Engineering Notes

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Magnetospheric Radiation Environment in a 12-Hour Circular Orbit

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Introduction

THE second Navigation Technology Satellite (NTS-2) carried as part of its payload a dosimeter which directly measured the radiation dose in silicon under three different thicknesses of aluminum shielding. The NTS-2 satellite was launched on June 23, 1977 into a 12-h, circular orbit with an inclination of 63.2 deg. This orbit, in current use by the Global Positioning System (GPS) satellites, results in the greatest radiation dose experienced to date by long-lived Earth-orbiting satellite systems.

The purpose of this Note is to present some of the data from this dosimeter and compare them with the predictions for the NTS-2 orbit of the NASA AE-7HI model.

Dosimeter Description

The dosimeter consisted of three separate, single-detector sensors. These semi-omnidirectional sensors used 2-mm^3 lithium-drift silicon detectors centered under hemispherical shells which were heavily shielded over the rear 2π solid angle relative to the hemispherical shell. The shell thicknesses surrounding the three sensors were 75, 250, and 400 mils of aluminum.

Very briefly, the operation of each sensor was as follows. A particle that passed through the active volume of a silicon detector produced a number of electron-hole pairs which were directly proportional to the amount of energy deposited in the detector. These charges were collected by the detector electrodes, fed to a charge-sensitive preamplifier, and ultimately produced a pulse at the amplifier output. The area of this pulse (integral over time) was directly proportional to the energy which the particle deposited in the silicon detector and, by summing all amplifier pulses, the total energy released in the silicon was determined. Given the energy deposited in the detector, the accumulated dose in rads was readily calculated since the silicon detector size was known. As a result of the geometry of the dosimeter, with the heavily shielded rear 2π solid angle, these measurements gave one-half of the free-space dose. A very similar sensor was flown aboard the Defense Meteorological Satellite Program (DMSP) F-1 satellite.[1]

Results

The on-orbit operating temperature of the dosimeter proved to be much higher than planned. As a result thermal noise soon rendered the 250-mil channel useless and caused a substantial background in the 400-mil channel which made the data suspect. However the performance of the 75-mil channel was nominal; only the data from it will be discussed here.

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Data that were collected between day 22, 1978 and day 303, 1979, a total of 448 days, have been analyzed. These results are presented in Fig. 1 as a plot of rads/day vs day number. It can be seen that the radiation dose varies greatly from day to day. The largest dose per day was above 3500 rads, and the lowest just over 30 rads – a difference of a factor of more than 100!

In Fig. 2, the cumulative distribution of the radiation dose per day is plotted binned into 100-rad increments. This figure shows that on a few days the radiation dose greatly exceeded its mean value. In fact 10% of the total dose accumulated in 448 days was received in under 6 days and 25% in 25 days.

Figure 3 gives the running average of the daily dose as a function of the cumulative number of days of data. The average dose per day over the entire 448-day interval was 404 rads/day with a total dose of 1.81×10^5 rads. The NASA AE-7HI model gives 625 rads/day for the NTS-2 orbit. Thus during this 448-day period the measured dose in silicon under a 75-mil aluminum was 65% of the prediction of the NASA model. Many modern digital IC technologies have a total dose

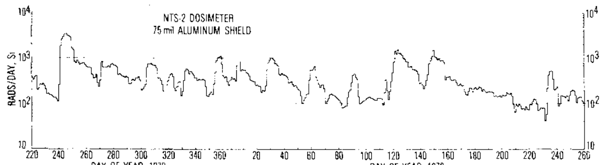

Fig. 1 Radiation dose in the 75-mil aluminum channel of the NTS-2 dosimeter.

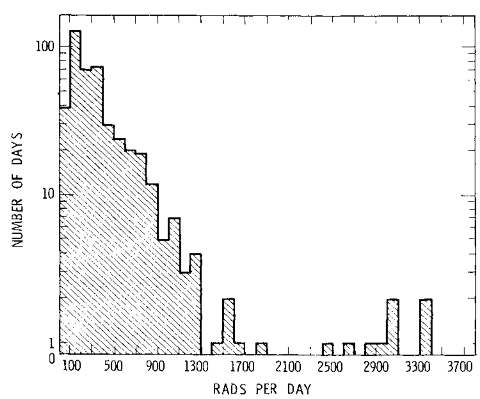

Fig. 2 The distribution of daily radiation dose.

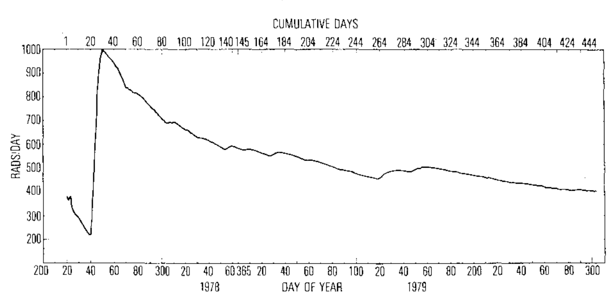

Fig. 3 The running average of the accumulated dose in the 75-mil channel.

hardness substantially smaller than this dose observed aboard NTS-2.[2] Obviously substantially more shielding than 75 mils of aluminum is required to use these components in the GPS orbit.

A quasiperiodicity can be seen in the data presented in Fig. 1, with an apparent period of approximately 1 month. In order to more accurately determine the period of this variation in the daily radiation dose, the power spectrum of the time series of dose per day was estimated using the Hamming lag window method.[3] The only significant frequency found was in the range of 0.0350-0.0375 cycles/day (and its harmonics). The corresponding period of 26.7-28.6 days brackets the 27.1 days required for the same location on the sun to face the Earth. This result suggests, as have other studies,[4] that modulation of the trapped electron intensity by the solar wind is the cause of the 27-day periodicity observed in the data. High-speed solar wind streams are associated with coronal holes and, since coronal holes persist for times long compared with a solar rotation, a correlation of the outer-zone radiation dose with the solar rotation period would be expected. The period of data collection was during the rise to solar maximum; the sunspot number peaked in November 1979. Several large magnetic storms occurred during this time interval with values of D_{st} substantially larger than $-100\ \gamma$.[5]

Conclusions

1) The radiation dose experienced in the GPS orbit due to energetic electrons was within a factor of 2 of the predictions of the NASA AE-7HI model for a period of more than 1 yr in 1978-1979. The shielding of 75 mils of aluminum corresponds to electrons of ~900 keV.

2) The energetic electron dose is extremely variable on several time scales. A large percentage of the total dose occurs during only a small fraction of the exposure days. The radiation dose rate due to outer zone electrons has a stochastic and periodic character. The stochastic nature is, in some ways, reminiscent of that of solar protons, although the electron dose never went to zero.

The past controversy over the magnitude of the fluxes of the outer-zone electrons would appear to be due substantially to their large variability in intensity. A few extended periods of high solar wind velocity, such as occurred in August 1978 (Fig. 1), would substantially enhance the integrated radiation dose whereas a period without any such enhancement would give a low dose. It should be noted that the higher the energy of outer-zone electrons, the larger the intensity fluctuations.[6] Therefore the highest-energy electrons will be present in significant numbers only occasionally but nevertheless will have a major role in damaging well-shielded components.

3) The electron dose is correlated with solar rotation. Thus it is possible to make relatively short-term predictions of the future radiation dose based upon records of the recent past. This feature of the outer-zone electrons might be quite useful for systems such as the GPS which could benefit from advanced warning of radiation enhancements.

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References

[1] Blake, J.B., Imamoto, S.S., Katz, N., and Kolasinski, W.A., "The GFE-3R Dosimeter," The Aerospace Corporation, El Segundo, California, Aerospace Report No. TOR-0077 (2630)-1, June 1977.

[2] Long, D.M., "Hardness of MOS and Bipolar Integrated Circuits," *IEEE Transactions on Nuclear Science*, Vol. NS-27, Dec. 1980, pp. 1674-1679.

[3] Otnes, R.K. and Enochson, L., *Digital Time Series Analysis*, John Wiley & Sons, New York, 1972, pp. 261-262.

[4] Paulikas, G.A. and Blake, J.B., "Effect of the Solar Wind on Magnetospheric Dynamics: Energetic Electrons at the Synchronous Orbit," *Quantitative Modeling of Magnetospheric Processes*, edited by W.P. Olsen, American Geophysical Union, Washington, D.C., 1979, pp. 180-202.

[5] Sirguira, M. and Poros, D.J., "Provisional Hourly Values of Equatorial D_{st}," National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Md.

[6] Vampola, A.L., Blake, J.B., and Paulikas, G.A., "A New Study of the Magnetospheric Electron Environment," *Journal of Spacecraft and Rockets*, Vol. 14, Nov. 1977, pp. 690-695.

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Information Adaptive System: An Investigation of Onboard Data Processing

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Introduction

THE NASA End-to-End Data System (NEEDS) program was initiated by NASA to improve significantly the state-of-the-art in acquisition, processing, and distribution of space-acquired data for the mid-1980s and beyond.[1] One element under Phase II of this program is the Information Adaptive System[2] which addresses sensor-specific processing onboard the spacecraft. The goal of the IAS effort is to design, develop, and demonstrate in early 1983 a system architecture that utilizes advanced technology for high-speed multispectral image data processing. Processing functions addressed by the IAS development include radiometric correction, data formatting, geometric correction, data editing, packetization, and adaptive system control.

IAS System Design

A functional block diagram of the Information Adaptive System is shown in Fig. 1. This design will serve as the basis for the contractual development of an IAS ground demonstration system. Hardware will be developed to the brassboard level; however, flight requirements will be taken into consideration to allow subsequent implementation in flight-qualified form.

The IAS demonstration system design employs a high-speed (>75 Megabits per second) pipeline architecture whose processing modules are under the control and supervision of a microcomputer-based control system, the adaptive system controller. Image data are input to the pipeline from the sensor simulator which consists of a high-speed buffer memory system. This memory is configured to simulate a pushbroom imaging system with six spectral bands. The IAS processed data are collected in the output buffer memory

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