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STUDY ON THE BIOLOGICAL EFFECT OF COSMIC RADIATION
AND THE DEVELOPMENT OF RADIATION PROTECTION TECHNOLOGY
L-11

Shunji Nagaoka
National Space Development Agency of Japan
Japan

Background

As the era of Space Station Freedom and solar system travel approaches, it becomes increasingly important to develop radiation protection for the people who will live and work in space for long durations. The space environment surrounding the Earth is known as the geosphere where the magnetic field of the Earth traps the so-called solar wind which results in a giant torus of radiation field of highly energized electrons and protons such as the Van Allen Belt. In addition, high-energy ionized particles are coming from the Sun and the cosmic galaxy. The latter is usually of extremely high energy which can easily penetrate a protected spacecraft.

Most of the human activities inside and outside the spacecraft occur in such a radiation field where the radiation environment, on the average, is remarkably high compared to that on the ground; because the Earth's atmosphere, a dense blanket of air, effectively protects us from most of the radiation, particularly against the high-energy radiation at levels lethal to most living species.

From the accumulated data in past space flights, we know the average radiation dose at the lower Earth orbit (300 - 500 km); for example, in the case of Skylab in 1973, the total dose for the astronauts during 84 days was measured by a conventional method to be approximately

7.7 rem which corresponds to 90 mrem/day. Similar results have been obtained from several recent missions of Spacelab. One can estimate from such data, based upon the altitude and inclinations, that the total dose for astronauts during the longest Mir Mission (366 days) was approximately 80 rem at skin level and 30 rem at bone marrow. The level is almost at the allowable limit (50 rem/year) for astronauts recommended by NCRP. It is well known that exposure to ionized radiation over a certain level can become suddenly toxic to living systems. Since the majority of studies on radiation effects and risks have been based on x-ray, gamma ray, or neutron studies on the ground, the question then arises, "Can the effects of such space radiation on biological systems be extrapolated from the results studied on the ground?" Recent developments, based on the ground-based-studies, as well as space experiments, have suggested that the Relative Biological Effectiveness (RBE) of the heavy ions may be much higher than that of gamma-rays (>20). Then, beyond the Earth's atmosphere, what and how can we protect life from such damaging radiation? Radiation research at NASDA has been undertaken to give answers to the questions above. The detailed analysis on the biological effects and data accumulated from those analysis must be used for precise risk estimations and for the development of the radiation protection technology necessary for the human occupation of the space radiation environment.

Flight Experiments

Equipment and Specimens

NASDA is now participating in a series of flight experiments on Spacelab missions. The first experiment was carried out on the first International Microgravity Laboratory Mission (IML-1) January 1992, and the second experiment will be conducted on the Spacelab-J Mission (FMPT). The equipment or Radiation Monitoring Container Devices (RMCD) (Figure 1) includes passive dosimeter systems shown in Table 1 and biological specimens. The experiments using this hardware are designed by NASDA to measure and investigate the radiation levels inside spacecraft like space shuttle and to look at the basic effects of the space environment from the aspect of radiation biology. The data gathered will be analyzed to understand the details of biological effects as well as the physical nature of space radiation registered in the sensitive Solid-State Track Detectors (SSTD).

Table 1. Flight Equipment List

Radiation Monitoring Container*	2 sets
Solid State Track Detectors TS-16, CR-39	50 sheets/cont.
Physical Dimensions	12.5 x 12.5 x 10.4 cm
Sample Holders	3 types/cont.
Dosimeter Package**	14 sets
TLD (LiF, MgSiO:Tb, LiF:Hg:Cu:P)	24/cont.
Physical Dimensions	12.1 x 12.1 x 0.9 cm

*Set in aft-end cone of Spacelab

**Set in incubator, stowage container, refrigerator, etc.

In this experiment, layers of the radiation detectors and biological specimens, bacterial spores (Bacillus subtilis), shrimp eggs (Altemia salina), and maize seeds (Zea mays) (Table 2) are sandwiched between the track detectors in the Radiation Monitoring Container. The detectors, sheets of plastic material called TS-16 and CR-39, register the nuclear track of cosmic radiation. The dosimeter package contains conventional detectors made of lithium fluoride or magnesium-silica-terbium. These are thermoluminescent materials (TLD) which, when heated moderately after radiation exposure, emit luminescent photons linearly depending upon the dose of radiation. The experiment consisting of the box-like container is mounted on the aft end cone of the Spacelab, where there is somewhat less radiation than at other locations.

Table 2. Biological Samples

Maize seeds (<i>Zea mays</i>) ($Yg_2 \times yg_2$)	100-120/holder	4 Sets
Brine shrimp eggs (<i>Artemia salina</i>)	2000-3000/holder	6 Sets
Bacterial spores (<i>Bacillus subtilis</i> 168)	10^4 - 10^5 /holder	6 Sets

Outline of Experiment Operations

The experiment operations including the pre- and post-specimen preparation are summarized below. The in-flight procedure is very simple, major activities are stowage and unstowage operations. The results are analyzed at Japanese laboratories after the specimens retrieval.

(1) Sample Preparation (Japan)

L-3 weeks: Prepared and fixed on sample holders

L-2 weeks: Shipped to KSC (while being protected from radiation) including biological samples/track detectors TLD with dosimeters.

(2) Hanger-L Operation (KSC)

**L-1 weeks: Packed into radiation monitoring containers and kept in refrigerator
until late access**

L-13 hrs.: Late access to STS middeck

(3) Onboard Operation

- a. Transfer the containers/dosimeters to SL after the activation.**
- b. Assemble containers/dosimeters/temp. sensor and set at aft end cone.**
- c. Set dosimeter near fly container, incubators, refrigerator and fungi growth chamber, and middeck locker.**
- d. All devices remain in position until SL deactivation.**
- e. The container/dosimeters are removed and restored.**

(4) Post-Flight Operations (landing site and KSC)

- a. Early removal from STS middeck and transfer to KSC.**
- b. Store at Hanger-L refrigerator until shipment.**

Post-Flight Analysis

Each plastic detector in the device can register individual nuclear tracks in three dimensions, and the TLD accumulates integrated radiation energy. The biological specimens in the device are exposed to cosmic radiation for 7 to 8 days during the mission. All specimens and radiation detectors are analyzed after the mission to correlate the radiation characteristics and biological effects. The plastic detectors are etched chemically to visualize the radiation tracks, called "etch-pits." The geometric properties of the etch-pits can reveal the physical characteristics of the radiation, such as incident angle, energy, and nucleon type. Three-dimensional trajectories are analyzed by a computerized microscopic image handler with a three-dimensional stage controller, and reconstructed through the piled detector sheets in relation to the positions of the biological specimens. The specimens will be evaluated by biological and biochemical methods using their intrinsic natures for radiation effects during the processes of development, sporulation, hatching, and germination. Primary genetic studies will also be conducted at the cellular, organ, and individual levels.

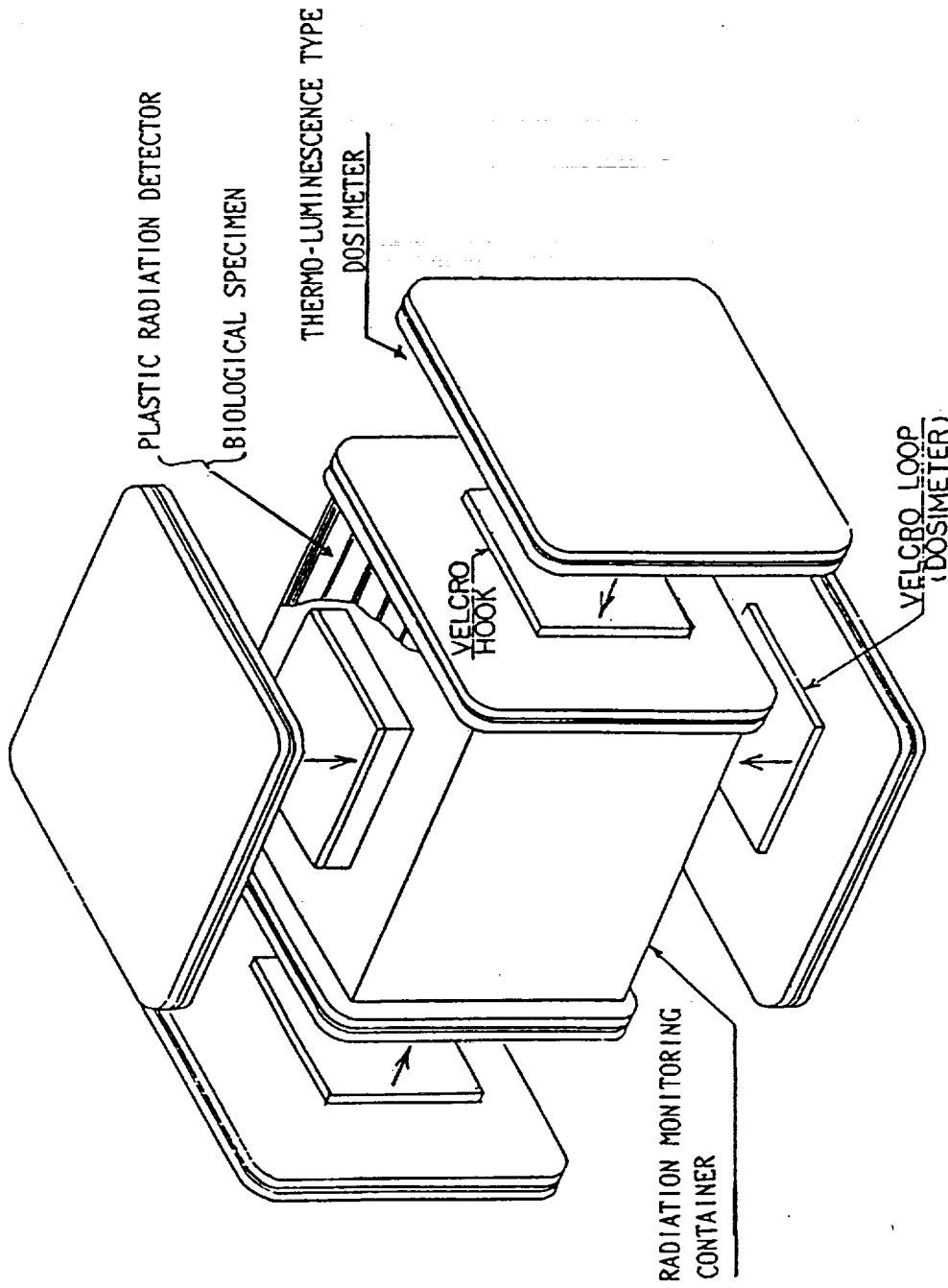


Figure 1. Monitoring container - dosimeter.