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CHARGED PARTICLE RADIATION ENVIRONMENT FOR THE LST

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16. ABSTRACT

Preliminary charged particle dose rates are presented for the LST orbit. The trapped proton component appears to dominate the total dose for the expected shielding available. Typical dose rates should range from 400 to 800 millirads/day.

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The nominal orbit for the Large Space Telescope (LST) is at an inclination of 28.8 deg and an altitude of 330 nautical miles (611 km). The lifetime of the LST is expected to be about 10 years. For this orbit and mission lifetime, any radiation-sensitive equipment onboard will be subjected to a substantial flux of high energy charged particles and charged particle induced secondary particles. Radiation hardening during the design of such equipment and careful placement to take advantage of shielding from spacecraft structure during spacecraft design can reduce or eliminate many radiation damage problems. This report defines the important components of the radiation environment and gives preliminary estimates of dose rates to be expected on the LST. This information will be useful in pointing up problem areas for more detailed radiation analysis later.

There are four possible sources of damaging radiation for the LST: geomagnetically trapped electrons and protons, solar event protons, galactic cosmic-ray particles, and onboard radiation sources (if there are any). Because of the high geomagnetic cutoff at 30 deg latitude (4 BeV for protons), solar flare protons should not be important. The cosmic-ray dose rate will also be reduced by the geomagnetic field. According to Burrell and Wright [1], the dose rate due to cosmic rays for the nominal orbit should be about 7.0 millirads/day (a rad is the deposition of 100 ergs of energy per gram of material receiving the dose). Hopefully, any onboard source will be small and well shielded. Thus, the major source of radiation is the Van Allen belt, with a minor contribution from cosmic rays.

Figures 1 and 2 show the average trapped electron and proton fluxes differential on energy for the proposed LST orbit. The fluxes were obtained by using James Vette's model environment [2] in a program [3] that averages the flux along the orbital trajectory for several orbits. There is an uncertainty factor of four in the electron environment and two in the proton environment. Also shown in Figure 2 are the proton fluxes at the center of an aluminum spherical shell shield of various thicknesses. The flux is assumed to be isotropic, an assumption which is good when the dose is to be averaged over a long mission. The use of a spherical shell shield is a simplifying assumption that allows a better understanding of shielding effectiveness. If problem areas

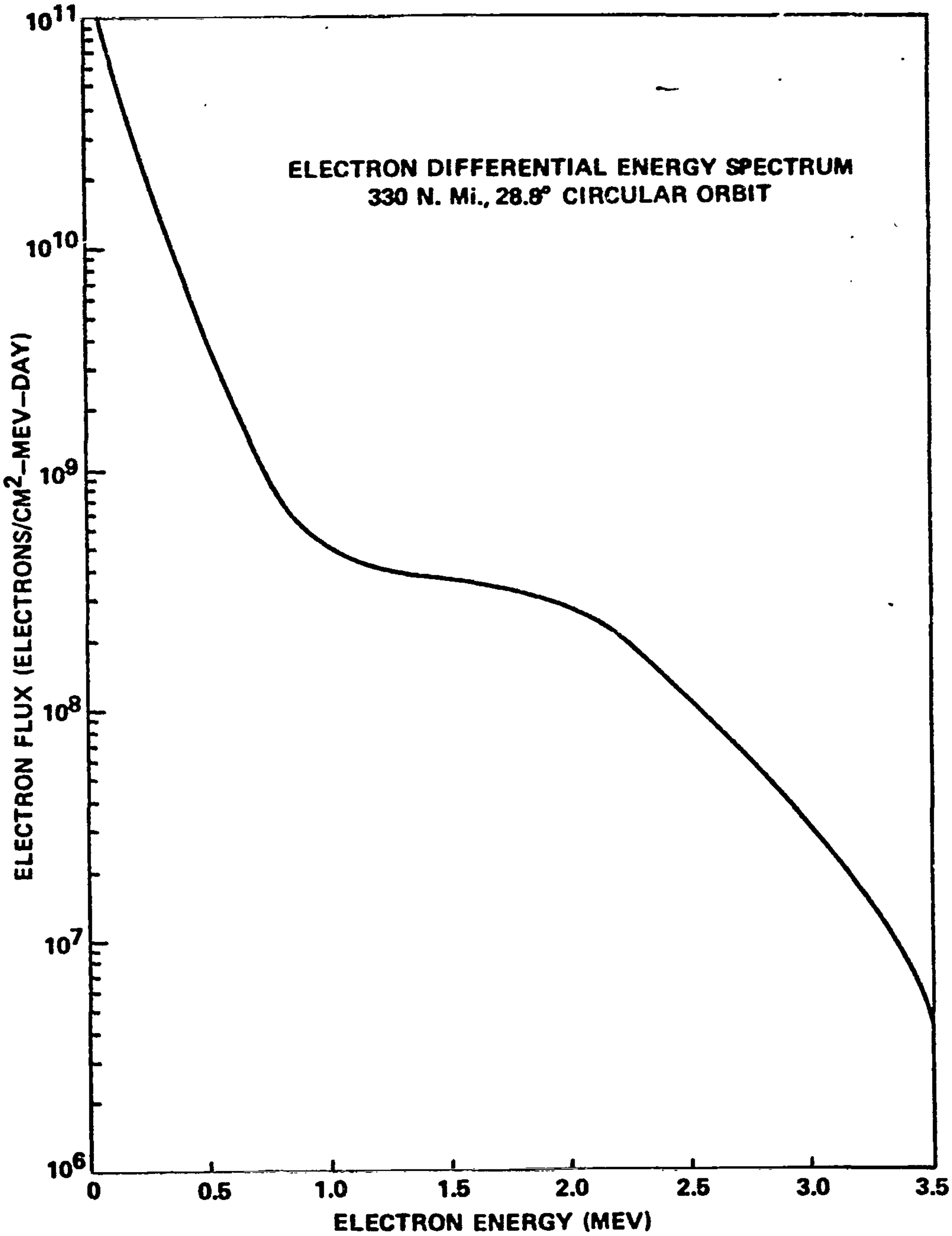

Figure 1. Average trapped electron flux differential with respect to energy for the LST orbit of 28.8 deg inclination and 330 nautical miles (611 km) altitude.

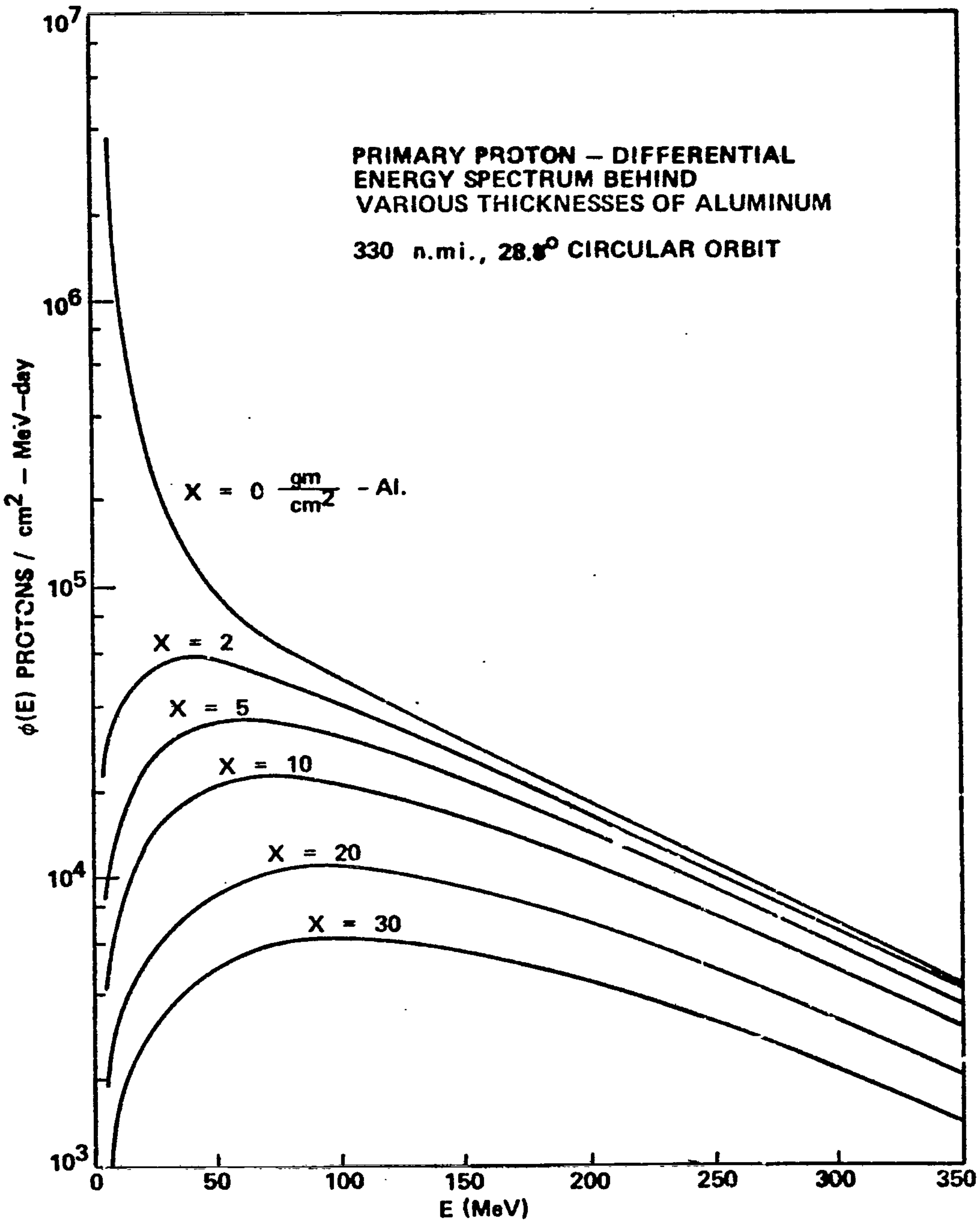

Figure 2. Average trapped proton flux differential with respect to energy at the center of a spherical aluminum shell of the given shield thicknesses for the LST orbit.

are found later, a mathematical model of the LST geometry will be constructed and doses calculated using the shield thicknesses and materials specified by the model. The unit grams per centimeter squared for shield thickness is typical in charged particle shielding work because different materials have approximately the same shielding effectiveness per unit length in these units. That is, 1.0 g/cm^2 of air is about as effective in stopping protons as 1.0 g/cm^2 of aluminum. The problem of density variation between samples of material with the same chemical composition is also avoided.

Figure 3 shows the dose rates in millirads/day due to protons and their secondaries [4], electrons [5], and electron-induced bremsstrahlung [5]. The same values are tabulated in Table 1. The proton dose rate is, again, for a spherical shield centered on an aluminum receiver. The geometry for the electron and bremsstrahlung dose rates is different. In these calculations, the electrons are assumed to be isotropically incident on an aluminum infinite plane shield rather than a sphere. The differences in dose rates for the two geometries are insignificant when compared to environmental uncertainties. The curves show that the proton component dominates the physical dose rate for shield thicknesses above 1.0 g/cm^2. For the exterior and very thinly shielded portions of the spacecraft, the electron component of dose rate is most important. The dose rate due to bremsstrahlung is about a factor of 400 below the proton dose rate for a given shield thickness and is less than the cosmic-ray dose rate for shield thicknesses greater than 1.0 g/cm^2.

Fears have been expressed that certain components would be exceptionally sensitive to damage by bremsstrahlung or that bremsstrahlung would introduce noise into the data. Figure 4 shows the bremsstrahlung energy flux differential with respect to energy for a point behind various aluminum infinite plane slab thicknesses. The spectra are sharply peaked toward low energies. The average energy appears to be in the range from 0.1 to 0.3 MeV. It is difficult to believe that interactions involving gamma rays at these energies would be as great as a hundred times more damaging than protons on a dose-deposited basis. Some photographic films are unusually sensitive to low-energy gamma rays. The response of one of these films to a typical bremsstrahlung spectrum was about 30 times higher than its response to protons on a dose basis. However, the authors believe that in general the proton component of the dose is the most important one to consider.

For the nominal orbit of the LST, most of the radiation damage will occur during passages through the South Atlantic Anomaly, a distortion in the geomagnetic field which results in higher trapped particle fluxes at lower altitudes than are usually seen over most of the earth's surface. The LST

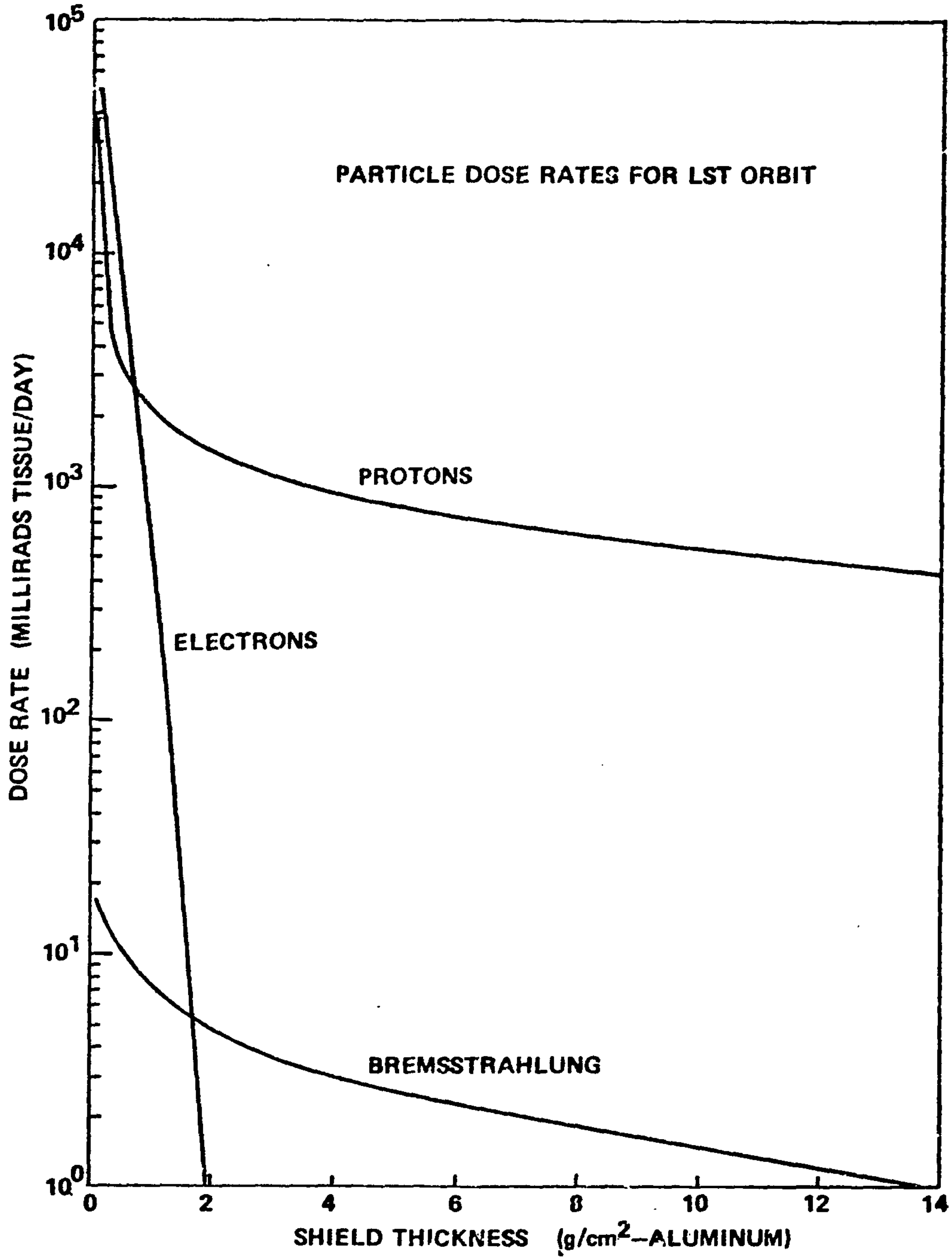

Figure 3. Dose rates due to protons, electrons, and bremsstrahlung versus shield thickness for the LST orbit.

TABLE 1. DOSE RATES DUE TO PROTONS, ELECTRONS, AND BREMSSTRAHLUNG AT THE GIVEN SHIELD THICKNESSES FOR THE LST ORBIT

Shield Thickness (g/cm^2 aluminum)	Proton Dose Rate (rads/day)	Electron Dose Rate (rads/day)	Bremsstrahlung Dose Rate (rads/day)	Total Dose Rate* (rads/day)
0	38.3	1900.0	--	1,940.0
0.1	10.2	49.7	0.0171	59.9
0.2	6.11	19.6	0.0142	25.7
0.4	3.63	8.59	0.0115	12.2
0.6	2.73	3.95	0.00971	6.69
0.8	2.30	1.61	0.00825	3.92
1.0	2.01	0.559	0.00713	2.58
1.5	1.60	0.0241	0.00545	1.63
2.0	1.35	5.25×10^{-4}	0.00457	1.36
3.0	1.08	1.83×10^{-7}	0.00357	1.08
4.0	0.937	1.07×10^{-10}	0.00296	0.940
5.0	0.831	7.70×10^{-14}	0.00256	0.834
10.0	0.535	--	0.00140	0.536

* The galactic cosmic ray adds approximately 0.007 rads/day to the above totals.

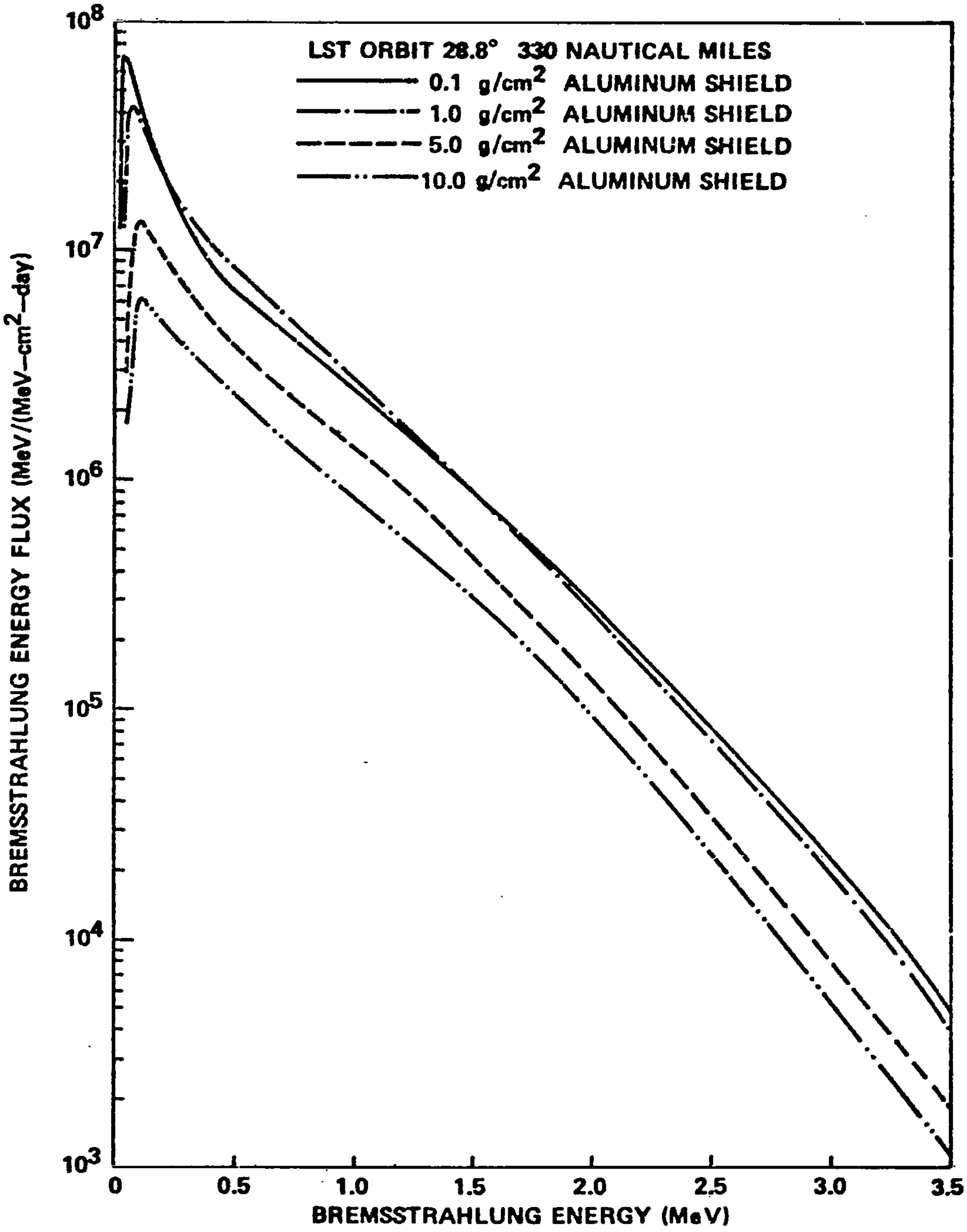

Figure 4. Bremsstrahlung energy flux differential in energy behind plane infinite aluminum shields of various thicknesses in the LST orbit.

orbit passes through the lower edge of the Van Allen belts in the anomaly. Thus, the dose rates encountered increase rapidly with increasing orbital altitude, as shown in Figure 5. Since the anomaly is centered at about 35 deg south latitude, the dose rates encountered also increase with orbital inclination, though not as rapidly as with altitude. This variation is shown in Figure 6. At higher inclinations (> 50 deg), the north and south "horns" of the outer trapped electron belts are encountered, and the geomagnetic cutoff for flare protons decreases so that these types of particles become more important; however, for typical shielding seen in most large spacecraft, the trapped proton component will still dominate the total dose.

The proton flux encountered by the LST will have two types of temporal variations, a very short term one and a long term one. The short term one is the variation seen as the spacecraft passes in and out of the South Atlantic Anomaly, with the flux rising and falling rapidly as the center of the anomaly is passed. Figure 7 shows the proton isoflux plot in the South Atlantic Anomaly; Figure 8 shows the proton flux during several passes through the anomaly. This plot is at a lower altitude than the LST orbit, but it is used to show the pattern of trapped radiation in and out of the anomaly region rather than the particle count rate. Almost all of the radiation damage will occur during these passages, which will usually last less than 15 minutes. The maximum dose rate during a pass may reach 40 to 50 times the average daily dose rate. The other temporal variation is associated with the 11-year solar cycle. There is an enhancement of the proton belt during the quiet part of the cycle by perhaps a factor of two, as a result of changes in the high altitude atmospheric density [6]. The Vette environment has this variation averaged out.

From experience with Skylab and Apollo, the authors find that the effective shielding for a typical point inside the spacecraft is considerably higher than would be expected from merely measuring spacecraft wall thickness. For Skylab, the wall thickness was about 1.0 g/cm^2, whereas typical points in the Workshop had an effective shield of approximately 10 to 15 g/cm^2 [7]. Because the LST is a somewhat smaller structure, a typical point would probably have from 5 to 10 g/cm^2 of shield. This corresponds to dose rates in the range 400 to 800 millirads/day. Actual dose rates depend strongly on the geometry. If sensitive equipment is near thinly shielded areas, the complex geometry dose calculation should be performed to get a better estimate of the problem.

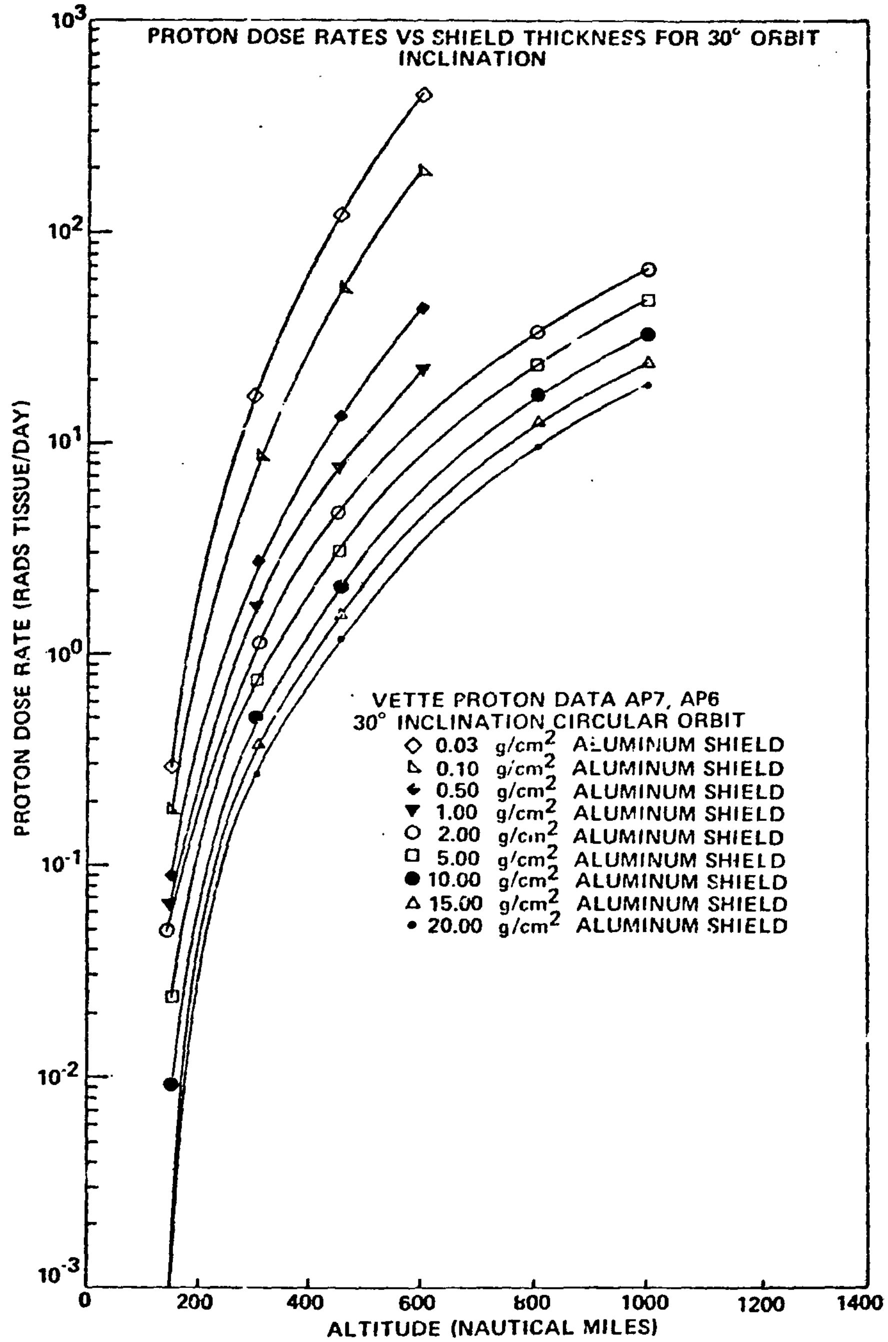

Figure 5. Proton dose rate at the center of a spherical aluminum shell of the given thicknesses versus orbital altitude for a circular 30-deg inclination orbit.

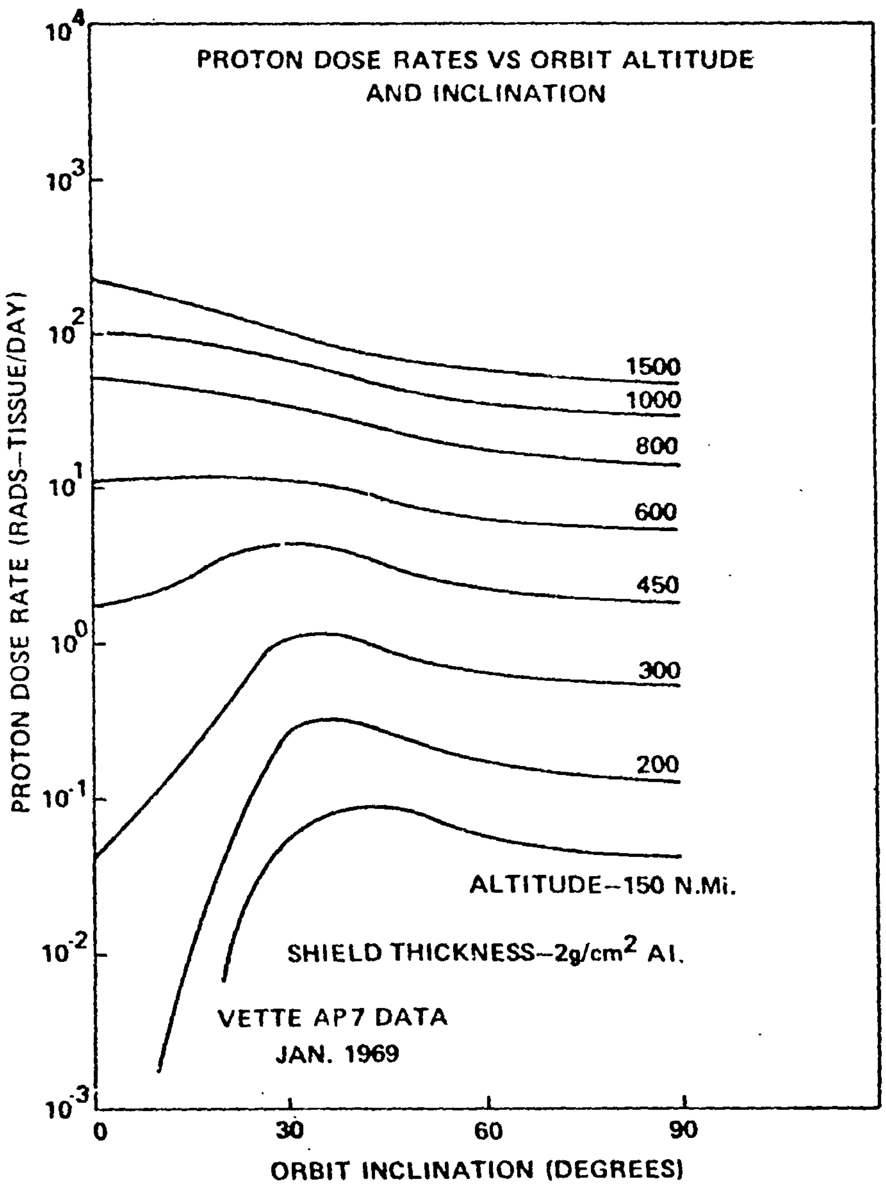

Figure 6. Proton dose rate at the center of a spherical aluminum shell of the given thickness versus orbital inclination at various orbital altitudes.

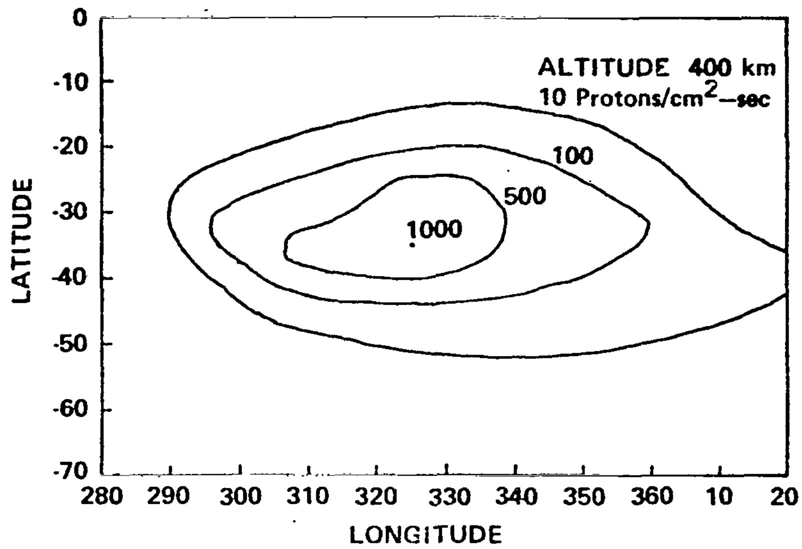

Figure 7. Proton isoflux plot at an altitude of 400 km in the South Atlantic Anomaly.

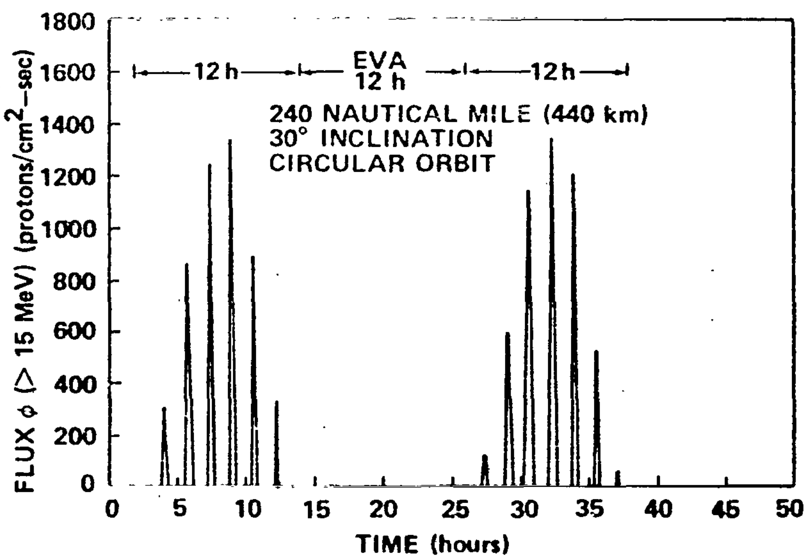

Figure 8. Integral proton flux received on a 30-degree circular orbit at an altitude of 240 nautical miles.

REFERENCES

1. Burrell, M.O.; and Wright, J.J.: The estimation of galactic cosmic ray penetration and dose rates. NASA TN D-6600, March 1972.

2. Vette, J.I.: Models of the trapped radiation environment. Vols. 1-6. NASA SP-3024, 1966-1967.

3. Burrell, M.O.; and Wright, J.J.: Orbital calculation and trapped radiation mapping. NASA TMX-53406, March 8, 1966.

4. Burrell, M.O.: The calculation of proton penetration and dose rates. NASA TMX-53063, August 25, 1964.

5. Watts, J.W., Jr.; and Burrell, M.O.: Electron and Bremsstrahlung penetration and dose calculation. NASA TN D-6385, June 1971.

6. Heckman, H.H.; Lindstrom, P.J.; and Nakano, G.H.: Long-term behavior of energetic inner-belt protons, Models of the Trapped Radiation Environment. Vol. VII: Long Term Time Variations. NASA SP-3024, 1971.

7. Hill, C.W.; and Neville, C.F.: Space Radiation Hazards to Project Skylab Photographic Film, Phase II. Lockheed-Georgia Company Report ER 11192, October 1971.

APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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