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Vienna, 15-26 February 2016
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

Note by the Secretariat

The present conference room paper contains a submission received by the Secretariat from Japan, and includes additional pictures and figures not included in document A/AC.105/C.1/110. The document is issued without formal editing.

* A/AC.105/C.1/L.336.

Report on Space Debris Related Activities in Japan
(For UNCOPUOS/STSC February, 2016)

1. Overview

Corresponding to the request from OOSA, Japan reports here its debris related activities conducted mainly in the Japan Aerospace Exploration Agency (JAXA).

The total figure of the JAXA Space Debris Strategic Plan was introduced by the Secretariat in the United Nations paper 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 2015 are considered a major progress in this field and thus selected to be introduced in the next section.

(1) Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA)

(2) Research on technology to observe LEO and GEO objects and determine their orbits

(3) In-situ Micro-Debris Measurement System

(4) Protection from impact of micro-debris

(5) Propellant tank easy to demise during re-entry

(6) Active debris removal

2. Status

2.1 Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA)

JAXA regularly receives conjunction notifications from JSpOC. For example, in September 2015, the number of notifications received was 64 which exceeded a specific conjunction threshold value. From 2009 to September 2015, JAXA has executed 15 collision avoidance manoeuvres for the LEO spacecraft.

In parallel, JAXA determines the orbit of space objects by using Kamisaibara Space Guard Center (KSGC) radar and Bisei Space Guard Center (BSGC) telescopes observation data, predicts close approaches using the latest orbit ephemerides of JAXA satellites, and calculates Probability of Collision (PoC) using our unique methods.

Also, JAXA evaluates the criteria for CA and Collision Avoidance Maneuver (CAM) through our experiences. In our evaluations, the trends of each conjunction condition and of prediction errors due to perturbations (e.g. uncertainty in air drag) are analysed.

JAXA succeeded in identifying the origin of GEO fragmentation debris by using the optical-observation data acquired in BSGC through our collaborative research with Kyushu University. The identification was performed by our simplified fragmentation model.

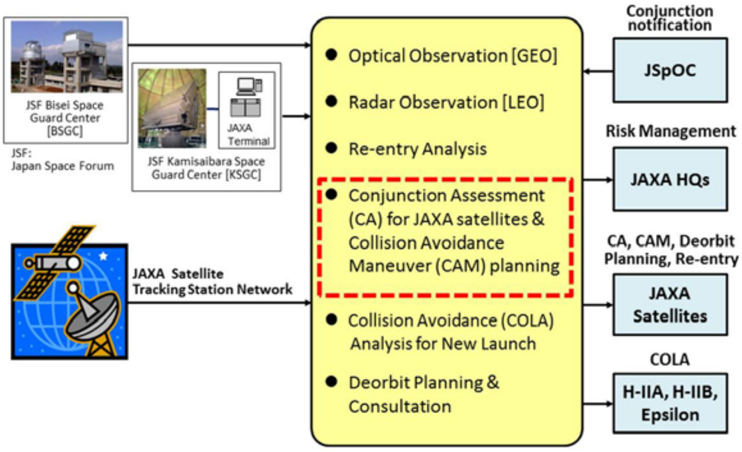


Fig.-1 Activity for the SSA in JAXA

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

Generally the observation of LEO objects is mainly conducted by a radar system, but JAXA has been working to apply an optical system to reduce the cost for both the construction and operation of conducting these observations. Fig.-2 shows the system which consists of many optical sensors to cover large regions of the sky. Survey observations using an 18 cm telescope and a CCD camera, one set of the system, showed that 30 cm-sized objects or larger at 1,000 km altitude were detectable with those sensors and 15 per cent of them were un-catalogued. For GEO observation, a FPGA board (Fig.-3) which can analyse 32 4K4K-frames within 40 seconds was developed and confirmed that 14 cm-sized objects were detectable by analysing CCD frames taken with a 1 m telescope at the Bisei Spaceguard Center of the Japan Space Forum. Today, the size limit to detect objects in GEO is reported to be 1 m, a result that can be considered effective in detecting small fragments caused by break-ups in the GEO region.

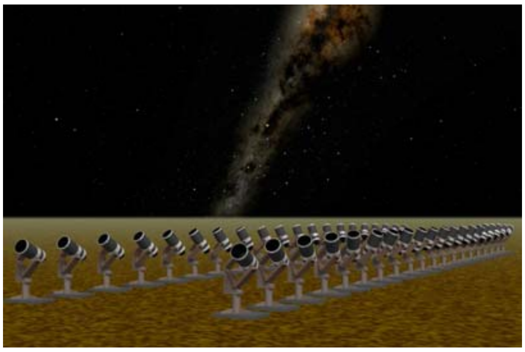


Fig.-2 The array of the optical sensor at one site. In order to detect many LEO objects twice, two narrow rectangle regions are observed by changing observational direction of each optical sensor.

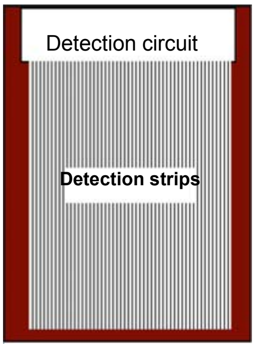
Fig.-3 The FPGA board manufactured by Technoscope which can analyse 32 4K4K-frames within 40 seconds.

2.3 In-situ Micro-Debris Measurement System

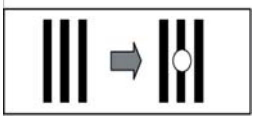
For micro-debris (sub-millimetre class) that cannot be detected on the ground, JAXA developed an on-board detector for in-situ measurement. This sensor, named SDM, is the first to use conductive (resistive) lines for detecting debris. Fig.-4 shows the sensing principle and Fig.-5 shows the SDM product.

If this were supplied to many spacecraft, the acquired data could help to improve the debris environment model. The first SDMI was launched with HTV-5 on August 19, 2015. This is the world’s first micro-debris measurement demonstration experiment on the ISS using conductive (resistive) strip lines for detection. Now, JAXA has been conducting an analysis of the acquired data.

Currently there are few measures available that could help us better understand the situation of tiny debris and meteoroids in outer space, despite the fact that it is essential for risk assessment, for survivability against debris impact, and for applying a cost-effective protection design for spacecraft. It is strongly expected and welcomed that international space agencies would launch an on-board detector attached to their spacecraft, and share the collected data, so as to contribute to improvements of the debris and meteoroid models.



(a) Detector strips on thin film



(b) Strips severed by debris particles

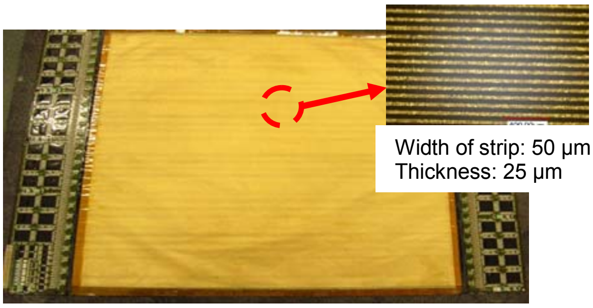


Fig.-5 Engineering Model

Fig.-6 Flight experiment on HTV

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

Fig.-4 Sensor principle

2.4 Protection from impact of micro-debris

The amount of micro-debris (less than 1 mm in diameter) has 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.

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.

The results of this research are reflected in the "Space Debris Protection Design Manual" (JERG-2-144-HB) (original version was published in 2009, and was revised in 2014).

JAXA has developed a debris impact risk assessment tool named "TURANDOT". TURANDOT analyses debris impact risks against a three-dimensional model of a spacecraft. This tool was updated to apply ESA's latest debris environment model (MASTER-2009).

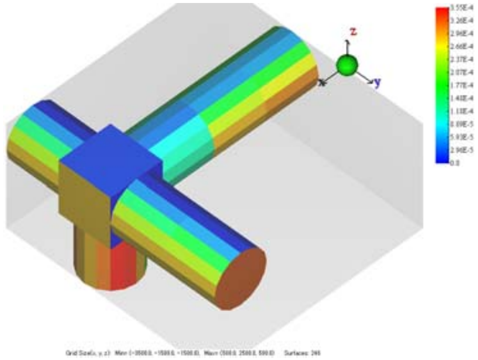


Fig.-7 an example of out from TURANDOT

2.5 Propellant tank easy to demise during re-entry

A propellant tank is usually made of titanium alloy, a superior material because of its light weight character 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 would pose a casualty risk on the ground.

JAXA conducted 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 made a prototype for the shape of Trial #1 (Fig.-8) which is shorter in size compared to the nominal tank as shown in Fig.-9. Vibration tests were conducted for PMD (Propellant Management Device) to confirm its tolerance to the launch environment shown in Fig.-10. The next step is scheduled for the trial manufacturing of a nominal size tank and the qualification test. Once it is qualified, we can enjoy lower costs and shorter manufacturing lead time than with previous titanium tanks.

Fig.-8 Prototype (Trial #1)

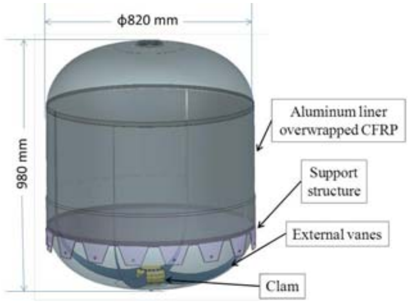


Fig.-9 Concept of CFRP propellant tank

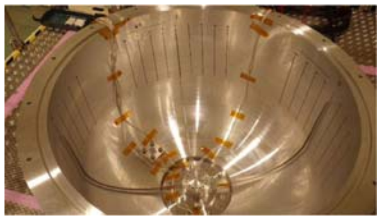


Fig.-10 Vibration test for PMD

2.6 Active Debris Removal

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. Key technologies for realizing active debris removal have been studied such as non-cooperative rendezvous using image sensors, and capture using extensible booms, harpoon, and others. An electrodynamic tether system is promising not only because it can de-orbit debris without any propellant, but also it is easy to be attached to the debris object. A demonstration flight of EDT is planned on the HTV-6 and manufacturing and testing of EDT components are being conducted in 2015.

Fig.-11 A demonstration flight of EDT using HTV-6