3 February 2014

English only

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Fifty-first session
Vienna, 10-21 February 2014
Item 8 of the provisional agenda[*]
Space debris

National research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

The present conference room paper contains submission received by the Secretariat from Japan on 23 January 2014. The document is issued without formal editing.

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[*] A/AC.105/C.1/L.332.

1. Overview

Research relating to space debris in Japan, mainly conducted in the Japan Aerospace Exploration Agency (JAXA), has focused on the following areas:

(1) Preventing damage to spacecraft caused by collision with debris and safeguarding mission operations;

(2) Preventing the generation of debris while spacecraft and launch vehicles are operated, including removing mission-terminated space systems from useful orbital regions, and ensuring ground safety from space systems removed from orbit and allowed to fall to Earth;

(3) Promoting research targeting the improvement of the orbital environment by removing existing system-level large debris from orbit.

Above is defined in the JAXA Space Debris Strategic Plan, which was introduced last year by the Secretariat in the United Nations document A/AC.105/C.1/107 “National research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris” dated 16 November 2012.

Here, the following debris related activities conducted in JAXA during 2013 are selected as major progress to introduce in the next section.

(1) Observation and Modelling:

(a) Technology to observe LEO (low-Earth orbit) and GEO (geosynchronous Earth orbit) objects and determine the orbit;

(b) In-situ Micro-Debris (less than 1 mm class) Measurement System.

(2) Protection:

(a) Protection from impact of micro-debris.

(3) Re-entry:

(a) Controlled re-entry and atmospheric re-entry observation of the HTV;

(b) Controlled re-entry of the second stage of H-IIB launch vehicle;

(c) Propellant tank easy to demise during re-entry.

(4) Remediation:

(a) Remediation of orbital environment by active removal.

2. Status

2.1. Research on technology to observe LEO and GEO objects and determine their orbits

Generally the observation of LEO objects is mainly conducted by radar system, but JAXA has been challenging to apply the optical system to reduce the cost for both construction and operation. In the past years JAXA has confirmed the availability of optical camera to detect debris and determine the orbit characteristics, now JAXA is studying to confirm the effectiveness of method applying the two observation sites located separately in longitudinal direction. Each site will have two arrays of optical sensors and track an object passing across those two fields of view (figure 1).

For GEO observation, JAXA is surveying the best location for optical observation which will depends on the atmospheric condition, the climate and the geographical features, and is evaluating the performance quantitatively in cases of Taiwan and Australia (figure 2).

Figure 1

The array of the optical sensor at one site. In order to detect many LEO objects two times, two narrow rectangle regions are observed by changing observational direction of each optical sensor

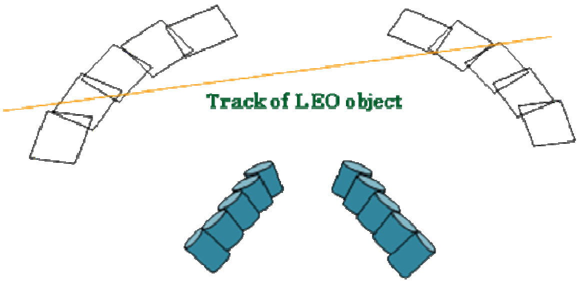
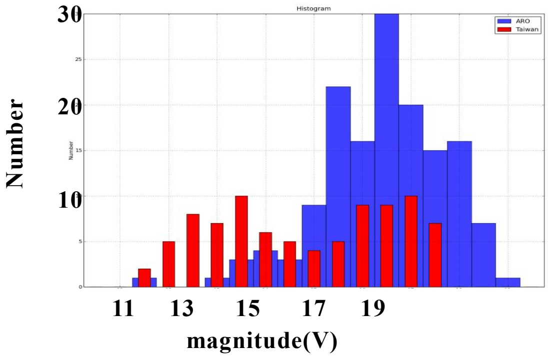


Figure 2

Brightness distribution of detected GEO objects using 50 cm telescope in Taiwan (red) and 18 cm telescope in Australia (blue)

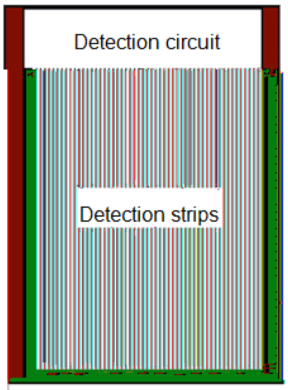


2.2. In-situ Micro-Debris Measurement System

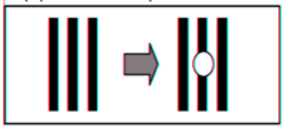
For micro-debris (submillimetre class) which cannot be detected on the ground, JAXA is developing an on-board detector for in-situ measurement. This sensor is the first to use conductive (resistive) lines. Figure 3 shows the sensing principle and figure 4 shows the Engineering Model (EM).

If this were supplied to many spacecraft, the acquired data could help improve the debris environment model. An improved flight model will be launched with HTV-5 in 2014. Now the environmental tests and impact verification tests are being conducted before the installation.

Figure 3
Sensor principle



(a) Detector strips on thin film



(b) Strips severed by debris particles

Numerous thin, conductive strips are formed with a fine pitch on a thin polyimide film (of nonconductive material). A dust particle impact is detected when one or more strips are severed by the perforation. **[US patent registered]**

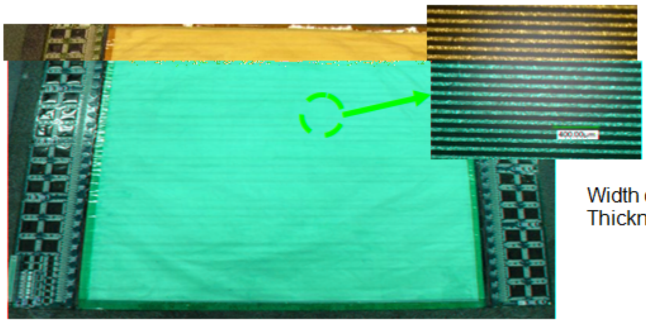


Fig.-4 Engineering Model

2.3. Protection from impact of micro-debris

The amount of micro-debris (less than 1 mm in diameter) increased in low-Earth orbit. The impact of micro-debris can inflict critical damage on a satellite because its impact velocity is 10 km/s on average. Figure 5 shows a satellite structure panel and the result of impact testing with micro-debris (1 mm in diameter). The debris perforated the panel, i.e. the debris can damage the electronic boxes installed in the satellite. This result will suggest to protect the key components of the satellite against the impact of micro-debris.

To assess debris impact on a satellite, JAXA is conducting hypervelocity impact testing and numerical simulations for structure panels and bumper shield materials. Internal damage to structure panels has also been investigated by numerical simulations as shown in figure 6. The debris breaks up on impact into fragments, which deform and perforate the honeycomb cell of the structure panel. Protection capability of fabric bumper shields made from alamido fibre, glass fibre covered with PTFE (Poly Tetra Fluoro Ethylene), and ceramic fibre has been investigated with hypervelocity impact testing. Weights of the bumpers are shown in figure 7. Fabrics made of high strength fibres are effective as bumper material. The fabric made from High-modulus Alamido fibre was the lightest bumper shield. Its weight was only 30 per cent that of an aluminium bumper shield. To incorporate the above research data into satellite design, the "Space Debris Protection Design Manual" (JERG-2-144-HB) was published in 2009, and has been updated.

Figure 5
Impact test on a honeycomb sandwich structure: (left) Test setting, (centre) Impacted surface of the honeycomb sandwich panel, (right) Back surface of the honeycomb sandwich panel

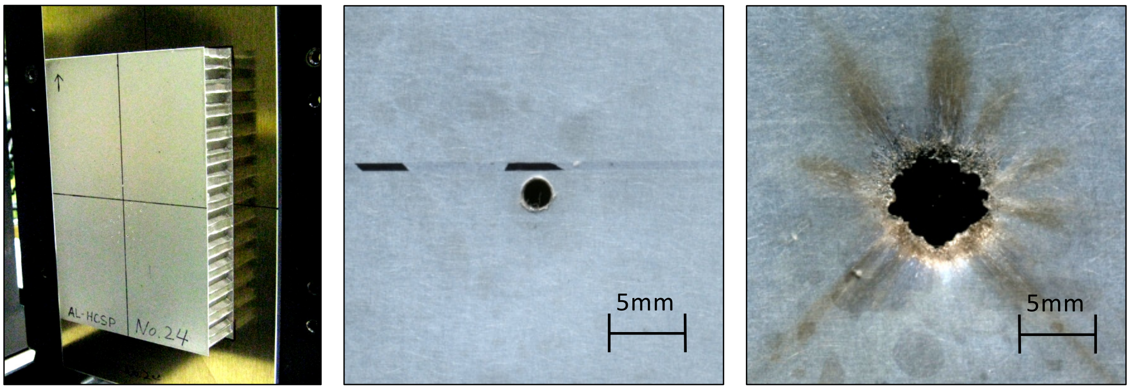


Figure 6
Debris fragmentation in a honeycomb core

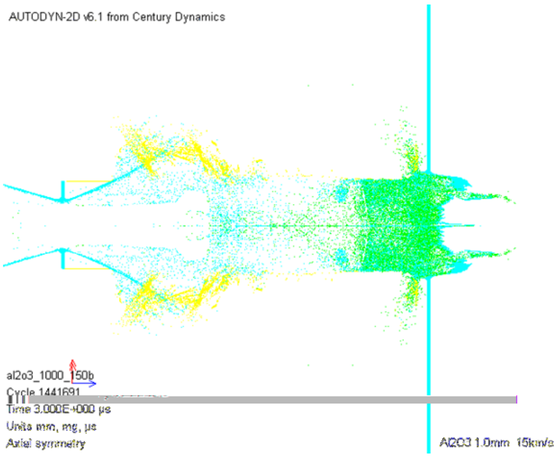
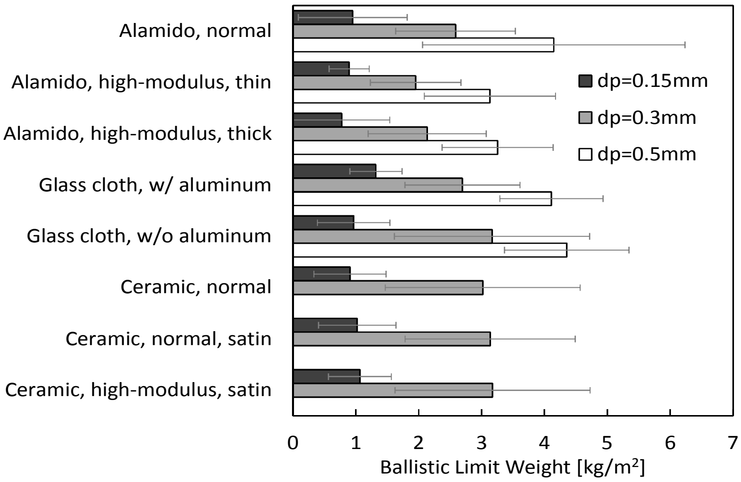


Figure 7
Protection capability of bumper shield materials



2.4. Controlled re-entry and atmospheric re-entry observation of the HTV

The H-II Transfer Vehicle (HTV) “KOUNOTORI” is an unmanned cargo transport and waste disposal vehicle for the International Space Station (ISS) developed and operated by JAXA. Four flights of HTV were successfully completed in 2009, 2011, 2012 and 2013. Subsequent flights are scheduled once per a year. All of missions were re-entered to the South Pacific Ocean. In addition, JAXA was observing HTV’s atmospheric re-entry using re-entry capsules. One of the re-entry observation capsule is the “Intelligent BALListic re-entry capsule” (i-Ball) which is manufactured by IHI Aerospace Co., Ltd. i-Ball contained in the Pressurized Logistic Carrier of the HTV3 and HTV4, and sent valuable data (acceleration, gyro, pictures, etc.) during atmospheric re-entry. These data will contribute to elucidate re-entry breakup phenomenon of the spacecraft.

Figure 8
HTV mission overview

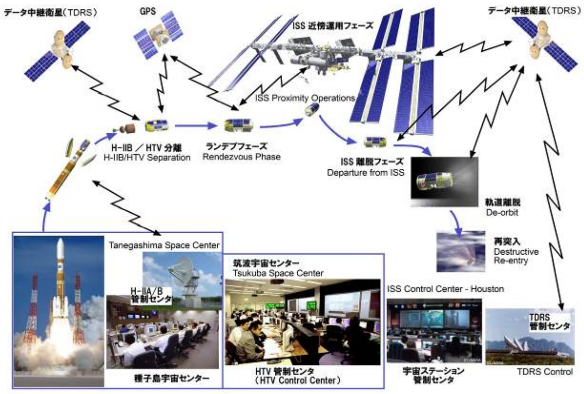


Figure 9
HTV4 (c)NASA

Figure 10
i-Ball

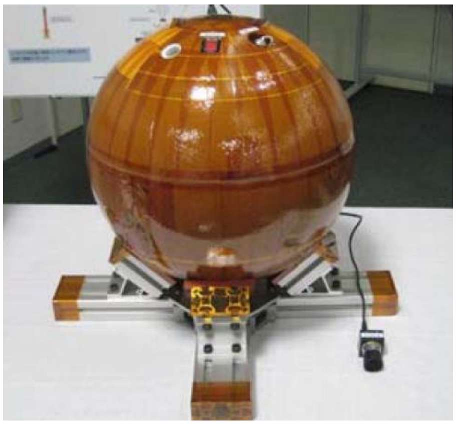


Figure 11
HTV3 debris taken by i-Ball

2.5. Controlled re-entry and re-entry observation of H-IIB launch vehicle second stage

H-IIB#4 flight was conducted on August 4th, 2013. The flight was very consistent with the pre-flight simulation, and successfully inserted HTV to its planned orbit. After the payload separation, the stage circulated around the Earth once, and performed a deorbit manoeuvre as planned. The performance of a low thrust level burn of LE-5B engine was close to the pre-flight predicted value. The event timeline was very consistent with the prediction analysis. Consequently, all acquired flight data indicated that the controlled re-entry of the second stage of H-IIB was conducted as planned.

In this controlled re-entry observation was attempted using i-Ball which is re-entry data collecting unit developed by IHI Aerospace.

Figure 12

i-Ball mounted on H-IIB#4 upper stage

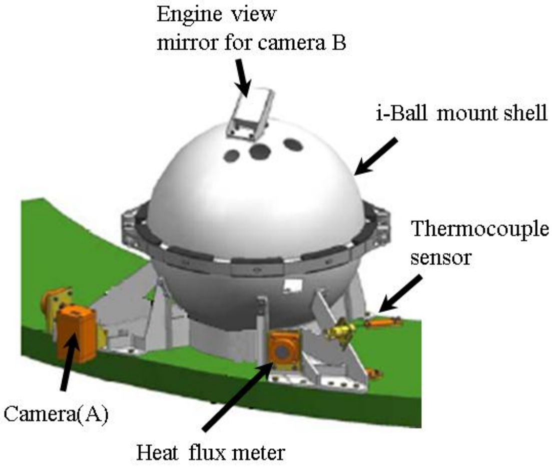
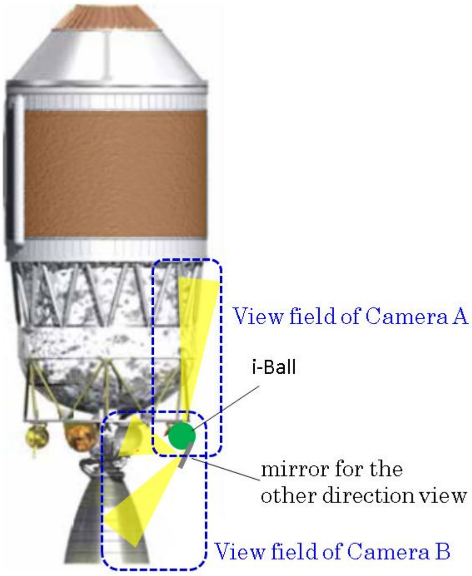


Figure 13

i-Ball camera geometric configuration

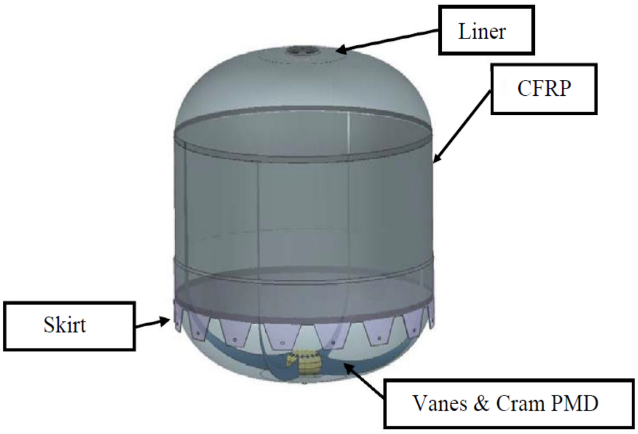


2.6. Propellant tank easy to demise during re-entry

A propellant tank is usually made of titanium alloy which is superior because of light weight and good chemical compatibility with propellant. But its melting point is so high that such a propellant tank would not demise during re-entry, and it would pose the risks of ground casualty.

JAXA is conducting research to develop an aluminium-lined, carbon composite overwrapped tank with a lower melting temperature. As a feasibility study JAXA conducted fundamental tests including a liner material aluminium compatibility test with hydrazine propellant and an arc heating test. JAXA also performed the preliminary design, testing of the scale model PMD (Propellant Management Device) under low gravity, acquisition of outgassing property from CFRP (carbon fibre-reinforced plastic), and CFRP resistance to radiation tests.

Figure 14
Concept of CFRP propellant tank



2.7. Remediation of orbital environment by active removal

The amount of space debris has been increasing, and many evolutionary models predict that it would continue to grow, even if new satellite launches were stopped, due to mutual collisions between existing objects. Under such circumstances, debris mitigation measures such as explosion prevention and end-of-mission de-orbit will be inadequate and active debris removal (ADR) will be needed to preserve the space environment. The Japan Aerospace Exploration Agency (JAXA) is investigating a cost-effective active debris removal system that can rendezvous with and capture non-cooperative debris objects in crowded orbits to de-orbit them using an adequate propulsion system that can transfer system-level large objects

At the first phase of the active debris removal (ADR) mission, a debris removal spacecraft has to approach the debris, which is a non-cooperative target, and attach a removal device on it. JAXA studies navigation and trajectory design for the ADR mission. Several types of navigation sensor candidates are compared from the viewpoints of functionality and performance, to characterize their features and select the best combination of sensors. Several trajectories are designed to evaluate its safety and efficiency of rendezvous operation. Then, a trade-off study of rendezvous trajectories is performed. A numerical simulation has been carried out to demonstrate its validity of the proposed trajectory.

Figure 15

Left: approach scenario to space debris, right: examples of rendezvous trajectories