JAXA developed SLR Reflector Mt.FUJI and Technical Demonstration on HTV-X

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Abstract

This paper describes the overview of JAXA developed SLR reflector, named Mt.FUJI, and the Mt.FUJI mission which is the technical demonstration on HTV-X. Mt.FUJI is a general-purpose SLR reflector with the concept of small size, light-weight, and reasonable prices for LEO spacecraft. The objectives of the Mt.FUJI mission is (1) to verify the performance of Mt.FUJI in orbit, and (2) to quantitatively evaluate the effectiveness of the attitude estimation method by SLR data. SLR is essential to achieve Mt.FUJI mission, and we believe that the results of this mission will provide new insights into space debris, as it will enable us high-accuracy orbit determination and attitude estimation of space debris.

1. Introduction

In recent years, the use of space has expanded rapidly, resulting in a drastic increase in the number of orbital objects. Space situational awareness (SSA) and active debris removal (ADR) have therefore attracted much attention, and thereby, the importance of grasping the orbital and attitude motion of space debris has increased. To observe space debris motion from the ground, radar and optical observations are commonly performed. However, those observation methods do not have sufficient resolutions for attitude estimation. Japan Aerospace eXploration Agency (JAXA) is now focusing on satellite laser ranging (SLR) as a means of accurately estimating attitude motion from the ground.

If a space object is equipped with an SLR reflector, its visibility from the ground can be ensured even after it becomes debris. However, because conventional SLR reflectors are expensive, heavy, and large, there are not many spacecrafts with an SLR reflector. Therefore, JAXA has developed a general-purpose SLR reflector, named Mt.FUJI (MulTiple reFlector Unit from Jaxa Investigation), with the concept of small size, lightweight, and reasonable price. Three Mt.FUJIs are installed on a new unmanned spacecraft HTV-X for demonstration in orbit. The objectives of the Mt.FUJI mission are:

(1) to verify in-orbit performance of Mt.FUJI as an SLR reflector

(2) to evaluate SLR-based attitude estimation technique compared with telemetry data

In particular, the latter will enable the world's first quantitative evaluation of the effectiveness of the attitude estimation method by SLR, as it has not been evaluated with true values.

In this paper, we will first introduce the overview of Mt.FUJI, and then, explain the Mt.FUJI mission.

2. Overview of Mt.FUJI

Figure 1 shows the outlook of Mt.FUJI. Mt.FUJI consists of seven 1.0 inch corner cube reflectors (CCRs) and an aluminium frame. Mt.FUJI was developed for the use of LEO spacecraft. The specifications are shown in Table 1. It should be noted that the target altitude of 800 km is only for the worst weather conditions, so it is possible that returns could be obtained for orbits at higher altitudes.

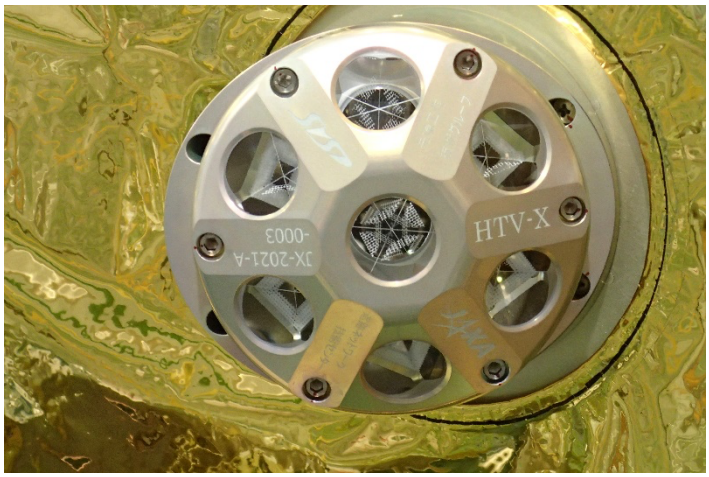

Figure 1. Outlook of Mt.FUJI

Table 1. Specifications of Mt.FUJI

Item	**Specification**
Target attitude (circular orbit)	≦ 800 km
Diameter	112 mm
Height	32 mm
Mass	260 g
CCR size	1 inch (25.4 mm)
Number of CCR	7
CCR coating	uncoated
Approx. FOV of Mt.FUJI	Cone shape with a half apex of 45 degrees
Material	Frame: aluminum CCR: fused silica

3. Mt.FUJI Mission

The Mt.FUJI mission is one of the technical demonstration missions conducted by the experimental platform of the HTV-X. In the Mt.FUJI mission, three different Mt.FUJIs are attached onto the backside of the HTV-X. The objectives of the Mt.FUJI mission are:

- To verify Mt.FUJI in orbit
- To evaluate the accuracy of SLR-based attitude estimation using true data (telemetry of the HTV-X)

The first one is achieved by detection of return signals. For the second one, HTV-X will fly with special attitude motion in orbit, and we will obtain SLR data affected by the attitude motion. The overview of operation in Mt.FUJI mission is shown in Figure 2. First, the attitude change command will be uploaded, and HTV-X will start a special attitude motion. During the special attitude motion, SLR stations try to get SLR data. After the special attitude motion, HTV-X will return to a nominal attitude (LVLH) and downlink its telemetry including attitude state. By repeating these and changing attitude motion, we can obtain the SLR data affected by the attitude motion. After obtaining data, we try to estimate the attitude motion by somehow (now we are considered to apply the global search method [1]) and then compare the results with the true values extracted from the telemetry.

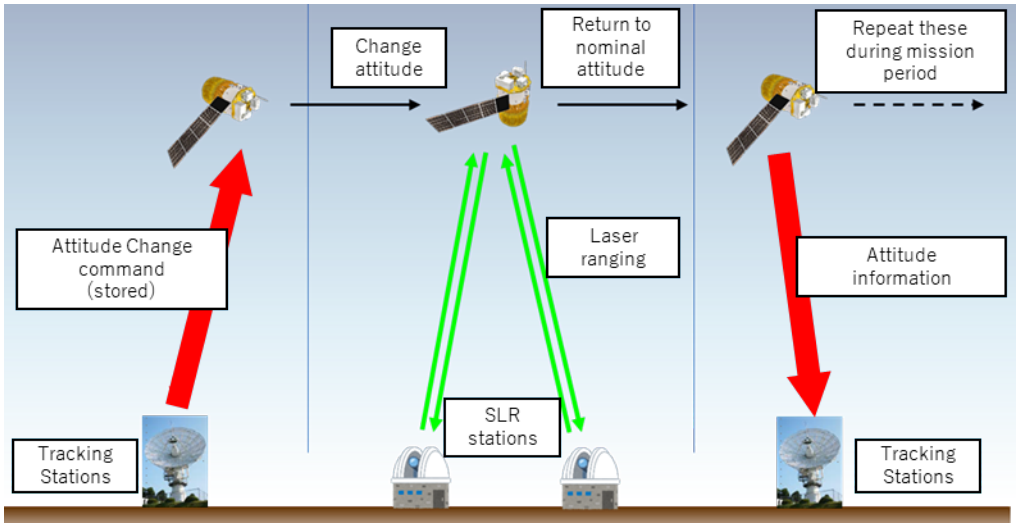

Figure 2. Operation overview in Mt.FUJI mission

As shown in Figure 3, there are currently four different flight modes under consideration:

- LVLH, a nominal attitude of the HTV-X. Due to the mounting positions and angles of Mt.FUJIs, only some CCRs of one Mt.FUJI point toward the Earth.
- Earth pointing mode, static attitude with respect to the LVLH attitude. One Mt.FUJI faces towards the ground so that all CCRs of one Mt.FUJI point toward the Earth.

- Along/Cross pendulum mode, dynamic attitude motion with respect to the LVLH attitude. HTV-X will fly while moving the “pseudo” pendulum motion in the along- and cross-track directions, respectively.

It should be noted that because it moves at a constant angular velocity due to the restrictions of the attitude change of the HTV-X, it is a “pseudo” pendulum movement. The expected constant angular velocity in this experiment is up to 2.00 deg/s.

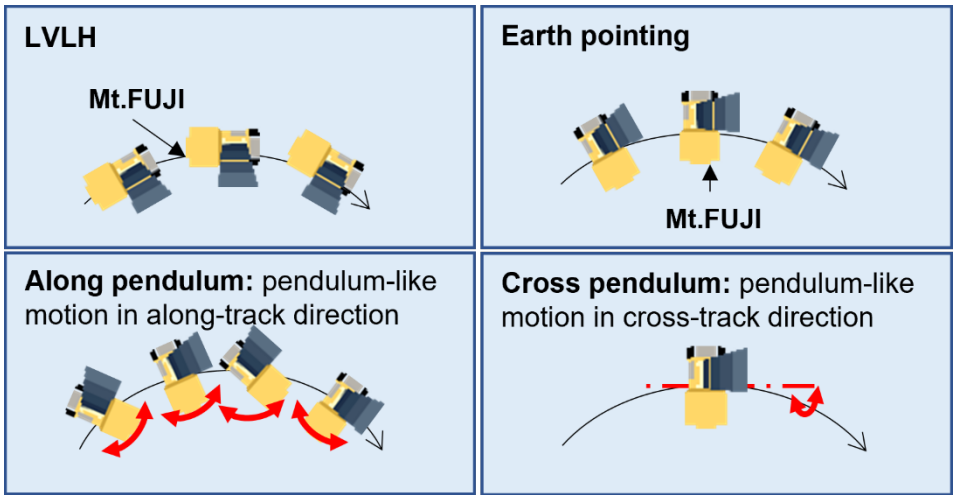

Figure 4. Four flight modes

The period of the Mt.FUJI mission is four to five weeks. Three weeks will be conducted after one to two weeks later departing from the ISS, and one week will be conducted before approaching to the ISS or after completing other demonstration missions.

4. Conclusions

JAXA has developed a general-purpose SLR reflector named Mt.FUJI and it will be verified in-orbit performance by the HTV-X. In addition, though the Mt.FUJI mission, we will conduct the quantitative evaluation of SLR-based attitude estimation technique by using true data (telemetry of HTV-X). SLR is essential to achieve Mt.FUJI mission, and we believe that the results of this mission will provide new insights into space debris, as it will enable us high-accuracy orbit determination and attitude estimation of space debris.

References

[1] Y. Akiyama, S. Kasho, H. Hinagawa, T. Matsumoto, M. Watanabe, S. Nakamura, Overview of Mt.FUJI Mission on HTV-X and Genetic Algorithm Based Attitude Motion Estimation by SLR Data, Journal of Evolving Space Activities, 2022 (in press).