MODELING THE REQUIREMENTS FOR RADIATION SHIELDING
How detailed should it be and when should it be done

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Introduction

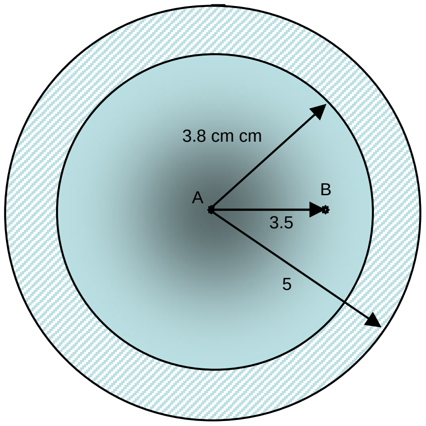
During past years the author has observed that radiation modeling of shield requirements for protection of electronic devices is frequently conducted after the design of the spacecraft and its contents has been completed and that the modeling is often overly simplistic. A popular modeling method is to determine the thickness of an aluminum hollow shell, or solid sphere, for which the dose at the center is less than the device's tolerance threshold. The aluminum shield thickness is then determined by subtracting the spacecraft's "equivalent aluminum thickness" from the sphere thickness. This aluminum thickness is then converted to that of the actual shield material using the ratio of material's density to that of aluminum. This paper examines the accuracy of the conventional equivalent thickness spherical aluminum modeling, ETSAM and suggests an improved method. The paper then demonstrates that mass reduction and risk reduction can be better achieved if radiation modeling using sophisticated modeling tools is conducted at the onset of the of spacecraft design, board design, and device layout.

Discussion

The radiation modeling code NOVICE is used for this study. For this abstract the environment is limited to a circular GSO orbit with a 5-degree inclination for normal solar maximum conditions. The MEO environment is included in the presentation. The shielding materials are PolyRAD®, which was developed with the support of a NASA SBIR contract, and tungsten. The targeted dose rate is 1 krad(Si)/year.

Figure 1 depicts an example of ETSAM. The 1.2-cm thick aluminum shell is the sum of a 0.254-cm (100-mil) equivalent aluminum representation of the spacecraft and a concentric 0.946-cm aluminum shield. The 2.35-Grad(Si) neat GSO per annum dose is reduced to 1.03 krad (Si) at the center, pt A.

Figure 1. – Cutaway view of a spherical, 1.2-cm thick aluminum shell equivalent representation of a spacecraft and shield.



If the spacecraft were spherically shaped, and homogenous, the shielding were concentric, and the electronics were at point A then the 0.946-cm value would be reasonably correct. But, for example, at B the annual TID is 0.71 krads(Si). So, if the location of the electronics were other than at the center then the mass of the shielding could be reduced. However a spacecraft is typically not spherical. For a hollow 5-cm OD aluminum cube with a 1.2-cm wall thickness the value at A is 0.805 krad(Si) and at B it is 0.640 krad(Si). Thus for even the simplest design accurate calculations require a more correct geometry than that which is used for ETSAM. If the shape is complex and/or the spacecraft's content is not homogenous it is reasonable to suspect that TID values are sensitive to the location of the boards and are also dependent on the design and layout of the boards themselves. These aspects will be examined using a generic satellite bus design.

A second major problem with the ETSAM is how the shield thickness is determined if the material if it not aluminum. A popular rule-of-thumb, frequently used for spot or conformal shielding, is to multiply the thickness of the aluminum shield by the ratio of the aluminum density to that of the other material. For example, if the shielding material is tungsten then, based on the 0.946-cm thickness for aluminum, the tungsten shield would be 0.132 cm. However, a TID calculation for a 100-mil Aluminum spherical spacecraft with a concentric 0.132-cm thick spherical tungsten shield yields 1.43 krad(Si) at A and 1.08 krad(Si) at B. So the tungsten shield should be thicker than the rule-of-thumb conversion predicts. For PolyRAD® , a conformal shielding material, the thickness predicted by the rule-of-thumb is 0.197 cm which results in 1.33 krad(Si) at point A and 0.99 krad(Si) at B. One reason for the error in using this rule-of-thumb method of conversion is that the stopping power for aluminum is higher than that for tungsten. The error is less for the PolyRAD® because the stopping power for a portion of its constituents is higher than for aluminum. An improved ETSAM method will be provided that minimizes the two problem associated with conventional ETSAM.

Conclusion

Popular simple methods for modeling radiation shield requirements, such as equivalent thickness spherical aluminum modeling, are inaccurate for all but the very shape, a sphere, and material, aluminum, used for the method. The errors may be to an extent that will jeopardize a mission. It is important for risk mitigation that radiation modeling correctly incorporates the spacecraft's structure and materials, as well as the location and layout of electronic boards. If this level of radiation modeling detail is included at the onset of the design of the spacecraft and its contents, including the boards, then at least an order of magnitude less TID can be achieved before additional radiation shielding is applied.