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REVIEW AND CROSS-COMPARISON OF MATROSHKA PHANTOM MEASUREMENTS IN DIFFERENT COMPARTMENTS OF THE INTERNATIONAL SPACE STATION

Michael Hajek[1], Thomas Berger[2], Paweł Bilski[3], Daniel Matthiä[2], Monika Puchalska[3], Andrea Zechner[1], Günther Reitz[2]

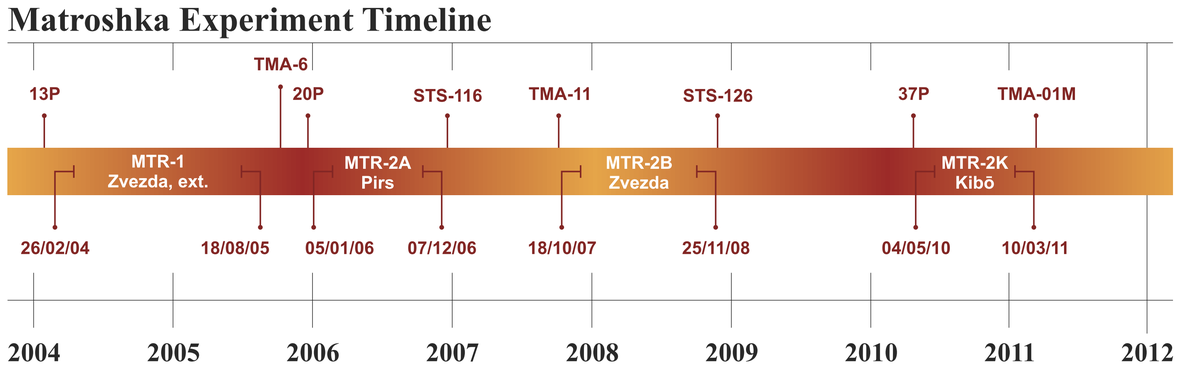
[1]Institute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria
[2]Institute of Aerospace Medicine, German Aerospace Centre, Linder Höhe, 51147 Cologne, Germany
[3]Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, ul. Radzikowskiego 152, 31-342 Krakow, Poland

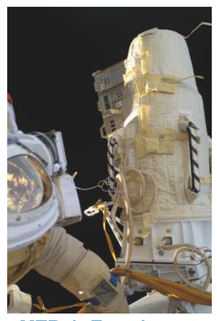
Introduction and Objectives

Astronauts working and living in space are exposed to considerably higher doses and different qualities of ionizing radiation than people on ground.

The European Space Agency's MATROSHKA experiment represents the most comprehensive effort so far in radiation protection dosimetry in space using an anthropomorphic Alderson Rando™ upper torso phantom known from radiotherapy treatment planning to map the dose distribution throughout a simulated human body on board the International Space Station (ISS). It will help improving cancer risk projections for human long-term space exploration beyond the Earth's magnetosphere.

Matroshka Experiment Timeline




MTR-1: Zvezda, ext.


MTR-2A: Pirs


MTR-2B: Zvezda

MTR-2K: Kibō

ESA MATROSHKA Facility


Torso


Poncho

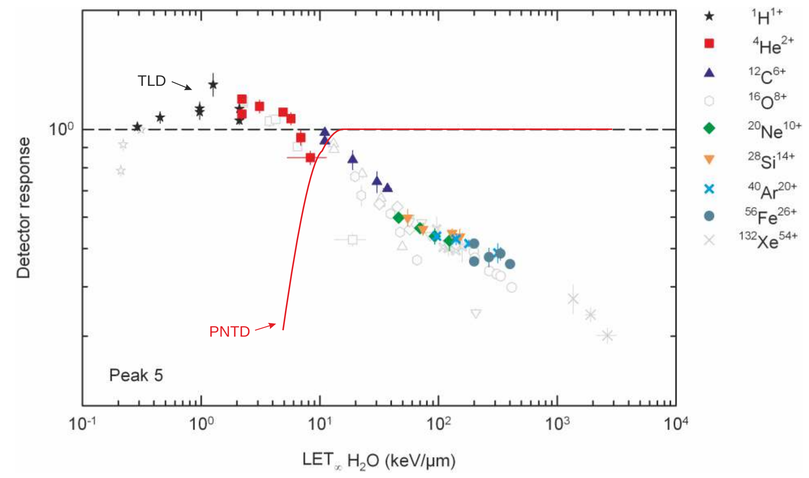

Containment


Insulation


MATROSHKA Sections


Organ and Poncho Boxes

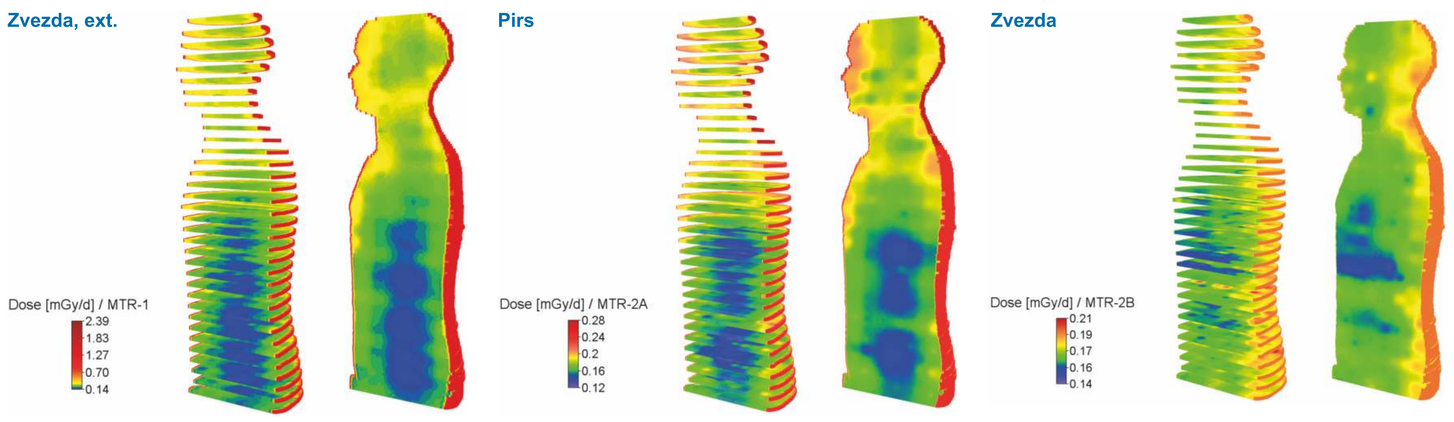
MATROSHKA is covered by a skin substitute, aka poncho, as well as a carbon fibre container and a multilayer thermal insulation to resemble the shielding properties of an astronaut's extravehicular activity spacesuit. It contains a complete set of active and passive instrumentation to account for the cosmic-ray charge and energy spectrum. Up to 5,800 thermoluminescence dosemeter (TLD) chips are used for dose mapping in a 25.4-mm orthogonal grid. Additional plastic nuclear track detector (PNTD) sheets are contained in organ and poncho boxes.



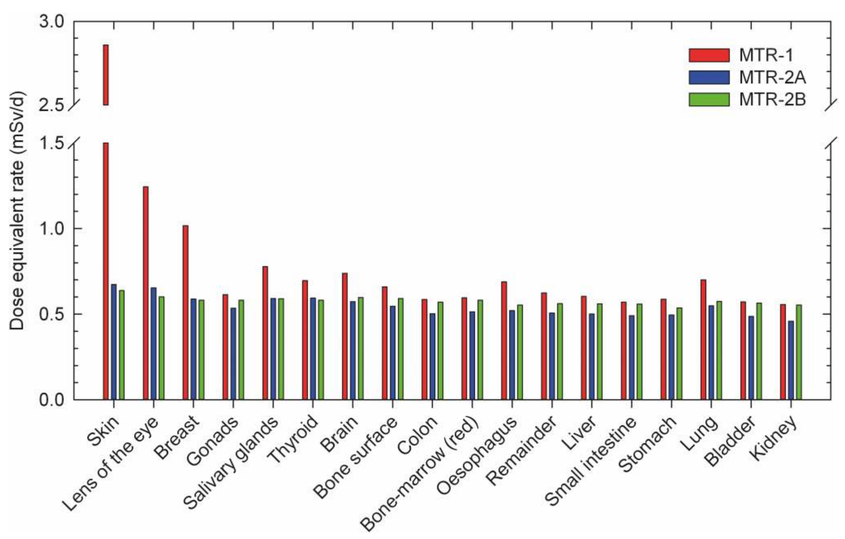
TLD and PNTD response complement each other to cover the cosmic-ray spectrum.

The operational radiation safety programme for astronauts (NCRP Report No. 142) proposed that for the complex mixtures of high- and low-LET radiations prevailing in low-Earth orbit, organ dose equivalent (based on absorbed dose and the quality factor relationship as a function of LET) should be used as the approximation for equivalent dose. Organ dose equivalent is derived from three-dimensional computational modelling, based on experimental input from TLD/PNTD measurements in the MATROSHKA phantom, and further used to provide an assessment of the effective dose for the radiation field in- and outside the ISS. A dedicated ground-based research programme was conducted at accelerator facilities in Germany, Japan and the USA in order to harmonize experimental protocols, cross-calibrate detector response and validate radiation transport codes.

Results and Discussion



The MATROSHKA experiment supports assessment of potential biological implications on the health of space crew. Both for extra- and intravehicular exposure conditions, dose hot spots in the human body could not be encountered, and the skin dose proved to be a conservative and failsafe estimate for the effective dose in both instances. The significant dose equivalent rate to the lens of the eye might, however, give rise for concern in long-duration missions. Epidemiological studies among astronauts, atomic bomb survivors, Chernobyl clean-up workers and radiological technicians indicated a potentially increased incidence of lens opacities at doses below 1 Gy. These findings make evident that cataracts induced by exposure to cosmic radiation might be an issue for future human space exploration.



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