JAXA Space Environment Measurement -Overview & Plan-

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1. Introduction

Studies of the flux variability (short- and long-term) of radiation belt particles in the inner magnetosphere are particularly important for improving our understanding of related phenomena and for engineering considerations such as spacecraft anomalies due to space environment effects, including Electro-Static Discharge (ESD) and Single-Event Upset (SEU).

Therefore, we must continue radiation measurements and monitoring by satellites. For this purpose, we operated the Technical Data Acquisition Equipment (TEDA) and Space Environment Data Acquisition Equipment (SEDA) on each JAXA application satellite. This paper reviews the current status of radiation measurements using JAXA satellites as well as electrostatic charge potential measured by Potential Monitors (POM) on three satellites (ETS-V for 10 years in GEO orbit, ETS-VI in GTO orbit, and ADEOS in Polar LEO orbit) (see [1]).

We assessed the effects of solar activity on the GEO-orbiting Data Relay Test Satellite (DRTS), also known as Kodama in Japanese, which entered the safety mode (slow-spin mode), essentially shutting down all non-critical functions, on 28 Oct. at 1842 (UT). Three-axis attitude control of Kodama was then recovered on 7 Nov. In this paper, we report what occurred on the satellite and on a high-energy electron enhancement (or Electo Static Discharge (ESD)) alert system using space weather technique.

In addition, I will report on the space environment measurement plan and spacecraft charging technology research plan (in-situ measurement including POM on ETS-VIII in GEO orbit).

2. Objectives of space environment measurement

Objectives of space environment measurement are to acquire space environment data, to improve radiation environment models, and to develop a space environment database.

Our strategies to accomplish these objectives are to install an environment monitor on every JAXA satellite (commercial satellites usually cannot carry environment monitors)and to research the relation between satellite anomalies and the space environment.

3. Current Data [2]

(1) HIMAWARI (GMS) series (Japan Meteorological Agency, and NiCT) (GEO, 140deg. E)

The space environment monitor (SEM) was installed on GMS-1 to GMS-4, but not on GMS-5, or the next MTSAT; data was gathered from Feb. 1978 to Sept. 1999 (21.5 years).

(2) KIKU-5 (Engineering Test Satellite-V) (JAXA) (GEO, 150 deg. E)

Dosemonitor (DOM) and Technical Data Acquisition Equipment (TEDA) were installed on Kiku-5; data was gathered from Aug. 1987 to Sept. 1997 (10 years). (see http://sees2.tksc.jaxa.jp/)

(3) KIKU-6 (Engineering Test Satellite-VI) (JAXA) (GTO; perigee 8,600 km, apogee 38,600 km)

Dosemonitor (DOM) and Magnetometer (MAM)/Technical Data Acquisition Equipment (TEDA) were installed on Kiku-6; data was gathered from Aug. 1994 to July 1996 (see http://sees2.tksc.jaxa.jp/).

(4) OHZORA (EXOS-C) (JAXA) (LEO; perigee 350 km, apogee 850 km, inclination 75 deg.)

High-Energy Particle (HEP) equipment was mounted on this satellite; data was gathered from Feb. 1984 to March 1987.

(5) MIDORI (ADEOS) (JAXA) (LEO-POLAR; altitude 800 km, inclination 98.6 deg.)

Dosemonitor (DOM) and Heavy Ion Telescope (HIT)/Technical Data Acquisition Equipment (TEDA) were installed on MIDORI; data was gathered from Aug. 1996 to July 1997 (see http://sees2.tksc.jaxa.jp/).

(6) MIDORI-2 (ADEOS-2) (JAXA) (LEO-POLAR; altitude 800 km, inclination 98.6 deg.)

Dosemonitor (DOM) and Technical Data Acquisition Equipment (TEDA) were installed on MIDORI-2; data was gathered from Dec. 2002 to Sept. 2003 (see http://sees2.tksc.jaxa.jp/).

(7) TSUBASA (MDS-1) (JAXA) (GTO; perigee 500 km, apogee 36,000 km)
Standard Dosemonitor (SDOM)[3], HIT, and Magnetometer(MAM)/Technical Data Acquisition Equipment (TEDA) were mounted on board; data gathered from Feb. 2002 to Sept. 2003. (see http://sees2.tksc.jaxa.jp/)

4. Current Measurement

(1) AKEBONO (EXOS-D) (JAXA)(LEO; perigee 270 km, apogee 10,500 km, inclination 75.1 deg.)
A Radiation Monitor (RDM) was mounted on AKEBONO; data has been gathered since Feb. 1989 (see http://www.darts.isas.ac.jp/akbn/akebono/RDM.html).

(2) KODAMA (DRTS) (JAXA) (GEO; 90.75 deg. E longitude)
A Standard Dosemonitor (SDOM) [2] and Technical Data Acquisition Equipment (TEDA) were mounted on KODAMA. Data has been gathered since Sept. 2002 (see http://sees2.tksc.jaxa.jp/).

5. DRTS (GEO) Anomaly

The Data Relay Test Satellite (DRTS), which has the same function as TDRS, was launched on Sept. 10, 2002, and remains in geostationary orbit (GEO) at 90.77 deg. East longitude. DRTS entered the safety mode, which means sun-pointing, slow-spin attitude control, and essentially shut down all non-critical functions on the Oct. 28 at 1842 (UT) just after the X-17 flare (Fig. 1).

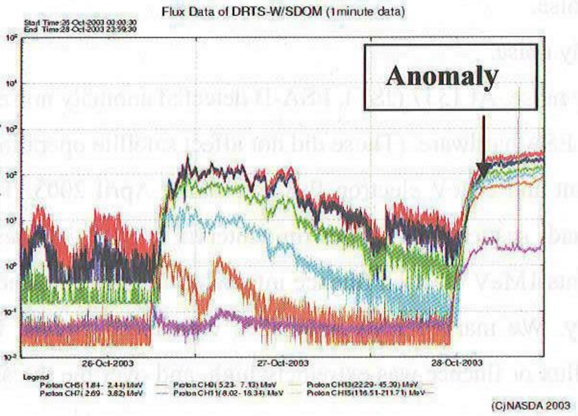

Fig. 1 Proton (1.4 to 2MeV, 3.7 to 5MeV, 8 to 18MeV, 22 to 45MeV) flux data measured by SDOM on DRTS from 26 to 28 Oct. 2003.

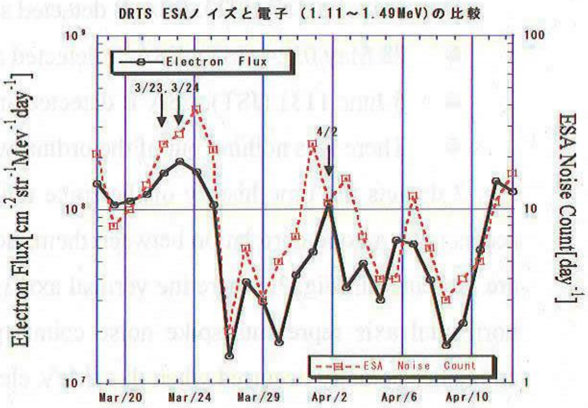

Fig. 2 Correlation between the DRTS /ESA spike noise (broken line) and the electron flux (1.1 to 1.5 MeV) (solid line) measured on board the same satellite. Anomalies on ESA are indicated by arrows.

5.1 Anomaly in the Earth Sensor aboard DRTS and the anomaly in DRTS attitude control

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

- At 1600 (UT), ESA-A detected an anomaly then switched automatically to the redundant ESA-B.
- At 1609 (UT), a ground command reset ESA-A's anomaly flag.
- At 1630 (UT), ESA-B detected an anomaly, then switched automatically to ESA-A. (This switching was repeated many times.)
- At 1804 (UT) and before being reset, ESA-A switched automatically to ESA-B (but retained 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.

5.2 DRTS Recovery

- After the sequence of extreme solar events and after mitigating the limit of fault detection level in Attitude Control Equipment (ACE), three-axis attitude control of DRTS was restored on Nov. 7 at 1219 (UT) by ground command.
- DRTS is now operating normally.

5.3 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 extreme solar events.

- 24 March 2003, 0406 (JST). ESA-A detected spike noise, then automatically switched from ESA-A to ESA-B.
- 25 March 0410 (JST). ESA-B detected spike noise.
- 3 April 0327 (JST). ESA-B detected spike noise.
- 28 May 0124 (JST). ESA-B detected anomaly noise.
- 6 June 1131 (JST). ESA-B detected anomaly noise. At 1537 (JST), ESA-B detected anomaly noise.
- There was nothing out of the ordinary in the ESA hardware. (Those did not affect satellite operation.)

Fig. 2 depicts the time history of the spike noise count and 1MeV electron flux for March-April 2003. There seems to be a good correlation between them, So we made scatter plots for this time interval in 2003. The results are presented in Fig. 3, where the vertical axis represents 1MeV electron fluence integrated for one day, and the horizontal axis represents spike noise counts per day. We marked ESA anomalies with mesh circles. 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. 3.

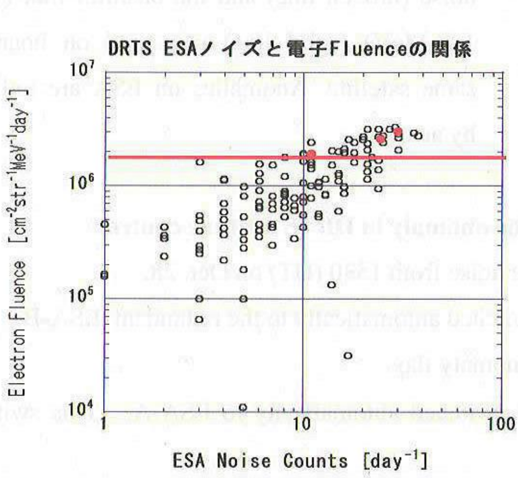

Fig. 3 depicts the time history of the spike noise count and 1MeV electron flux for March to April 2003

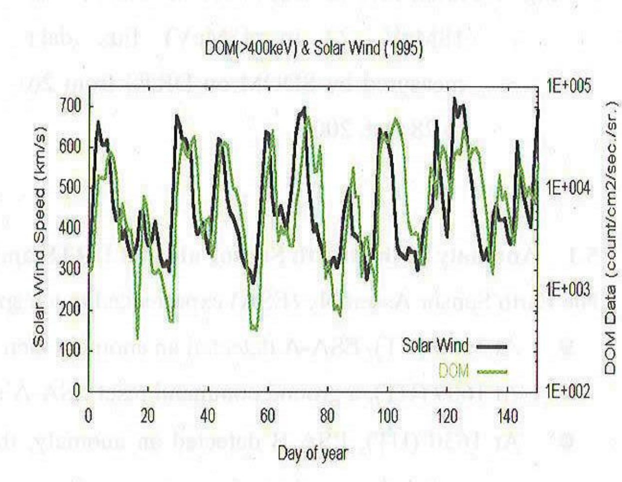

Fig. 4 ETS-V satellite DOM (dosemeter) electron flux (>400 keV) and solar wind speed (WIND: NSSDC) correlation[7].

5.4 High-Energy Electron (ESD) Alarm System

A 1MeV range electron flux enhancement causes internal charging (build-up of electron charge inside the bulk of a material) and induces electrostatic discharge (ESD) anomalies in satellites[4]. For safe satellite operation, it is essential to predict the 1MeV electron flux level and alert satellite operators. An alarm system for 1MeV electron flux enhancement at geostationary orbit, which is activated when predicted electron flux levels exceed a certain threshold determined by ESA anomalies, has been developed[7]. We applied the linear prediction filter method[5][6] to forecast electron flux, using the Solar wind speed and electron flux correlation at GEO, in Fig. 4[7].

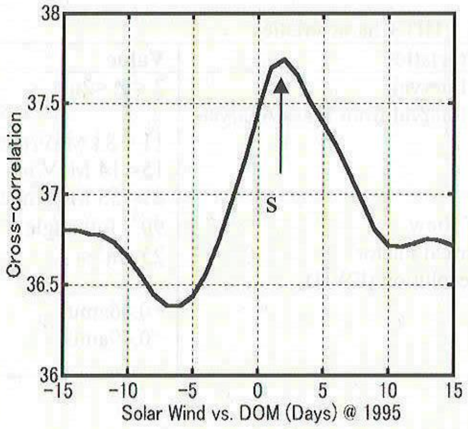

Fig. 5 Cross-correlation between solar wind (WIND: NSSDC) and electron flux at GEO (ETS-V)[7]

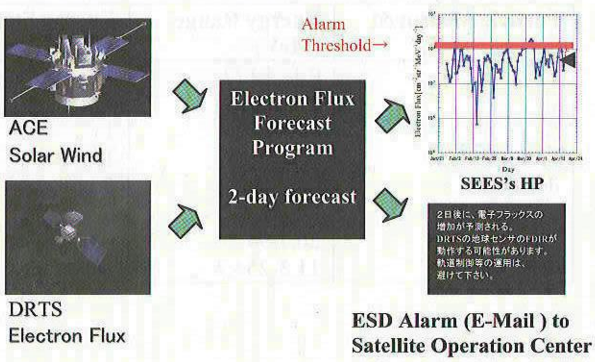

Fig. 6 High-Energy Electron Alarm System

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 in Fig. 5. We then applied this +2 day forecast relation to the High-Energy Electron (or ESD) Alarm System shown in Fig. 6.

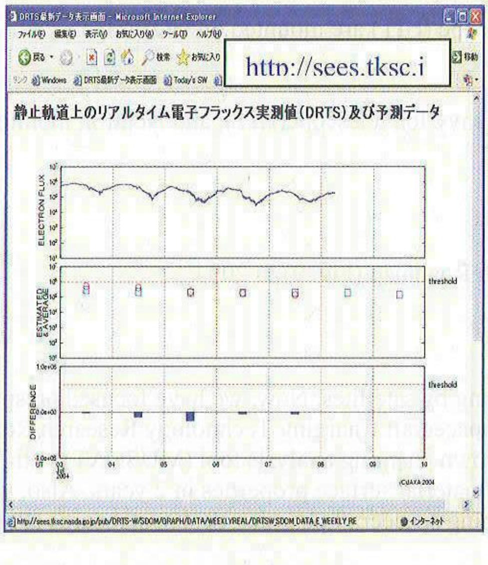

Fig. 7 Space Environment & Effects System (SEES) Web home page

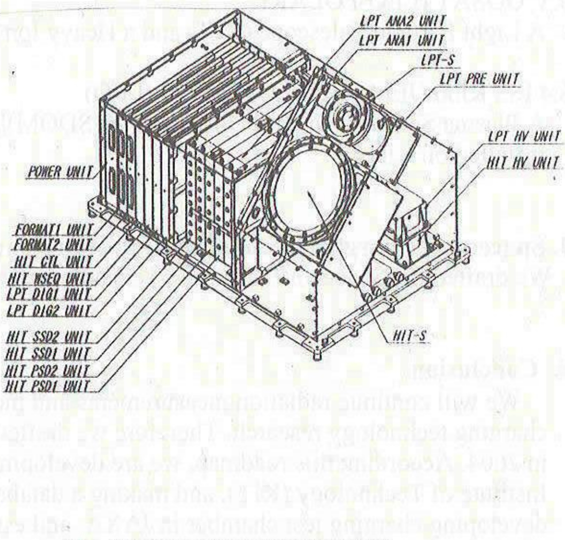

Fig. 8 Schematic of ALOS TEDA.

The second panel shows electron flux 1-day mean. Squares represent +1 and +2 day predictions, and circles indicate 1-day mean observation values. The third panel presents the difference from the previous day. Each threshold line in panels 2 and 3 is set based on DRTS and anomaly. This alarm system began operating in April 2004.

6. Future Measurement Plans

6.1 ALOS (LEO-POLAR; altitude 690 km, inclination 98 deg.)

A Light Particle Telescope (LPT) and a Heavy Ion Telescope(HIT) are mounted on ALOS (Fig. 8).

Table I LPT Characteristics

Particle Measured	Energy Range (MeV)	Energy Step
Electrons	0.1-4.122	14
	4.7-10.4	1
	>10.4	1
Protons	1.8-335.3	13
deuterons	8.0-26.6	6
tritons	9.2-26.9	6
3He	20.7-94	6
4He	11.3-254.7	14

Table II 1 HIT Characteristics

Characteristic	Value
Charge Interval	$2 < Z < 26$
Energy Interval from Mass Analysis	
O	11 – 83 MeV/nuc
Si	15-114 MeV/nuc
Fe	21-155 MeV/nuc
Field of View	90° full angle
Geometrical Factor	25 cm^2 sr
Mass Resolution (FWH)	
Li	<0.46amu
N	<0.49amu

Table III TEDA Resources

Mass	36.84 kg
Power	48 W
Bit Rate	3712 bps

6.2 ETS-8 (Engineering Test Satellite-VIII)(GEO, 146 deg. E longitude (tentative))

Potential Monitors (POM)[1], Dosimeter (DOS), and Magnetometer(MAM) are installed on ETS-8.

6.3 GOSAT (LEO-POLAR)

A Light Particle Telescope (LPT) and a Heavy Ion Telescope (HIT) are mounted on GOSAT.

6.4 ISS Kibo (JEM)-Exposure Facility (LEO)

A Plasma Sensor, Standard Dosemonitor (SDOM)[3] , Heavy Ion telescope(HIT), and Neutron monitor are installed on Kibo.

7. Spacecraft Charging Technology Research Roadmap

We drafted the Spacecraft Charging Technology Research Roadmap (Fig. 9) in 2004.

8. Conclusion

We will continue radiation measurements and monitoring by satellites. Now, we have focused on spacecraft charging technology research. Therefore we drafted the Spacecraft Charging Technology Research Roadmap in 2004. According this roadmap, we are developing our own charging analysis tool (MUSCAT) with Kyushu Institute of Technology (KIT), and making a database of material surface properties in 2 years. Also, we are developing charging test chamber in JAXA, and establishing spacecraft charging design standards (Polar and GEO) in 1 year.

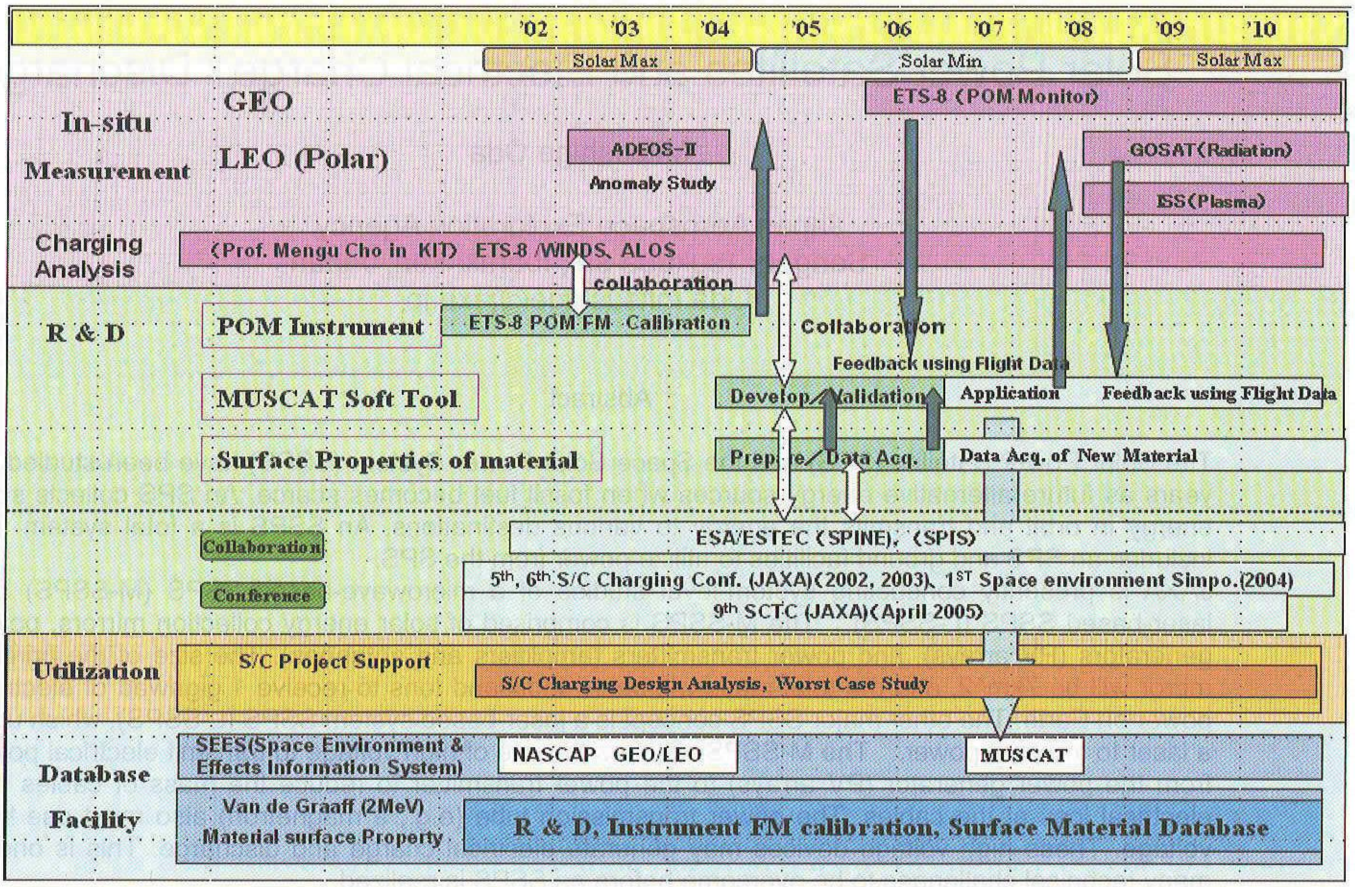

Fig. 9 Spacecraft Charging Technology Research Roadmap

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