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A Miniaturized Radiation Monitor for Continuous Dosimetry and Particle Identification in Space

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Space radiation poses a threat not only to human space flight missions, but also to the electronic equipment of any space mission. Some dramatic space system failures and disturbances in recent years have been assumed to be radiation-induced malfunction of critical electronics parts. The space radiation environment consist of a variety of particle species, including electrons, protons and heavy ions, which may pose threats at different levels to different electronic devices. Therefore, the presence of a radiation monitor on-board of any mission is highly desirable to provide the capability to take protective measures in-flight and to contribute with flight-data to the improvement of existing radiation environment models. This contribution describes the development of a novel Miniaturized Radiation Monitor (MIRAM) for this purpose. Compared to the currently used devices, it is cheaper, has lower weight and power consumption. It is capable of providing a continuous measurement of dose as well as an estimation of the particle species composition of the radiation environment.

MIRAM has the dimensions 80 x 60 x 30 mm. It's nominal power consumption is 1.2 W with a peak consumption of 1.8 W. The device features four single pad diodes and a Timepix3 pixel detector with 256 x 256 pixels in a 55 μm pixel pitch. The diodes and the Timepix3 are separated by a 4 mm thick copper shield to separate electrons. Sensor material of diodes and the Timepix3 are made of Si and each is 300 μm thick. The electronic parts are low-power consuming and radiation tolerant commercial off-the-shelf components. The device further features a high-voltage power supply, 4 MB data storage M-RAM with an optional 16 MB DRAM and a CAN interface. MIRAM is capable of on-board real-time self-diagnostic. The device can be seen in Figure 1 with the box opened.

The MIRAM device supports on-board analysis of the measured data to be able to work autonomously. The dose rate is calculated continuously based on the energy deposition in the Timepix3 detector. For the estimation of the particle species composition of the radiation environment, two methods are applied depending on the current flux. At lower fluxes ($< 10^4$ particles per cm^2 per s), a more thorough analysis will be utilized. Particles are selected and determined based on the pixels temporal coincidence. The pixels are then sorted into three categories: low, medium and high energy, and the deposited energy is summed up. This data set is then compared with a data base, where typical values for electrons and protons are stored. The particle is classified according the closest similarity or, if there is no similarity, as heavier ion. At higher fluxes, the deposited energy is measured over a fixed time window. Then the average energy per pixel is calculated. The average energy per pixel varies very little around a constant value for a certain composition of different particle species. Towards lower fluxes, the variation around that value increases, so that different compositions cannot be resolved anymore. At this point, a track-by-track analyses is utilized.

Both methods have been developed with the help of reference measurements of monoenergetic electrons, protons and heavier ions of different energies on the ground in conjunction with measurement of the Space Application of Timepix Radiation Monitor (SATRAM), which measures the space radiation environment in a Low Earth Orbit (LEO) on-board the Proba-V satellite since 2013, in space. The measurements were supported by a Monte Carlo simulation of the MIRAM device.

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