

Process management for avionics — Atmospheric radiation effects —

Part 5: Guidelines for assessing thermal neutron fluxes and effects in avionics systems

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National foreword

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A review of this Draft for Development will be carried out not later than 3 years after its publication.

Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development, will be made in an announcement in the appropriate issue of *Update Standards*. According to the replies received, the responsible BSI Committee will judge whether the validity of the PAS should be extended for a further three years or what other action should be taken and pass their comments on to the relevant international committee.

Observations which it is felt should receive attention before the official call for comments will be welcomed. These should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

The UK participation in its preparation was entrusted to Technical Committee GEL/107, Process management for avionics.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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PROCESS MANAGEMENT FOR AVIONICS – ATMOSPHERIC RADIATION EFFECTS –

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1 General

The purpose of this PAS is to provide a more precise definition of the threat that thermal neutrons pose to avionics as a second mechanism for inducing single event upset (SEU) in microelectronics. There are two main points that will be addressed in this PAS: 1) a detailed evaluation of the existing literature on measurements of the thermal flux inside of airliners and 2) an enhanced compilation of the thermal neutron SEU cross section in currently available SRAM devices (more than 20 different devices). The net result of the reviews of these two different sets of data will be two ratios that we consider to be very important for leading to the ultimate objective of how large a threat is the SEU rate from thermal neutrons compared to the SEU threat from the high energy neutrons ($E > 10$ MeV). The threat from the high energy neutrons has been dealt with extensively in the literature and has been addressed by two standards ([2]¹ in avionics and [1] in microelectronics on the ground).

The two ratios that this PAS considers to be so important are: 1) the ratio of the thermal neutron flux inside an airliner relative to the flux of high energy (> 10 MeV) neutrons inside the airliner and 2) the ratio of the SEU cross section due to thermal neutrons relative to that due to high energy neutrons. These ratios are considered to be important because with them, once we know what the SEU rates are from the high energy neutrons for an avionics box, a topic which has been dealt with extensively, such as [1], then the additional SEU rate due to thermal neutrons can be obtained with these ratios. Thus, given the SEU rate from high energy neutrons, multiplying this by the two ratios gives the SEU rate from the thermal neutrons. The total SEU rate will be the combination of the SEU rates from both the high energy and thermal neutrons.

The process for calculating the SEU rate from the thermal neutrons is shown in the following set of equations, (1) to (5).

$$\begin{array}{ll} \text{SEU Rate} & \Phi_{\text{Hi}} (\text{neutron flux} = 6000 \text{ n/cm}^2\text{hr}) \times \sigma(\text{Hi E, SEU X-Sctn. cm}^2/\text{dev}) \\ (\text{Hi E, Upset/dev}\cdot\text{h}) & \end{array} \quad (1)$$

$$\begin{array}{ll} \text{SEU Rate} & = \text{SEU Rate (Hi E)} \times \frac{\Phi_{\text{therm}}(\text{neutron flux})}{\Phi_{\text{Hi}}(\text{neutron flux})} \times \frac{\sigma(\text{therm SEU X-Sctn.})}{\sigma(\text{Hi E SEU X-Sctn.})} \\ (\text{thermal neutron,} & \\ \text{Upset/dev}\cdot\text{h}) & \end{array} \quad (2)$$

$$\begin{array}{ll} \text{Ratio-1} & = \frac{\Phi_{\text{thermal}}(\text{neutron flux})}{\Phi_{\text{Hi}}(\text{neutron flux})} \\ & \end{array} \quad (3)$$

$$\begin{array}{ll} \text{Ratio-2} & \frac{\sigma(\text{therm SEU Cross Section})}{\sigma(\text{Hi E SEU Cross Section})} \\ & \end{array} \quad (4)$$

¹ Numbers in square brackets refer to the bibliography.

$$\frac{\text{SEU Rate (thermal neutron, Upset/dev}\cdot\text{h)}}{\text{SEU Rate (Hi E neutron Upset/dev}\cdot\text{h)}} \times \text{Ratio-1} \times \text{Ratio-2} \quad (5)$$

The objective of this PAS is to provide values of Ratio-1, the ratio of the thermal to high energy neutron flux within an airplane, and of Ratio-2, the ratio of the SEU cross section due to thermal neutrons relative to that due to high energy neutrons. We believe that Ratio-1 should be relatively similar in various types of commercial airliners, but it could vary significantly in other types of aircraft, such as military fighters. However, in the larger type of military aircraft, such as AWACS (Advanced Warning and Command System, E-3, which is based on either a Boeing 707-320-B or 767) and JSTARS (Joint Surveillance Target Attack Radar System, E-8C, which is based on Boeing 707-300 airframe), the ratio should be very similar to that in airliners.

With regard to the ratio of the thermal neutron SEU cross sections, until recently, not very many such SEU cross sections were reported in the literature. There were a few, and these were cited in [1], but they were relatively few. Due to the data that has recently become available, the number of devices in which the thermal neutron SEU cross section has been measured has increased significantly. This additional data allows us to have good confidence on the values that have been measured and the resulting average value of the ratio.

2 Thermal neutron flux inside an airliner

2.1 Definition of thermal neutron

Thermal neutrons have been given this name because while most neutrons start out with much higher energies, after a sufficient number of collisions with the surrounding medium, the neutron velocity is reduced such that it has approximately the same average kinetic energy as the molecules of the surrounding medium. This energy depends on the temperature of the medium, so it is called thermal energy. The thermal neutrons are therefore in thermal equilibrium with the molecules (or atoms) of the medium in which they are present.

In a medium that has only a small probability of absorbing, rather than scattering, neutrons, the kinetic energies of the thermal neutrons is distributed statistically according to the Maxwell-Boltzmann law. Therefore, based on this Maxwell-Boltzmann distribution, the neutron kinetic energy that corresponds to the most probable velocity is kT , where T is the absolute temperature of the medium and k a constant. For a temperature of 20 °C, room temperature, this is 0,025 eV. This is based on a highly idealized model of elastic collisions between two kinds of particles, nuclei and neutrons, within a gaseous medium, and so there are departures from it in the real world.

Therefore, even though a neutron energy of 0,025 eV is officially taken to be the true definition of thermal neutrons, for purposes of this PAS, we will consider neutrons with energies < 1 eV to be thermal neutrons. Additional details on this are found in 3.2.

2.2 Overview

In a modern airliner, we know that the thermal neutron flux inside the aircraft should be higher than the thermal neutrons outside of the airplane because of the presence of all of the hydrogenous materials within it (fuel, plastic structures, baggage, people, etc.). The hydrogenous materials “slow down” the high energy neutrons through nuclear collisions, primarily with the hydrogen atoms. After a large number of such interactions, the high energy neutrons (energy > 10 MeV) have had their energy reduced by about seven orders of magnitude. For practical purposes, we consider neutrons with $E < 1$ eV as thermal neutrons. However, the more accurate definition of thermal neutrons are neutrons with energies close to 0,025 eV (equivalent to those at room temperature, hence the term “thermal”). Thus, we expect, and have seen it verified by measurements, that the high energy neutrons inside an airliner and outside it within the atmosphere would be very similar. However, for thermal