Applied Astronomy: An Optical Survey for Space Debris at GEO

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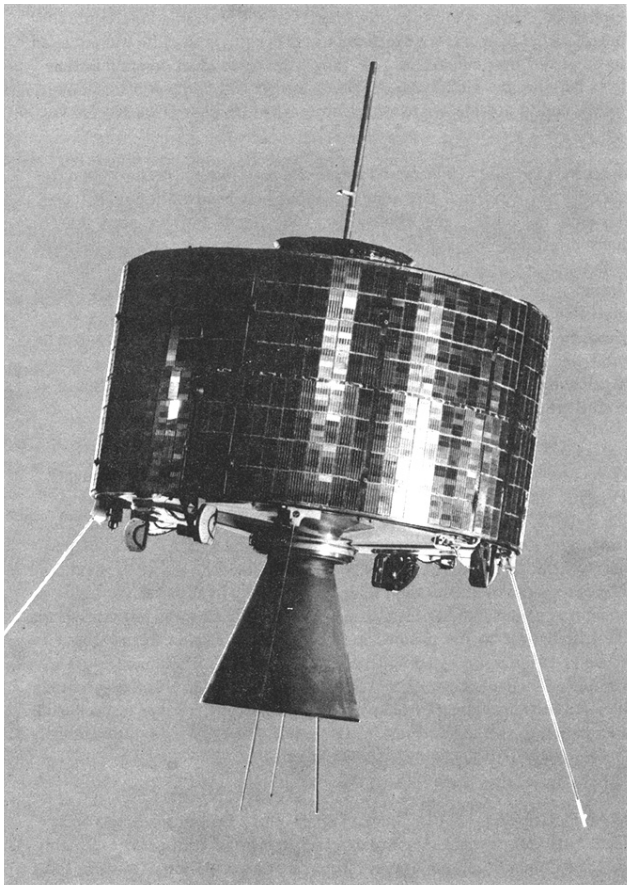
- What is space debris?
  - Uncontrolled spacecraft
  - Rocket bodies
  - Junk – small parts, etc

- Why track? Collision risk that could disable active satellities.

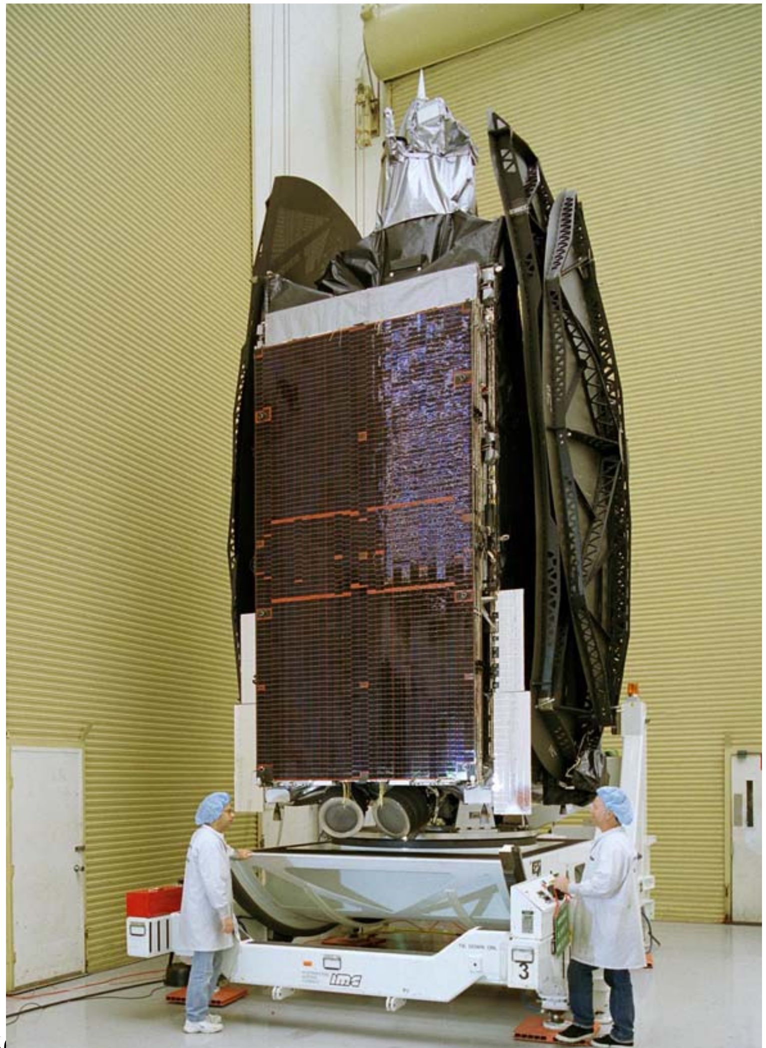
- Why study in optical?
  - Radar 1/r**4 versus optical 1/r**2
  - Radar better at LEO (Low Earth Orbit)
  - Optical better at GEO (Geosynchronous Earth Orbit)
    - Period = 23 hours 56 minutes 4 seconds (1 sidereal day)
    - Radius = 42,164 km

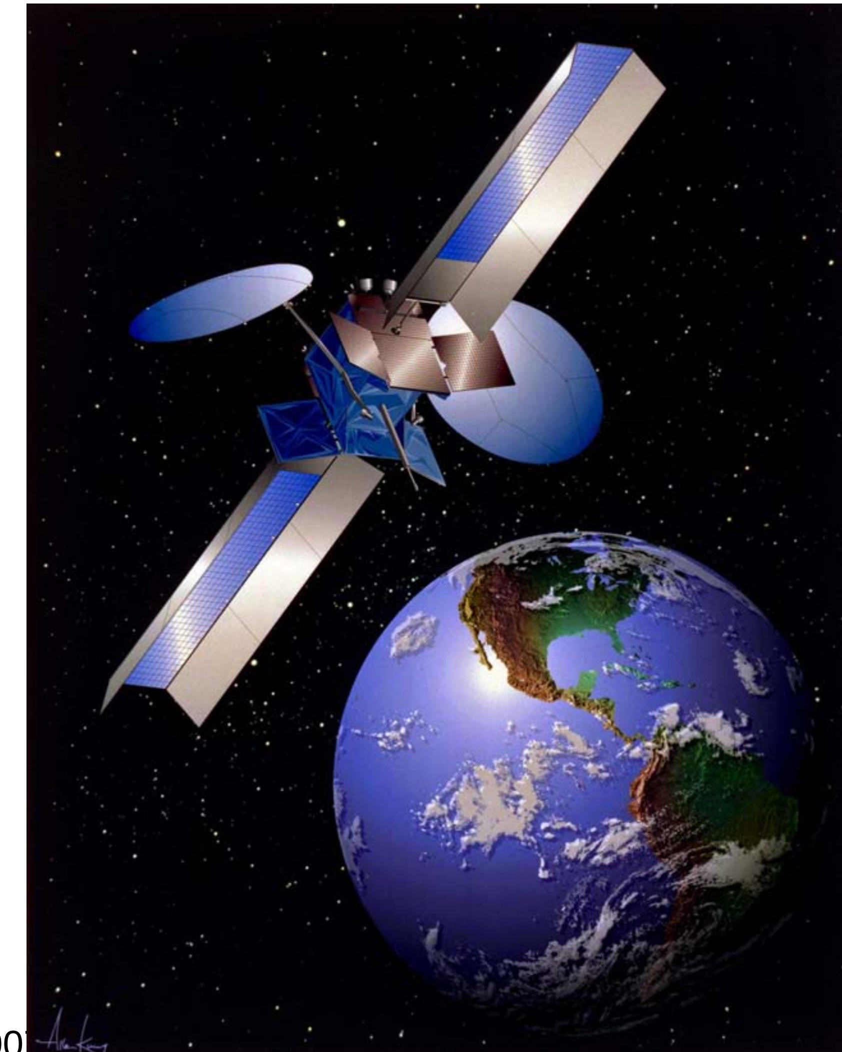
Syncom 1 – launched February 14, 1963

Failed on orbit insertion – 1st piece of GEO debris!



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





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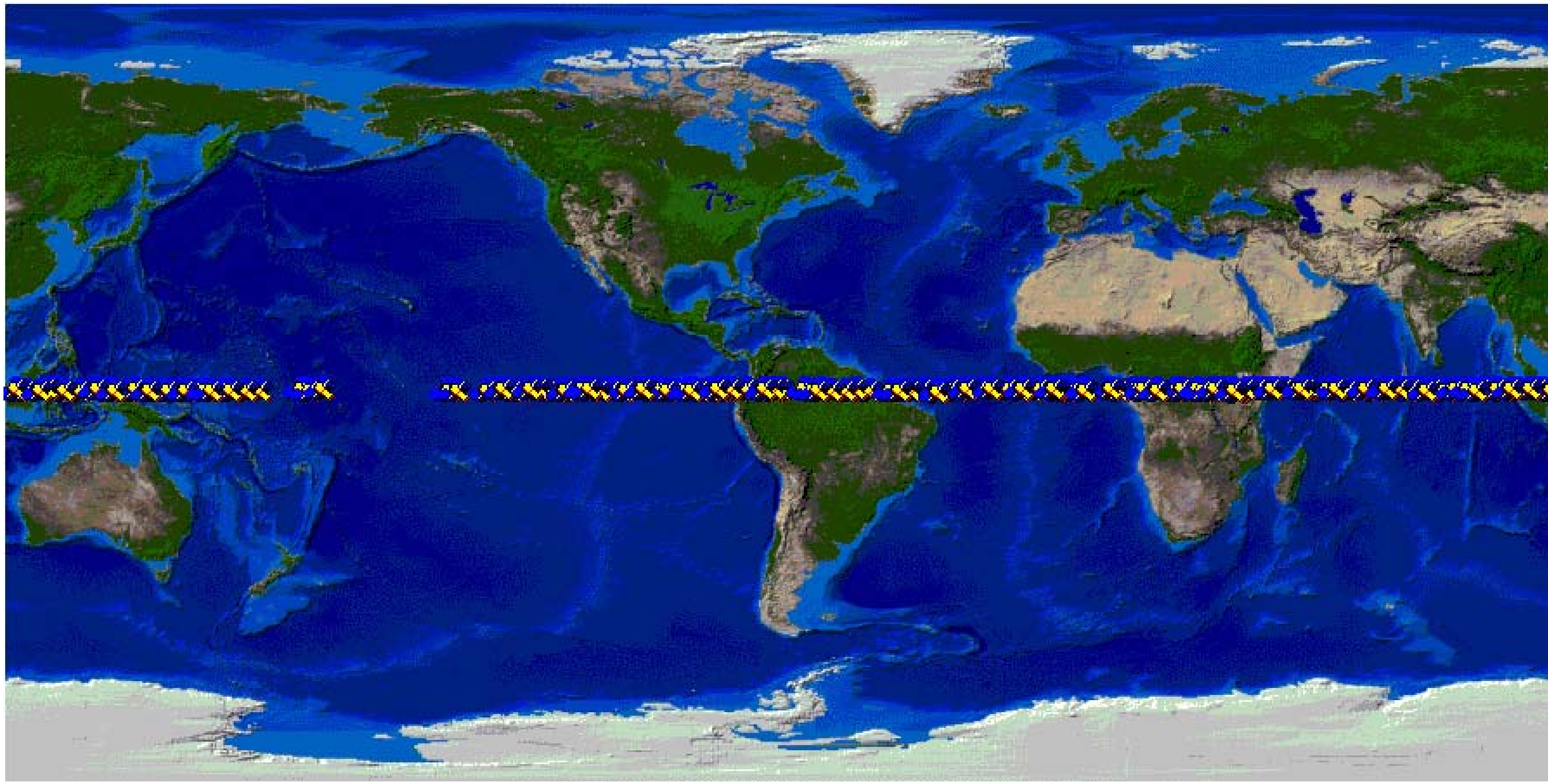
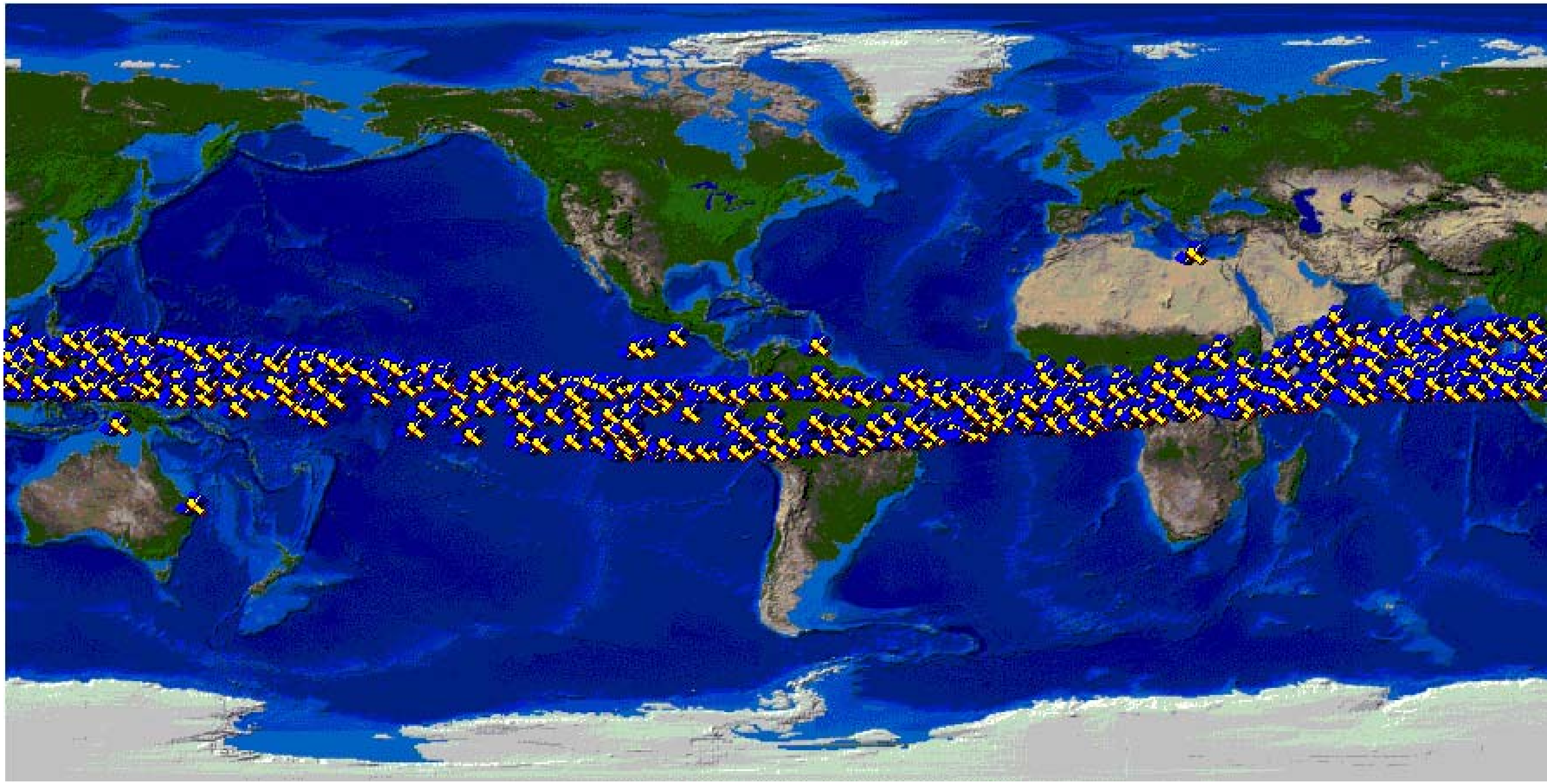


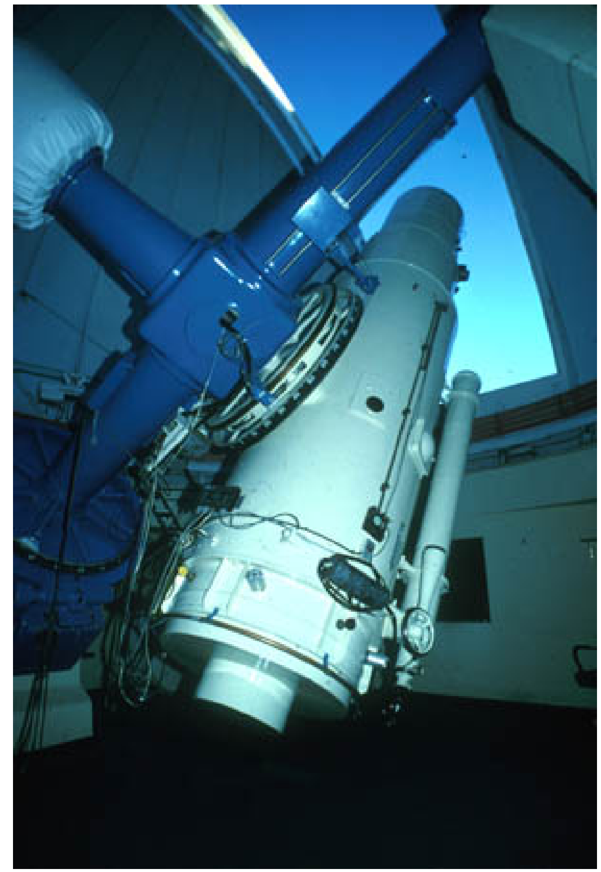


MODEST – Michigan **O**rbital **DE**bris **S**urvey **T**elescope

the telescope formerly known as the Curtis-Schmidt

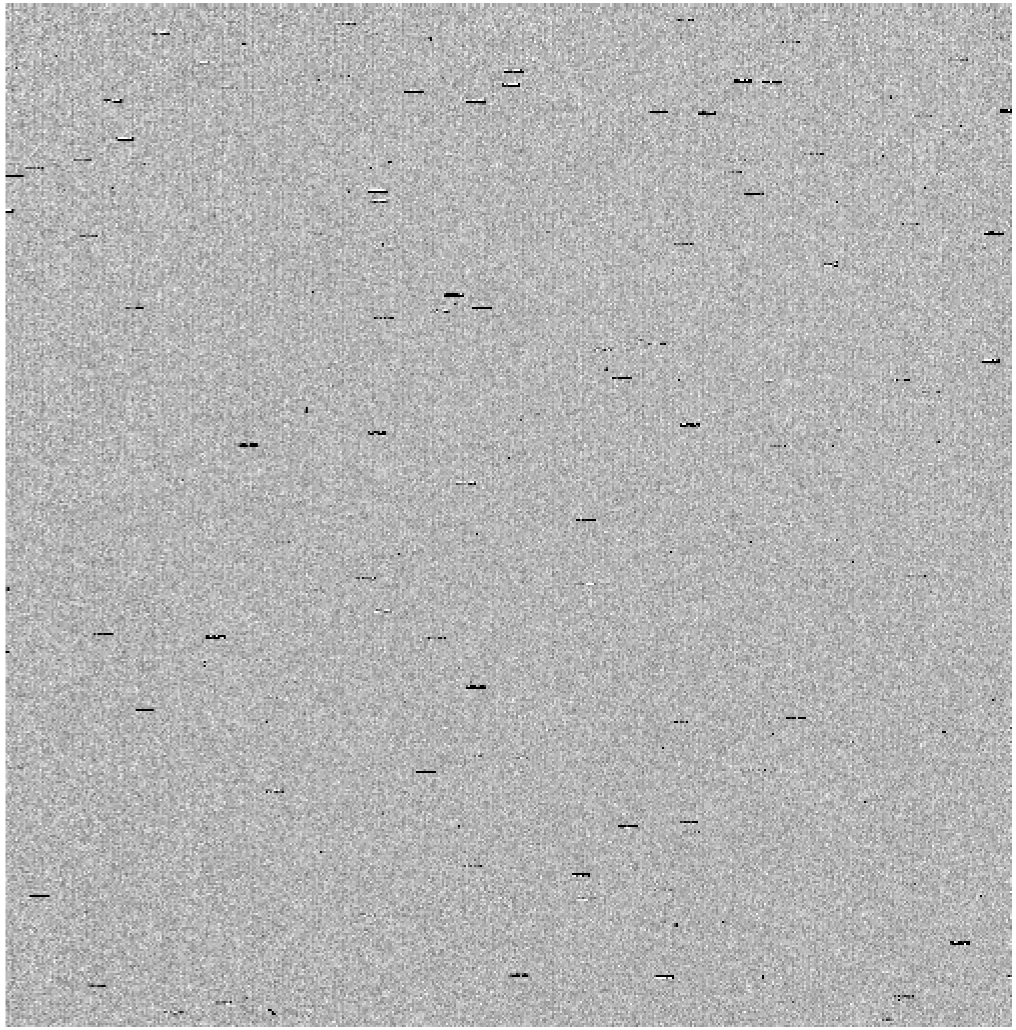
Cerro Tololo Inter-American Observatory, Chile

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

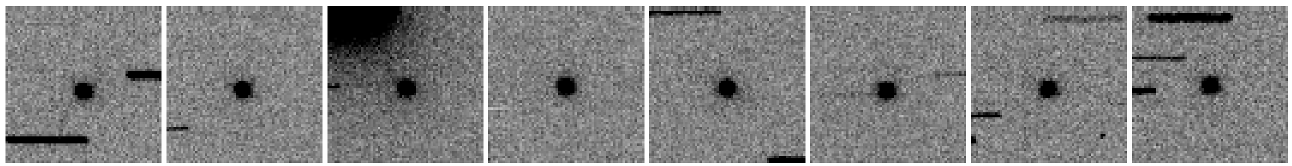


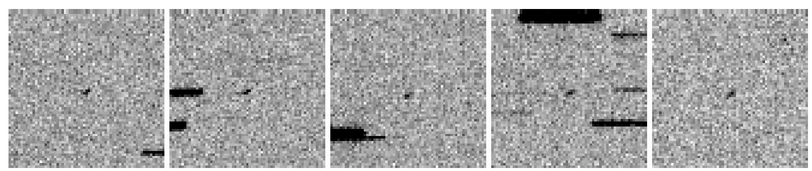
GEO Debris Survey

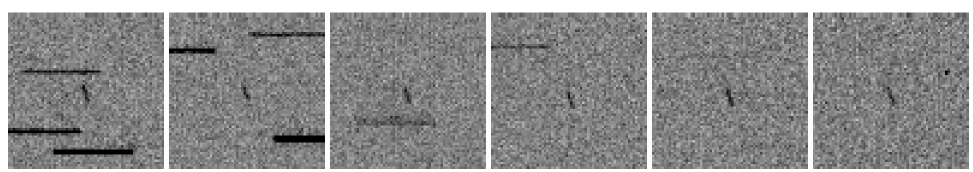
- Scanning CCD through a broad R filter (V+R).
- 5 second exposure every 37.9 seconds as track position of constant right ascension and declination all night long close to anti-solar point.
- Cover strip over 100 degrees long by 1.3 degrees high each night.
- Average of 8 detections of each GEO object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



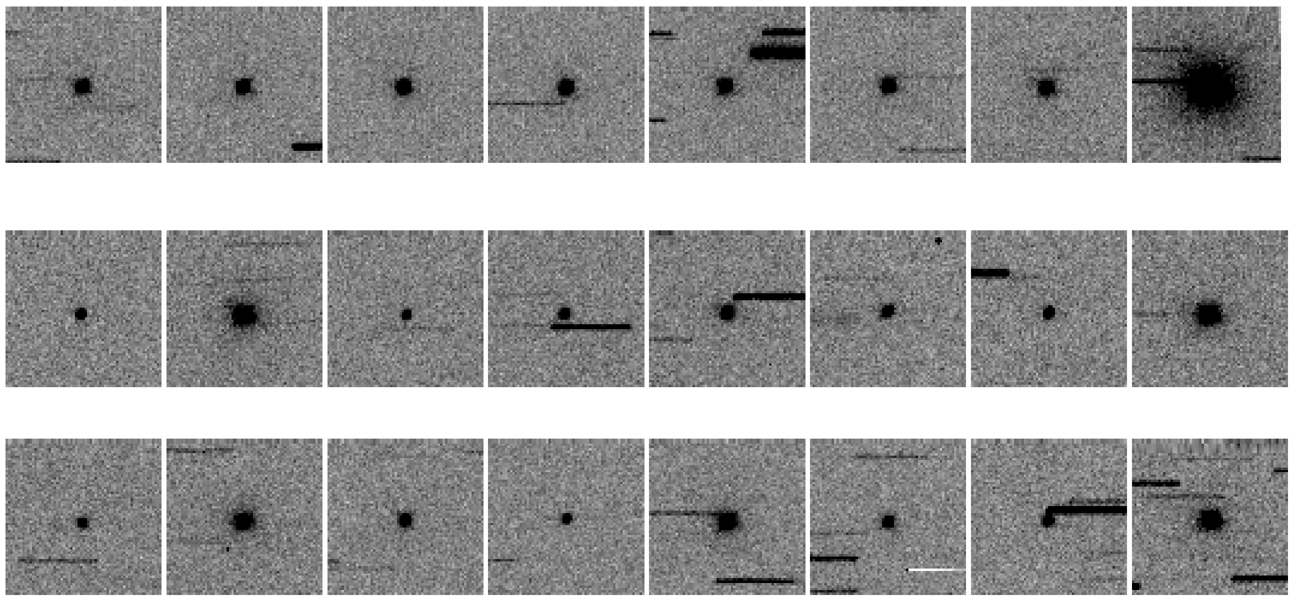
Examples of Detections

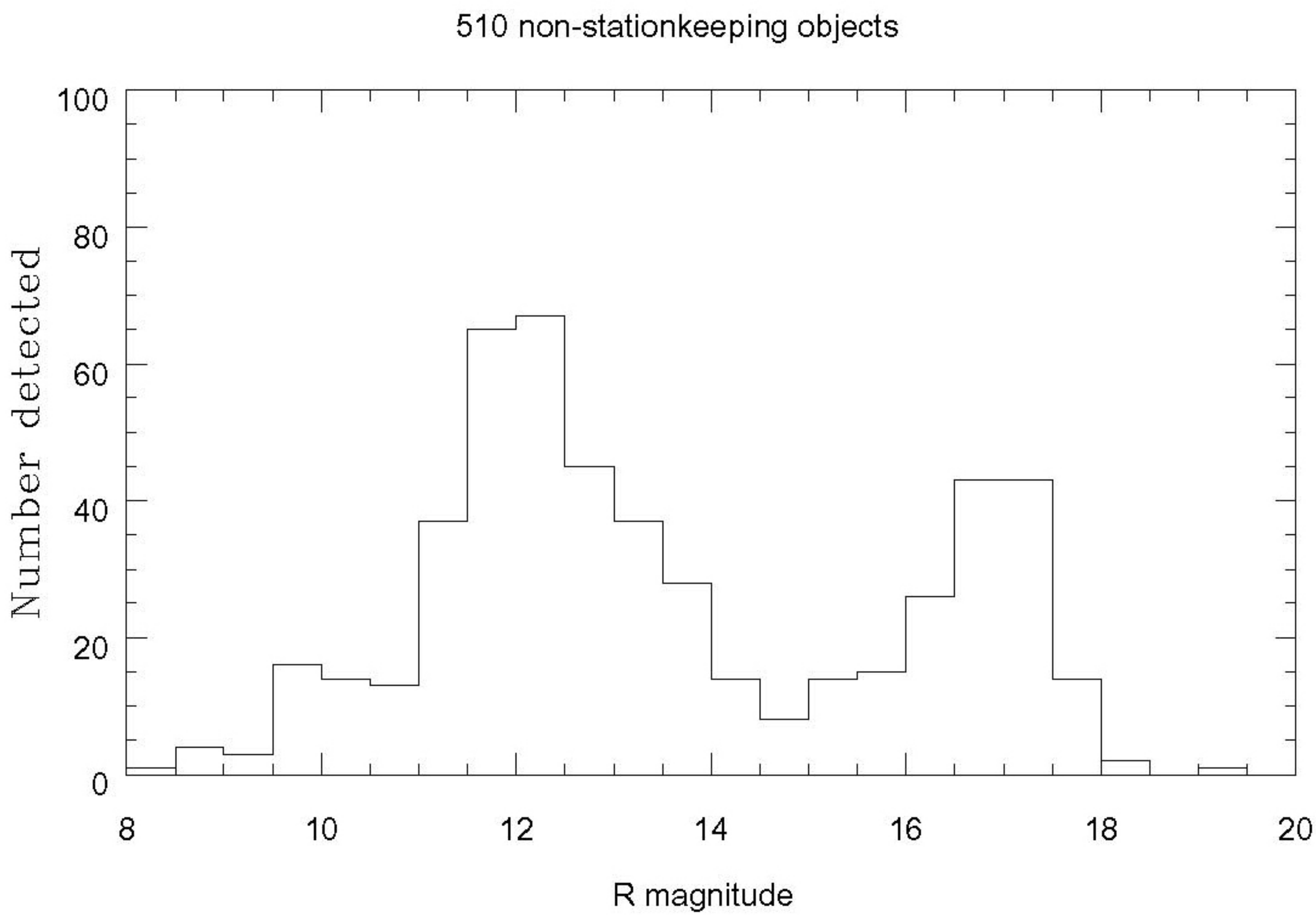




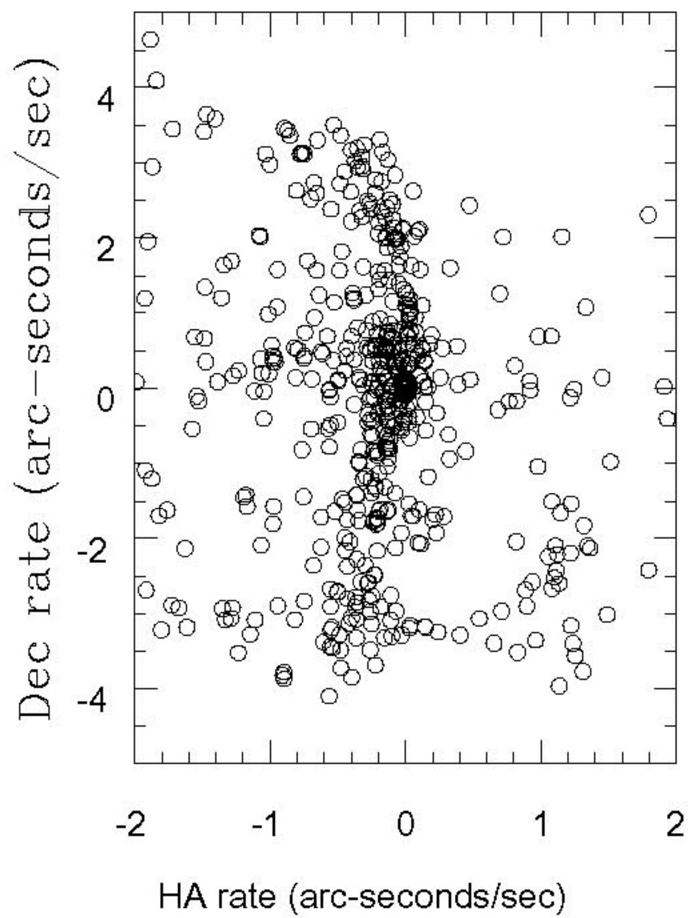


Brightness Variations Common

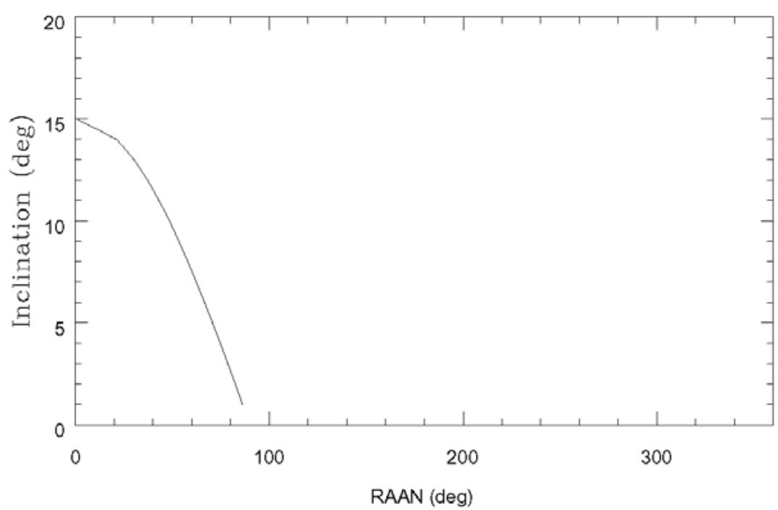


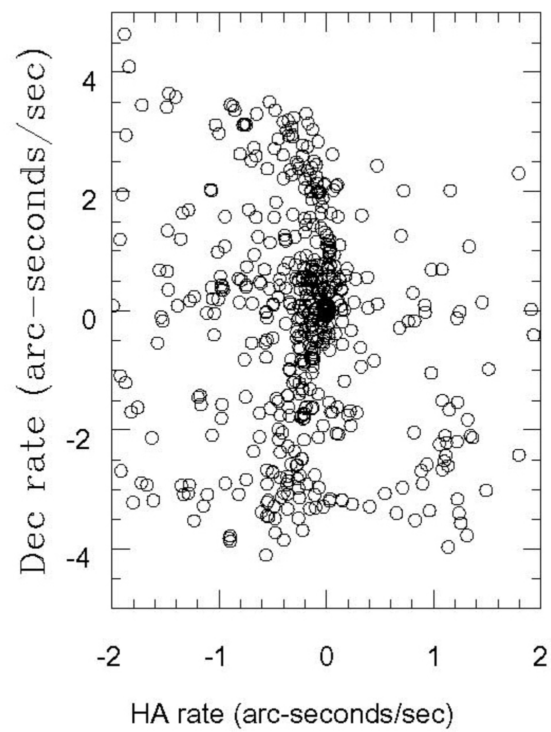

510 non-stationkeeping objects
Number detected
0
20
40
60
80
100
8
10
12
14
16
18
20
R magnitude

Observed Angular Rates

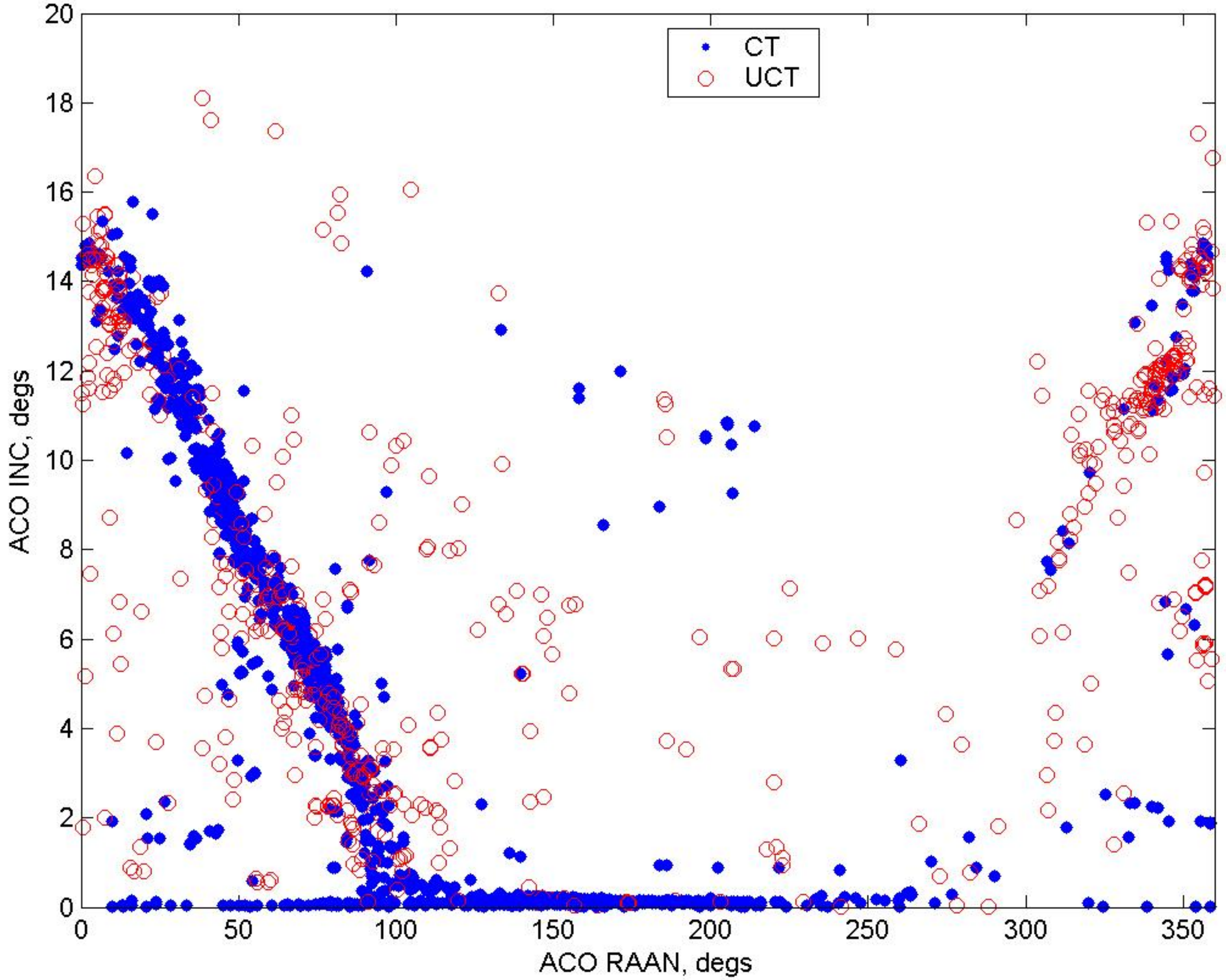


What rate distribution is expected?

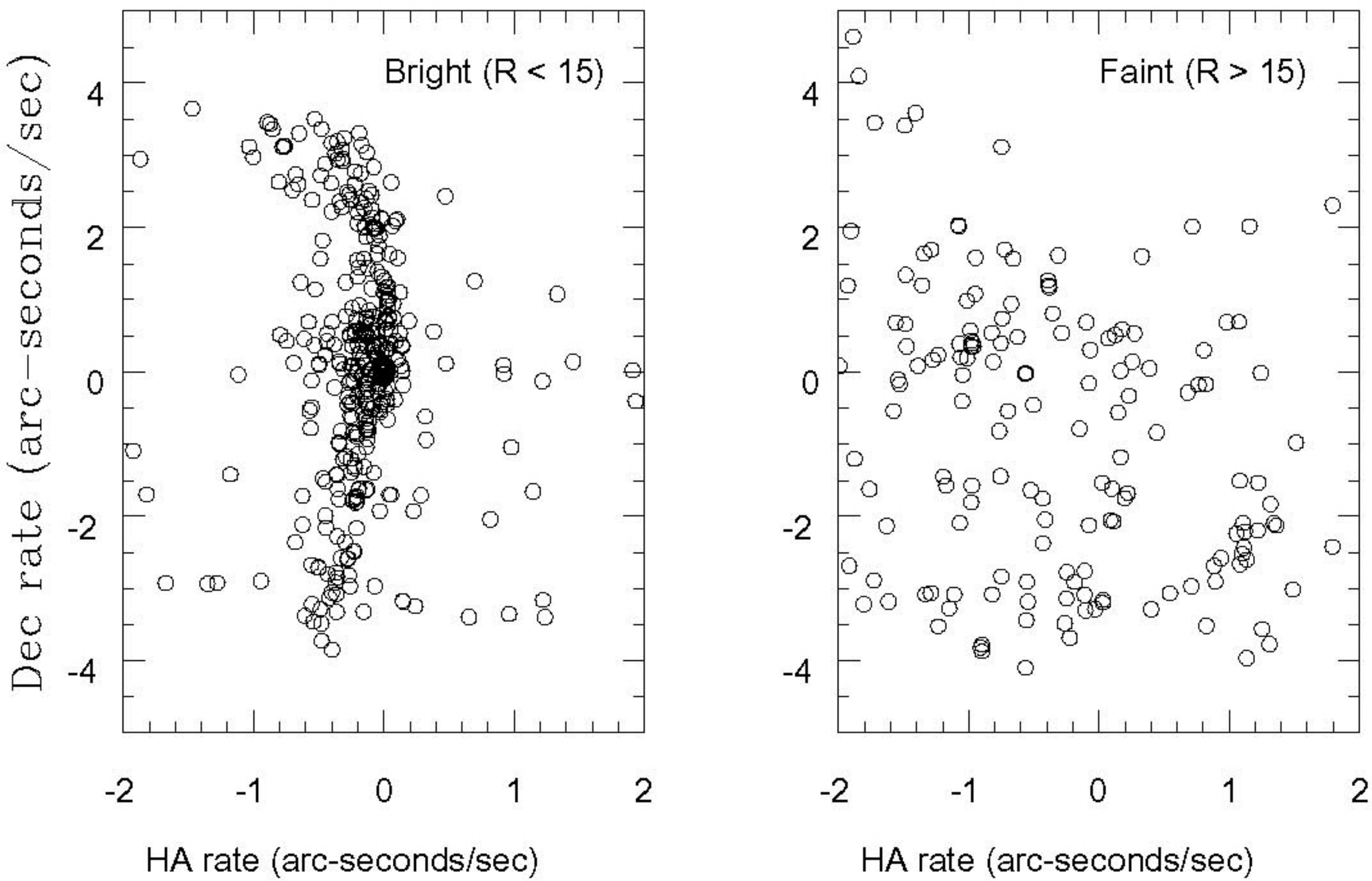




Object released from station-keeping follows well defined RAAN-inclination relationship with time. So expect locus of objects in angular rate box.


CT
UCT
ACO INC, degs
ACO RAAN, degs
0
2
4
6
8
10
12
14
16
18
20
0
50
100
150
200
250
300
350

Two Populations at GEO

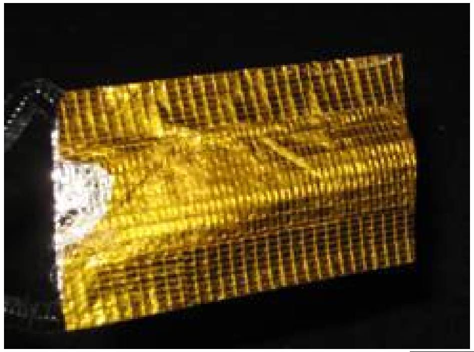


High Area-to-Mass Ratio Material (A/M)

- 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)

Space-facing MLI (A/M=22)

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

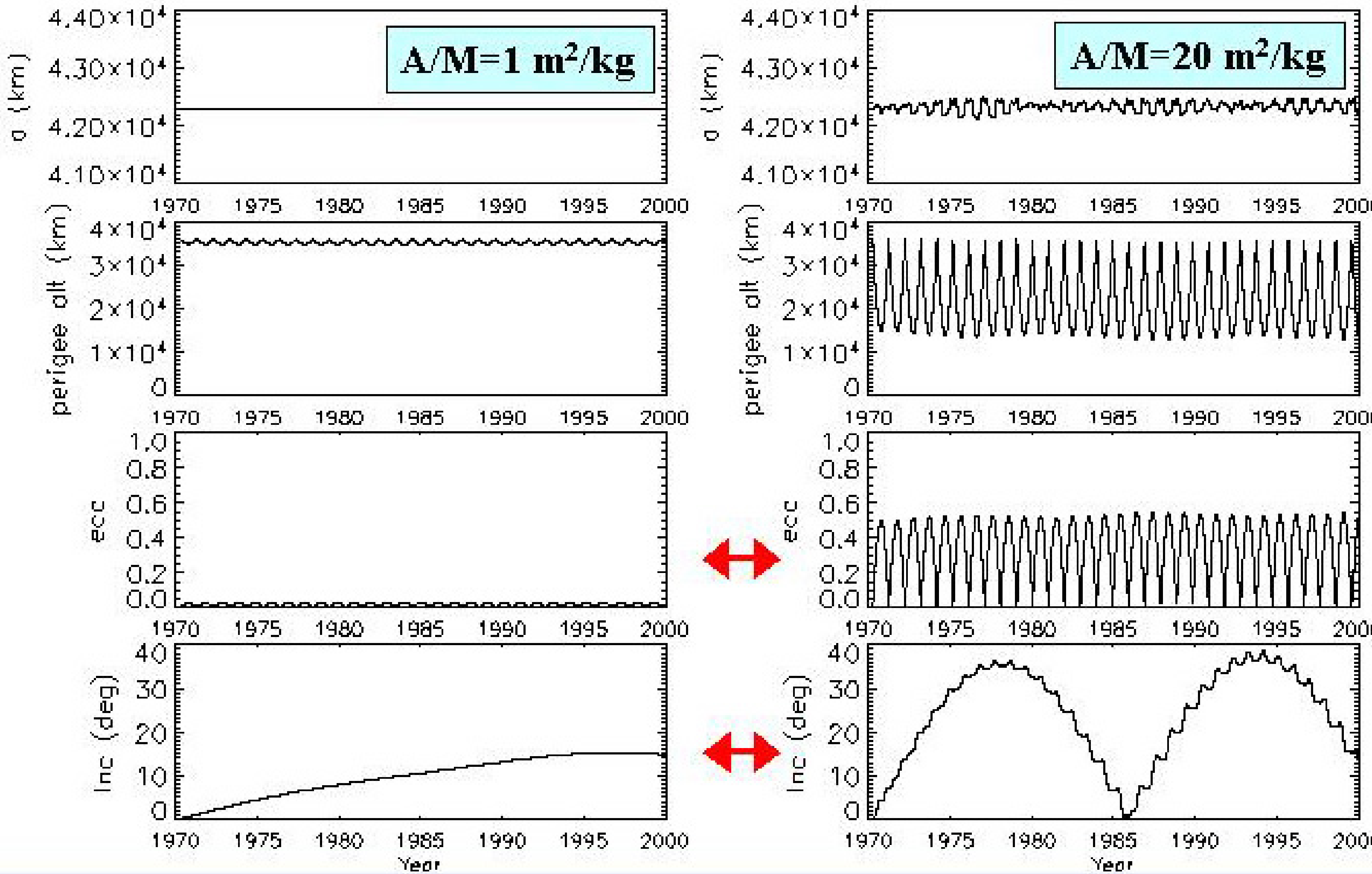
Interior piece of MLI:
white fabric (A/M=43)

Examples of MLI Release in LEO

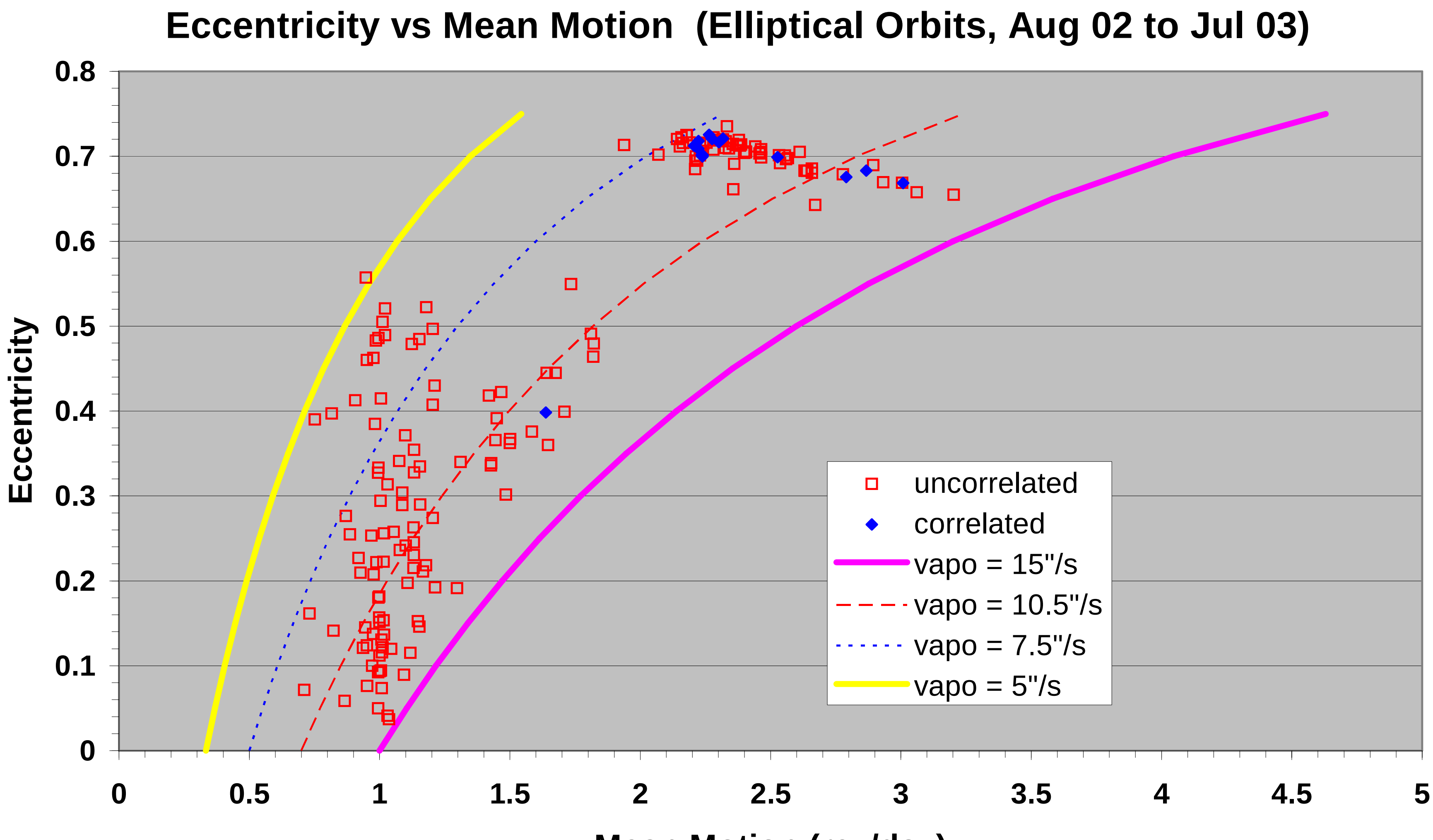
FUSE spacecraft being prepared for launch.

- 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

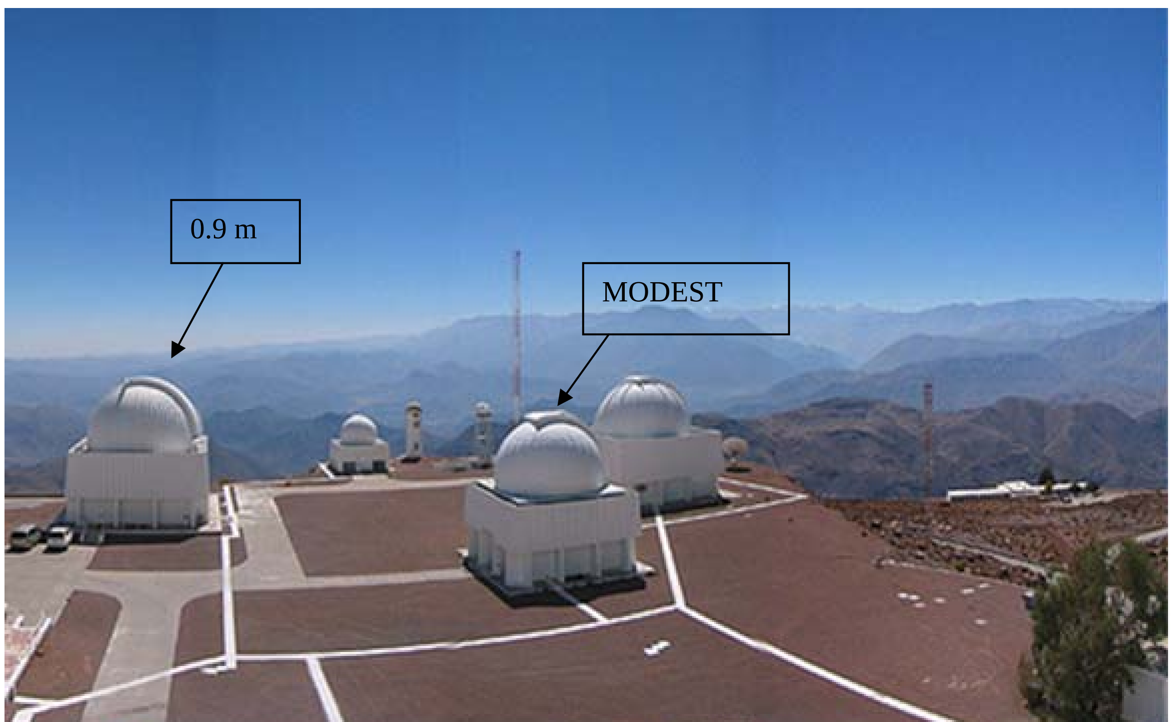


(Courtesy T. Schildknecht/ESA)

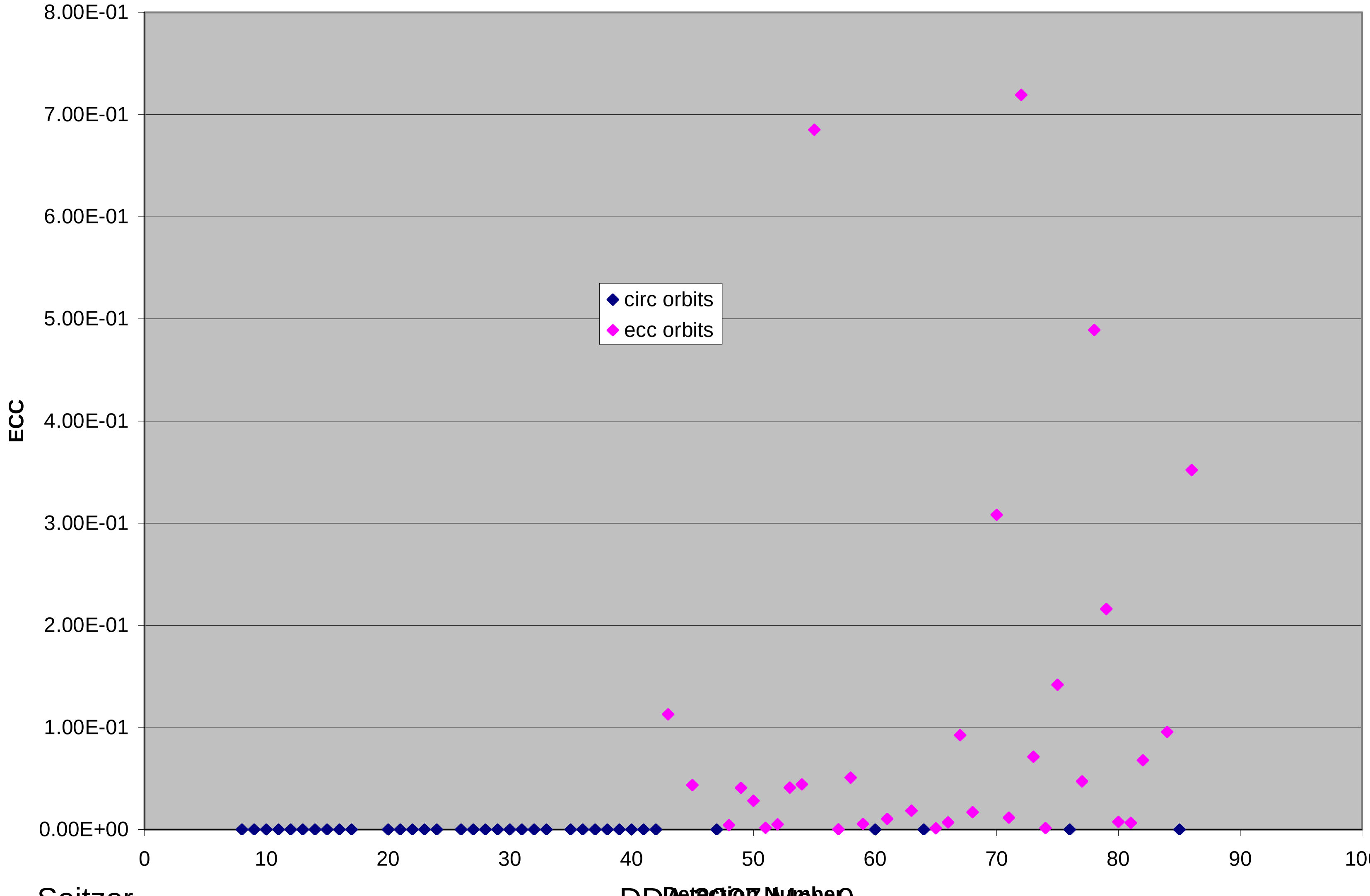
Two Telescopes March 2007 Survey and Follow-up

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