

SPACECRAFT RADIATION ANALYSIS

Dale W. Harris

Radioisotope thermoelectric generators (RTG's) are being used as the primary power supply for the Pioneer F and G spacecraft and for the Viking Lander System. RTG's have also been proposed for deep space missions. The inherent nuclear radiation from the RTG's, which consists of neutrons and gamma photons, will probably have a detrimental effect on the spacecraft electronic systems and the scientific experiments. Consequently, the radiation interface must be accurately defined to minimize its impact on spacecraft design.

To demonstrate the capability for defining the radiation interface, an analysis of an RTG-powered spacecraft was performed. Analyses of this type have been used prior to this calculation to characterize the radiation fields of other spacecraft concepts. However, the accuracy of these analyses is questionable, since analytical methods suitable only for very thick shields were used. Additionally, radiation scattered by the spacecraft structure was not considered previously. In this analysis, the scattered radiation was included, and a Monte Carlo technique was employed to increase the accuracy of the results. The accuracy of this analysis is dependent only on the statistics of the Monte Carlo method and the uncertainty of the material cross sections used in the calculation.

The spacecraft model assumed for the analysis is shown in Figure 1. It is a spin stabilized spacecraft powered by four SNAP-27-type RTG's, and each RTG contains 1300 W of fuel in the form PuO_2 . The scientific experiment package is positioned 6.1 m from the RTG's to take advantage of the decrease of the radiation field with distance. A magnetometer experiment is similarly located on the opposite side of the spacecraft to provide spin balance. The RTG's are positioned at an angle to the spacecraft so that they "point" toward the experiment package.

The first step in the analysis is to isolate a pair of RTG's from the spacecraft and determine the uncollided (unscattered) radiation fields as a

function of distance from the RTG center line. These results for both neutrons and gamma photons are shown in Figure 2 (dashed lines) as isoflux contours (lines of constant flux). The photon flux results are shown by solid lines. As can be seen in the figure, the photon flux is significantly depressed in the RTG axial direction because of self-shielding. Based on this result, the RTG's were "pointed" toward the science package as shown in Figure 1.

The total flux values (scattered plus unscattered) are then determined by converting the uncollided flux values of Figure 2 into an equivalent RTG surface source and then performing a Monte Carlo analysis for each specific dose point. Three of the dose points considered and the results for each point are shown in Figure 3. Point 1 is located at the geometric center of the spacecraft, point 2 is located at the center of an electronics compartment, and point 3 is located at the science package. For points 1 and 2, the total flux values are listed in the table of Figure 3. The scattered and unscattered flux values are shown separately for point 3 to aid the determination of shield requirements.

These results and the energy distribution of the particle spectra completely define the radiation interface for this spacecraft model. These results can then be used to determine shield requirements. The method of analysis used in this study can also be used to determine shield thicknesses as well as the radiation interface for other spacecraft models.

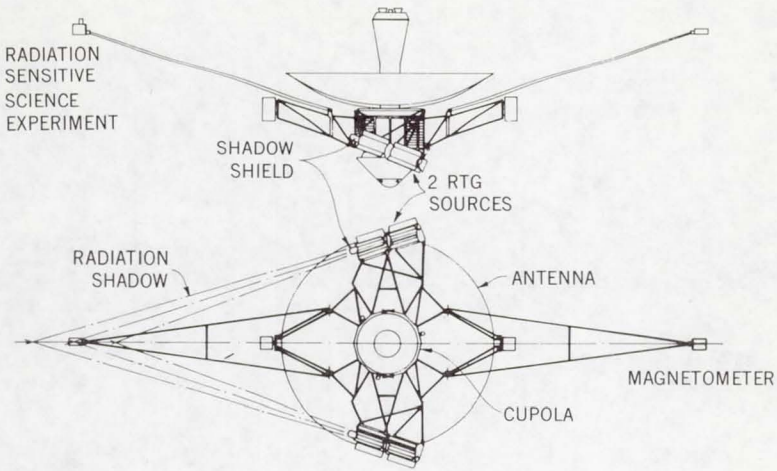


Figure 1—Schematic of typical spacecraft with RTG's.

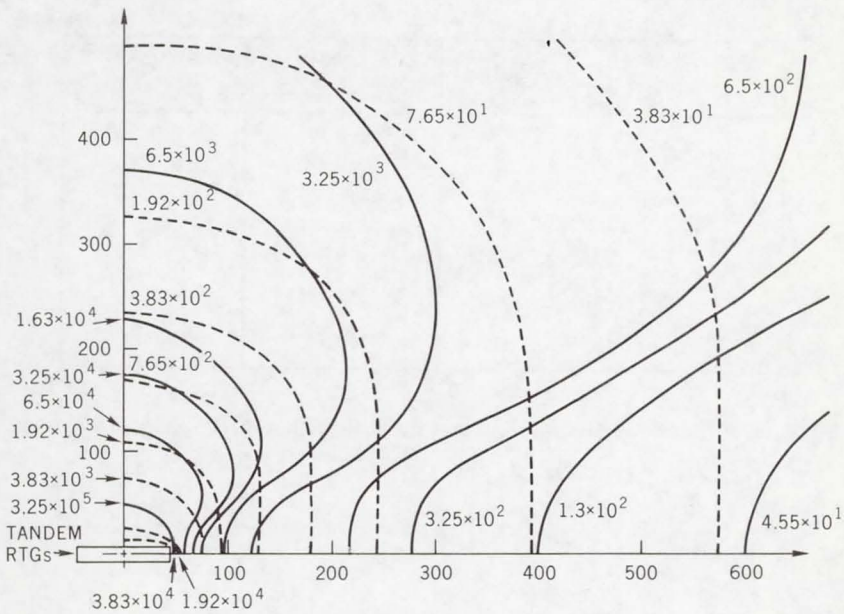
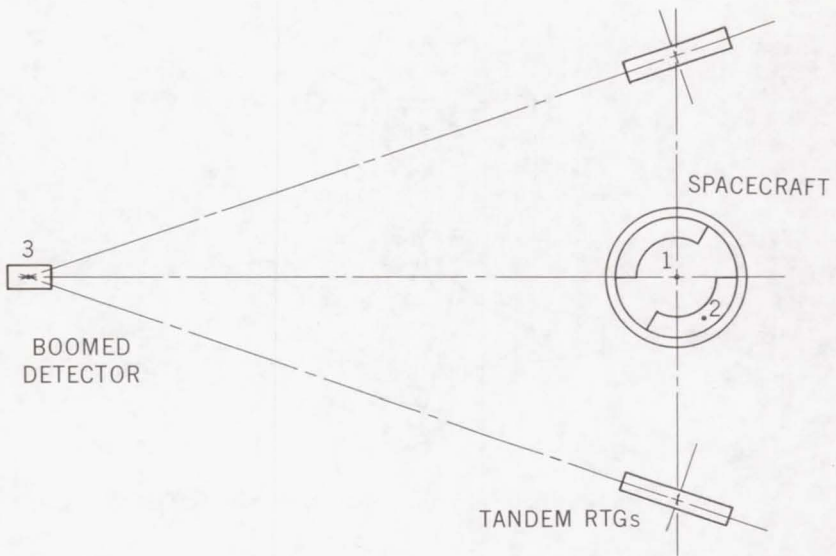


Figure 2—Photon (solid) and neutron (dashed) isoflux contours.



DETECTOR NO.	NEUTRONS $n/cm^2\text{-sec}$	PHOTONS $\gamma/cm^2\text{-sec}$
1	9.85×10^1	5.55×10^3
2	2.55×10^2	5.35×10^4
3	DIRECT CONTRIBUTION	5.29×10^1
	SPACECRAFT SCATTER COMPONENT	4.36×10^0
	TOTAL	5.73×10^1
		2.02×10^2
		1.01×10^1
		2.12×10^2

Figure 3—Location of point detectors within the RTG spacecraft system.