Status of JEM/MPAC&SEED Experiment Onboard SEDA-AP on KIBO Exposed Facility

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Abstract

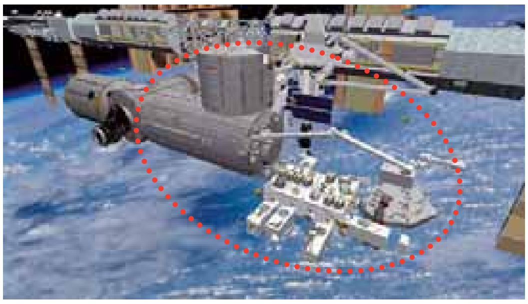
To improve the lifetime and performance of spacecraft in a low-earth-orbit, it is very important to investigate space environment effects on materials applied to spacecraft. In a low-earth-orbit, atomic oxygen greatly affects spacecraft surfaces. It is produced by dissociation of molecular oxygen by solar ultraviolet (UV) rays. For investigation of degradation mechanisms of exposed materials and for accumulation of experimental data, a space-environment exposure experiment was planned for use with the Russian Service Module (SM) and Exposed Facility of the Japanese Experiment Module (JEM) of ISS. The exposure experiment at SM/MPAC&SEED has been completed. We are preparing the next experiment for JEM, which is scheduled for launch next year. Those experiments are expected to yield details of characteristic changes of exposed materials and mechanisms of their degradation by atomic oxygen, UV, and other radiation.

Keywords: MPAC&SEED, Space Exposure Experiment, Material, Space Environment, Low Earth Orbit, ISS, KIBO, Zvezda

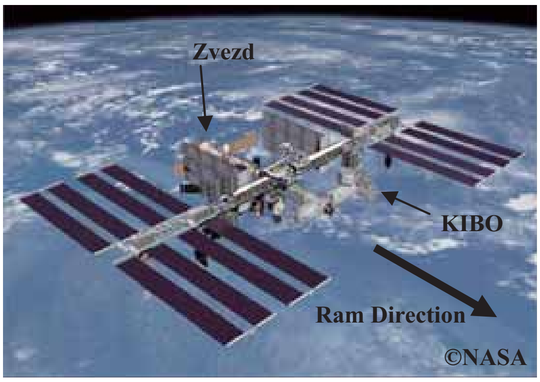
1. Introduction

The Low Earth Orbit (LEO) altitude space environment affects the outside of spacecraft flying. It causes degradation from atomic oxygen, ultraviolet rays, radiation, etc. Past examinations of flight hardware show that atomic oxygen attacks organic materials of spacecraft; such materials are frequently used in spacecraft as thermal control material, paint, adhesive, etc. Carbon Fiber Reinforced Plastic (CFRP) is applied to the orbiter as a construction material. For improvement of the spacecraft lifetime and the performance, it is very important to obtain fundamental knowledge related to the compatibility of space materials with the LEO environment and to develop advanced materials having excellent resistance to space environments. In Japan, materials exposure experiments in space, Evaluation of Oxygen Interaction with Materials-3 (EOIM-3), Exposure Facility Flyer Unit (EFFU) [1], and Evaluation of Space Environment and effect on Materials (ESEM) [2] were conducted using space shuttles and satellite units. Nevertheless, the behavior of materials exposed to space environment has not been well understood. For that reason, the Japan Aerospace Exploration Agency (JAXA) has planed to perform exposure experiments in space using the Russian Service Module "Zvezda" and the Japanese Experiment Module "KIBO" of the International Space Station (ISS). Both KIBO and Zvezda are presented in Fig. 1.

(a) Russian Service Module "Zvezda"



(b) Japanese Experiment Module "KIBO"



(c) Positions of KIBO and SM on ISS

Figure 1 External views of KIBO and Zvezda

2. Purpose of experiments

These experiments are designed to elucidate characteristic change behaviors and to clarify degradation mechanisms of exposed materials to the LEO environment over a long period. Fig. 1 shows that the positions of the KIBO and the Zvezda differ on the ISS. In fact, the KIBO is situated in the front of the ISS, with the Zvezda in the back. They provide opportunities for exposure experiments in different space environments and orientations. Through on-orbit experiments, irradiation of atomic oxygen, ultraviolet rays, and electron beams will be performed on the ground as a reference experiment to establish an evaluation method of space environmental effects on materials [3].

3. SM/MPAC&SEED experiment

The experiment on the Zvezda is called the Service Module / Micro-Particles Capture and Space Environment Exposure Device (SM/MPAC&SEED). The orbital position of SM/MPAC&SEED on ISS is depicted in Fig. 2.

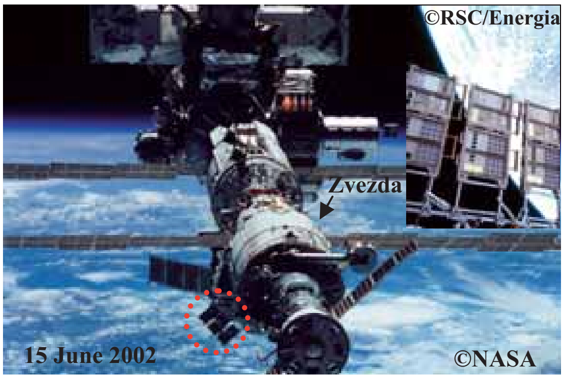


Figure 2 Orbital position of SM/MPAC&SEED

Actually, SM/MPAC&SEED includes both MPAC and SEED. The latter is a passive experiment designed simply to expose materials; it is shown in Fig. 3. The part enclosed in a red dotted line in the figure is MPAC. It is mounted on a collapsible frame that is 1 m long when open, which it shares with MPAC: it is a passive experiment designed to sample the micro-meteoroid and space-debris environment, and to capture particle residue for later chemical analysis using aerogel, polyimide foam, and 6061-T6 aluminum. More detailed descriptions of the MPAC and SEED on the Zvezda are reported elsewhere [4]–[7].

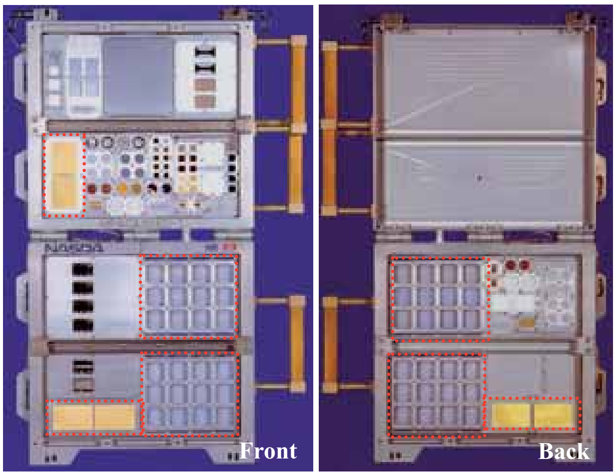


Figure 3 Photographs of SM/MPAC&SEED (570 (W)×900 (H)×156 (D) [mm])

Three identical SM/MPAC&SEED units (MPAC&SEED #1, #2, and #3) were attached to the Zvezda. The SM/MPAC&SEED was launched aboard a Progress M-45 on 21 August 2001. MPAC&SEED #1, was retrieved during EVA after 315 days of on-orbit exposure. Subsequently, MPAC&SEED #2 was retrieved on 26 February 2004 (after 865 days). Finally, MPAC&SEED #3 was retrieved on 18 August 2005 (after 1403 days).

4. JEM/MPAC&SEED experiment

4.1 Outline of KIBO

The experiment conducted on the KIBO is called the Japanese Experiment Module / Micro-Particles Capture and Space Environment Exposure Device (JEM/MPAC&SEED).

Here, the KIBO lightly is explained. The KIBO is composed of six main part; such as the Pressurized Module (PM), the Experiment Logistics Module-Pressurized Section (ELM-PS) in the pressurizing part, the Exposed Facility (EF), the Experiment Logistics Module-Exposed Section (ELM-ES) in the exposure part, the Remote Manipulator System (JEMRES) of the manipulator only for KIBO, and the Inter-orbit Communication System (ICS). These are presented in Fig. 4. The EF installs various experiment equipments. One of these experiment equipments is a experiment equipment that is called the Space Environment Data Acquisition Equipment-Attached Payload (SEDA-AP). JEM/MPAC&SEED is installed in the SEDA-AP.

The KIBO is divided into three parts, carried to the ISS respectively by the space shuttle, and assembled. The ELM-PS has already been launched by 1J/A mission (STS-123 mission). The PM and JEMRES will be launched by 1J mission (STS-124 mission) as follows. Finally, the EF and the ELM-ES will be launched by 2J/A mission (STS-127 mission).

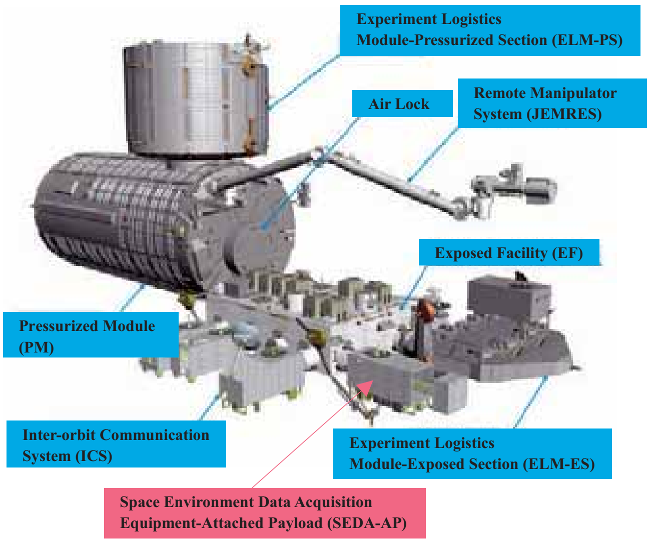


Figure 4 Composition of KIBO

4.2 Outline of SEDA-AP

The SEDA-AP has eight space environments and effect monitoring experiment sensors [8]: JEM/MPAC&SEED is one experiment component. Fig. 5 shows the composition of the SEDA-AP. To investigate interaction with the space environment and its effects on the KIBO/EF, SEDA-AP measures the space environment (neutrons, plasma, heavy ions high-energy light particles, atomic oxygen and MMOD) and environmental effects on space materials and electronic devices. The sensors are the following: (1) NEutron Monitor (NEM), (2) Heavy Ion Telescope (HIT), (3) Plasma Monitor (PLAM), (4) Standard Dose Monitor (SDOM), (5) Atomic Oxygen Monitor (AOM), (6) Electronic Device Evaluation Equipment (EDEE), (7) MPAC, and (8) SEED. Also, JEM/MPAC&SEED comprises MPAC and SEED hardware.

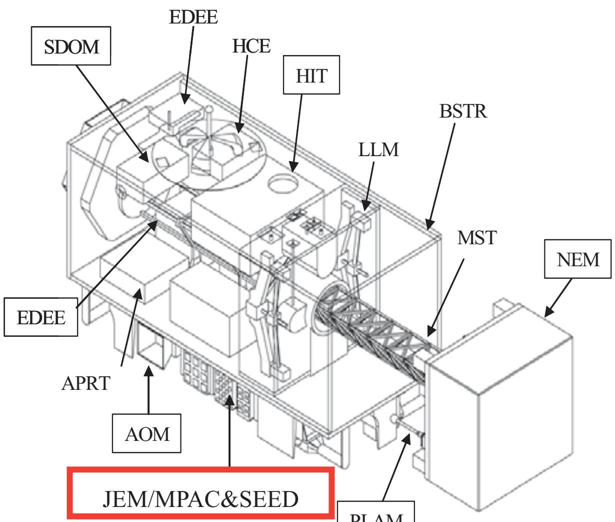


Figure 5 Composition of SEDA-AP

4.3 Outline of JEM/MPAC&SEED

The positions of the SEED samples, including the space environment monitoring samples and silica aerogel and gold plate for MPAC are shown in Fig. 6 and Table 1. The MPAC and the SEED samples are installed on Sample assembly (Sample Units 1–3 etc.).

Sample Unit 1: Silica-aerogel for MPAC
Sample Unit 2: Gold plate for MPAC and SEED
Sample Unit 3: SEED

Figure 6 Photographs of JEM/MPAC&SEED ((450 (W)×220 (H)×190 (D) [mm])

The MPAC has two functions; capturing space debris and micrometeoroids of 0.001–0.1 mm diameter and measuring their flux on orbit. Silica aerogel is used for MPAC on Sample Unit 1 to capture microparticles with minimum damage. Gold plate is used for MPAC on Sample Unit 2 to investigate the flux of impacts on it.

The SEED has holders to expose nine material samples (25.4 mm (1 inch) dia. and 32.3 mm (1.27 inch) dia) and space environment monitoring samples on Sample Units 2 and 3. Some SEED samples, MoS_2 on Ti-6Al-4V, white paint, modified polyimide film and UPILEX-125S were also on board SM/MPAC&SEED. Degradation data from these materials will be compared with the SM/MPAC&SEED result. The sample newly installed is five of the following; such as Ge-coated Black Kapton, Black Kapton, BSF-30, ITO coated UPILEX-25S and Black paint (Only the black paint is not exposed to space.). Although it is a commercial polyimide that was not fundamentally intended for space use, BSF-30 is expected to have high durability against AO. This material is expected to be useful for applications for space use on LEO.

Actually, JEM/MPAC&SEED is exposed to the space environment attached on the SEDA-AP which is on the KIBO/EF. The exposure experiment period will be about ten months. After the exposure experiment end, the sample assembly is detached from the SEDA-AP, and returned to the ISS. The sample is scheduled for retrieval to the ground on the final shuttle flight (19A mission).

Table 1 SEED material list

SEED samples	SEED space environment monitoring samples
Solid lubricants / MoS_2 on Ti-6Al-4V	**UV monitor / ITO coated DUS601 (Urethane Sheet)**
White paint / NOVA 500 ASTRO WHITE	**Dosimeter1 / RADFET**
Black paint / NOVA 500 ASTRO BLACK	**Dosimeter2 / ALANINE Dosimeter**
Ge-coated Black Kapton	**Dosimeter2 / TLD**
Black Kapton	**AO monitor / Vesplel**
Polysiloxane-Block-Polyimide Film "BSF-30"	**Temperature / Thermo Label**
Modified Polyimide film /Siloxane Coated PI	
ITO coated UPILEX-25S	
UPILEX-125S	

5. Ground Reference Experiment

For detailed clarification of the degradation mechanism of exposed materials, reference experiments will be conducted on the ground. Irradiation of atomic oxygen, ultraviolet rays, electron beams and their combined irradiation will be carried out under the same conditions as those in orbit. Irradiated materials will be measured for their changes of mass, solar absorptivity, emissivity, etc.; in addition, their irradiated surfaces will be observed. These results of ground reference experiments are effective to clarify damage mechanisms of irradiated materials by atomic oxygen, ultraviolet rays, and electron beams. It is also exposed such that not only the influences of each single irradiation to materials but also synergistic effect of combined irradiation to materials can be observed from results of ground reference experiments.

6. Conclusion

The KIBO Exposed Facility is located on the front side of the ISS. There is no payload except for the ICS in the field of view of JEM/MPAC&SEED. For that reason, contamination effects are expected to be smaller than for SM/MPAC&SEED.

Degradation data from JEM/MPAC&SEED will be compared with results of SM/MPAC&SEED. In addition, a new finding is expected to be obtained according to the data new samples in JEM/MPAC&SEED. Moreover, the examination result of JEM/MPAC&SEED and SM/MPAC&SEED is expected to lead to the improvement of the experiment accuracy of Ground Reference Experiment.

7. Acknowledgment

We appreciate the work of all people involved in the development and operation of the SM/MPAC&SEED and JEM/MPAC&SEED projects.

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