



Modeling Multi-Layer Insulation Debris in GEO

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Outline

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GEO Observations

- In GEO regions, objects with high area-to-mass ratios are being observed
- Observations by:
 - Astronomical Institute, University of Bern (ESA's Space Debris Telescope, ZIMLAT, ZIMSMART)
 - Keldysh Institute of Applied Mathematics using the ISON (International Scientific Optical Network)

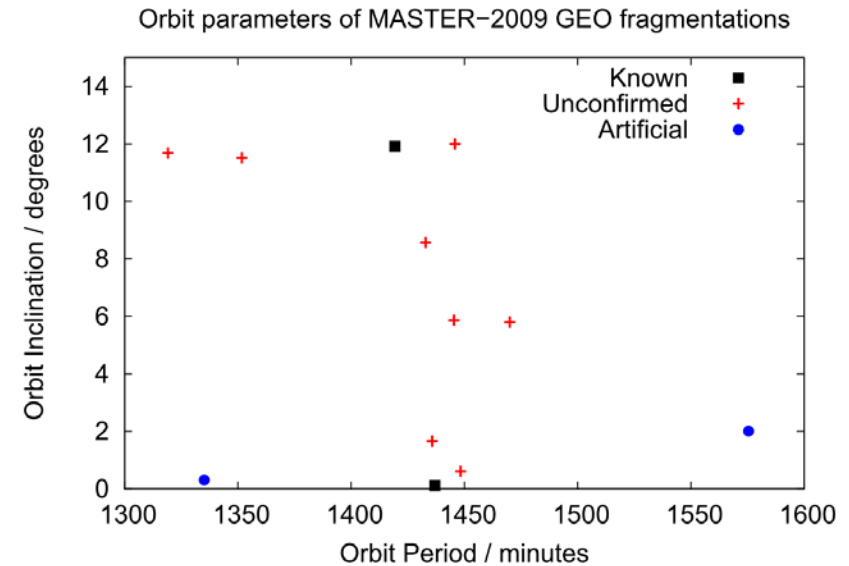
Parameter	Approximate Range
Size	> 10cm
Effective A/m	0,1 .. 86,7 m ² /kg
Orbit period	1100 .. 1700 minutes
Eccentricity	< 0,75
Inclinations	< 30°

Could the observed objects have been created through fragmentation events in GEO?

Fragmentations in GEO

- Basis for investigation was GEO fragmentation list of ESA *MASTER-2009* Model:

Art	Objekt	Epoche
Known	Ekran-2	1978
Known	Titan 3C Transtage 5	1992
Unconfirmed	Titan 3C Transtage 24	1981
Unconfirmed	Titan 3C Transtage 30	1982
Unconfirmed	Titan 3C Transtage 28	1987
Unconfirmed	Titan 3C Transtage 11	1987
Unconfirmed	Titan 3C Transtage 14	1994
Unconfirmed	Ekran-4	1982
Unconfirmed	SatCom 1	1999
Unconfirmed	Telecom 1C	2002
Artificial	--	1998
Artificial	--	1992



- Transtage upper stage uses little MLI
- Ekran, SatCom, Telecom: 3-axis stabilized with typical exterior MLI thermal insulation



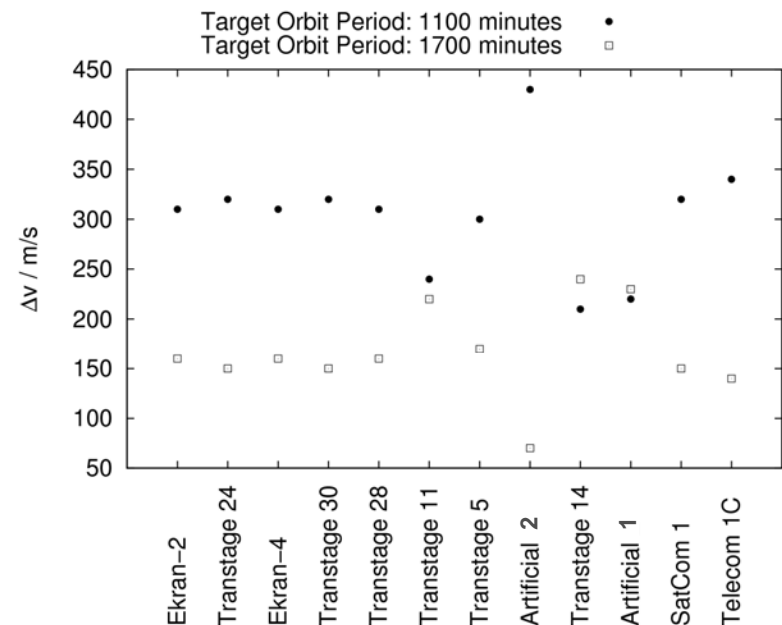
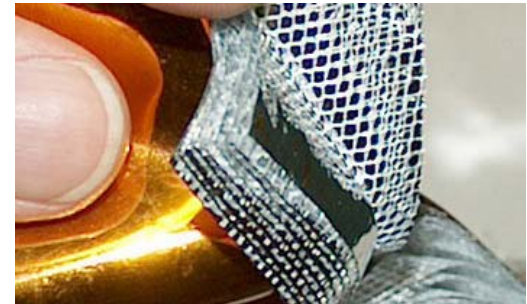
Boundary Conditions for Modeling

Multi-Layer Insulation

- Kapton®, Mylar®, Tedlar® PVF, Teflon® FEP
- Metalized surface: gold, silver, aluminium, copper, germanium
- 2 cover layers (outer & inner):
ca. 3.8 – 5.6 m²/kg
- ~ 10 – 20 reflector layers:
up to 111 m²/kg

Added velocity

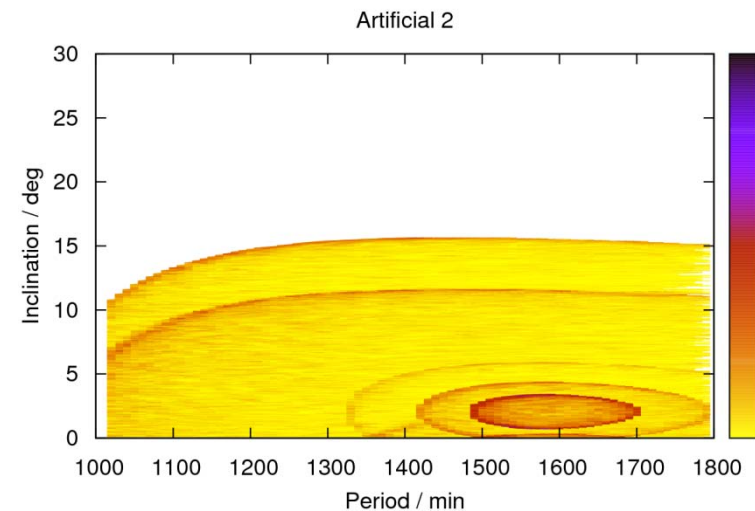
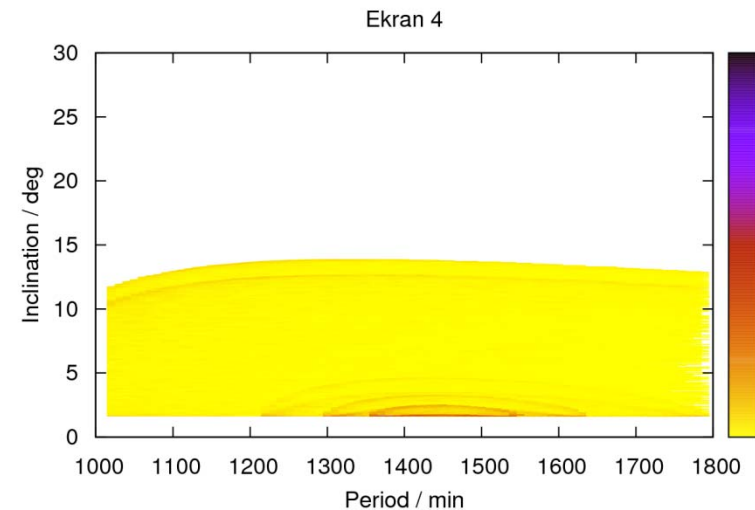
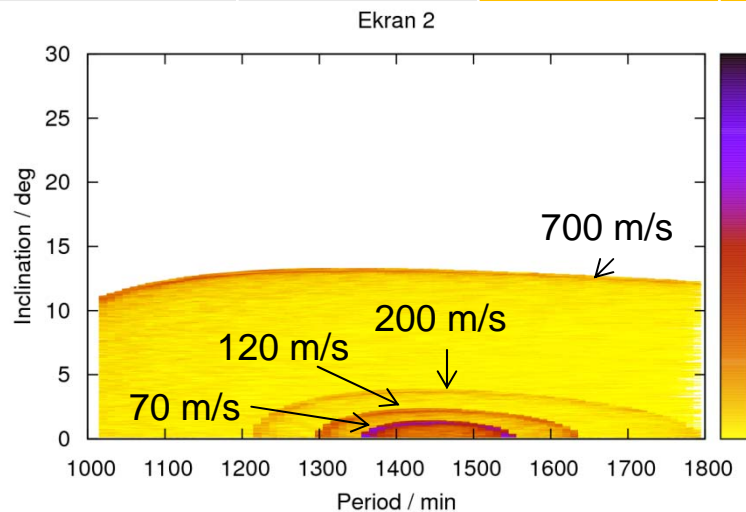
How much velocity would have to be imparted on fragments for them to attain the highest & lowest observed altitude?



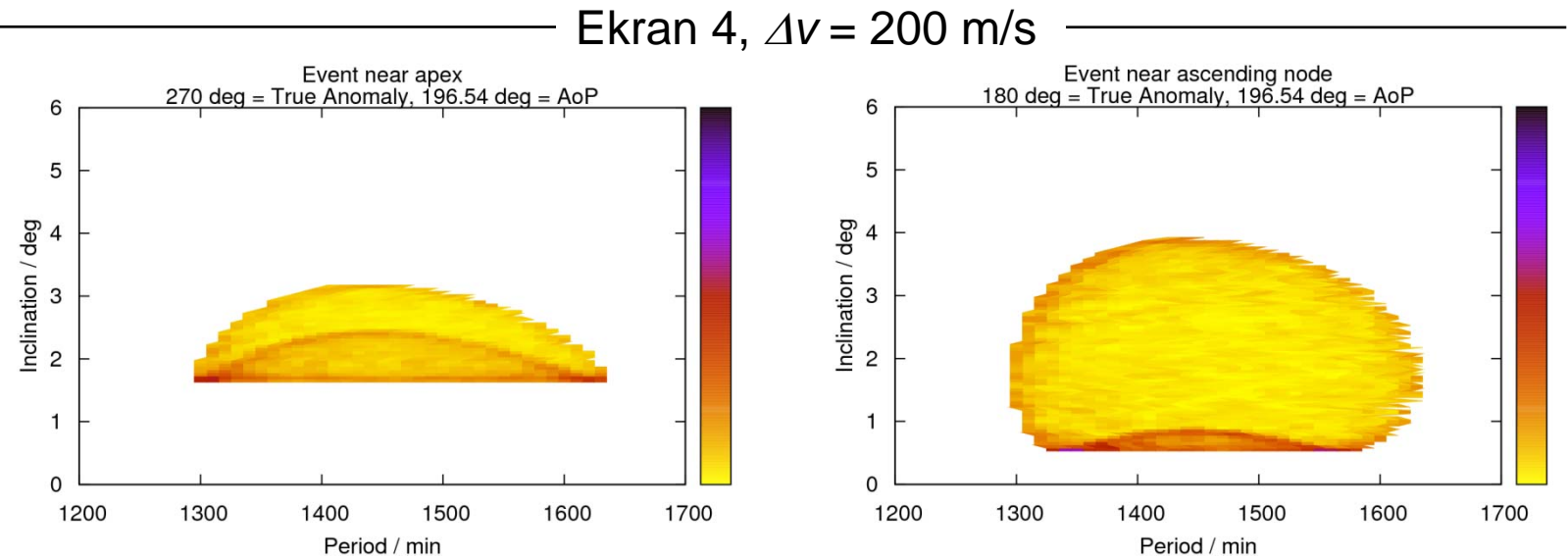
Added Velocity

- Adder velocity for MLI-fragmentation model taken from NASA Breakup Model
- **NASA Breakup Model NOT calibrated for MLI!**

AMR m ² /kg	$\mu - \sigma$ m/s	μ m/s	$\mu + \sigma$ m/s
1	30	70	180
10	50	120	300
40	70	200	700



Event location along orbit



- Perturbation theory for small accelerations:
 - Inclination change only by acceleration normal to orbit-plane
 - Change largest at orbit nodes
- Orbit inclination can only become zero, if event takes place at either node

Solar Radiation Pressure

Perturbing Accelartion

- Solar radiation pressure, cylindrical shadow
- **Not accounted for:**
 - thermal re-radiation,
 - earth-/moon albedo

Reflectivity

- $CR = 1 + R$,
where $R = f(\text{diffuse, specular reflectance})$
- Degrades through external influences
- Assumption: reflectivity asymptotes towards end-value

Perturbing acceleration through
external radiation

depends on:

reflectivity (diffuse/specular),
orientation, (A/m), shape

$$\rightarrow (A/m)' = (A/m) \cdot CR$$

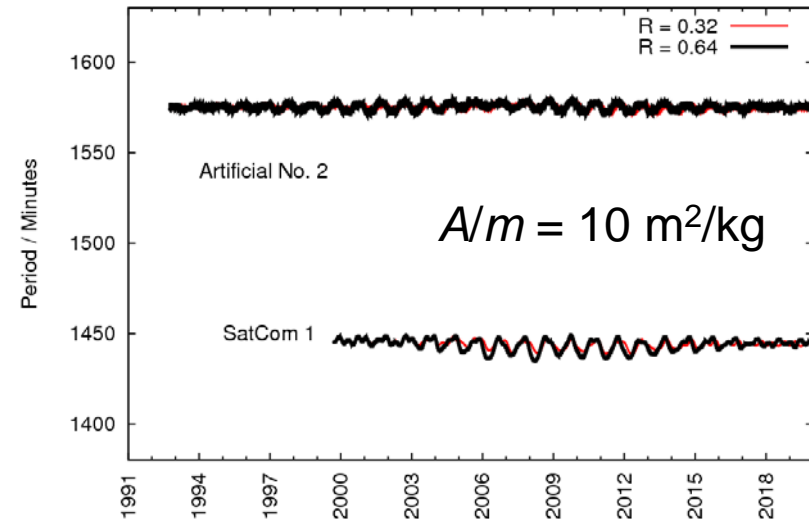
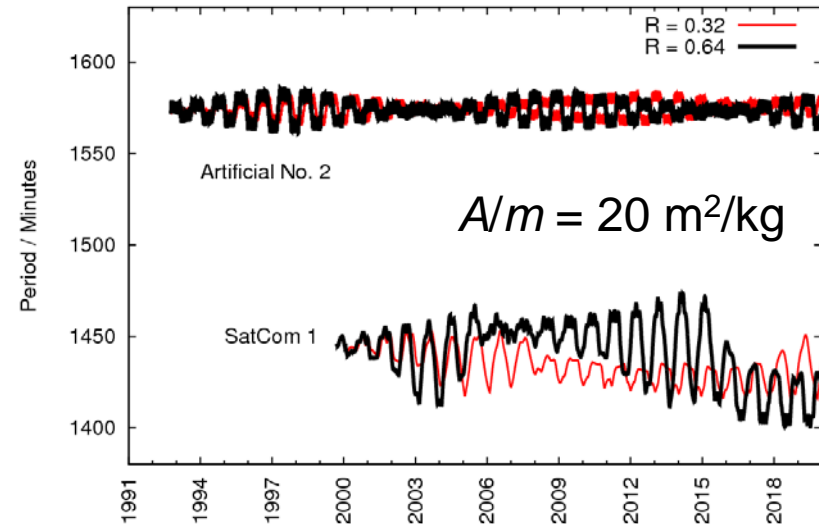
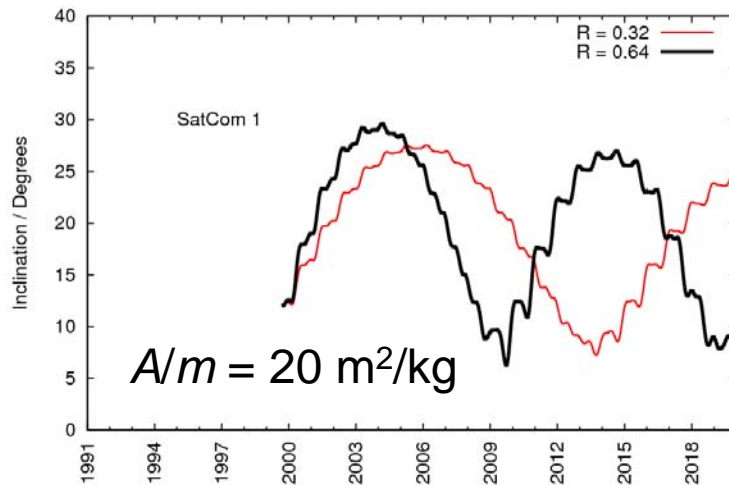
CR = reflectivity coefficient (1 .. 2)

Average Reflectivity R values
from different publications:

Starting reflecitivity	Reflectivity after degradation
0.64	0.32

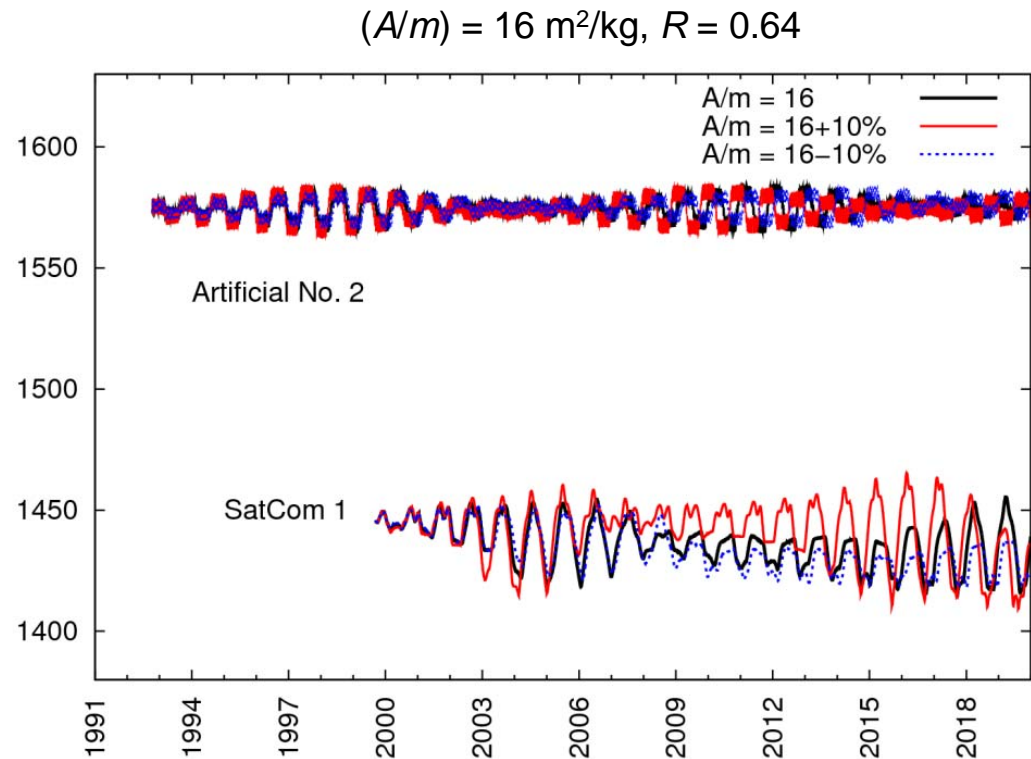
Influence of Reflectivity and A/m

- **Orbit period:**
 - Certain circumstances can lead to secular changes
 - Pronounced periodic perturbation with period of 1 year
- **Inclination:**
 - Long-periodic change
 - Period is influenced by CR and A/m



Influence of Orientation

- Transverse accelerations through orientation not yet taken into account
- Influence on orbit period through varying of sun-oriented surface area $\rightarrow A/m$
- Change of (A/m) by 10% has negligible influence on orbit period



Conclusions

Initial Orbit

- Maximum inclination change at $\Delta v = 700$ m/s: **12 degrees**
- $\Delta v = 250$ m/s → All events produce orbit periods (upper end) > 1700 Minuten
- $\Delta v = 300$ m/s → All events produce orbit periods (lower end) ~ 1100 Minuten

Perturbations

- **Amplitude of oscillations**, minimum and maximum values of orbit period and inclination **depend on initial orbit**
- Amplitude of orbit period oscillations through modelled perturbations:
 - $10 \text{ m}^2/\text{kg} \rightarrow < 50$ minutes
 - $20 \text{ m}^2/\text{kg} \rightarrow < 100$ minutes
- Under certain conditions also secular orbit changes possible

Summary

- GEO event list of the ESA *MASTER*-2009 Model
- Transtage upper stages have lowest probability for having created MLI fragments
- Realistic velocities imparted on MLI fragments in fragmentations not known
- Using imparted velocity distribution from NASA breakup model covers all observed orbits
- Oscillations in inclination through orbit perturbations covers all observed inclinations
- Current work is starting point for further investigations into such matters