SLR Return Analysis for SOHLA-1

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Abstract

SOHLA-1, which is planned to be launched in 2009, is a 50kg-class spin stabilized satellite. One of the missions of SOHLA-1 is the tech-demo of the low-cost, micro-GPS receiver developed by JAXA(Japan Aerospace Exploration Agency) based on COTS automobile technology. SLR is needed for the calibration of GPS based satellite positioning. The SLR data are intermittently observed because of the satellite's spin. To evaluate the impact of spin on return availability, the patterns of observation data are simulated.

Introduction

SOHLA-1 is a 50kg-class spin stabilized satellite based on JAXA's Micro-LabSat which was launched in 2002 by a Japanese H-IIA launch vehicle as a piggyback payload[Kato05]. Table.1 lists the main characteristics of SOHLA-1. The mission of SOHLA-1 is the engineering demonstration by a 50kg-class micro satellite for validation of technique to identify a location of discharge of thunder on the Earth. The goal also includes a short period of development time and at low cost. A characteristic feature of SOHLA-1 is that some components of the satellite are manufactured by universities and middle and small-sized enterprises joining in an organization called SOHLA(Space Oriented Higashiosaka Leading Association) established to embark on space business. Since SOHLA had no experience to be engaged in the space project, JAXA has given them wide range of technical support covered from design phase to assembly integration and test phase. In JAXA, the project is defined as the first attempt of the technical transfer in the field of small satellite technology to industry.

SOHLA-1 carries newly developed miniature GPS receiver and the Laser Reflector Array(LRA). One of the missions of SOHLA-1 is to evaluate the GPS receiver's performance. Then, SLR data are needed in order to calibrate the GPS receiver's data.

Since SOHLA-1 is a spin-stabilized satellite, and LRA is mounted only one side, SLR data are expected to be obtained intermittently. To evaluate the impact of spin on return availability, the patterns of observation data are simulated.

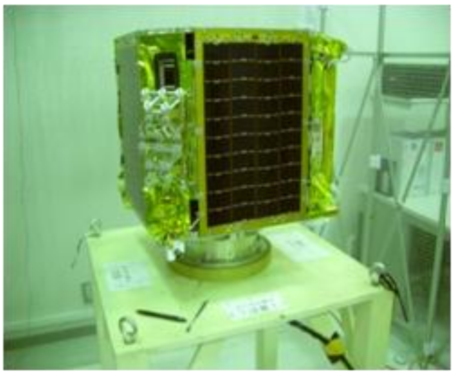

Figure 1. SOHLA-1

Table 1. Main Characteristics of SOHLA-1

Configuration	Shape of octagonal prism dimensioned by 500×500×500mm
Mass	56.9 kg
Attitude	Spin stabilized
Power	30-40W
Mission Duration	1 year
Orbit	Sun-synchronous Altitude:666km Inclination: 98.06deg Cycled period: about 1.6 hours

Condition for SLR

Figures.2~4 show the Laser Reflector Array mounted on SOHLA-1. LR consists of 12 corner cube retro-reflectors(CCR), and the shape of each CCR is the same as that of AJISAI (size of 42mm in each side of rectangular shaped aperture). Its material is BK7, and the viewing angle coverage of the LR is about 60 degree along the spin axis, and is about 30 deg in the direction of perpendicular to spin axis. This LRA is mounted at only one side of the spinning satellite. Therefore, LRA spins along with satellite.

Figure.5 shows the direction of spin axis in equatorial coordinate system. The spin axis lies in the plane containing the solar direction and the normal to the orbital plane. The angle of spin axis and the solar direction is 45 degrees. This indicates that direction of spin axis depends on the solar direction, and spin axis changes slowly in one year cycle.
The spin rate of SOHLA-1 is set nominally 3rpm and is controllable within a range of +/-1rpm.

From these conditions, we expect that SLR return pulse is intermittently observed. Whether SLR return is available or not depends on spin axis direction, spin rate and relative position with respect to the SLR stations. If return availability is too low to gather SLR data under the specific condition, JAXA should inform SLR colleagues of the information whether each pass can be tracked or not. The return availability is simulated in the following section.

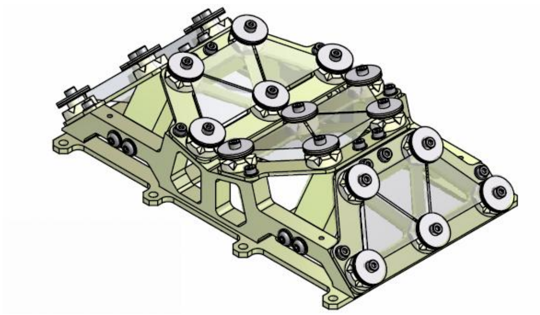

Figure 2. Overview of LRA

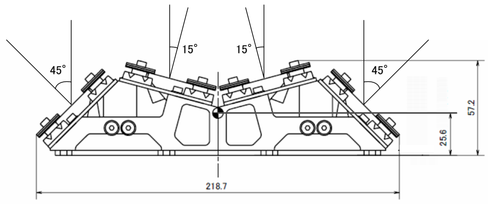

Figure 3. Coverage of LRA

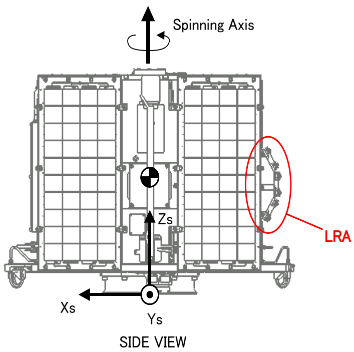

Figure 4. Mounted Position of LRA

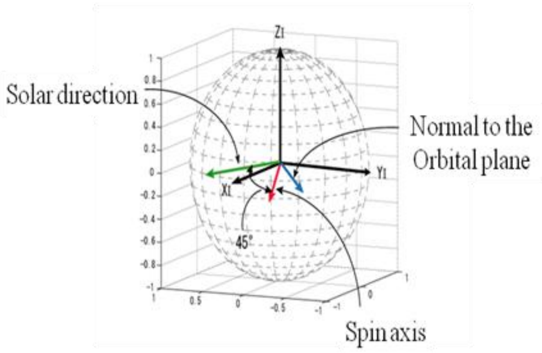

Figure 5. Direction of Spin Axis

Simulations of return availability

At first, we simulate the return intermittency. We study two typical cases return variation like Figure.6 and 7. In Fig.6, SLR station "sees" LR all the time at each spin during the pass, and in Fig7, it does not always because spin axis direction is oriented so that LR is not responding to SLR station during the part of the pass. Each case shows the time series of distance variation between SLR station and LRA on SOHLA-1. The number of zero in vertical axis in the figures means the O-C distance between the SLR station and the CoM of SOHLA-1.

Each case shows that the distance variation changes cyclically because of the spin. Its period of time depends on the spin rate. The thick red points at the bottom of the curve are return available points. So, we can get the return laser pulse only while appropriate incident angle, its period is about 3~4 seconds in every spin, which period is 15~30 seconds. Smaller bin size in comparable to 3-4 seconds for QLNP is desirable. In practical we see that QLNP with 5 seconds bin size can be acceptable.

If we can get the return through the pass like Figure.6, nominal return availability is about 0.15 and the amount of return data will be acceptable to generate the QLNP. However, the amount of return data will not be enough if the pass like Figure.7 is dominant.

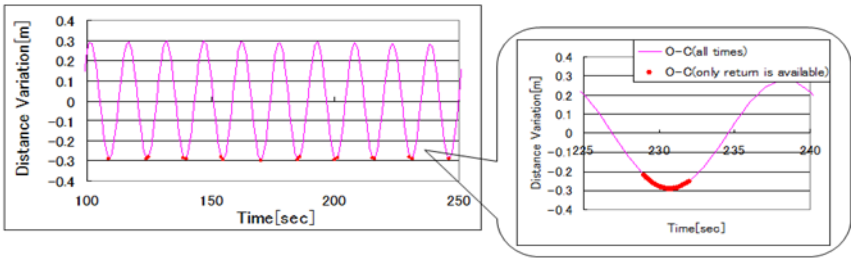

Figure 6. Return Intermittency ~case1~

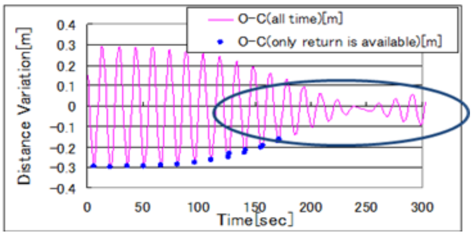

Figure 7. Return Intermittency ~case2~

Then, we have analysed the availability of return data which depends on three major parameters, which are relative position, spin axis direction, and spin rate.

Figures.8~10 show the results of the simulations and Tables.2~4 show the corresponding condition, respectively. In the Figures, the return availability means the proportions of the return available time in one pass. The value of y-axis shows the probability distribution of passes. From the results, there are two peaks in all cases. We can find that strong peak at 10% of return availability is the case that intermittent return is available through the pass like Fig.6. And we also find that weaker peak at between 5~10% of return availability is the case like Figure.7. Therefore, the case of Figure.6 is dominant, and we can get enough return data in all the cases.

Table 2. Condition of Return Analysis
~Dependency on Spin Axis Direction~

Period of time	Num. of passes	Spin rate [rpm]	Station
2009/ 03/15~05/01	~100	3	GMSL
2009/ 07/01~08/01	60~70		
2009/ 11/01~12/01	60~70		

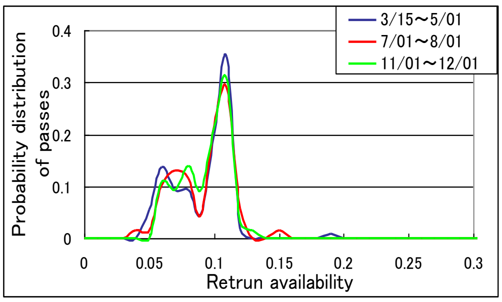

Figure 8. Result of Return Analysis
~Dependency on Spin Axis Direction~

Table 3. Condition of Return Analysis
~Dependency on Spin Rate~

Period of time	Num. of passes	Spin rate [rpm]	Station
2009/ 03/15~05/01	~100	2	GMSL
		3	
		4	

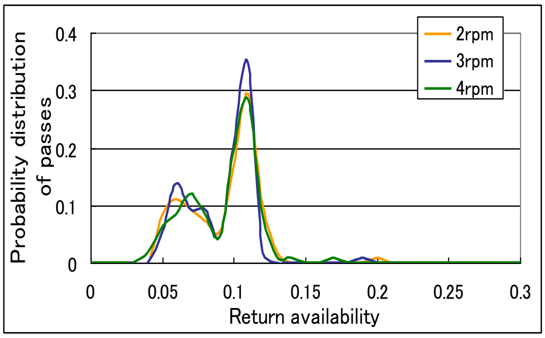

Figure 9. Result of Return Analysis
~Dependency on Spin Rate~

Table 4. Condition of Return Analysis
~Dependency on Relative Position~

Period of time	Num. of passes	Spin rate [rpm]	Station
2009/ 03/15~05/01	~100	3	MLRO
			GMSL
			HA4T
			YARL

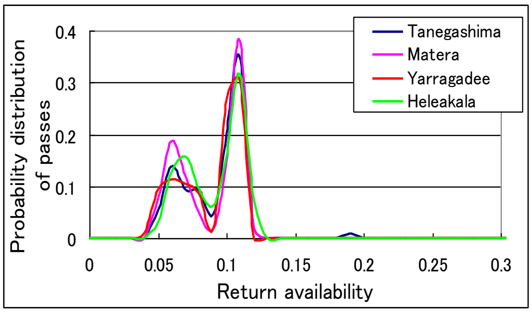

Figure 10. Result of Return Analysis
~Dependency on Relative Position

Summary and future plan

The return availability of SOHLA-1 is simulated. From the simulations, we find that the SLR return is intermittently observed, and its nominal cycle is 20 seconds. In a 20 seconds cycle, the duration of continuous return is less than 5 seconds. Then QLNP with 5 seconds bin size can be practically accepted. We also find that the laser pulse return is not available in case of inappropriate incident angle, but this case is uncommon. So, we can get enough return at all the passes as long as stations know the characteristics of intermittency of returns and adapt to observe it.

SOHLA-1 has been launched successfully in January 23 and ILRS tracking campaign is scheduled on March 9th to 22nd. JAXA is ready to generate prediction and to track SOHLA-1 by JAXA/SLR. We expect to obtain SLR data enough to succeed in SOHLA-1's mission.

Reference

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