

Time series of SpinSat return intensity: How long can BK7 reflectors survive in space?

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SpinSat and BK7 Reflectors

SpinSat is a spherical satellite developed by the Naval Research Laboratory (NRL), USA [Nicholas et al., 2013], and was deployed from the International Space Station in November 2014. Since then it has been tracked by a number of satellite laser ranging (SLR) stations.

It carries 68 retroreflectors on its surface. The size of each reflector is 12.7 mm in diameter. Unlike the other geodetic satellites that are equipped with fused-silica retroreflectors, its reflectors are made of BK7. Whereas the fused-silica reflectors have survived for many decades, the BK7 reflectors are not radiation resistant and are expected to degrade in a relatively short time. This study is to look into the long-term (20-month) performance of the BK7 reflectors through the SpinSat operational period, during which the altitude descends from 425 km at the beginning to 320 km just a few months before the end of the mission (re-entry).

SpinSat Tracking from Herstmonceux

The SLR tracking station at Herstmonceux, UK, has an observation policy that the detection energy is always controlled at zero or one photoelectron [Sherwood, 2016]. This policy is primarily applied for highly accurate SLR measurement but it is also useful for energy level measurement.

The optical energy is controlled by a neutral-density (ND) filter wheel installed just before the detector, and the attenuation level (g) is recorded and archived at the station. The number of successful returns per normal-point bin (r) is also collected and recorded in the standard CRD format. The link budget is inversely proportional to the fourth power of the distance (ρ ; in km), and let us assume that the distance is normalized at 800 km in this study. Using these three observables, the number of photons per normal-point bin before the ND filter normalized at 800 km (N) is then inferred as:

$$N = (r/g) (800/\rho)^4$$

We excluded a small portion of observations when the ND filter wheel changed rapidly (> factor

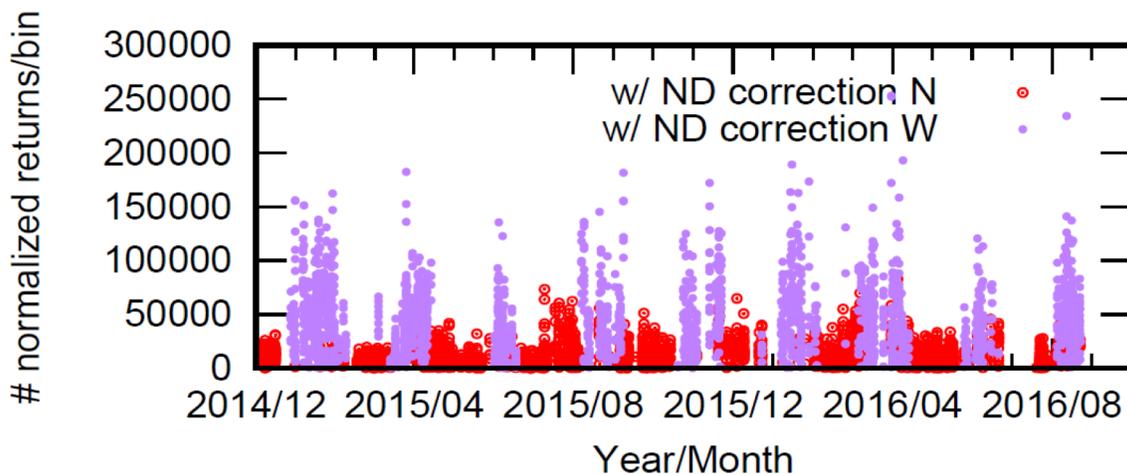


Fig. 1. The normalized intensity (N) from Herstmonceux's Starlette tracking data. The red and purple points correspond to daytime and nighttime ranging respectively.

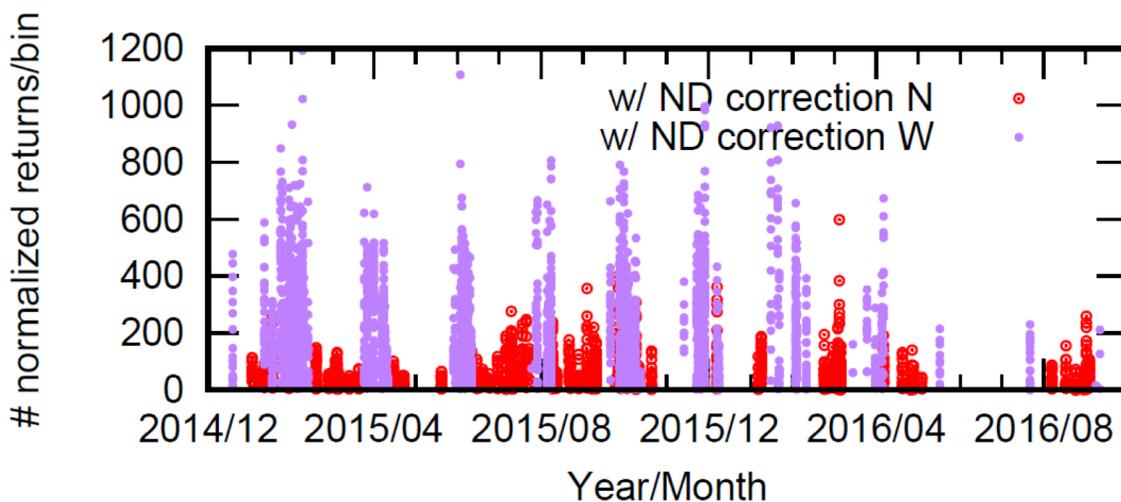


Fig. 2. The normalized intensity (N) from Herstmonceux's SpinSat tracking data. The red and purple points correspond to daytime and nighttime ranging respectively.

of 2) in a short time (5 second) so that multi-photoelectron-suspicious observations are removed. It should be noted that the transmission beam divergence was almost kept constant for SpinSat and Starlette tracking at the Herstmonceux station. Data obtained with a significantly different beam divergence are not used in this study.

The N value represents the intensity level and it should be stable assuming unchanged station operation/configuration and unchanged reflectivity of a satellite.

We first examine the N value of Starlette tracking data, and the time series are shown in Fig. 1. Day/night difference is easily noticeable and it is due to the use of a narrow wavelength filter during daytime. There is also a step-wise improvement in daytime data in July 2015, which is a result of the change of the wavelength filter. Apart from those, we observe no significant change of the N value, and this is used as a baseline for the SpinSat time series.

20-month Time Series of Intensity

Fig. 2 shows the time series of the N value for SpinSat.

We observe that the intensity has kept at the initial level for the first 15-16 months. This fact suggests that the BK7 reflectors in such a low orbit can survive for that period.

However, the intensity has not reached the initial level since the spring of 2016. This may be caused by the degradation of the BK7 reflectors, but we also encountered the difficulty in the tracking observation itself as the orbit altitude gets lower and the orbit prediction becomes poorer. It is getting hard to keep the the satellite around the center of the beam, and the N value would be low if it is hit by the edge of the beam. Also considering the atmospheric transmission variability from day to day, the reason of this intensity drop has not been conclusive.

Let us now examine the cross section for the two satellites. Excluding the exceptionally high (top 2%) N value, the peak N values are approximately 140,000 for Starlette and 750 for SpinSat. The normal-point bin sizes are 30 seconds for Starlette and 5 seconds for SpinSat, and the standard beam divergences are 20 arcseconds for Starlette and 24 arcseconds for SpinSat. Applying these factors, the effective retroreflection cross section of SpinSat is estimated at approximately 4 to 5 % of that of Starlette.

Conclusions and remarks

Using 20 months of SpinSat SLR data from Herstmonceux, the time series of return intensity are monitored. The BK7 retroreflector on SpinSat has survived for 15-16 months, and, after that, the intensity has not been as strong but we cannot reach a conclusive result. The optical cross section of SpinSat is estimated at 4-5 % of that of Starlette.

We would like to collaborate if there are stations in which the return signal intensity can be monitored.

Acknowledgements

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References

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