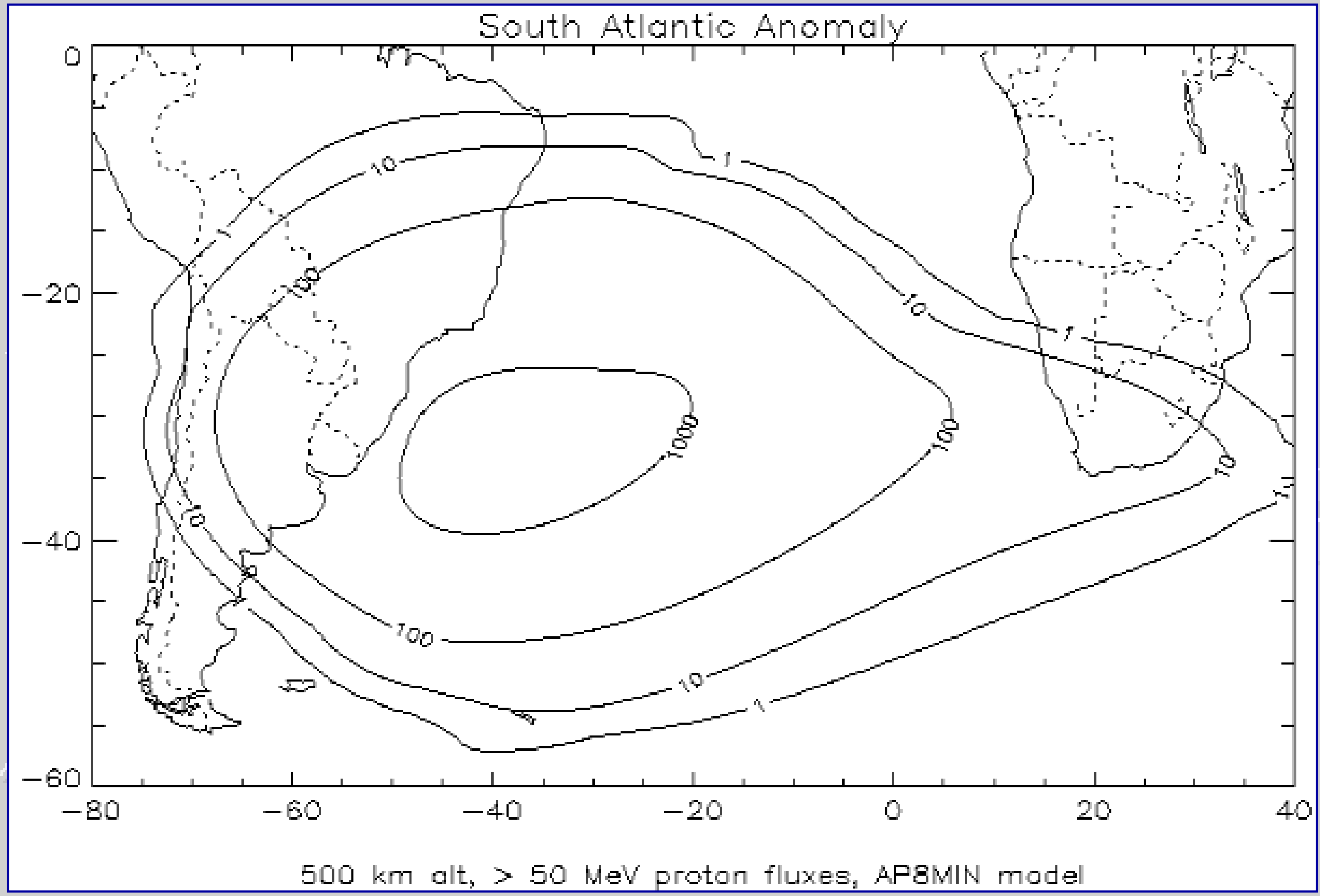

Figure 4: Particle fluxes at 500km altitude

Solar Particle Events

During solar events (Fig. 5), large fluxes of energetic protons are produced which reach the earth. The August 1972 event produced a peak flux in excess of 1E+06 protons/cm²/sec above 10 MeV energy. Such events are unpredictable in their time of occurrence, magnitude, duration or composition. The earth's magnetic field shields a region of near-earth space from these particles (*geomagnetic shielding*) but they easily reach polar regions and high altitudes such as the geostationary orbit.

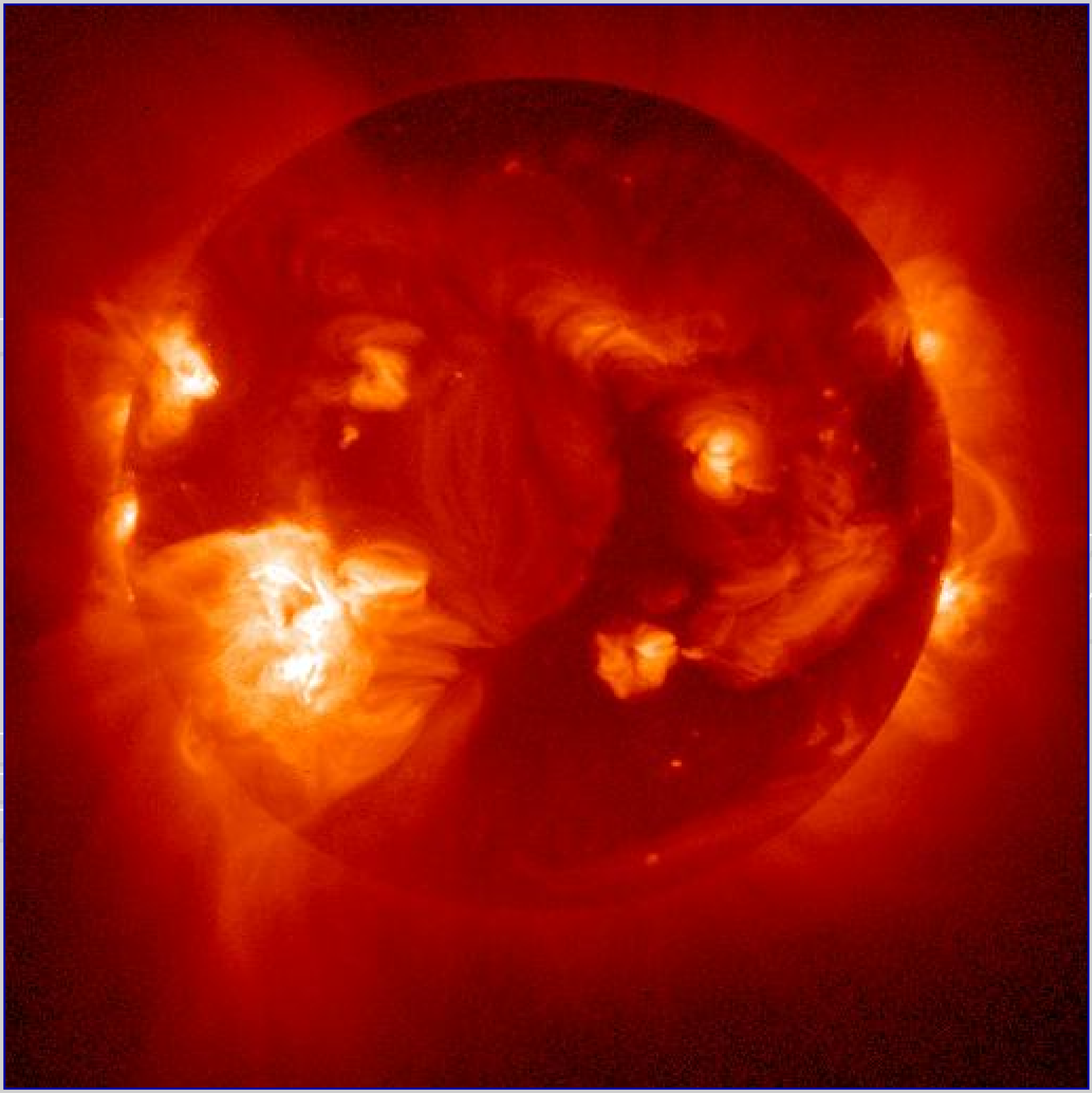

Figure 5: Sun spots and solar flares

Cosmic Rays

Cosmic Rays originate outside the solar system. Fluxes of these particles are low but, because they include heavy, energetic ("HZE") ions of elements such as iron, they cause intense ionisation as they pass through matter, are difficult to shield against, and therefore constitute a significant hazard. They give rise to single-event processes (SEU, latch-up) in large-scale integrated electronic components, as well as interference and an uncertain radiobiological effect.

Other Radiation

Other aspects of the radiation environment include induced radioactivity, planetary environments (Jupiter and Saturn have particularly hostile radiation environments), trapped ions and spacecraft nuclear generator systems.

References

- Hess W.N., "*The Radiation Belt and the Magnetosphere*", Blaisdell Publ. Co. (1968).
- Daly E.J., "*The Evaluation of Space Radiation Environments for ESA Projects*", ESA Journal 12, 229 (1988).

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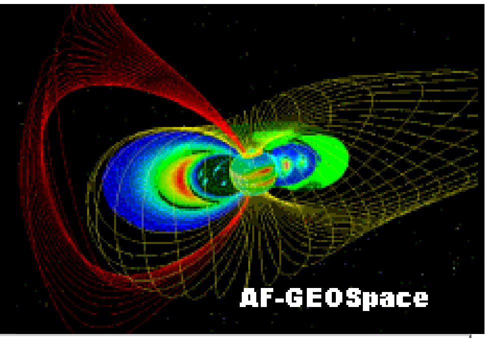
Radiation and Long-Term Space Flight



HOME

Phantom Torso from NASA/JSC

DOSMAP from Germany

Bonner Ball neutron detector from Japan

The International Space Station (ISS) will monitor radiation levels and will support radiation experiments on-board.

A great deal of the information known about radiation levels in LEO was obtained from measurements made on the Russian MIR station and on U.S. Space Shuttle missions.

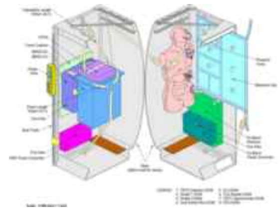
Three radiation experiments will soon be operating on ISS:

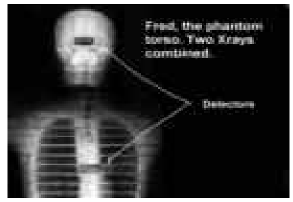
1) From the U.S.A., Johnson Spacecraft Center (JSC) will fly a "phantom torso". The Principal Investigator is Gautam Badhwar

Background: The primary radiation risk to astronauts arises due to induced cancer for which organ level dose equivalent measurements are required. The issue in assessing radiation risk in manned spaceflight is related to the estimation of organ level dose-equivalent. Currently, both experimental and operational methods are limited to the measurement of surface (skin) dose. Organ level dose is conservatively estimated by calculations using the radiation environment model and the appropriate radiation transport models. If the accuracy of these models were refined, the more experienced astronauts would be less flight limited by measured, accrued skin dose.
Purpose: The overall goal of the Torso experiment is to develop the capability to accurately calculate organ-absorbed dose and dose equivalent in humans exposed to ionizing space radiation. This experiment proposes using a fully instrumented phantom torso (with head) to provide the necessary depth-dose-equivalent measurements. Depth-dose-equivalent measurements will be taken as a function of spacecraft altitude, attitude, location and time. Measurements internal to the phantom torso will be supported by other radiation measurements from the Tissue Equivalent Proportional Counter and the Charged Particle Direction Spectrometer.

The hardware for this experiment consists of three major pieces Similar equipment was flown on earlier shuttle missions.

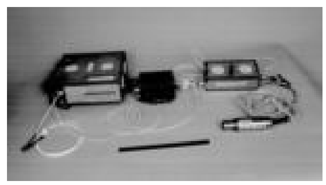
a) The Phantom Torso itself is a tissue-muscle plastic equivalent anatomical model of a male head and torso comprised of 35 sliced "sections" housed in a Nomex suit. Each section is connected via a system of pins and holes. Voids within the phantom are used for active and passive radiation detectors. The five small active dosimeters are located at strategic radiobiological points of interest (head, neck, heart, stomach and colon) within the phantom and will provide real time measurements.





b) A Tissue Equivalent Proportional Counter (TEPC) will be placed near the phantom to measure external dose. This instrument provides an efficient method of determining radiation dose and dose-equivalent in complex (mixed) radiation fields. It records the linear energy spectra for determining dose-equivalent exposures.

c) A Charged Particle Direction Spectrometer (CPDS) will be placed near the phantom to measure particle energy and direction in the same general environment as the TEPC. Since the interactions of heavy ions and their secondaries with tissue are not at all well understood, proton and heavy ion spectra both incident upon and inside the spacecraft will be measured.

The CPDS and TEPC units together	

The Phantom Torso will be deployed in the US lab of the ISS in a location that will not interfere with the daily activities of the crew. Photo in mockup. Data collection occurs without crew intervention. Every 7-10 days a crewmember downloads data from all three hardware components to the HRF PC. These data are then downlinked to the Telescience Center at JSC in Houston.

2) A package called Dosimetric Mapping (DOSMAP) is provided by the Deutsches Zentrum fur Luft und Raumfahrt (DLR) in Germany. The Principal Investigator is Guenther Reitz.

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. German Aerospace Center

Radiation constitutes one of the most important hazards for a human during long-term space missions. Leaving the Earth's surface exposes man to a wide spectrum of radiation particles and energies. The International Space Station provides shielding, but some radiation gets through. This experiment attempts to map the different types of radiation that gets inside the space station, which could cause harm to humans by using devices called dosimeters that detect radiation. Due to the variety of particles and energies that make up radiation, no single type of dosimeter is capable of providing sufficient information. Several different types of dosimeters are used in this experiment.

Nuclear Track DetectorPackages (NTDP) will provide an integral measurement of energy and charge of the heavy ion component. These small packages will be placed around the station to monitor incoming radiation. Each package contains 3 strips of CR39 plastic, one for each of 3 perpendicular axes. The graphic at left shows a typical track in this plastic due to the passage of a high energy particle. These films are returned to the ground where the tracks are analyzed.

The DOSimetry TELescopes (DOSTEL) containing two thin silicon detectors will be used to measure the flux (and the LET distribution) of charged particles.Two of these will be placed near each other in an empty rack space in the U.S. Lab.

Several small mobile dosimetry units (MDU) can be used by crewmembers as a personal dosimeter or placed throughout the station. Twelve thermoluminescence dosimeters (TLD) will measure the neutron dose of the incoming radiation and the mission average absorbed dose.

Picture of MDU plugged into the Control and Interface unit : 

The dosimeters, placed in various locations throughout the space station, will absorb radiation during a three-month period. Some of the dosimeters will be gathered up every two weeks and taken to a device that will record the radiation information and allow it to be saved on one of the station computers. Other dosimeters will simply record all the radiation absorbed and be brought back to Earth for analysis. The radiation gathered by the various dosimeters will provide scientists information on the nature and distribution of radiation inside the space station.

Dosimetric Mapping experiments carried out on previous Space Shuttle missions.

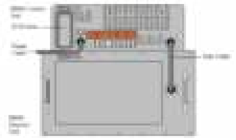
3) The Japanese space agency NASDA will contribute a radiation detector called the "Bonner ball". The Principal Investigator is Ted Goka.

The Bonner Ball Neutron Detector (BBND) is a piece of equipment developed by the National Aeronautics/Space Development Agency of Japan (NASDA) as part of a set of experiments to study the environmental and biological effects of space radiation.

In January of 1998, the Bonner Ball Neutron Detector first flew aboard the Space Shuttle Endeavor to perform neutron radiation measurements inside the vehicle during the penultimate U.S. mission to the Russian Space Station Mir (STS-89). In fact, this was the first time that neutron radiation was ever measured with an "active" detector inside the Space Shuttle. (Previous neutron measurements were made using emulsions and foils. These passive techniques require that the detection media be returned to the Earth for analysis. BBND allows one to see how the neutron flux varies with time during a mission.) The BBND was able to differentiate between neutron and proton radiation which up to that point was considered to be very difficult to carry out.

A Japanese web site about this neutron detector

The Bonner Ball Neutron Detector will fly again aboard the International Space Station to collect continuous neutron measurements for approximately six months. The BBND will consist of two units permanently attached to each another: The BBND Control Unit (not flown during the STS-89 mission) and the BBND Detector Unit. The control unit will feature a removable computer drive where the measurements will be stored; also, the BBND Control Unit (BBND-CU) will be able to control the quality of the data recorded by performing system calibrations, making adjustments, and using a time stamp on the recorded neutron measurements. The Detector Unit (BBND-DU) is composed of six detector spheres that contain a form of the gas Helium (3He) where the neutron radiation is measured.



Neutrons are uncharged atomic particles that have the ability to penetrate living tissues. Particularly, neutron radiation can affect the blood-forming marrow in the mineral bones of humans and other animals. By operating the BBND in space, neutron radiation information can be used for the development of safety measures to protect Astronauts during long missions aboard the International Space Station.

Click to learn how the Bonner Ball detector works

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The Phantom Torso

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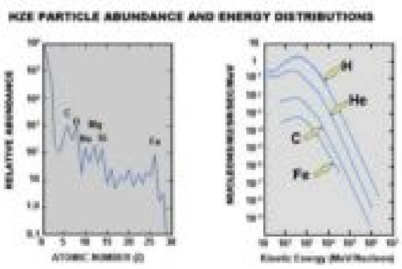
Hi! I thought you'd be interested in this story from Science@NASA: An unusual space traveler named Fred is orbiting Earth on board the International Space Station. His job? To keep astronauts safe from space radiation. http://science.nasa.gov/headlines/y2001/ast04may_1.htm?friend (or The Phantom Torso .)

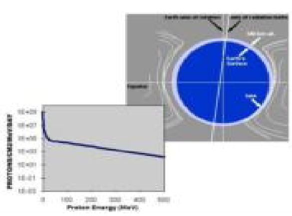
Curator: Bryan Walls
NASA Official: Ron Koczor

A collection of graphs showing what is known about the identity and number of energetic particles encountered in space. (click graphs to enlarge)

This graph shows the flux of particles seen near Earth. It covers an extremely wide range of particle energies. This is an "integral" distribution, that is, it shows the flux of particles with energies above the energy shown on the horizontal axis. Note that only those particles at the higher end of the energy scale (towards the right hand side) can penetrate the aluminum skin of a spacecraft which is typically around 1 gm/cm2.



Galactic Cosmic Rays are composed of many elements but the lighter nucleii dominate. Note that the vertical axes are logarithmic. For example, in the right graph, the hydrogen (H) peak is about 10 times higher then the helium (He) peak and almost 10,000 times higher than the iron (Fe) peak.



Both Galactic Cosmic Rays and the solar wind contribute particles to the Earth's radiation belts (although GCR is thought to be the predominate source). Because the Earth's magnetic field is not symmetric, there is a "hot spot" above the east coast of Brazil called the South Atlantic Anomaly. This graph shows the energy distribution of the protons which are a primary component of the radiation in the SAA.

Energetic particles from the sun, mostly protons and helium nucleii, present a significant danger to men and equipment during solar storm activity. This graph shows the energy distribution of protons arriving in Low Earth Orbit during various solar storms, identified by their date. The curves indicate the flux of particles with energies above the energy shown on the horizontal axis (integral distribution). For example, the 1972 event produced over 10000 protons/cm2/sec/sr with energies above 10MeV.

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Ionizing Radiation

OVERVIEW

Environment Definition

The particles associated with ionizing radiation are categorized into three main groups relating to the source of the radiation: trapped radiation belt particles, cosmic rays, and solar flare particles. Results from recent satellite studies suggest that the source of the trapped radiation belts (or Van Allen belts) particles seems to be from a variety of physical mechanisms: from the acceleration of lower-energy particles by magnetic storm activity, from the trapping of decay products of energetic neutrons produced in the upper atmosphere by collisions of cosmic rays with atmospheric particles, and from solar flares. Solar proton events are associated with solar flares. Cosmic rays originate from outside the solar system from other solar flares, nova/supernova explosions, or quasars.

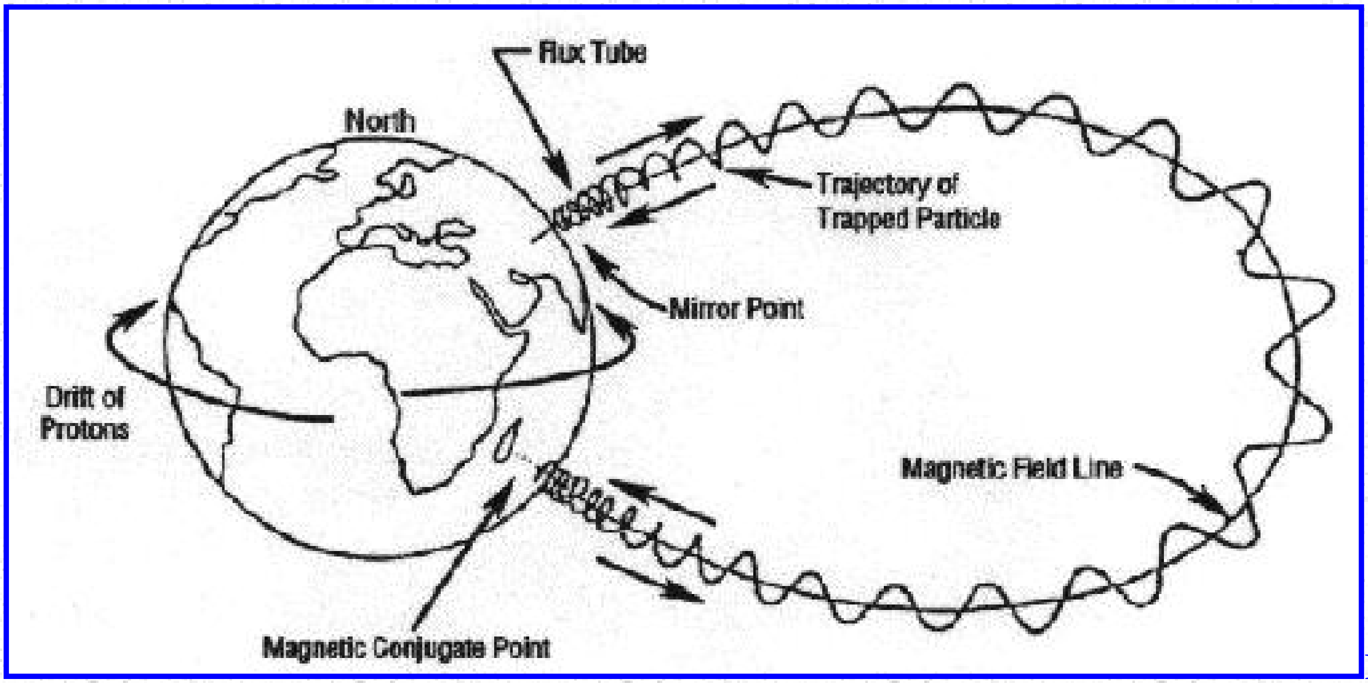

Fig 1

The Earth's magnetic field concentrates large fluxes of high-energy, ionizing particles including electrons, protons, and some heavier ions. The Earth's magnetic field provides the mechanism which traps these charged particles within specific regions, called the Van Allen belts. The belts are characterized by a region of trapped protons and both an inner and an outer electron belt. The radiation belt particles spiral back and forth along the magnetic field lines (fig. 1). Because the Earth's approximate dipolar field is displaced from the Earth's center, the ionizing radiation belts reach their lowest altitude off the eastern coast of South America. This means as particles travel into this region they will reach lower altitudes, and particle densities will be anomalously high over this region. This area is termed the South Atlantic Anomaly (SAA). For the purpose of this document, the term "cosmic rays" applies to electrons, protons, and the nuclei of all elements from other than solar origins. Satellites at low inclination and low altitude experience a significant amount of natural shielding from cosmic rays due to the Earth’s magnetic field. A small percentage of solar flares are accompanied by the ejection of significant numbers of protons. Solar proton events occur sporadically, but are most likely near solar maximum. Events may last hours or up to more than a week, but typically the effects last 2 to 3 days. Solar protons add to the total dose and may also cause single-event effects in some cases (figs. 2 and figs. 3).

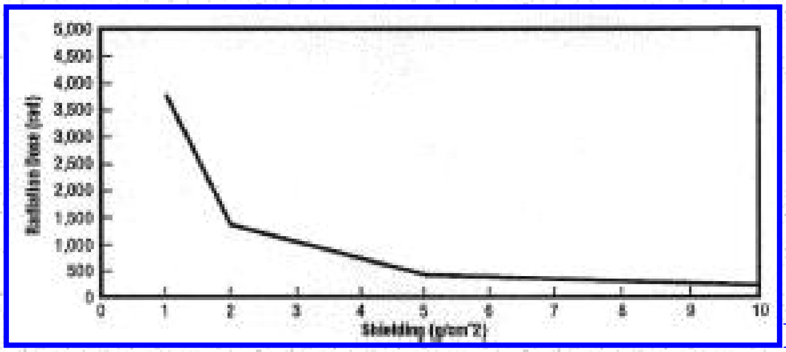

Fig 2

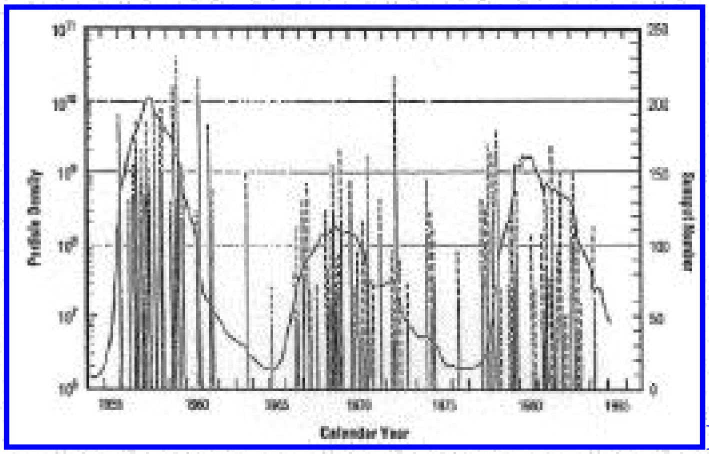

Fig 3

Spacecraft Effects

The high-energy particles comprising the radiation environment can travel through spacecraft material and deposit kinetic energy. This process causes atomic displacement or leaves a stream of charged atoms in the incident particle’s wake. Spacecraft damage includes decreased power production by solar arrays, failure of sensitive electronics, increased background noise in sensors, and radiation exposure of the spacecraft crew. Modern electronics are becoming increasingly sensitive to ionizing radiation.

back to Ionizing Radiation TWG

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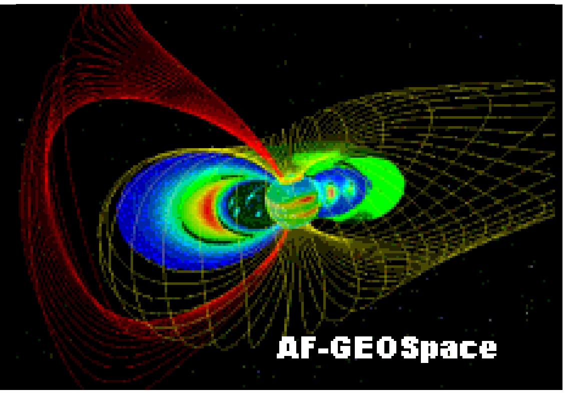
Radiation and Long-Term Space Flight



HOME

- **What is ionizing radiation?**
- **Where does it come from?**
- **Can't astronauts simply be shielded from radiation effects?**

Atoms and molecules (such as those making up the cells in your body) exist normally in the neutral or uncharged state, the number of positive protons in the nucleus balancing the number of negative orbiting electrons outside the nucleus. If an electron is lost (due to being struck by an energetic particle) the resulting atom/molecule is called an ion and its properties are greatly changed. The particles that can cause this type of event are called Ionizing Radiation Not only does the ion now appear from a distance as a charged particle, the missing electron causes profound changes in the way the molecule bonds or interacts with other molecules. For this reason, radiations which lack sufficient energy to ionize common molecules (referred to as non-ionizing radiation) are of much less concern than those higher energy particles which can easily ionize and break chemical bonds. A typical high energy particle of radiation found in the space environment is ionized itself and as it passes through material such as human tissue it disrupts the electronic clouds of the constituent molecules and leaves a path of ionization in its wake. These particles are either singly charged protons or more highly charged nucleii called "HZE" particles. (Z is the symbol for nuclear charge and the disruption caused is proportional to Z squared. Thus a particle with High Z and High Energy is called HZE.) Particles encountered in space commonly have enough energy to disrupt the nucleus of target atoms and these collisions can cause nuclear reactions which generate new and potentially more damaging particles. Nuclear reactions make the analysis of ionizing radiation collisions much more difficult. More on ionizing radiation

Electromagnetic waves exist as particles and vary according to their energy (proportional to frequency), ranging from low frequency, non-ionizing radio waves, up through the visible light frequencies, and then even higher to x-rays and gammas. It is interesting that the energy of light particles (photons) is just below that required to ionize molecules. At energies just above the visible, ultraviolet photons are able to remove electrons from some of the most easily ionized types of molecules such as those found in and around human cells. Fortunately, these "electromagnetic" types of ionizing radiation are not a great threat to humans in space. This is true because they can either be stopped with thin shields or, as in the case of x-rays and gamma rays, their intensity is fairly low in most volumes of space where humans desire to go. Some have claimed that low frequency electromagnetic fields from power lines are responsible for increased cancer risk but this has been discredited. This leaves the highly energetic particles which can pass through shielding materials as the most obvious threat to humans in space.

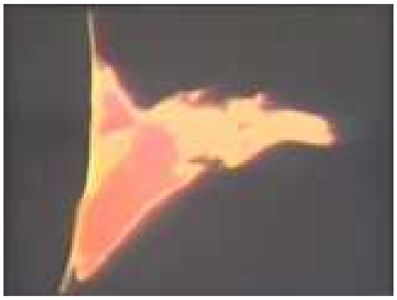
There are three major components of ionizing radiation which are of concern to the health of astronauts in space: GALACTIC COSMIC RAYS, SOLAR PARTICLE EVENTS and the Earth's SOUTH ATLANTIC ANOMALY.

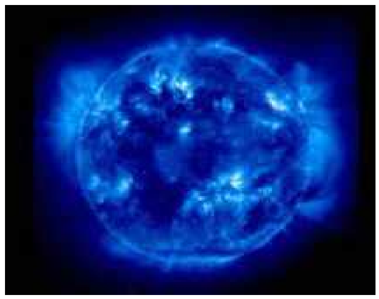
GALACTIC COSMIC RAYS

	Galatic Cosmic Rays (GCR) are called galactic because their source is clearly outside the solar system (and thus are assumed to be generated somewhere in our galaxy). Typically, these particles are highly charged and very energetic. They pass practically unimpeded through the skin of a typical spacecraft and the skin of the astronauts. GCR is the dominant radiation to be dealt with on the International Space Station and on Mars missions.

These particles are affected by the sun's magnetic field and their average intensity is highest during the period of minimum sunspots when the solar magnetic field is weakest and thus is less able to deflect them. The sun's magnetic field increases as we move towards solar maximum (expected around the year 2000). As the sun's field increases, GCR particles are more easily deflected and less are seen near the Earth. One good thing is that the GCR component of radiation is relatively predictable (especially when compared to SPE as explained below) over the short term.

SOLAR PARTICLE EVENTS





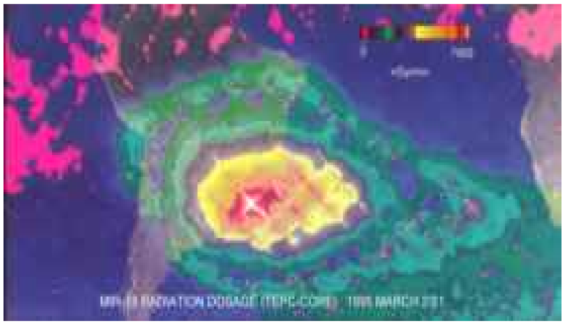
Solar Particle Events (SPE) are of special interest to those concerned with radiation health because the particle flux from the sun can change quickly and dramatically with very little notice. The particles streaming into the solar system along the sun's magnetic field lines are mostly fairly low energy protons and normally this presents an acceptable radiation level to humans, even in rather thin-walled space suits. Sometimes, with very little warning, an eruption (sometimes seen as a "flare") near the sun's surface spews out particles which can reach the vicinity of the Earth in less than an hour. The severity of this radiation can easily increase by factor of 10. A moderate eruption on 1989 October 22, just before STS-34 returned to Earth from its orbital mission, did not produce great danger to the astronauts mainly because its low orbit inclination kept the spacecraft under the Earth's protective magnetic field. A mission at high latitudes would have made this event more serious. These events that can be very dangerous to astronauts on a time scale from hours to days are called Coronal Mass Ejections. See a CME in slow motion

Short-term space weather forecasts: NOAA Space Environment Center provides one to three day estimates of the solar flare probability, mostly based on human forecaster judgement. A component of the prediction is related to several indices of solar activity, a principle one being the intensity of a common x-ray band (1-8 angstroms) constantly monitored on the Earth and satellites. Click here to view a prediction site. Another major consideration is how well the Earth is connected magnetically to the unsettled area of the sun mostly responsible for the x-radiation (which is found with optical telescopes specially designed to monitor the sun). See Solar Telescopes.

Most people have heard of sunspots which are dark-appearing splotches on the sun and have been observed for a long time. The ancient Chinese recorded the largest sunspots on the just-setting sun when they could be observed with the naked eye without harm. These areas are slightly lower in temperature than the normal surface of the sun and are the result of local disruptions in the magnetic field. Eruptions which can be dangerous to astronauts are typically associated with the areas around these unsettled sunspots. Observing sunspot counts over many decades reveals that the number of spots varies widely over a period of approximately 11 years. Later study has shown that the sun's huge magnetic field reverses direction every 11 years and that the actual period of the solar cycle is 22 years. More detail on the solar cycle

SOUTH ATLANTIC ANOMALY

Early in the space age it was found that the Earth's magnetic field acts as a trap to contain energetic charged particles. These are referred to as the Van Allen belts. Some of these particles originate from the solar wind but most are produced by the decay products of galactic cosmic rays. Spacecraft travelling to points far from the Earth must pass through these areas but, in this case, the hazard for humans is low because the passage time through these radiation belts is short. The passage time is not necessarily short for spacecraft in Low Earth Orbit (LEO). It is fairly well-known that the Earth's magnetic field axis is significantly out of line with its rotation axis. Although the north magnetic pole is still in the north it is not very close to the north pole at all. What is less well-known is that the rotation and magnetic axes are also displaced, meaning that the Earth's field has a significant assymetry as seen on its surface. The result of this is that there is an area near the coast of Brazil above which particles trapped in the Earth's magnetic field exist at much lower altitudes. This area is called the South Atlantic Anomaly (SAA). Lots of SAA graphics At typical Low Earth Orbit (LEO) altitutes of 300- 500km, the radiation intensity in the SAA is much higher than that found anywhere else in orbit.



Here's a nice color map of the SAA.

Note that the hottest spot is off the east coast of Brazil. In Space Shuttle operations, Extra Vehicular Activities (EVA) are prohibited on orbits near any passages through the SAA to avoid this extra radiation risk. Also, during SAA passage, equipment is often turned off to minimize the probability of damage due to the ionizing trails of particles through electrically charged components. (Click to enlarge)

Click for more SAA details

How many particles are going HOW fast? Click here for some graphic details.......

Can't astronauts be shielded from this potentially harmful radiation? The simple answer is no, not completely. Shielding provided by the typically-available structural aluminum skin on a spacecraft (around 5mm thick) is significant but it provides very little reduction in the number of energetic ionizing particles. And, the shielding itself produces secondary neutrons and other energetic particles which pose an additional hazard. The amount of aluminum shielding required to eliminate the currently-perceived risk from these heavy ions would produce a spacecraft so heavy that it could never be launched. And, even if this were done, astronauts working outside the spacecraft would still be exposed (especially if a solar event occurred). Hydrogen rich compounds such as polyethelyne and water are much more effective than aluminum and are being considered for spacecraft use (water, which must be on board for consumption anyway may have a secondary use as shielding in the future). Estimating the risk in any given situation (orbital inclination and altitude if in Earth orbit, type of shielding, current state of the solar wind, etc) is the real challenge. Currently, NASA's plan is reduce the uncertainty of long-term risk to 600% by 2002 and reduce it further to 300% by the year 2008. See NASA's Strategic Plan for more detail.

The overall uncertainty in the risk to humans due to ionizing radiation in space can be attributed to three broad categories:

1. Uncertainty in the radiation itself; how much of what kind, etc.
2. Uncertainty in the effects of shielding. Shields produce a great variety of secondary particles which are generally a hazard too.
3. The most uncertainty in estimating risk lies in the response of cells and tissues to the radiation they encounter.

See how lunar or Martian dirt can be used as shielding material for space colonizers.

One group which does studies on the general problem of radiation shielding is at Oak Ridge National Laboratory.

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YEAR 2001 HEADLINES

Subject	August Articles Date & Title
Comets	**August 24:** A New Comet - Last weekend an amateur astronomer peered through his telescope and found a new comet the old-fashioned way -- by looking!
Moons of Jupiter	**August 22:** The Strange Spires of Callisto - NASA's Galileo spacecraft has spotted curious icy spires jutting from the surface of Jupiter's moon Callisto. The bizarre-looking natural features have researchers wondering if the surface of the frigid moon might be a more dynamic place than they once thought.
Earth Science	**August 21:** Smoke Sentry in Space - In the past firefighters looked toward the sky for relief from relentless wildfires, wishing for rain or perhaps a cool breeze. Now there's a different kind of aid beaming down from the heavens.
Mars Exploration	**August 17:** Having a Ball on Mars - An amusing accident in the Mojave desert has inspired a new kind of Mars rover -- a two-story high beach ball that can descend to the Martian surface and explore vast expanses of the Red Planet.
Earth Science	**August 16:** Into the Storm - While most people are trying to avoid the perils of this year's hurricanes, scientists will soon be flying right into the mighty storms!
Materials Science	**August 15:** Samples of the Future - The advanced space ships of tomorrow will be crafted from far-out materials with extraordinary resistance to the harsh environment of space. An experiment strapped to the outside of the ISS aims to put such materials through their paces.
Comets & Meteors	**August 09:** Horse Flies and Meteors - Like bugs streaking down the side window of a moving car, long and colorful Perseid Earthgrazers could put on a remarkable show before midnight on August 11th.

Living in Space	**August 07**: Mixed Up in Space - Humans can become confused and disoriented (and even a little queasy) in an alien world where up and down have no meaning.
Moons of Jupiter	**August 03**: Another Daring Adventure for Galileo - NASA's durable Galileo space probe is heading for a close encounter with an alien volcano on Jupiter's moon Io. Galileo could fly right through a volcanic plume for the first time.
Living in Space	**August 02**: Gravity Hurts (So Good) - Strange things happen to the body when humans venture into space and the familiar pull of gravity vanishes. Scientists say exercise is the key to adapting to life in orbit -- and returning to Earth.

Subject	**July Articles** **Date & Title**
Comets & Meteors	**July 31**: Anticipating the Perseids - The 2001 Perseid meteor shower peaks on August 12th. Will it be an extraordinary sky show like last year -- or a moonlit disappointment? This story explains how to see for yourself.
Asteroids	**July 27**: Meteorites Don't Pop Corn - A fireball that dazzled Americans on July 23rd was a piece of a comet or an asteroid, scientists say. Contrary to reports, however, it probably didn't scorch any cornfields.
Space Station	**July 25**: Space Seeds Return to Earth - Seed pods from a commercial gardening experiment aboard the International Space Station are back on Earth. The far-out pods could hold the key to long-term habitation of space.
International Space Station	**July 23**: Building a 'Droid for the International Space Station - Inspired by science fiction classics, NASA scientists are building a talking, thinking and flying robot to help astronauts with their chores in space.
Mars Exploration	**July 20**: Happy Anniversary, Viking Lander - On July 20, 1976, NASA's Viking 1 lander descended safely to the surface of Mars, revealing an alien world that continues to puzzle scientists and tempt explorers.
Planetary Exploration	**July 19**: A Propitious Alignment of Planets - In ancient times many people thought heavenly alignments influenced daily life on Earth. Nowadays they set the schedule for space exploration.

Mars Exploration	**July 16:** Planet Gobbling Dust Storms - An enormous dust storm has erupted on Mars, shrouding the planet in haze and raising the temperature of its atmosphere by a whopping 30 degrees.
Astronomy	**July 11:** Sizzling Comets Circle a Dying Star - Astronomers have detected a massive cloud of water vapor around an aging star. It could be the telltale sign of innumerable dying comets and a glimpse of things to come in our own solar system.
Looking Up	**July 10:** Morning Coffee and Planets - Beginning Friday the 13th -- a lucky day for stargazers -- four planets, the Moon, and a giant red star will put on a dazzling show for early-rising sky watchers.
International Space Station	**July 06:** Even Homes in Space Need a Door - A new airlock soon to be installed on the International Space Station is critical for assembly and maintenance of the orbiting outpost.
Earth Science	**July 03:** Aphelion Away! - On the 4th of July, Earth will lie at its greatest distance from the Sun -- an annual event astronomers call "aphelion." But don't expect any sudden relief from the heat.

Subject	**June Articles** **Date & Title**
Astronomy	**June 29:** Wandering Mystery Planets - Scientists using the Hubble Space Telescope have spotted mysterious planet-sized objects apparently running loose in a distant cluster of stars.
Earth Science	**June 28:** El Niño Repellent? - New satellite images of the Pacific Ocean hint that El Niño will not return this winter. Instead, La Niña-like weather patterns will persist thanks to a "Pacific Decadal Oscillation" that might also repel strong El Niños.
Earth Science	**June 26:** All the World's a Stage ... for Dust - Tune in to a NASA website and watch giant dust clouds as they ride global rivers of air, cross-pollinating continents with topsoil and microbes.
Looking Up	**June 21:** A Close Encounter with Mars - Today Earth and Mars will experience their closest encounter in a dozen years. Stargazers won't want to miss the Red Planet blazing bright in the midnight sky.

Looking Up	**June 19:** Eclipse Safari - On Thursday, June 21st, the Moon's shadow will race across southern Africa for the only total solar eclipse of 2001. The display will delight some creatures and put others to sleep.
Earth Science	**June 18:** Mobile Homes for Microbes - African dust that crosses the Atlantic Ocean and brings beautiful sunsets to Florida also carries potentially harmful bacteria and fungi, a new study shows.
Space Weather	**June 12:** The Biggest Explosions in the Solar System - Scientists hope NASA's HESSI spacecraft will unravel an explosive mystery: the origin of solar flares.
Astrophysics	**June 07:** Where No Telescope Has Gone Before - Astronomers at NASA's Marshall Space Flight Center have captured the first focused hard x-ray images of the cosmos, opening a new window of the electromagnetic spectrum for practical exploration.
Planetary Exploration	**June 06:** Bracing for an Interplanetary Traffic Jam - NASA is improving its already-extraordinary traffic control system for interplanetary spacecraft, the Deep Space Network, in preparation for a flurry of activity in deep space.
Living in Space	**June 01:** Jellyplants on Mars - Scientists are creating a new breed of glowing plants --part mustard and part jellyfish-- to help humans explore the Red Planet.

Subject	**May Articles** **Date & Title**
Living in Space	**May 30:** What Space Needs: The Human Touch - NASA's Human Exploration and Development of Space enterprise tackles one of the toughest and most redeeming problems of all: sending humans into space.
Robots	**May 29:** Brainy 'Bots - NASA's own 'Bionic Woman' is applying artificial intelligence to teach robots how to behave a little more like human explorers.
Mars Exploration	**May 24:** Unmasking the Face on Mars - New high-resolution images and 3D altimetry from NASA's Mars Global Surveyor spacecraft reveal the Face on Mars for what it really is: a mesa.

Earth Science	**May 23:** Water-Witching From Space - Farmers will soon have a new tool for getting the most out of their fields. NASA's Aqua satellite will provide crucial information about the water in the ground and the weather on the horizon.
Earth Science	**May 22:** Dust Begets Dust - Everyone knows that dry weather leads to dusty soils, but new research suggests that dust might in turn lead to dry weather.
Comets	**May 18:** A Taste for Comet Water - When Comet LINEAR broke apart last year it revealed what many scientists thought all along: Water in Earth's oceans could have come from outer space.
Earth Science	**May 17:** The Pacific Dust Express - North America has been sprinkled with a dash of Asia! A dust cloud from China crossed the Pacific Ocean recently and rained Asian dust from Alaska to Florida.
Looking Up	**May 15:** The Great Mars Rush - Hurtling toward Mars at 22,000 mph, Earth is heading for its closest encounter with the Red Planet in a dozen years. Mars is already a brilliant morning star and it will soon become a dazzling all-night spectacle.
Living in Space	**May 10:** Teaming Up on Space Plants - This week students, scientists, and astronauts will join forces to learn more about how plants grow on the International Space Station.
Mars Exploration	**May 08:** Roses for the Red Planet - What makes the Red Planet red? Right now the answer is iron oxide, but one day it could be roses say NASA scientists debating the prospects for plant life on Mars.
International Space Station	**May 04:** The Phantom Torso - An unusual space traveler named Fred is orbiting Earth on board the International Space Station. His job? To keep astronauts safe from space radiation.
Pioneer 10	**May 03:** Seven Billion Miles and Counting - Last week NASA received a weak signal from Pioneer 10, twice as far from the Sun as Pluto and speeding toward the constellation Taurus.
Mars Exploration	**May 01:** Space Weather on Mars - Future human explorers of Mars can leave their umbrellas back on Earth, but perhaps they shouldn't forget their Geiger counters! A NASA experiment en route to the Red Planet aims to find out.

Subject	**April Articles** **Date & Title**
Space Weather	**April 27**: The Transparent Sun - Giant sunspot 9393 is making a rare second transit across the face of the Sun. Its unusual reappearance came as no surprise to scientists who tracked the behemoth by peering right through our star.
The Moon	**April 26**: The Mysterious Case of Crater Giordano Bruno - A band of 12th century sky watchers saw something big hit the Moon 800 years ago. Or did they? A new study suggests the event was a meteoritic trick of the eye.
Astrobiology	**April 25**: 20,000 Leagues Under the Sea: The Webcast - Astrobiologists are visiting the Indian Ocean to explore a bizarre undersea ecosystem that doesn't need sunlight to flourish. You can join them via a live webcast on April 26th!
Materials Science	**April 23**: Look Ma -- No Hands! - Using a force field to float molten test samples precisely in mid-air, NASA's Electrostatic Levitator creates a unique environment for space-age materials processing.
Looking Up	**April 19**: Look, Listen, Lyrids! - The Lyrid meteor shower peaks on Sunday, April 22nd. Looking at the Lyrids can be fun, but now you can listen to them, too, using NASA's online meteor radar.
International Space Station	**April 18**: The Amazing Canadarm2 - Crawling around the International Space Station like an agile worm, the newest Canadian robotic arm will be essential for building and maintaining the ISS.
Astrobiology	**April 17**: Solving Charles Darwin's 'Abominable Mystery' - About 130 million years ago the first flowering plants suddenly appeared -- an event Charles Darwin described as an 'abominable mystery.' Now, scientists using chemical fossils are unraveling this ancient puzzle.
Astrobiology	**April 13**: Life as We Didn't Know It - Biologists always thought life required the Sun's energy, until they found an ecosystem that thrives in complete darkness.
International Space Station	**April 09**: Leafy Green Astronauts - NASA scientists are learning how to grow plants in space. Such far-out crops will eventually take their place alongside people, microbes and machines in self-contained habitats for astronauts.
Astrobiology	**April 05**: Was Johnny Appleseed a Comet? - A new experiment suggests that comet impacts could have sowed the seeds of life on Earth billions of years ago.

Science Education	**April 04**: Tireless Science Communication Pays Off - Last night, the Science@NASA family of web sites received the 2000 Pirelli INTERNETional, a prestigious international award for science communications.
Space Station	**April 03**: Plumbing the Space Station - Nothing goes to waste on the International Space Station where nearly everything is recycled. What makes this ecologist's dream world work? Some of the fanciest plumbing in the solar system!
Cosmology	**April 03**: A Supernova Sheds Light on Dark Energy - A discovery by astronomers using the Hubble Space Telescope supports the notion that the Universe is filled with a mysterious form of energy pushing galaxies apart at an ever-increasing rate.

Subject	**March Articles** **Date & Title**
Astrobiology	**March 30**: Back-to-School Time for Astrobiologists - NATO and NASA are joining forces to host an Advanced Study Institute for students and practitioners of astrobiology.
The Red Planet	**March 28**: The Lure of Hematite - On rusty-red Mars, a curious deposit of gray-colored hematite (a mineral cousin of common household rust) could hold the key to the mystery of elusive Martian water.
Space Weather	**March 27**: Cannibal Coronal Mass Ejections - Fast-moving solar eruptions that overtake and devour their slower-moving kin can trigger long-lasting geomagnetic storms when they strike Earth's magnetosphere.
Solar Power	**March 23**: Beam it Down, Scotty! - Solar power collected in space and beamed to Earth could be an environmentally friendly solution to our planet's growing energy problems.
Space Station	**March 21**: Staying Cool on the ISS - The International Space Station's thermal control systems maintain a delicate balance between the deep-freeze of space and the Sun's blazing heat.
Mars 2001	**March 19**: 2001 Mars Odyssey - NASA's latest mission to Mars, an orbiter scheduled for launch on April 7th, will seek out underground water-ice and explore space weather around the Red Planet.

Astronomy	**March 15**: Welcome Interference - NASA scientists have combined starlight from two of the largest telescopes on Earth to form an extraordinary new tool in the search for planets outside the solar system.
International Space Station	**March 14**: Home, Space Home - On the ground, the International Space Station would be an odd looking building -- but space is an odd place to live! Find out how space weather, orbital free fall, and the Space Shuttle's payload bay shapes the architecture of the ISS.
Space Station	**March 10**: The End is Mir - On March 22, 2001, the Russian Space Agency will ignite the engines of a Progress rocket attached to Mir and send the 135-ton space station to a watery grave in the remote south Pacific. The space station will join a surprising parade of Mir-sized objects that hit Earth every year.
Earth Science	**March 09**: Science Out of Africa - Not all NASA adventures happen in space. In this story a scientist describes his down-to-Earth encounters with poisonous snakes, charging elephants and more!
Climate Science	**March 06**: After Three Strikes, Is La Niña Out? - La Niña-like conditions that have persisted in the Pacific Ocean for three years might finally subside this Fall.
The Cutting Edge	**March 01**: Buck Rogers, Watch Out! - NASA researchers are studying insects and birds, and using smart materials with uncanny properties to develop mindboggling new aircraft designs.

Subject	**February Articles** **Date & Title**
Astrobiology	**February 28**: Magnetic Chains from Mars - Curious chains of magnetic crystals have turned up in a meteorite from Mars. Scientists say ancient martian microbes may have kept them in line.
Asteroid Eros	**February 27**: Gamma-rays from an Asteroid - Perched on the surface of asteroid 433 Eros, NASA's NEAR spacecraft is beaming back measurements of gamma-rays leaking from the space rock's dusty soil.
Optical Computing	**February 27**: Fire Photon Torpedoes! - A NASA alliance with minority colleges and universities is working to create futuristic computers that operate using particles of light.

Earth and Moon	**February 23**: The Great Moon Hoax - Yes, there really is a Moon hoax, but the prankster isn't NASA. Moon rocks and common sense prove Apollo astronauts really did visit the Moon.
Asteroids	**February 23**: Apocalypse Then - A violent collision with a space rock, like the one that doomed the dinosaurs, may have also caused our planet's greatest mass extinction 250 million years ago.
Space Weather	**February 21**: Nature's Tiniest Space Junk - NASA scientists are using an experimental radar to monitor a swarm of tiny meteoroids surrounding our planet. Listen to the echoes, live!
Looking Up	**February 20**: Blazing Venus - This is a good time to keep an eye on the fiery second planet from the Sun as it approaches Earth and delivers a dazzling sky show.
Space Weather	**February 15**: The Sun Does a Flip - NASA scientists who monitor the Sun say that our star's awesome magnetic field is flipping -- a sure sign that solar maximum is here.
Asteroid Eros	**February 14**: It's Not Over Yet! - Following one of the softest planetary landings ever, ground controllers have decided to extend the NEAR mission and gather unique data from the very surface of asteroid Eros.
The Red Planet	**February 09**: Global Warming on Mars - Artificial greenhouse gases that are bad news on Earth could provide the means to make Mars a more comfortable place for humans to live.
Earth Science	**February 07**: What Next, Galapagos? - The worst of the recent fuel spill in the Galapagos has passed ... or has it? Researchers plan to use NASA satellite data to keep an eye on the islands' unique ecosystem.
The Red Planet	**February 05**: Carbonated Mars - Here on Earth the only way to make carbonate rocks is with the aid of liquid water. Finding such rocks on Mars might prove, once and for all, that the barren Red Planet was once warm and wet.

Subject	**January Articles** **Date & Title**

The Red Planet	**January 31**: The Solar Wind at Mars - Scientists think Mars once had a thicker atmosphere than it does today, perhaps even comparable to Earth's. But where did all that Martian air go? New evidence from NASA's Mars Global Surveyor spacecraft supports a long-held suspicion that much of the Red Planet's atmosphere was simply blown away -- by the solar wind.
International Space Station	**January 30**: Students make First Contact with the ISS - Last month a group of Chicago students talked to astronauts on the International Space Station via amateur radio.
Astrobiology	**January 26**: Greening of the Red Planet - A hardy microbe from Earth that thrives where others perish might one day transform the barren ground of Mars into arable soil.
Space Weather	**January 25**: Earth's Invisible Magnetic Tail - The first global views of our planet's magnetosphere, captured by NASA's IMAGE spacecraft, reveal a curious plasma tail that stretches toward the Sun.
Water on Mars	**January 23**: Layers of Mars - If layered regions on Mars are sedimentary deposits that formed underwater, as some scientists suspect, they could be the best places to hunt for elusive Martian fossils.
Planet Earth	**January 19**: Earth Songs - If humans had radio antennas instead of ears, we would hear a remarkable symphony of strange noises coming from our own planet.
Planet Earth	**January 18**: The Eastern U.S. Keeps Its Cool - While surface temperatures across most of the globe are on the rise, the eastern U.S. appears to be slowly cooling.
Astrobiology	**January 17**: Precocious Earth - Tiny zircon crystals found in ancient stream deposits suggest that Earth harbored continents and liquid water remarkably soon after our planet formed.
Black Holes	**January 12**: New Evidence for Black Holes - By seeing almost nothing, astronomers say they've discovered something extraordinary: the event horizons of black holes in space.
Cosmic Rays	**January 12**: Ballooning for Cosmic Rays - Astronomers have long thought that supernovas are the source of cosmic rays, but there's a troubling discrepancy between theory and data. A balloon flight could shed new light on the mystery.

X-ray Astronomy	**January 11**: Chandra Links Pulsar to Historic Supernova - New evidence from NASA's Chandra X-ray Observatory suggests that a known pulsar is the present-day counterpart to a stellar explosion witnessed by Chinese astronomers in 386 AD.
Looking Up	**January 08**: A Total Eclipse of the Sun -- on the Moon! - This Tuesday, January 9th, sky watchers across some parts of Earth will enjoy a total lunar eclipse. But what would they see if they lived, instead, on the Moon?
Water on Mars	**January 05**: The Case of the Missing Mars Water - Plenty of clues suggest that liquid water once flowed on Mars --raising hopes that life could have arisen there-- but the evidence remains inconclusive and sometimes contradictory.
Planet Earth	**January 04**: Earth at Perihelion - This morning at 5 o'clock Eastern Standard time Earth made its annual closest approach to the Sun -- an event astronomers call perihelion.
Science Education	**January 03**: A New Look for the New Year - The Science@NASA home page has a new look and we're pleased to offer a host of new services as well, including Spanish-language science stories ... and more!

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Curator: Bryan Walls
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The Phantom Torso

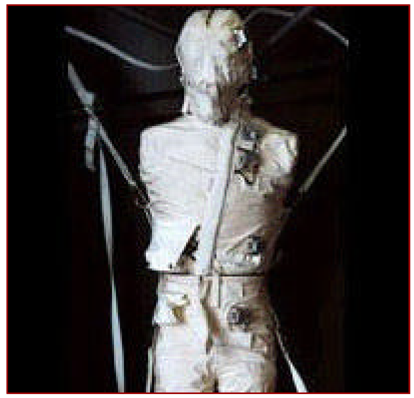
Marshall Space Flight Center

An unusual space traveler named Fred is orbiting Earth aboard the International Space Station. His job? To keep astronauts safe from space radiation.

Listen to this story (requires RealPlayer)

May 4, 2001 -- Fred has no arms. He has no legs. His job is keeping astronauts safe.

Fred is the Phantom Torso, an approximately 95-pound, 3 foot high mockup of a human upper body. Beneath Fred's artificial skin are real bones. Fred's organs -- the heart, brain, thyroid, colon and so on -- are made of a special plastic that matches as closely as possible the density of human tissue.



Right: The Phantom Torso, also known as "Fred," is an anatomical model of a human torso and head. Fred contains hundreds of radiation monitoring devices. [more information]

Fred, who's spending the next four months on board the International Space Station (ISS), will measure the amount of radiation to which astronauts are exposed. High-energy particles that pass through the human body can disrupt the way cells function. Although no astronaut has ever been diagnosed with space radiation sickness, excessive exposure could lead to health problems.

"We believe the current dose [of radiation to the crew of the ISS] is too small to be of concern," says Dr. Gautam Badhwar, the study's principal investigator at the Johnson Space Center. "The one possibility for radiation sickness might be an EVA situation during a solar event, if perhaps a crew member couldn't be brought back inside safely." But there's still lots to learn, he added, and that's where Fred can help.

The Phantom Torso is designed to do three things, explains Badhwar. First, it will determine the distribution of radiation doses inside the human body at various tissues and organs. Second, it will provide a way to correlate these doses to measurements made on the skin. "In the past we've typically recorded doses *only* on the skin," explains Badhwar, "whereas the risk to crew members is established by exposure to internal organs." Finally, the Phantom will help check the accuracy of models that predict how radiation moves through the body.

Three types of radiation can endanger astronauts in space.

The most energetic are Galactic Cosmic Rays (GCRs) -- the nuclei of atoms accelerated by supernova explosions outside our solar system. Cosmic ray nuclei can be as light as hydrogen, as heavy as iron, or almost anything in between. Because they lack their surrounding coat of negatively-charged electrons, GCRs are positively charged. The heavier nuclei carry the greatest charge, explains Badhwar. "As the charge increases, the amount of energy that the particle can deposit in tissue increases as well."

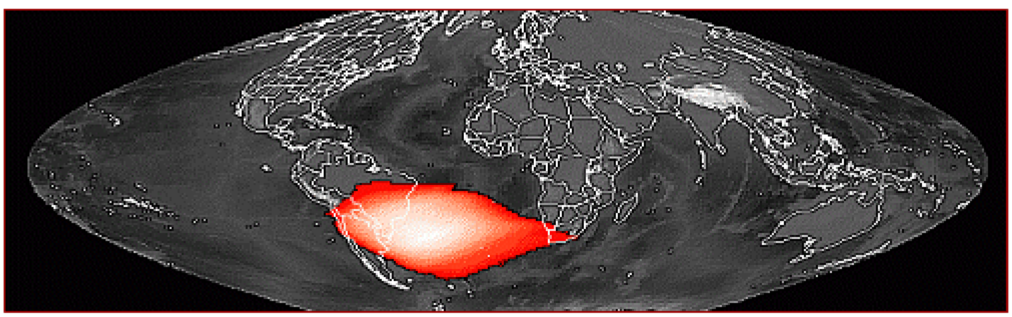
Left: Supernova explosions like this one accelerate atomic nuclei to nearly light speed. The resulting "cosmic rays" pose a potential hazard to astronauts. [more information]

The other forms of particulate radiation consist mostly of protons. Most high-energy protons in the solar system come from the Sun. Although their charge is not great and they are less energetic than GCRs, solar protons can still be dangerous when they come in intense bursts known as solar flares.

The third kind of radiation, which surrounds Earth in areas known as Van Allen belts, consist mostly of decayed products from galactic cosmic ray interactions that have been trapped by Earth's magnetic field.

Some of this trapped radiation is confined to a region above the coast of Brazil, known as the South Atlantic Anomaly. "The Space Station goes through that Anomaly roughly five times a day," says Badhwar. The passage takes, at most, 22 or 23 minutes. That's good, he says.

"If you go through the trapped radiation belt in less than twenty minutes or so, then for the next seventy minutes the body has time to do some repair to the damage done by the radiation." The radiation from solar flares can actually do more harm, he says, simply because it comes at a rate that doesn't give the body time to recover.

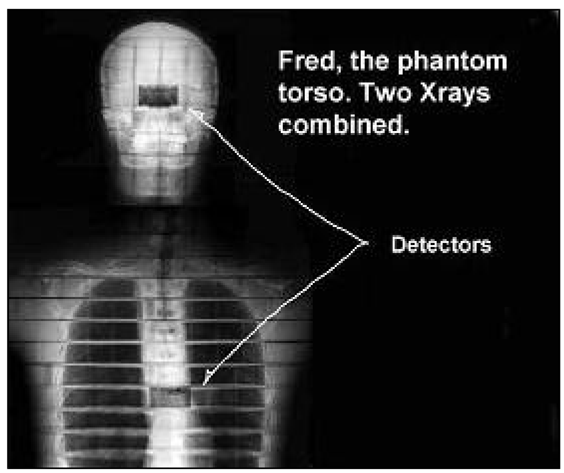


Above: The "South Atlantic Anomaly" is an area of trapped radiation located over the east coast of Brazil. [more information]

In order to measure space radiation as it propagates through Fred's body, Badhwar and his team have sliced Fred horizontally into 35 one-inch layers. In each section they've made holes for radiation detectors called dosimeters. The torso carries 416 lithium-crystal based passive dosimeters, which simply record the total radiation dose received throughout the mission. Fred is also equipped with 5 active detectors. These, placed at the Phantom's brain, thyroid, heart, colon, and stomach, can track the times that the radiation exposures took place.

"With the active detectors, we can correlate the time the radiation was received with the position of the spacecraft," explains Badhwar. "We can separate out quite reliably when we were in the Anomaly and when we were in the Galactic Cosmic Ray region." This kind of split makes radiation models derived from such data applicable to interplanetary missions, too. To assess astronaut exposure on a trip to Mars, for example, "we'll just switch off the Van Allen Belt particles," says Badhwar.

Radiation models devised by Badhwar and colleagues will be able to estimate how much radiation reaches an astronaut's internal organs simply by looking at the dose on his or her skin. That's important, because while the permissible radiation limits are based on internal exposures, practically speaking, all that can be measured is what occurs on the skin.



Right: The Phantom Torso consists of 35 sliced "sections" housed in a Nomex suit. [more information]

Such models are also scalable. Rather than giving a blanket risk assessment for all crew members, they can be customized to each individual in terms of height, weight, and even personal histories: how the astronaut flies an aircraft, or what medical tests he or she might have taken. All this contributes, says Badhwar, to total radiation exposure.

Even our internal bacteria rate a careful look: If a crew member gets too much radiation, it could kill the digestive bacteria essential for breaking down food.

Space station crew members will be sending data from the Phantom's five active dosimeters back to Earth about every ten days. When the device returns to Earth next fall, Badhwar and his team will be able to examine results from Fred's passive detectors as well.

"The thing that we're really going after is to get as good a handle as we can on what the organ exposures really are." he says. The goal is to make sure that the crew is exposed to the least amount of radiation possible.

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Web Links

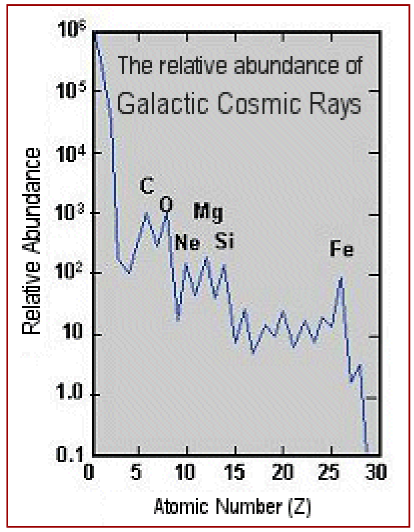
Space Radiation: Effects on Humans -- from the National Space Biomedical Research Institute

Ionizing Radiation in Space -- the basics, from the NASA/MSFC Space Environment & Effects Group

The Phantom Torso Fact Sheet -- from the NASA Marshall Space Flight Center newsroom

Galactic Cosmic Rays -- Galactic cosmic rays (GCRs) come from outside the solar system but generally from within our Milky Way galaxy. Find out more at this site from NASA/Goddard.

ISS Radiation Experiments -- Three radiation experiments are underway on the International Space Station.



Right: Galactic Cosmic Rays consist of many elements, but the lighter nuclei dominate. Heavier nuclei carry a greater charge and are more damaging to human tissue. [more information]

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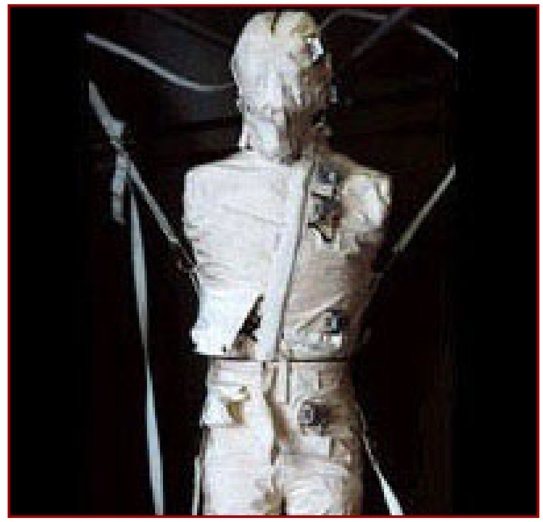
El Torso Fantasma

Un extraño viajero espacial llamado Fred gira en órbita alrededor de la Tierra en la Estación Espacial Internacional. ¿Su trabajo? Proteger a los astronautas de la radiación espacial.



Mayo 4, 2001 -- Fred no tiene brazos. No tiene piernas. Su trabajo es proteger a los astronautas.

Fred es el Torso Fantasma, una maqueta de aproximadamente 43 Kg de peso y 90 cm de altura de la parte superior del cuerpo humano. Debajo de la piel artificial de Fred se encuentran huesos verdaderos. Los órganos de Fred -- el corazón, cerebro, tiroides, colon y demás -- están hechos de un material plástico que duplica, tanto como es posible, la densidad de los tejidos humanos.

Arriba: El Torso Fantasma, conocido también como "Fred," es un modelo anatómico del torso y la cabeza humanos. Dentro de Fred existen cientos de dispositivos para detección de radiación [más información]

Fred, quien por los próximos cuatro meses estará a bordo de la Estación Espacial Internacional (EEI), medirá la cantidad de radiación a la que los astronautas estarán expuestos. Las partículas de alta velocidad que pasan a través del cuerpo humano pueden trastornar la manera como funcionan las células. Aunque ningún astronauta ha sido diagnosticado con enfermedad de radiación espacial, una exposición excesiva podría resultar en problemas de salud.

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"Creemos que la dosis actual de radiación que recibe la tripulación de la EEI es demasiado pequeña para preocuparnos," dice el Dr. Gautam Badhwar, principal investigador del estudio del Centro Espacial Johnson. "Una posible causa de enfermedad de radiación podría aparecer durante una caminata espacial simultánea con un evento solar, en el caso hipotético de que un miembro de la tripulación no pudiese ser transportado dentro de la seguridad de la Estación." Pero aún nos queda mucho por aprender, agregó y aquí es donde Fred puede ayudar.

El Torso Fantasma está diseñado para hacer tres cosas, explica Badhwar. Primero, determinará la distribución de dosis de radiación dentro del cuerpo humano en varios órganos y tejidos. Segundo, proveerá una manera de correlacionar esas dosis con medidas tomadas sobre la piel. "En el pasado, hemos registrado *sólo* las dosis sobre la piel," explica Badhwar, "mientras que el riesgo para la tripulación se determina por la exposición de los órganos internos."

Finalmente, el Fantasma ayudará a verificar la precisión de modelos que predicen cómo la radiación se mueve dentro del cuerpo.

Tres tipos de radiación pueden presentar peligros para los astronautas en el espacio.

La más seria proviene de Rayos Cósmicos Galácticos (Galactic Cosmic Rays, GCRs en inglés) -- el núcleo de átomos acelerados por explosiones de supernovas fuera de nuestro sistema solar. Los núcleos de los rayos Cósmicos pueden ser tan livianos como el hidrógeno, tan pesados como el hierro, o cualquier cosa entre estos dos extremos. Puesto que no tienen el manto de electrones con carga negativa que los rodean, los GCRs tienen carga positiva. Cuanto más pesado es el núcleo, más aumenta la carga eléctrica, explica Badhwar. "Los aumentos en la carga eléctrica aumentan también la energía que las partículas pueden depositar en los tejidos."

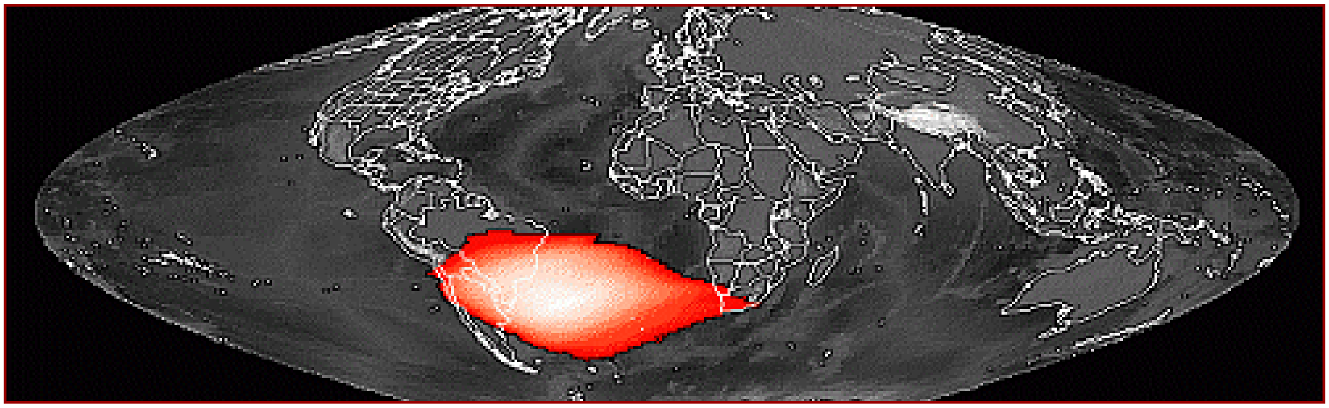
Arriba: Las explosiones de supernova como esta aceleran el núcleo atómico hasta cerca de la velocidad de la luz. Los "rayos cósmicos" que resultan son un peligro potencial para los astronautas. [más información]

Otras formas de radiación de partículas consisten, en su mayoría, de protones. La mayor parte de los protones de alta energía encontrados en el sistema solar provienen del Sol. Aunque su carga eléctrica no es tan alta y tienen menos energía que los GCRs, los protones solares pueden también ser peligrosos cuando se presentan en estallidos intensos que se conocen como erupciones solares.

La tercera clase de radiación, que se encuentra alrededor de la tierra en áreas conocidas como Cinturones Van Allen, consiste, en su mayoría, de productos secundarios de la interacción de rayos cósmicos galácticos, que han sido atrapados por el campo magnético de la Tierra.

Parte de esta radiación atrapada se encuentra en una región sobre la costa de Brasil, conocida como la "Anomalía del Atlántico Sur". "La Estación Espacial pasa sobre esta Anomalía aproximadamente cinco veces al día," dice Badhwar. El recorrido sobre la Anomalía dura cuanto mas de 22 a 23 minutos. Eso está bien, dice.

"Si usted cruza el área de radiación atrapada en menos de 20 minutos, esto quiere decir que por los siguientes setenta minutos el cuerpo tiene tiempo de reparar, al menos parcialmente, los daños causados por la radiación." La radiación originada por las erupciones solares puede causar más daño, dice, simplemente por que ésta llega en una concentración que no le da tiempo al cuerpo para recobrarse.

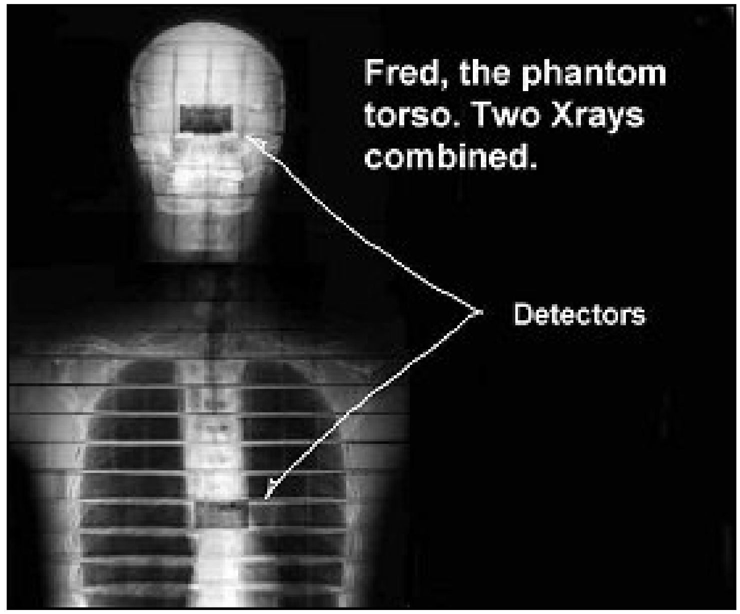


Arriba: La "Anomalía del Atlántico Sur " es un área de radiación atrapada localizada sobre la costa oriental del Brasil. [más información]

Para medir la radiación espacial mientras esta se propaga por todo el cuerpo de Fred, Badhwar y su grupo han rebanado a Fred horizontalmente en 35 tajadas de 2,5 cm (una pulgada.) En cada sección han hecho orificios para insertar detectores de radiación llamados dosímetros. El Torso contiene 416 dosímetros pasivos basándose en cristales de litio, los cuales simplemente registran la dosis de radiación total recibida durante la misión. Fred está también equipado con cinco detectores activos. Estos, colocados en el cerebro, la tiroides, el corazón el colon y el estómago del Fantasma, pueden registrar la hora en que la exposición a la radiación tuvo lugar.

"Con los detectores activos, podemos establecer la relación entre el momento cuando se recibió la radiación y la posición de la nave espacial," explica Badhwar. "De forma muy confiable podemos separar los tiempos durante los cuales estábamos en la Anomalía y cuando estábamos en la región de los Rayos Cósmicos Galácticos." Esta clase de separación permite que los modelos derivados de esta información sean también aplicables a misiones interplanetarias. Para determinar la exposición de los astronautas en un viaje a Marte, por ejemplo, "solo tenemos que descontar las partículas del Cinturón Van Allen," dice Badhwar.

Los modelos de Radiación inventados por Badhwar y sus colegas permitirán estimar cuanta radiación llega a los órganos internos de los astronautas, simplemente observando las dosis sobre la piel. Esto es importante, porque siendo que los límites aceptables de radiación se basan en la exposición de los órganos internos, para propósitos prácticos lo único que puede medirse es lo que ocurre sobre la piel.



Derecha: El Torso Fantasma consiste de 35 "secciones" recubiertas por un "vestido" Nomext. [más información]

Estos modelos son también escalables. En lugar de producir una evaluación de riesgo generalizada para todos los miembros de la tripulación, la evaluación puede ser "hecha a la medida" para cada uno de ellos teniendo en cuenta su estatura, peso e inclusive sus historias personales: la manera como un astronauta vuela en una nave espacial, o qué exámenes médicos ha tenido él o ella. Todo esto contribuye, dice Badhwar, al total de radiación a que un tripulante puede estar expuesto.

Hasta nuestra bacteria interior debe observarse con cautela: Si un miembro de la tripulación recibe una alta dosis de radiación, esto podría matar las bacterias digestivas que son esenciales para descomponer el alimento que recibe.

Los miembros de la tripulación de la Estación Espacial enviarán información tomada por los cinco dosímetros activos del Fantasma hacia la tierra, más o menos cada diez días. Cuando el Torso regrese a la Tierra el próximo otoño, Badhwar y su grupo podrán también examinar los resultados de los detectores pasivos de Fred.

"Lo que más nos interesa de todo este ejercicio, es la seguridad de que podemos tener una evaluación confiable de cual es la exposición real de los órganos," dice. El objetivo es asegurarnos que la tripulación está expuesta al mínimo posible de radiación.

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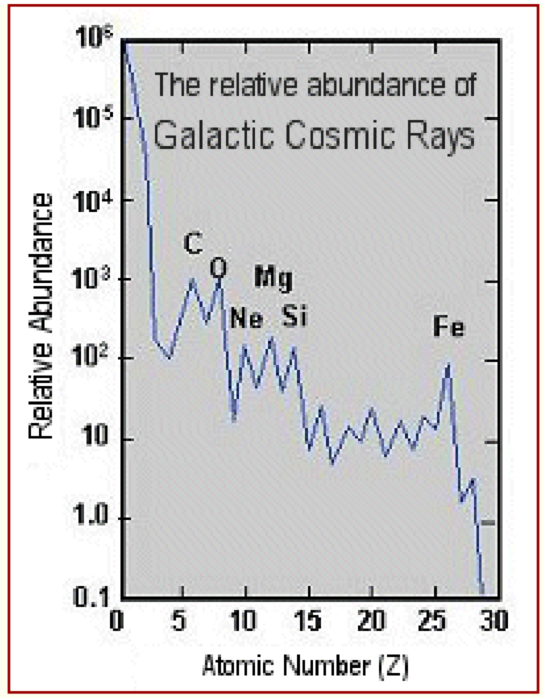
Radiación Ionizante en el Espacio -- estudios básicos del Grupo de Ambiente y Efectos Espaciales de NASA/MSFC

Especificaciones del Torso Fantasma -- de la sala de redacción del Centro Marshall de Vuelo Espacial

Rayos Cósmicos Galácticos -- Estos Rayos (GCRs) provienen de más allá de nuestro sistema solar, pero generalmente de la Vía Láctea. Aprenda más sobre este tópico en la Página de Internet de NASA/Goddard.

Experimentos sobre Radiación en la EEI -- Tres experimentos sobre radiación se llevan a cabo en la Estación Espacial.



Arriba: Los Rayos Cósmicos Galácticos consisten de muchos elementos, aunque predominan los núcleos livianos. Los núcleos pesados tienen una carga eléctrica más alta y son más dañinos para los tejidos humanos. [más información]

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