SM/MPAC & SEED Experiment Overview

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A space materials exposure experiment was performed on the International Space Station (ISS) using the Micro-Particles Capturer and Space Environment Exposure Device (MPAC&SEED) developed by the Japan Aerospace Exploration Agency (JAXA). The experiment was executed on the exterior of the Russian Service Module (SM) of the ISS. The SM/MPAC&SEED consists of the MPAC, which captures space debris, and SEED, which exposes polymeric materials, paint, adhesives, bearings, and compound materials. Three identical MPAC&SEED units were launched on 21 August 2001. The three units were retrieved individually after exposure of 315 days (about 10 months), 865 days (about 28 months), and 1403 days (about 46 months). This paper presents an overview of the SM/MPAC&SEED project and experiment.

Keywords: SM/MPAC&SEED, ISS Service Module

1. Introduction

Space environment effects on materials are very severe and complex because orbital environments include factors such as high-energy radiation particles, atomic oxygen (AO), micro-level particles, and UV irradiation. In addition, surface degradation associated with contamination can negatively impact optics performance. The space environment and data related to its effects are therefore very important for spacecraft design. The National Space Development Agency of Japan (NASDA), the forerunner of the Japan Aerospace Exploration Agency (JAXA), implemented the space materials exposure experiment on the space shuttle and the ISS. The Russian Service Module (SM)/ Micro-Particle Capturer and Space Environment Exposure Device (MPAC&SEED) experiments were executed on the exterior of the SM of the ISS.

2. History of space materials exposure experiments

Since the first space shuttle launch in the 1980s, research of the characteristics of materials in space environments has shifted from evaluation of data collected by telemetry to that of materials exposed in a real space environment and returned to the ground. NASA implemented space materials exposure experiments using both the space shuttle cargo bay and spacecraft launched to space from the space shuttle and retrieved by the space shuttle after a long period. NASA's Long Duration Exposure Facility (LDEF) can gather important results related to the interaction between materials and the space environment because of the large number of deployed samples and the long exposure period [1–3]. The Low Earth Orbit (LEO) space environment is known to have severe effects on spacecraft materials and coatings, so contamination should be an important consideration in spacecraft design.

Japan launched the Exposed Facility Flyer Unit on the Space Flyer Unit (SFU/EFFU) [4], and performed the Evaluation of Oxygen Interaction with Materials-3 (EOIM-3) in 1992 [5] and the Evaluation of Space Environment and Effects on Materials aboard the Manipulator Flight Demonstrator (MFD/ESEM) [6] on space shuttles in 1997. Results of these experiments show that AO irradiation was the most important cause of material degradation in the LEO environment [7].

3. Service Module (SM) / Micro-PArticles Capturer and Space Environment Exposure Device (MPAC&SEED)

3.1 Overview

The SM/MPAC&SEED experiments are space exposure experiments on the exterior of the Russian Service Module of the ISS. The most unique aspect of the SM/MPAC&SEED experiments is that three identical components were manufactured; the three were exposed simultaneously, and each was retrieved individually after different periods of time. It was the world's first such trial. This method can compare aging deterioration of materials at virtually the same position. Another unique feature is that samples capture micrometeoroid and space debris. This MPAC is a passive experiment designed to sample the micro-meteoroid and space-debris environment and to capture particle residue for later chemical analyses using aerogel, polyimide foam, and 6061-T6 aluminum plate[8]. Another point is that some samples are arranged on both the ram and wake sides. This method should demonstrate the effect of AO, which collides with and erodes materials on the front and back of the spacecraft.

Two MPAC & SEED projects exist. One is for the Japanese Experiment Module Exposed Facility (JEM/EF) on the ISS. The other is for the Service Module (SM) on the ISS [9]. The MPAC & SEED on the JEM/EF (hereinafter JEM/MPAC&SEED) is an instrument of the Space Environment Data Acquisition equipment – Attached Payload (SEDA-AP) [10]. In fact, SEDA-AP has seven sensors that measure neutrons, plasma, heavy ions, high-energy light particles, atomic oxygen, cosmic dust, and their effects. This project began in 1997.

Actually, SM/MPAC&SEED was expected to encounter a different artificial space environment than JEM/MPAC&SEED because the SM is located at the rear of the ISS and JEM is scheduled to be attached at the front (see Fig. 1). Contamination from obstacles and the thruster is expected to be much lower at the front of the ISS than at the rear. Comparing results of the two missions provides a complementary analysis of contamination effects on material degradation that are dependent on location.

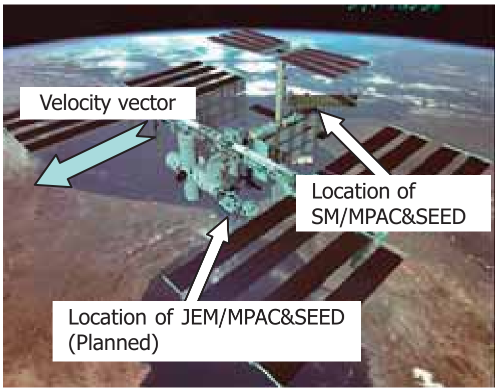

Fig. 1 Illustration of the ISS and location of both SM/MPAC&SEED and JEM/MPAC&SEED.

3.2 History of the SM/MPAC&SEED development

In September 1998, NASDA began consulting with the Russian Federal Space Agency (Roskosmos) about utilization of the Russian SM as a precursor mission to JEM & JEM/EF. An implementation plan was developed, and a contract for multipurpose experiment projects for MPAC&SEED and High Definition Television (HDTV) was signed in June 1999 [11]. In addition, NASDA began to develop SM/MPAC&SEED in early 1999. Figure 2 presents the schedule of SM/MPAC&SEED development in Russia and Japan.

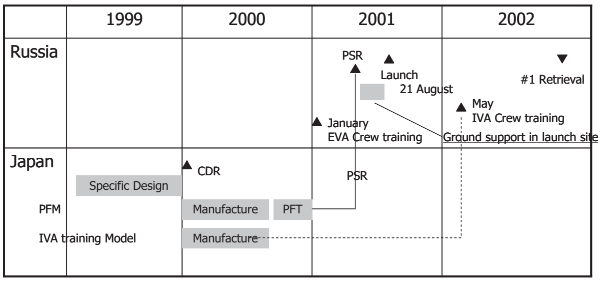

Fig. 2 Schedule of the SM/MPAC&SEED development

Some photographs of the development phase are shown. Figure 2 shows an External Vehicle Activity (EVA) training scene in Gagarin Cosmonauts Training Center (GCTC) in January 2001. Figure 3 depicts a SM/MPAC&SEED launch container in a sterilization room in the Baikonur Cosmodrome immediately before launch.

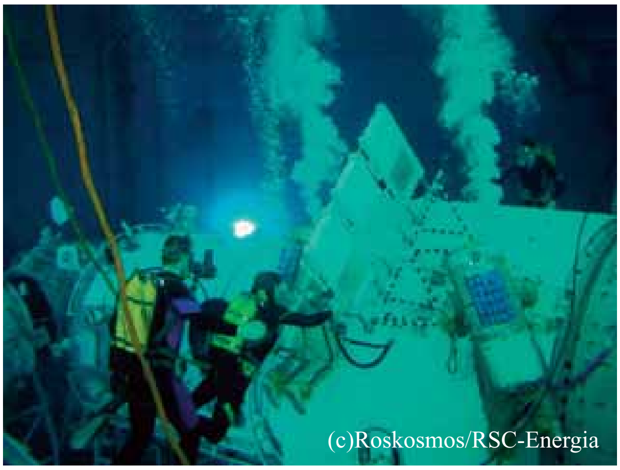

Fig. 3 EVA training in GCTC

Fig. 4 A SM/MPAC&SEED launch container in sterilization room immediately before launch

3.3 System description in the orbit

The overall dimensions of a flight SM/MPAC&SEED unit are W570 mm × H900 mm × D158 mm. Figure 5 depicts one unit of SM/MPAC&SEED. Ram and wake sides of the unit correspond to the ram and wake directions of the ISS. Samples are installed on holders stored in the SM/MPAC&SEED. Sample holders can be extracted from the SM/MPAC&SEED to reduce the return weight. The sample holder was packaged by an ISS astronaut and returned to the ground by a Soyuz spacecraft. Three identical SM/MPAC&SEED units (MPAC&SEED #1, #2, and #3) were flown and attached to the SM.

3.3.1 MPAC experiment

The MPAC is a passive experiment designed to sample micrometeoroids and space debris. Samples of three types were prepared to capture and measure micro-particles for MPAC. Silica-aerogel (hereinafter, aerogel) is a transparent and porous solid with nanosized holes. It is used for intact capturing of dust particles and also used for estimations of impact parameters (incident direction, particle diameter, and impact velocity) based on the impact track morphology. Polyimide foam was prepared to capture large debris. An aluminum plate was used to record the number of impacts from space debris and micrometeoroids.

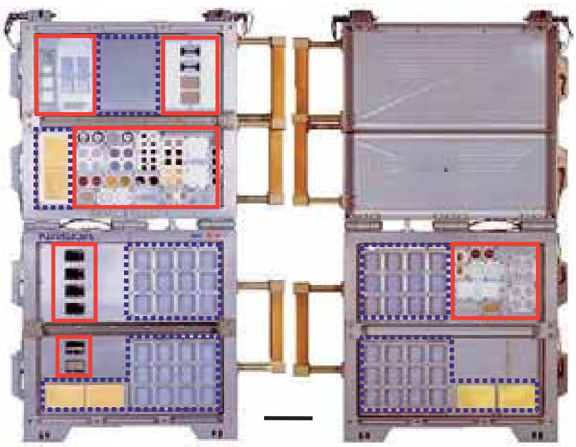
100 mm
Ram side **Wake side**
Solid line: SM/SEED and monitoring samples
Dashed line: SM/MPAC samples

Fig. 5 An SM/MPAC&SEED unit with both front (Ram side) and back (Wake side) shown.

3.3.2 SEED experiment

The SEED is a space material exposure experiment. The SEED consists of 28 samples, as outlined in Table 1. Samples were proposed by JAXA, universities, and companies in Japan and were selected by JAXA based on the frequency of use and prospective future use [12–14]. The SEED experiment also includes space environment monitoring samples, which monitor the total dose of AO, UV, space radiation, and temperature [15].

Table 1 SEED samples

Sample name	Organization	Main Use
CF/polycyanate, PIXA	Fuji Heavy Industries Ltd.	Structural materials
PEEK (loaded & unloaded)	Hokkaido University	Deployable structures
AlN	Tokyo Institute of Technology	Structural and functional materials
SiC (reaction sintering / Hot pressed)		
TiN-coated Al / Al_2O_3		
Ball-bearing (3 types)	Tohoku University	Mechanism application
SUS304	National Institute for Materials Science	Lubrication
Cu-/ $CuBN/TiN/MoS_2$-coated SUS304		
MoS_2 coated Ti alloy	IHI Aerospace	Lubrication
Loaded & unloaded polyimide film (UPILEX-S)	Japan Aerospace Exploration Agency	Deployable structures
Modified polyimide film		Thermal control
Flexible OSR		Thermal control
White paint		Thermal control
Adhesive		Adhesion
Potting compound		Potting

3.3.4 SM/MPAC&SEED launch & operation

Three identical SM/MPAC&SEED units (SM/MPAC&SEED #1, #2, and #3) were flown and attached to the SM. The SM/MPAC&SEED was launched aboard a Progress M-45 on 21 August, 2001. The SM/MPAC&SEED was unpacked and constructed during Intra Vehicular Activity (IVA) (see Fig. 6). At 09:17 UT on 15 October 2001, all three units were mounted on the handrail outside the SM by extra-vehicular activity (EVA) (see Fig. 7). On 26 August 2002, the first unit of SM/MPAC&SEED, SM/MPAC&SEED #1, was retrieved by EVA after 315 days of on-orbit exposure. Figure 8 portrays the EVA for deconstructing SM/MPAC&SEED #1. Figure 9 shows the configuration of the SM/MPAC&SEED after the EVA. Subsequently, SM/MPAC&SEED #2 was retrieved on 26 February 2004 (after 865 days). Later, SM/MPAC&SEED #3 was repositioned to the location that had been occupied by MPAC&SEED #2. Figure 10 depicts the SM/MPAC&SEED configuration after this second EVA. Finally, SM/MPAC&SEED #3 was retrieved on 18 August 2005 (after 1403 days) (see Fig. 11). All SM/MPAC&SEED holders arrived on the ground in the Republic of Kazakhstan and were moved to Moscow. A primary check was performed there before transport to Japan. Figure 12 shows the third primary check out scene in October 2005.

Fig. 6 IVA for SM/MPAC& SEED construction

Fig. 7 Orbit configuration of the entire MPAC& SEED (October 2001)

Fig. 8 EVA for deconstructing SM/MPAC&SEED #1 (August 2002)

Fig. 9 Orbit configurations of MPAC& SEED #2 & #3 (August 2002)

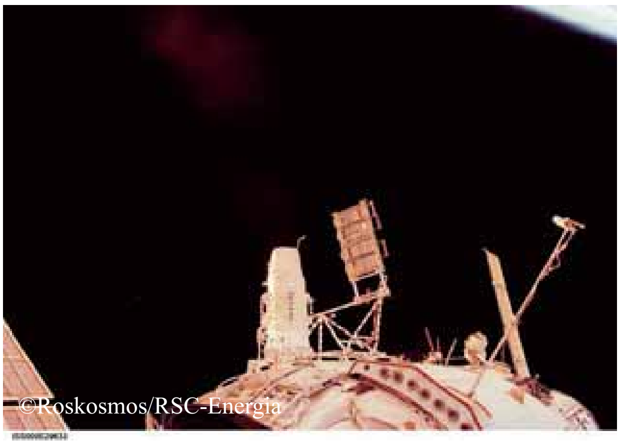

Fig. 10 Orbit configuration of the MPAC& SEED #3 and other external payloads (February 2004)

Fig. 11 Removal of the MPAC& SEED #3 from the ISS by an astronaut, who is visible on the right. (August 2005).

Fig. 12 Primary check-out in Moscow after retrieval (October 2005).

Three sets of the retrieved samples were analyzed. The first conference on the post retrieval analysis results was held on 8 March 2004 [16]. The second conference was held on 21 January 2006 [17]. Finally, the third conference, the international symposium for comprehensive analysis for all retrieved samples, was held in 10–11 March 2008.

4. Summary and conclusions

A unique space material exposure experiment, the SM/MPAC&SEED experiment, was conducted. For this experiment, three identical components were manufactured: the three were exposed simultaneously; each was retrieved individually after a different period of time. It was the world's first such trial. This method can compare aging deterioration of materials placed at almost the same position.

Analysis results are reported in this special publication.

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