S11-4 Spacecraft Anomaly and Space Environment, Space Weather and Satellite Alert system

衛星障害と宇宙環境　宇宙天気と衛星障害

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We assessed the effects of space environment on two Japanese spacecraft anomalies in JAXA during an Oct. 2003 radiation storm. We revealed these anomalies were related spacecraft charging with energetic electron, and developed satellite operation alert system using space weather technique.

1. Introduction

Space is filled with hot and low density plasma building up high differential voltages resulting in electrostatic discharges, sometimes causing spacecraft anomaly. A recent spacecraft anomaly statistic study [1] based on 326 environmentally related anomaly records, concluding that spacecraft charging has caused about 50 % portion in total records, and the most serious ones (i.e., mission lost).

On Oct. 23, 2003, the first big large solar flare (X-ray magnitude class X5.4) was observed in the sunspot region 486, where the subsequent ultra- large flare occurred (X17 on Oct. 28, X10 on Oct. 29, and X28e on Nov. 04).

The NASA Goddard Space Flight Center Space Science Mission Operation Team indicates that approximately 59 % of the Earth and Space Science missions experienced effects from the October -November activity [2].

We assessed the space environment effects of solar activity during the Oct. 2003 radiation storm on two Japanese spacecraft anomalies in JAXA.

2. DRTS (GEO) Anomaly

The Data Relay Test Satellite (DRTS), which has just the same function as TDRS, was launched on Sept. 10, 2002, and stayed in a geo-stationary orbit (GEO) at longitude 90.77 deg. east. DRTS entered safety mode, which is means sun-pointing slow- spin attitude control, and essentially shutting down all non-critical functions, on the Oct. 28, at 18:42 (UT) just after the X-17 flare.

(1) Anomaly in the Earth Sensor and attitude control.

The Earth Sensor Assembly (ESA) experienced much spike noises from 1530 (UT) on Oct. 28.

At 18:04 (UT) and before being anomaly flag reset by ground command, ESA-A switched automatically to redundant ESA-B (retaining its anomaly flag). The Attitude Control Equipment detected an anomaly, then, automatically entered safety mode (from three-axis attitude control mode to slow- spin stabilized and sun-pointing mode) and Light Load Mode (LLM), essentially shutting down all non-critical functions.

(2) The DRTS Recovery

After sequence of the extreme solar events, and after mitigating the limit of fault detection level in Attitude Control Equipment (ACE), three-axis attitude control of DRTS was recovered on Nov. 7, at 12:19 (UT) by ground command. DRTS is now operating normally.

(3) Relation between Anomaly and space environment

We found that the Earth sensor (exterior unit) produced spike noise when 1MeV electron (also known as relativistic electron) flux is high, before the solar extreme solar events, on 24 March, 2003, 04:06 (JST). 25 March, 04:10 (JST), 3 April, 03:27 (JST), 28 May, 01:24 (JST), and 6 June, 11:31 (JST). There was nothing out of the ordinary in the ESA hardware. Those anomalies did not affect satellite operation.

We made scatter plots for this time interval in 2003. The results are presented in Fig. 1, where the vertical axis represents 1MeV electron fluence integrated for one day (measured on DRTS) and the horizontal axis represents spike noise counts per day. We marked ESA anomalies with mesh circles.

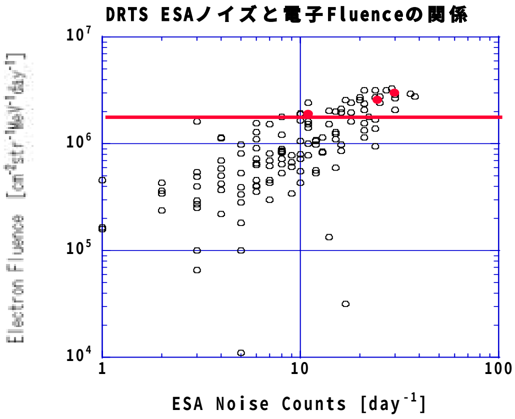

Fig. 1: Correlation between DRTS/ESA spike noise and measured electron fluences, mesh circles indicate anomalies.

ESA anomalies actually occurred when the 1MeV electron flux or fluence was extremely high, and over the threshold values, which is shown in the solid horizontal line in Fig.1.

(4) High-Energy Electron Alert System

A 1MeV range electron flux enhancement causes internal charge (build-up of electrons charge inside the bulk of a material) and induces electrostatic discharge (ESD) anomalies in satellites [3]. For safe satellite operation, it is essential to predict the 1MeV electron flux level and alert satellite operators. An alert system for 1MeV electron flux enhancement at geostationary orbit, which is activated when predicted electron flux levels exceed a certain threshold, which is determined by ESA anomalies, has been developed [4],

We applied the linear prediction filter method [5, 6] for electron flux forecasting method, using the solar wind speed and electron flux correlation at GEO, in Fig.2.

We calculated the cross-correlation between solar wind (WIND: NSSDC) and 1MeV electron flux at GEO (ETS-V) in 1995. The cross-correlation at +2 days after solar wind velocity increasing is the highest correlation with electron flux enhancement. We then applied this +2 days forecast relation to the high-energy electron (or ESD) alert System, shown in Fig.2 and SEES home page (http://sees.tksc.jaxa.jp). This alert system began operating in 2003.

3. ADEOS-II (LEO-Polar) Anomaly

The Advanced Earth Observing Satellite II (ADEOS-II), also called Midori-II in Japanese, a low-altitude polar sun-synchronous satellite with an altitude of 800 km, suffered a catastrophic failure during on October storm. Solar cell power output dropped from 6 kW to 1 kW in three minutes from (16:13 to 16:16 (UT)) on October 24 [7]. We will report what occurred on the satellite, and related space environment effects.

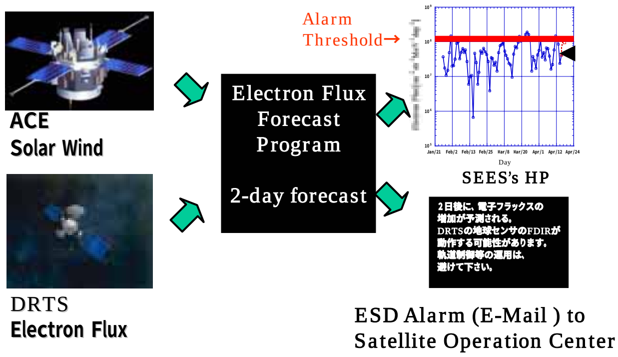

Fig. 2: High-Energy Electron Alert System

It was probable that a short- or open- circuit failure occurred on solar array paddle or solar array paddle harness. For the latter, the laboratory test verified that the sustained arcing between harnesses could destroy the bundled power lines. Space environment analysis demonstrated that the >30keV electron fluence (observed by NOAA-17) was two orders of magnitude greater than a quiet day on the just a quarter hours before the ADEOS-2 power down outage anomaly at over the north pole aurorla region.

References

[1] H. C. Koons, et al., The impact of the space environment on space systems, aerospace report, No. TR-99(1670)-1(1999) p7-10.

[2] D. L. Evans, et al., Intense Space Weather Storms October 19 – November 07, 2003, Service Assessment, NOAA, (2004)

[3] NASA, Avoiding Problems Caused by Spacecraft On-orbit Internal Charging Effects, NASA-HDBK-4002, Feb.17, (1999).

[4] K. Koga, H. Matsumoto, H. Koshiishi, K. Ueno, T. Goka, Forecasting Relativistic Electron Variations in the Outer Radiation Belt, 35th COSPAR scientific Assembly (2004), COSPAR-04-A-03741 PSW1-0023-04,

[5] T. Nagai, Space Weather Forecast: Prediction of Relativistic Electron Intensity at Synchronous Orbit, Geophysics. Res. Let., Vol. 15, No. 5, p425-428, May (1988).

[6] D.N. Baker, et. al., Linear Prediction Filter analysis of relativistic electron properties at 6.6 Re, J. Geophysics. Res., 95, 15133, (1990)

[7] H. Maejima, S. Kawakita, H. Kusawake, M. Takahashi, T. Goka, T. Kurosaki, M. Nakamura, K. Toyoda, M. Cho, Investigation of Power System Failure of a LEO Satellite, AIAA, Proceeding of 2nd International Energy Conversion Engineering Conference (IECEC), Providence, RI, (2004).