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SMARTnet™ - Status and Statistics

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Abstract

Situation awareness of objects in the geostationary regime is of great interest for collision avoidance by active satellites as well as for scientific research on the space debris population and their evolution over time. As the number of satellite operators and researches in this field is large, it makes sense to set up a sensor network with multiple entities to combine all available sensor measurements for a comprehensive situational picture. This will allow for cost sharing and optimising observation strategies to gain as much information as possible about the desired objects. Therefore, the German Space Operation Center, GSOC, together with the Astronomical Institute of the University of Bern, AIUB, are setting up a global optical sensor network called SMARTnet™: the Small Aperture Robotic Telescope Network. The main objective is the free exchange of all information gathered, mainly in form of tracklet observations, within all partners involved.

In this paper, the operation of the first half year of SMARTnet™ is presented. Results on object correlation, loss of objects of the catalogue, statistics on observable nights as well as accuracy on orbit determination is shown. Furthermore, an outlook on future stations is given. Additionally, the partnering system is introduced including constraints how other entities can join the network and how tracklets are exchanged.

Keywords: (SMARTnet™, collision avoidance, geostationary satellites, space debris)

Acronyms/Abbreviations

AIUB Astronomical Institute of the University of Bern
BACARDI Backbone Catalogue of Relational Debris Information
GSOC German Space Operation Center
CDM Conjunction Data Message
JSpOC Joint Space Operation Center
TIRA Tracking and Imaging Radar
SMARTnet Small Aperture Robotic Telescope Network

1. Introduction

Increasing space debris is a challenge for spacecraft operators. To ensure safe operations of their own satellites, the operators must have knowledge about the orbits of the objects crossing or approaching to avoid any collision. To gain this knowledge, the United States Strategic Command (USSTRATCOM) is using several sensors and sensor systems to surveil Low Earth Orbits (LEO) as well as Geostationary Orbits (GEO). The sensor data is processed to catalogues by the Joint Space Operation Center, JSpOC, and partially published. As an extra service, JSpOC also informs spacecraft operators by sending warnings to the operators in form of Conjunction Data Messages (CDM) in case of a close approach of an object. If receiving such a warning, the operator can analyse the event and, in case of a collision with high probability, decide to perform an avoidance manoeuvre or not. Here, the term "high probability" is interpreted differently by each individual satellite and each satellite mission and is not discussed in this paper. In any case, each avoidance manoeuvre costs mission time, man power, and extra fuel which cannot be used for the mission. Hence, each operator tries to constrain the number of such avoidance manoeuvres.

One of the parameters which go directly into the collision avoidance analysis is the accuracy of the orbit of the primary and secondary object – in most cases the covariance matrix. To get as precise orbit information as possible for the secondary object, it would be of great help to receive additional measurements. This would be feasible for low Earth orbiting objects with e. g. a Radar which is able to track the object. Nevertheless, for small objects in GEO, this is not feasible as the distance to the objects is too large. To gain better warnings in this region require more sensors with certain accuracy and a distribution of such sensors worldwide. Therefore, the German Space Operation Center (GSOC) together with the Astronomical Institute of the University of Bern (AIUB) are planning and setting up multiple telescope stations worldwide to survey the geostationary ring and labelling all objects within a data bank. This survey is not only for collision avoidance but also for better understanding physics of the geostationary regime. Hence, tracking of objects is one task which will be fulfilled by SMARTnet™ while the other task will be collecting as much information as possible.

2. SMARTnet™ Principles

SMARTnet™ consists at present of two telescope stations: Zimmerwald in Switzerland and Sutherland in South Africa. To monitor the complete geostationary regime, these two stations do not suffice. Three telescopes evenly distributed between 20°-40° North or South would allow for observing theoretically all objects. But, due to seasonal variations of the length of the night and due to weather conditions, it is more proficient to set up three telescopes on the northern hemisphere and three on the southern hemisphere. With such a set-up, the averaged observation time will be enhanced to more than 11 hours per night while the Sun is below 12° under the horizon. With these considerations, the minimum number of stations would be six. Of course, it is not necessary to operate all the required stations by AIUB and DLR alone, cooperation – comparable to e. g. the ILRS network – with existing telescopes would alleviate to collect all data necessary. Within this cooperation, data collected by the network will be freely available for every joining partner. This is the main idea behind SMARTnet™: contribute with one or more operational sensors and receive all tracklets produced by all contributors to SMARTnet™ for free. A schematic view of the network can be seen in Fig. 1:

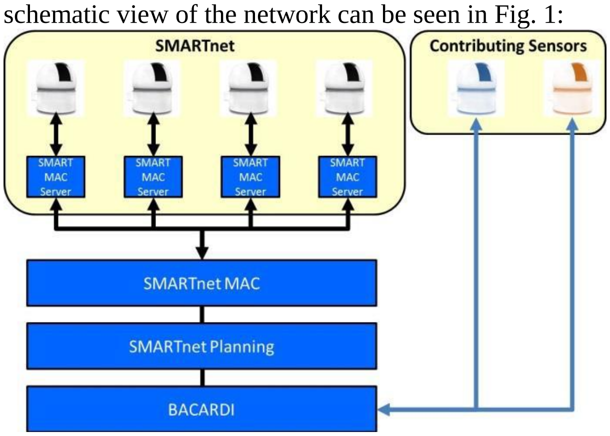

Fig. 1. SMARTnet™ network with internal and external telescope stations.

The planning for SMARTnet™ is performed internally, optimisation algorithms for observations are under development [1, 2]

Of course, some constrains shall be fulfilled to partner in SMARTnet™ like operational generation of tracklets, minimum aperture of the contributing telescope, ITAR-free production within the complete generation chain, no export limitations on tracklets etc. If a partner is accepted after an assessing period of approx. one month, there are different possibilities to contribute to SMARnet™: make own operations and exchange data, get support for planning for own telescopes, or even get operations from SMARTnet™. The exchange of data is set up by a pick-up point at GSOC. Once a partner has complete access to all tracklets, the partner has the right to process all data exchanged, develop own algorithms, sell products with the limitation not selling any tracklets or products which allows for retrieving tracklets by reverse engineering.

At present, two partners are almost in the application phase which will add approx. 4-5 telescopes stations each to SMARTnet™.

3. First Stations: Zimmerwald and Sutherland

Zimmerwald is the first station of SMARTnet™ and is located at the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald, near Bern, Switzerland. It is designed as a fully automated wide field 20cm telescope. The sensor is used every clear night to provide tracklets from uncued survey observations of the GEO.

The second station was set-up during mid-March to mid-April 2017 in Sutherland, cf. Fig. 2. The station is fully automated, consisting of two telescopes. The smaller telescope with an aperture of 20cm serves for fast survey and the larger telescope with an aperture of 50cm for follow-up observations and deep survey. All image raw data is pre-processed at the station to keep transferring data rates as low as possible. Here, pre-processing and on site operations are conducted from computers located in the near-by container (cf. Figure 2, right side). This system is adjusted to operate the station for one week on its own without connection to AIUB or GSOC. Of course, a set-up of a longer period is also possible. After that time, an emergency plan will close the dome, park the telescopes and go to sleep mode until the operators from AIUB or GSOC will wake up the system to normal mode.

Additionally, a graphical user interface running at AIUB and GSOC allows for easy monitoring and controlling the status of the station. Some of the main information displayed is e. g. an error list of the system, dome status (open or closed), weather conditions, UPS status and much more. In case of errors which are not solved by the system, an operator can log into the system remotely from Switzerland or Germany and resolve the error. Safety implementations like boot-on-power-on of the computers are prerequisite for remote operations.

Fig. 2. SMART-01 station near Sutherland, South Africa

4. Processing Chain

The processing is performed by two different systems, one allocated in Bern, the other located in Oberpfaffenhofen. While the system of AIUB is well-established, the system at GSOC still is under development. It is foreseen that the Backbone Catalogue of Relational Debris Information (BACARDI) will handle all processing tasks, such like

- correlating objects and object candidates
- determining orbits
- predicting orbits
- detecting of manoeuvres within ephemeris data
- tracking all meta- and log data (provenance data)
- prediction close approaches between objects and satellites
- predicting long-term evolution and re-entry of objects.

BACARDI will be operated in autonomous mode where the processing tasks are triggered by events. Every time, new data is entering the system, is it checked if it is possible to correlate it to an object within the data base. If this is not the case, it will be tested with all data of the "object candidates" to see if one object candidate fits to the new data. If this is also not possible, it will be placed into the pool of "object candidates".

Some of the other above mentioned algorithms are already operational while other tasks have to be completed. The algorithms foreseen are described in more detail in e.g. [3]. The task of BACARDI, exchanging data within SMARTnet™ and also with partners, is already tested and operational.

For correlating measurements to TLE-objects, 20.712 tracklets between 2016-07-18 and 2016-08-23, mostly from ZimSMART and SMART-01-B-SUTH, are correlated and compared against all TLE published on Space-Track.org within the same time period. 57% of all tracklets from ZimSMART are accepted TLE objects, 71% for SMART-01-B-SUTH respectively. The differences may be explained by different observation strategies and different false detection rates among sensors. For all sensors, 1216 TLE objects have been observed on an average number of 8.6 image series. The results are shown in Figure 3:

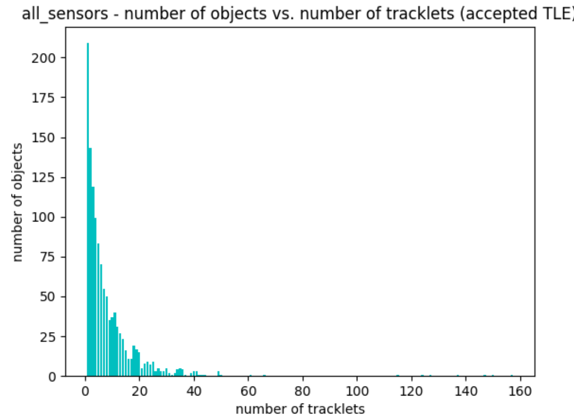

Fig. 3 Results for TLE-tracklet association

5. First Results

The SMARTnet™ sensor in Zimmerwald is producing data on a regular basis. In the first eight months of 2017, tracklets were acquires in 122 observational nights. The sensor yields about 2800 single observations corresponding to about 500 tracklets during a clear winter night. These tracklets are then used to maintain the AIUB-internal catalogue of high-altitude objects. Figure 4 shows the position of 329 objects in the geostationary ring as detected by the Zimmerwald sensor during one night.

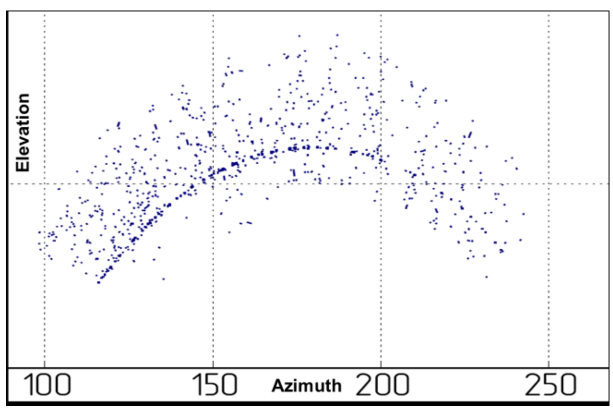

Fig. 4 Result of observations of the sensor in Zimmerwald from one night showing the position of 329 objects in the geostationary ring as seen from Zimmerwald in an azimuth-elevation system

On April 4th, the second station at Sutherland has experienced first light. This second station has started regular observations from end of April. Since then, it produced 30.869 scientific observations with additional 1.320 calibration observations during 73 observational nights, producing 8.030 tracklets consisting of 49.464 measurements. Due to extensive testing and hence non-optimum observation planning, it is expected that the number of measurements and tracklets will rise in the near future.

6. Outlook

The next station of SMARTnet™ will be set-up in Australia beginning 2018. The site is already selected, and the contract in negotiations. For the fourth site, a survey is planned in 2018 in South America, and setting-up is planned in 2018. For partners, SMARTnet™ is open and negotiations are going on.

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