# Environmental Challenges To Space Security

## (Space Debris and Space Weather)

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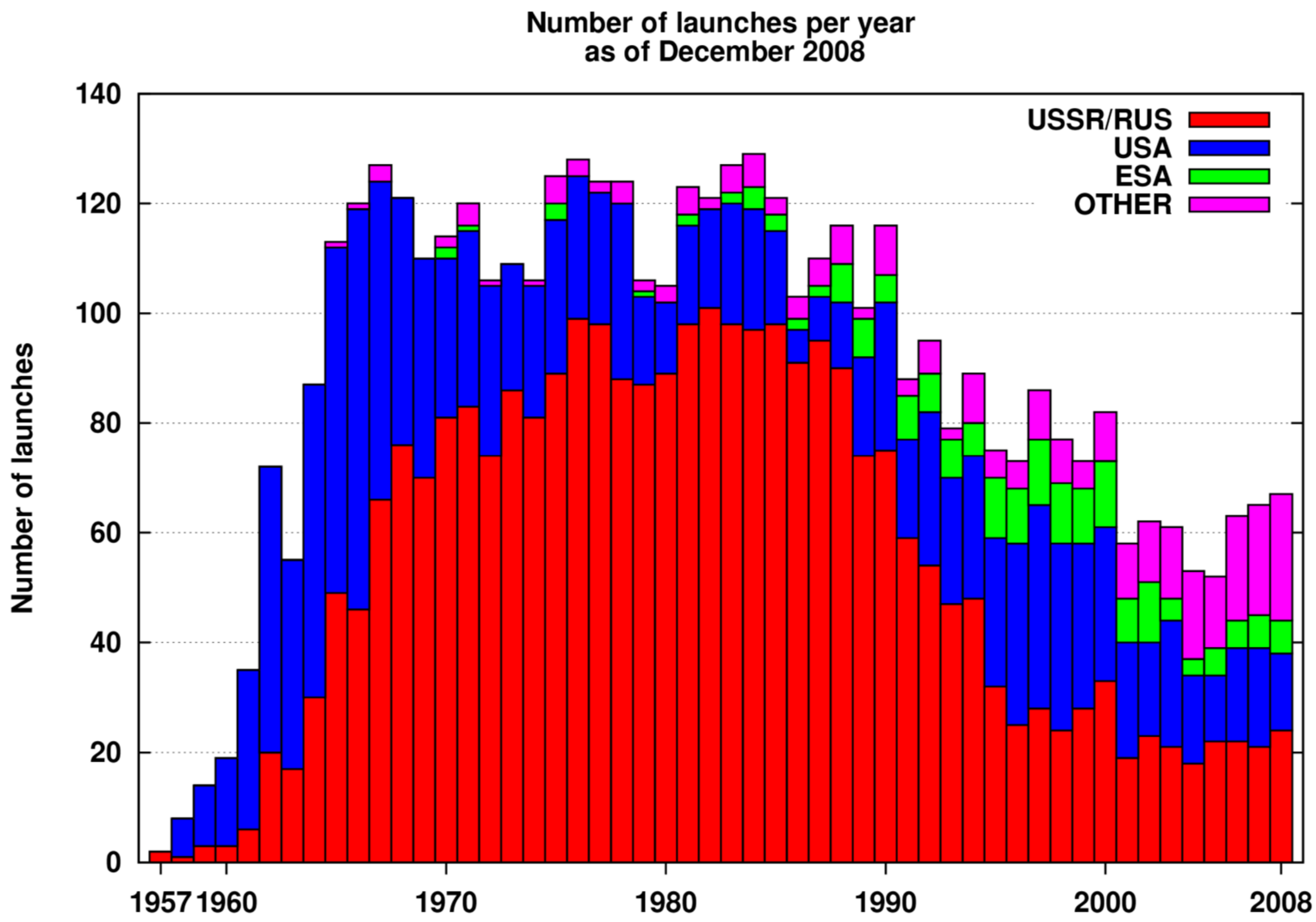
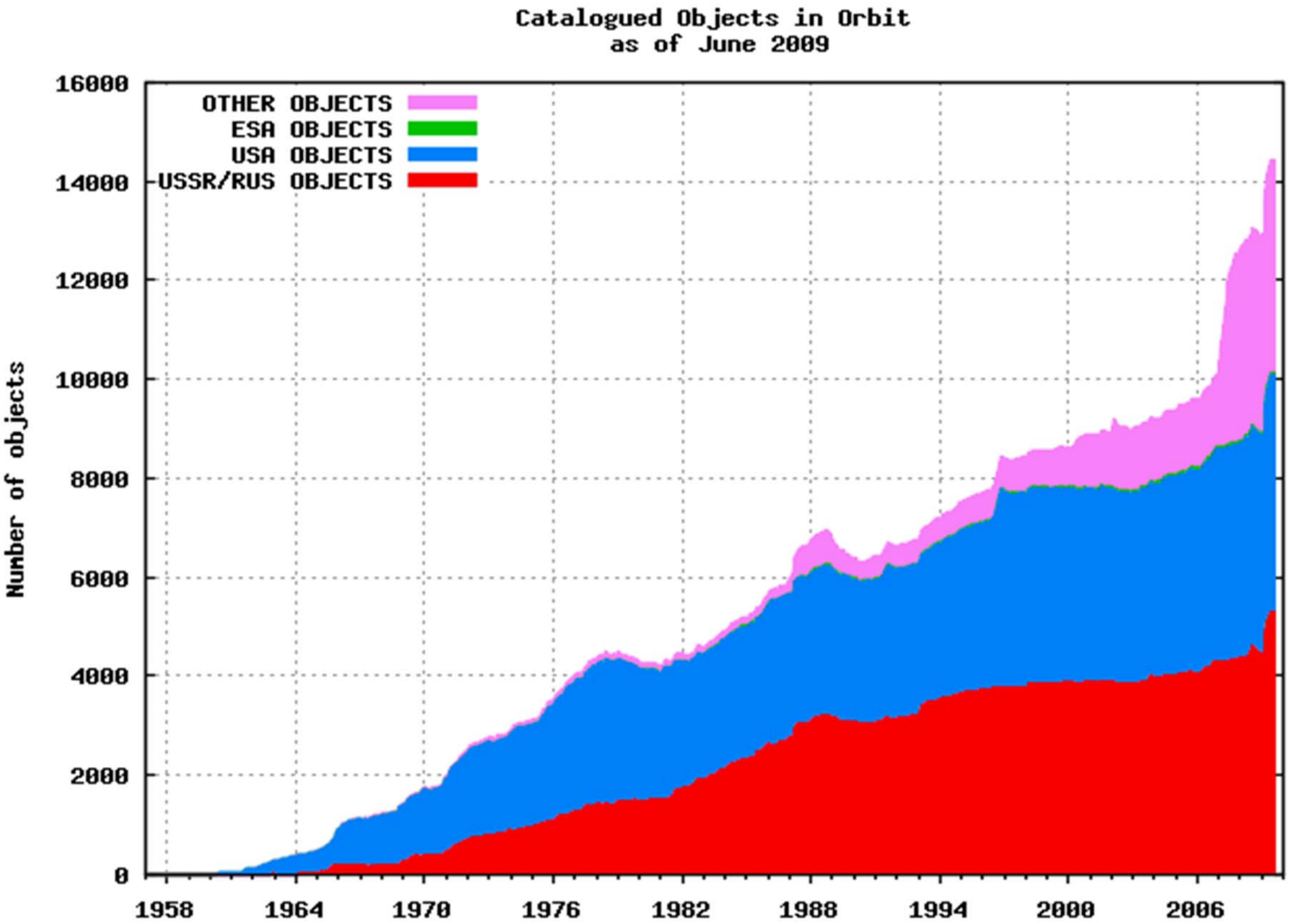
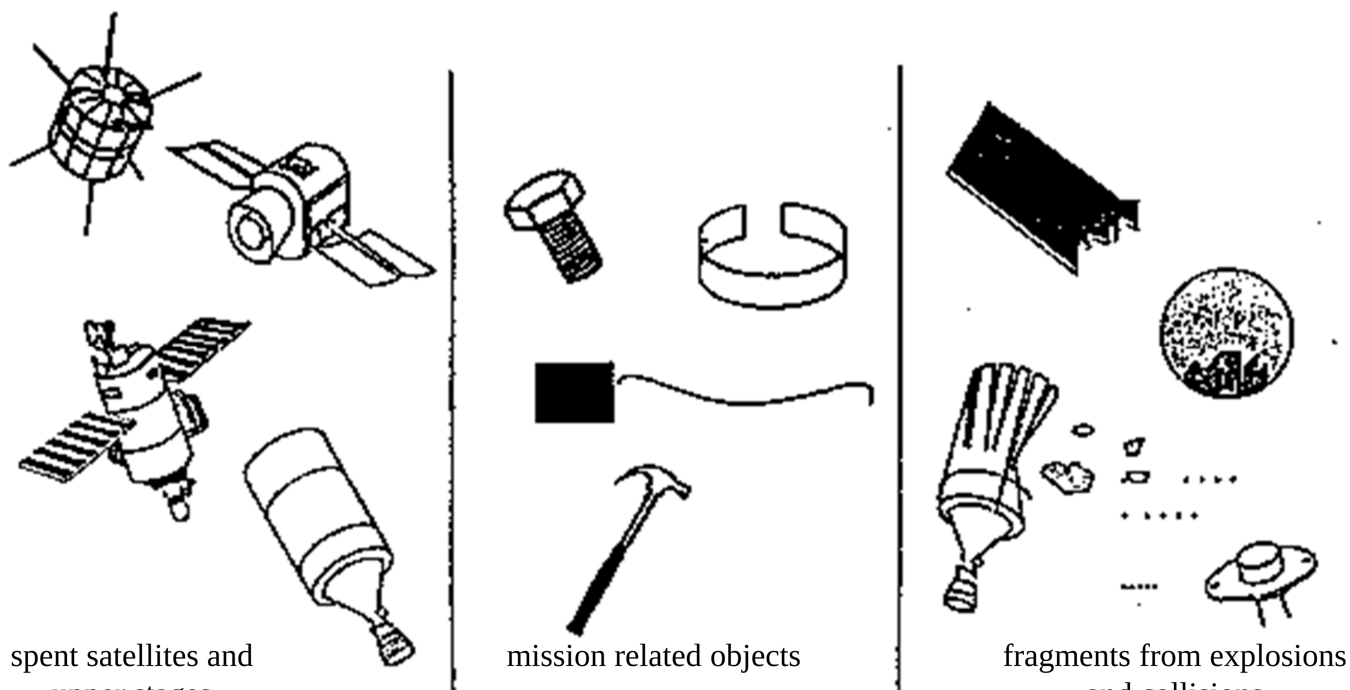



Approx. 4,600 launches led to about 34,000 catalogued objects



Catalogued Objects in Orbit
as of June 2009
OTHER OBJECTS
ESA OBJECTS
USA OBJECTS
USSR/RUS OBJECTS
Number of objects
16000
14000
12000
10000
8000
6000
4000
2000
0
1958
1964
1970
1976
1982
1988
1994
2000
2006

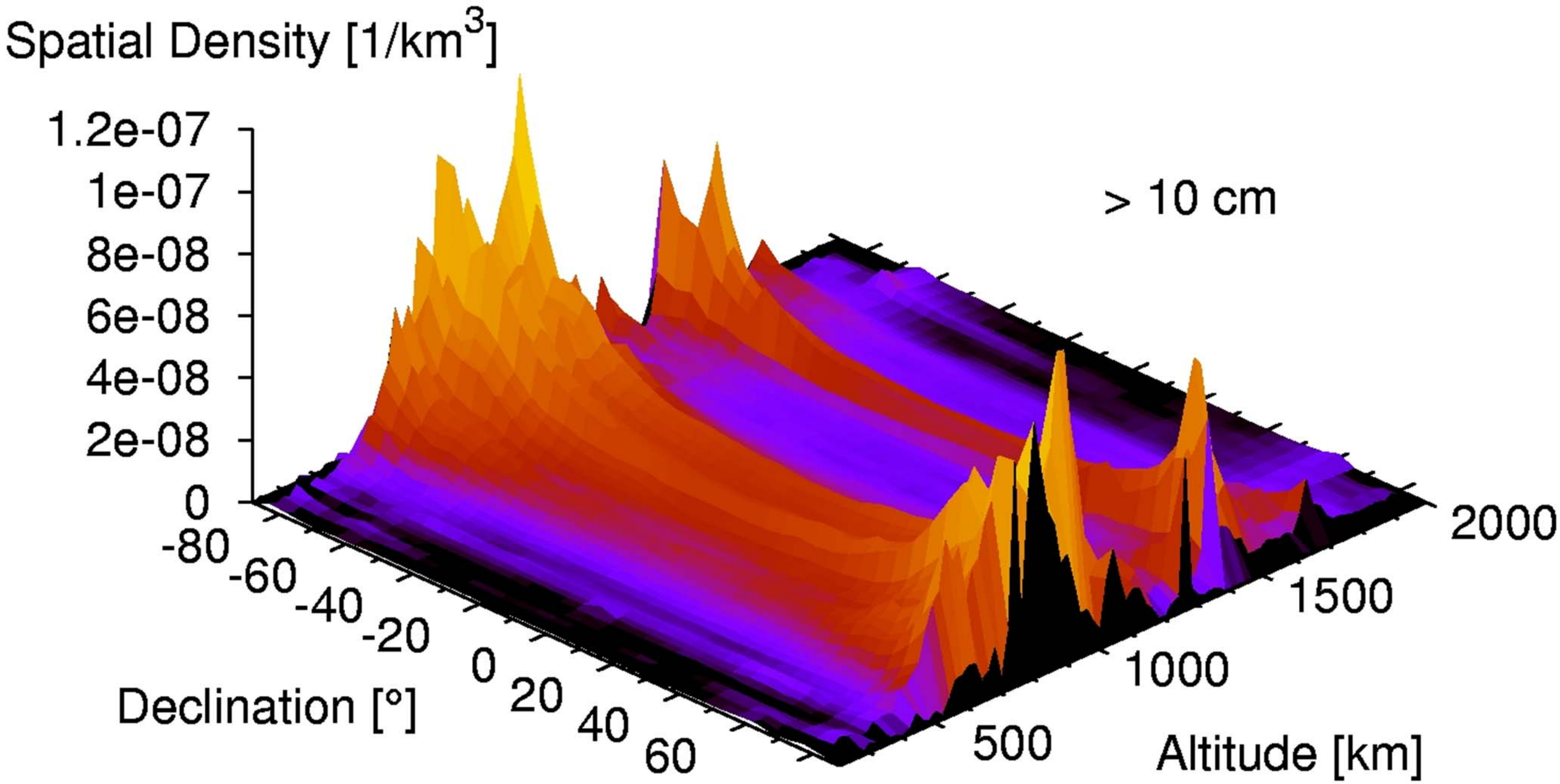
# Sources of Space Debris



# 200 explosions in space

# Known Collisions in Space

- December 1991: Kosmos 1934 is hit by a fragment of Kosmos 926 (both Russia)
- July 1996: Cerise (French military satellite) is hit by a fragment of an Ariane 1 rocket (exploded in 1986)
- January 2005: old US rocket is hit by a fragment of a Chinese rocket (exploded in 2000)
- 10 February 2009: Iridium 33 and Kosmos 2251 crash into each other. 1300 fragments at 800 km altitude


Spatial Density [1/km3]
1.2e-07
1e-07
8e-08
6e-08
4e-08
2e-08
0
> 10 cm
-80
-60
-40
-20
0
20
40
60
Declination [°]
500
1000
1500
2000
Altitude [km]

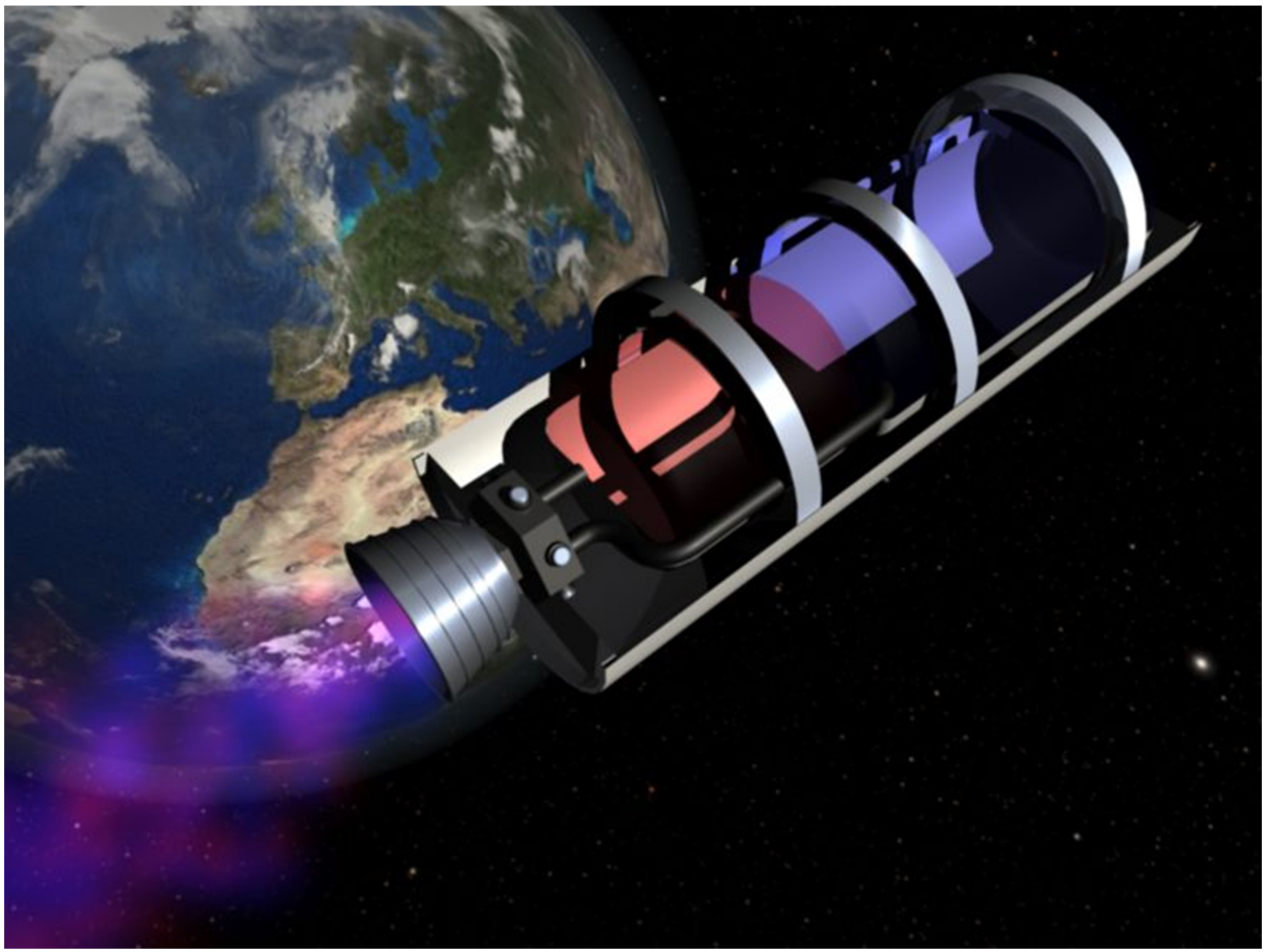
| Mean time between debris impacts for A=100m$^2$ | | | | |
|---|---|---|---|---|
| altitude | 0.1mm | 1mm | 1cm | 10cm |
| 400km | 4.5d | 3.9y | 1,214y | 16,392y |
| 800km | 2.3d | 1.0y | 245y | 1,775y |
| 1,500km | 0.9d | 1.5y | 534y | 3,190y |
| GTO | 16.8d | 17.7y | 7,650y | 96,591y |
| GEO | 78.1d | 264y | 154,006y | 414,749y |

# Protection against debris

12 mm aluminium sphere into aluminium block (v=6.8 km/s)

# Counter Measures
# (Mitigation)

# Passivation



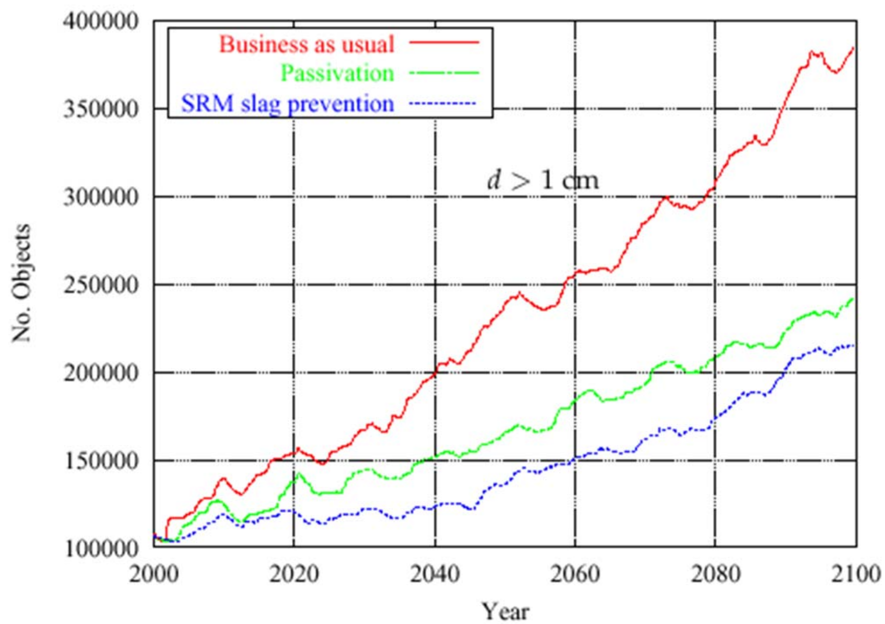
## Re-orbiting of Geostationary Satellites

$$\Delta v = \frac{\mu}{2va^2}\Delta a$$

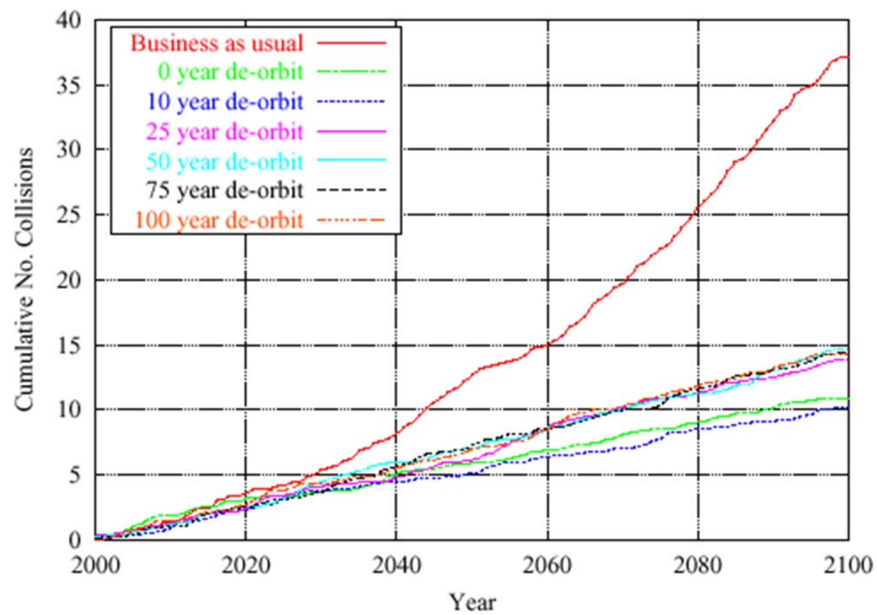
a=42,164 km, v=3.073 km/s
For Δa=100km: Δv=3.64 m/s

The re-orbit Δv equals approximately the Δv needed for 1 month of station keeping per 100km separation from the GEO ring. The minimum altitude increase is 300km.

# Long-term Effectiveness of Mitigation Measures




cases considered: business as usual scenario, passivation at EOL, and Solid Rocket Motor slag prevention




cases considered: business as usual and de-orbiting strategies with varying orbital lifetimes.

**Mitigation Options Category III:** require new developments and, in general, suitability of the method (technical feasibility, cost-efficiency) must be demonstrated.

1. Removal with an orbiting manoeuvering vehicle
2. Removal of objects with drag devices
3. Removal with a tether satellite
4. Destruction by laser
5. Debris catchers/sweeper

# International Cooperation

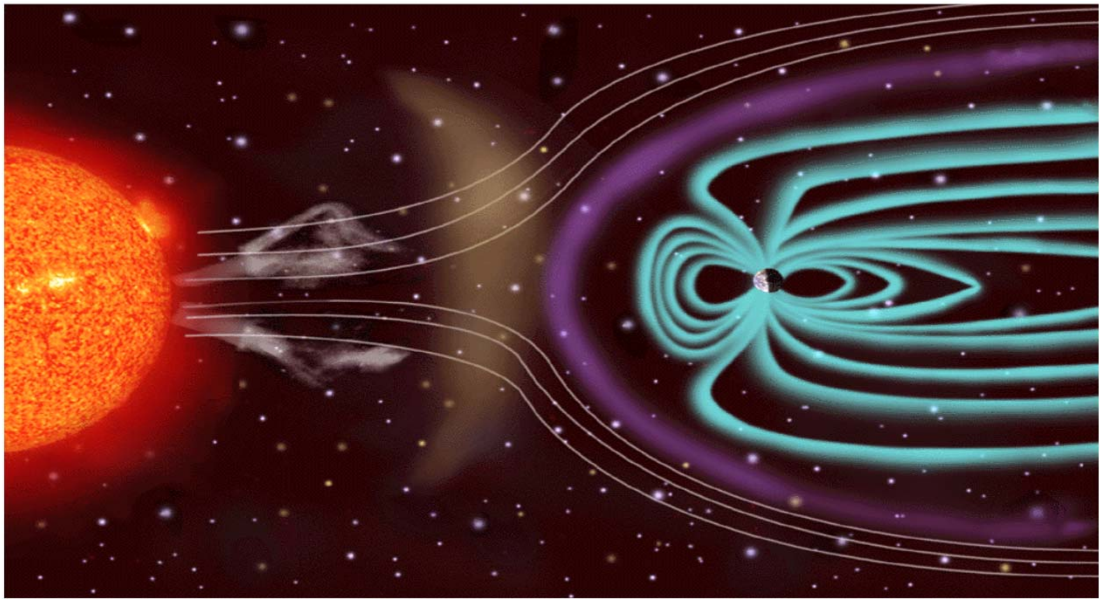
## Inter-Agency Space Debris Coordination Committee (IADC)

Members are ESA, ASI, BNSC, CNES, CNSA (China), DLR, ISRO (India), Japan, NASA, NSAU (Ukraine), and Rosaviakosmos (Russia)

Purpose:

- to exchange information on space debris research activities
- to review progress on cooperative activities
- to facilitate opportunities for cooperation in debris research
- to identify and evaluate mitigation options

| Environment | Effects | Anomalies / degradation |
|---|---|---|
| Solar particle events, solar wind, magnetic fields, trapped belts, ionospheric electrons | Charging, dose, single event effects, displacement, phase delay, scintillation | Single and multiple event upsets, component failure, solar array degradation, RF link margin |



| | Instrument | | |
|---|---|---|---|
| **Measurement** | **SOHO** | **GOES** | **ACE** |
| Solar wind speed and density | CELIAS (frequency?)<br>SWAN (frequency?) | | SWEPAM |
| IMF (B field) | | | MAG |
| Solar EUV / Xray images | SUMER, EIT | | |
| Solar coronagraph image | LASCO, UVCS | | |
| X-ray flux | | XRS | |
| UV flux | CELIAS, EIT | (in future s/c) | |
| > 10Mev ions | | EPS | CRIS, SIS |
| Interplanetary radio bursts | | | |
| Cold ions, total density only | | | |
| > 100Mev ions | | EPS | |
| 1-100kev electrons (good spectral information) | | | |
| Relativistic electrons (>0.3MeV) including spectra | | EPS | |

| | |
|---|---|
| **Immediate gaps** | |
| Solar wind speed | non full time instrument on SOHO |
| GEO low energy particles | No known operational sensors |
| MEO low and high energy particles | No operational sensors (GIOVE aimed at modelling and mapping, GPS operational data not released externally) |
| Additional gaps after the SOHO mission | |
| Solar EUV / Xray images | |
| Solar coronagraph image | |
| UV flux | |
| Additional areas of dependence on non-European data | |
| Solar wind density | non full time instrument on SOHO |
| Interplanetary magnetic field | non full time instrument on SOHO |
| X-ray flux | Dependent on GOES |
| GEO high energy particles | (electrons and ions) Dependent on GOES |