A Search for Debris from Two Titan 3C Transtage Breakups at GEO with a 6.5-m Magellan Telescope

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ABSTRACT

There are two confirmed breakups of Titan 3C Transtage rocket bodies at GEO. The first was the breakup of 1968-081E (SSN03432) in 1992, resulting in a number of tracked objects in the public catalog. The second was 1969-013B (SSN03692) in 2014, which to date has no objects in the public catalog. The 6.5-m Magellan telescope, 'Walter Baade', at the Las Campanas Observatory in Chile has been used in an optical search for faint debris from these two breakups. All observations were rate tracked at the expected rate of debris. For 1968-081E, rates were generated using artificial TLEs using a range of mean anomalies from an average TLE for known objects from this breakup. For the search for 1969-013B, rates were generated from a simulated debris cloud produced using the NASA Standard Satellite Breakup Model. Based on the observed angular rates of detected objects, no objects brighter than 20th magnitude (approximately 10 cm) could be associated with the 1968-081E breakup, while one object brighter than 20th magnitude could be associated with 1969-013B.

1. INTRODUCTION

The Titan 3C Transtage was used in the late 1960's and early 1970's for placing objects into geosynchronous orbit (GEO). There are over a dozen in the public catalog. After the payload was deployed, the Transtage was left in the GEO regime. These are some of the oldest GEO objects in the catalog.

Two of these Transtages are known to have been in debris generating events. The first was the fragmentation of 1968-081E (SSN 03432) in 1992, some 24 years after the object was launched. To date, over 20 objects classified as debris are associated with this parent object. It is not known whether all these objects are due to the 1992 event.

The second event involved 1969-013B (SSN 03692) in June 2014. To date, no objects associated with this event have been added to the public catalog.

In this study we report on a search for optically faint debris (R ~ 20th magnitude, or smaller than 10 cm assuming an albedo of 0.2) associated with both of these events. This size is representative of a 1U CubeSat or a small smartphone.

2. OBSERVATIONS

The purpose of this study was search as faint as possible for objects at GEO associated with both of these events. We used the IMACS f/2 camera on the 6.5-m Magellan Telescope 'Walter Baade' at the Las Campanas Observatory in Chile. This camera has a mosaic of 8 CCDs with a field of view of 0.5 degrees in diameter. Pixels were binned 2x2 for an effective pixel size of 0.4 arc-seconds. To reach very faint limiting magnitudes in standard astronomical observations one would normally use long exposure times of 100 seconds or longer. But when observing GEO objects, the limitation is the confusion caused by background star streaks. Short exposure times are therefore necessary on a large telescope. We used 5-second exposures for all these observations. An example of an IMACS frame is in Fig. 1.

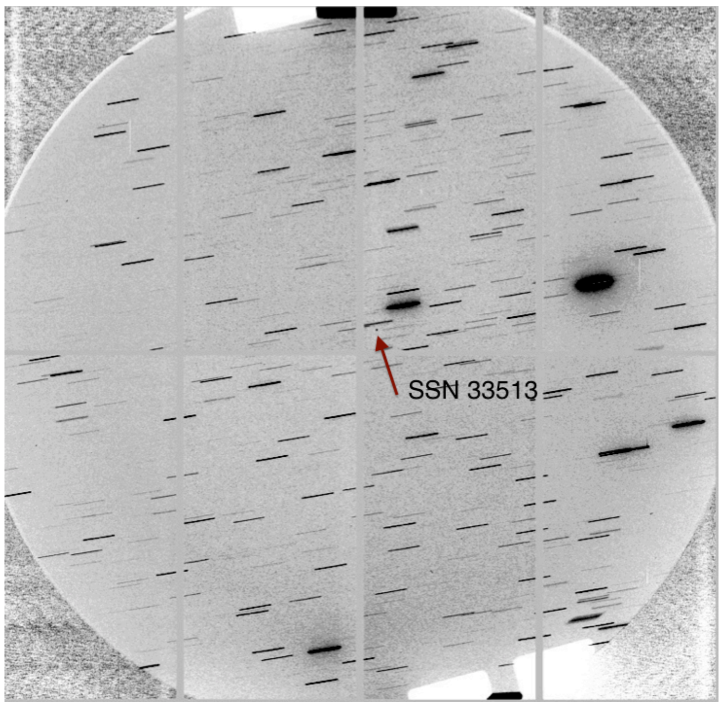

Fig. 1. Sample image from 6.5-m Magellan IMACS f/2 camera. This is a rate-tracked 5-second exposure centered on a piece of debris from 1968-081E: SSN 33513.

The observations of debris from 1968-081E were conducted through a Sloan r' filter. This produced a signal-to-noise (S/N) of 10 for a single 5-second exposure for a tracked object at R ~ 20th magnitude. The 1969-013B observations were done through a broad filter with half power points at 480nm and 780nm.

To avoid streak loses, all observations reported here were done at the expected median rates of the debris distribution. This maximizes the S/N of a detection against a noisy background, since the signal is concentrated in as few pixels as possible.

A typical observing sequence was of 16 or 30 images obtained sequentially all while rate-tracking at the expected rate of the debris.

3. SELECTION OF RATES

The key here is to select the position to initially point the telescope to, and the non-sidereal rates that the telescope should track at to match the expected rates of debris. Positions are chosen as described below, with the additional constraint that the fields are as close as possible to the anti-solar point to minimize the topocentric solar phase angle and yet not be in Earth shadow (eclipse).

For observations of possible 1968-081E debris, we note that all cataloged pieces of debris are closely packed in the RAAN (Right Ascension of the Ascending Node) versus Inclination plane, as would be expected for low area-to-mass ratio objects on low eccentricity orbits (Fig. 2.).

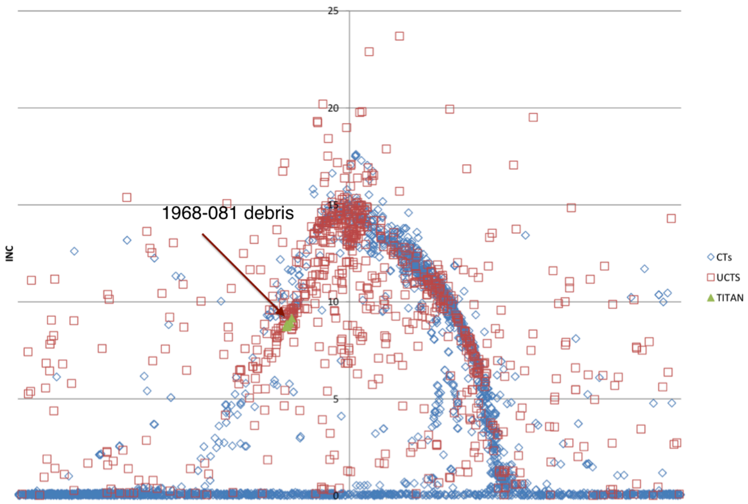

Fig. 2. Plot of Right Ascension of the Ascending Node (RAAN) versus Inclination for sample of GEO objects on low eccentricity orbits. Debris from 1968-081 is tightly clustered.

In observable coordinates on the sky, this results in a 'string of pearls' of cataloged debris and the parent object (1968-081E) as shown in Fig. 3.

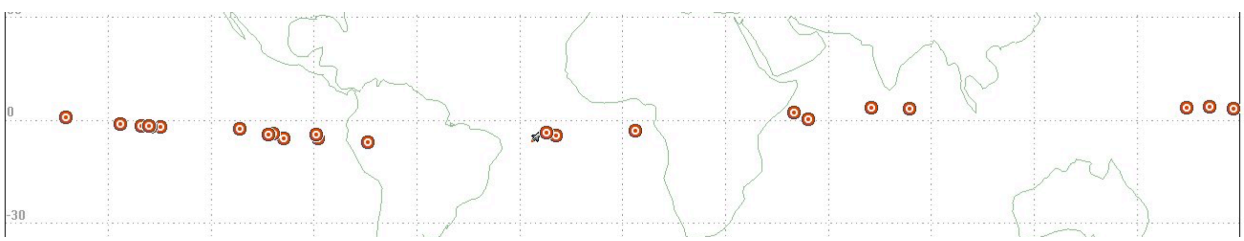

Fig. 3. Predicted positions for 1968-081E (indicated by spaceship symbol) and cataloged debris pieces (indicated by red dots) generated by TLEs from the same epoch as possible.

For this observation, we took the TLE of 1968-081E just prior to the epoch of telescope observation, and generated 'debris' TLEs by changing the mean anomaly of the parent body in 5-degree increments. All other quantities in the TLE were left unchanged. This approach might be appropriate for a slow fragmentation, where released pieces slowly drift along the orbit and are subject to the same gravitational perturbations as the parent body. This produced a number of TLEs to observe - the positions were chosen to be just out of Earth shadow at the time of observation. The appropriate angular rates for telescope motion could then be computed.

For 1969-013B, a different approach was chosen using NASA's Standard Breakup Model. Predictions were done for sizes in the 5 - 10 cm range, and positions and rates were computed for the observing time window available.

Fig. 4 shows an example of the spatial density of debris as projected onto the sky. Positions could be determined from this plot.

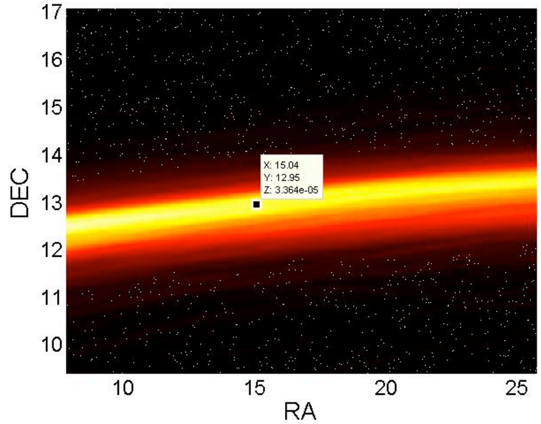

Fig. 4. Projected density of debris onto the sky in the 5-10 cm size range as predicted from the NASA Standard Breakup Model. Yellow is greatest density.

Similarly the predicted topocentric rates to move the telescope at can be computed as well. Fig 5 shows those rates for the same debris population as shown in Fig. 4.

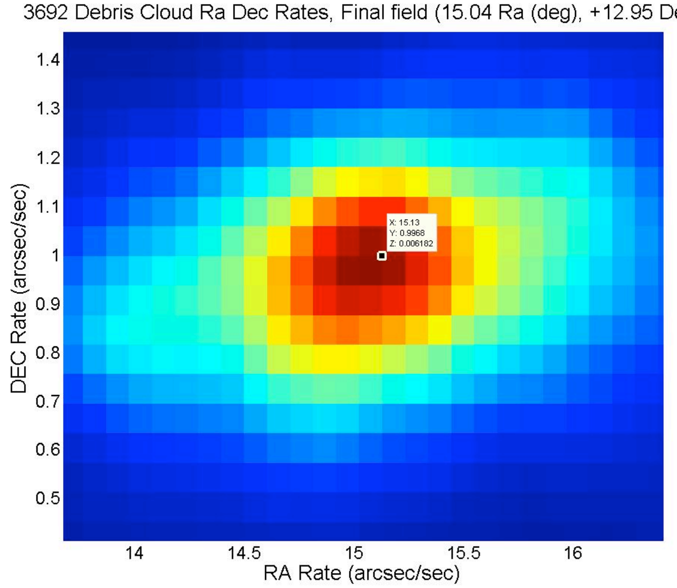

Fig. 5. Predicted angular rates in RA (Right Ascension) and DEC (declination) for the debris population shown in Fig. 4. The size distribution is 5-10 cm.

4. RESULTS

A total of one night of 6.5-m Magellan time spread over several years was used for these observations.

For 1968-081E, a total of 0.8 square degrees were surveyed and no objects brighter than R = 20th magnitude with an angular rate within 0.1 arcsec/sec of the peak of predicted values shown in Fig. 5 were detected.

For 1969-013E, a total of 2.0 square degrees were surveyed, and one object brighter than R = 20th magnitude was found with an angular rate within 0.1 arcsec/sec of the peak of predicted values shown in Fig. 5.

5. DISCUSSION

The detection of only one object brighter than 20th magnitude (smaller than 10cm) for one night of 6.5-m telescope time comes as a disappointment. Why is the detected number so small? Reasons:

1. The small size debris population from these events is small.
2. The field of view of the telescope (0.5 degrees) is too small to be useful here. Note that smaller telescopes used for debris surveys typically have a field of view of 1 degree or larger.
3. The method used for predicting where to look, and how fast to move the telescope, are incorrect for the events described here.

Unfortunately with the available data, it is not possible to distinguish which one of the above is the primary reason for the lack of debris detection.

6. Future

The limiting detectable magnitude above is for a single frame. Since the objects are likely moving between images, coadding images does not gain you anything. In fact, one is just adding noise since the object could be in a slightly different point in each image. However, we can expect to gain at least a magnitude by sending the above datasets through a 'digital tracking' pipeline, where images are shifted at a range of rates and position angle before coadding. This procedure is used in the asteroid community, but is extremely compute intensive.

Finally, more telescope time would be extremely desirable.