DELTA (DEBRIS ENVIRONMENT LONG-TERM ANALYSIS)

B. Bastida Virgili

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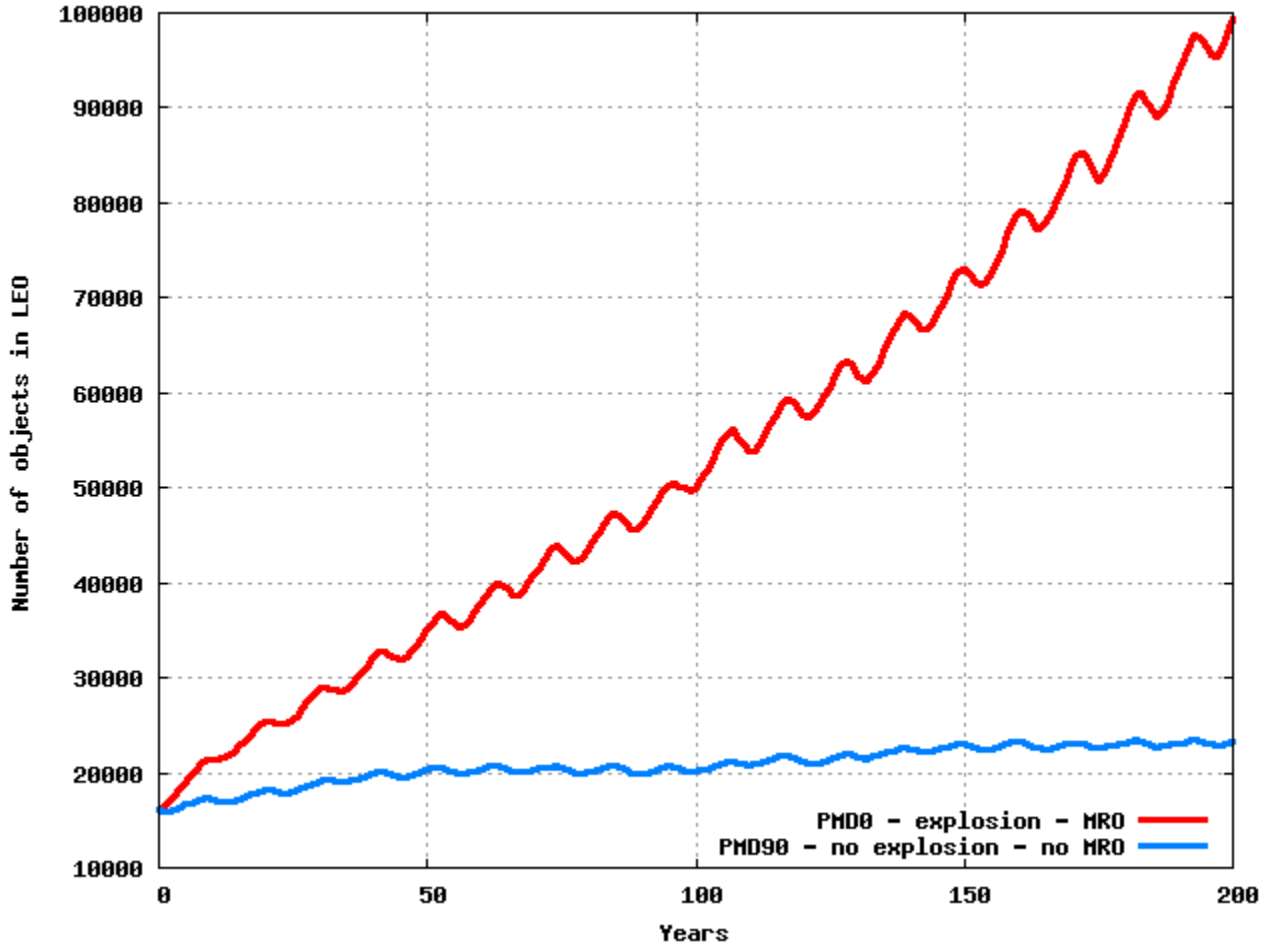
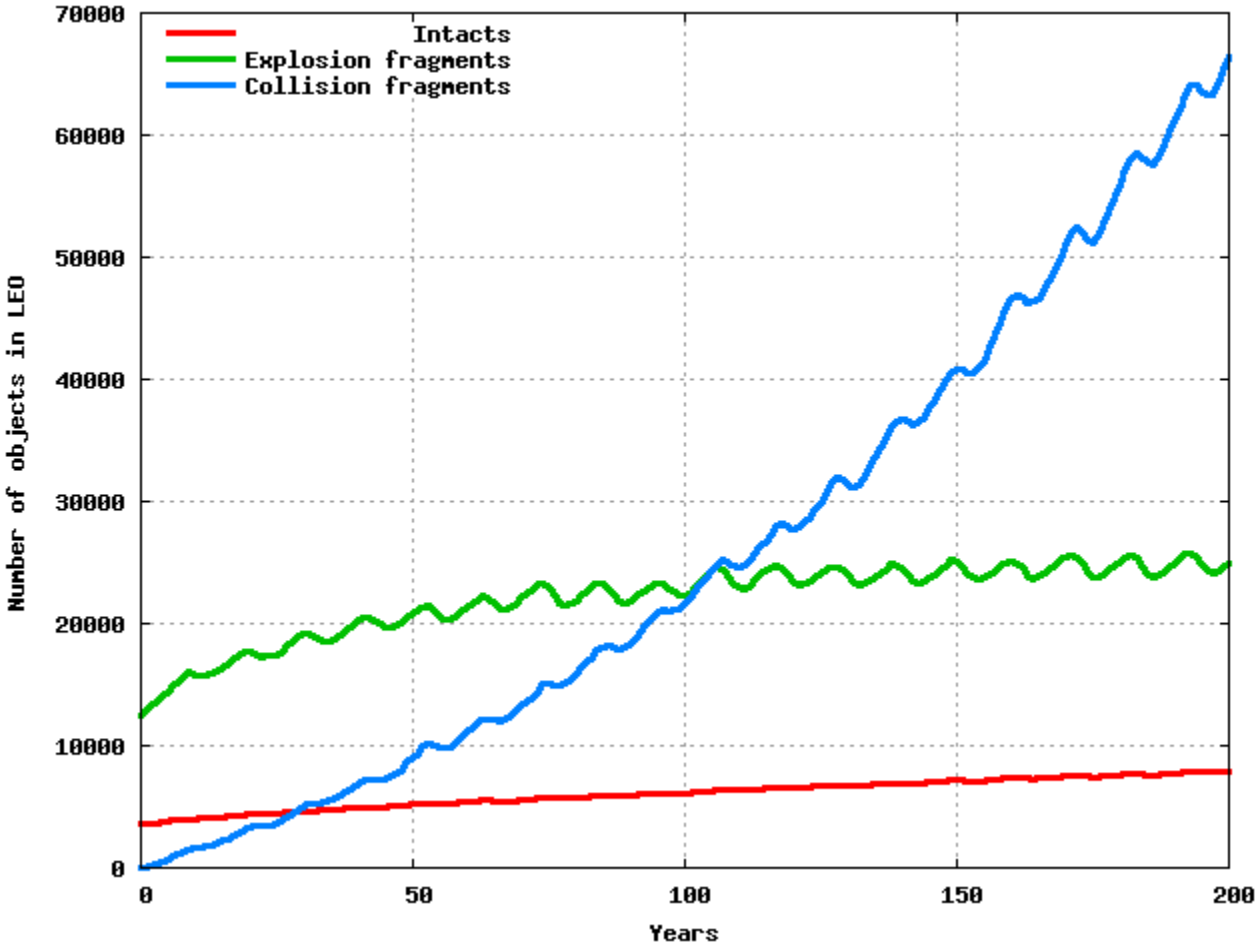
Contents

- Introduction
  - Future evolution of the environment
- DELTA
  - Architectural design
  - Collision prediction
- Simulation results
- Conclusion

Future evolution of the environment

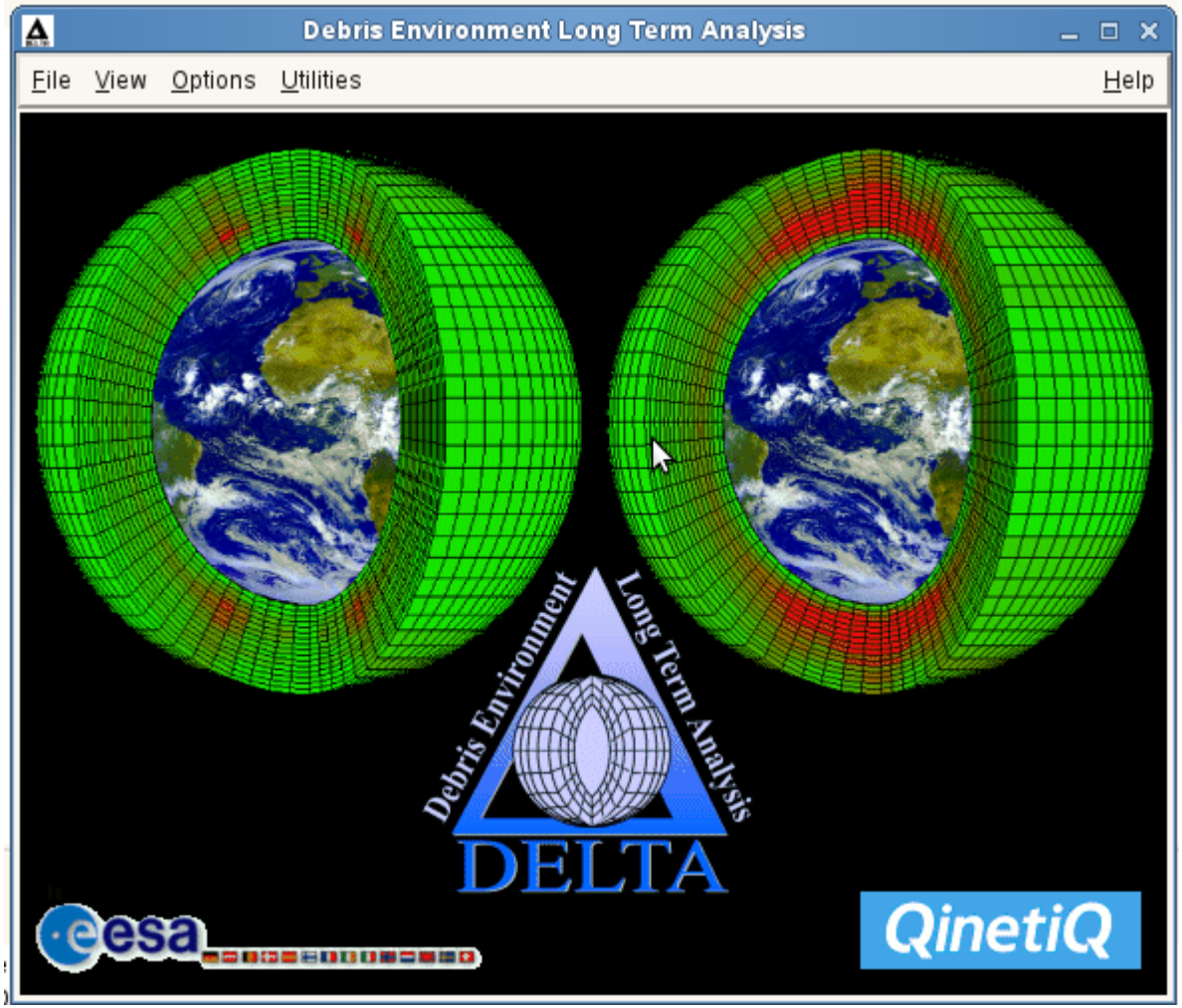


Future evolution of the environment



Origin of objects in PMD0 – explosion - MRO scenario

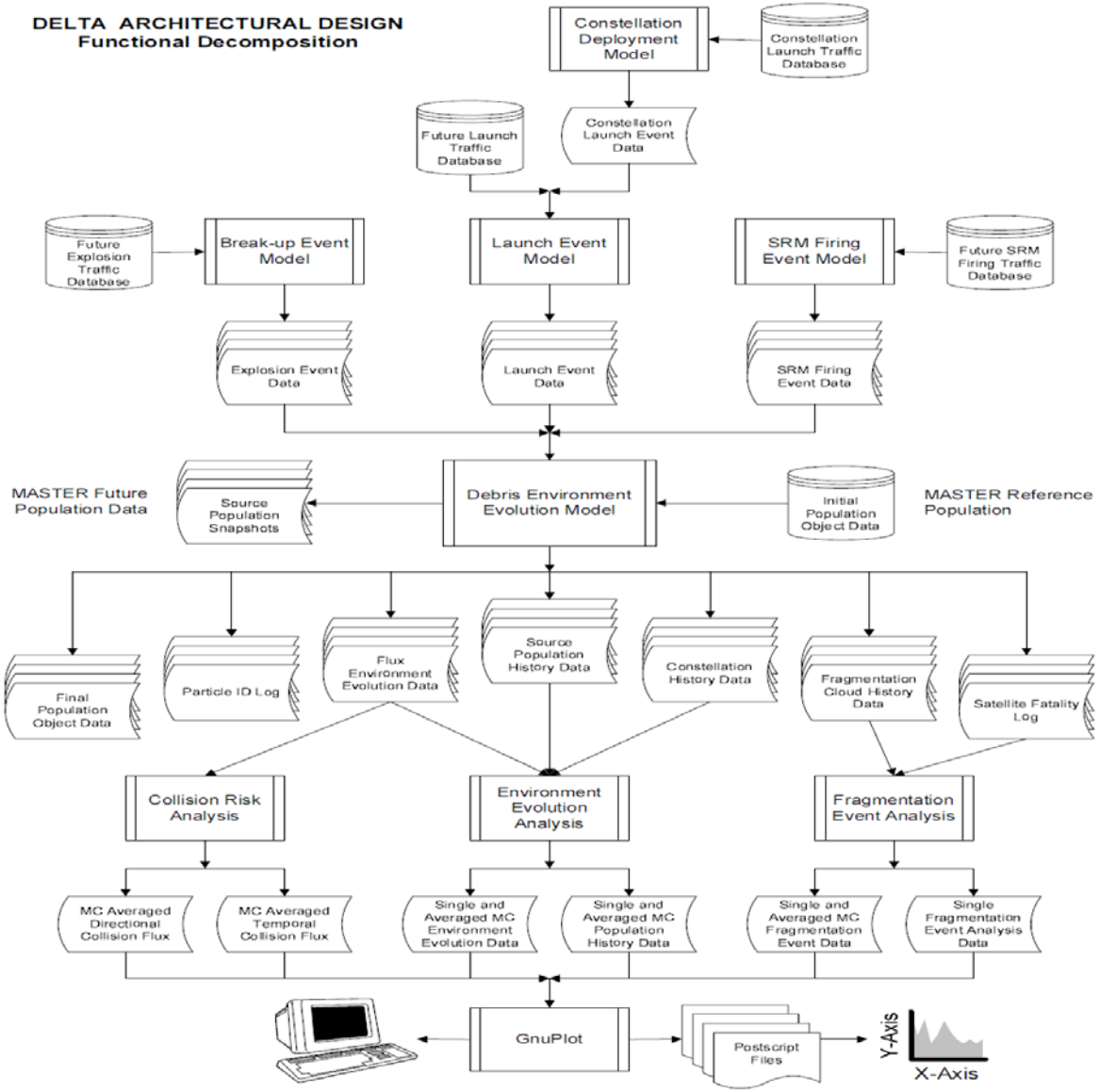
DELTA:
Debris Environment Long Term Analysis



DELTA

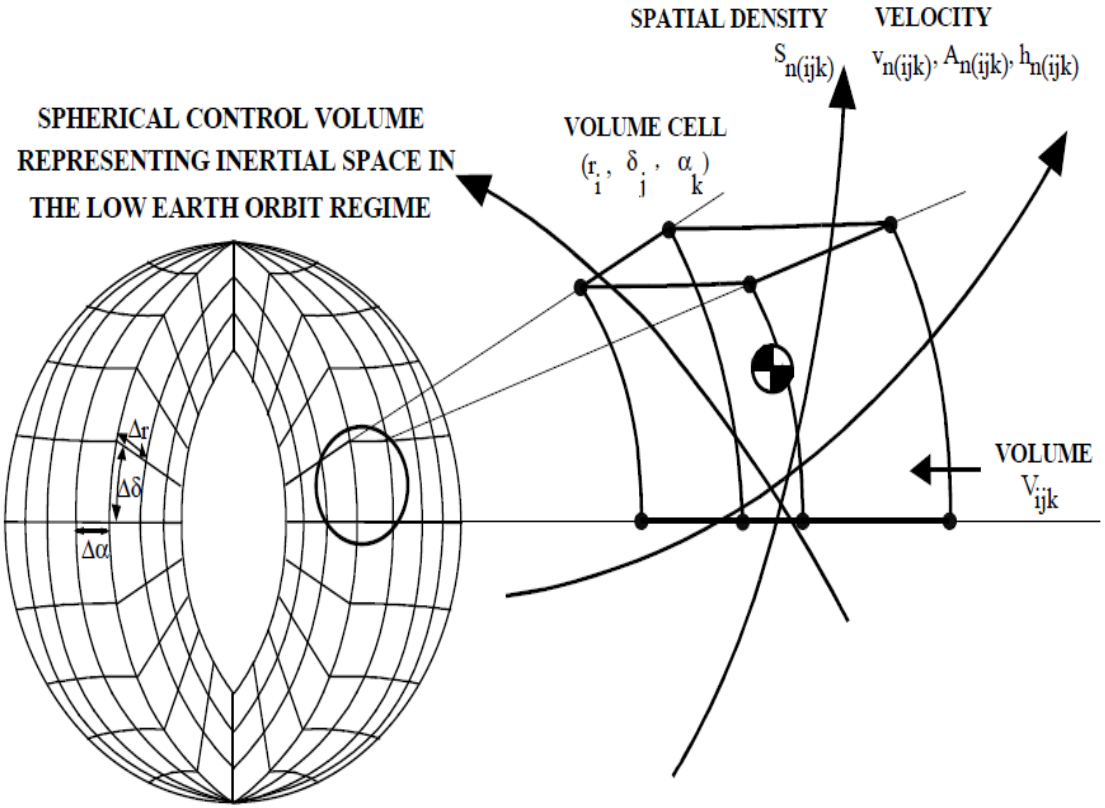
- DELTA v3.1
  - Debris Environment Long-Term Analysis software, developed by QinetiQ
  - 3-D semi-deterministic model
  - Evolution of space debris environment and collision risks over the future in LEO, MEO and GEO
  - Different traffic profiles (launch, explosion, solid rocket motor firing)
  - Debris mitigation measures (passivation, end-of-life disposal)
  - Adaptation by ESA to add active debris removal
  - Different tools to post-process the results:
    - FEA: Fragmentation Event Analysis
    - EEA: Environment Evolution Analysis
    - CRA: Collision Risk Analysis
    - CEA: Collision Event Analysis

DELTA architectural design



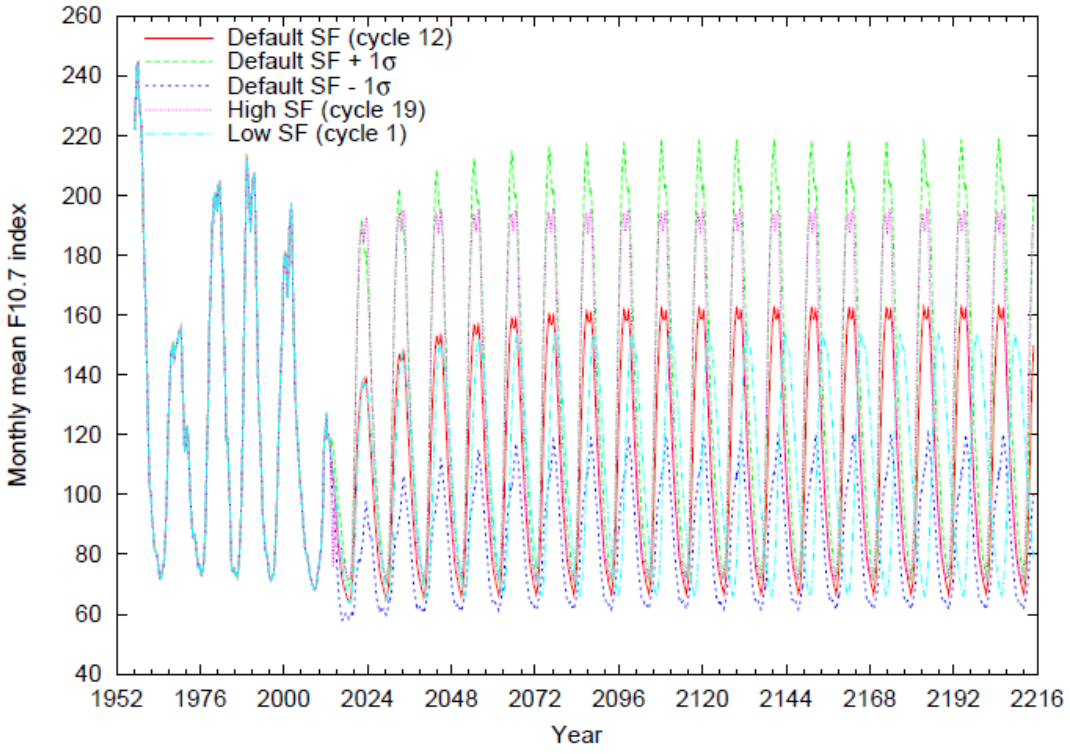
DELTA collision prediction

- Target centered approach, based on flux
- $P_c = F_t\sqrt{\sigma_t^2 + \sigma_p^2}\Delta t$
- Poisson distribution to predict collisions
- EMR > 40J/g → catastrophic collision
- EMR < 40J/g → non-catastrophic
- Chaser selected from same size bin, source bin and orbital regime



Influence of solar activity on long term propagations

- DELTA with different solar fluxes (F10.7 monthly, fix Ap=9), 50MC runs



- Default SF: uses data from cycle 12 (cycle from which there were both sunspot and geomagnetic activity observations) onwards for the fitting and prediction
- 1σ: standard deviation to the mean from cycles 1 to 21
- High SF: uses data from cycle 19 onwards
- Low SF: uses data from cycle 1 onwards

Influence of solar activity on long term propagations

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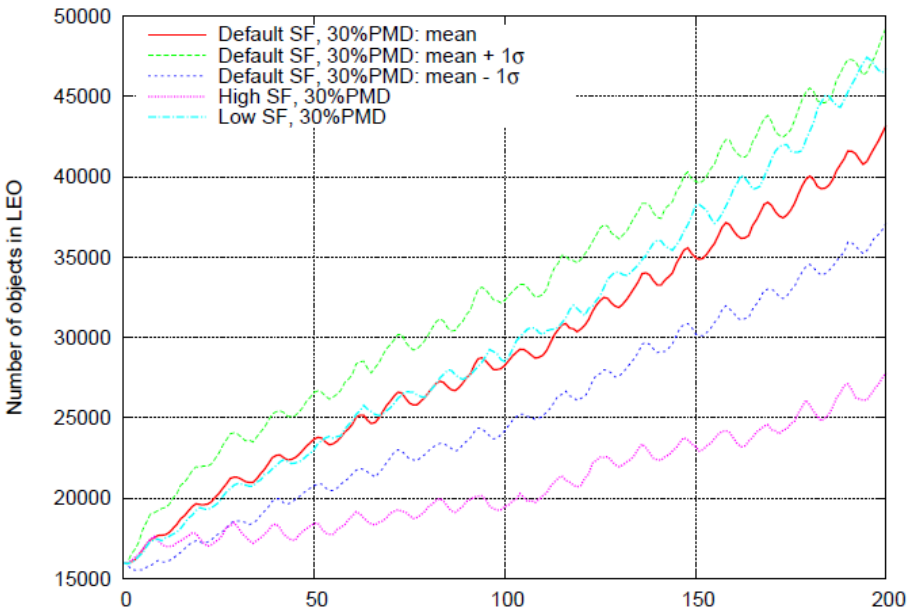
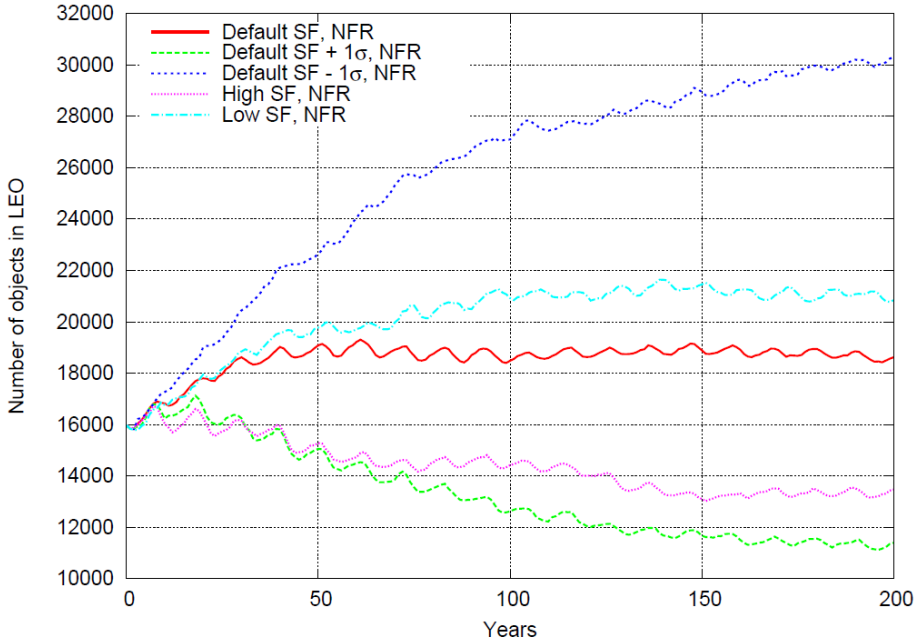




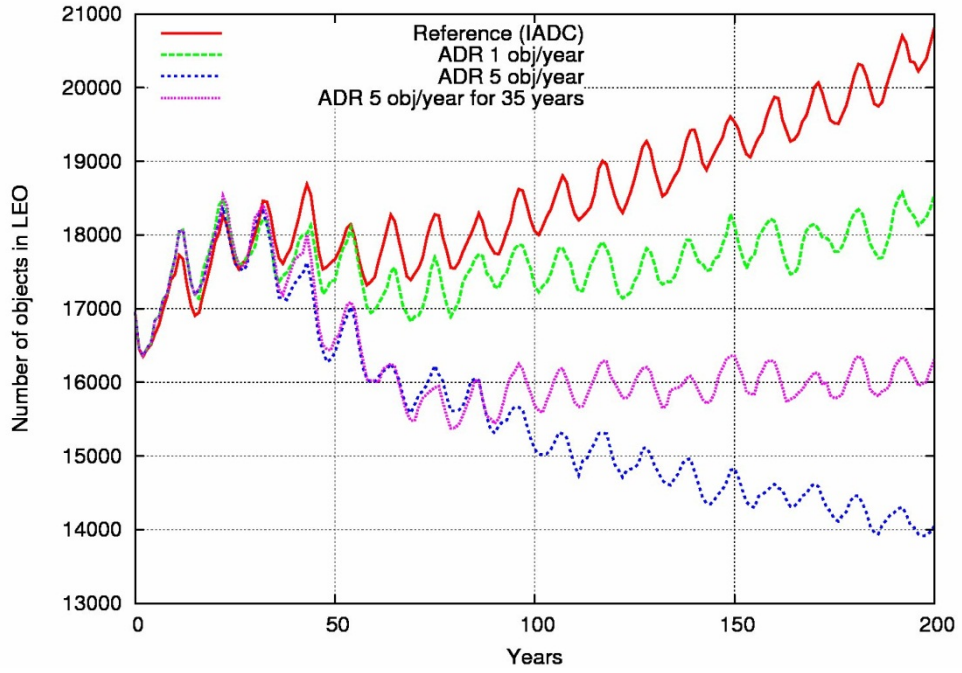
30%PMD: 30% compliance with post-mission disposal, launches as for past 8 years

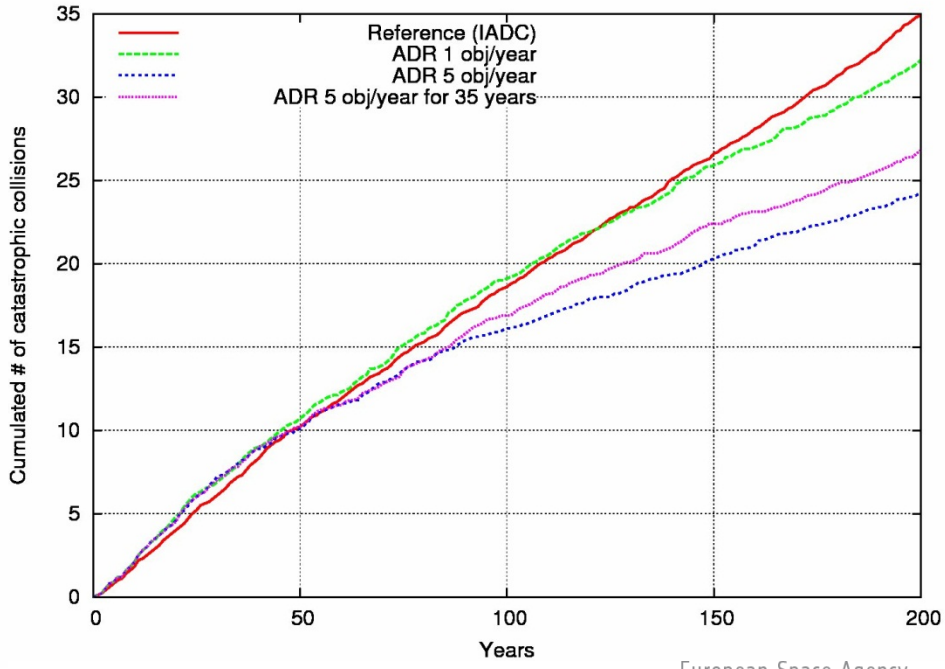
NFR: no-further-release (no launches)

- Default +/- 1σ are extreme case very unlikely to happen

ADR on LEO missions

- Reference scenario: partial mitigation with 90% success
- ADR removal start in 2024
  - 1 object removed per year until end of simulation
  - 5 objects removed per year until end of simulation
  - 5 objects removed per year for 35 years



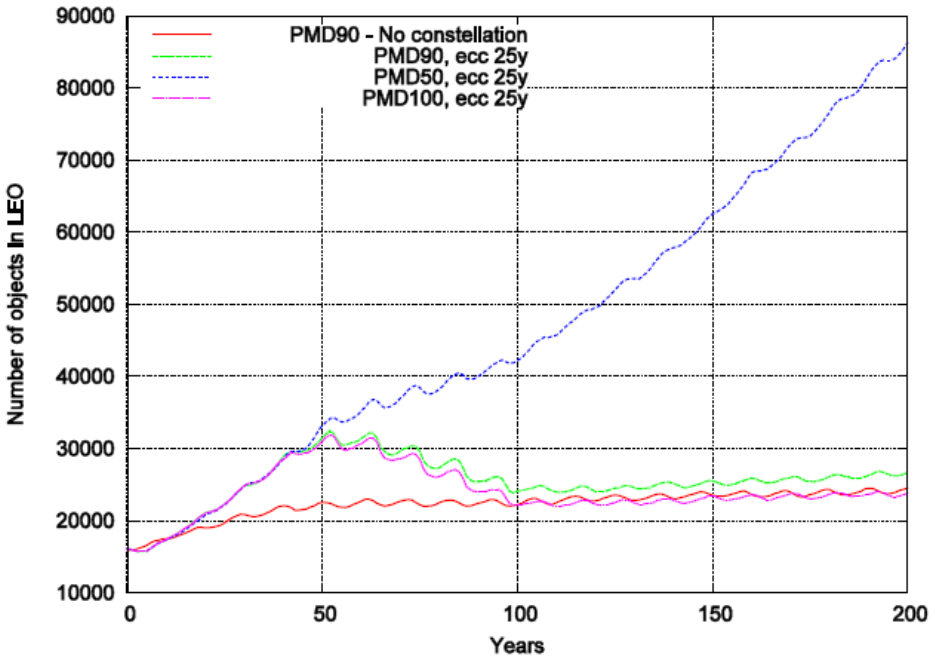


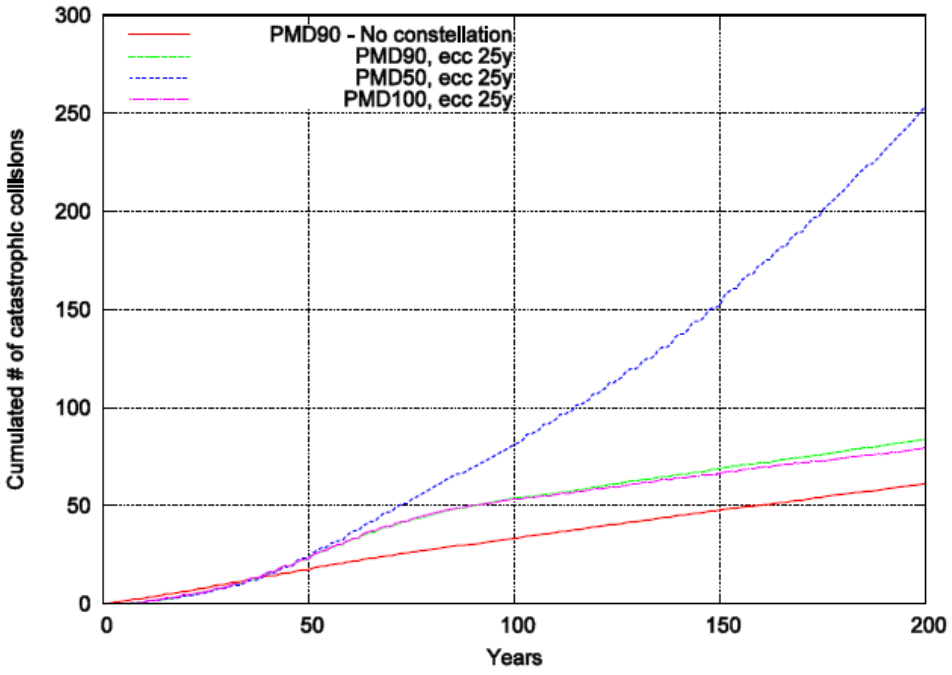
Quantitative results of ADR

	1 obj/yr	5 obj/yr	5 obj/yr for 35y
Reduction in # objects (a)	2450	6760	4500
Reduction in # collisions (c)	2.7	10.6	8.1
# AR objects (b)	177.9	802.2	162.9
ORF (a/b)	13.77	8.43	27.62
CRF (b/c)	65.89	75.68	20.11
Population growth (%)	9.3	-17.1	-3.8
Years with AR missions	185	185	35

- ORF: Orbit reduction factor. CRF: collision reduction factor (results after 200 years)

Level of compliance of mega-constellations





- Compliance to the mitigation guidelines (post-mission disposal) has huge effect in environment

- → try to comply as much as possible (in own interest of constellation operator too)

Conclusion

- DELTA is a very powerful tool developed and maintained by ESA
- Allows to simulate the long-term evolution of the space environment under a large variety of conditions
- It has been used for many studies under international collaboration (IADC)
- It has been also used to further analyze the main space debris topics at the time these are detected
- Structure and modular design of DELTA has been explained, focus on collision detection algorithm
- Past results to exemplify the wide range of possibilities that the tool offers
- DELTA is under constant improvement and revision process
- Current efforts
    - using different collision detection algorithms,
    - improving the atmospheric model usage without losing performance