Optical Observations of GEO Debris with Two Telescopes

P. SEITZER, K. ABERCROMBY, H. RODRIGUEZ, AND E. BARKER

For several years, the **M**ichigan **O**rbital **DE**bris **S**urvey **T**elescope (MODEST), the University of Michigan's 0.6/0.9-m Schmidt telescope on Cerro Tololo Inter-American Observatory in Chile has been used to survey the debris population at GEO in the visible regime. Magnitudes, positions, and angular rates are determined for GEO objects as they move across the telescope's field-of-view (FOV) during a 5-minute window.

This short window of time is not long enough to determine a full six parameter orbit so usually a circular orbit is assumed. A longer arc of time is necessary to determine eccentricity and to look for changes in the orbit with time. MODEST can follow objects in real-time, but only at the price of stopping survey operations. A second telescope would allow for longer arcs of orbit to obtain the full six orbital parameters, as well as assess the changes over time. An additional benefit of having a second telescope is the capability of obtaining BVRI colors of the faint targets, aiding efforts to determine the material type of faint debris.

For 14 nights in March 2007, two telescopes were used simultaneously to observe the GEO debris field. MODEST was used exclusively in survey mode. As objects were detected, they were handed off in near real-time to the Cerro Tololo 0.9-m telescope for follow-up observations. The goal was to determine orbits and colors for all objects fainter than R = 15th magnitude (corresponds to 1 meter in size assuming a 0.2 albedo) detected by MODEST. The hand-off process was completely functional during the final eight nights and follow-ups for objects from night-to-night were possible.

The cutoff magnitude level of 15th was selected on the basis of an abrupt change in the observed angular rate distribution in the MODEST surveys. Objects brighter than 15th magnitude tend to lie on a well defined locus in the angular rate plane (and have orbits in the catalog), while fainter objects fill the plane almost uniformly. We need to determine full six-parameter orbits to investigate what causes this change in observed angular rates. Are these faint objects either the same population of high area-to-mass (A/M) objects on eccentric orbits as discovered by the ESA Space Debris Telescope (Schildknecht, et al. 2004), or are they just normal debris from breakups in GEO?

Our success rate in handing off was greater than 85%, despite the very small FOV of the 0.9-m telescope (only 0.22°, compared with 1.3° for MODEST). The average time from last detection on MODEST to first detection on the 0.9-m telescope was 17 minutes; the quickest was 4 minutes. Thus, the statistical completeness of the follow-up sample is very high.

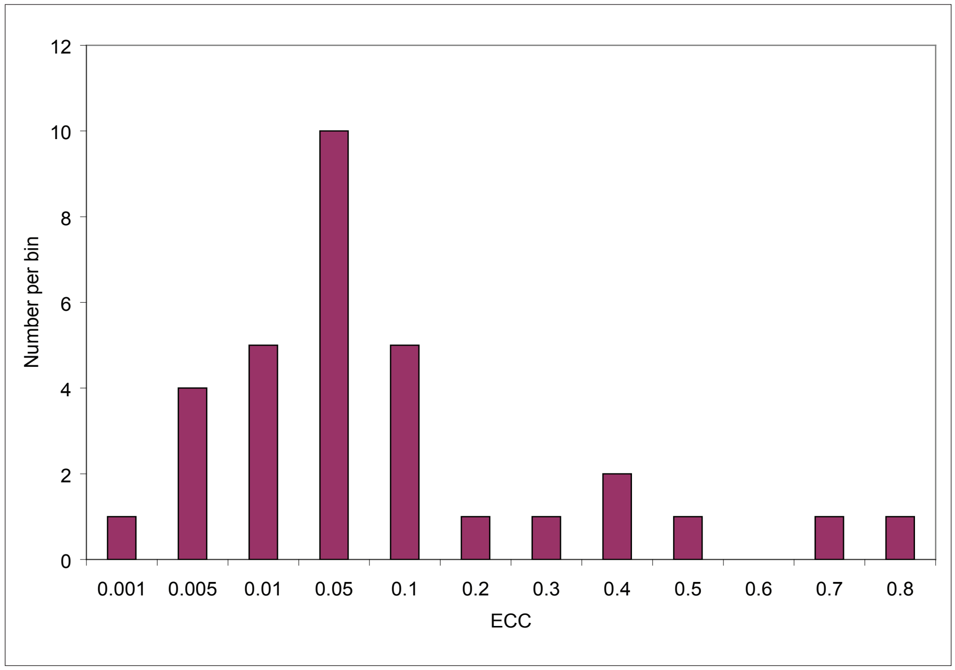

Figure 1. The histogram of all objects (32) for which enough data exists to determine a full six-parameter orbit without the a circular orbit assumption.

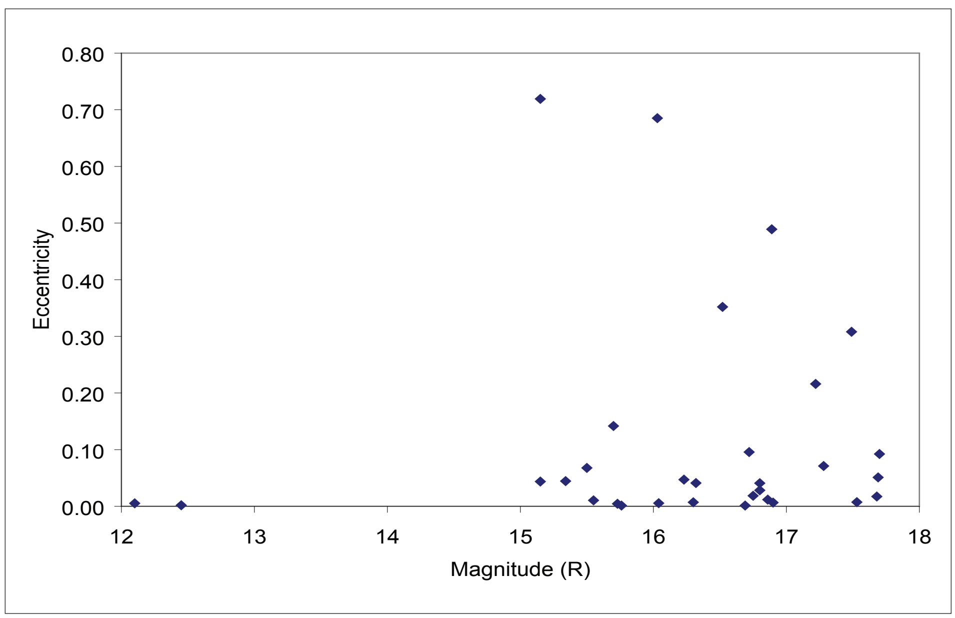

Figure 2. Eccentricity versus magnitude for each of the 32 objects for which a full six-parameter orbit was calculated.

Figure 1 shows a histogram of the 32 objects for which enough data was collected to determine the full orbit parameters. The majority of the objects were in circular orbits, but 20% of the objects had eccentricities greater than 0.2. Figure 2 depicts eccentricity versus magnitude and Figure 3 shows inclination versus right ascension of ascending node (RAAN) for the same set of objects.

The ability to run two telescopes simultaneously provides a very powerful probe of the GEO debris field. Initial observations indicate that we are seeing both a circular and

continued on page 7

Optical Observations

continued from page 6

an eccentric debris populations. We look forward to continuing these observations in the future. Our next run is planned for November 2007.

1. Schildknecht, *et al.*, *Properties of the High Area-to-mass Ratio Space Debris Population in GEO*, AMOS Technical Conference Proceedings, Kihei, Hawaii, pp. 216-224, September 2-5, 2005. ♦

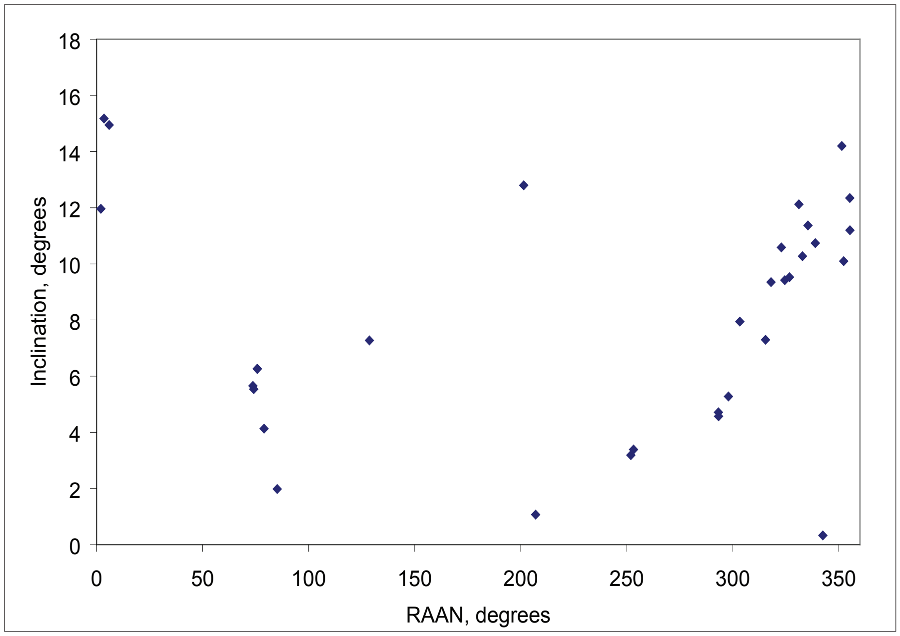

Figure 3. Inclination versus RAAN for each of the 32 objects in this specific dataset.

Optical Measurement Center Status

H. RODRIGUEZ, K. ABERCROMBY, M. MULROONEY, AND E. BARKER

Beginning in 2005, an optical measurement center (OMC) was created to measure the photometric signatures of debris pieces. Initially, the OMC was equipped with a 300 W xenon arc lamp, a SBIG 512 x 512 ST8X MEI CCD camera with standard Johnson filters, and a Lynx 6 robotic arm with five degrees of freedom[1]. As research progressed, modifications were made to the equipment. A customized rotary table was built to overcome the robot's limitation of 180 degree wrist rotation and provide complete 360 degree rotation with little human interaction. This change allowed an initial phase angle (source-object-camera angle) of roughly 5 degrees to be adjusted to 7, 10, 15, 18, 20, 25, or 28 degrees. Additionally, the Johnson R and I CCD filters were replaced with the standard astronomical filters suite (Bessell R, I). In an effort to reduce object saturation, the two generic aperture stops were replaced with neutral density filters.

Initially data were taken with aluminum debris pieces from the European Space Operations Centre ESOC2 ground test and more recently with samples from a thermal multi-layered insulation (MLI) commonly used on rocket bodies and satellites. The ESOC2 data provided light curve analysis for one type of material but many different shapes, including flat, bent, curled, folded, and torn[2]. The MLI samples are roughly the same size and shape, but have different surfaces that give rise to interesting photometric light curves. In addition, filter photometry was conducted on the MLI pieces, a process that also will be used on the ESOC2 samples. While obtaining light curve data an anomalous drop in intensity was observed when the table revolved through the second 180 degree rotation. Investigation revealed that the robot's wrist rotation is not reliable past 80 degrees, thus the object may be at slightly different angles at the 180 degree transition. To limit this effect, the initial rotation position begins with the object's minimal surface area facing the camera.

Figure 1. Digital Images of sample MLI debris. Top images are part of the space-facing layer and the bottom images are part of the space-craft facing layer. The A/M for these samples is ~ 10 m^2/kg.

The MLI used for the current study consists of space-facing copper-colored Kapton with an aluminized backing for the top and bottom layers and alternating layers of DARCON or Nomex netting with aluminized Mylar for the middle layers. This material is significant to the study of space debris due to its high area-to-mass ratio (A/M) and the effect solar radiation pressure perturbations have on its orbital evolution. Measurements were taken at an 18 degree phase angle with one intact piece and three different layers of MLI, using the standard astronomical filters mentioned previously. The A/M ratios range from 8 to 43 m2/kg (3 m2/kg and greater is considered to be a high A/M). In Figure 1, a digital image of two pieces of MLI layering is displayed. The top left and right images are part of the outermost layer of MLI. The copper-colored Kapton is space-facing, while the silver color borders the interior MLI layers. The bottom left and right images are part of the spacecraft-facing MLI layer, with the copper-color Kapton facing the spacecraft while the silver color is positioned to the interior MLI layers.

The following figure shows an example of intensity versus rotation over 360 degrees for the intact piece of MLI (see Figure 2). The pseudo-debris piece was rotated through five degree increments at a seven degree phase angle. Filter photometry data was taken through all five filters mentioned previously. The two intensity maxima around 90 and 270 degrees correspond to the maximum surface area of the object facing the CCD camera. The object was rotated space-craft side first, then space-facing side during the remaining 180 degrees

continued on page 8