Laser Retroreflector Array Development for STSAT-2

Sang-Hyun Lee, Kyunghee Kim (1)**, Jun Ho Lee** (2)**, Jonghan Jin** (3)**,**
Noh Hoon Myung (1)

(1) Satellite Technology Research Center (SaTReC), KAIST.
(2) Department of Optical Engineering, Kongju National University.
(3) BUPE Group, KAIST

shlee@satrec.kaist.ac.kr /Fax: +82-42-8610064

Abstract

STSAT-2(Science and Technology Satellite-2) is a microsatellite to experiment advanced satellite technology and research space science and now has been completed the flight model development. STSAT-2 will be launched by KSLV-1 at Naro space center of Korea in 2009 and injected an elliptical orbit having 300km at the perigee and 1500km at the apogee. It has three missions: as the first mission is to predict total precipitable water using microwave radiometer (DREAM); the secondary mission is to measure precise distance between STSAT-2 and SLR ground station for precision orbit determination of STSAT-2; the last mission is to verify the space core technologies of bus. STSAT-2 is equipped with a laser retroreflector array having hemispherical configuration with one-nadir-looking corner cube in the center and surrounded by an angled ring of eight corner cubes like Shunzhou-IV, ERS-1&2, and Envisat. This paper introduces STSAT-2 mission and describes the development result of LRA.

Introduction

STSAT-2 is the first Korean satellite, which is equipped with laser retroreflector array for SLR. The objectives of STSAT-2 consist of three missions, which are the domestic development of a low earth orbit 100kg satellite which will be launched by KSLV-1(Korea Space Launch Vehicle-1) from the domestic space center (Naro Space Center), the development of advanced technology for small spacecraft, and the development and operation of world-class space science payloads (Jun Ho Lee, 2005).

STSAT-2 has an elliptical orbit having 300km at the perigee and 1500km at the apogee. Some period among one year has partially sunlight period without eclipse. The minimum eclipse time has 0% and the maximum eclipse time about 35% (Kyunghee Kim, 2007).

STSAT-2 has two payloads: the main payload, microwave radiometer (DREAM, Dual-channel Radiometer for Earth and Atmosphere Monitoring) and the secondary payload, laser retroreflector array. The DREAM mission objectives are to acquire brightness temperature of the liquid water from Earth atmosphere and surface and to predict the total precipitable water after post-processing. The mission objective of spacecraft technologies is to develop a thermally, mechanically, electrically stable and radial resistant spacecraft system having high precision attitude determination and control capability in a high eccentric ellipsoidal orbit. For spacecraft technology experiments, STSAT-2 has the following instrumentations onboard:

(1) Pulsed Plasma Thruster (PPT)

(2) Dual-Head Star Tracker (DHST)
(3) Fine Digital Sun Sensor (FDSS)
(4) Compact on-board computer
(5) High-speed data transmission (10Mbps)

Figure 1 shows the STSAT-2 configuration and table 1 summarizes the specifications of STSAT-2 (SaTReC, 2005).

Figure 1. STSAT-2 configuration

Table 1. STSAT-2 specifications

Items	Values	Items	Values
Orbit	300×1500km, Circular orbit Inclination : 80°	Expected Life	2 years
Launch Date	July 31, 2009 (STSAT-2A) January 31, 2010 (STSAT-2B)	Payloads	DREAM : 10.66kg LRA : 0.82kg
RF Link Margin	S-band : 3dB @ 10deg X-band : 3 dB @ 10deg	Attitude Control	3-axis stabilization
Power	200W @ BOL	Weight	100kg
Eccentricity	0.082435	Period	102.998min

Satellite Laser Ranging Mission

The SLR mission objectives are to determine the more precise orbit of STSAT-2 than possible with S-band tracking data alone, to calibrate the main payload DREAM, and finally to support the science research such as earth science and geodynamics. Additionally, the precise orbit determination of STSAT-2 can be used to evaluate the performance of the first Korean launcher (KSLV-1). SLR data of STSAT-2 will provide the unique opportunity to investigate the variations of an ellipsoidal orbit.

Laser Retroreflector Array

LRA consists of nine corner cubes and symmetrically mounted on a hemispherical surface with one nadir-looking corner cube in the center and surrounded by an angled ring of eight corner cubes like Shunzhou-IV, ERS-1&2, Envisat, ALOS, GFO-1 and Jason-1. LRA configuration is shown in Figure 2.

The diameter of corner cube is 31.5mm and the height 22.3mm. Corner cubes were made of fused silica. Corner cube assembly consists of corner cube housing, corner cube, PTFE ring, flexture, corner supporter, and cover. PTFE ring is a kind of Teflon and was inserted to absorb vibration and shock and isolate thermal conduction between corner cube and flexture.

LRA is equipped on the satellite's earth panel and allows laser ranging in the field of view angles of 360 degree in azimuth and 60 degree elevation. The dimensions of laser retroreflector array have 200mm in diameter and 65mm in height. The beam divergence is fourteen arcsec in STSAT-2A and twelve arcsec in STSAT-2B. Table 1 summarizes the specifications of laser retroreflector array (SaTReC, 2005).

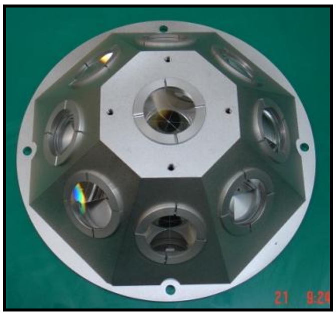

Figure 2. Laser retroreflector array configuration of STSAT-2

Table 2. Specifications of laser retroreflector array

Items	Values	Items	Values
Corner Cube Diameter	31.5mm	Corner Cube Height	22.3mm
LRA Size	ϕ200×65(Height)mm	Field of View	±60°
Dihedral Angle Offset	1.5″ (STSAT-2A) 1.2″ (STSAT-2B)	Weight	815g
Divergence	14±2arcsec (STSAT-2A) 12±2arcsec (STSAT-2B)	Material	Fused Silica
Surface Flatness	λ/10	Coating	No Coating

Phase Center of Laser Retroreflector Array

Figure 3 shows the center of gravity of satellite and the phase center of laser retroreflector array. O is satellite-based origin and CG the satellite center of gravity. The vector C is from satellite-based origin to the center of gravity of satellite, C=(-7.6, 381.4, 1.9)mm in the STSAT-2A and (-0.18, 412.16, 0.03)mm in the STSAT-2B. The distances between the center of gravity of satellite and the optical center of LRA are 267mm in the STSAT-2A and 271.2mm in the STSAT-2B. Here, PC is the phase center. The vector L is from the satellite-based origin to the LRA mass center, (-0.34, 381.92, 310.98)mm.

For the nadir-facing cube, the phase center is -h×n in the z direction from the plane of the front faces of that cube. For the STSAT-2 cubes, h=22.3mm and n=1.464. So the phase center for the nadir cube is -32.65mm in z direction. The z-component of array phase center for that cube is +2.87mm from the mass center of laser retroreflector array, but will vary at the level of a few mm depending upon which of the other cubes are visible from the tracking station. However, ignoring that effect here, and defining vector L′ as the vector from the satellite-based origin to the phase center of the retroreflector array, we have L′=(-0.34, 381.92, 313.85)mm. The plane of the front faces of the cubes is +35.52mm in the z direction from the LRA mass center. Finally, the vector PC from the satellite center of gravity to the phase center of the retroreflector array is PC=L′-C. So, PC=(7.26, 0.52, 311.95)mm in the STSAT-2A and (-0.16, -30.24, 313.82)mm in the satellite fixed frame. Figure 3 shows the phase center of laser retroreflecture array.

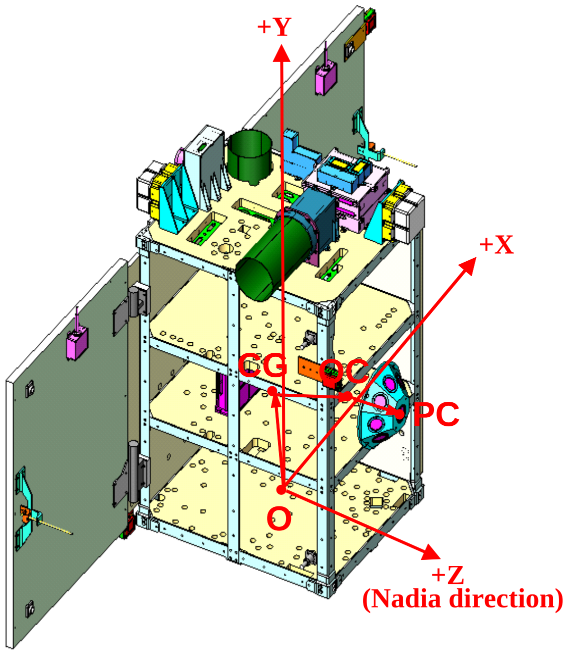

Figure 3. Phase center of laser retroreflector array

Beam Divergence Test Results

The beam divergence and dihedral angle offset test of corner cubes were performed by single pass method using Zygo interferometer with 632nm wavelength He-Ne laser. The dihedral angle offsets change between 1.08 arcsec and 2.03 arcsec in the STSAT-2A and 0.9 arcsec and 1.66 arcsec in the STSAT-2B. The average beam divergences of corner cubes have 14.5″ in the STSA-2A(Sang-Hyun Lee, 2007) and 10.4″ in the STSAT-2B (Sang-Hyun Lee, 2007).

Environmental Test Results

The vibration and thermal vacuum test of laser retroreflector array were performed. The test level is acceptance level. The vibration test levels are 9.5grms in random test and 2g for lateral and 3g for vertical in sine test. After vibration test, the visual inspections were without cracks appeared at the edge of corner cube in engineering model. This result is because the anti-vibration material, PTFE ring , were inserted between corner cube and flexture to isolate vibration and shock.

The thermal vacuum test of laser retroreflector array was integrated on +z satellite's earth panel and performed by system level and acceptance level. In order to measure temperature difference between corner cube (Fused silica) and housing (Al 6061), two thermocouples were attached on the center of corner cube and housing. The test conditions are as follows:

- Number of cycle : 3
- Dwell time : 6 ~ 7 hours
- Shroud temperature : -120°C ~ 100°C

The minimum temperature of corner cube is -21.1°C and the maximum +62.8°C. The temperature difference between corner cube and housing is 2.7°C. As the temperature difference is small, the effect of the thermal expansion coefficient difference of two materials was not appeared in corner cubes. Therefore, the thermal vacuum test was successfully without damage and crack of corner cubes. Figure 4 shows the temperature profile of thermal vacuum test and test result and Figure 5 shows the environmental test pictures (Sang-Hyun Lee, 2007).

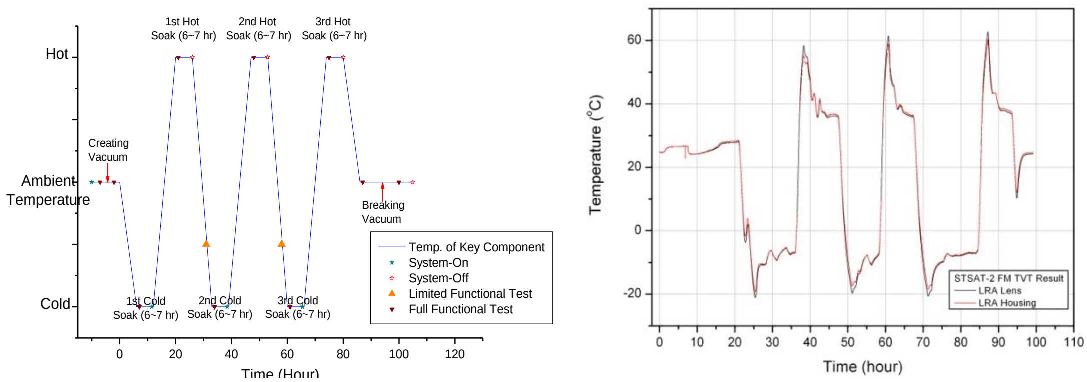

Figure 4. Temperature profile of thermal vacuum test and test result

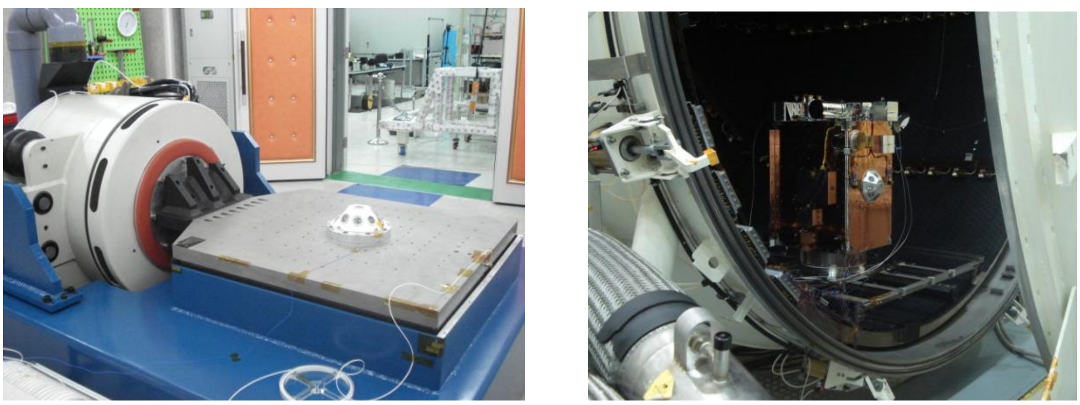

Figure 5. Environmental test pictures (vibration (left) and thermal vacuum (right))

Conclusion

The corner cubes and laser retroreflector arrays for STSAT-2 were manufactured and performed the various tests. The dihedral angle offset and beam divergence measurements were performed and have 14.5 arcsec in the STSAT-2A and 10.4 arcsec in the STSAT-2B. Also, the vibration and thermal vacuum test were performed successfully. After testing, we made sure the safety of laser retroreflector aray through visual inspections.

Acknowledgement

The authors would like to thank for their help of manufacturing laser retroreflector array of STSAT-2 to professor Yang Fumin, CHEN Wanzhen, and Zhang Jongping (Shanghai Astronomical Observatroy, CAS); professor Guo Tanyoung and Wang Peiyuan (Institute Seismology of China Earthquake Administrations).

References

Jun Ho Lee, Sung Bum Kim, Kyung Hee Kim, Sang Hyun Lee, Yong Jo Im, Yang Fumin, Chen Wanzhen, *Korea's first satellite for satellite laser ranging*, *Acta Astronotica*, pp.547—553, 2005.

Kyunghee Kim, Sang-Hyun Lee, Jun Ho Lee, Hyung-Myung Kim, "*Link Budget Analysis of SLR for STSAT-2*", 2007 Korean Space Science Society Spring Conference, 2007.

SaTReC, KAIST, *STSAT-2 CDR Data Package,*2005.

SaTReC, KAIST, *LRA CDR Data Package for STSAT-2,*2005.

Sang-Hyun Lee, Kyunghee Kim, Jun Ho Lee, Jonghan Jin, Hyung-Myung Kim, "*Protoflight Model Development of Laser Retroreflector Array for STSAT-2*", Journal of the Korean Society for Aeronautical and Space Sciences, Vol. 35, No. 12, 2007, pp.1135-1142.

Sang-Hyun Lee, Kyunghee Kim, Jun Ho Lee, Jonghan Jin, Seung-Woo Kim, "*Flight Model Development of Laser Retroreflector Array for STSAT-2*", 2007 Korean Space Science Society Spring Conference, 2007.