RADIATION ENVIRONMENT STUDY DURING PHOBOS SAMPLE RETURN MISSION BY CHARGED PARTICLE TELESCOPE LIULIN-PHOBOS.

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Introduction: With regards to the human exploration of Mars, the radiation exposures to be received by astronauts in transit to Mars and on the Mars surface have to be assessed including the understanding of the modification of cosmic rays by the Martian atmosphere and identifying shielding optimisation approaches. Some calculation models [1-3] have been elaborated but still there arelarge uncertainties aboutthe dose evaluation, because of the lack of knowledge of the source term (precise radiation composition, energy spectrum, flux) as well as the influence of the environment (atmosphere, surface). Another important issue is the biological effect of cosmic highly energetic particles in the heavy ion component, typically referred to as HZE particles, that is still not well known and is the subject of several research programs at international level [4,5]. HZE particles play a particularly important role in space dosimetry. Those particles, especially iron, have high linear energy transfer (LET) and are highly penetrating, giving them a large potential for radiobiological damage [6]. The "late effects" caused by GCR heavy ions have been identified by the National Research Council [7] as the principal radiation risk to astronauts on extended stays outside LEO.

The effective dose expected for an exploratory space mission is very large compared to the effective dose limits recommended by the International Commission on Radiological Protection (ICRP) [8] for the general public (1 mSv.year^{-1}) and for occupational exposures (20 mSv.year^{-1}) and is expected to be higher than the exposure limits recommended by the National Council of Radiation Protection and Measurements (NCRP) [9] for astronauts during exploration missions at low Earth orbit (LEO) (0.5 mSv maximum annual dose to the blood-forming organs). This NCRP report specifies that these limits do not apply to interplanetary missions because of the large uncertainties in predicting the risks of late effects from heavy ions.

The current models for radiation risk assessment lead to evaluations with very large uncertainties because of the lack of knowledge of: i) the source term (precise radiation composition, energy spectrum, flux); ii) the interactions of cosmic radiation with matter for each particular case, needed for the calculation of shielding and dose in human body and, iii) the biological effects of cosmic particles, especially the HZE particles.

Development of techniques and methods for investigation of the radiation hazards during future exploratory missions as well as components of the radiation safety system for manned deep space missions is demanded. Recently the near-Mars charged particles radiation environment was explored by the MARIE experiment aboard the 2001 Mars Odyssey spacecraft [10]. Data have revealed on the one hand that the radiation exposure in the transit period was "approximately double" that which astronauts are receiving on the International Space Station (ISS) and on the other hand that the exposure to the heavy nuclei, up to and including iron nuclei, is "approximately three times" what the astronauts are receiving on the ISS. The obtained dose equivalent in Mars orbit was about 2.5 times larger than on ISS [11]. The GCR dose obtained was about 250 μGy/day, which corresponds to about 0.3 to 0.4 Sv/yr dose equivalent. Because the NASA career limit for astronauts is 1-4 Sv, depending on the age and gender of the individual, it means that a three year mission to Mars and back would put some astronauts in danger of exceeding their career limit.

The Liulin-Phobos radiation environment en route and on Phobos surface is described and modeled in a separate LPSC 2009 paper by G. De Angelis.

Scientific Objectives of Liulin-Phobos experiment: An instrument Liulin-Phobos for a new experiment in radiation research is under development to be flown onboard the future Phobos - Soil sample return mission to the satellite of Mars – Phobos. Launch of the spacecraft is scheduled for late 2009 [12]. The main goal of the Liulin-Phobos experiment is the investigation of the radiation environment and doses in the heliosphere at distances of 1 to 1.5 AU from the Sun and in the near-Mars space. This research will be used for the assessment of radiation risk to the crewmembers of future exploratory flights.

Description of Liulin-Phobos experiment: The instrumentation will qualitatively and quantitatively characterize, in terms of dose rate and linear energy transfer spectrum, the radiation environment. There is a special telemetry command "Request of current dose rate". It will be used if a need arises to access the radiation conditions at a given moment. By receiving this command, Liulin-Phobos will provide the last measured dose rate.

Fig.1. Photography of the Liulin – Phobos engineering model.

The perpendicular arrangement of two dosimetric telescopes will allow distinguishing between the solar and galactic cosmic rays contributions in the measured dose.

Liulin- Phobos particle telescope (see Fig.1) will be mounted on the Descent Module of Phobos – Soil spacecraft. Liulin-Phobos instrument consists of two dosimetric telescopes - D1&D2, and D3&D4 arranged at two perpendicular directions. The block-diagram of the instrument is shown in Fig. 2. It is adaptated from the Liulin-5 techniques developed for investigations of the radiation environment on ISS [13].

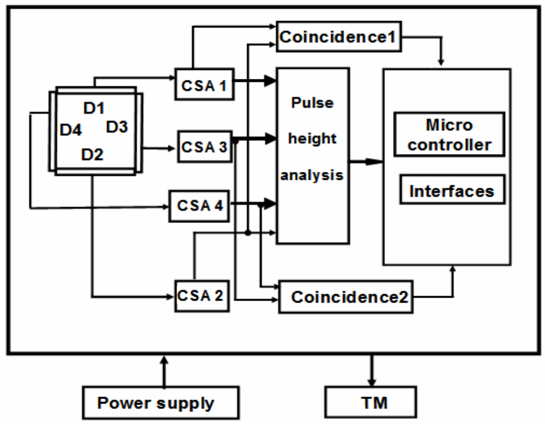

Fig. 2. Block –diagram of Liulin – Phobos charged particle telescope.

Every pair of telescopes consists of two 300 µm thick Si PIN photodiodes, operating in coincidence mode to obtain LET. The detectors, the charge – sensitive preamplifiers - shaping amplifiers CSA1-CSA4, and the voltage bias circuits are mounted in a separated volume inside the box of the Liulin-Phobos instrument and are connected to printed circuit boards that contain threshold discriminators, pulse height analysis circuits, coincidence circuits, and other circuitry, mounted in another separated volume. That volume also contains a CPU board, including microprocessor, flash memory for data storage, timer, DC-DC converter, and an interface to the board telemetry/command system. The entire package has a mass of 0.5 kg and consumes 1.4 W. The telemetry data rate is 250 kB/day. The gains of Liulin – Phobos preamplifiers are a compromise between the conflicting goals of measuring high - energy protons (which have very low LET and hence require high gains) and covering the HZE spectrum (which require low gains to measure highly ionizing particles such as iron). As a result of the compromise one of the detectors in every telescope measures the energy deposition spectrum in the range 0.1-10 MeV, and the other in the range 0.45-90 MeV. In that way every dosimetric telescope provides data in the energy deposition range 0.1 - 90 MeV. The instrument will measure absorbed dose rate and particle flux every 60s, energy deposition spectra and LET spectrum every 60 min.

The parameters featured by Liulin-Phobos are: Absorbed dose rate in the range 0.04 x 10^{-6} Gy/h - 0.1 Gy/h, and absorbed dose D, measured by every single detector; Particle flux in the range 0 - 10^4 particle/(cm^2.sec), measured by every single detector; Energy deposition spectra in the range 0.1-90 MeV, measured by every dosimetric telescope; LET spectrum (in H_2O) in range 0.75–155 keV/µm, measured by every dosimetric telescope; Quality factor Q = f(LET) and average quality Qav; Dose equivalents H = Q_{av} D D, measured by two dosimetric telescopes.

We plan to calibrate the flight model with protons, ^{4}He, and light and heavy ions in NIRS at the beginning of 2009. After the calibration the flight model will be delivered to IMBP-RAS, Moscow, for acceptance and complex tests.

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