SPACE ENVIRONMENT DATA ACQUISITION WITH THE KIBO EXPOSED FACILITY ON THE INTERNATIONAL SPACE STATION (ISS)

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ABSTRACT

The Space Environment Data Acquisition equipment (SEDA), which was mounted on the Exposed Facility (EF) of the Japanese Experiment Module (JEM, also known as "Kibo") on the International Space Station (ISS), was developed to measure the space environment along the orbit of the ISS. This payload module, called the SEDA-Attached Payload (AP), began to measure the space environment in August 2009. This paper reports the mission objectives, instrumentation, and current status of the SEDA-AP.

Keywords: Space Environment, International Space Station (ISS), Japanese Experiment Module (JEM), Space Environment Data Acquisition equipment -Attached Payload (SEDA-AP)

1 INTRODUCTION

To support future space activities, it is very important to acquire space environmental data related to the space radiation degradation of space parts and materials and spacecraft anomalies. Such data are useful for spacecraft design and manned space activity.

On several satellites of the Japan Aerospace Exploration Agency (JAXA) put into obit after the Engineering Test Satellite-V (ETS-V), Technical Data Acquisition Equipment (TEDA) and Space Environment Data Acquisition Equipment (SED) have been installed to obtain the space environment data.

These data have been used to develop various kinds of space environment models for satellite design, to investigate space radiation degradation of space parts and materials, and to examine satellite anomalies caused by the space environment.

The Space Data Acquisition Equipment is attached to the Exposed Facility of the Japanese Experimental Module (JEM-EF) on the International Space Station (ISS). This is called the SEDA-AP because it is expected to conduct in-orbit verification of APBUS (Attached Payload Bus) technology, which furnishes necessary functions when mounted on the KIBO exposed facility. The SADA-AP was launched by the Space Shuttle Endeavour (STS-127) on July 16, 2009 (JST), and attached to the JEM-EF on July 24, 2009. The SADA-AP began to measure the space environment on August 11, 2009.

The SEDA-AP comprises a power/communication interface with JEM-EF, an extendable mast that extends the neutron monitor sensor one meter away from the bus structure and the equipment that measures the space environment. Figure 1 portrays an artist's rendering of the Kibo and the Exposed Facility. Figure 2 depicts a perspective drawing of the SEDA-AP.

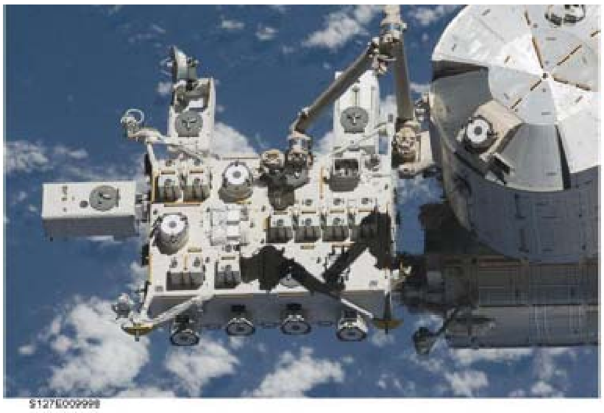

Figure 1. Picture of the ADA-AP (left) and the EF on the ISS

2 PURPOSE AND INSTRUMENTATION

The SEDA-AP has two main purposes:
1) Development of various space environment data bases for many utilization needs, such as
   - making and maintenance of a space environment model for satellite design,
   - investigation of space radiation degradation of parts and materials and satellite anomalies caused by the space environment,
   - support for astronauts exposed to space radiation,
   - support for space weather forecast, and
   - contributions to space science;
2) In-orbit verification of the KIBO exposed facility utilization technology, including
   - in-orbit verification of the APBUS technology that utilizes the KIBO exposed facility and
   - in-orbit verification of experimental payload integration technology that utilizes the KIBO exposed facility.

Figure 2 illustrates the SEDA-AP eight environment monitoring sensors. Its total weight is about 480 kg; its dimensions are 1850 × 1000 × 800 mm (neutron monitor storing condition). An overview and the principle of each instrument are as follows.

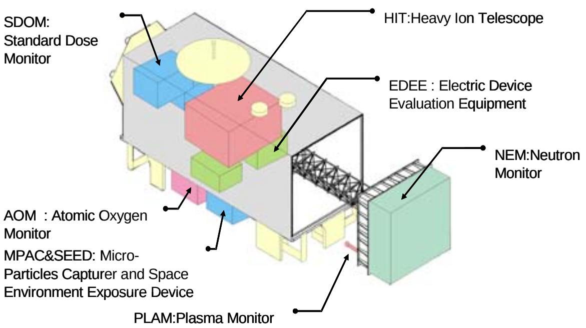

Figure 2. Perspective drawing of the SEDA-AP. The SEDA-AP has been equipped with eight sensors.

2.1 Neutron Monitor (NEM)

Neutrons are very harmful radiation because of their strong permeability attributable to their electrical neutrality. The Neutron Monitor (NEM) measures the energy of neutrons from thermal to 100 MeV in real time using a Bonner Ball Detector (Matsumoto, Goka, Koga, Iwai, Uehara, Sato, & Takagi, 2001) and a Scintillation Fiber Detector (Koga, Goka, Matsumoto, Muraki, Masuda, & Matsubara, 2001). Figure 3 depicts an image of the NEM.

The Bonner Ball Detector discriminates neutrons from other charged particles using 3He counters, which have high sensitivity to thermal neutrons. It also measures neutron energy using the relative response, which corresponds to different polyethylene moderators' thickness (6 pcs.).

The Scintillation Fiber Detector is assembled with mutual perpendicular scintillation sticks (16x16). It measures tracks of recoil protons in each lot by multi anode photomal and estimates the energy and incident direction of neutrons by the amount of light emission and tracks. Discriminating neutrons from protons can be achieved by finding the anti-coincidence with light emission from the scintillator at the outer most layer (a charged particle will emit light at the outermost scintillator). Discriminating neutrons from photons can be achieved by noting the difference of tracks (neutron: 1 track, photon: 2 tracks).

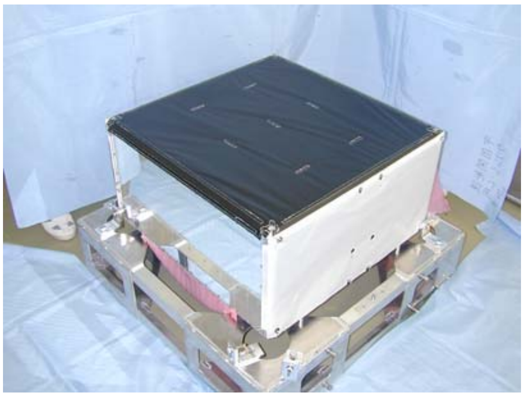

Figure 3. Picture of the NEM

2.2 Heavy Ion Telescope (HIT)

Using a Solid State Detector, the Heavy Ion Telescope (HIT) measures the energy distribution of heavy ions (Li–Fe), which cause single event anomalies and damage electronic devices. Incident charged particles coming into PSDs (Position Sensitive Detectors) and 16 Solid State Detectors (SSDs) produce pulses with electric potential that is in proportion to the dissipative energy of the incident particles.

The HIT utilizes this principle. It measures the dissipative energy (ΔE) in each detector and also measures the total energy (E) of the particles that stopped in the detectors. It discriminates particles from obtained energy and dissipative energy in each detector by the $\Delta E \times E$ method. Figure 4 is a picture of the HIT.

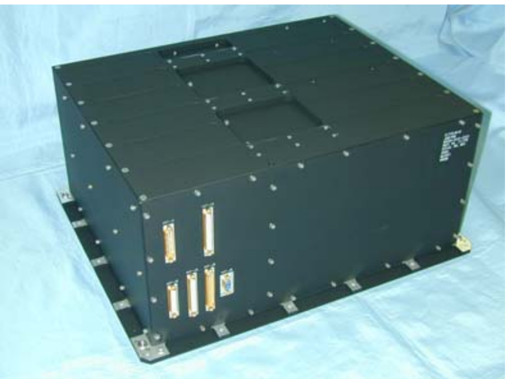

Figure 4. Photograph of the HIT

2.3 Plasma Monitor (PLAM)

Using a Langmuir probe, the Plasma Monitor (PLAM) measures the density and electron temperature of space plasma, which causes charging and discharge of the spacecraft.

A metal sphere is used as a probe for the PLAM sensor. It measures the density and temperature of electrons by analyzing current-voltage characteristics and also measures plasma potential by a floating probe. Figure 5 depicts the PLAM.

Figure 5. Picture of the PLAM

2.4 Standard Dose Monitor (SDOM)

The Solid State Detector and scintillator of the Standard Dose Monitor (SDOM) measure the energy distribution of high-energy light particles, such as electrons, protons, and alpha particles, which cause internal charging, single event anomaly, and damage to electronic devices.

The energy of incident particles is measured by three SSDs, and in case the energy penetrates these SSDs, this energy is measured by the scintillator behind the SSDs. The distribution of particles is observed using a combination of wave heights from each detector. Figure 6 shows a photograph of the SDOM.

Figure 6. Photograph of the SDOM

2.5 Atomic Oxygen Monitor (AOM)

The Atomic Oxygen Monitor (AOM) measures the amount of atomic oxygen in the orbit of the ISS. The AOM measures the resistance of a thin carbon film that is decreased by atomic oxygen erosion (Galica et al., 2006). Because atomic oxygen is very active, it interacts with the thermal control materials and paints, lessening their thermal control ability.

The thickness of the thin carbon film will be decreased by erosion from atomic oxygen. The change in the thickness is calculated as its resistance value. The integration flux of atomic oxygen is measured by preparing a table showing the relationship between the change in resistance value and integration flux of atomic oxygen in advance. Figure 7 shows a picture of an AOM.

Figure 7. Photograph of the AOM

2.6 Electronic Device Evaluation Equipment (EDEE)

The Electronic Device Evaluation Equipment (EDEE) collects the data from electronic parts to measure single-event effect (SEE) and radiation damage to these parts. Single-event phenomena are induced by the impact of an energetic heavy ion or proton. The occurrence of single-event phenomena is detected by bit flips of memorized data, the sudden increase of power supply current, etc. V70-MPU, IMSRAM, and Power MOSFET were selected because they have sensitivity to SEEs. For V70-MPU and IMSRAM, Single Event Upset (SEU) and Single Event Latch-up (SEL) are expected to happen. Power MOSFET is for SEB (Single Event Burnout). SEE is induced by radiation particles entering the electronic parts.

EDEE detects SEU, SEL, and SEB by monitoring the storage data inversion, the power supply current, and the electric charge, respectively. The results can contribute to improving the accuracy of the prediction of how a part will behave in space by a comparison with a ground radiation test. Furthermore, the data are used to find the causes if these problems were detected on the JEM system. Figure 8 depicts the EDEE.

Figure 8. Photograph of the EDEE

2.7 Micro-Particle Capturer (MPAC)

The Micro-Particle Capturer (MPAC) is a device used to capture micro-particles (space debris and micrometeoroids) that exist in orbit. The MPAC consists of two materials: silica-aerogel and gold plates. The former allow us to determine particle impact directions and velocities from tracks left in the material. Chemical analysis of impactor residues then yields the particle composition. The golden plate provides a means for measuring particle fluxes and estimating impact velocities by analyzing craters in the material. After the MPAC has retrieved its data, the size, composition, collision energy, etc. of captured particles are evaluated (Kimoto et al., 2008).

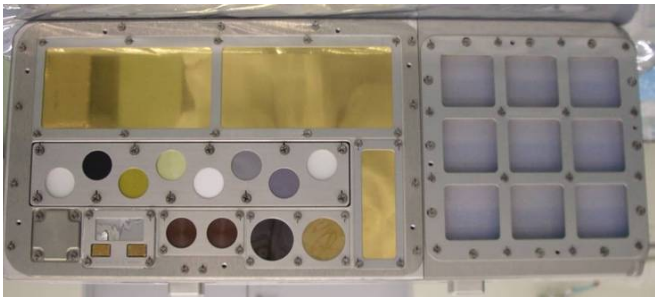

Figure 9. Photograph of the MPAC & SEED

2.8 Space Environment Exposure Device (SEED)

The Space Environment Exposure Device (SEED) exposes materials for space use (thermal control materials, solid lubricants, etc.) to the space environment. After SEED retrieval, degradation of these materials by the space environment, such as high energy radiation, atomic oxygen, and UV, will be evaluated. Figure 9 portrays a picture of both MPAC and SEED hardware (Kimoto et al., 2008).

Table 1 summarizes the specifications of all instruments.

Table 1. The basic specifications of the SEDA-AP

	Item	Specification
Major element	Dimensions	Mast stowed : W800 x H1000 x L1850 mm, Mast extended : W800 x H1000 x L2853 mm
	Weight	Approx. 450 kg
	Power consumption	Approx. 220 W (Nominal operation)
	Extension capability	NEM Sensor extends over 1 m from structural body
Specifications of SEDA / Sensors	NEM	Bonner Ball Neutron Detector (BBND) Measuring energy range : 0.025 eV (thermal neutron) ~15 MeV Maximum number of particles measurable : 1 x 10^4 count/sec Scintillation Fiber Detector (FIB) Measuring energy range : 15 MeV~100 MeV Maximum number of particles measurable : 50 event/sec
	HIT/PLAM	Heavy Ion Telescope (HIT) Li : 10~43 MeV/nuc C : 16~68 MeV/nuc O : 18~81 MeV/nuc Si : 25~111 MeV/nuc Fe : 34~152 MeV/nuc Plasma Monitor (PLAM) Langmuir probe mode : High Gain -0.2 μA ~+2 μA Low Gain -0.04 mA ~+0.4 mA Floating probe mode : High Gain ±5 V Low Gain ±100 V
	SDOM	Electron : 0.5~21 MeV (7 ch) Proton : 1.0~200 MeV (15 ch) Alpha : 7.0~200 MeV (6 ch) Heavy Ion : ID only (1 ch)
	AOM	Measuring range : 3 x 10^{17}~3 x 10^{21} atoms/cm^2 Resolution : 3 x 10^{17} atoms/cm^2
	EDEE	3 devices : Memory (1MSRAM) Microprocessor Unit (V70-MPU) Power MOSFET
	MPAC&SEED	Micro-particle capturer : Silica-aerogel (34 mm x 34 mm x9 pcs) Golden plate (119 mm x 60 mm x2 pcs 76 mm x 25.5 mm x1 pcs) SEED onboard sample : Scheduled to be selected by launch

3 MISSION OPERATION

The SEDA-AP was launched by NASA's Space Shuttle and installed on the KIBO's exposed facility (KIBO-EF). Its observation experiments began through each sensor or measurement instrument after the extendable mast successfully extended over one meter from the main structure body of the SEDA-AP, on which NEM sensors and PLAM sensor are mounted.

The in-orbit experiments (observation and data acquisition) by each sensor or measurement instrument have been conducted simultaneously and continuously for approximately 3 years. After the experiments are finished, the MPAC and SEED sample assembly will be returned to the earth. Other SEDA-APs will be mounted on the HTV that is to be launched to bring supplies to ISS, and the experiments will be expanded with the HTV.

4 INITIAL RESULTS

4.1 BBND Neutron measurement results

Figure 10 shows the BBND S-1 sensor's geographical plot data, and Figure 11 shows the BBND S-6 sensor's geographical plot data at 350 km altitude on October, 2009. The South Atlantic Anomaly region was clearly observed.

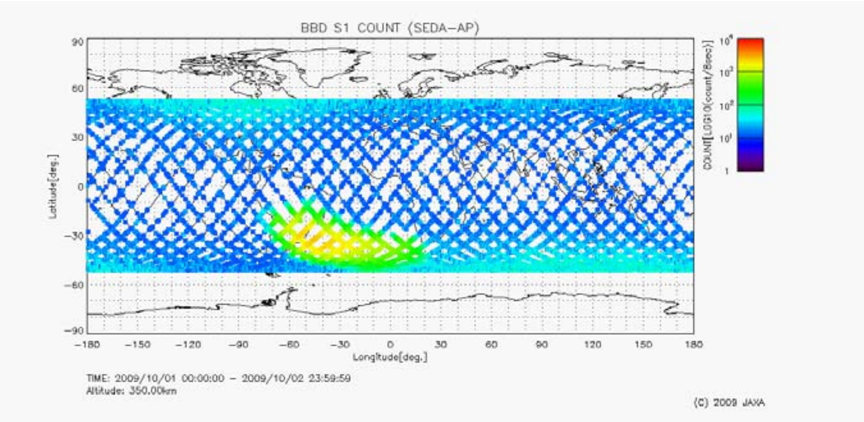

Figure 10. The BBND S-1 sensor's geographical plot data

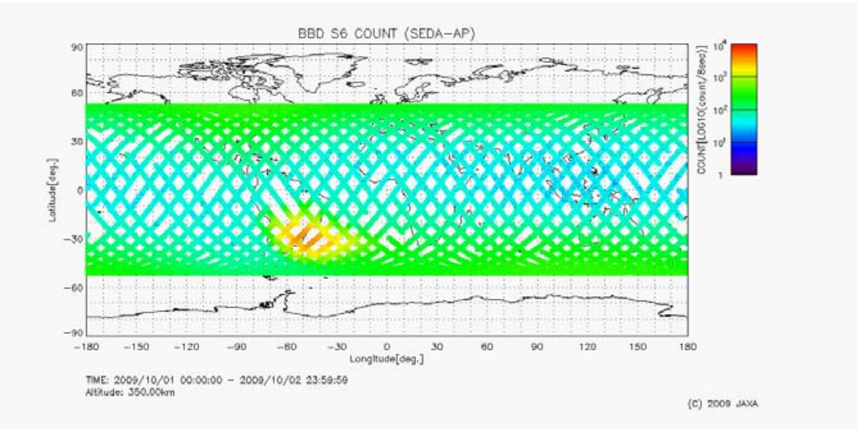

Figure 11. The BBND S-6 sensor's geographical plot data

4.2 FIB Neutron measurement results

Figure 12 shows the neutron tracks obtained by the onboard sensor. The left side is the Y-Z plane projection, and the right is the X-Z projection. Both directions have 256 (16x16) squares. The track shows the neutron track because the track starts within the scintillation fiber.

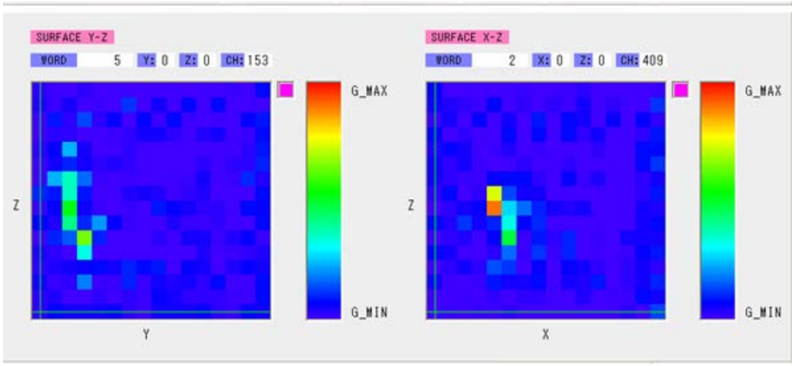

Figure 12. The neutron track obtained from the FIB

Figure 13 shows the proton track which started from the first layer of the fiber.

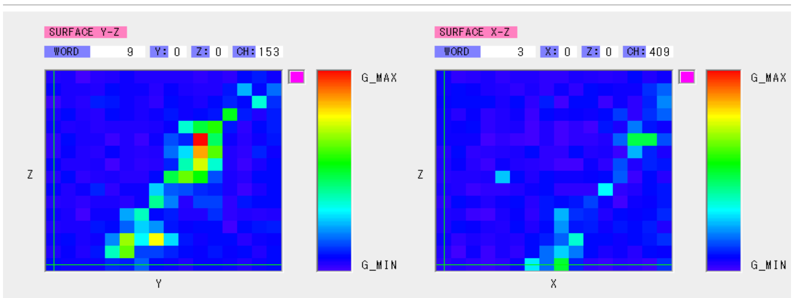

Figure 13. The proton track obtained from the FIB

4.3 SDOM Measurement results

Figure 14 shows the electron (0.28-0.79 MeV) measurement from the SDOM, which is plotted on a world map. In the SAA (South Atlantic Anomaly) region and the horn region of the outer radiation belt, large amounts of flux are observed.

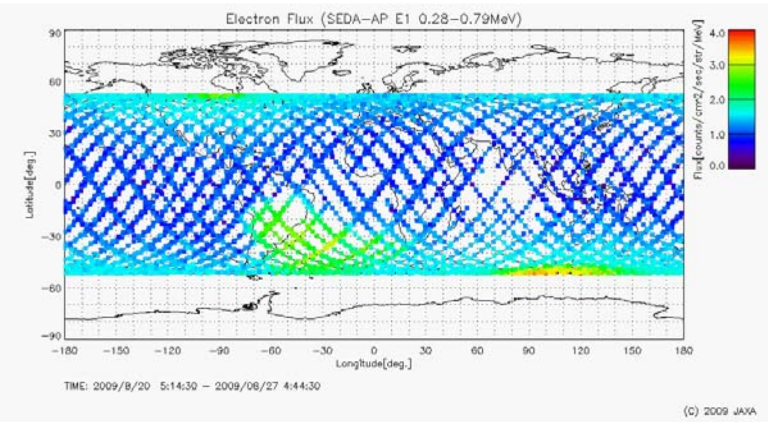

Figure 14. The SOM Electron (0.28-0.79 MeV) measurement

Figure 15 shows the proton (0.78-1.09 MeV) measurement from the SDOM, which is plotted on a world map. In the case of protons, the SAA is clearly observed.

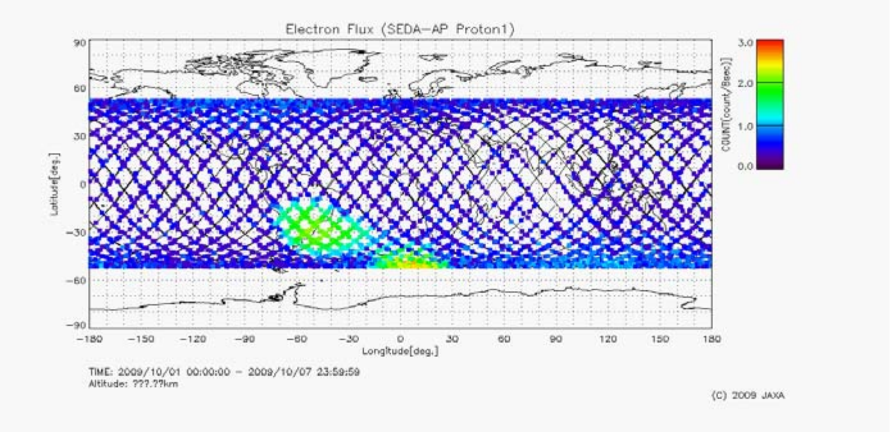

Figure 15. The SDOM Proton (0.78-1.09 MeV) measurement

4.4 EDEE Measurement results

The results of the EDEE instrument from August 15, 2009, to October, 23, 2009, (almost two months) are as follows:

V70-MPU SEU(Single Event Upset)/SEL(Single Event Latch up) : Not observed
1M SRAM SEU: 5 upsets
SEL: Not observed
PowerMOSFET SEB(Single Event Burnout) : Not observed

5 SUMMARY

The SEDA-AP has successfully launched and attached to the JEM. All the sensors have begun observations collecting space environment data along the ISS orbit, without problems.

Space environment data from the SEDA-AP are available to the public as data from the Space Environment and Effect System (SEES; http://sees.tksc.jaxa.jp). Those data will be used widely by academic and industrial users in laboratories and universities, by JEM experiment investigators, and by others in spacecraft operation, engineering fields, and scientific research. Data from the SADA-AP will also be used to develop the Japanese space environment model.

6 REFERENCES

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