SMARTnet™ - An Update

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ABSTRACT

Operation of satellites and research of their orbital regions 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. If concentrating on the geostationary regime, it is assumed that a detection size of an object 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 developed, allowing for interchanging data, especially tracklets, within the community of sensor owners or sensor operators on a no exchange of funds basis. The first contributors to SMARTnet™ are operating optical telescopes and produce tracklets. In this context, a tracklet is a series of the angle pair right ascension and declination including the corresponding epoch of a single object. In 2017, 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. Since then, Applied Defense Solutions has joined SMARTnet™ and is the first Partner. A basic statistic of the data available through SMARTnet™ is shown as well as first results with respect to a first data bank of objects, which can be derived from this data.

1 INTRODUCTION

The increasing number of 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 their satellites 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 passive optical measurements, and in high altitudes like e. g. geostationary orbits, this is mostly performed with telescopes. The recorded measurements are then processed to orbits, which are propagated for a certain time span. With these data, it is possible to calculate 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. Nevertheless, the accuracy of the data in the form of e. g. covariance information is not always provided, leaving the calculations in an unknown state.

Therefore, the German Space Operation Center (GSOC) together with the Astronomical Institute of the University of Bern (AIUB) have started SMARTnet™, a worldwide initiative to gather and exchange sensor data of resident space objects. It started with telescope stations distributed 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 can be fulfilled by SMARTnet™ while the other task will be collecting as much information as possible to analyse and understand the space environment better.

2 SMARTNET™ PRICIPLES

SMARTnet™ is managed by the Consortium consisting of AIUB and DLR. Other contributors to SMARTnet™ are called Applicants or Partners, depending on their status. An Applicant is in an application phase where the Consortium and the Applicant are exchanging data to prove mutually quality and quantity. When agreed upon those two, the Applicant becomes a Partner with full access to all data within SMARTnet™. This partnership sustains until summer and winter solstice, where all data of SMARTnet™ is assessed. In case of a

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positive assessment of the Partner, 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.

Applied Defense Solutions (ADS) has joined SMARTnet™ January 2018 as a Partner. 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 Benson in the USA, operated by ADS. A description of the telescope stations of AIUB and DLR may be found in [1].

Figure 1 Contributing Members of SMARTnet™

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 have been deployed at Zimmerwald by end of 2018, which are almost operational and will contribute to SMARTnet™ shortly. 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 mid of 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 a 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 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. All data are exchanged in CCSDS TDM-Format.

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, this is not a problem.

3 SMARTNET™ DATA

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

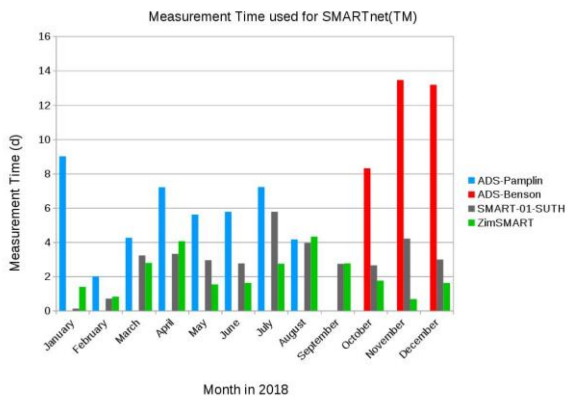

Figure 3 Measurement times in days for each Telescope Station for 2018.

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:

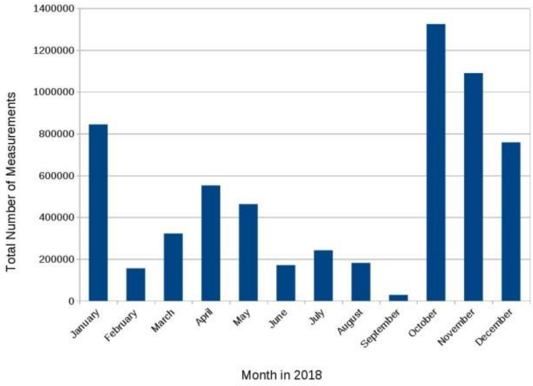

Figure 4 Number of measurements from all contributing sensors.

From these measurements, the following distribution of Tracklets was generated:

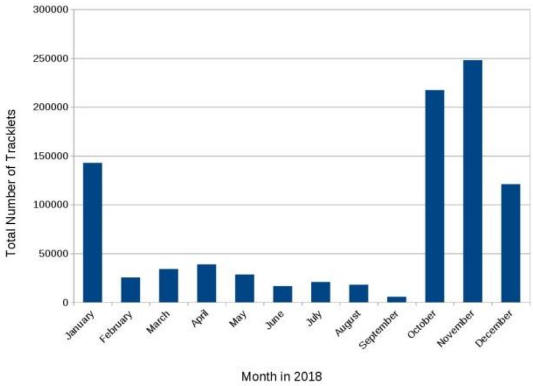

Figure 5 Number of Tracklets in SMARTnet™

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^{mag} as this is the limiting magnitude for this telescope in this environment,
- to show a minimum 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 or Near Earth Objects. These data should be, if observed, inside the “withheld” folder.

From all measurements, objects with brightness between 0^{mag} and approx. 18.5^{mag} 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^{mag} could be observed, which converts to an objects size of approx. 30-40cm. In the near future, even smaller objects might be detected with the new ZimMAIN in Zimmerwald.

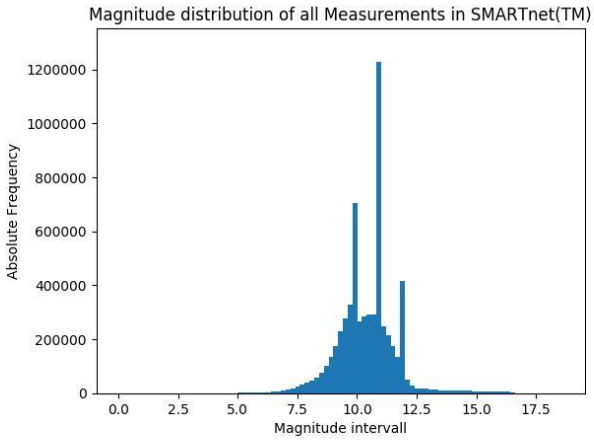

Figure 6 Brightness distribution of all measurements.

4 OUTLOOK

As described before, the next station of SMARTnet™ will be set-up in Australia mid of 2019. The site is already selected, and the contract is signed. For another already financed site located in South America, a survey is planned for 2019, and the deployment of the station is planned for 2020. Right now, a new entity is in its negotiation phase and will contribute with several stations within few years.

For new Partners and Applicants, SMARTnet™ is open and several other Applicants are in negotiation.

5 ACRONYMS

ADS	Applied Defense Solutions
AIUB	Astronomical Institute of the University of Bern
CCSDS	Consultative Committee for Space Data Systems
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

6 REFERENCES

1 Fiedler, Hauke und Herzog, Johannes und Prohaska, Marcel und Schildknecht, Thomas und Weigel, Martin (2017) SMARTnet™ - 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