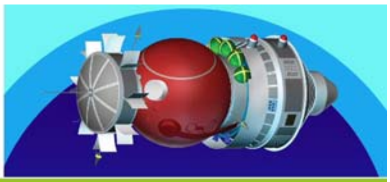
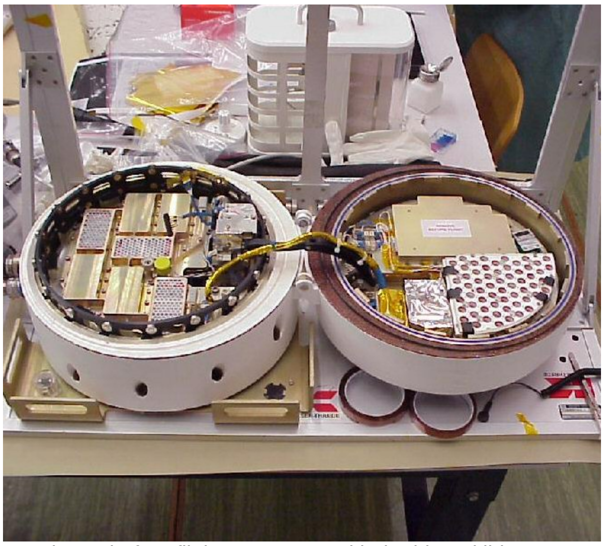


Biopan Experiment Facility

Biopan was developed in the early nineties as a multi-user experimental facility, designed to investigate the effect of the space environment on biological material as well as for carrying out material science investigations requiring exposure to the space environment. As such the experiments in Biopan are exposed to solar and space radiation, the space vacuum and weightlessness, or a selection thereof. Optionally, the experiment temperature can be stabilised. In this way Biopan can evaluate the combined or individual effects of radiation, vacuum, extreme temperatures and weightlessness on biological samples, material specimens and electronic components.



Biopan before flight at ESTEC, with the hinged lid open. Experimenter-provided packages are mounted on support plates in the bottom and the lid. (Image: ESA)

Designed for medium-duration missions on Russian retrievable satellites, Biopan filled the gap between the Russian KNA exposure containers* and the advanced ERA facility on Eureca**. Biopan completed four successful missions on a test flight in 1992, Foton-9 in 1994, Foton-11 in 1997 and Foton-12 in 1999. A fifth attempt failed in 2002 due to a launcher failure.

The Biopan facility is installed on the external surface of the Foton descent capsule protruding from the thermal blanket that envelops the satellite. It has a motor-driven hinged lid, which opens 180° in orbit to expose the experiment samples to the harsh space environment. For re-entry, the closed facility is protected with an ablative heat shield.

The facility is equipped with thermometers, UV sensors, a radiometer, a pressure sensor and an active radiation dosimeter. If controlled, the temperature can be stabilised between 5°C and 25°C. If uncontrolled, the temperature can fluctuate from less than -35°C to more than +30°C Biopan can also be flown in a mixed mode with one set of experiments being thermally controlled, and another not. Data acquired by the sensors is stored by Biopan throughout the mission and can be accessed after flight.

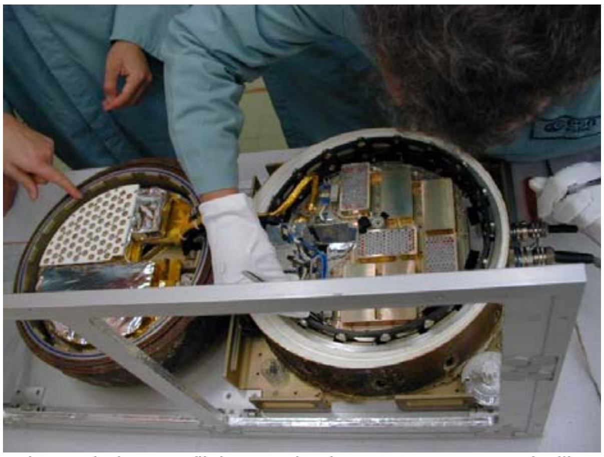
Biopan experiment facility installed on external surface of Foton-12 spacecraft prior to launch. 6 September 1999
(Image: ESA)

For the Foton-M2 mission, the Biopan facility has had some internal modifications including a new microcontroller for more efficient data handling, a new radiometer, an increased number of temperature sensors, new software, a larger emergency battery and a new lid structure to accommodate more and heavier experiments.

The experiment packages inside are individually designed and provided by the experiment investigators themselves. These packages are mounted on simple support plates either in the bottom or in the lid of Biopan, providing a total surface area of 1080 cm^2. The maximum experiment mass is 4 kg with a maximum experiment height of 25 mm (50 mm if only the bottom or the lid are occupied). The surface area and the experiment mass are shared between four to nine different experiments.

Biopan after landing with the lid closed. The facility is covered by a massive ablative skin to shield the experiments against the re-entry heat.

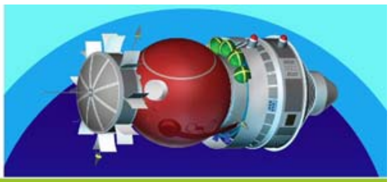
Biopan will be hosting nine individual experiments for the Foton-M2 mission: two in radiation biology (**PHOTO**, **YEAST II**), three in radiation dosimetry (**RADO**, **RD3-B**, **LETVAR**) and four in exobiology (**ORGANICS**, **LICHENS**, **MARSTOX**, **PERMAFROST**).



Biopan during postflight examination at ESA's ESTEC facility in Noordwijk, the Netherlands (Image: ESA)

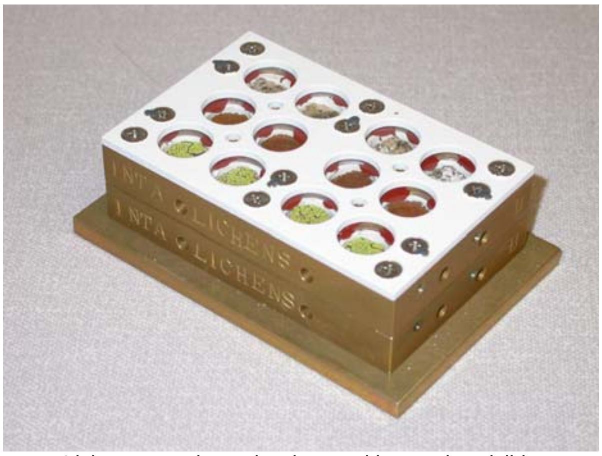
The experiment packages are hermetically sealed before launch with an internal environment maintained at 1 atmosphere in an inert atmosphere of dry nitrogen. In orbit, Biopan is first evacuated and then opened to expose the experiments to free space. One day before landing Biopan is hermetically closed by telecommand. Three to four days after landing, Biopan is returned to ESA's ESTEC facility in the Netherlands, remaining hermetically closed and evacuated. One day later Biopan is re-pressurised and opened, after which the experiments can be returned to the investigators.

* Used by ESA from 1987 until 1992 on three consecutive Bion missions for radiobiological exposure experiments.
** Exobiological Radiation Assembly on the European Retrievable Carrier; first (and only) flight 31 July 1992 - 7 August 1993.



LICHENS

Lichens as extremophile organisms in space



Lichens experiment hardware with samples visible

Lichens are well-known "extremophiles", able to stay alive under the most adverse environmental conditions on Earth. The limits of survival will be further probed in this experiment, by exposing lichens to the harsh conditions of space. Two types of samples are foreseen: thallaconidia (a-sexual fungal spores) and thallus fragments.

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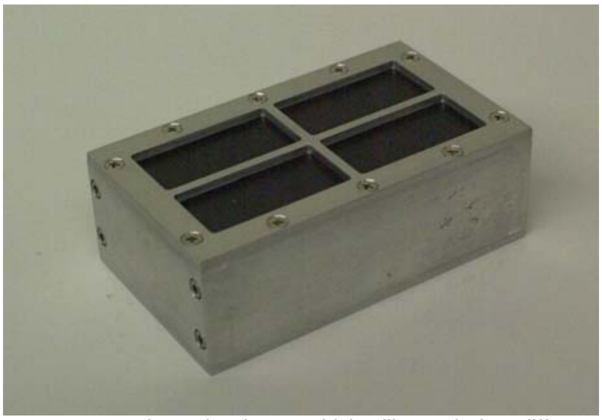
LETVAR

Measurement of the change of averaged linear energy transfer in various shielding materials by the use of thermo-luminescence detectors.

Shielding materials do not only affect the quantity of cosmic rays that go through them, but also the quality. In this experiment, the effectiveness of four different shielding materials will be compared: aluminum and three types of polymers (plastic). (LETVAR = Linear Energy Transfer variations)



LETVAR experiment hardware, which will contain four different types of shielding material

The total dose absorbed behind these four materials will be measured, as well as the decrease in the average linear energy transfer of passing through the shielding materials. Linear energy transfer is the energy the radioactive particles lose over distance. In this case the distance equates to the thickness of the shielding materials.

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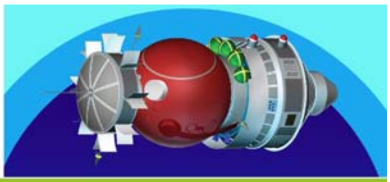
Human Spaceflight
SPACE FOR LIFE

Foton-M2
Mission



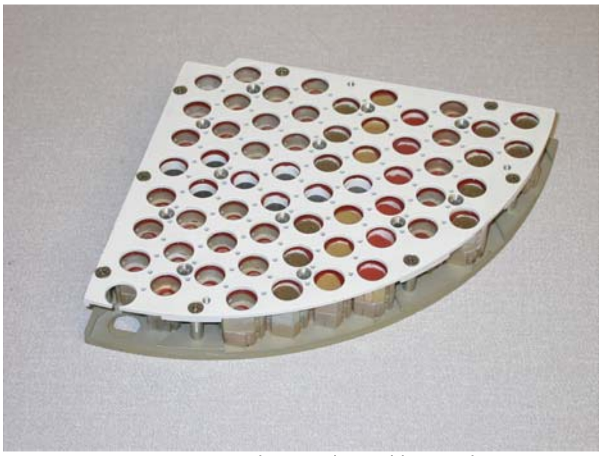
Space Exposure Experiments

MARSTOX

Martian soil, solar UV radiation and spores: protection and toxicity

In the experiment MARSTOX, the survivability of bacterial spores of *Bacillus subtilis* will be investigated under the extreme environmental conditions as they exist on the surface of Mars.

The results obtained from the two Viking missions to Mars indicated that the top layer of the soil of this planet is sterile. This may be explained by toxic effects, due to a combination of intense UV radiation and the specific chemical composition of the Martian soil.



MARSTOX sample container with samples

In the MARSTOX experiment, the alleged toxicity of the Martian soil will be tested. Bacterial spores, mixed with a substance simulating Martian soil will be exposed to solar UV at dose and wavelength levels comparable to those on Mars.

The MARSTOX experiment will be a preparatory step for the future exploration of Mars as another planet, which has had the potential for evolution of life.

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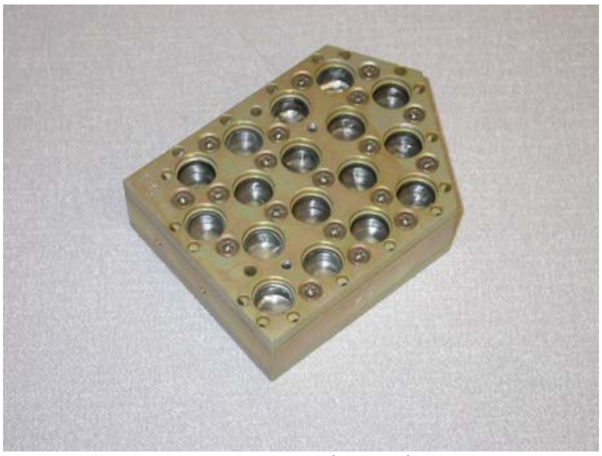
ORGANICS

Extraterrestrial delivery of organic molecules

Organic molecules, the building blocks for life, may have originated from lightning, which interacted with simple molecules in the atmosphere of the Earth (Miller-Urey experiment from 1953). Modern research however indicates that the organic (carbon-containing) molecules on Earth may have an extraterrestrial origin. Many pre-fabricated organic molecules have been detected in meteorites, comets and cosmic dust. Such molecules may have landed on Earth (and probably, they still do).



ORGANICS sample container

In the ORGANICS experiment, organic molecules and derivatives thereof which are known to occur in meteorites, comets and cosmic dust – such as polycyclic aromatic hydrocarbons (PAHs), fullerenes and amino acids – will be tested for their stability when exposed to the harsh space environment in low Earth orbit. The results will help to understand the role that import of organics from space may have played in the onset of life on Earth.

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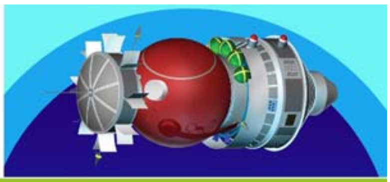

PERMAFROST

The influence of the space environment on the viability of the ancient permafrost microbial communities

In ancient samples of permafrost soil from Siberia, a multitude of viable cells have been identified that, after a multi-million year period of hibernation in the frozen ground, are still able to germinate when transferred to non-frozen conditions. Most planets of our solar system, their satellites, comets and asteroids are of a cryogenic nature, i.e. at a very low temperature.

Permafrost hardware showing soil samples

To investigate if such cryogenic bodies could carry viable cells though our solar system, two samples of permafrost soil will be exposed to the space environment. After flight, the samples will be assessed for effects on survival, biodiversity (variation of organisms), DNA structure and metabolic activity.

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R3D-B

Active monitoring of the UV and ionising radiation conditions in the Biopan facility

R3D-B experiment dosimeter

The R3D-B (Radiation Risks Radiometer-Dosimeter for Biopan) is an environmental monitor which records, over time, the dose of solar light over four different wavelength ranges (UV-A, UV-B, UV-C and photosynthetic active light) as well as the flux of heavy cosmic particles.

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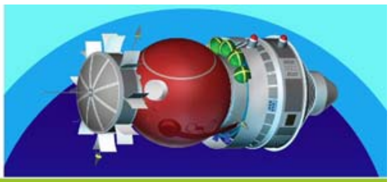

PHOTO-I

An automatic photosystem-II based bio-device to reveal the effect of space radiation on mutants of photosynthetic oxygenic microorganisms

PHOTO-I experiment hardware, which will contain unicellular algae

Photosynthesis is the conversion of light energy into chemical energy. Photosynthetic organisms are unique as they can use light energy to split water molecules and develop oxygen by means of what is known as photosystem II apparatus, in a process that produces storable energy-rich products from atmospheric carbon dioxide. Algae and cyanobacteria, which can grow in the presence of nutrients and carbonate are expected to be utilised in the future to maintain an oxygenic-atmosphere and to give biomass for astronauts in spacecraft and on the ISS.

However, space is permeated by radiation, which damages the D1 protein of the photosystem II apparatus and greatly reduces its oxygen-evolving efficiency. Recent advancement of knowledge demonstrated that tolerance in the form of defence mechanisms has been evolved in photosynthetic organisms to cope with presence of radiation, based on a repair cycle of D1 protein.

Later experiments in stratospheric balloons have indicated that much lower doses (mGy) of natural radiation, in conjunction with visible sunlight, also leads to degradation of the D1 protein. This effect will further be investigated in the PHOTO (PHOTO-I and PHOTO-II*) experiment. Unicellular algae, mutated or not, will be exposed to space radiation in combination with solar light, to test the effects on the turnover of D1 protein and photosystem II activity.

PHOTO-I is accompanied by a complementary experiment inside the capsule, named PHOTO-II.

PHOTO-II is a sensor developed by Carso, able to monitor automatically in flight fluorescence and photosynthetic activity of several mutated algae (Chlamydomanas reinhardtii).

A dosimeter and fluxmeter joined to the PHOTO-II sensor will monitor space radiation inside Foton enabling a comparison of the radiation dose revealed in Biopan. The two experiments differ in that the PHOTO-II experiment will determine the biological effects during the course of the flight, whereas PHOTO-I experiment will determine the net effect of absorbed radiation on completion of the flight.

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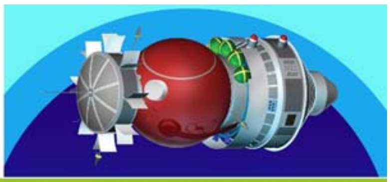


RADO

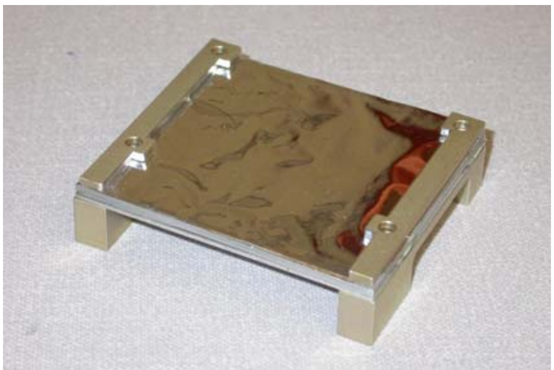
Radiation dosimetry outside the recoverable Foton spacecraft

RADO (RAdiation DOsimetry) is a diverse experiment to measure radiation doses, comprising a set of five different detection methods. Special attention is paid to measuring radiation doses behind extremely thin levels of shielding. The detection methods are as follows:

1. Teflon rods loaded with thermo-luminescence detectors. After flight, the rods will be sliced into ultra-thin disks, which are separately analysed. This will provide a highly detailed picture of the absorbed radiation dose throughout the depth within the Teflon.

Teflon rods

2. Thermo-luminescence detectors covered by 1, 2, 3 or 4 super-thin foils (1.3 mg/cm^2 per foil). The differences in absorbed dose due to the number of foils will make it possible to assess the energy spectrum of the softest electrons in the space radiation spectrum.

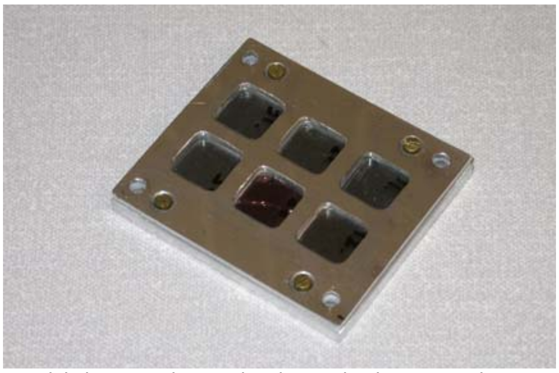


Foil covering thermo-luminescence detectors

3. The High Temperature Ratio method will be applied to lithium fluoride thermo-luminescent detectors. In this method the detectors (crystals) are steadily heated to a certain temperature, post-flight. The pattern of intensity of light that the detectors emit at different temperatures (the glow curve) is used to determine the types of radioactive particles that have come in contact with the detectors.

4. A stack of solid state nuclear track etch detectors will be used to determine the incidence of neutrons. Neutron particles are produced by high-energy cosmic rays in Earth's atmosphere.

5. Thermo-luminescence detectors are placed behind a layer of special glass, to measure the protective properties of electrically-charged glass coatings against space radiation.



Special glass panels covering thermo-luminescence detectors

In addition, a complementary set of six RADO detectors (thermo-luminescence detectors plus plastic detectors) is placed inside the Foton capsule distributed over six different locations. This forms the RADO II experiment.

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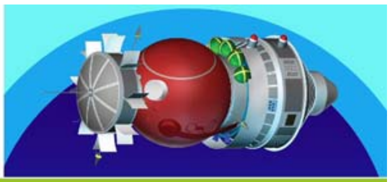
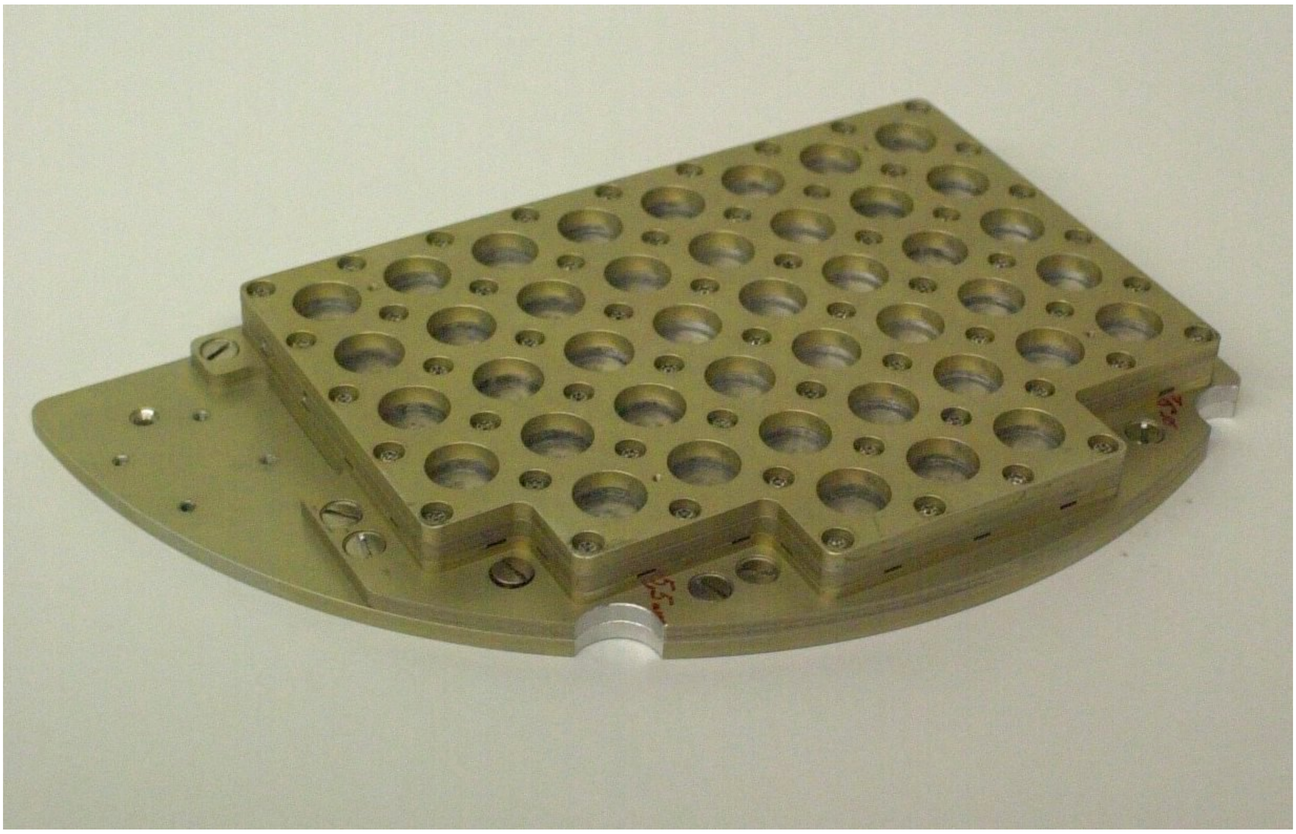


YEAST

Biological assessment of space radiation in low-Earth orbit



Yeast experiment hardware

In the YEAST experiment, a simple type of eukaryotic cells (yeast) is exposed to space radiation. This is protected by a minimal amount of shielding materials to optimise the exposition to soft radiation rays. Soft radiation, as opposed to hard radiation, is of lower frequency and less penetrating.

The YEAST experiment made its maiden flight on Biopan-3 in 1999. For the first time, a biological effect (a decreased rate of survival in yeast cells) was determined caused by the soft components of the space radiation spectrum. The new YEAST experiment on Biopan-5 will be a repetition, augmented with improved radiation dosimeters to measure with a higher precision the total dose of soft radiation absorbed during the flight.

Whereas most radio-biological studies in space have been focussed on the harder parts of the radiation spectrum (in particular HZE particles), little is known about the biological effects of the abundant softer components, i.e. belt electrons and low-energy protons. The soft space rays, which make up more than 99.9% of the total radiation dose absorbed in low-Earth orbit, usually do not permeate inside a spacecraft – a shielding level of just 2 g/cm^2 is enough to stop them. However, soft radiation certainly plays a role during spacewalks (EVAs), when the astronauts are no longer protected by the spacecraft structure.

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