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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

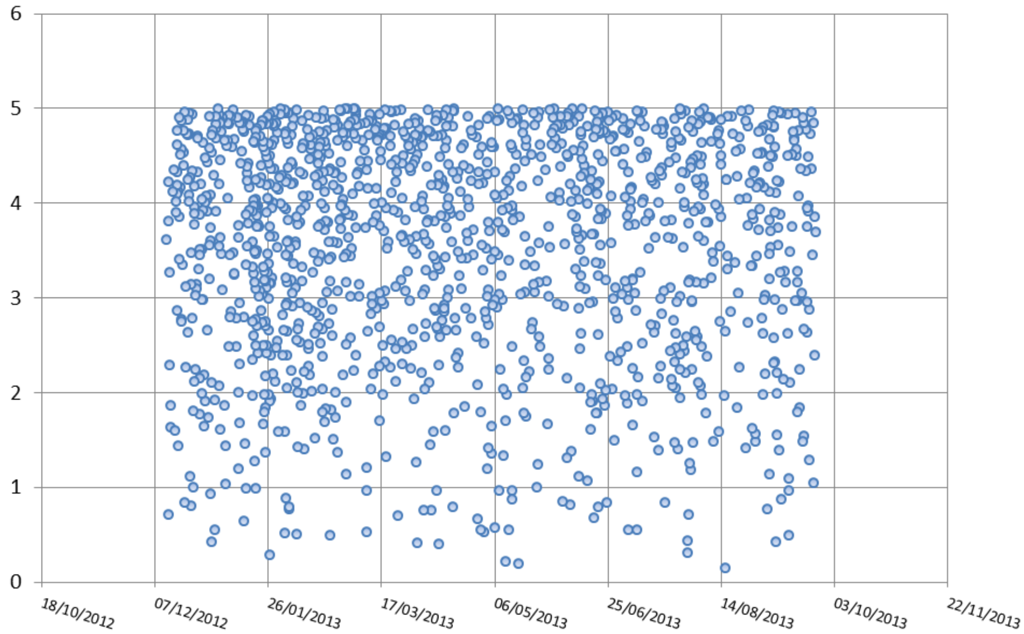
The present conference room paper contains submission received by the Secretariat from Thailand, and includes additional pictures, tables and figures not included in document A/AC.105/C.1/108*. The document is issued without formal editing.

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

Thailand Earth Observation System (THEOS) space debris monitoring

Thailand Earth Observation System (THEOS) ground station has two sources of space debris surveillance, JSpOC (Joint Space Operating Center) and SDA (Space Data Association). JSpOC has provided close approach notification once space debris approaches THEOS with miss distance lower than 1 kilometre whereas SDA has notified any space debris coming close to THEOS within 5 kilometres threshold as presented in Figure 1.

Figure 1
THEOS Close Approaches between Dec 2012-Oct 2013



THEOS Close Approaches

THEOS has experienced several close approaches since it has been operated at 822 kilometres of altitude where space debris is dense the most. There are two criteria THEOS ground station used to consider the necessity of collision avoidance manoeuvre:

1. Radial miss distance < (primary object error in radial) + 3 (secondary object error in radial) + primary object radius + secondary object radius;

2. Radial miss distance < 100 m, In-track miss distance < 300 m and cross-track miss distance < 100 m.

THEOS Experiences in Collision Avoidance Manoeuvre

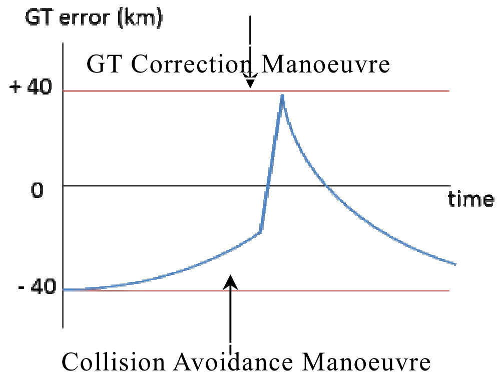
So far, 3 collision avoidance manoeuvres have been performed to avoid collision, one time for IRIDIUM 33DEB and two times for COSMOS 2251 DEB as presented in Table 1:

Table 1
THEOS Collision Avoidance Manoeuvre Experience

No.	Manoeuvre	Date of Manoeuvre	Semi-major axis adjustment (km)	Inclination adjustment (deg)	Propellant Consumption (kg)	Remaining Propellant (kg)
1	Collision Risk Reducing	15 Dec 2010	-0.080	–	0.020	50.383
2	Collision Risk Reducing	7 May 2011	-0.105	–	0.086	50.335
3	Collision Risk Reducing	11 Jun 2012	0.107	–	0.122	50.208

Unanticipated or Collision avoidance manoeuvre casts 2 impacts on THEOS operation; propellant usage and operation interference. Once the altitude adjustment has been executed so as to escape the collision, the controlled parameter (Ground Track error) is tended to evolve out of defined windows at the greater rate. Therefore, altitude correction has to be done sooner than it was supposed to be as illustrated in Figure 2 which leads to more spending propellant.

Figure 2
Impact of Collision Avoidance on Ground Track error

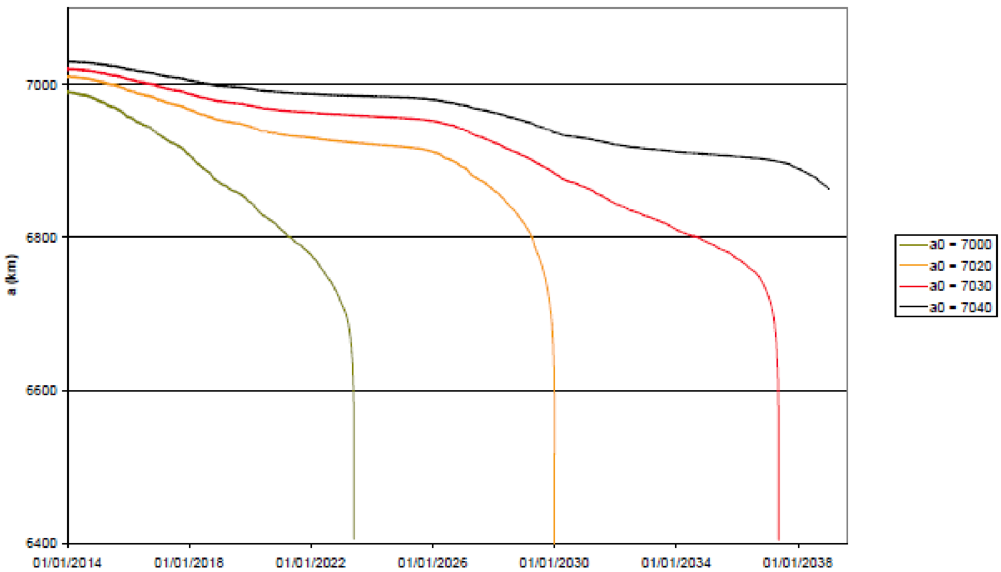


THEOS De-orbit plan

There are two reasons causing an increase in the number of space debris: satellite self-explosion and collision between no longer used satellites.

For this reason, 24.1 kilograms of propellant has been reserved for THEOS de-orbit once THEOS operation is terminated. In order not to create more space debris, THEOS semi-major axis will be decreased from 7,200 km to 7,030 km which not only allows THEOS de-orbitation within 25 years according to LEO (low-Earth orbit) disposal standard but also removes the satellite from the altitude congested with space objects hereby reducing the risk of collision with other space objects later on. The simulation of THEOS de-orbit is presented in Figure 3:

Figure 3
Evolution of the mean semi-major axis over 25 years



In figure 3, a distance of 7,040 kilometres of semi-major axis does not allow a de-orbitation for the spacecraft within 25 years. Therefore, 7,030 kilometres semi-major axis is a good compromise to copes with the de-orbitation requirements while using low propellant as possible. A synthesis of the different de-orbitation duration is presented in Table 2:

Table 2
De-orbitation duration VS Semi-major axis

Semi-major axis (km)	De-orbitation duration (years)
7,000	7.7
7,020	15.2
7,030	23.5
7,040	–

In order to reach this target orbit, Δa = 170 kilometers will be needed which is required ΔV = 87.8 m/s. As the specific impulse at EOL (End Of Life) is 210.6 seconds, the corresponding mass decrement or Δm is 24.1 kilograms. All of the propellant will be depleted during de-orbitation so as to prevent self-explosion of the satellite which leads to an increase in the number of space debris.

Table 3
THEOS Operating lifetime

Mission	Propellant per time of manoeuvre (kg)	No. of manoeuvre	Required Propellant (kg)
LST error correction (2013-2029)	4.02	5	**20.1**
GT error correction (2013-2029)	0.1	15	**1.5**
Reserved for Collision Avoidance Manoeuvre	0.1	3	**0.3**
Reserved for de-orbit	24.1	1	**24.1**
Remaining Propellant			**46**

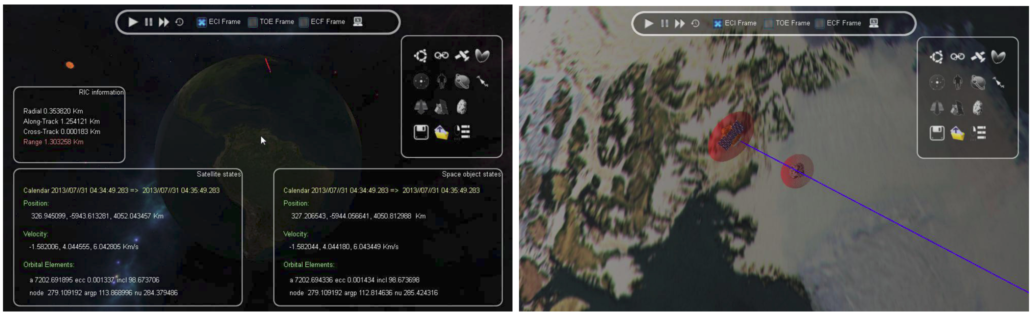
Based on the remaining propellant, 46 kilograms, it can support THEOS in operation for more than 16 years from now on. The propellant spending plan for 16 years from October 2012 until the middle of 2029 has been presented in Table 3.

Research/Project related to collision avoidance

1. THEOS Collision Avoidance Software (TCAS-plus)

The development of software for illustrating the conjunction between space objects in 3D so as to facilitate the close approach analysis. It enables the satellite operators to make a better decision on whether or not collision avoidance manoeuvre is required leading to no wasting propellant on unnecessary manoeuvre and no risk of collision.

Figure 4
TCAS-plus



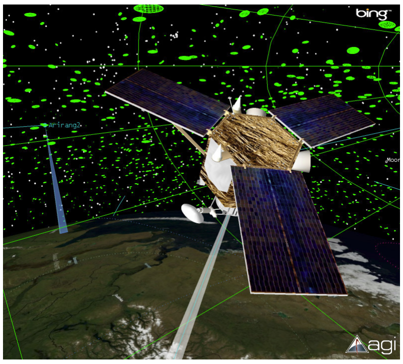
2. Space Environment Surveillance System (SSS)

The future project for enhancing TCAS-plus capability focuses on 2 segments:

1. In-house Space Debris Monitoring software

At present, since THEOS ground station has been relying on other space debris surveillance system, we planned to develop our own one as a redundant. The monitoring software will retrieve TLE of space debris from NORAD, then propagate their positions with respect of time and determine the miss distance.

Figure 5
Space Debris Surveillance (STK)



2. Improve the collision avoidance manoeuvre criteria and develop methodology for conjunction analysis

The current criteria are quite sensitive consequently, 3 times of collision avoidance manoeuvres has already been performed for the past 5 years of operation. The new criteria may take international criteria for robotic spacecraft into consideration (if probability of collision is greater than 10-4, collision avoidance manoeuvre should be performed) along with the concrete direction of conjunction analysis.