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DESCRIPTION OF THE R3D INSTRUMENT FOR THE ROSE EXPERIMENT ON ISS

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Abstract

The external platform of the International Space Station (ISS) will provide a unique testbed for exobiological studies of processes under free space conditions. To this end, ESA is developing the EXPOSE facility that is to be attached to the External Pallet of the truss structure of the ISS for 1.5 years during the ISS early utilization period. EXPOSE will support long term *in situ* studies of microbes in artificial meteorites as well as of microbial communities from special ecological niches, such as endolithic and endoevaporitic ecosystems. The Radiation Risks Radiometer-Dosimeter (R3D) is a low mass and small dimensions automatic device, which will measure solar radiation in 4 channels and cosmic ionizing radiation. The four-channel: UV-A (315-400 nm), UV-B (280-315 nm), UV-C (<280 nm) and Photosynthetic Active Radiation (PAR) (400-700 nm) filter dosimeter will measure the solar UV irradiance in W/m^2. Additional measurements of the temperature of the UV detectors are performed for more precise UV irradiance measurements. The deposited energy spectra of the cosmic ionizing radiation will be measured in a 256-channel spectrometer. The analysis of the spectra will give as well the total dose in µGy/h and the particle flux in particle/cm^2 s. Measurements of the UV and ionizing radiation parameters will have 10 second time resolution and will be transmitted by the ISS telemetry system to the ground. All available data will be organized in a specialized database, which will support the analysis of the experiments on the EXPOSE facility.

Scientific background of the experiment SPORES

Recent discoveries have given new support to the theory of Panspermia. These include the detection and analysis of Mars meteorites, the high UV resistance of microorganisms at the low temperatures of deep space, and the high survival of bacterial spores over extended periods in space. Although it will be difficult to prove that life could be transported through our solar system, estimates of the different steps of the process to occur will be obtained from the experiments of the ROSE consortium. In the experiment SPORES, it will be investigated whether meteorite material offers enough protection against the harsh environment of space for spores to survive a long-term journey in space. For this purpose, biological test systems of known adaptive strategies to survive extreme conditions, such as bacterial, fungal and lycopod spores, will be embedded in artificial meteorites and exposed to space within EXPOSE. After a 1.5 year lasting journey in Earth orbit, their viability and impairment will be analyzed in the laboratory by a set of biological and biochemical assays. The experiment is lead by Dr. Gerda Horneck and will be performed in cooperation with B. Hock, H. Wänke, P. Rettberg, C. Baumstark-Khan, D.-P. Häder, D. Mishev, T. Dachev, and G. Reitz [1].

The first objective will be to produce a snapshot of a hypothetical journey of spores inside a meteorite by mimicking the natural conditions of a meteorite in space as close as possible within the constraints of EXPOSE. For this purpose, an artificial meteorite harboring spores at different depths from the surface will be exposed to space under the conditions, given by the Space Station, i.e. free access to space vacuum, minimal protection against solar and cosmic radiation, no special orientation requirements.

The second objective is based on the fact that sunlight is one of the most critical factors for spores limiting their survival in space. Therefore mounting the artificial meteorite in one of the pockets of EXPOSE, which will be oriented to the sun, will substantially increase the total period of insolation. Otherwise, the scenario will be similar to that constructed for the first objective. Assuming an orientation to the sun for 15 min every orbit, after 1.5 years the upper layers of this meteorite will receive a UV (110-400 nm) dose of approximately 5 x 10^8 J/m². A spherical but in its orientation to the Sun freely moving meteorite receives at each surface unit a mean UV flux of one quarter of the total UV flux at its location. Hence, for the time a meteorite spends at 1 AU (Earth orbit), the irradiation conditions will be very similar to those of the proposed experiment. Depending on their parent body (Mars or asteroid belt) meteorites spend only a fraction of their lifetime at 1 AU. Hence, the UV flux to which a meteorite is exposed during its lifetime as a free object in space (≈ mys) is approximately a factor of 2 to 10 lower.

The third objective will be to determine systematically the protective effects of meteorite material against the different parameters of space, applied individually or in selected combinations, especially space vacuum, cosmic radiation and different spectral ranges of solar UV radiation. For this purpose, spores, either isolated as dry multilayers or tablets or embedded in meteorite material will be exposed to defined and controlled parameters of space within EXPOSE. In addition, the shielding by thin layers cut from meteorites will be assessed.

The specific objectives of the R3D instrument are as follows:

To determine the radiation climate (UV and ionizing) outside of ISS at SEBA or close to the EXPOSE facility by three independent and complementary procedures as follows:

- Solar UV radiation outside of ISS at the SEBA-EXPOSE unit by use of an automatic electronic UV dosimeter, which measures irradiances in W/m^2, physically weighted in accordance to the minimal erythema response curve [2] for the UV radiation;
- Solar irradiation in the UV-C (<280 nm), UV-B (280 - 315 nm), UV-A (315- 400 nm) and PAR (400 - 700 nm) channels with a four channel filter dosimeter;
- Cosmic ionizing radiation unit by use of a automatic electronic particle dosimeter, which measures in μGy/h and in particle/cm^2 s as the two space radiation parameters.
- Investigation of the global distribution of absorbed dose, dose equivalent and flux;
- Study of the dose composition under normal and disturbed conditions in space;
- Verification and improvement of space dosimetry methods for long-duration space flights.

Earth radiation environment at the orbit of the ISS in great detail are similar to those observed aboard the MIR space station, because of the same orbit attitudes. The space radiation ranges of the measurements with the proposed R3D instrument are based on the experience obtained during the long-time experiment LIULIN on the MIR space station [3-5].

Predicted doses and fluxes behind 6-15g/cm^2 shielding for periods of high solar activity, at different altitudes of ISS, inside of SAA are given in Table 1. The prediction is based on the LIULIN data extrapolation from the

Table 1 Predicted doses and fluxes at different altitudes of ISS

Altitude [km]	Dose [μGy/h] minimum	Dose [μGy/h] maximum	Flux [cm^{-2} s^{-1}] minimum	Flux [cm^{-2} s^{-1}] maximum
400	253	305	21	28
425	493	616	38	57
450	923	1197	65	111
475	1672	2244	107	207
500	2936	4073	174	377

altitudes of the MIR space station (360-425 km) up to 500 km. More than 1,500,000 with 10-s resolution data points in 1991 are used to be obtained the values in Table 1:

Instrument description

R3D is a low-mass and low-dimension automatic device which measures solar UV radiation in 4 channels and cosmic ionizing radiation. Figure 1 shows the block diagram of the instrument. The size of the aluminum box of the instrument is 76x76x34 millimeters. The expected weight is 200±20 grams. The instrument will be mounted by 4 (4 mm) bolts in one of the pockets of the EXPOSE facility under a MgF_2 cover. From EXPOSE the instrument obtains two fixed voltages +15 V DC and -15 V DC with 90 +10/-30 and 40 +10/-30 mA current consumption, respectively. The telemetry output from the instrument is arranged as RS422 serial interface with a maximum rate of 19.2 kbps.

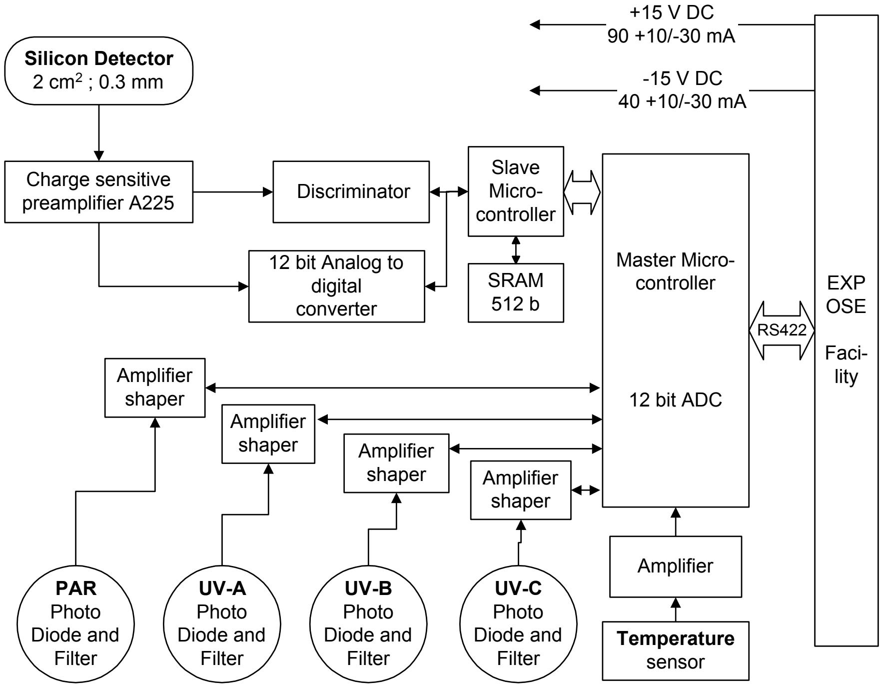

Figure 1 Block-diagram of R3D instrument

The instrument is managed by a master microcontroller, which contains a 12 bit ADC and multiplexer. The master controller, the ADC and the multiplexer are directly engaged with the UV and the temperature measurements. These measurements are described in detail in [6,7].

The dose and flux measurements are arranged by a slave microcontroller where the deposited energy spectrum is composed. Then the spectrum is transferred to the master microcontroller and to the telemetry. The measurement cycle of the instrument is fixed at 10 s. During this time 256 measurements of the UV and temperature channels are performed. The averaged values are transferred to the telemetry. In the same time one energy deposition spectrum from the cosmic ionizing radiation channel is accumulated.

There is a protocol between EXPOSE and R3D of the type "master-slave". EXPOSE is the master, R3D is the slave. EXPOSE is synchronized by the board time with 10 s intervals. A one byte command is sent to R3D meaning "Request for Data". To this command the R3D answers with a fixed size (1024 byte) packet of information with 19200/9600 baud rate and then stops till the next "request for data". To this packet of information is attached a header from EXPOSE, which contains the board time which will be used for the data interpretation on the ground.

The Functional Test Equipment (FTE) of R3D instrument consists of a Personal Computer, embedded programs and a power block. It allows full functional checkout of the R3D instrument before integration into EXPOSE, and without any need for further test equipment. Connectors are of high quality to allow multiple connections/disconnections. The equipment operates on 115V/60Hz or 230V/50Hz electrical mains supply. In addition to the simulation of the power and data interfaces it is highly recommended to include the means to check the different sensors separately (light sources). The specialized software product, which is developed in "WIN95/NT" environment and permits the user: 1. to adjust the frequency of the measurements and the measurement parameters levels; 2. to transmit these initialization parameters to the R3D instrument; 3. to order the instrument to transmit back to the PC the measured data; 4. to organize the file directory and "Quick look" data view on the monitor of the PC.

Figure 2 shows one example of the "Quick look" data view. The 3 panels contains data as follows: panel 1 contains the ET-diagram of the ionizing radiation channel, which by color coding presents the spectra of the deposited energy; panel 2 presents the total amount of counts in the ionizing radiation channel, which is proportional to the dose; panel 3 is devoted to the UV radiation and temperature measurements.

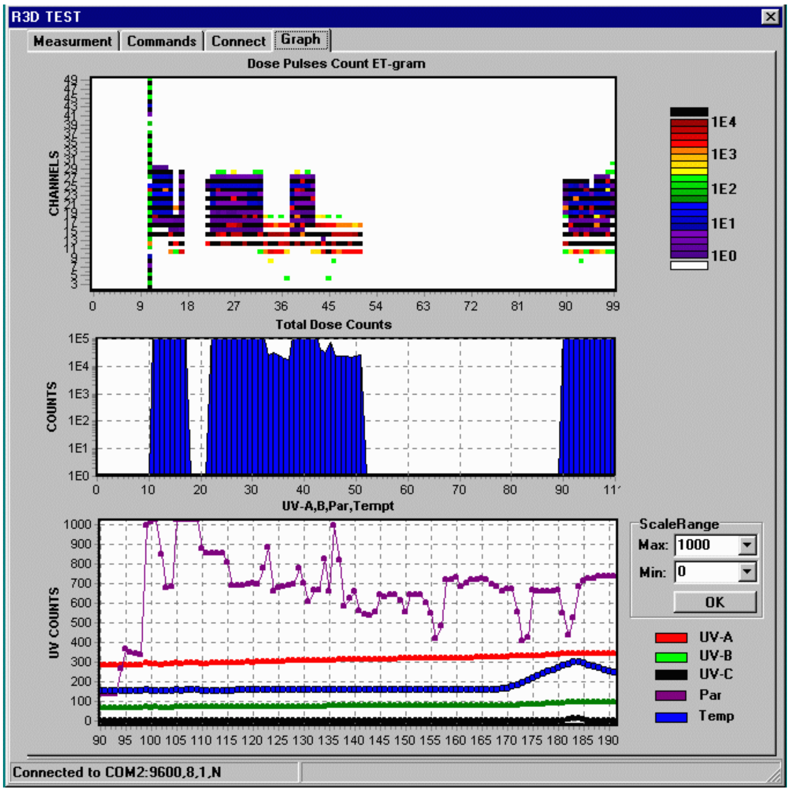

Figure 2 Example of the output display from the Functional Test-Equipment of R3D instrument

Acknowledgements

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