ESA OPTICAL SURVEYS TO CHARACTERIZE RECENT FRAGMENTATION EVENTS IN GEO AND HEO

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ABSTRACT

Two major fragmentation events in GEO and HEO were observed in 2018. Based on measurements of the International Scientific Optical Network (ISON) and the Roscosmos Automated Warning System on Hazardous Situations in Outer Space (ASPOS OKP) a fragmentation of the Titan 3C Transtage 1969-013B, SSN #3692 on February 28, 2018 was identified. More than 150 objects detected by optical instruments operated by ASPOS OKP, the Astronomical Scientific Center, ISON, ISTP RAS and other Russian scientific and research organizations could be clearly identified as fragmentation debris related to this event. Another massive fragmentation event in HEO related to the Atlas Centaur upper stage 2014-055B, SSN #40209, which occurred on August 30, was identified based on the same data sources. Many of the fragment of this event are crossing the operational GEO region.

ESA performed a coordinated survey campaign in October 2018 using its 1-m telescope at the OGS, Tenerife, complemented by sensors of the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald, Switzerland. The paper will describe the development of the survey strategy to search for additional fragments of the two mentioned events, the execution of the actual observation campaign including the handover of newly discovered objects to other sensors and the subsequent follow-up observations, and the main results of and lessons learned from this campaign.

1 INTRODUCTION

ESA has a long-standing program to perform optical observations to detect and characterize space debris. The main objectives of this program are to:

- maintain and validate space debris environment models, in particular ESA's Meteoroid and Space Debris Terrestrial Environment Reference (MASTER) model [1],
- support spacecraft contingencies,
- to provide independent tracking and orbit improvement for conjunction assessment,
- support tracking during re-entry of risk object.

The Astronomical Institute of the University of Bern (AIUB) is executing this program on behalf of ESA by regularly conducting survey observations with ESA's 1m telescope at the OGS in Tenerife, Spain, by performing follow-up observation to establish 6-parameter orbits of debris objects, and by dedicated tracking campaigns to improve the orbits for different purposes including the estimation of area-to-mass rations. The latter two task are supported by observations from sensors of the Swiss Optical Ground Station and Geodynamics Observatory (SwissOGS) (see Figure 1).

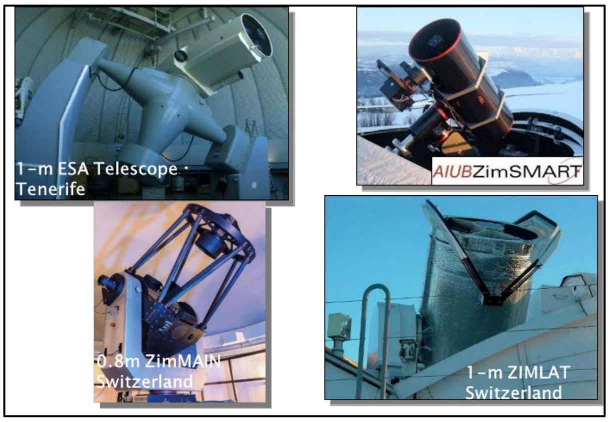

Figure 1: Sensors used in ESA/AIUB space debris observation campaigns. Clockwise from top left: ESA 1m telescope at the OGS in Tenerife, 0.2m ZimSMART telescope, 1m ZIMLAT telescope, and 0.8m ZimMAIN. The latter three are located at the SwissOGS.

A typical result of statistical observations used to validate the MASTER model are provide in Figure 1 and Figure 2.

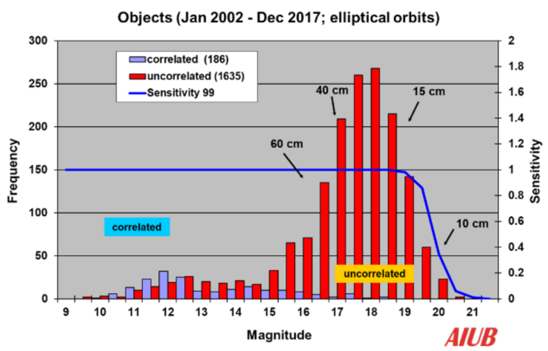

Figure 2: Magnitude Histogram of objects discovered

during ESA statistical surveys of the GEO region (correlation was performed with the DISCOS TLE catalogue).

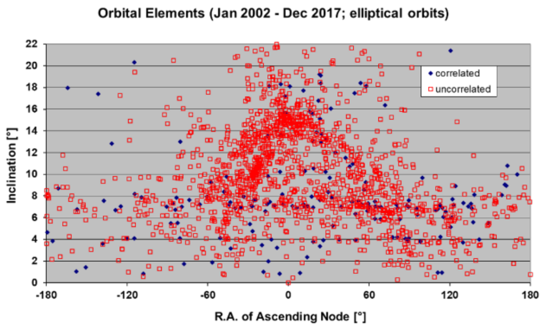

Figure 3: Orbital planes of objects discovered during ESA statistical surveys of the GEO region (correlation was performed with the DISCOS TLE catalogue).

The AIUB has long-standing scientific collaborations with the International Scientific Optical Network (ISON) operated by the Keldysh Institute of Applied Mathematics, Moscow and the Astronomical Scientific Center and is regularly sharing observation data with them. Russian colleagues timely informed AIUB/ESA after the following two events:

- a fragmentation of the Titan 3C Transtage 1969-013B, SSN #3692 on February 28, 2018, and
- a massive fragmentation event in HEO related to the Atlas Centaur upper stage 2014-055B, SSN #40209, which occurred on August 30.

The events were identified in the data collected by optical sensors operated by ASPOS OKP [2], the Astronomical Scientific Center, ISON, ISTP RAS and other Russian scientific and research organizations. By the end of September, there were more than 150 fragments with well determined orbits from the Transtage breakup recorded. 65% of these objects are crossing the protected GEO region. At this time almost 500 fragments from the Centaur upper stage were tracked by the Russian sensors, which corresponds to an 25% increase of the population of objects tracked in this orbital region.

ESA decided to perform a dedicated campaign to search for fragments of these two breakup events and dedicated 13 observation nights of the OGS telescope in October for this purpose.

2 PREPARATION OF OBSERVATION CAMPAIGN

The observation campaign was planned to consist primarily of survey observations at the OGS telescope combined with real-time follow-up observations with the same sensor and complemented by additional follow-up measurements using the 1m ZIMLAT telescope at the SwissOGS. The survey fields were selected in a way to maximize the number of fragment orbital planes covered by the fields, and the tracking parameters were optimize the match the expected angular velocities of the objects (for details of the survey technique see [3]). The baseline for this selection were sets of orbital elements of fragments from both events provided by Vladimir Agapov.

Figure 3 shows the geocentric apparent ephereides of 252 fragments of the Centaur upper stage breakup event. The pinch-point visible from the OGS is located at RA=20h48m / DE=-21°48', only 26° away from the perigee (20181001). The apparent velocities in right ascension of 252 fragments of the Centaur upper stage breakup event, defining the optimum tracking during the survey, are given in Figure 4. The red circle at about 15 arcseconds per second motion in RA indicates the search field position.

The selection of the survey fields for the fragments of the Transtage event was done by optimizing the coverage of the orbital poles of the fragment orbits by the survey field. Figure 5 shows a polar plot (RA/DEC) of debris orbits and the search field (03:45.0/+05:00) for the Transtage fragment survey (the field is covering all poles within the stripe indicated in the figure). The Transtage fragment cloud is indicated by the red ellipse.

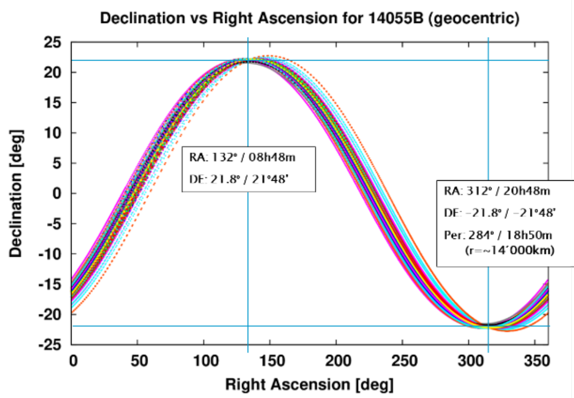

Figure 4: Geocentric apparent ephemerides of 252 fragments of the Centaur upper stage breakup event.

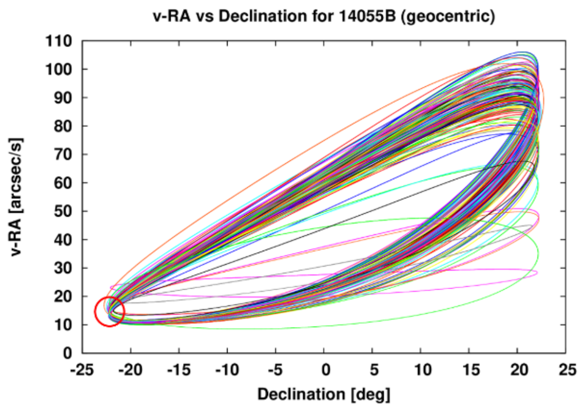

Figure 5: Apparent velocities in right ascension of 252 fragments of the Centaur upper stage breakup event. The red circle indicates the search field position.

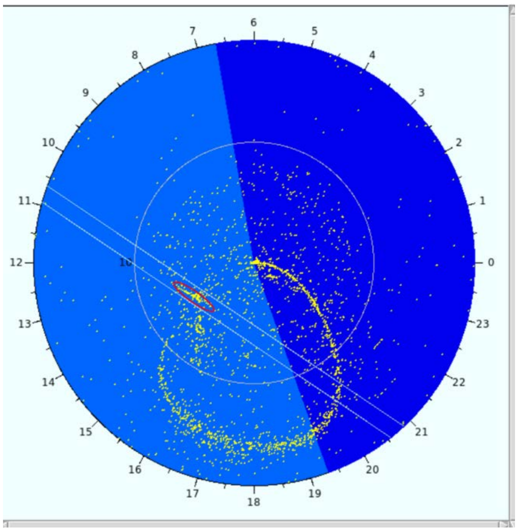

Figure 6: Polar plot (RA/DEC) of debris orbits and search field (03:45.0/+05:00) for the Transtage fragment survey (the field is covering all poles within the stripe indicated in the figure). The Transtage fragment cloud is indicated by the red ellipse.

3 OBSERVATION RESULTS

Out of the 13 planned observation nights one was completely clouded and 4 resulted in less than 4 hours of observations due to bad weather conditions (Figure 6).

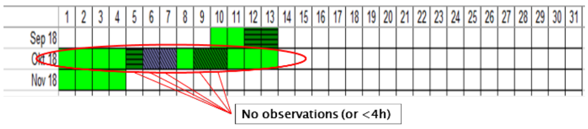

Figure 7: Fragment survey observation nights (red ellipse).

The actual survey observations are performed in batches of 15 minutes, i.e. an uninterrupted series of observations of the same survey field is acquired during 15 minutes. These batches are then automatically processed immediately afterwards, and the newly detected objects are presented to the observer. The latter then decides for which of these object a follow-up observation shall be initiated. Each follow-up observation takes about 5 minutes of observation time. For "new" objects that could not be correlated with any known fragments at least two follow-up observation series were attempted. By the end of the observation night all observation data are transferred to AIUB for further analysis during the following day. This post processing includes the build-up and maintenance of the orbit catalogue of newly detected (and known) objects. Based on this catalogue, objects requiring immediate follow-up observations are then identified and corresponding observations scheduled for the next night for the OGS telescope and the SwissOGS sensors.

The campaign resulted in 159 tracklets of "new" objects, i.e. tracklets that could not be correlated with orbits of known objects. All of these tracklets consist of two observations only. This is characteristic for tracklets stemming from survey observations of the OGS telescope and due to the small field of view of the sensor. For most of the discovery tracklets real-time follow-up observations were attempted. These observations are planned based on circular orbits determined from the discovery tracklets (which corresponds mostly to a linear extrapolation of the apparent motion of the object) and the first follow-up executed about 15 minutes after discovery.

Only 9 "new" objects could be final extracted from the data, where two of them could be associated with the Transtage fragment cloud.

4 SUMMARY AND CONCLUSIONS

AIUB performs regular optical survey campaigns on behalf of ESA at the ESA OGS to provide statistical data to validate space debris population models, and to maintain a catalogue of high A/m-ratio objects.

During 2018 two major breakup-events occurred in GEO and HEO. On February 28 a Titan 3C Transtage (1969-013B, SSN #3692) in GEO fragmented resulting in more than 150 debris pieces tracked by optical sensors operated by various Russian scientific and research organizations. The second event was a breakup of an Atlas V Centaur upper stage (2014-055B, SSN #40209) in HEO with more than 500 fragments tracked by the Russian sensors. ESA performed a dedicated survey campaign to search for fragments of these two events using 13 nights of the ESA OGS telescope supported by sensors of the SwissOGS. A total of 159 tracklets which did not correlated with any known objects were collected. From these tracklets 9 "new" objects were identified, among them two which seem to be associated with the Transtage fragmentation event.

This campaign also allowed identifying as series of shortcomings of the current procedures and software tools used for the observation planning, the data acquisition, and the processing of the observations. In particular, the real-time follow-up observations at the OGS are currently performed in a semi-automated way and require a large part of the available observation time. A hand-over of new objects to the sensors of the SwissOGS would be an alternative. Similarly, the post processing and the data exchange with the Russian colleagues need to be further automatized.

ACKNOWLEDGEMENTS

The authors would like to thank Vladimir Agapov for providing orbits of fragments and for correlating the tracklets with his orbit catalogue.

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