Required Improvements of Debris Laser Ranging to Support Operational Collision Avoidance

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Introduction

Debris laser ranging is highly interesting for supporting operational collision avoidance as it has the potential to improve the uncertainties on the chaser object orbit, possibly at a significantly lower cost than radar measurements. This is especially the case for small debris objects, where the available orbit is of reduced quality.

With more laser ranging stations building up debris ranging capabilities, operational support for collision avoidance is getting in reach. It is the goal of this study, to investigate the current capabilities and readiness of networking operations for this task.

Method

- Analyse high risk close approaches of ESA satellites since 2009 for the potential of a (hypothetical) debris laser ranging support
- Take into account three existing SLR stations with debris ranging capabilities (Graz, Wettzeell and Yarragadee) and two hypothetical stations (Andørja, Tenerife)
- Start laser ranging four days before the close approach
- Conditions for pass:
  - Elevation > 15˚
  - Range < 3000 km
- Additional conditions for successful acquisition:
  - Station in nautical twilight or darker (sun elevation < -12˚)
  - Satellite illuminated by the sun (twilight condition)
- Weather constraints and station availability not considered
- Only track the chaser, as the target (own satellite) orbit should be known well enough

Single station

With a single station (Graz in this case) about 65 % of the events can't be tracked at all. Of the trackable events about 30 % of the passes can be tracked. If an event can be tracked, it is early enough in almost all cases to support the collision avoidance process.

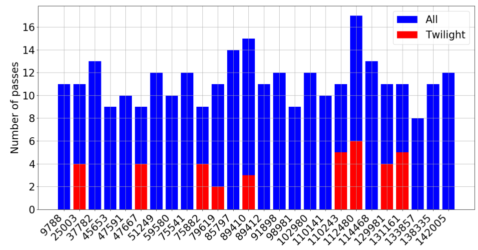

Figure 1: Bar plot showing the share of all passes (blue) of the chaser object per event which can be tracked with debris laser ranging by the Graz SLR station (red). The x-axis lists individual close approach events with their IDs.

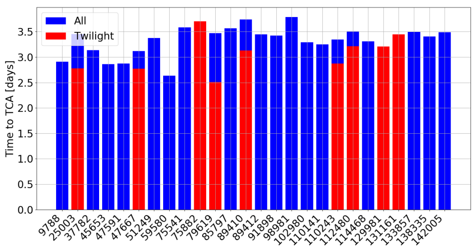

Figure 2: Bar plot showing the earliest pass (blue) and earliest pass with met conditions for debris laser ranging (red). The time is given in days before time of closest approach (TCA). The x-axis lists individual close approach events with their IDs.

All Five Stations

When combining passes of all five stations (Andørja, Graz, Tenerife, Wettzell, Yarragadee), the percentage of trackable events increases, but three events remain untrackable. The percentage of passes fulfilling the acquisition criteria is still low.

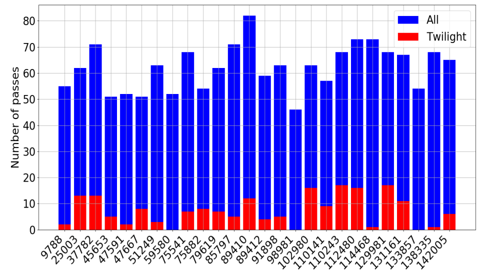

Figure 3: Bar plot showing the share of all passes (blue) of the chaser object per event which can be tracked with debris laser ranging by all five SLR stations combined (red). The x-axis lists individual close approach events with their IDs.

Latitude distribution of events

For collision avoidance it is mainly important to improve the orbit at the location of the close approach. It is thus also interesting to look at the spatial distribution of close approaches. As expected from the orbital debris population, close approaches are more likely to occur near the poles.

As measurements close to the same point on the orbit as the close approach are more valuable for collision avoidance, northern stations are beneficial for close approaches near the north pole and vice versa. There exist a number of northern stations with debris ranging capabilities, but very few southern stations.

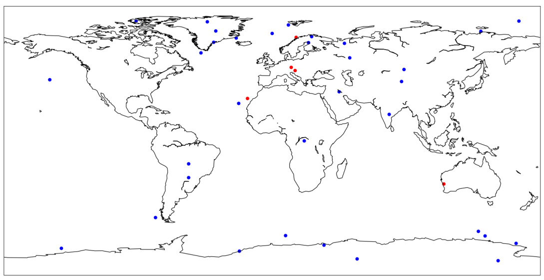

Figure 4: Map showing the positions on ground of studied close approaches (blue) and SLR stations considered in this study (red).

Conclusion

This study shows that the support of debris laser ranging for operational collision avoidance is getting in reach. However, the current acquisition success rate and debris laser ranging station distribution are suboptimal.

The following improvements can help to increase reliability:

- Automatic search with increased search volume could lead to dropping the twilight condition
- Automated collaboration between stations with frequent prediction updates can help other stations with the acquisition
- More debris laser ranging stations in the southern hemisphere