Dosimetric Results on EURECA

G. Reitz
DLR, Institute for Aerospace Medicine, Radiation Biology
Linder Höhe, 51147 Köln, Germany
Phone: (49) 2203 601 (0) 3137; Fax: (49) 2203 61970

Abstract

Detector packages were exposed on the European Retrievable Carrier (EURECA) as part of the Biostack experiment inside the Exobiology and Radiation Assembly (ERA) and at several locations around EURECA. The packages consist of different plastic nuclear track detectors, nuclear emulsions and thermoluminescence dosimeters (TLDs). Evaluation of these detectors yields data on absorbed dose and particle and LET spectra. Preliminary results of absorbed dose measurements in the EURECA dosimeter packages are reported and compared to results of the LDEF experiments. The highest dose rate measured on EURECA is 63.3 ± 0.4 mGy d^{-1} behind a shielding thickness of 0.09 g cm^{-2} in front of the detector package.

Introduction

The radiation environment in space comprises ionising radiation of all types and energies. Its spectral intensities show a large variability with individual mission profiles and the timing of the mission within the solar cycle. The complexity of an adequate description of the external radiation field in near Earth orbits is matched by the complexity of calculating the transport of the various components through realistic configurations of heterogeneous shielding materials. This transport involves not only attenuation of the separate components, but also, depending on the ratios of the respective free interaction lengths to the absorber thickness, the build-up of some components at the expense of other ones.

At altitudes between 200 and 600 km and at low inclinations the major contribution to the absorbed dose is delivered inside the South Atlantic Anomaly (SAA) by the geomagnetically trapped protons and electrons of the radiation belt. Below shielding thicknesses of 1 g cm^{-2} the contribution from electrons dominates the absorbed dose. The SAA is an area where the radiation belt comes closer to the earth surface due to a displacement of the magnetic dipole axis from the Earth's centre. In this region fluxes are varying extremely rapidly with altitude because of interactions of the charged particles with the nuclei of the upper atmosphere. The flux in the SAA is anisotropic with most of the flux arriving perpendicular to the magnetic field lines. In addition, an energy-dependent east-west anisotropy of the proton flux is observed. Since the westward travelling protons pass a denser atmosphere, more get lost which results in a higher flux coming from the east.

So far, models which are used to describe the radiation environment have a limited capability to predict doses for future missions, especially for those in atmospheric cut-off regions, where particle fluxes drop off rapidly with altitude. For example, radiation levels measured on LDEF are underpredicted by such models /1/. Since available data are limited /e.g. 2-4/, more data are needed in order to validate shielding and dose calculations and to improve the prediction of doses in future missions.

Since the beginning of manned space flight, the problem of radiation protection from the multiple sources of ionising radiation of the space environment has been a permanent topic of experimental biomedical research in nearly all space flight missions. In the present investigation, the sparsely and the densely ionising components of the radiation field shall be measured with thermoluminescence detectors (TLDs), plastic nuclear track detectors and nuclear emulsions.

In this report, data about absorbed dose measurement with TLDs (TLD 700) will be reported only. The investigation on the other detector types is in progress.

MATERIALS AND METHODS

The experiments on EURECA may be divided into two different experiment sets. The first set comprises nine thin detector units which were attached to the EURECA core facilities and to parts of the platform (Fig. 1). The detector units are covered by a multi-layer insulation (MLI) of 0.08 g cm^{-2} thickness only. Each unit consists of up to nine plastic nuclear track detectors, cellulose nitrate (CN), diallylglycol-carbonate (CR39) and polycarbonate (Lexan) between 0.1 and 0.3 mm thickness and of TLD 600 and TLD 700 lithium fluoride (LiF) chips embedded in a polyethylene foil. In Dos 1 through Dos 3 the TLDs formed the bottom layers and in Dos 4 through Dos 9 the top layers. All packages are equipped with celsi-strip temperature indicators and are wrapped twice in a one-sided aluminized Kapton foil of 25 µm thickness. The temperature of 40° C was exceeded for Dos 1 and Dos 2 only, in which temperatures rose up to 54° C .

The second experiment set was located in the ERA as part of the Biostack experiments (Fig. 2). Each Biostack provides three hermetically sealed cylindrical compartments made of aluminium in which the detector stacks are accommodated. A detector stack consisted of more than 100 layers of nuclear track detectors - partly interspersed with monolayers of biological objects. The top and the bottom of some stacks were formed by two TLD layers.

The doses in the TLD chip were measured with a Harshaw 2800 TLD analyser at standard settings. Calibration was done using a Cs 137 source.

FLIGHT PARAMETERS

EURECA was deployed from the Space Shuttle (flight STS 46) on July 31, 92 at an altitude of 424 km and an inclination of 28°. With its own propulsion system it was transferred to the operational altitude of 508 km, where it remained from Aug. 7, 92 to May 24, 93. It was retrieved at 476 km on June 24, 93 and returned to Earth on July 1, 93. The mission duration was 336 days. During almost the whole mission the EURECA payload was directed towards the sun (+z). This orientation of EURECA is shown on Fig. 3. EURECA was launched at a time when the solar activity was already significantly decreased compared to the maximum solar activity and it decreased further during the mission. On the average, the status of the sun might be comparable to that during the LDEF mission, but this needs detailed investigation.

RESULTS AND DISCUSSION

Table 1 lists the absorbed doses and dose rates obtained from the evaluation of Dos 1 through Dos 9 and table 2 those obtained from the Biostack detector packages. The highest dose rates are measured in Dos 6 through Dos 9 with the highest measurement in Dos 7 with 63.3 ± 0.4 mGy d^{-1}. The ROEU support and the AMF position provide the dosimeter packages with the lowest shielding distribution around them. Shielding thickness in front of the packages was 0.09 g cm^{-2}. The TLDs in Dos 3 formed the bottom layer of the detector package and had an additional shielding by the other detectors of 0.19 g cm^{-2}, and therefore 0.28g cm^{-2} in total. This may explain the by about a factor of 10 lower value than observed in the location AMF (+Z). Dos 2 and Dos 4 and Dos 5 were facing other payloads which certainly results in a higher shielding. The TLDs exposed in the Biostack A4 which faced to -x were shielded by 0.6 g cm^{-2} in this direction . The observed dose rate of 1.25 ± 0.01 mGy d^{-1} is lower than the dose rates obtained for LDEF with 0.7 g cm^{-2} shielding (see table 3 /5/). The shielding thickness in front of TLD layer A4-1 was about 16 g cm^{-2}; also the shielding in y-direction was higher which results in a reduction of the dose by a factor of three. The doses in A2 were expected to be close together with A4-1 dose and lower than all A3 doses, which is actually the case. Measurements in the topmost TLD foils in A1-3 and A3-T-163 agree excellently.

For a promising comparison of the EURECA and LDEF data a mass shielding model is essential. This is planned in co-operation with Rockwell International.

References:

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Table 1: Dose and dose rates measured in Dos 1 to Dos 9. For the location see fig. 1; the axes given in brackets are the viewing direction of the dosimeter packages.

Dosimeter	**Location**	**Dose [mGy]**	**Dose Rate [mGy d^{-1}]**
Dos 1	ERA (+X)	236 ± 3	0.70 ± 0.01
Dos 2	ERA (+Y)	405 ± 18	1.21 ± 0.05
Dos 3	RITA (+Z)	785 ± 13	2.34 ± 0.04
Dos 4	AMF (+X)	2022 ± 41	6.02 ± 0.12
Dos 5	AMF (+Y)	873 ± 83	2.60 ± 0.25
Dos 6	AMF (+Z)	6372 ± 265	18.96 ± 0.79
Dos 7	ROEU (-X)	21260 ± 1350	63.3 ± 0.4
Dos 8	ROEU (+Y)	4475 ± 116	13.32 ± 0.35
Dos 9	ROEU (+Z)	8109 ± 434	24.1 ± 1.3

Table 2: Dose and dose rates measured in the Biostack units. TLD layers have been positioned in the four Biostack container A1 to A4 in the lower (L), middle (M) and upper (T) compartment of each stack.The number represents the sheet number in the compartment.

Location in Biostack Unit	**Dose [mGy]**	**Dose Rate [mGy d^{-1}]**
A1-3	312 ± 12	0.93 ± 0.04
A2-L-1	194 ± 3	0.58 ± 0.01
A2-L-105	163 ± 3	0.49 ± 0.01
A2-T-1	159 ± 2	0.47 ± 0.01
A2-T-91	177 ± 2	0.53 ± 0.01
A3-L-1	209 ± 9	0.62 ± 0.03
A3-L-184	221 ± 11	0.66 ± 0.03
A3-M-1	231 ± 9	0.69 ± 0.03
A3-M-10	237 ± 8	0.71 ± 0.02
A3-T-1	234 ± 8	0.70 ± 0.02
A3-T-163	318 ± 7	0.95 ± 0.02
A4-1	161 ± 3	0.48 ± 0.01
A4-170	421 ± 4	1.25 ± 0.01

Table 3: Doses and dose rates measured in two different locations on LDEF behind different shieldings in front of the dosimeters.

Experiment location	Shielding [g cm^{-2}]	Absorbed dose [Gy]	Dose rate [mGy d^{-1}]
Earth tray (E1)	0.7 12	3.9 ± 0.2 2.2 ± 0.2	1.85 ± 0.09 1.04 ± 0.09
Side tray (S7)	0.7 5 12	4.7 ± 0.3 3.2 ± 0.2 2.5 ± 0.3	2.23 ± 0.14 1.52 ± 0.09 1.19 ± 0.14

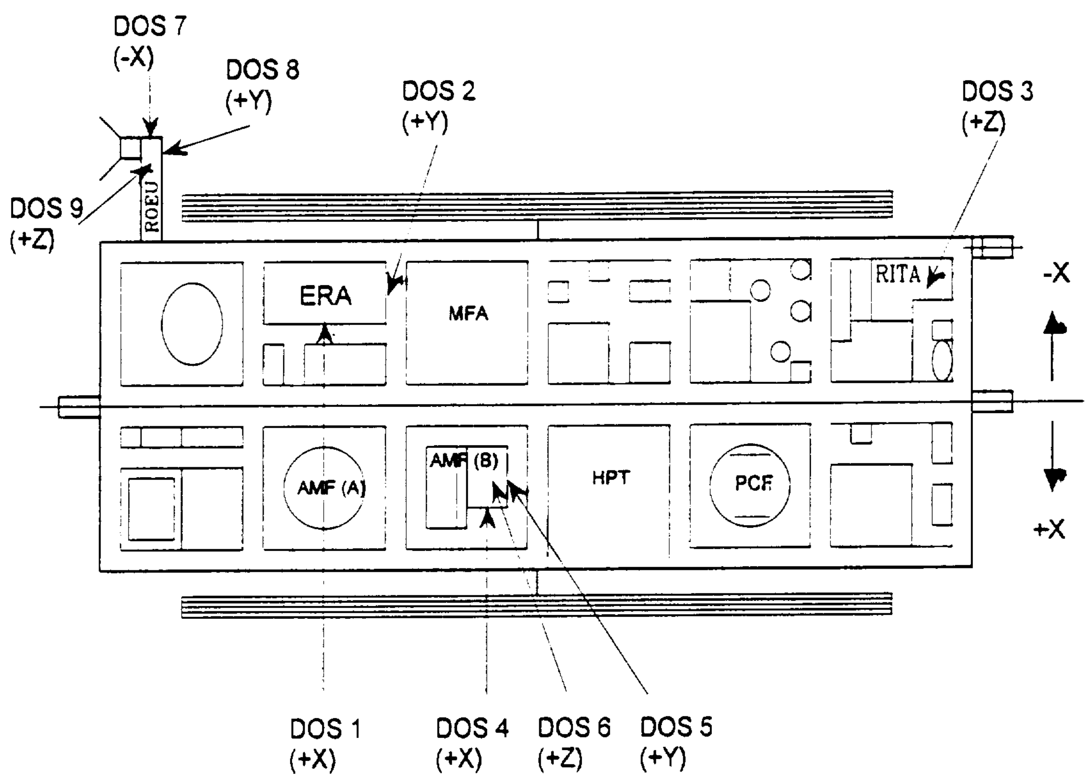

Fig. 1 Distribution of Dos 1 through Dos 9 on EURECA. The axes given in brackets for the single units are the viewing directions of the dosimeter packages. The axes +z are always directed to the sun.

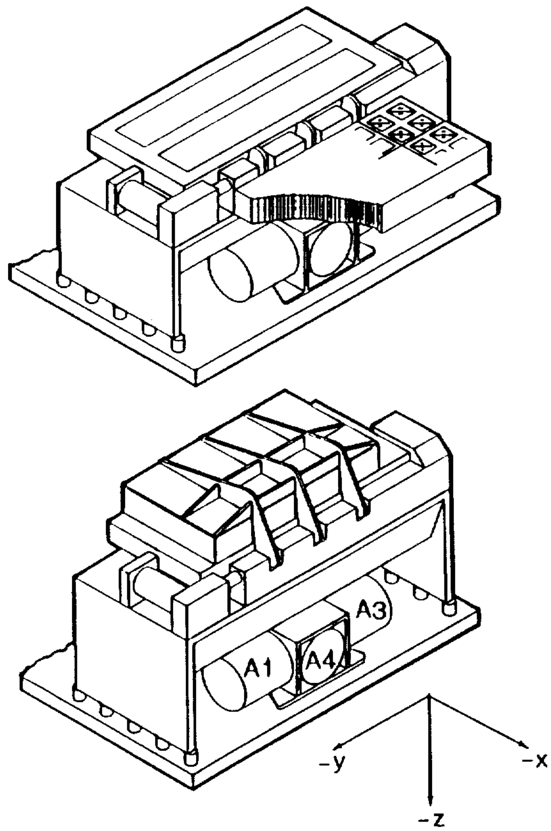

Fig. 2 Location of Biostack experiment units A1 through A4 inside ERA. Unit A4 is directed to -x, unit A1 to -y, unit A3 to +y and unit A2 (not visible, located behind the other Biostacks) to +z.

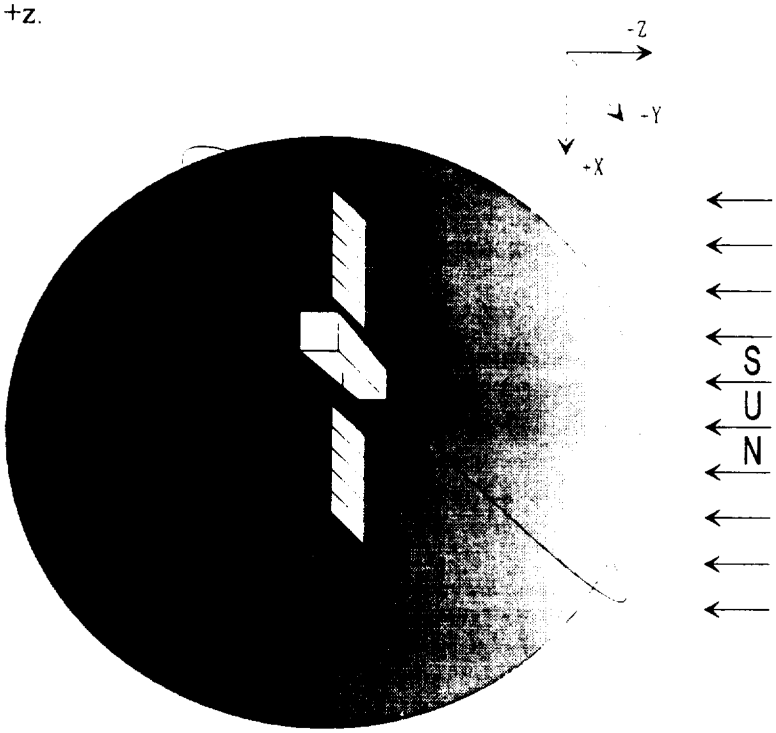

Fig.3 Schematics of the EURECA orbit with its coordinate system. +Z is always directed to the sun; the velocity vector is in direction of Y.