SMARTnet: A SENSOR FOR MONITORING THE GEOSTATIONARY RING

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Abstract: *As the number of space debris is increasing in the geostationary ring, it becomes mandatory for any satellite operator to avoid any collisions. Space debris in geosynchronous orbits may be observed with optical telescopes. Other than radar, that requires very large dishes and transmission powers for sensing high-altitude objects, optical observations do not depend on active illumination from ground and may be performed with notably smaller apertures. The detection size of an object depends on the aperture of the telescope, sky background and exposure time. With a telescope of 50 cm aperture, objects down to approximately 50 cm may be observed. This size is regarded as a threshold for the identification of hazardous objects and the prevention of potentially catastrophic collisions in geostationary orbits. In collaboration with the Astronomical Institute of the University of Bern (AIUB), the German Space Operations Center (GSOC) is building a small aperture telescope to demonstrate the feasibility of optical surveillance of the geostationary ring. The telescope will be located in the southern hemisphere and complement an existing telescope in the northern hemisphere already operated by AIUB. These two telescopes provide an optimum coverage of European GEO satellites and enable a continuous monitoring independent of seasonal limitations. The telescope will be operated completely automatically. The automated operations should be demonstrated covering the full range of activities including scheduling of observations, telescope and camera control as well as data processing.*

Keywords: *Space Debris, Telescope Network, Geostationary Ring.*

1. General Specifications

1.1. Location

In the process of selecting a possible observation site, several criteria had to be taken into account. To be independent of seasonal limitations like length of the nights, the site should be located on the southern hemisphere. This telescope will complement the existing telescope on the northern hemisphere, ZimSMART, located at the Zimmerwald observatory near Bern (Switzerland). There, complementary conditions prevail: short nights on the northern hemisphere correspond to long nights on the southern hemisphere and vice versa.

At the Zimmerwald observatory, there are located three telescopes, operated by the University of Bern. ZimSMART, a small aperture telescope with a large field of view (FoV), is surveying the geostationary ring since 2008. Details may be found in [1, 2, 3, 4].

As an optimum coverage of European GEO satellites shall be established, the longitude of the observation site must correspond to Central Europe. Only then also observations of satellites covering Eastern and Western Europe are ensured. The observation site, where the telescope is planned to be built up, is near Sutherland (South Africa). There is already located the South African Large Telescope (SALT), operated by the South African Astronomical Observatory (SAAO), and infrastructure is well-established, too. Coordinates of both, the Zimmerwald observatory and Sutherland may be found in Tab. 1.

Table 1: Co-ordinates of the selected observation sites

	Geographic co-ordinates		Co-ordinates in Earth-centered, Earth-fixed reference frame (ECEF), WGS84	
Zimmerwald	$\lambda =$	$7.465°$	$X =$	$4\,331\,300\,\mathrm{m}$
	$\varphi =$	$46.877°$	$Y =$	$567\,600\,\mathrm{m}$
	$h =$	$970\,\mathrm{m}$	$Z =$	$4\,633\,100\,\mathrm{m}$
Sutherland	$\lambda =$	$20.813°$	$X =$	$5\,041\,500\,\mathrm{m}$
	$\varphi =$	$-32.937°$	$Y =$	$1\,916\,400\,\mathrm{m}$
	$h =$	$1700\,\mathrm{m}$	$Z =$	$-3\,396\,400\,\mathrm{m}$

Figure 1 shows the distribution of objects in the publicly available USSTRATCOM TLE catalogue. The objects were selected to move on geosynchronous orbits, with a semi-major axis between 35 000 km and 45 000 km, and an eccentricity between 0 and 0.1. The blue lines represent the station visibility at a minimum elevation of 20° at Zimmerwald and Sutherland, respectively, above which geosynchronous objects may be observed. Figure 1 also shown that a large area of the geostationary ring is covered by both telescopes. Nonetheless, due to a location closer to the Equator and more to the East than the Zimmerwald observatory, also a larger fraction of satellites above the Indian Ocean will be observed by a telescope in South Africa.

Figure 2 shows the begin and end of the nautical twilight in thick coloured lines, where blue represents Zimmerwald and green Sutherland. Additionally the dashed lines are the length of night. The thick black line represents the length of the combined observation time for any object, i. e. the duration between the earliest evening twilight and the latest morning twilight. Most of the year this length is equal to the length of the night of one single site. In a period in spring and autumn, respectively, the length of the combined observation time is longer, because the morning twilight starts later in Zimmerwald than in Sutherland although the evening twilight ended earlier in Sutherland. Assuming perfect observation conditions throughout the year, the average observation time at the Zimmerwald observatory is about 9.3 h, and in Sutherland about 10.0 h. With both sites combined, one achieves an average length of observation time for any visible object in the geostationary ring of about 11.6 h, with a minimum of about 10.4 h.

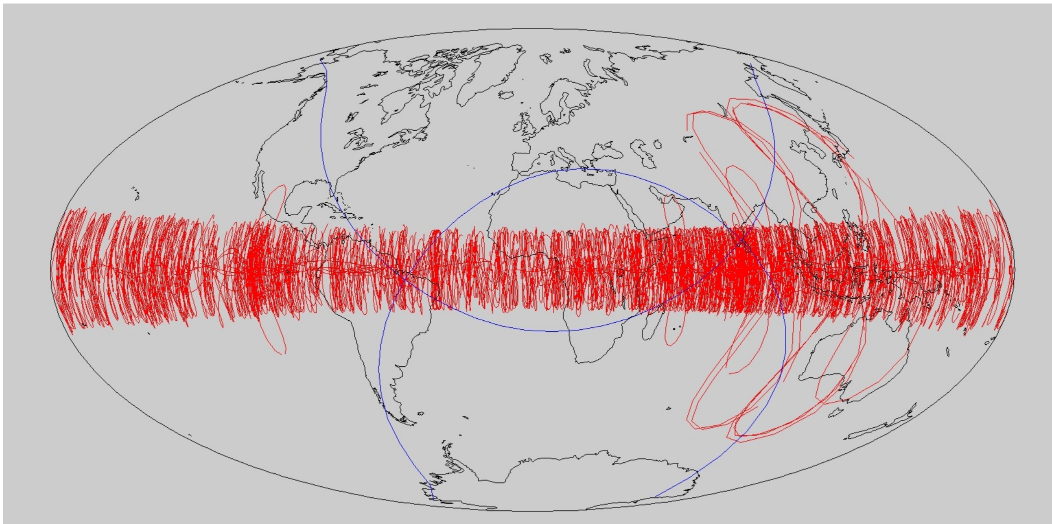

Figure 1: Distribution and ground-tracks of objects on geosynchronous orbits in the publicly available USSTRATCOM TLE catalogue on March 24th, 2014.

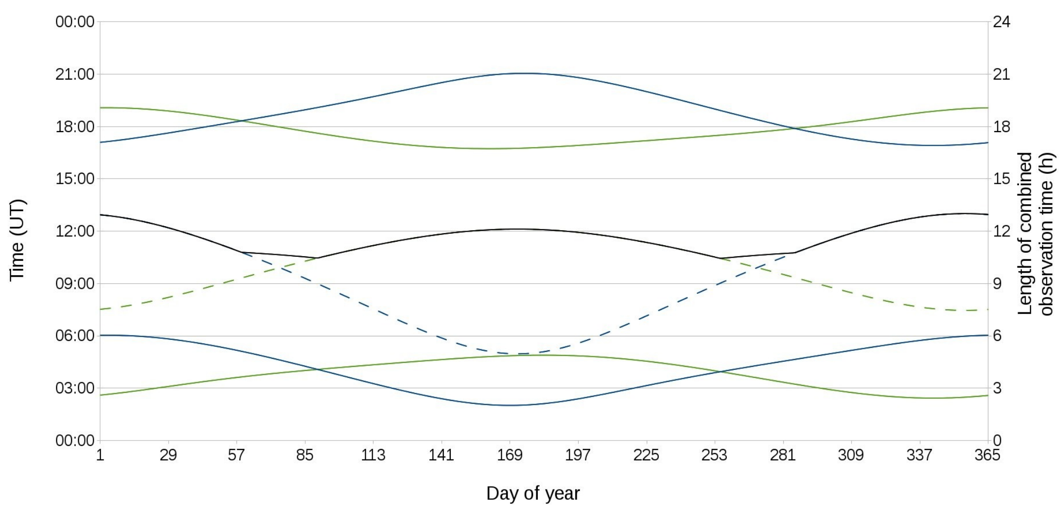

Figure 2: Begin and end of nautical twilight for Zimmerwald (blue) and Sutherland (green). The black line gives the combined length of observation time for both sites.

1.2. Telescope Equipment

Major task of the telescope will be optical surveillance of the geostationary ring, especially covering European GEO satellites. Building up a global telescope network is a proposed option at GSOC. To avoid custom products if possible, commercially available components and their spare parts shall be used.

Two telescopes with different aperture sizes will be installed on the same mount. One telescope has a primary mirror with a diameter of 20 cm and a focal length of 500 mm, resulting in a FoV of about $2^\circ \times 2^\circ$. The second telescope has a diameter of the primary mirror of 50 cm and a focal length of 3000 mm. The resulting FoV is about $42' \times 42'$.

The chosen camera is a CCD camera with a dimension of 4096×4096 pixels, where each pixel has a size of 9 µm. The peak quantum efficiency of the chip is about 60 %.

Telescope control, image processing and extraction of astrometric positions will be performed with software developed by AIUB and will be validated at the existing ZimSMART telescope.

2. Main Purposes

First of all, the selected telescopes are meant to be demonstrator telescopes to test and validate strategies and processes. This needs developing observation strategies and adapting them to the given tasks. In brief, they are discussed in the following sections.

2.1. Observation Strategies

The selected aperture sizes make it possible to perform and optimise two different tasks: on one hand surveying the visible part of the geostationary ring, and on the other hand performing follow-up observations of specific objects of interest.

The 20 cm-telescope will be used to obtain survey observations on a routine basis. The visible part of the geostationary ring is scanned to achieve a complete coverage within a few nights. These observations are used to update orbits and to perform collision risk analyses.

If updated orbits and results require further investigation of some objects, they will be performed with the 50 cm-telescope. Objects are observed more often within one night to improve their orbits. Especially in the scope of collision avoidance analyses for certain satellites, observations of targets with close encounters and more precise orbits will be needed.

The observations of both telescopes will be triggered by previous observations: the 20 cm survey telescope observes surveys field which might have been skipped the preceding night. Additionally, it may be used to perform observations of objects whose orbit have high uncertainties and which requires a larger FoV to secure detection. The 50 cm follow-up telescope also focuses on newly detected objects with good orbits from the preceding night, which are candidates for upcoming close encounters. Also depending on the dinstance to the time of closest approach, individual satellites and objects will be observed more often than others in certain nights.

2.2. Object Monitoring and Collision Risk Analyses

For internal uses, a list of objects is maintained which have close encounters with observed European GEO satellites, including the SATCOMBw-satellites. All objects, including these satellites, will be observed regularly to maintain their orbits. With these orbits updated collision avoidance analyses are performed. Details on the topic of collision avoidance analysis at DLR may be found in [5].

Furthermore, when globally positioned sites are included into the network, observations must be exchanged to obtain recently updated and most accurate results. This is crucial for inclined and drifting objects (“drifters”), which cross the orbits of operational satellite. The range of geographic longitudes of the geostationary ring visible from Zimmerwald is about 92.5°, assuming a minimum elevation of 20°, which means that drifters are only observable for about one fourth of their drifting period. For example, a semi-major axis of an orbit of about 41 500 km leads to a mean longitude drift rate (see [6] for the definition) of about $8.5^\circ\,\mathrm{d}^{-1}$ and that object would only be observable for 11 days.

From Sutherland, about 111.8° of the geostationary ring is visible, assuming again a minimum elevation of 20°. With both stations combined, the total visible range of geographic longitudes is about 115.5°. The aforementioned object is then observable for approximately 13.5 d from at least one station. Therefore, when observations are scheduled for a globally distributed telescope network, drifters are observed more frequently.

The planning of the observations, the tracklet linking, and the orbit determination and propagation are subject of ongoing research at DLR. Preliminary results thereof may be found in [7, 8].

3. Conclusions and Outlook

In this paper an optical sensor network is presented, which will monitor objects in the geostationary ring and on geosynchronous orbits in general. Two observation sites are discussed, one site is located on the northern hemisphere in Zimmerwald (Switzerland), while the second is located on the southern hemisphere in Sutherland (South Africa). At each site, a double telescope consisting of a 20 cm survey telescope and a 50 cm follow-up telescope, respectively, will be installed. These two sites will cover the European GEO satellites, independent of seasonal limitations.

Observations, performed with the telescopes on both sites, are not only used to maintain orbits of the aforementioned satellites, but also to monitor other objects, which might have close encounters with these satellites. Collision avoidance analyses will base on these observations.

Future work will connect planning, acquisition and processing of the observations together with the following analyses on a routine and automated basis.

4. References

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