

IAC-18-A6.1

SMARTnet™ - Evolution and Results

Hauke Fiedler
German Aerospace Center, 82234 Wessling, Germany, hauke.fiedler@dlr.de

Johannes Herzog
German Aerospace Center, 82234 Wessling, Germany, johannes.herzog@dlr.de
Andreas Hinze
German Aerospace Center, 82234 Wessling, Germany, andreas.hinze@dlr.de
Marcel Prohaska
Astronomical Institute of the University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland, marcel.prohaska@aiub.unibe.ch
Thomas Schildknecht,
Astronomical Institute of the University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland, thomas.schildknecht@aiub.unibe.ch
Martin Weigel
German Aerospace Center, 82234 Wessling, Germany, martin.weigel@dlr.de

Operation of geostationary satellites and research of the geostationary region depend on both modelling e. g. of the environment and data banks consisting of objects with preferably high accuracy ephemerides and, if possible, completeness of the number of objects in this region. Of course, due to physical reasons, not all objects are detectable, but for now it is assumed that an object size of 30cm or larger is sufficient for the aforementioned topics. It is of international interest to exchange and access this data on a low cost basis. For this reason, SMARTnet™ was started, allowing for interchanging data, especially tracklets, within the community of telescope owners or telescope operators on a no exchange of funds basis. In this context, a tracklet is a series of the angle pair right ascension and declination including the corresponding epoch of the same object.

Over one year ago, SMARTnet™ was opened for international co-operations. The main objective of SMARTnet™ is the exchange of tracklets, allowing for each participating entity to develop own catalogues, own algorithms, and own products. In this paper, the consortium, consisting of the Astronomical Institute of the University of Bern (AIUB) and the German Space Operation Center (GSOC) at DLR, is presenting the current partners of SMARTnet™, statistics of data collected as well as results like e. g. tracklet correlation. Furthermore, an outlook of future contributions is given.

I. SMARTNET™ - THE OBJECTIVE

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, measurements of these objects must be taken by sensors. For Low Earth Orbits, this is normally performed by Radar, Laser tracking or other passive optical measurements, and in high altitudes like e. g. geostationary orbits, this is mostly performed with telescopes. The recorded measurements are then processed into orbits, which are propagated for a certain time span. With these data, it is possible to calculated close approaches of objects to own satellites and, if necessary, perform avoidance manoeuvres if required.

Worldwide, the United States Strategic Command (USSTRATCOM) is the largest operator of such sensor systems. It is surveilling Low Earth Orbits (LEO) as well as Geostationary Orbits (GEO). The sensor data is processed to catalogues, and partially published. As an extra service, USSTRATCOM 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. The operator then has the possibility to decide to take an action. 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 more sensors with certain accuracy and a distribution of such sensors worldwide is desirable.

Therefore, the German Space Operation Center (GSOC) together with the Astronomical Institute of the University of Bern (AIUB) have started SMARTnet™, a worldwide distribution of telescope stations 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 to understand the space environment better.

II. SMARTNET™ STATIONS AND PRINCIPLES

L SMARTnet™ is managed by the consortium consisting of AIUB and DLR. Additionally, Applied Defense Solutions (ADS) has joined SMARTnet™ January 2018. At present, three telescope stations are contributing data to the system: Zimmerwald in Switzerland, operated by AIUB, Sutherland in South Africa, operated by DLR, and Pumpkin in the USA, operated by ADS. A description of the telescope stations of AIUB and DLR may be found in [1].

Fig. 1 Contributing Members of SMARTnet™ October 2018

To monitor the complete geostationary regime, these stations do not suffice. Hence, a two-fold approach is envisaged: first, more telescope stations and sensors are planned by AIUB and DLR, and second, it is aimed to accommodate more existing telescope stations within SMARTnet™, which are already set up and operational.

For the first point, three more telescopes are already deployed at Zimmerwald, which shall be operational and contributing to SMARTnet™ by the end of the year. These new telescopes are called ZimMAIN and ZimTWIN. ZimMAIN (Zimmerwald Multiple Applications Instrument) is an altazimuth 80cm Ritchey-Chrétien telescope (ASA AZ800 [2], CCD camera SI1100, field of view 0.63°x0.63°) mainly for the follow up and characterization of space debris objects. ZimTWIN (Zimmerwald Twin Widefield Instrument) is a parallactic twin optic consisting of two 40cm primary focus astrographs (mount ASA DDM160A [2], optics ASA Deltagraph 16’’ f2.4, CCD camera FLI PL16803, image field 2.2°x2.2°) mainly for search for space debris objects in high altitude orbits.

Furthermore, a telescope station consisting of a 25cm telescope and 50cm telescope is planned to be deployed at the East Coast of Australia beginning 2019. The 25cm telescope is manufactured by Astrosysteme Austria and has a parabolic main mirror with 10” diameter. The CCD camera is located at the Newton focus. The 50cm telescope is manufactured by Planewave and has a prolate ellipsoid main mirror with 20” diameter. Here, the CCD camera is placed at the Dall-Kirkham focus. In both cases, the CCD camera FLI16803 by FingerLakes Instruments is used. Both telescopes are on one mount, namely ASA Direct Drive DDM160 Twin [2]. In this configuration, there is one telescope on each side, which results in a compact design when using two telescopes.

In South Africa, instead of the 25cm telescope there is a 20cm telescope with hyperbolic main mirror. The mount is different, too, as both telescopes are on one side with a counter weight rod on the opposite side. This design has a much higher total weight. Another telescope station in South America is scheduled to be installed by early 2020.

For the second point, such cooperation – comparable to e. g. the ILRS network – with existing telescopes would alleviate to collect all data necessary. This is the main idea behind SMARTnet™: contribute with one or more operational sensors and receive all data produced by all contributors to SMARTnet™ for free. The contributing sensor shall be able to detect objects in space, measure their position by range, range rate, or angles, with an ITAR-free sensor and ITAR-free processing chain. The result of the measurements are so-called tracklets, which are exchanged free of charge within SMARTnet™ via a server located at GSOC.

Once the tracklets are exchanged, each participant of SMARTnet™ is allowed to process all data to products and provide, distribute or sell the products. There is one exception: it is not allowed to provide, distribute, or sell the tracklets to third parties or provide products to third parties which allow for retrieving tracklets by reverse engineering. But, if a participant e. g. wants to create an own catalogue and sell this product, it is not a problem.

If a sensor operator wants to join SMARTnet™, she or he becomes an applicant for a period of approx. one month. During this time, the consortium and the applicant are exchanging data to assess the quality, the accuracy, and the amount of the data. The data received by the applicant is DLR and AIUB data only. If both sides agree and wish to set up a permanent exchange of data, the applicant will become a partner of SMARTnet™. This partnership sustains until summer and winter solstice, where the data of each partner is assessed. In case of a positive assessment, the partnership is extended to the next winter or summer solstice. A description of the assessment procedure may be found in [3].

Of course, there are other possibilities to exit SMARTnet™ e. g. at the discretion of a partner.

III. SMARTNET™ DATA

In this paper, data from SMARTnet™ in the period from January 2018 until August 2018 is presented. First, we want to show the measurement time per month, which is displayed in Fig. 1:

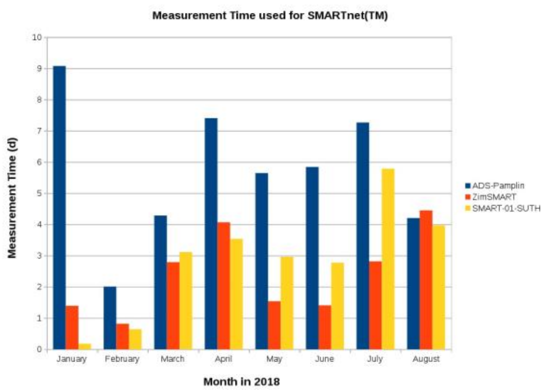

Fig. 1: Measurement times in days for each Telescope Station from January to August 2018.

Please note that ADS consists of up to 8 telescopes operated simultaneously, ZimSMART consists of one telescope, and SMART-01-SUTH consists of 2 telescopes operated sequentially.

Within the above shown measurement times, the following number of measurements had been taken (cf. Fig. 2):

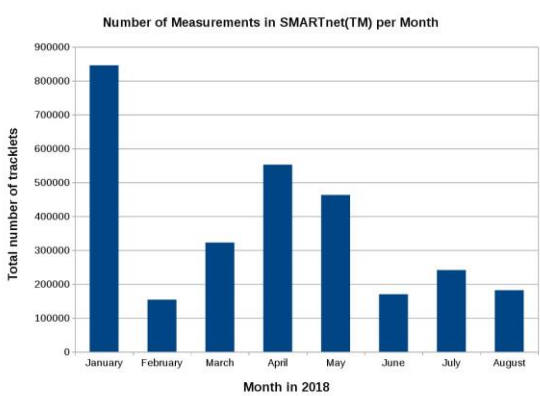

Fig 2: Number of measurements from all contributing sensors.

From these measurements, the following distribution of Tracklets was generated (cd. Fig. 3):

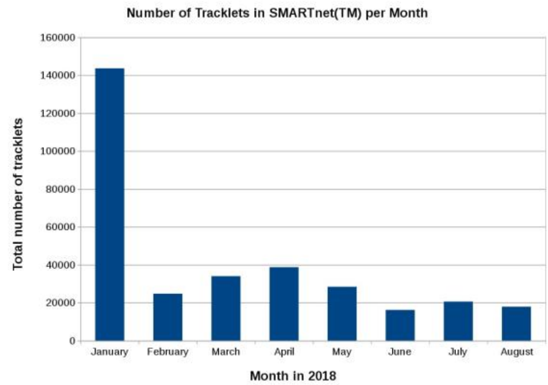

Fig 3: Number of Tracklets in SMARTnet™

It can be seen that both the number of measurements and the number of tracklets is decreasing from January to the following months drastically. This had been turned out to be an error in one of the systems where measurements had been counted as correct. To avoid such errors, filter criteria are applied to the data. The criteria can differ between sensors, filtered data is sorted in a folder called “withheld” while data passing the filter is sorted into the folder “accepted”. Of course, both folders are accessible by all partners.

As an example, data gained with the 20cm telescope located in Zimmerwald is filtered

- to have at least three measurements within one tracklet to avoid identifying false objects by e. g. cosmic ray hits or bad pixel,
- to have a magnitude below 16.5^m as this is the limiting magnitude for this telescope in this environment,
- to show a maximum velocity of 0.3”/s to exclude asteroids and other objects,
- and finally reveal a maximum time gap of 180s between two consecutive measurements: during this time, an object could leave the field of view of this telescope.

With such filter applied, it can be seen that all data which is provided by partners are not deleted or removed, which keeps transparency high, and allows also for e. g. searching for objects in the data base like asteroids. These data should be, if observed, inside the “withheld” folder.

From all measurements, objects with brightness between 0^m and approx. 18.5^m had been detected. The largest telescope in SMARTnet™ right now is located in Sutherland and has an aperture of 50cm. With this instrument in this environment, objects of 18.5^m could be observed, which converts to an objects size of approx. 30-40cm.

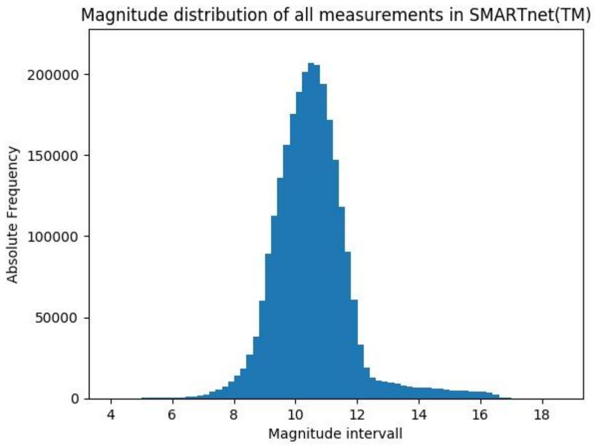

Fig 4: Brightness distribution of all measurements.

Around 70% of all tracklets from ZimSMART telescope could be correlated to objects from the publically available TLE catalogue from Space-Track.org, and around 40% of tracklets from SMART-01-B telescope. The remaining tracklets could be other objects, or also objects which are in the TLE catalogue but with a larger deviation due to uncertain position, time bias estimation, and errors in timestamp correction. The tracklets of ADS telescopes were not processed, since the measurement corrections to be applied have to be confirmed.

IV OUTLOOK

As described before, the next station of SMARTnet™ will be set-up in Australia beginning 2019. The site is already selected, and the contract is signed. For another already financed site located in South America, a survey is planned in 2018, and the deployment of the station is planned for early 2020. For partners, SMARTnet™ is open and several applicants are in negotiation.

Acronyms

ADS Applied Defense Solutions
AIUB Astronomical Institute of the University of Bern
CDM Collision Data Message
GEO geostationary orbit
GSOC German Space Operation Center
ITAR International Traffic in Arms Regulations
LEO Low Earth Orbit
SMARTnet™ Small Aperture Robotic Telescope Network
USSTRATCOM United States Strategic Command

References

[1] Fiedler, Hauke und Herzog, Johannes und Prohaska, Marcel und Schildknecht, Thomas und Weigel, Martin (2017) SMARTnet(TM) - Status and Statistics. In: International Astronautical Congress 2017, IAC 2017. International Astronautical Congress, Adelaide, Australia

[2] ASA Astrosysteme Austria. WebSite at http://www.astrosysteme.com and links therein. Retrieved September 12th, 2018

[3] Weigel, Martin und Fiedler, Hauke und Schildknecht, Thomas (2017) Scoring Sensor Observations to Facilitate the Exchange of Space Surveillance Data. Advances in Space Research, 60 (3), pages 531-542. Elsevier. DOI: 10.1016/j.asr.2017.04.010 ISSN 0273-1177