Applied Astronomy: An Optical Survey for Space Debris at GEO

Patrick Seitzer
Department of Astronomy
University of Michigan

Kira Abercromby, Ed Barker, and Heather Rodriquez

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• What is space debris?
  – Uncontrolled spacecraft
  – Rocket bodies
  – Junk – small parts, etc

• Why track? Collision risk that could disable active satellites.

• Why study in optical?
  – Radar $1/r^{**4}$ versus optical $1/r^{**2}$
  – Radar better at LEO (Low Earth Orbit)
  – Optical better at GEO (Geosynchronous Earth Orbit)
    • Period = 23 hours 56 minutes 4 seconds (1 sidereal day)
    • Radius = 42,164 km
Syncom 1 – launched February 14, 1963
Failed on orbit insertion – 1st piece of GEO debris!
Example of recent GEO payload: XM-2 “Rock” satellite for direct broadcast radio
MODEST – Michigan Orbital DEbris Survey Telescope

the telescope formerly known as the Curtis-Schmidt

Cerro Tololo Inter-American Observatory, Chile

0.61/0.91-m Schmidt telescope
GEO debris survey began February 2001
GEO Debris Survey

- Scanning CCD through a broad R filter (V+R).
- 5 second exposure every 37.9 seconds as track position of constant right ascension and declination all night long close to anti-solar point.
- Cover strip over 100 degrees long by 1.3 degrees high each night.
- Average of 8 detections of each GEO object as it crosses field of view in 5.2 minutes – allows determination of position, brightness, and angular motion.
- 4 detections required for real object, corresponds to S/N = 10 for each detection.
- Assume circular orbit for analysis.
Examples of Detections
Brightness Variations Common
Observed Angular Rates
What rate distribution is expected?

Object released from station-keeping follows well defined RAAN-inclination relationship with time. So expect locus of objects in angular rate box.
Two Populations at GEO

Bright (R < 15)

Faint (R > 15)

Dec rate (arc-seconds/sec)

HA rate (arc-seconds/sec)
High Area-to-Mass Ratio Material (A/M)

- Consider sheets of
  - Aluminum foil
  - Spacecraft insulation blankets (MLI)
  - Highly reflective, not very massive.
  - Orbits significantly perturbed by solar radiation pressure.
  - See models by Liou & Weaver (2005)

- ‘Dark matter’ debris (ball bearings) have low A/M; dominant perturbations from gravitational effects.
Examples of MLI

Intact MLI
Kapton outer layers, Mylar insulation layers with netting (A/M=8)

Space-facing MLI (A/M=22)

Space Craft-facing MLI (A/M=17)

Interior piece of MLI: white fabric (A/M=43)
Examples of MLI Release in LEO

• NASA’s Far Ultra-violet Spectroscopic Explorer (FUSE) released 9 pieces of debris that were detected and tracked by US SSN in June 2004.
• Tracking data suggested they were consistent with the evolution of high A/M MLI pieces.
Liou & Weaver (2005) models

A/M = 1 m²/kg

A/M = 20 m²/kg
ESa 1-m Telescope Survey

Eccentricity vs Mean Motion (Elliptical Orbits, Aug 02 to Jul 03)

(E Courtesy T. Schildknecht/ESA)
Two Telescopes March 2007
Survey and Follow-up

* obtain orbits and colors of all faint debris *

- MODEST
  - 1.3 x 1.3 degree FOV
- 0.9 meter
  - 0.22 deg FOV
Final Eccentricity

The graph shows the distribution of final eccentricities for different detection numbers. The x-axis represents the detection number range from 0 to 100, and the y-axis represents the eccentricity range from 0.00E+00 to 8.00E-01. The data points are color-coded: blue for circular orbits and red for eccentric orbits.
How control Space Debris?

• At LEO (Low Earth Orbit) – atmospheric effects important on orbit:
  – Design for minimum debris generation during operation
  – Actively force reentry into South Pacific (MIR station)
  – Maximum 25 year lifetime after end of mission

• At GEO – no natural cleanup mechanism:
  – Design spacecraft and rockets for minimum debris generation
  – Boost active spacecraft at end of lifetime 300-600 km above GEO orbit