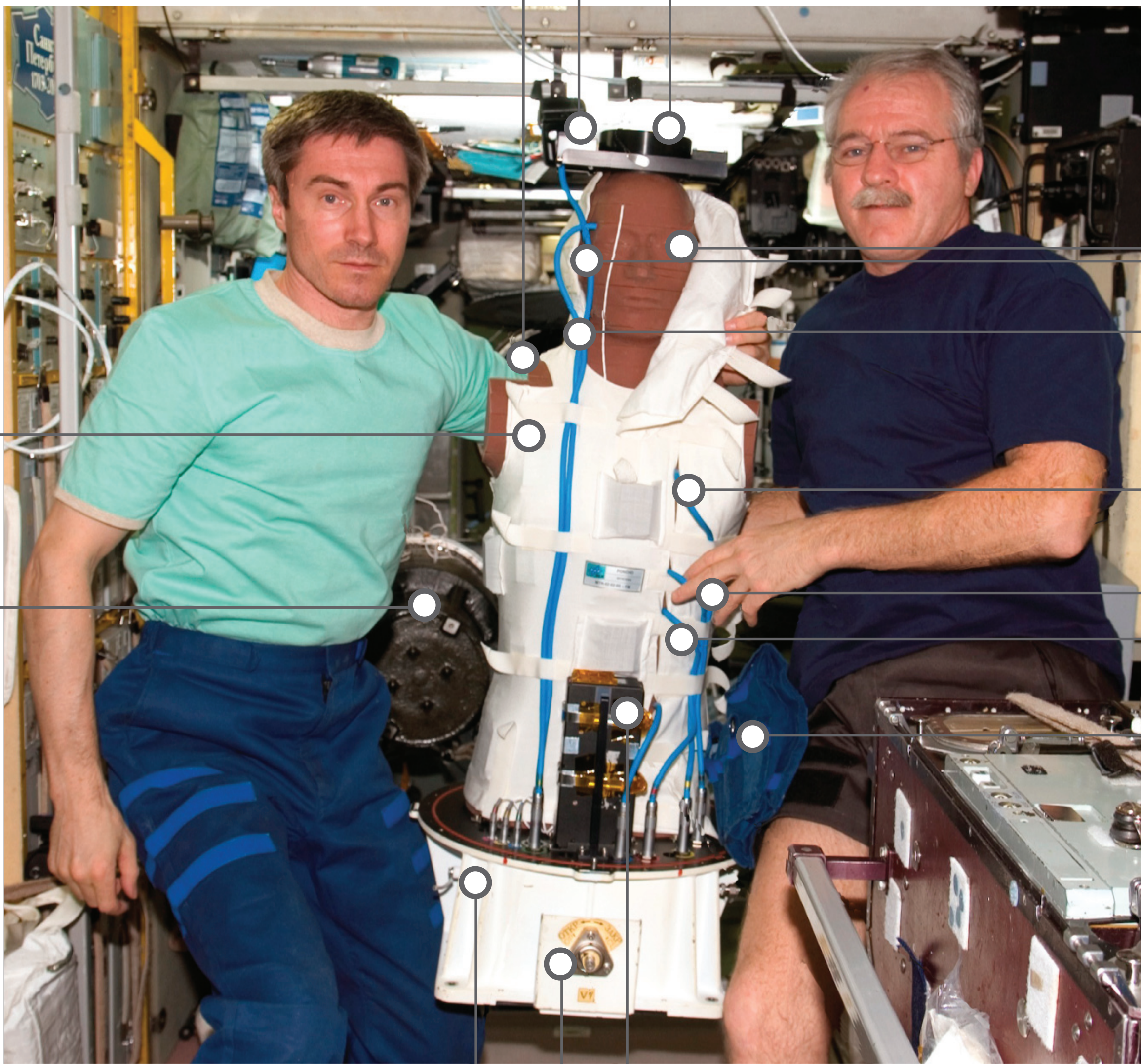
# → MATROSHKA

## Space Radiation Experiment

Matroshka measures the radiation dose at different depths in a human mannequin during external and internal space station exposure.

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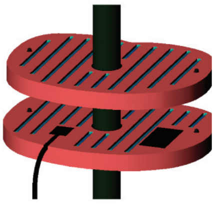
## Facility Description

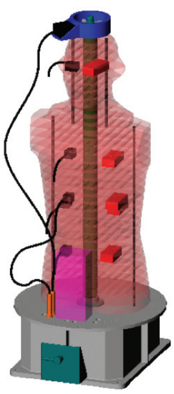
Matroshka consists of a human shape (head and torso) called the phantom, which is mounted on a base structure and placed inside an outer container of carbon fibre and reinforced plastic to simulate a spacesuit. This configuration is the reason for the name, which comes from the Russian wooden dolls, where a smaller doll always fits inside a larger one.

Inside the outer container of the experiment facility, the phantom simulates the human body with relation to size, shape, position, mass, density and nuclear interactions. It is structured of 25 mm slices, which consist of natural bone and a material, simulating natural tissue. A lower-density material is used to simulate the lungs.



25 mm slices of Matroshka's torso.

Passive and active sensors are located at various positions around and within the experiment facility to measure doses of all different types of radiation at different key organ sites such as kidney, stomach, lungs, colon and eyes. In addition the skin dose is also measured. Therefore, the phantom is clothed with a jacket carrying strips of Thermo-Luminescence Dosimeters (TLDs) embedded in Polyethylene foils and sewn into the jacket. The jacket itself also serves to fix the cables for the active experiments. Active sensors measure different radiation levels on a real time basis, with results being monitored from the Mission Control Centre in Moscow while passive sensors are analysed on return to Earth. These will provide data on the overall radiation doses experienced. Further detectors will also be monitoring the atmospheric pressure and temperature.



Concept of sensors on Matroshka.

One major design criteria of Matroshka is the simple exchange of the passive experiment sensors onboard the International Space Station. Therefore each slice of the phantom has a centre hole, which allows assembling the whole phantom over a rod, which is fixed to the Base Structure.

In order to remove the experiments from the phantom the container is removed. The central rod on top of the head is extended by unscrewing an additional rod, which allows each single layer to be lifted off. This is a convenient way to exchange the passive experiments.

Russian Cosmonaut Sergei Krikalev aboard the ISS with Matroshka in his hands and the sealed container (floating to the left) providing structural support and fixation to Zvezda's exterior.

Matroshka training model with simulated MLI (Multi-layer Insulation).

### EXPERIMENTS

Two types of experiment detectors are integrated in the phantom:

- Passive experiment packages (e.g. solid state nuclear track detectors, Thermo-Luminescence Dosimeters (TLDs) which are returned to the ground after experiment execution for their further investigation.
- Active experiment packages consisting of a sensor and associated electronics for processing of sensor data during experiment execution.

### Active Dosimeters:

**DOSTEL (Dosimetric Telescope)**

It is based on two identical passive implanted planar silicon (PIPS) detectors (Canberra Semiconductors). The produced charge is a measure of the radiation dose. It is designed to continuously monitor temporal variation of the particle count rate, the dose rate, particle and Linear Energy Transfer (LET) spectra of radiation from the Van Allen belts, deep space and the Sun.

**TEPC (Tissue Equivalent Proportional Counter)**

It is a low-pressure ionisation chamber surrounded by a 1.9 mm tissue-equivalent layer (A-100). The gas volume simulates the volume of a cell of 1 µm diameter. Electrons produced through interactions with the wall material and entering the gas volume are collected in an electric field. The TEPC measures the micro-dosimetric distribution of the radiation as a function of the linear energy, which can be used as a surrogate measurement of LET. It provides a measurement of the equivalent dose.

**SSD (Silicon Scintillator Dosimeter)**

SSD consists of a plastic-scintillator cube surrounded by silicon dosimeters and is used for light and anti-coincidence measurements. The light quantity is proportional to the radiation dose. The SSD distinguishes between charged particles and therefore allows measurement of the neutron dose.

### Passive Dosimeters:

**TLD (Thermo-Luminescence Dosimeter)**

Electrons are trapped in lattice imperfections in the TLD crystal under the impact of the radiation. When heated, the emitted luminescence signal is directly proportional to the radiation dose. The dosimeters are distributed every 2.5 cm to give a depth-dose profile within the phantom.

**PNTD (Plastic-Nuclear Track Detector)**

Particle radiation produces latent tracks, which can be made visible by an etching process. From these, scientists can generate LET-spectra, particle fluxes and energy spectra.

## SCIENTIFIC BACKGROUND

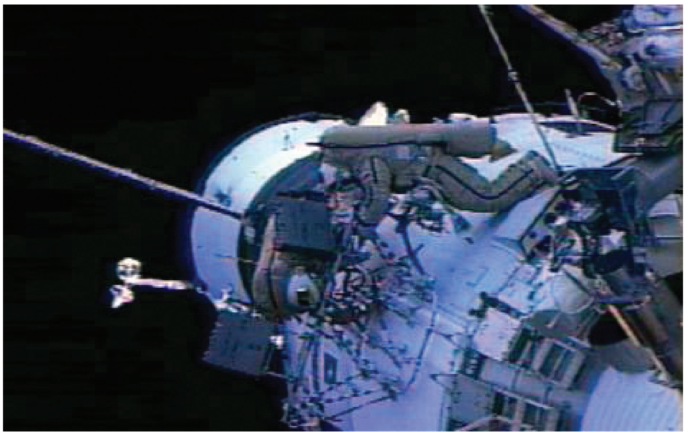
Due to the nature of the experiment, it is clear that the only way to obtain precise measurement of the radiation levels experienced by astronauts on spacewalks is by taking these measurements in-situ outside of the International Space Station.

The radiation exposure of astronauts inside the ISS during solar minimum conditions arrives at 1 mSv/day (the mean exposure on ground level is 2.5 mSv/year; Sv=Sievert). During space walks this exposure is higher by at least a factor of three. Astronauts belong therefore to the highest exposed persons. Special radiation protection guidelines exist for the European Astronaut Corps, which limit the exposure per year to 500 mSv and to 1Sv for the whole career of an astronaut.

By carrying out this experiment, details of radiation levels can be obtained without having to expose an astronaut to the environment of open space. Knowing the radiation doses suffered by sensitive body organs is crucial for assessing the hazards from cosmic radiation. Surprisingly, these are still not well known. The results obtained from this experiment can help in the development of countermeasures to the effect of cosmic radiation experienced by astronauts.

Matroshka is a cooperation between ESA and Roscosmos. Scientists from the German DLR and the Russian IBMP worked out the science involved in Matroshka. Next to ESA and DLR, Kayser Italia and DTM Technologies (Italy) contributed to the project.

NASA Astronaut Michael Foale with Matroshka inside Zvezda module.



Alexander Kaleri and Michael Foale of ISS Expedition Crew 8, mounting Matroshka during a spacewalk on 15 March 2004.

## ACCOMMODATION & TRANSPORT

The Matroshka facility has been used on the ISS for radiation science experiments since 2004.

Matroshka-1 (MTR-1) was sent to the ISS aboard the Soyuz-U/Progress M1-11 supply vehicle launched from Baikonur Cosmodrome on 24 January 2004, and was placed on the outside of the Russian Zvezda module during a spacewalk during Expedition 8 by Alexander Kaleri and Michael Foale on 15 March 2004, and brought inside during Expedition 11 on 18 August 2005. The passive detectors were removed and returned to Earth with that crew on 11 October 2005. The phantom itself including the active detectors remained on board of the ISS.

Two months later, a fresh set passive detectors was uploaded aboard Progress 20P. After installation in the phantom, the recordings were resumed but this time not outside, but inside the ISS, in the PIRS module. This part of the project was known as Matroshka-2a (MTR-2a). MTR-2a was followed by MRT-2b in 2007, with the phantom moved from the PIRS module into the Zvezda module.

The fourth experiment performed with the Matroshka facility was referred to as Matroshka-KIBO; it covered for the first time measurements inside the Japanese KIBO JPM (JEM Pressurized Module), complementing the earlier Matroshka results by adding radiation data acquired during a different phase of the solar cycle. Matroshka-KIBO was in action from May 2010 till March 2011.

## OPERATIONAL CONCEPT

Active sensors measure different radiation levels on a real time basis, with results being monitored from the Mission Control Centre in Moscow while passive sensors are analysed on return to Earth.

## UTILISATION SCENARIO

The container as well as the phantom were mounted to the base structure, which serves as a footprint for the human phantom. The container is a Carbon Fiber structure and forms with the Base Structure a closed volume that contains a dry oxygen atmosphere and protects the phantom against e.g. space vacuum, space debris, solar UV, and material off-gassing. It acts also as a simulation of the space suit. The container is pressed over the phantom at the head and the shoulders to stabilize the total structure. In the Base Structure the facility and experiment electronics are accommodated. The facility electronics provide the interface between Matroshka and the Russian Service module. Temperature, pressure and experiment data are collected during the mission and transferred to the onboard computer system, and from there, downlinked to the ground.

Russian cosmonauts Alexander Kaleri (left foreground), Oleg Skripochka (right foreground), Dmitry Kondratyev (left background) and European Space Agency astronaut Paolo Nespoli, all Expedition 26 flight engineers, pose for a photo with the European Matroshka-R phantom experiment in the Zarya Functional Cargo Block (FGB) of the International Space Station.

Matroshka in the Japanese Kibo laboratory.