The architecture of nanosatellite module for FPGA-based cosmic radiation sensing with artificial intelligence

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Abstract. This paper is devoted to the study of cosmic radiation and its effects on electronics, as well as ways to measure it in order to help the idealization of the proposed cosmic radiation sensing satellite module architecture depicted in Fig.1. This module contains two types of standard radiation sensors, an FPGA device and several individual semiconductor memories. The FPGA device contains arrays of radiation sensing elements based on its internal memories while the external memories complement/extend this capability. The module includes an AI model for the classification and real-time analysis of the cosmic radiation-induced fault patterns. This intelligent module could be employed for adjusting and optimizing the radiation tolerance of satellite electronic systems.

The cosmic radiation environment represents radiation risk to all electronic components of Earth-orbiting satellites. The radiating particles in this environment consist mainly of high-energy electrons, protons, alpha particles and cosmic rays [1]. The development of cosmic radiation sensor based on artificial intelligence would give the possibility to more adequately assess the

state of space weather and will give the possibility to mitigate its negative effects.

The architecture of a prototype satellite module is proposed, the objectives being to verify the value of a demonstration mission to assess the feasibility of using a radiation sensor based on artificial intelligence and realized on COTS components. At the core of this module is an FPGA-type circuit [2-4], in which several SEU detector arrays are embedded uniformly placed on the silicon area of the FPGA circuit, in a matrix configuration.

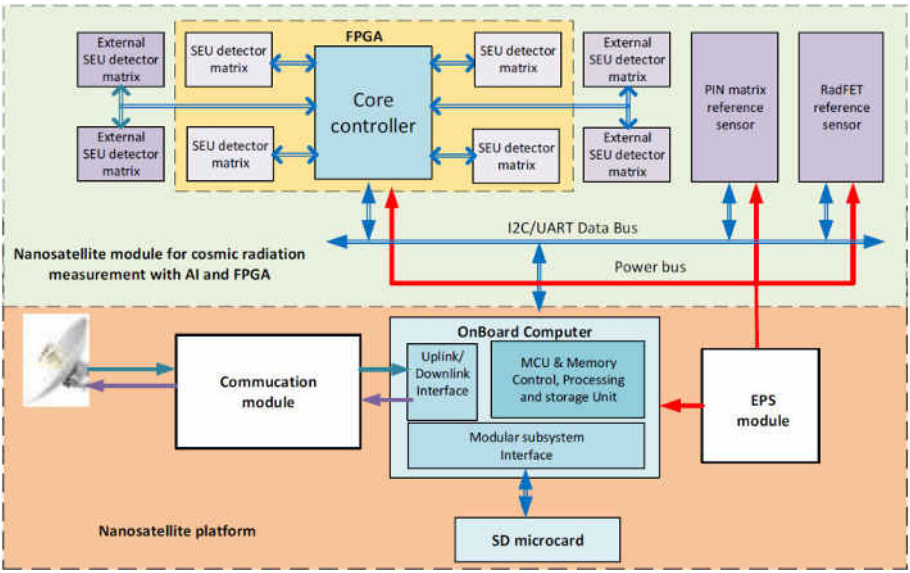

Figure 1. The diagram of the satellite module of cosmic radiation sensors for classification and real-time analysis of cosmic radiation.

The FPGA device will be configured with a custom design aimed at detecting SEUs and then clustering and classifying the patterns using an AI model. The device will be hosted on an auxiliary printed circuit board (PCB) interfaced to the OBC main board through a connector. The four objectives of the AI-based hardware Cosmic Radiation Sensor (AICoRS) system are: i) evaluating the feasibility of using an FPGA device as a cosmic radiation sensor,

ii) measuring and classifying the cosmic radiation patterns, iii) evaluating the effectiveness of SEU mitigating mechanisms (e.g. TMR, ECC) and iv) evaluating the feasibility of using such a modern, low-cost general-purpose FPGA device for space applications.

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