Radiation hazard in space

Human Phantom in Orbit

PAWEŁ BILSKI
Institute of Nuclear Physics, Kraków
Polish Academy of Sciences
Pawel.Bilski@ifj.edu.pl

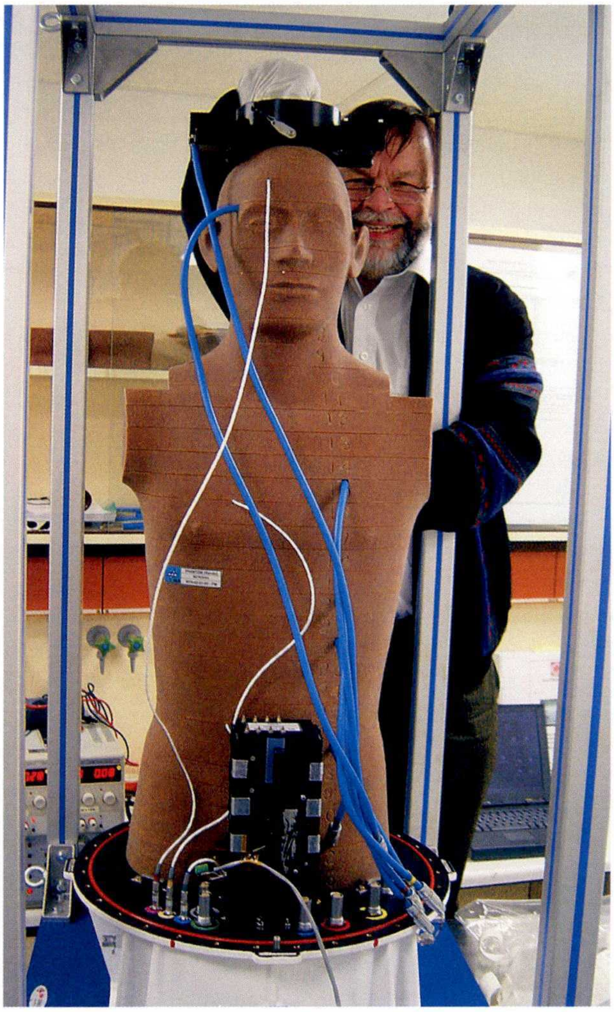
On January 29, 2004 an unmanned Progress spacecraft was launched from the Baikonur Cosmodrome in Kazakhstan, heading for the International Space Station (ISS). Scientists who study the radiation environment in space, including a group of Polish researchers, were watching this launch with special interest

The reason for this was a so-called "human phantom," i.e. a mannequin simulating a human body, which was carried on board this vehicle. Its purpose is to measure the cosmic radiation doses absorbed by the particular organs, which would be experienced by astronauts in free space. The "phantom" is equipped with a large number of radiation detectors, most of which were prepared at the Institute of Nuclear Physics in Kraków. This project, dubbed "Matroshka," was organized by the European Space Agency and led by Dr Guenther Reitz of the German Aerospace Centre (DLR) in Cologne, and is one of the most ambitious space dosimetry experiments ever to have been carried out.

The phantom is an anatomical model of the human head and torso. It consists of 33 layers (2.5 cm thick), composed of natural bones embedded in tissue-equivalent synthetic materials of differing density for the tissues and lungs. Such phantoms are quite often used to check doses in cancer radiotherapy. This time, however, one will be used to simulate, as exactly as possible, an astronaut spending time outside a spacecraft in order to work in free space.

The model was prepared to accommodate various radiation measuring experiments. The main task of the project is to determine the penetration (doses) of cosmic radiation in the human body. In order to achieve this goal, some very miniature detectors were needed. Practically the only type of detectors suitable for this application are thermoluminescent detectors (TLD), which are small, autonomous, and do not require any cables or power supply. Herein lies the reason for Polish scientists' involvement in this project: the Health Physics Laboratory of the Institute of Nuclear Physics in Kraków has extensive experience with such TLDs. This topic of research was initiated at the end of the 1960s by the late Dr Tadeusz Niewiadomski. Nowadays our laboratory (led by Dr Paweł Olko) is one of a few laboratories in the world which combine basic research in thermoluminescence phenomena with

DLR Cologne



The phantom and Dr G. Reitz

IFJ Kraków

A small TLD pellet - a miniature detector measuring cosmic radiation doses

many practical applications and the design of detectors tailored to special needs, including the ability to manufacture them in large numbers. This is why we were invited to participate in the Matroshka project.

What is thermoluminescence? When radiation encounters matter, it reacts with the atoms by ionizing them. In some materials, the electrons so generated can be trapped at metastable energy levels, and may stay there for a practically unlimited duration. When such material is heated, the electrons escape from their traps and recombine, emitting light. This light can be measured, and its intensity is proportional to the dose of radiation that was absorbed.

The most commonly used thermoluminescent material is lithium fluoride, to which different chemical activators can be added. We usually produce TLDs in the form of ceramic pellets. Even very small TLDs can measure radiation doses precisely. For this experiment we manufactured more than 4000 detectors, 4.5 mm in diameter and 0.6 mm in thickness. We used four different TLDs types, to identify the contribution of different types of cosmic radiation.

In each layer of the phantom, special channels were made to accommodate tubes containing miniature TLDs, spaced every 2.5 cm. The whole phantom is thus filled with over 5000 detectors in a 2.5 cm grid, more than 3000 of which were prepared in Kraków. Additionally, packages containing more detectors (not only TLDs but also larger nuclear track detectors) were placed at the positions of some of the important organs. A number of detectors were also located on the surface of the phantom. This will enable the doses experienced by particular human organs to be correlated with measurements taken on an astronaut's skin.

The phantom will be located outside of the ISS for one year. After that time the detectors will be retrieved and sent back to Kraków for evaluation and analysis. We believe that the results of the Matroshka project will bring us one step closer to a permanent human presence in space. ■

Further reading:

Benton E.R, Benton E.V. (2001). Space radiation dosimetry in low-Earth orbit and beyond. *Nuclear Instruments and Methods B, 184*, 255-294

Bilski P. et al (2004, in press). LiF:Mg,Ti TL detectors optimised for high-LET radiation dosimetry. *Radiation Measurements*

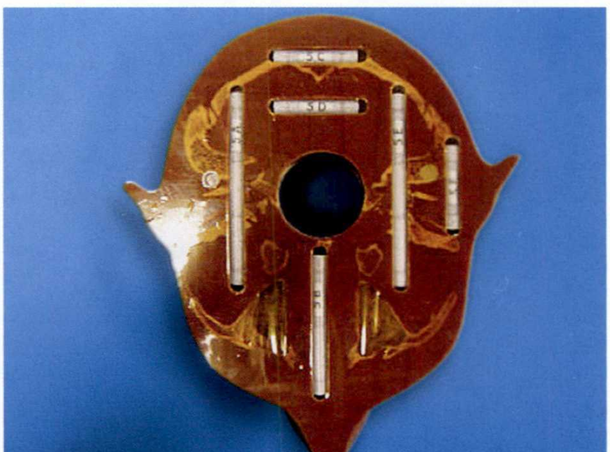
Cosmic radiation

Radiation presents an important risk to manned space flights. Although cosmic radiation is also present on the Earth's surface, we are well shielded by the atmosphere and by the magnetic field of our planet, which deflects charged particles.

In orbit, on the other hand, there are three sources of radiation: solar cosmic rays, galactic cosmic rays and Radiation Belt particles. Solar radiation is emitted from the Sun in sporadic bursts. Large events, with potentially life threatening consequences, occur rarely - four such events were observed during the last 11-year cycle of solar activity. Nevertheless, in the worst-case scenario astronauts could receive lethal doses when outside their spacecraft. Galactic cosmic radiation, in turn, originates outside the solar system. It consists of particles (mostly protons, but also heavy ions) with energies much higher than those of solar radiation. It is consequently much more penetrating, and spacecraft do not offer sufficient shielding. Radiation belts are the result of interactions between galactic and solar radiation and the Earth's magnetic field. Such belts mainly consist of trapped electrons and protons. The dose received from trapped radiation depends strongly on the parameters of the orbit. For the ISS's orbit (at an altitude of about 400 km), about half of the radiation dose comes from trapped protons, another half from the galactic component.

In summary, radiation encountered in space is a mixture of all possible types of radiation, with an extremely wide energy spectrum, so it is very different from what we can experience on Earth. This is what makes space radiation dosimetry so difficult and so interesting.

DLR Cologne



One of the slices with tubes containing TLDs. The whole phantom is filled with over 5000 TLD detectors in a 2.5 cm grid