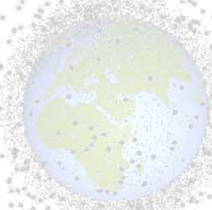
Space Debris
Status and Outlook



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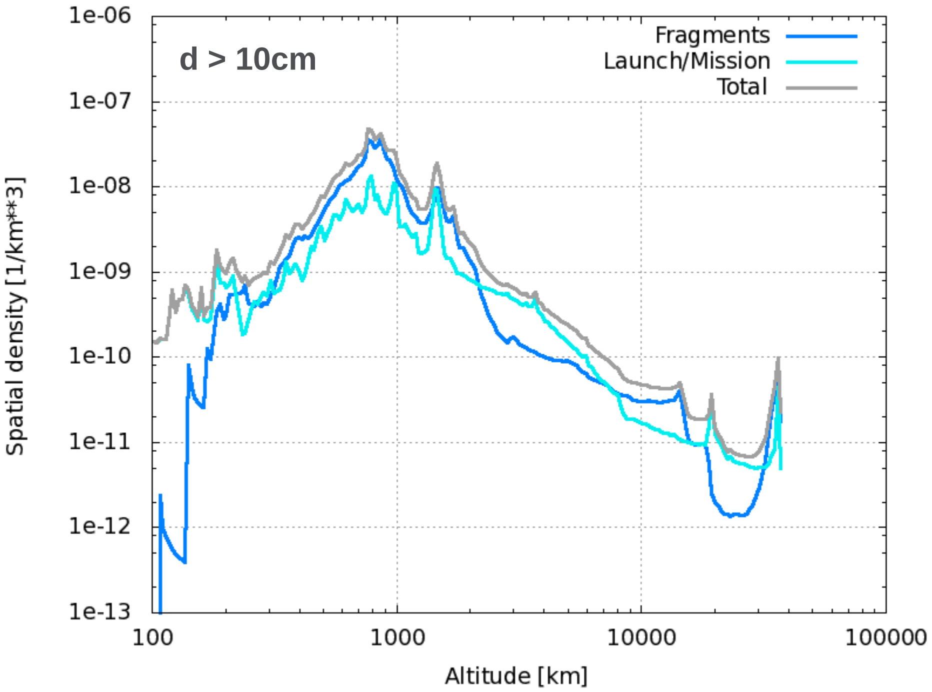
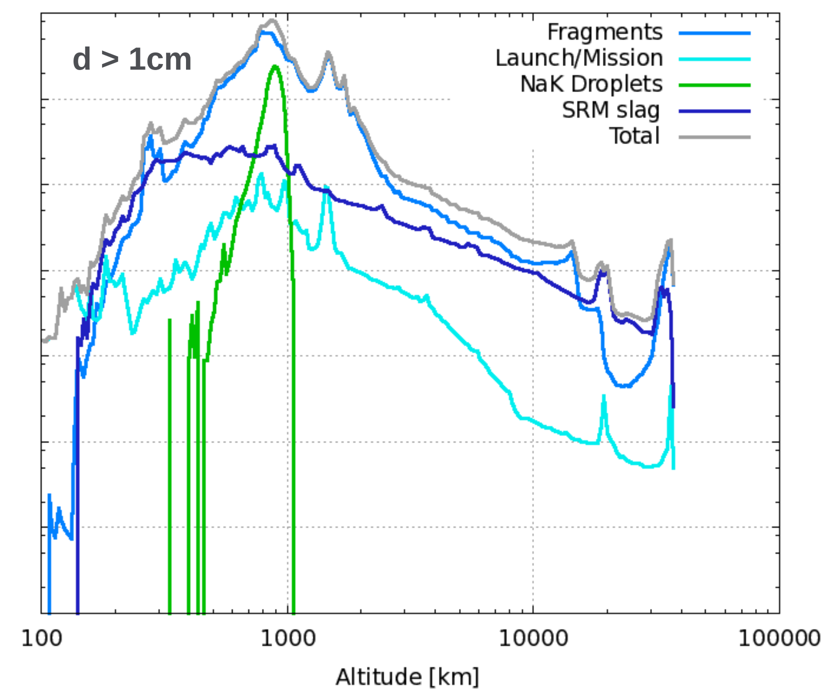
Space Debris of Critical Sizes





- intacts & debris of d ≥ 10cm:
  - total number ≈ 21,000
  - total mass ≈ 5,800 t
    [➡ Al-cube of 13m side length]

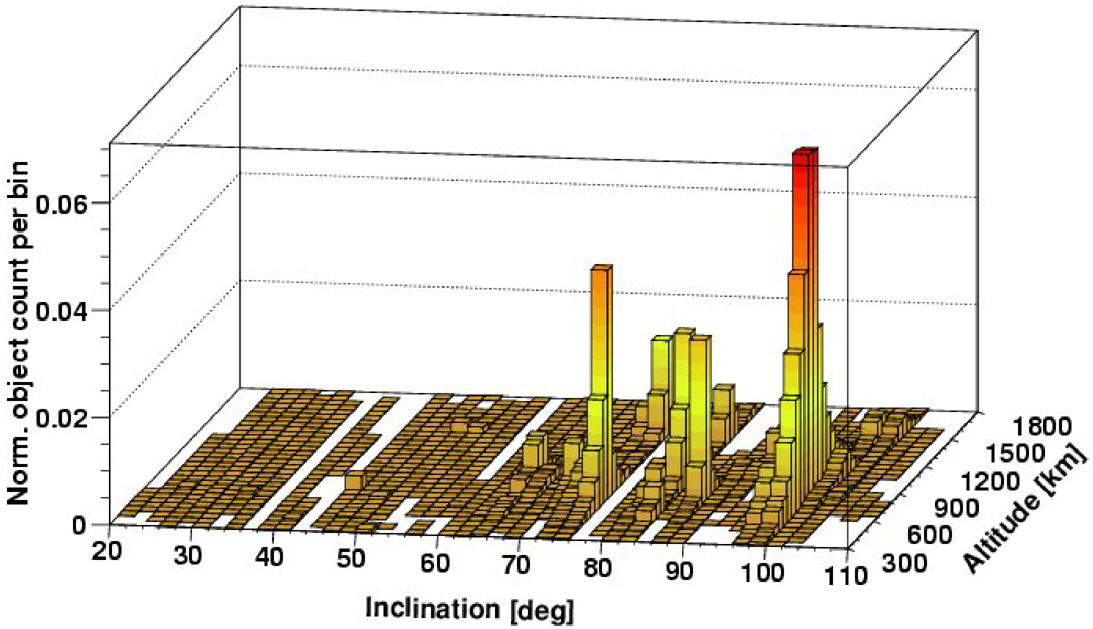
- debris of 10cm > d ≥ 1cm :
  - number increase ≈ +600,000
  - mass increase ≈ +2.8 t
    [➡ Al-cube of 1m side length]

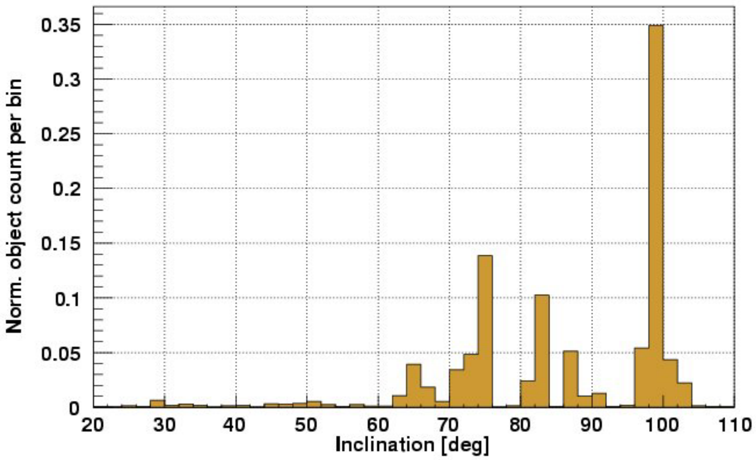
Characteristics of Critical-Size Space Debris

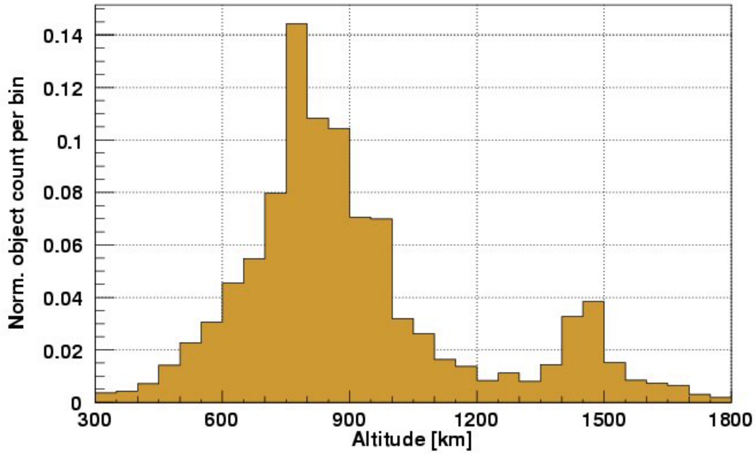
- assumptions used:
  - "critical-size space debris" impose impact energies that lead to a catastrophic break-up of the target object (typically for d > 10cm)
  - "critical-size space debris" ≈ 21,000 (≈ US SSN tracked objects)
  - mass in orbit ≈ 5,800 metric tons
- distribution of "critical-size space debris" across orbit regimes:
  - LEO (altitude 200 km to 2,000 km, all inclinations)
    - mass ➡ 40% ; fraction of LEO-to-GEO volume ➡ 0.3%
    - count ➡ 76.7% (20.5% intacts + 56.2% fragments)
  - GEO (altitude 35,678 km ± 2000 km, inclination < 20º)
    - mass ➡ 33% ; fraction of LEO-to-GEO volume ➡ 8.6%
    - count ➡ 6.3% (6.2% intacts + 0.1% fragments)
  - other orbits
    - mass ➡ 27% ; fraction of LEO-to-GEO volume ➡ 91.1%
    - count ➡ 17.0% (9.4% intacts + 7.6% fragments)

Distribution of Critical-Size Debris in LEO

- of 16,000 critical-size LEO objects …
  - up to 14.5% are in a 50km altitude bin
  - up to 36.0% are in a 2º inclination bin
  - up to 6.5% are in a 50km × 2º bin (mainly at 950±100km and 98±2º)

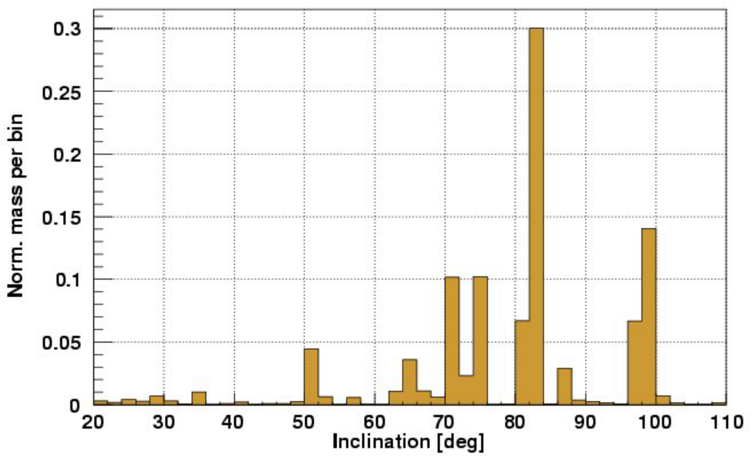


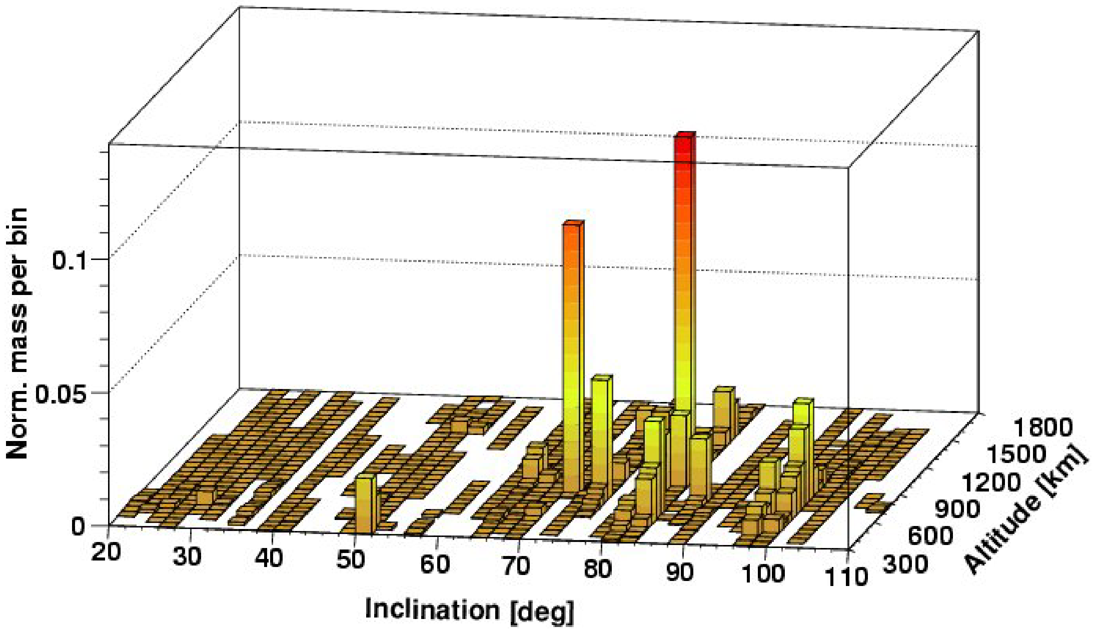


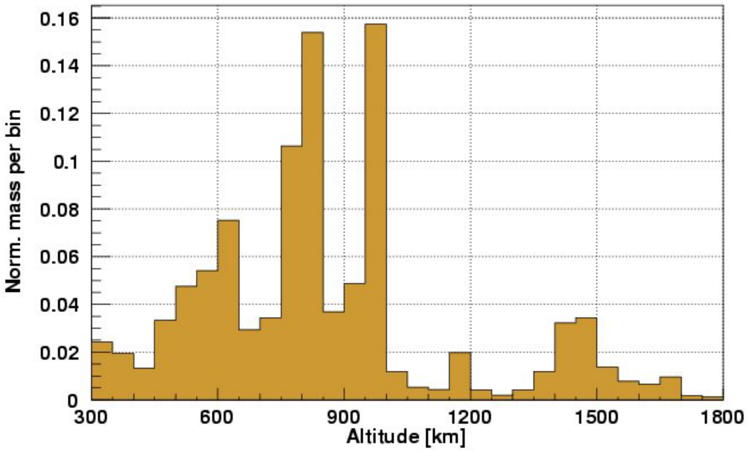


Mass Distribution in LEO

- of 2,300 metric tons in LEO …
  - up to 15.8% are in a 50km altitude bin
  - up to 30.0% are in a 2º inclination bin
  - up to 14.3% are in a 50km × 2º bin (mainly at 950km / 82º and 800km / 72º)

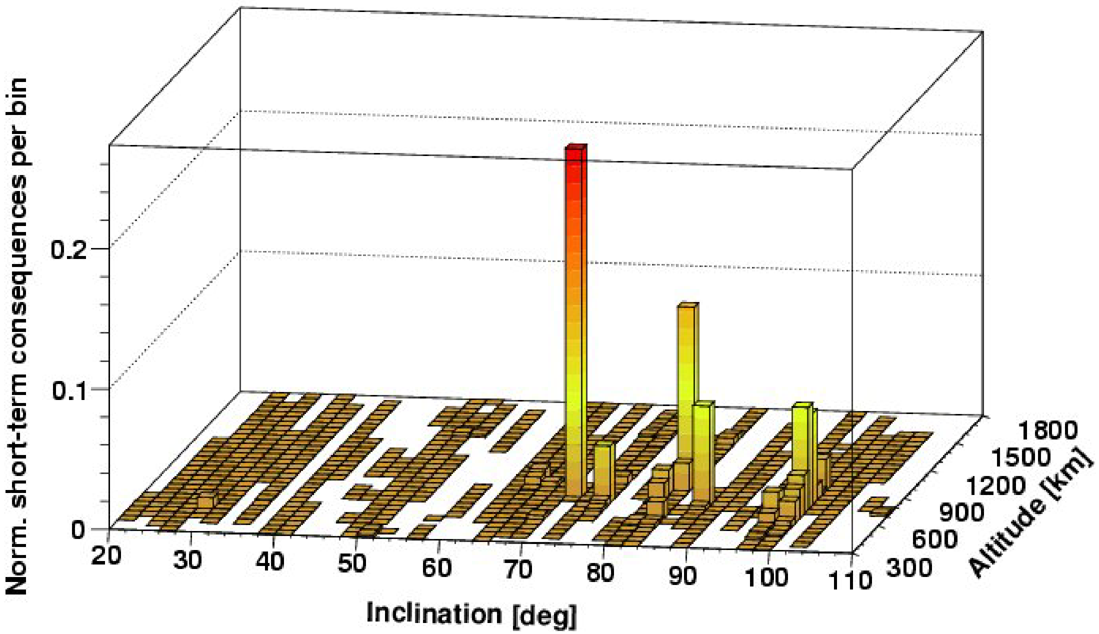


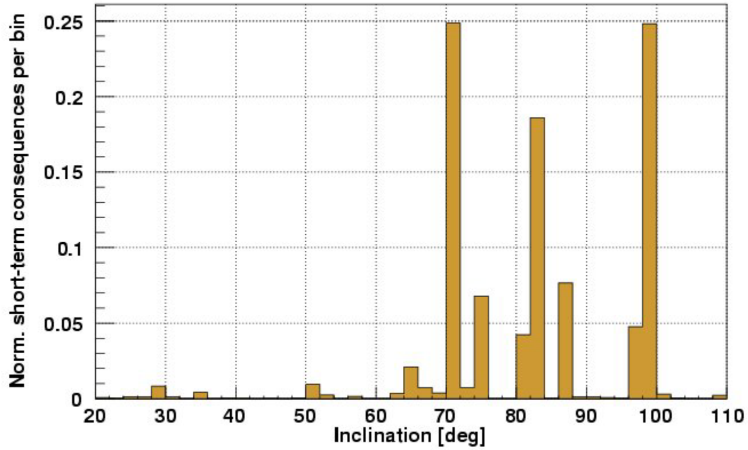


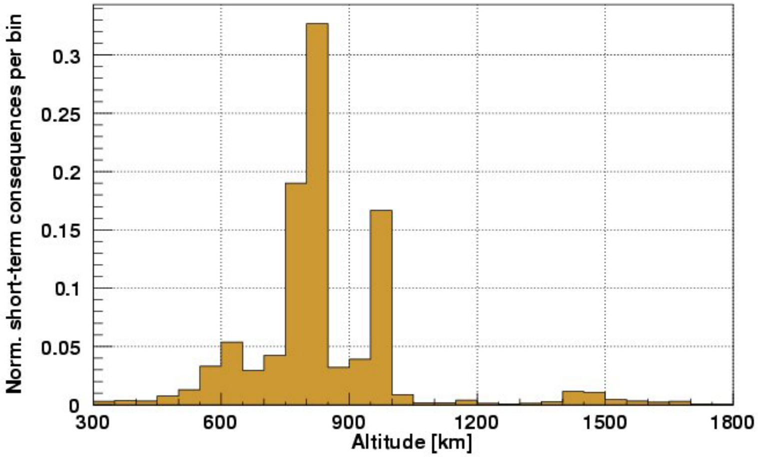


Short-Term Consequences in LEO

- [short-term consequences] = [collision flux] × [cross-section] × [mass]
  - up to 26.5% of the short-term effects are concentrated in a 50km × 2º bin (mainly at 800km / 72º and 950km / 82º)

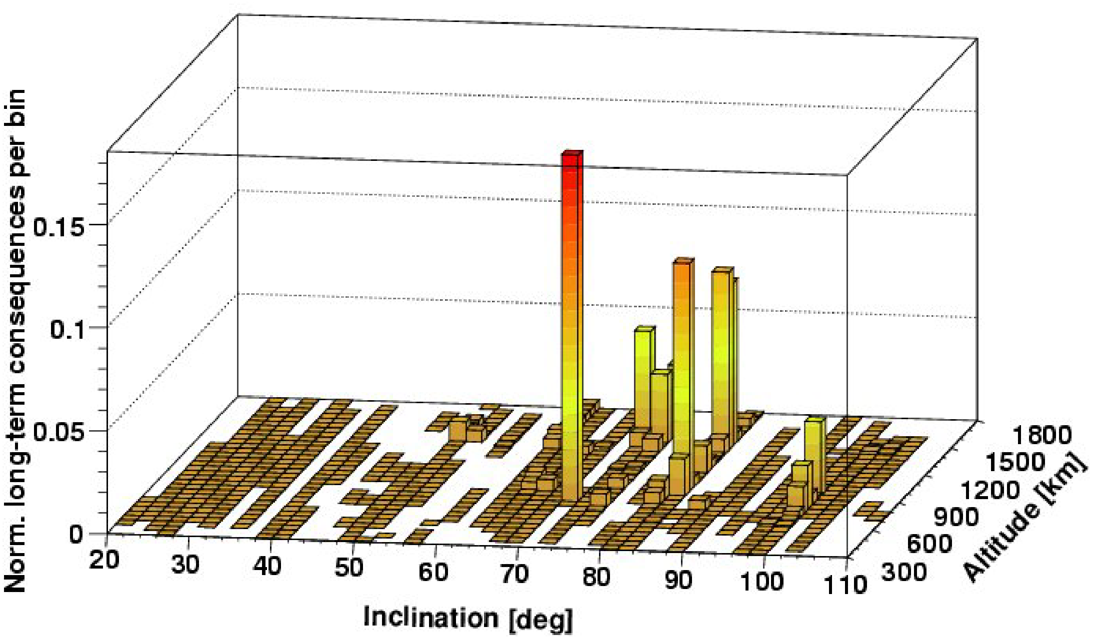


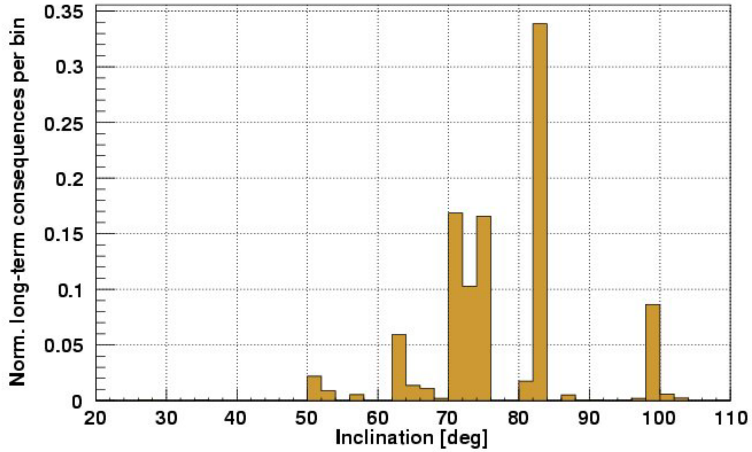


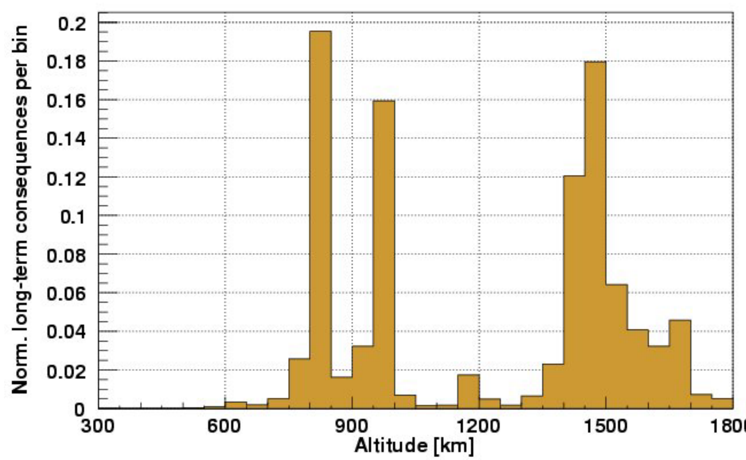


Long-Term Consequences in LEO

- [long-term consequences] = [collision flux] × [cross-section] × [mass] × [orbit lifetime]
  - up to 17.5% of the long-term effects are concentrated in a 50km × 2º bin (mainly at 800km / 72º and 1,500km / 84º)







Conclusions

- the highest count (~73%) and mass concentration (~40%) of critical-size space objects is in low Earth orbits (LEO), within only 0.3% of the populated orbital space
- an Iridium-33/Cosmos-2251 type of collision is likely to re-occur in the LEO regime within less than 10 years for today‘s debris environment; no catastrophic collisions are predicted outside LEO for the next 100 years
- major contributions to collision risk, and to derived metrics of short- and long-term consequences are correlated with a few distinct classes of LEO inclinations and altitudes; highest mass removal rates and most efficient debris control can be accomplished by servicing these orbit regions