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RADIATION EFFECT ON IMAGERS FOR SPACE APPLICATIONS

Abstract

Radiation fields are identified as a major reliability issue for electronics systems for decades. Studies of space environment and its effects on electronic systems are therefore fundamental for space applications and risk mitigation. These effects have been classified between cumulated effects (continuous exposure to ionizing particles) and Single Event Effects (SEE) (transitory perturbation produced by a single particle). Among many optical applications, like earth or space observation, the guidance system in a spacecraft (launcher or satellite) is particularly critical. It is based-on imagers, i.e. Charge-Coupled Device (CCD) or Active Pixel Sensor (APS), and allows for determining spacecraft attitude by matching an observed star field to a star catalog. Optical trackers impose new and complex challenging requirements such as component mass and power consumption reductions, but also radiation hardness and operational risk estimate. Recently, APS technology has been proposed as a successor for CCD technology because of the several advantages specifically appealing for star tracker subsystems, i.e. miniaturization, random access within the pixel array etc. Thus, an important effort is currently dedicated to the APS technology. The performance of CCD and APS is permanently degraded by total ionizing dose (TID), displacement damage effects (DD) and Single Event Effect. TID produces threshold voltage shifts and leakage current increase, degrading for example dark current. Displacement damage is responsible of dark current increase in term of mean value and non-uniformity, creates a random telegraph noise signal in individual pixels and degrades the image smearing (case of CCD). In addition to these long term effects, cosmic ray, trapped or solar flare proton transients also interfere with device operation on orbit with SEE events. Moreover SEE risk concern the pixel structure but also the functional part of the device (register, addressing, multiplexing ...). Thus, it is still a challenge to take into account the radiation effects on a complete imager system, including transient and cumulative effect. In this paper, we will present the global approach defined and carried out at the Department of Space Environment of the French Aerospace Lab. (ONERA) for investigating the radiation overall problematic for CCD and APS. The complementary physical modeling and semi-empirical approaches are used to study the operational risk induced by the cumulative effects, whereas the SEE risk is modeled with the Multi-Scale Single Event Phenomena Predictive Platform (MUSCA SEP3). We will illustrate implications of this global approach in the area of risk assessment, hardening of devices and environment monitoring.