RADIATION DOSIMETRY FOR RECOVERABLE PAYLOADS.

*L. Adams, R. Demets, R. Harboe-Sørensen and R. Nickson

ESA-ESTEC,
POB 299, 2200AG Noordwijk, Netherlands.
*Phone +31 71 5653872, Fax +31 71 5656637, e-mail ladams@estec.esa.nl

K. Gmuerr.

Paul Scherrer Institute, CH5232 Villigen PSI, Switzerland.

W. Heinrich.

Universität-GH, Fachbereich Physik, D-57068 Siegen, Germany.

ABSTRACT

Monitoring of the radiation environment of microgravity payloads, in particular in the field of life sciences, is an essential 'housekeeping' function which should be performed as routinely as temperature monitoring. A number of passive dosimetry techniques are available and the dosimeters themselves occupy very little mass and volume. Technology demonstrations have been carried out by ESA-ESTEC on three Foton missions [Table 1] to see to what extent 'in house' dosimetry facilities can be used to support microgravity missions and to determine the appropriate 'standard dosimetry packages' to meet various needs. This paper describes the results achieved using ThermoLuminescent Dosimeters and CR-39 nuclear track detector foils in various configurations.

INTRODUCTION

The first opportunity to perform recoverable payload dosimetry came as a result of discussions in ESA regarding the possible use of commercial non-volatile memory cards in a personal computer for future manned missions. A proposal was made to program a number of cards, expose them to the space environment using the ESA BIOPAN facility and check the memory content after recovery. There is significant interest in the ESA radiation effects group regarding single event effects and it was suggested to expand the scope of the experiment by performing ground based accelerator testing on the memory cards and interleaving CR-39 track detector foils with the memory cards in the flight unit. It was hoped to correlate any changes in memory content with the passage of HZE particles through the stack of memory cards and foils. This experiment became known as 'CARD' [1] and flew in BIOPAN-0 on Foton-8. A schematic of 'CARD' is given in Fig 1, two of these units were mounted in BIOPAN.

The radiation effects ground test facility at ESTEC includes a ThermoLuminescent Dosimetry (TLD) capability, mainly used for dose monitoring during the test of components or complete circuit boards. This facility was used as the basis for the 'RADBLOCK' experiment, Fig 2, which flew in BIOPAN-1 on Foton-9. 'RADBLOCK' contained 400 TLDs of various compositions arranged in 14 layers. The aim of this experiment was to evaluate various types of TLD for this application, to study calibration and read-out procedures and to obtain dose-depth information.

The third flight was with the ESA BIOBOX on Foton-10. Two experiments were performed on this occasion, 'RADSTACK' and 'RADPATCH'. 'RADSTACK', Fig 3, combined 26 layers of CR-39 track detectors with a single layer of 100 TLDs. 'RADPATCH', Fig 4, comprised a number of small aluminium foil envelopes, each containing 9 TLDs. These were intended as passive, non-intrusive dose monitors and 10 'patches' were distributed around the payload

RESULTS

The 'CARD' experiment received just 15 days of exposure to the space environment with the BIOPAN lid being open for about half of this time. The orbital parameters were 226 x 349 km with an inclination of 62.8 degrees. No memory upsets were noted on post flight analysis. Analysis of the CR-39 foils at Univ of Siegen, showed 392 tracks for one box and 267 for the other. The threshold LET for track recording was estimated to be 0.2 MeV/(mg/cm^2). The locations of the memory chips in the module were established using X-ray inspection and these locations correlated with the tracks recorded in the CR-39. This showed between 6 and 11 particles traversing each of the 4 memory chip locations in the two units. Fig 5 shows

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the distribution of tracks in two memory chip locations for one of the flight units.

The 'RADBLOCK' experiment received similar duartion exposure on the outside of the spacecraft to 'CARD'. In order to be able to estimate the terrestrial environmental exposure an identical unit accompanied the flight unit during all shipping operations and was retained in the Moscow laboratory during the flight. The TLDs were read out within 1 month of recovery using a HARSHAW 3500 reader. with a pre-conditioning of 1 hour at 100°C and a read-out cycle of an 8°C/sec ramp to 240°C and an integration time of 30 seconds.

So far, only the TLD 200 (CaF_2) have been evaluated in detail and these show a dose of about 0.5 and 1.0 R/day in the upper layer behind a shielding of 1mm aluminium and about 0.04 R/day in the deepest layer. A typical depth-dose curve for one stck of TLDs is shown in Fig 6. Lateral dose variations at the same depth were noted which can be as much as a factor of 2-3. These may be due to 'shadowing' from other payload elements, possibly combined with spacecraft attitude variations and are still being studied. The doses reported are 'equivalent Co-60' as this was the source used for calibration..

The Foton-10 capsule which carried the experiments 'RADSTACK' and 'RADPATCH' was severely damaged during recovery but fortunately most of the TLDs were intact. Evaluation of the 'RADSTACK' CR-39 foils at the Paul Scherrer Institute showed similar track densities to those found in 'CARD'. Fig 7 shows a representative
1 cm^2 area from the foils with tracks from the top and bottom of the stack.. The dose recorded in the TLDs was 0.014 R/day.

Ten 'RADPATCH' detectors were recovered from the payload, the location and doses recorded by the flight patches are shown in Fig 7. The total doses at the various locations were found to vary by a factor > 2, as anticipated taking into account shielding from the space environment and the existence of an 'on-board' radiation source in the bottom of the spherical re-entry capsule. The actual doses are well within the estimates provided by KB Photon [2].

CONCLUSIONS

The three flights performed so far have enabled us to develop techniques for radiation dosimetry in support of microgravity payloads. Standard packages have been developed to meet the differing requirements of various payloads and the 'RADPATCH' technique has been shown to be particularly useful for monitoring the dose in a number of locations of interest.

REFERENCES

[1] R. Harboe-Sørensen, H. Meijer, J-C. Ronnet, R. Demets & L. Adams. Biopan Flight Experiment 'CARD'. IEEE Trans. Nucl. Sci. Vol 41, No 6. pp 2340-2345. (1994).

[2] Photon Spacecraft : Scientific Hardware Specification, Cosmos Group. (1993).

Mission	Experiment	Detectors	Launch Date	Flight Duration
Foton-8	CARD	CR-39 foils	8 Oct. 1992	15.6 days
Foton-9	RADBLOCK	TLDs	14 June 1994	17.6 days
Foton-10	RADSTACK RADPATCH	CR-39 foils; TLDs TLDs	16 Feb. 1995	14.6 days

Table 1. Foton Flight Data
all three flights 62.8 degrees, LEO (200 - 400 Km altitude)

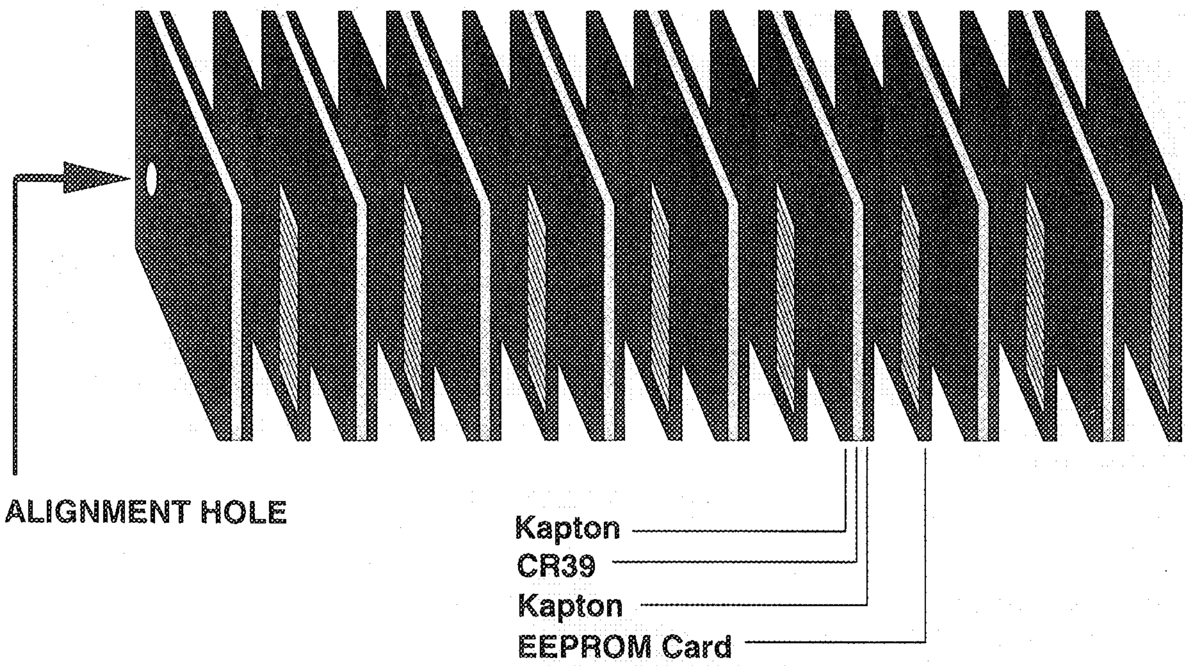

Fig. 1 'CARD' Stack Layout

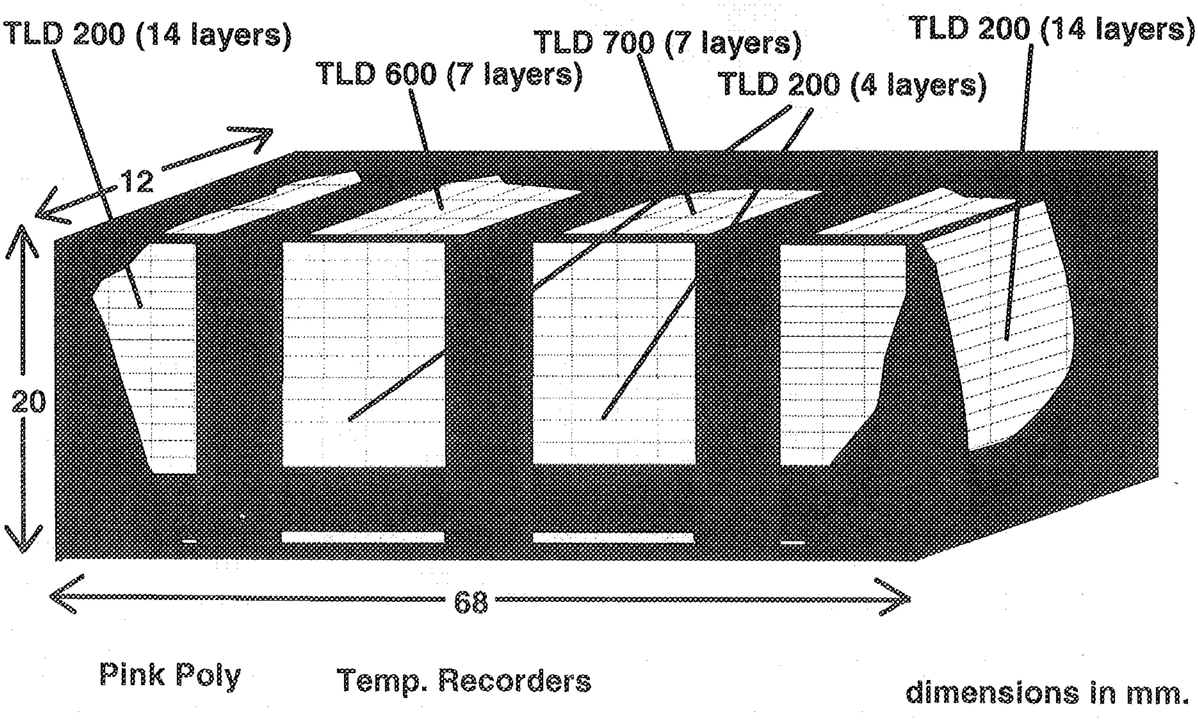

Fig. 2 'RADBLOCK'

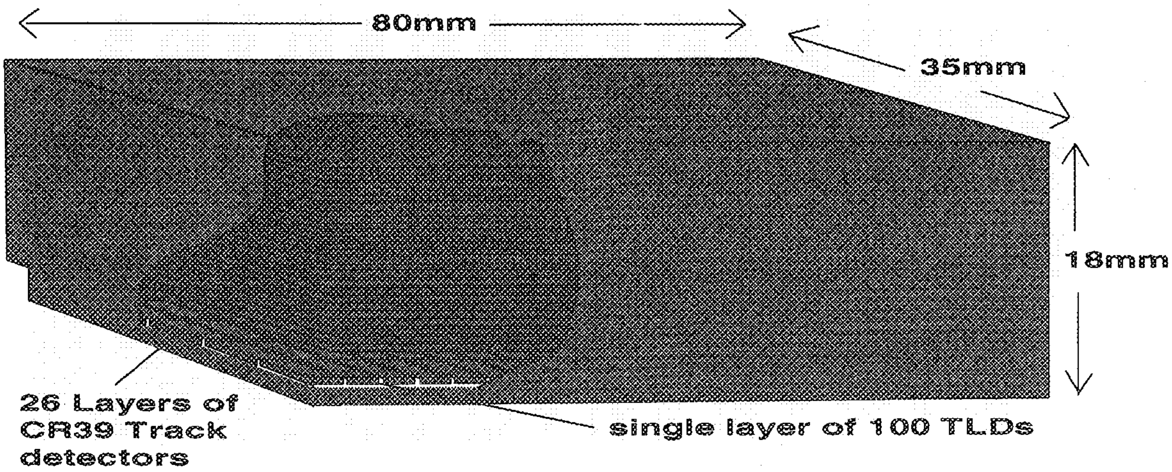

Fig. 3 'RADSTACK'

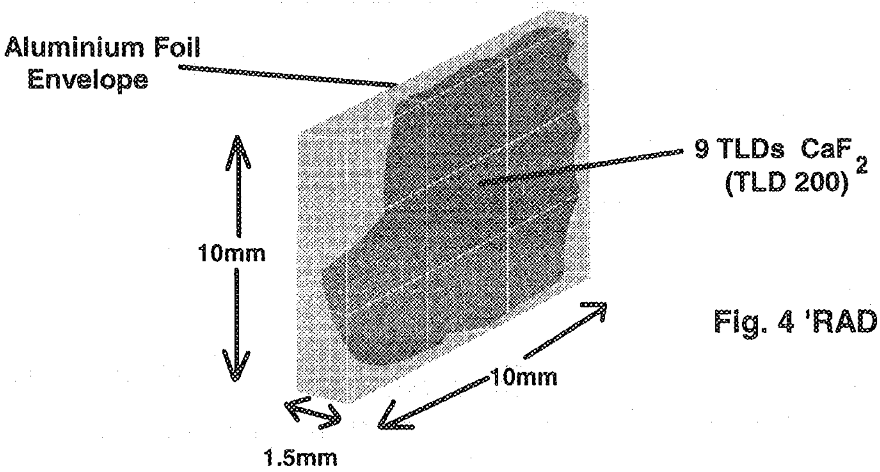

Fig. 4 'RADPATCH'

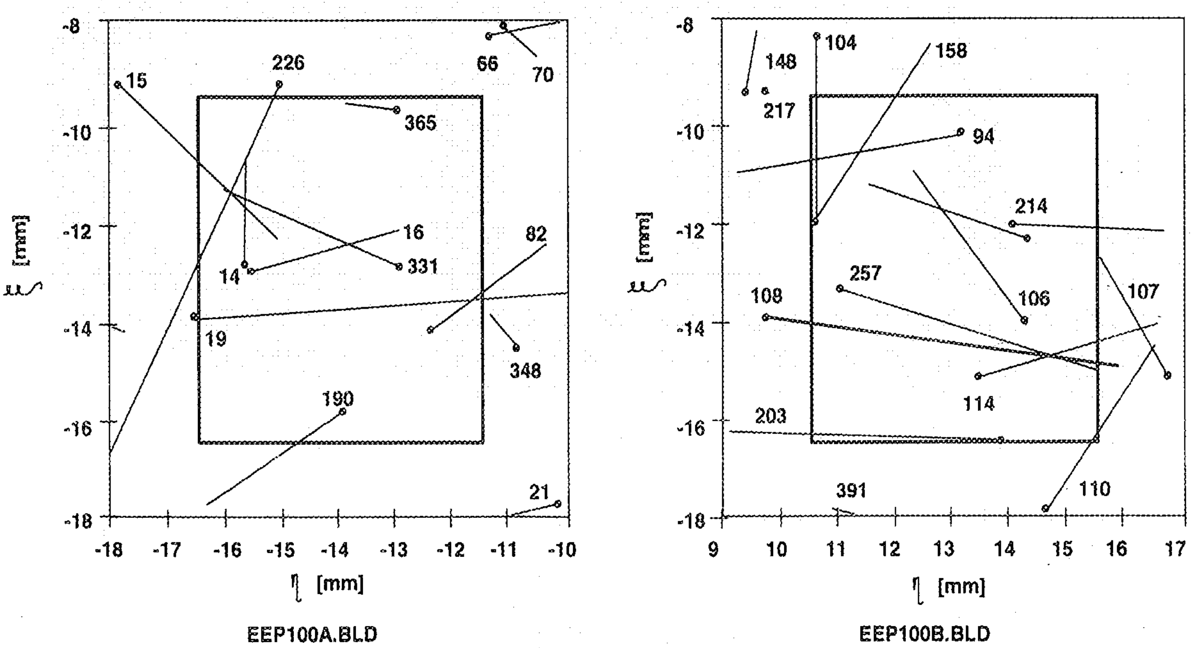

Fig. 5 Track Distribution in 'CARD'

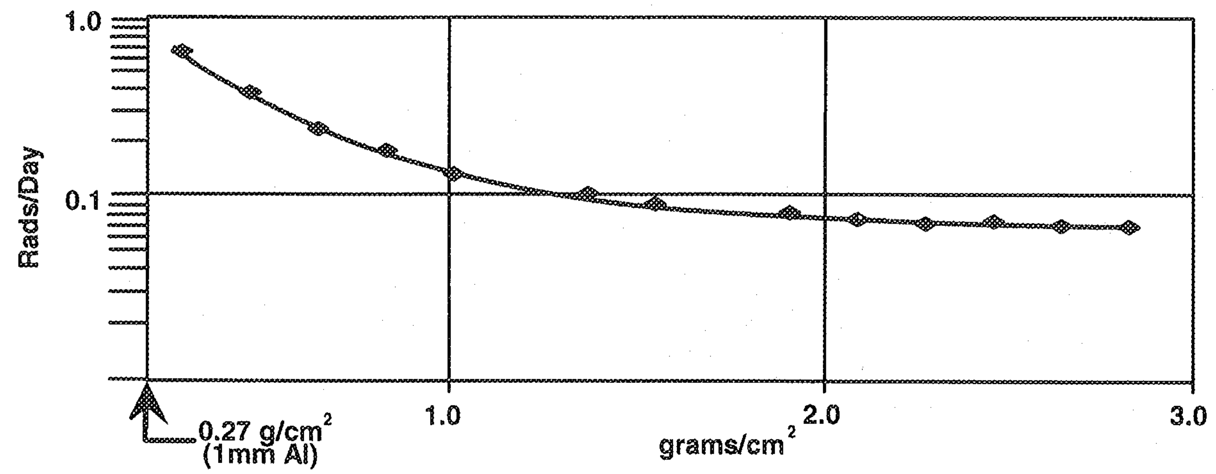

Fig. 6 Typical Dose-Depth Curve for a TLD Stack from "RADBLOCK"

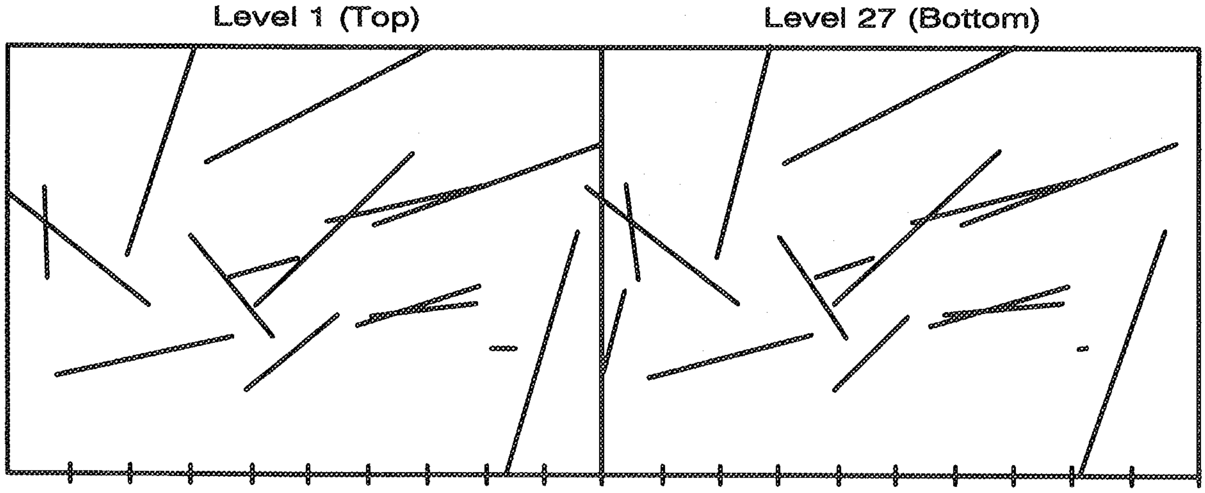

Fig. 7 Tracks on 1cm^2 CR-39 Detector Foils from "RADSTACK"

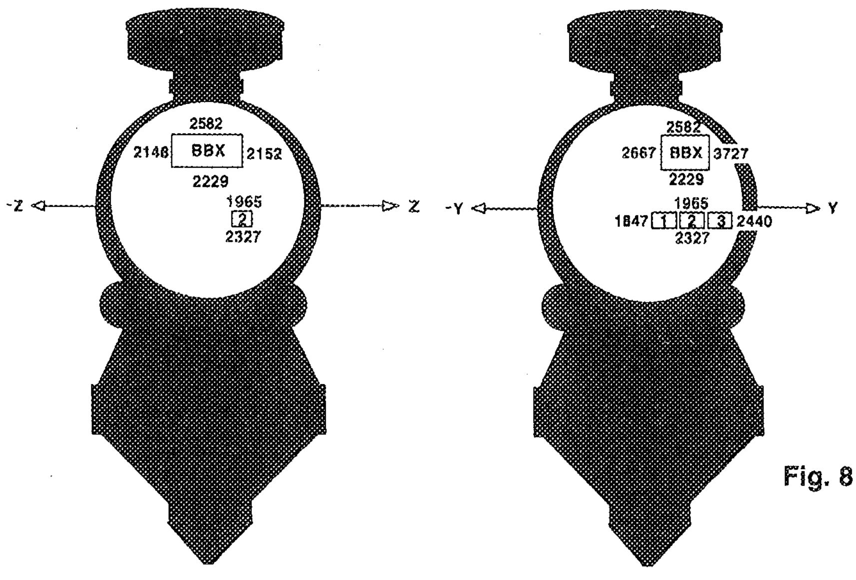

Fig. 8 Cross-sections of the Foton-10 spacecraft with location & Doses for 'RADPATCH' (total absorbed dose in μGy).

BBX = Biobox