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Scientific and Technical Subcommittee
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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 the following member State of the Committee on the Peaceful Uses of Outer Space: Japan. The document is issued without formal editing.

* A/AC.105/C.1/L.310.

Report on Space Debris Related Activities in Japan
(For UNCOPUOS/STSC February, 2012)

1. Overview

The researches relating to space debris in Japan, mainly conducted in Japan Aerospace Exploration Agency (JAXA), have been concentrated as shown below. The principle stance of JAXA on the debris issue is:

(1) Firstly, to prevent damage of spacecraft caused by collision with debris and ensure the mission operation,

(2) secondly, to prevent generating debris during operation of spacecraft and launch vehicles, including removal of mission-terminated space systems from useful orbital regions, and ensuring the ground safety from removed space systems from orbit fallen to the ground,

(3) and thirdly, to promote research aimed towards the improvement of the orbital environment by removing existing large debris from orbit.

The JAXA Space Debris Strategic Plan defines mainly following R&D.

(1) Observation and Modelling

(a) Technology to observe GEO objects (10 cm class)

(b) Optical observation for LEO objects

(c) Dust sensor to detect sub-millimetre size

(d) Propagation model to predict future population

(2) Protection

(a) Hyper –Velocity impact testing and analysis to estimate the damage by impact of tiny debris, and develop shielding methods

(3) Re-entry

(a) Research and development of demise propellant tank upon re-entry

(b) Improvement of re-entry analysis tool

(4) Remediation

(a) Active debris removal system that employs electrodynamics tether

(5) Other measures

(a) Slag-less solid motor propellant

The next section introduces the status of several R&D items, and related works.

2. Status of R&D and other activities

2.1 Debris mitigation requirements and compliance with them

JAXA Space Debris Mitigation Standard was developed and requires/ recommends the following;

(1) Refraining from releasing mission related objects

(2) Preventing on-orbit break-ups

(3) Reorbiting mission terminated Geosynchronous Satellites from the GEO protected region

(4) Removal of mission terminated spacecraft passing through the LEO protected region

(5) Preventing collision with large debris

(6) Preventing damage from collision with tiny debris

In February 2011, the Standard was revised to be equivalent to ISO-24113 “Space Debris Mitigation Requirements”. The major changes are following requirements;

(1) Pyrotechnic devices shall not generate combustion products larger than 1 mm.

(2) The eccentricity of a geosynchronous orbit satellite after reorbit shall be less than 0.003.

(3) Break-up probability during operation shall be less than 0.001.

(4) Conditional success probability for reorbit manoeuvre shall be larger than 0.9.

(5) The orbital lifetime of objects passing through LEO (lower than 2000 km) shall be shorter than 25 years after the end of operation

The compliance of each project with the requirements is reviewed in the safety review held at the end of each design phase.

2.2 Research on Observational Technologies for Space Debris in GEO and LEO

Innovative technology research centre of JAXA is developing technologies for detection of un-catalogued GEO debris and determination of their orbits. The stacking method, using multiple CCD images to detect very faint objects that are undetectable on a single CCD image, has being developed since 2000. The only weak point of the stacking method is the time required to analyse the data when detecting an unseen object whose movement is not known, because a range of likely paths must be assumed and checked. In order to reduce analysis time of the stacking method, we are developing FPGA (field programmable gate array) system as shown in Fig.-1. This year, we have installed the FPGA system to JAXA’s Mt. Nyukasa optical facility for GEO debris observation.

We are also trying to developing optical observation system for LEO debris (Fig.-2). Using wide field optics and high-speed large CCD camera, detection and orbit determination of small-sized LEO debris will be possible with this system.

Fig.-1. The FPGA board system manufactured by iDAOS

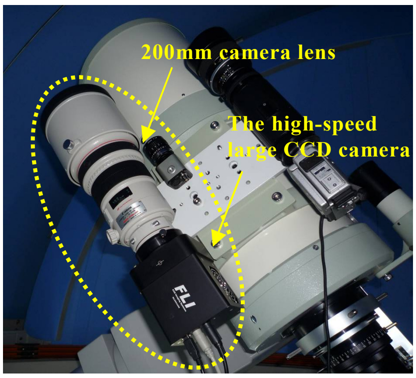

Fig.-2. The Optical observation system for LEO

2.3 Development of in-situ Micro-Debris Measurement System

JAXA has been developing the micro-debris measurement system. The objective of the system is to measure small size debris (between 100 μ m and several cm) . The distribution and flux of the debris of the small size are not well understood. The micro-debris is difficult to observe on the ground observation, although the impact risk can't be ignored. For the measurement system on the size range, combination of an optical sensor and a dust detector is under study by JAXA. The in-situ measurement of the size range is useful for; 1)verifications of meteoroid and debris environment models, 2)verifications of meteoroid and debris environment evolution models, 3)real time detection of unexpected events, such as explosions and/or collisions on an orbit. In present status, in-situ optical observation system is under conceptual study and a dust sensor is already in BBM (Bread Board Model) phase. The dust sensor especially to monitor the size range 100 μ m to a few mm, must have a large detection area, while the constraints of a space environment deployment require that these systems be low in mass, low in power, robust and have low telemetry requirements. JAXA has been developing a simple in-situ sensor to detect dust particles ranging from a hundred micrometres to several millimetres. Multitudes of thin, conductive strips (material: copper) are formed with fine pitch (pitch: 100 μ m)on a thin film of nonconductive material (thickness: 12.5 μ m, material: polyimide). A dust particle impact is detected when one or more strips are severed by the perforation hole. The sensor is simple to produce and use and requires almost no calibration as it is essentially a digital system. BBM model was manufactured successfully with applying printed wiring board product technology. The sensor area of BBM is 35 cm x 35 cm, and thermal-strain experiments and hypervelocity impact experiments on the BBM model were performed.

2.4 Debris modelling and analysis tools

An orbital debris evolutionary model NEODEEM developed in collaboration with Kyushu University has been updated. Fig.-3 shows the effective number of objects in LEO predicted by NEODEEM, under some assumptions set for IADC study for investigating the stability of the LEO debris environment. It shows that even with a good implementation of the commonly-adopted mitigation measures, the LEO debris population is expected to increase in the next 200 years, which agreed well with other agencies' results. A debris collision risk analysis tool named TURANDOT has also been updated and used for evaluating JAXA projects.

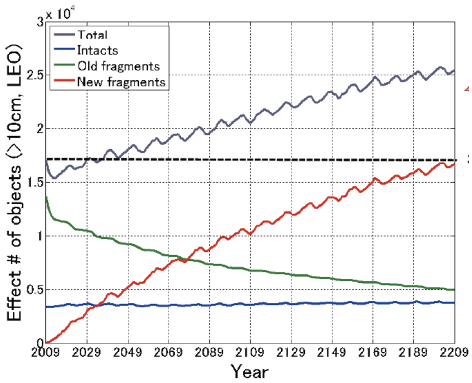

Fig.-3. Projection of the LEO populations predicted by NEODEEM.

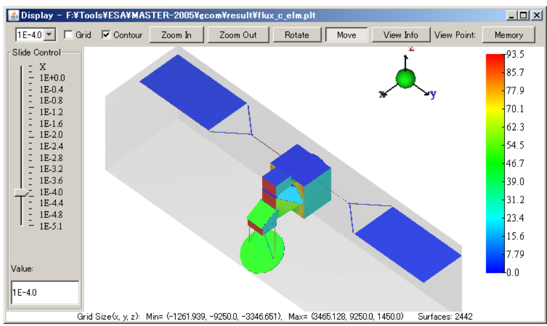

Fig.-4. Output of debris collision risk analysis tool.

2.5 Investigation of impact damages

Historically, debris impact damages have been investigated for manned-system to confirm for the impact with several millimetre size. However, since an usual satellite tend to be damaged even smaller debris than 1 mm, additional data is needed. Debris impact damages of satellites are investigated as shown in Fig.-5 by hypervelocity impact experiments, and then damage limit equations are developed. Also the impact experiment can hardly cover higher speed than 10 km/sec, numerical simulation as shown in Fig.-6 is essential to verify the effect caused by higher velocity up to 10 km/sec or higher. To incorporate the experiment and numerical simulation data in satellite design, “Space Debris Protection Design Manual” (JERG-2-144-HB) was published in 2009, and it is updated. Moreover, JAXA is developing “Standard of Micro Debris Impact Risk Assessment”.

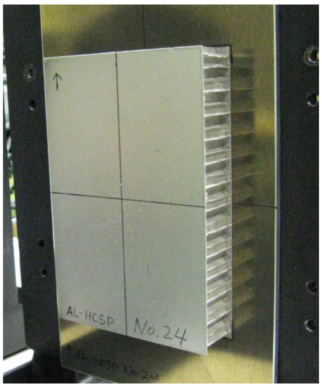

Fig.-5 impact experiment on honeycomb sandwich structure.

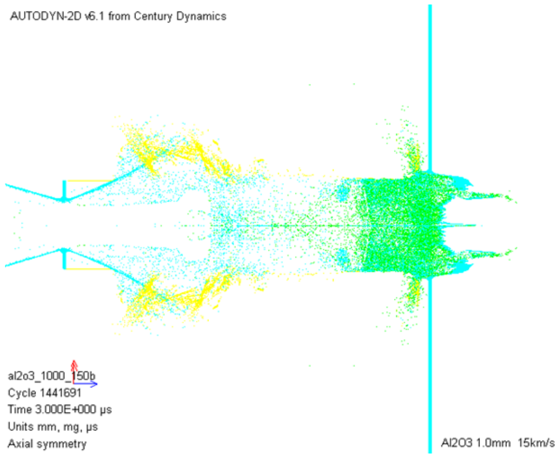

Fig. -6 Calculation results and fragment phenomena in case of putting honeycomb core.

2.6 Controlled re-entry of the second stage of H-IIB launch vehicle

H-IIB launch vehicle (H-IIB) was developed in order to launch H-II Transfer Vehicle (HTV) to the International Space Station (ISS), and to satisfy various customer’s needs of a heavy launch. At its second flight, Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries, Ltd. (MHI) added the new function to perform controlled re-entry to the second stage of H-IIB.

The design changes includes;

(a) a new He bottle to re-pressurize the LH2 tank,

(b) thermal protection for several components to withstand the thermal effect due to longer ballistic phase.

(c) modification of the avionics system to receive a deorbit command from ground stations,

(d) new algorithm for the guidance control to send an engine cut-off command during the deorbit burn. It also optimizes the burn duration in real time to minimize the impact footprint.

H-IIB second flight was conducted on January 22, 2011. 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-2 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.

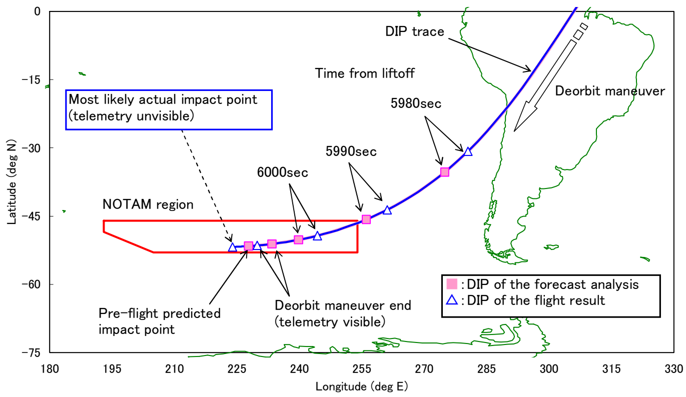

Fig.-7 Flight result of the upper stage impact footprint

2.7 Research and Development of 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 a propellant tank would not demise during re-entry, and it is one of the major risks of ground casualty. JAXA is conducting research to replace the titanium tank with the demise one upon re-entry for hazard prevention. The targeted specification including mass, volume, maximum expected operating pressure, propellant expulsion efficiency and propellant storage life are determined. The compatibility test with propellant hydrazine and the arc heating test are being planned.

2.8 Remediation of orbital environment

The amount of space debris has been increasing, and many evolutionary models predict that it would increase even if new satellite launches were stopped because of mutual collisions between existing objects. In such a case, debris mitigation measures such as explosion prevention and end-of-mission de-orbit will be inadequate and an active debris removal (ADR) will be needed to preserve the space environment. JAXA is therefore studying an active removal system that can rendezvous with and capture non-cooperative debris objects in crowded orbits for de-orbiting them. The propellant requirements of conventional propulsion systems make them infeasible for transferring multiple objects, and instead the electrodynamic tether (EDT) is considered to be one of the most promising propulsion systems for de-orbiting debris in low earth orbit. As a first step towards realizing an ADR, a flight demonstration using a small satellite for demonstrating some key technologies such as non-cooperative rendezvous and EDT is being studied.

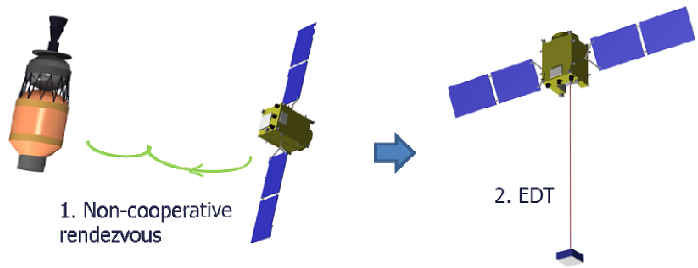

Fig.-8 Demonstration of non-cooperative rendezvous and EDT using a small satellite