

Applied Astronomy: An Optical Survey for Space Debris at GEO

Patrick Seitzer
Department of Astronomy
University of Michigan

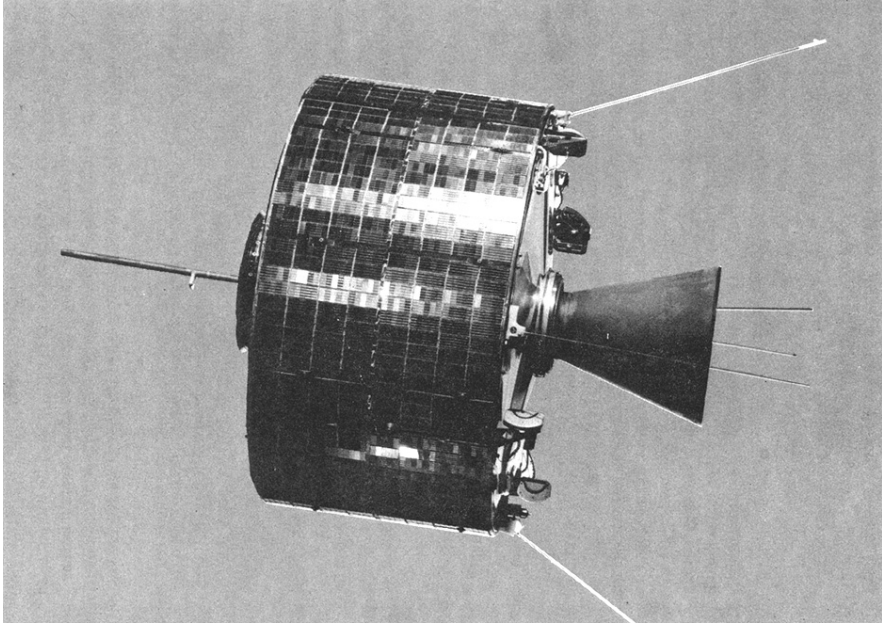
Kira Abercromby, Ed Barker, and Heather Rodriguez

Supported by:
Orbital Debris Program Office
NASA Johnson Space Center
Houston, Texas
Seitzer

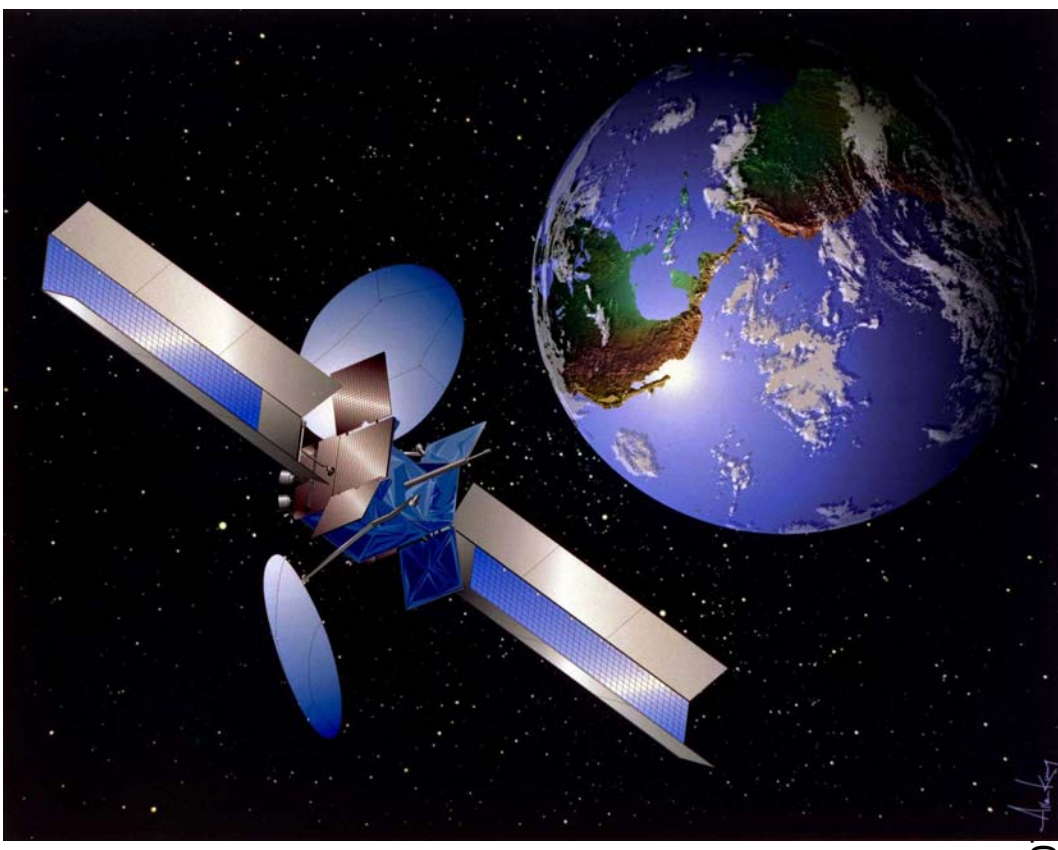
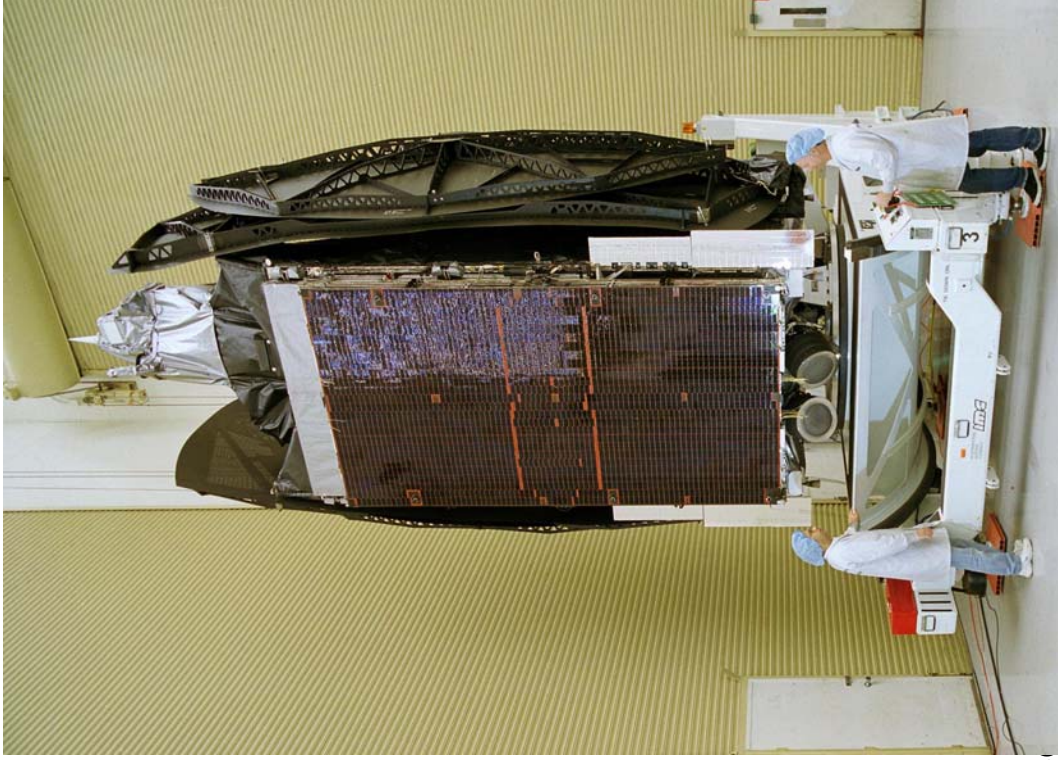
DDA 2007 May 9

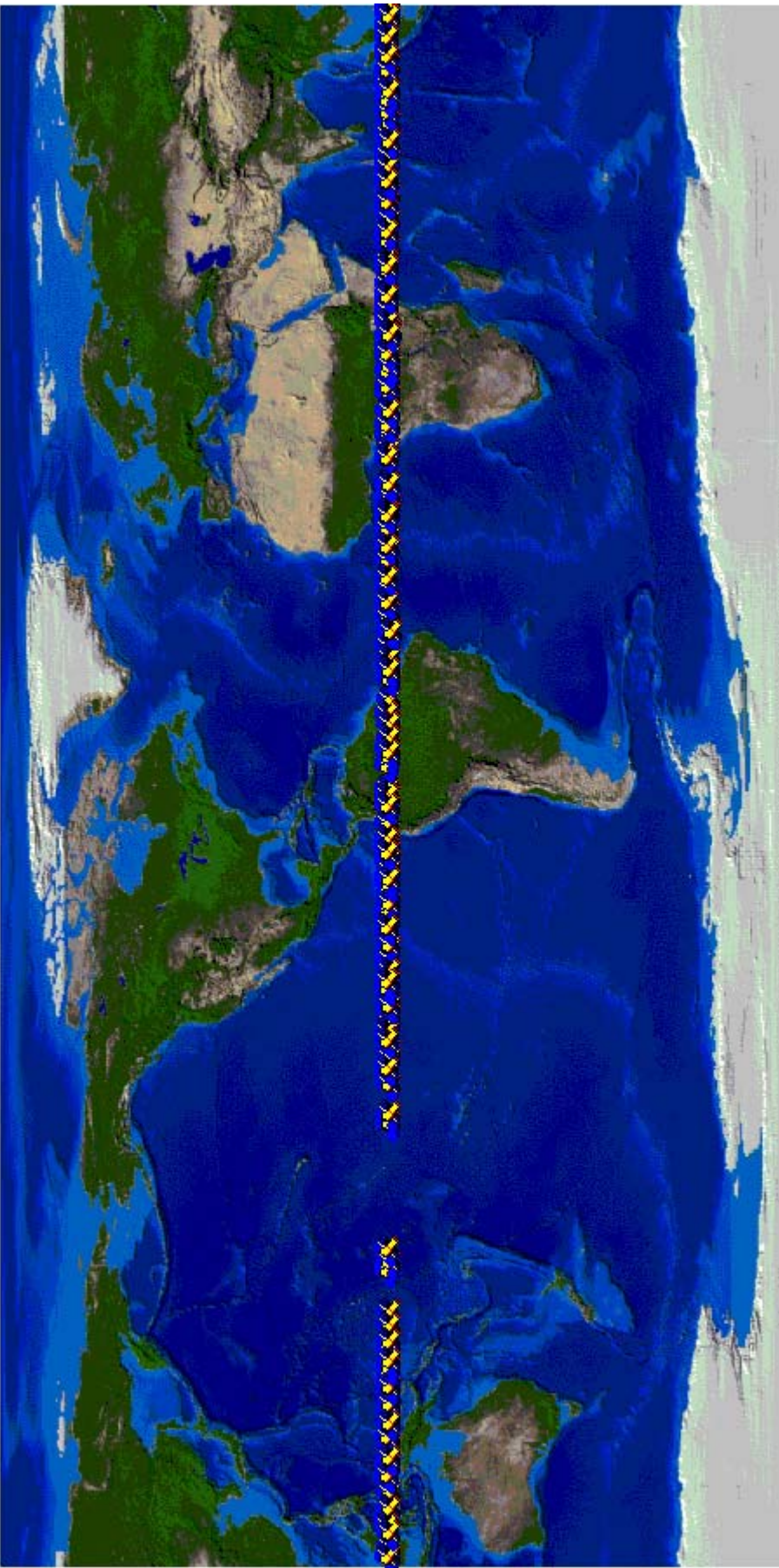
- What is space debris?
 - Uncontrolled spacecraft
 - Rocket bodies
 - Junk – small parts, etc
- Why track? Collision risk that could disable active satellites.
- Why study in optical?
 - Radar $1/r^{**4}$ versus optical $1/r^{**2}$
 - Radar better at LEO (Low Earth Orbit)
 - Optical better at GEO (Geosynchronous Earth Orbit)
 - Period = 23 hours 56 minutes 4 seconds (1 sidereal day)
 - Radius = 42,164 km

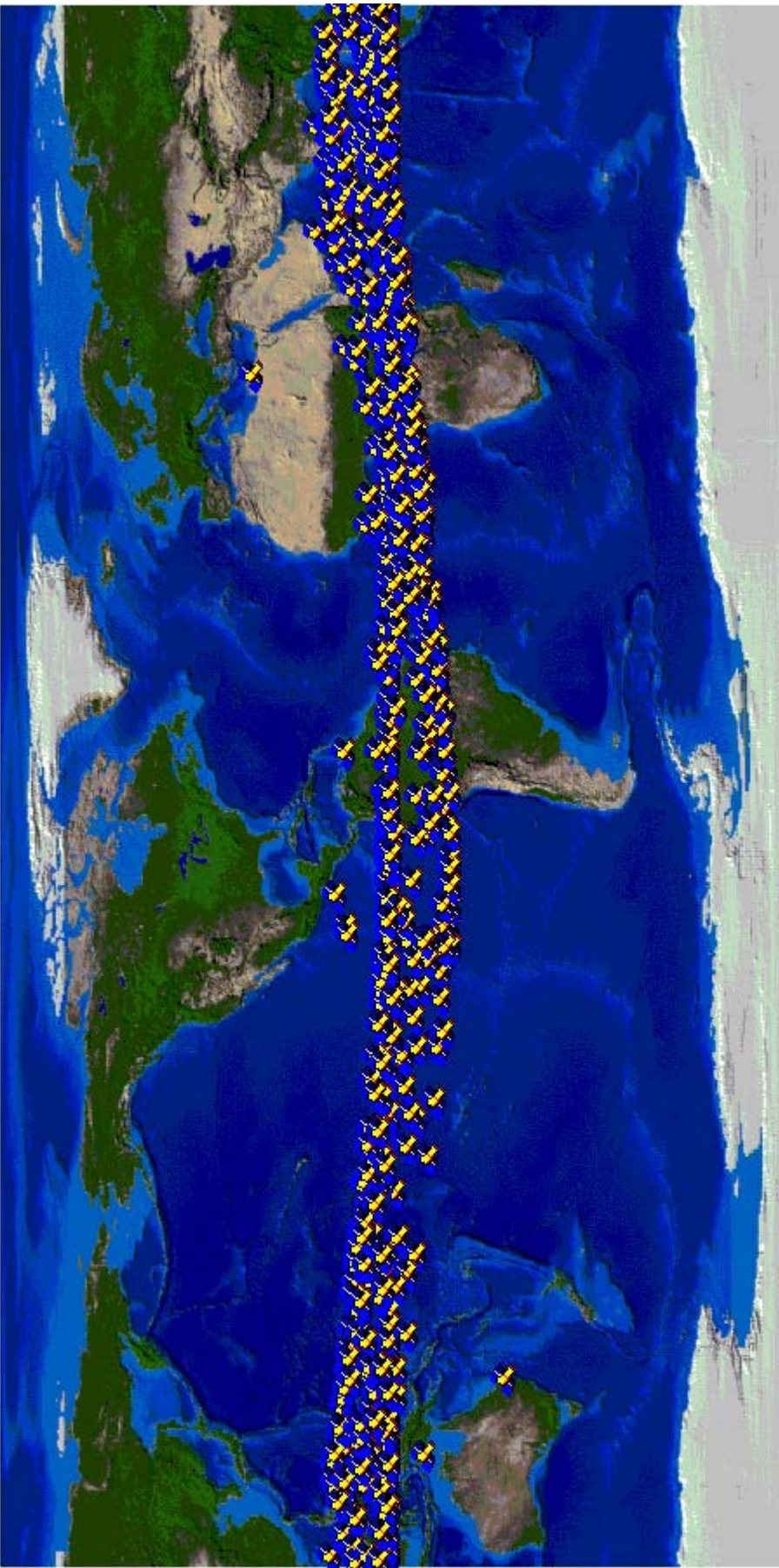
**Syncom 1 – launched February 14, 1963
Failed on orbit insertion – 1st piece of GEO debris!**



Example of recent GEO payload: XM-2 “Rock” satellite for direct broadcast radio





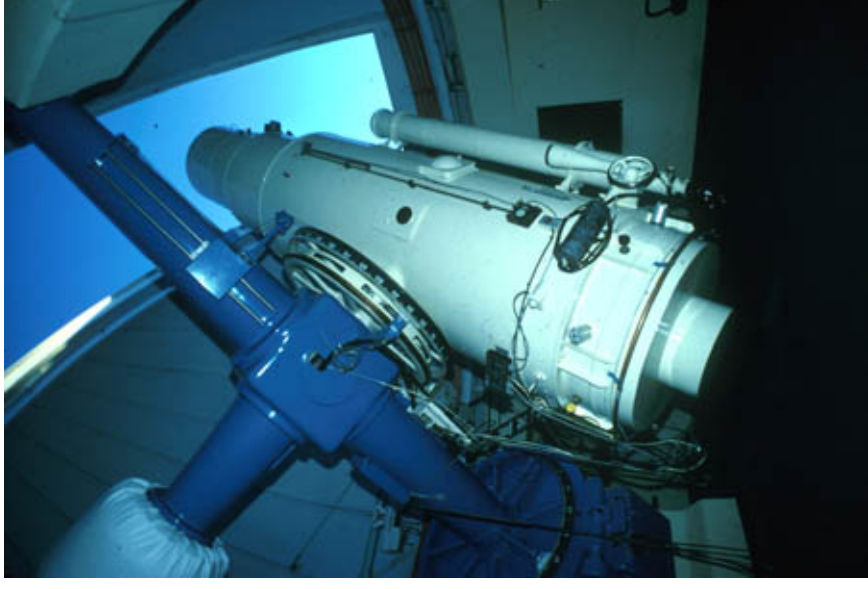


MODEST – Michigan Orbital DEbris Survey Telescope *the telescope formerly known as the Curtis-Schmidt*

Cerro Tololo Inter-American Observatory, Chile

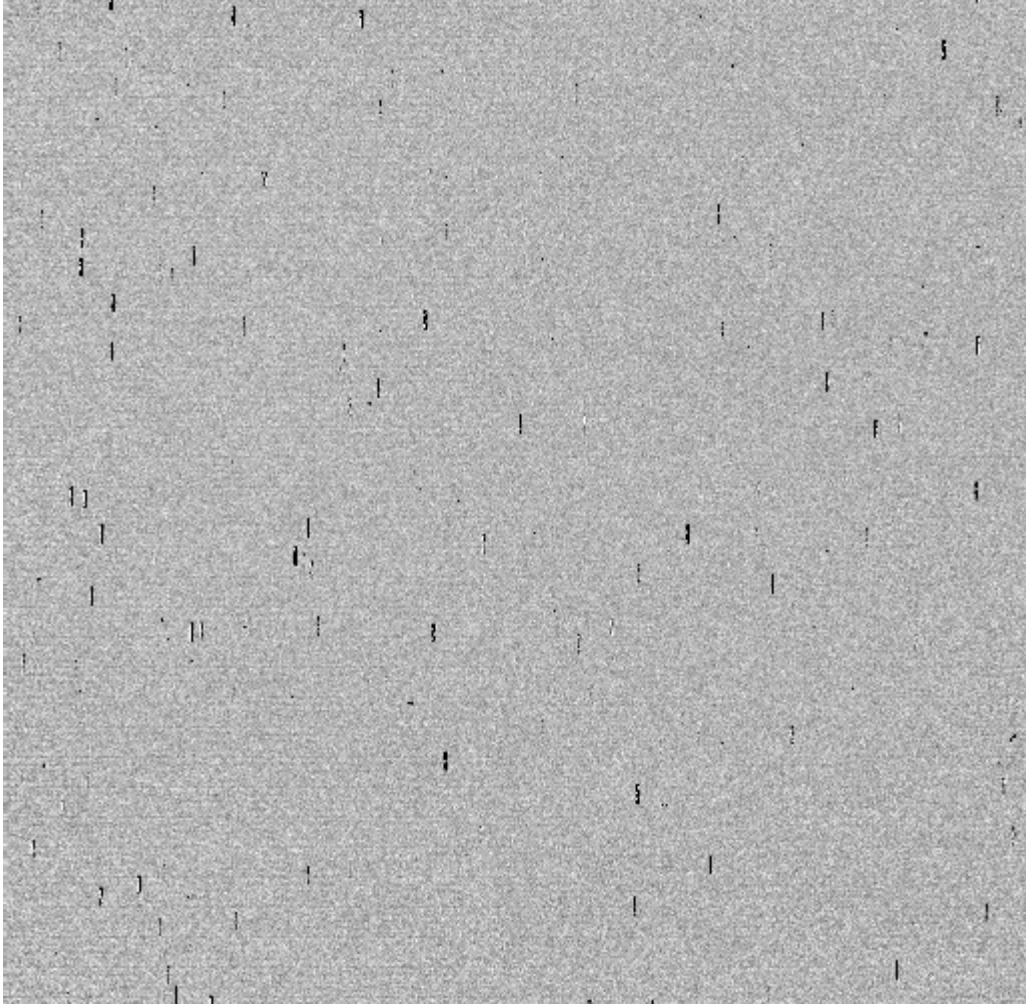


0.61/0.91-m Schmidt telescope
GEO debris survey began February 2001

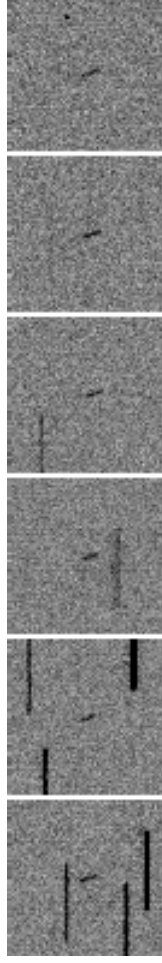
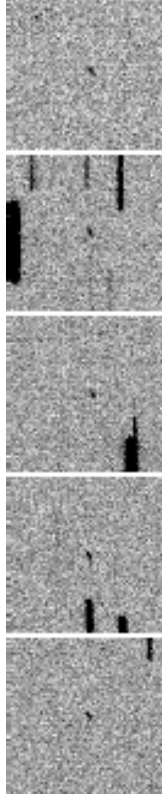
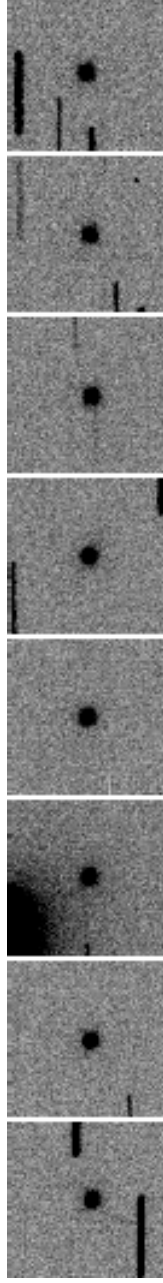


GEO Debris Survey

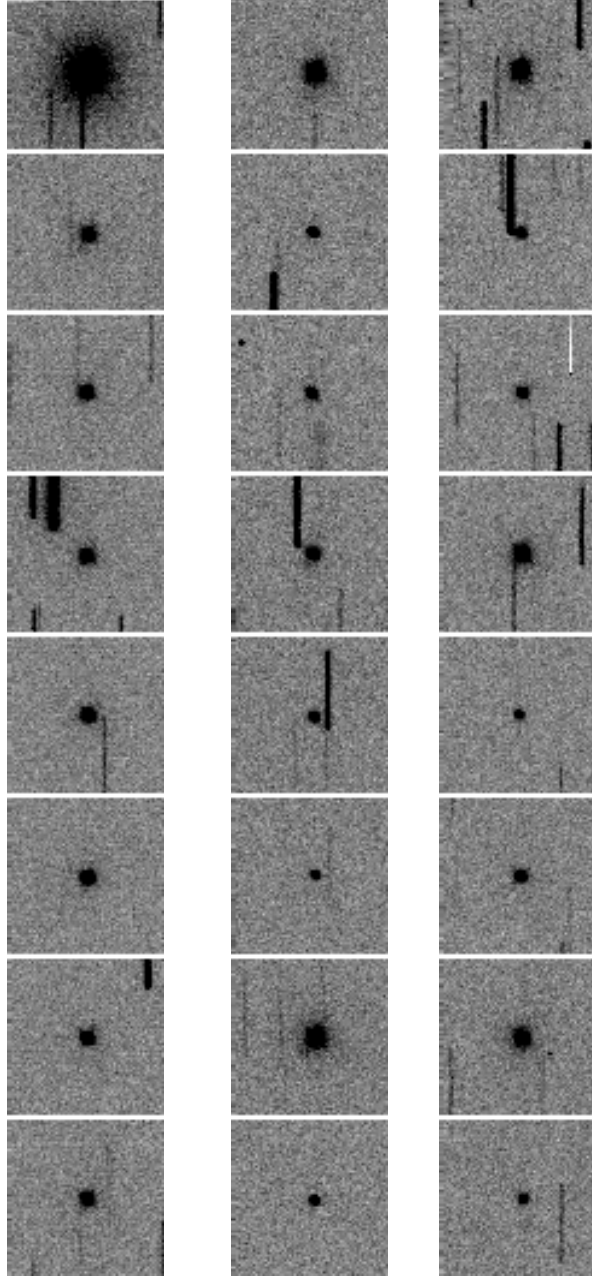
- Scanning CCD through a broad R filter (V+R).
- 5 second exposure every 37.9 seconds as track position of constant right ascension and declination all night long close to anti-solar point.
- Cover strip over 100 degrees long by 1.3 degrees high each night.
- Average of 8 detections of each GEO object 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.



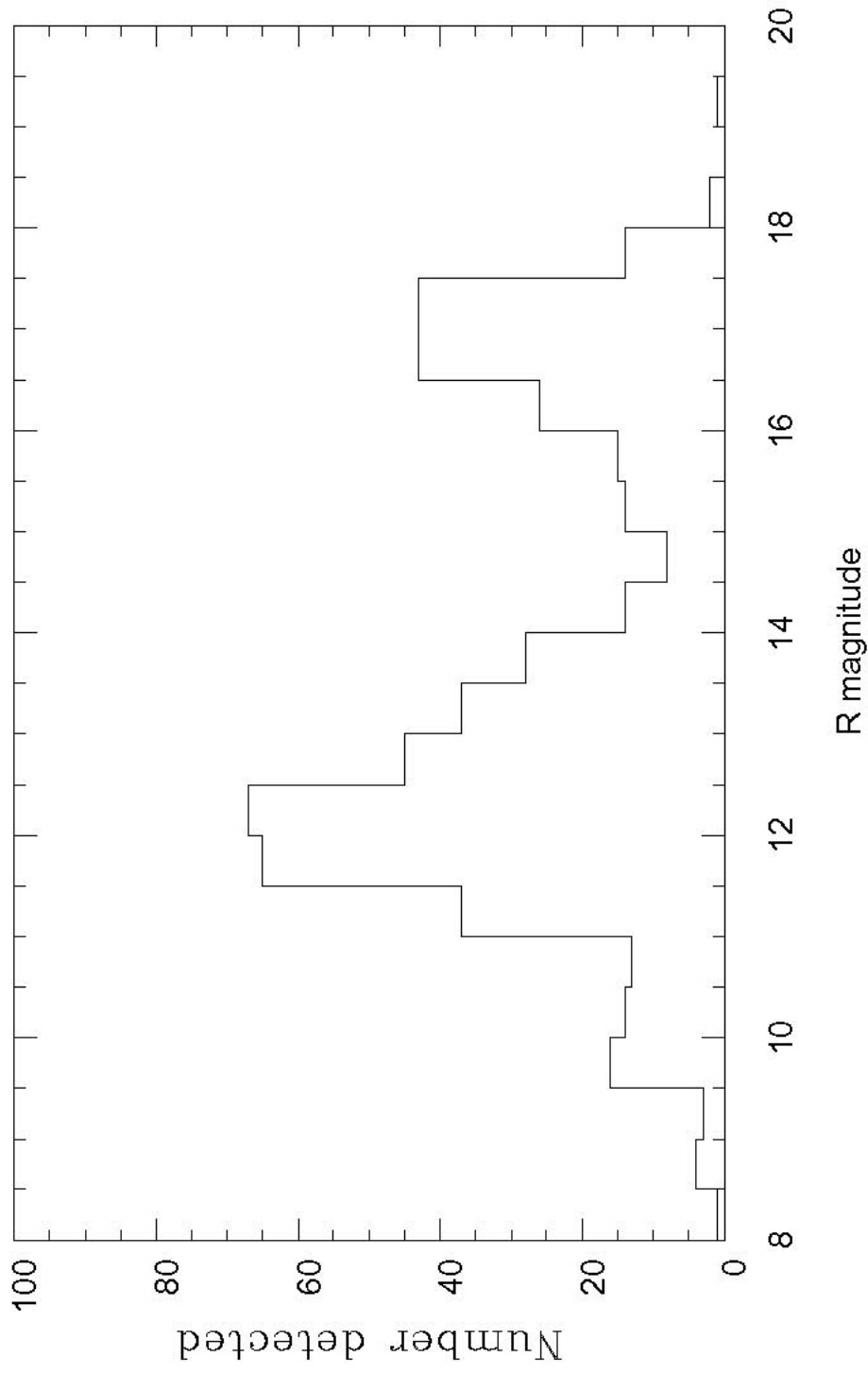
Examples of Detections



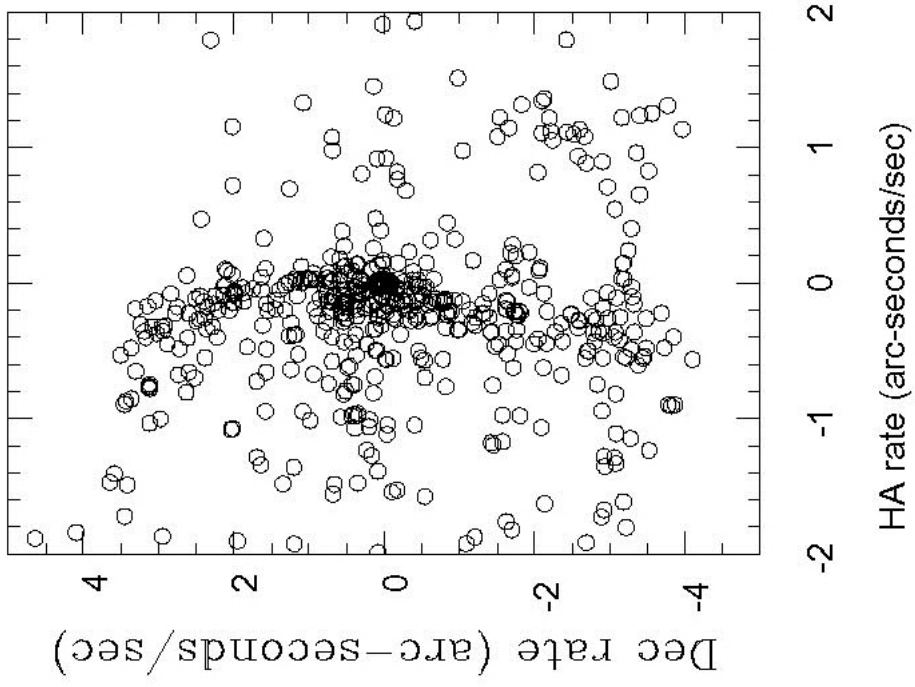
Brightness Variations Common



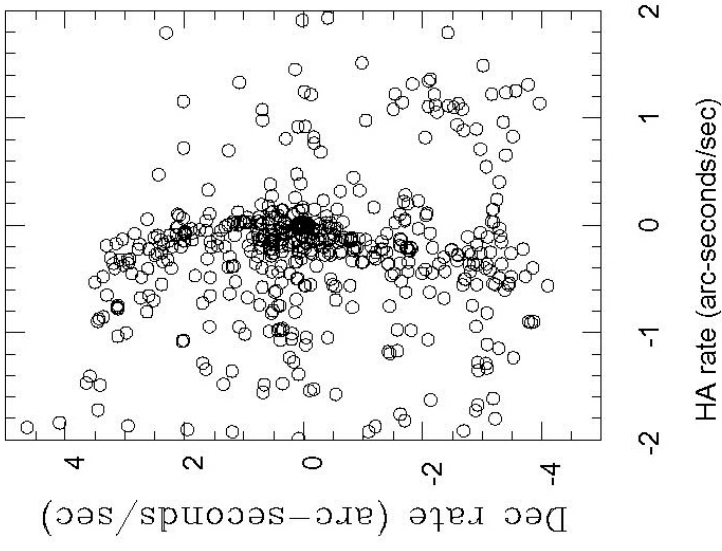
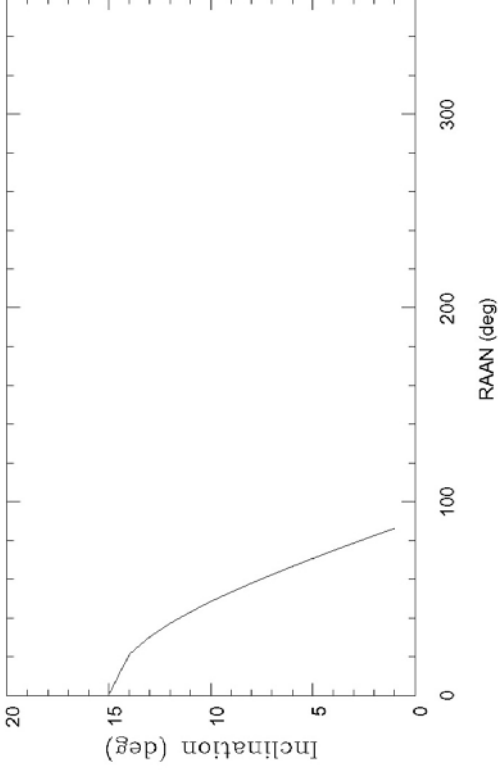
510 non-stationkeeping objects



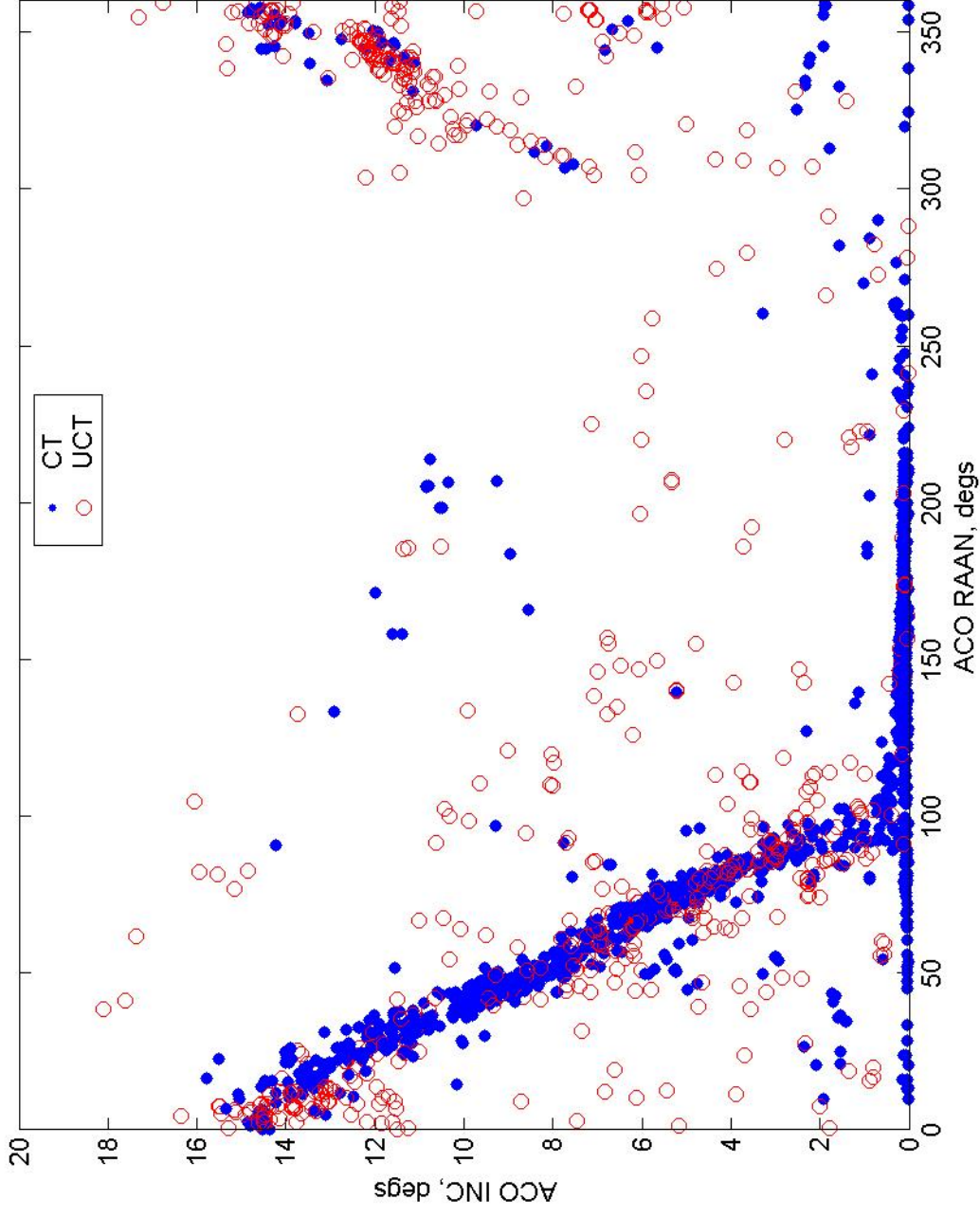
Observed Angular Rates



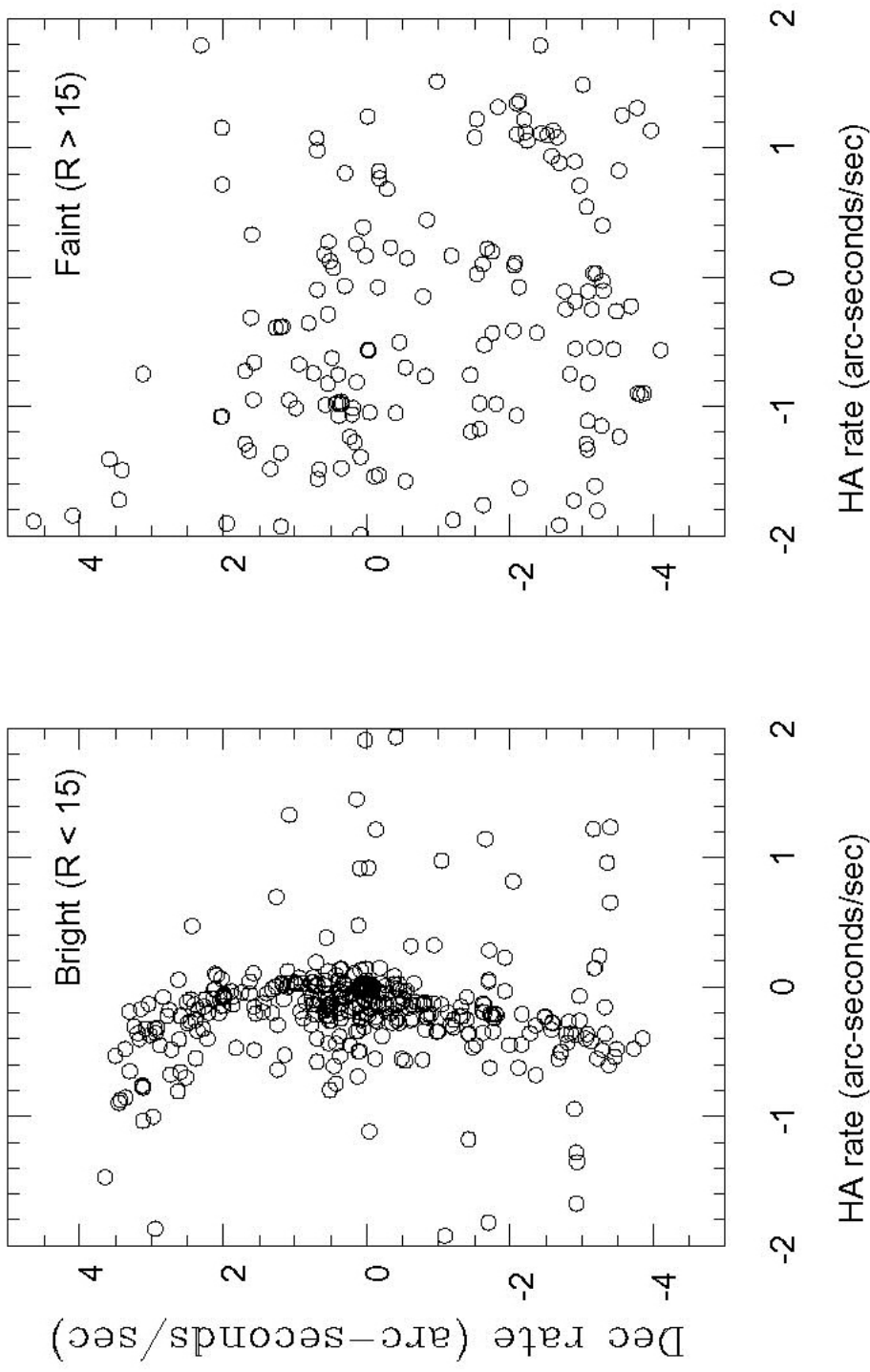
What rate distribution is expected?



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



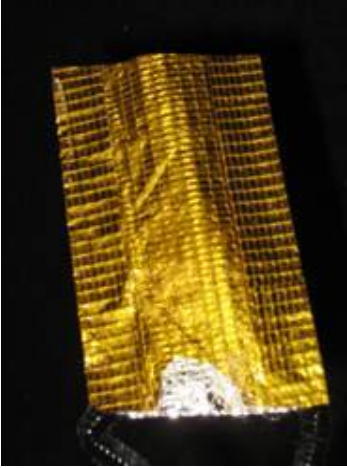
Two Populations at GEO



High Area-to-Mass Ratio Material (A/M)

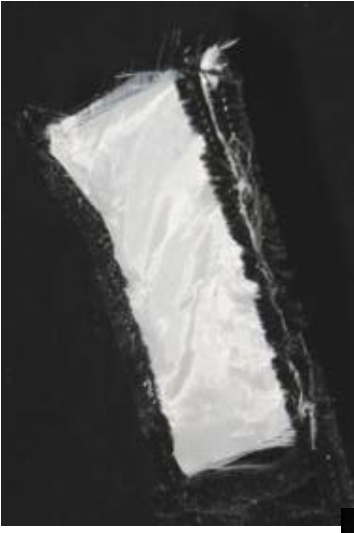
- Consider sheets of
 - Aluminum foil
 - Spacecraft insulation blankets (MLI)
 - Highly reflective, not very massive.
 - Orbits significantly perturbed by solar radiation pressure.
 - See models by Liou & Weaver (2005)
 - ‘Dark matter’ debris (ball bearings) have low A/M; dominant perturbations from gravitational effects.

Examples of MLI



Intact MLI

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



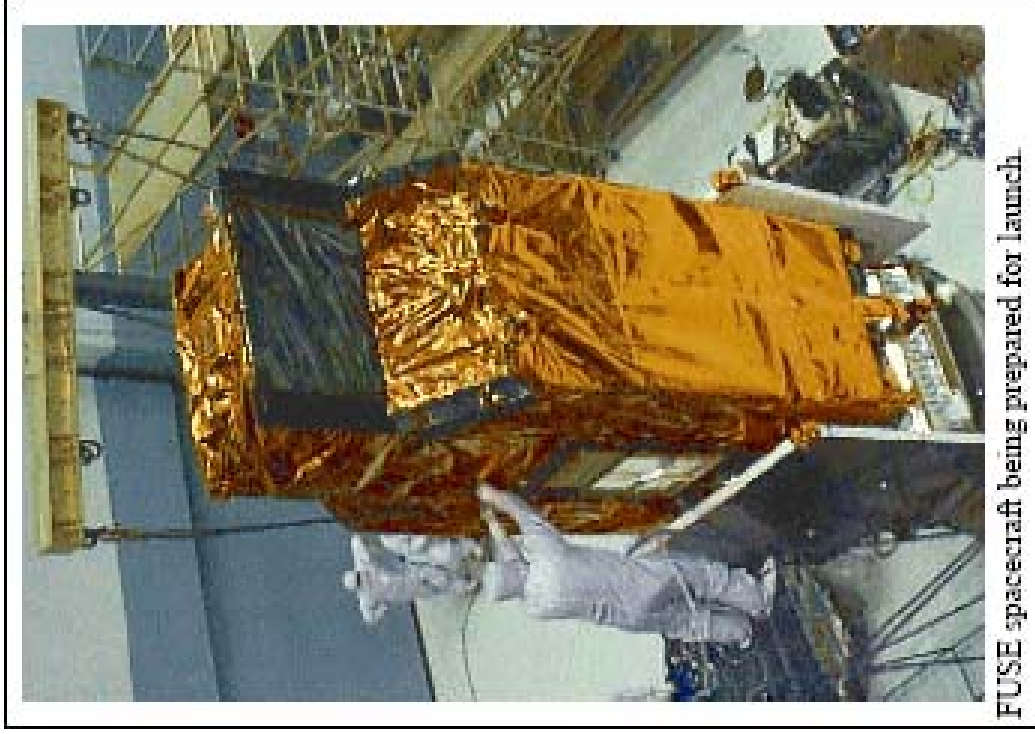
Interior piece of MLI:
white fabric (A/M=43)

Space-facing MLI (A/M=22)



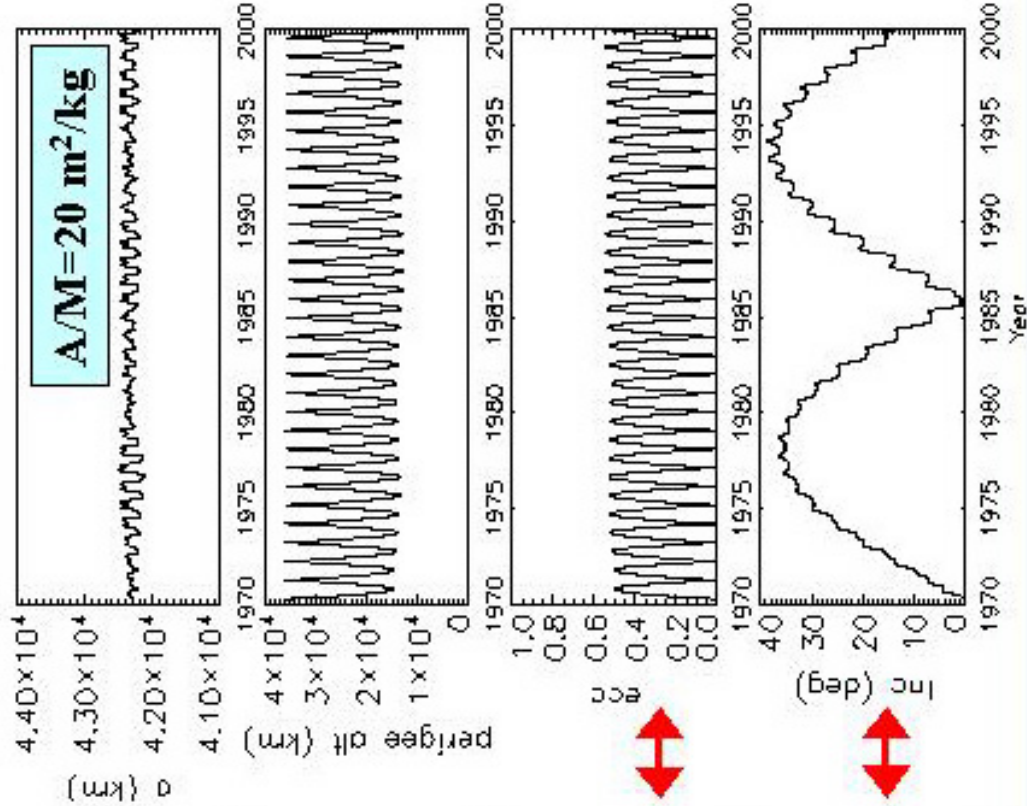
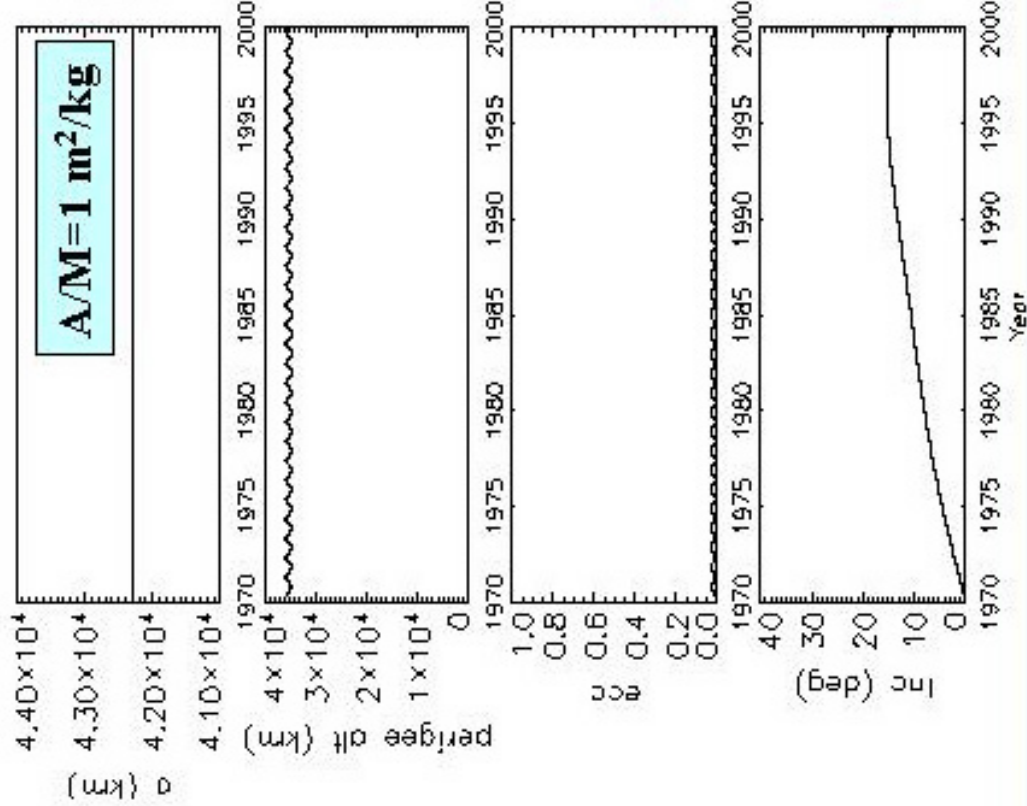
Space Craft-facing MLI (A/M=17)
DDA 2007 May 9

Examples of MLI Release in LEO



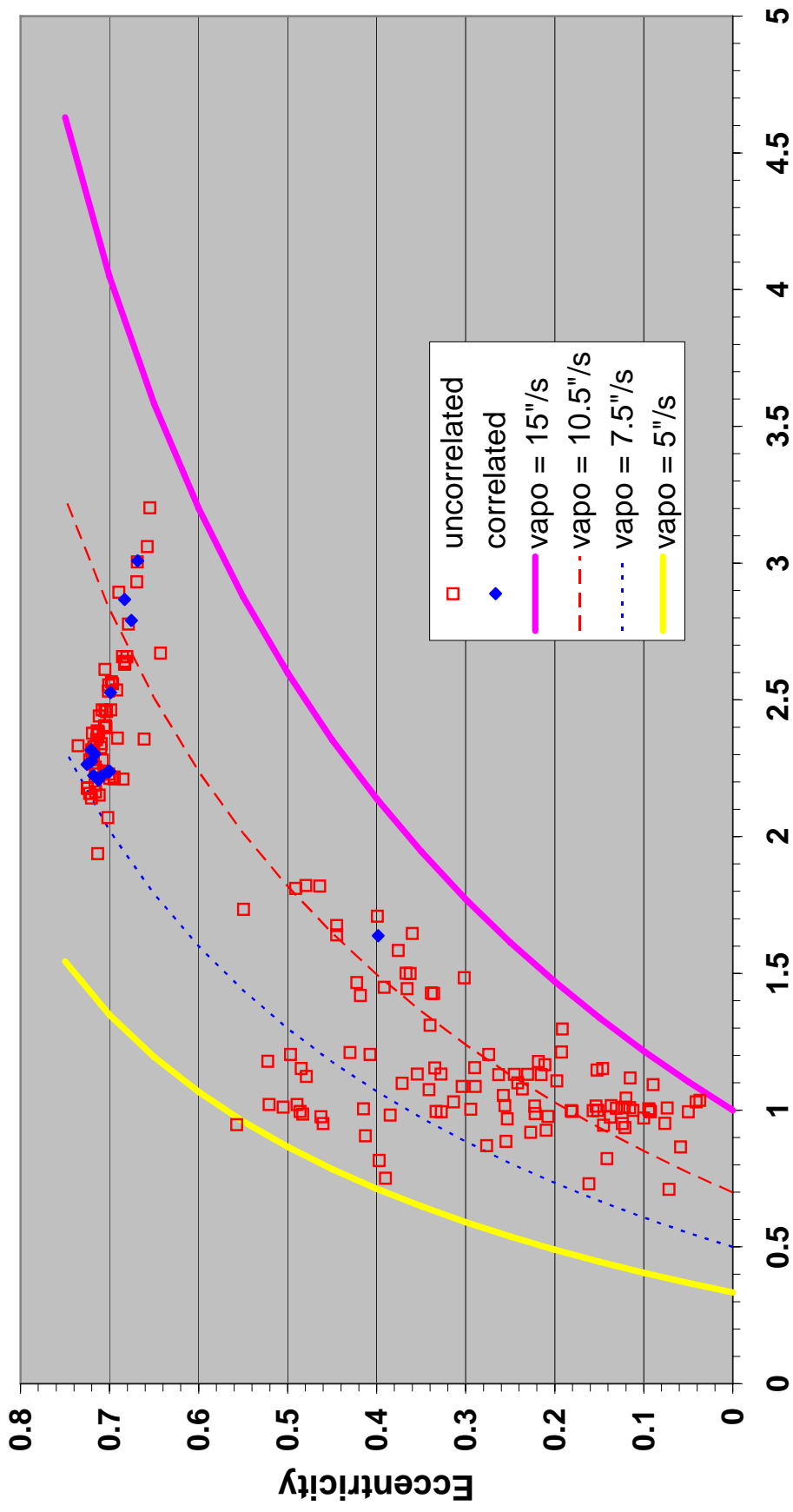
- NASA's Far Ultra-violet Spectroscopic Explorer (FUSE) released 9 pieces of debris that were detected and tracked by US SSN in June 2004
- Tracking data suggested they were consistent with the evolution of high A/M MLI pieces.

Liou & Weaver (2005) models



ESA 1-m Telescope Survey

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



Mean Motion (rev/day)

Seitzer

DDA 2007 May 9

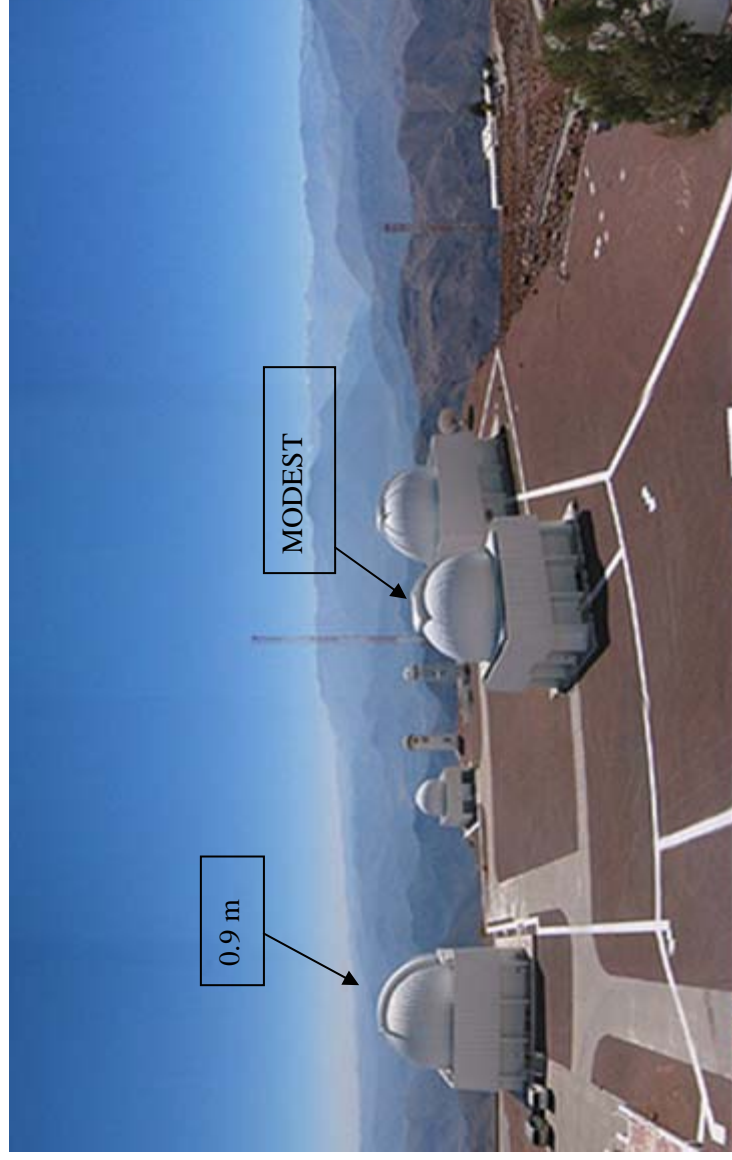
(Courtesy T. Schildknecht/ESA)

Two Telescopes March 2007

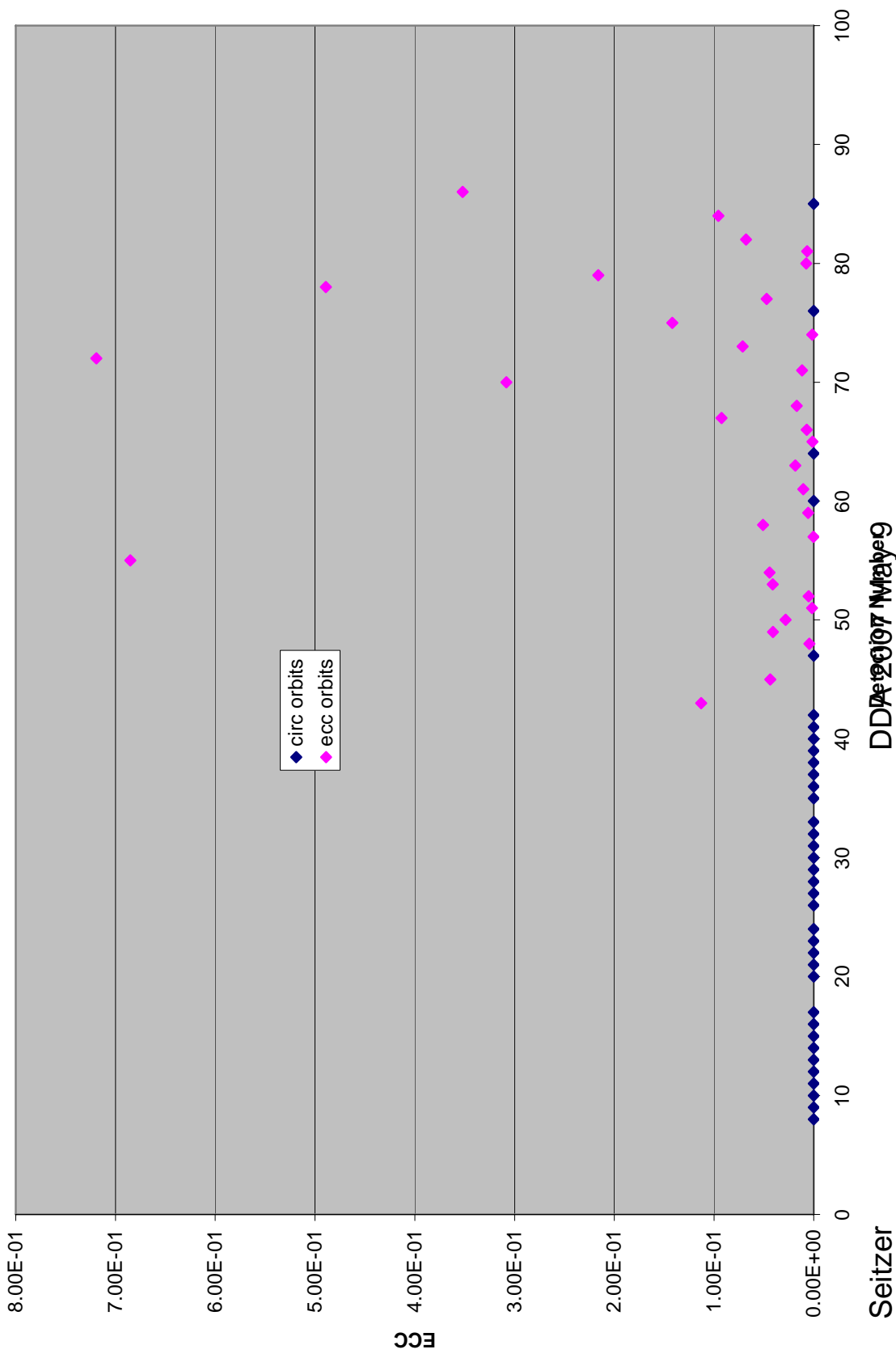
Survey and Follow-up

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



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