# Poznań SST telescope

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A project of building a cluster of optical telescopes dedicated to satellite and space debris tracking has been recently started in the Astronomical Observatory of Adam Mickiewicz University in Poznań. The instrument will be composed of 5 independent OTAs (optical tube assembly) ranging from 0.2 to 0.7 m and will allow to collect hundred thousands of astrometric positions of Earth-orbiting targets per night. Fully robotic operation of the new telescope will include automatic decision making, based on changing weather conditions and observing alerts received, as well as automatic detection and identification of new objects with on-line re-scheduling of one of the telescopes for the follow up of new detections. Initial simulations show that it should be possible, weather permitting, to regularly update up to 4000 orbits of Earth-orbiting objects every night.

## 1 Introduction

There are currently over 20,000 Earth-orbiting objects of sizes equal to 10 cm or larger. Most of them are uncontrollable space debris, such as not functioning satellites, rocket bodies or fragments produced during explosions and collisions. Because of complicated and time varying forces acting on these objects, their orbits change relatively fast and, as a result, their positions are difficult to predict with satisfactory accuracy. For example, American SOCRATES (Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space) system (Kelso & Alfano, 2005) is using USSTRATCOM TLE (United States STRATegic COMmand Two Line Elements) catalog to predict close encounters and estimate the collision threats. Their typical reports predict about 250 encounters below 1 km threshold every week, but the accuracy of these predictions is rarely better than a few hundred meters and quickly deteriorates with time. Therefore, it is necessary to monitor all threatening objects regularly to update their orbital parameters at a frequency of roughly once per day. Construction of the european system of sensors monitoring near-Earth space has been recently the aim of European Space Agency and European Comission.

## 2 The optical satellite sensors

Regular observations of the artificial Earth satellites are carried out using primarily radar and optical techniques. Radar sensors are used for Low Earth Orbit (LEO) targets and higher orbits are mainly monitored by optical telescopes. Since LEO objects are the most numerous, radars are considered the primary tools for orbital catalog maintenance. Recent advancements made in optical telescopes and detectors allow to observe LEO objects with optical sensors much more efficiently and accurately than ever before (Herzog et al., 2013). Such targets have very high proper

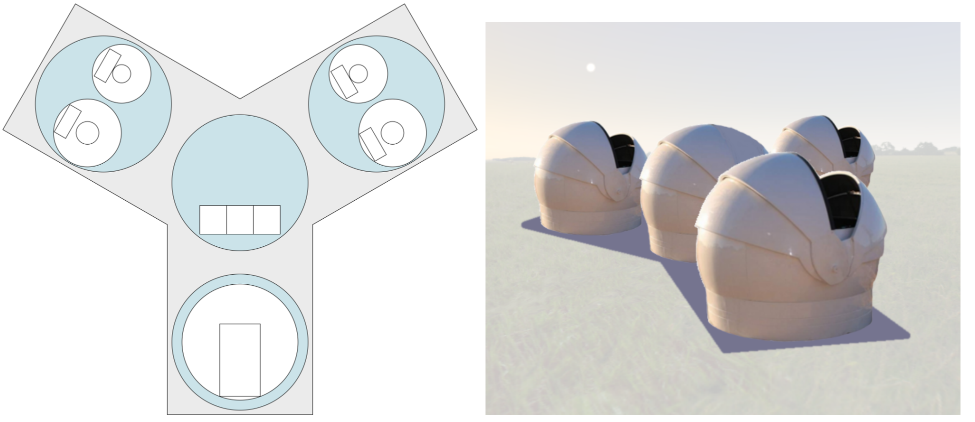

Fig. 1: Schematic layout and visualisation of the planned new telescope cluster. The central dome will contain all the electronics and computers necessary to analyse observations in real time.

motions, up to $2^{\circ}\mathrm{s}^{-1}$, and therefore require very short exposure times (from fractions to several s), very low readout noise (of the order of $1e^{-}$) and very accurate image timing (up to 0.1 ms). This has become possible thanks to a new type of cameras, such as electron multiplying CCDs, or new advancements in the CMOS (complementary metal–oxide–semiconductor) technology.

## 3 Poznań SST telescope

The new optical SST (Space Surveillance and Tracking) sensor project began in 2017, funded by the Polish Ministry of Science and Higher Education. The instrument will be composed of one 0.7 m telescope, two 0.3 m telescopes and two 0.2 m telescopes (Fig. 1). Such a cluster of sensors has been selected to allow observations in both survey and tracking mode.

Using satellite TLE catalog we performed simulations to estimate the performace of the future sensors. We assumed that only satellites above 30° altitude and outside the Earth's shadow will be observed. We have also taken into account the manufacturer's data regarding the direct-drive mount's performance and assumed 0.5 s exposure time. According to the test observations with our 0.7 m Poznań Spectroscopic Telescope 2 in Winer Observatory (Arizona), such exposure time should be sufficient for most targets even with apertures as small as 0.2 m (Figs. 2 and 3). The results of our simulations show that it should be possible to collect several hundred thousands of astrometric measurements for about 2,500 different objects during a single clear night when using all telescopes in the cluster. Depending on the details of selected observing strategy, this number can be either lower, or significantly higner, up to about 4,000 targets. Considering that the average number of satellites observable from a single location during one night is of the order of 10,000, it is clear that the new sensor should allow to observe a significant fraction of that number, which is unprecedented for the optical technique. Our simulations of the survey mode show that a few hundred of detections of both known and unknown objects should be possible when focusing on this type of observations. The new telescope

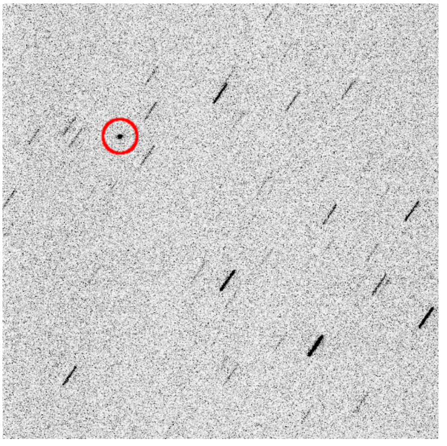

Fig. 2: The image of a 10 cm POPACS satellite (in red circle) taken in 2016 with a 0.7 m telescope using 0.05 s exposure time. The satellite was tracked by the telescope, and therefore star images are trailed.

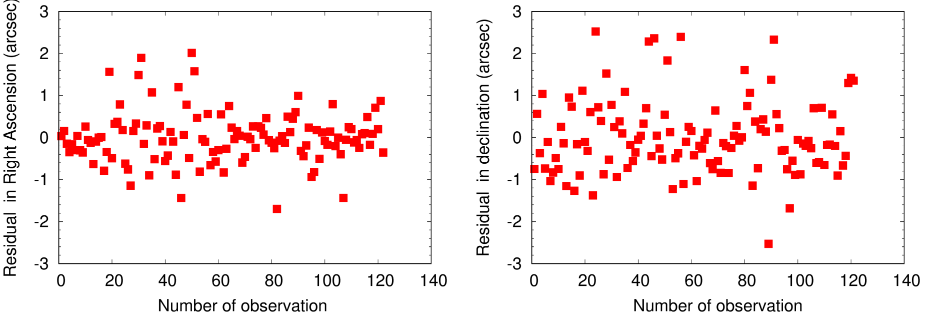


Fig. 3: POPACS satellite RA position residuals (RMS= $0.6''$) are presented in left panel, while Dec position residuals (RMS= $0.9''$) – in right panel. Orbital calculations were made with GEODYN II.

will be capable of combining tracking and survey observations simultaneously and its control software will automatically identify all detected objects and re-schedule one or more telescopes to follow the newly detected targets in order to determine their orbits with maximum achievable accuracy.

## References

Herzog, J., et al., in 6th European Conference on Space Debris, *ESA Special Publication*, volume 723, 139 (2013)

Kelso, T. S., Alfano, S., in D. Danesy (ed.) 4th European Conference on Space Debris, *ESA Special Publication*, volume 587, 737 (2005)