FUTURE LARGE CONSTELLATIONS IN LEO AND THE SPACE DEBRIS ENVIRONMENT – A TECHNICAL ANALYSIS

H. Krag, H. Lewis, J.-C. Dolado, J. Radtke, B. Bastida Virgili, S. Lemmens, C. Colombo, C. Cazeaux, M. Metz, R. Crowther,

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Reference:

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Introduction

- Announced LEO telecommunication constellations with > 100 satellites:

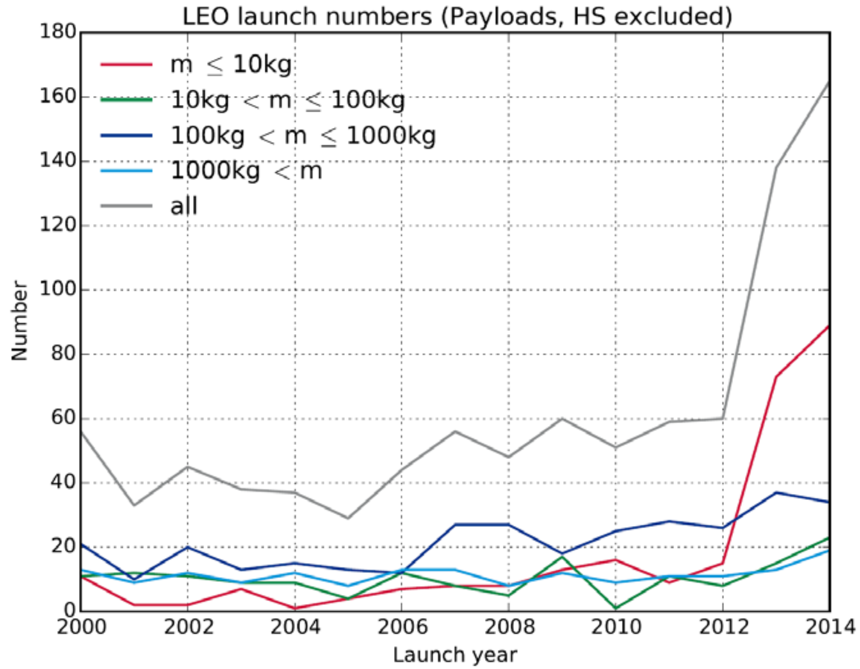
Constellation Name	Number of satellites	Orbital altitude [km]
Samsung	4600	1400
SpaceX	4000	1100
Oneweb	650	1200
Leosat LLC	140	1800
Yalini	135	600

Source: Various News Articles

- Core aspects of current mitigation guidelines for LEO:
  - Passivation (release of residual energy)
  - Prevention of the release of mission-related objects
  - Limitation of the post-mission orbital lifetime for:
    - The upper-stages
    - The satellites themselves

A Potential Concern (1/2)

- The operation of a mega constellation would mean a "step increase" in the use of the LEO region: > 100 additional mid-size objects per year
- So far, most environment evolution studies assumed a constant space traffic at rates of 50-70 per year (avg. of the past)
- How will this "step increase" influence the environment, assuming different levels of adherence to current guidelines



Source: ESA's DISCOS database

The Study Case: A Synthetic Constellation

1. Neutrality: no “picking” of a particular case
2. Generality: Only common effects are studied
3. Practicability: No public detailed definition of constellations

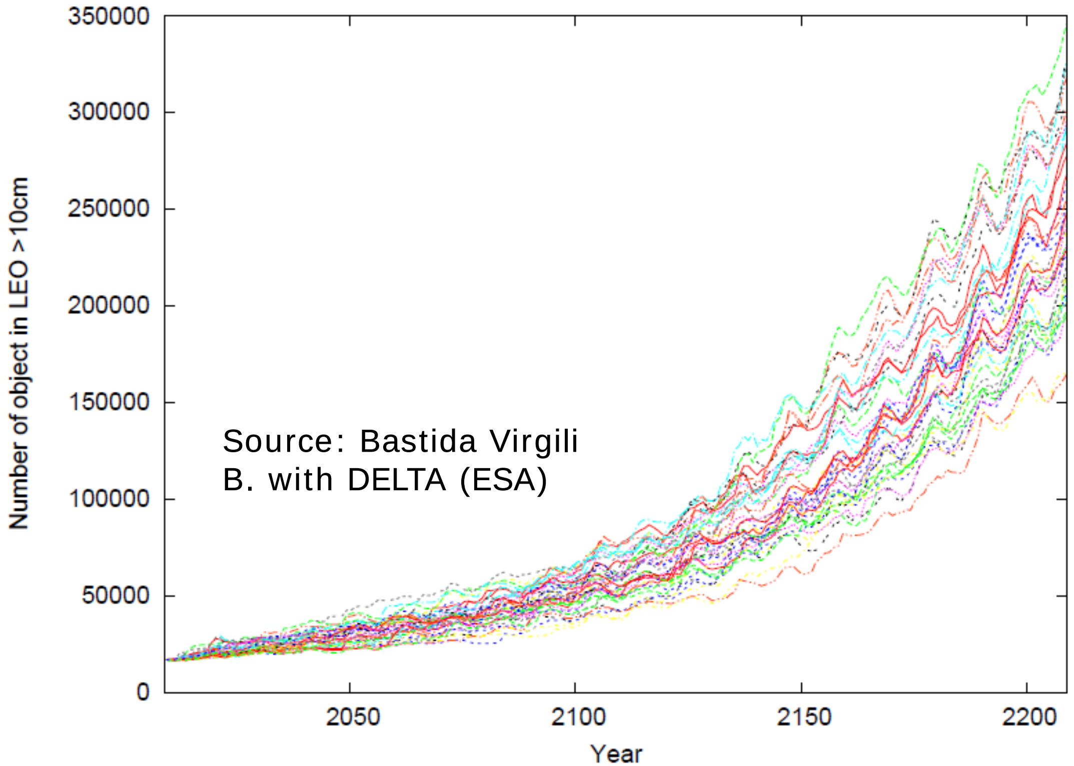
Constellation	**1080 satellites** **1100km altitude** **20 orbital planes** **85deg inclination**
Mission	Jan 2021 to Jan 2071
Satellite	200kg mass 1m² effective cross-section 5 years of mission lifetime
Constellation build-up	2018-2010 20 launches per year 18 satellites per launch
Constellation maintenance	2021-2071 18 objects per launch 12 launches per year
Mitigation behaviour	Launcher stages perform a direct re-entry No mission-related objects are released

4. Background: continuation of current traffic, excellent application of mitigation guidelines

Environment Projections

- 3-D time dependent semi-deterministic models
- Computation of collision risks between 1 and 70 times per simulated year
- Simulation of environment response to mitigation actions
- 200 years projection (2013
- Population 10 cm and abov

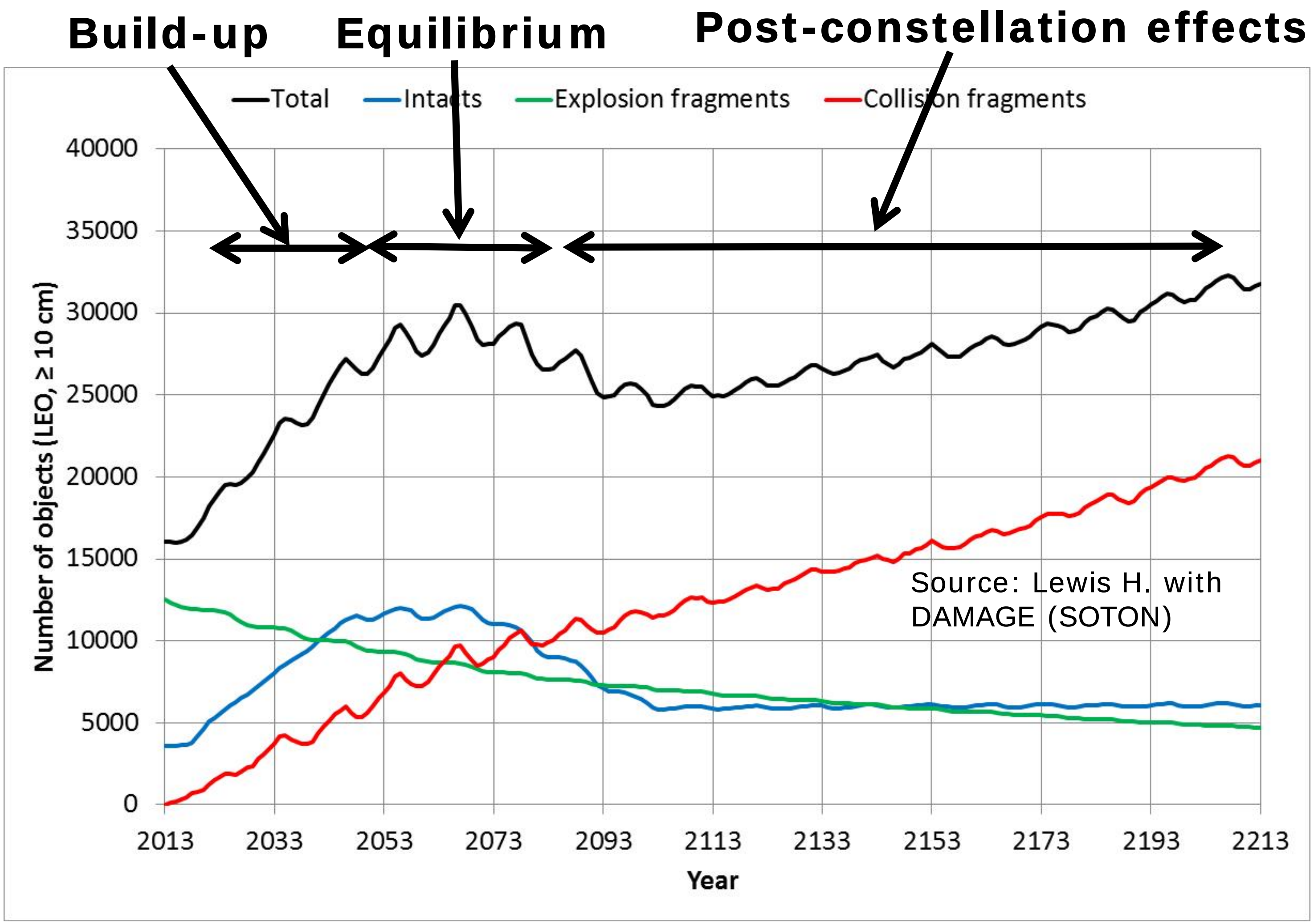
1. More than 40 Monte Carlo F
2. 4 different tools used:
    - MEDEE (CNES)
    - DELTA (ESA)
    - DAMAGE (SOTON)
    - LUCA (TUBS)



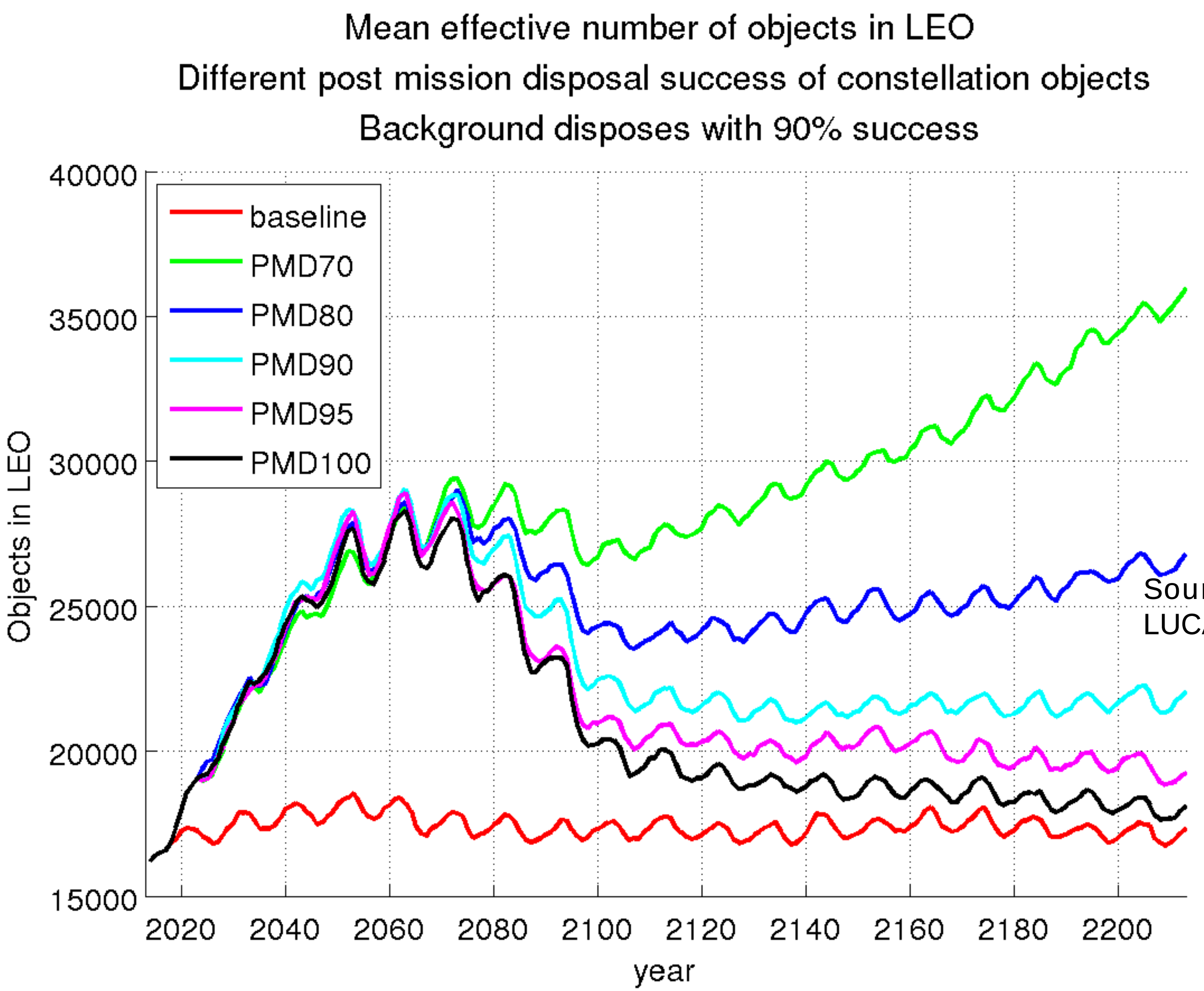
Assumptions and Limitations

1. The presented data are statistical averages generated from the outputs of environment prediction tools
2. The results come with significant error margins that are not shown here for simplicity
3. A sample constellation is studied. This means that the results are “indicative” only
4. This study is “general” and cannot address the particularities of a given constellation of interest (e.g. effect of the constellation altitude, constellation design, propulsion technique, etc...)
5. Assumptions on the background population are optimistic compared to the currently observed behaviour
6. The study results may be used to:
    - Understand the general effect of a large constellation
    - To study the effect of different levels of adherence to current guidelines

Results Characteristics



Post Mission Disposal Success

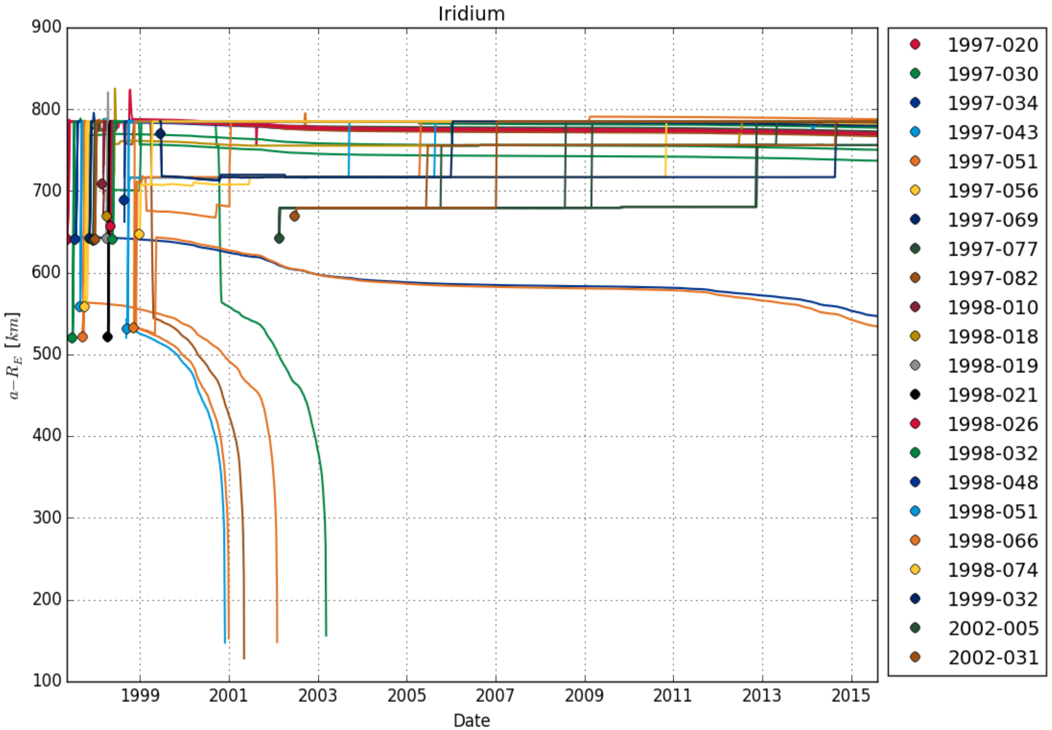


Source: Radtke J. with LUCA (TUBS)

Current Disposal Efforts of LEO Constellations

- Break-even altitude for de-orbit/re-orbit: ca. 1350km
- Spacecraft design of current constellation satellites dates back several years

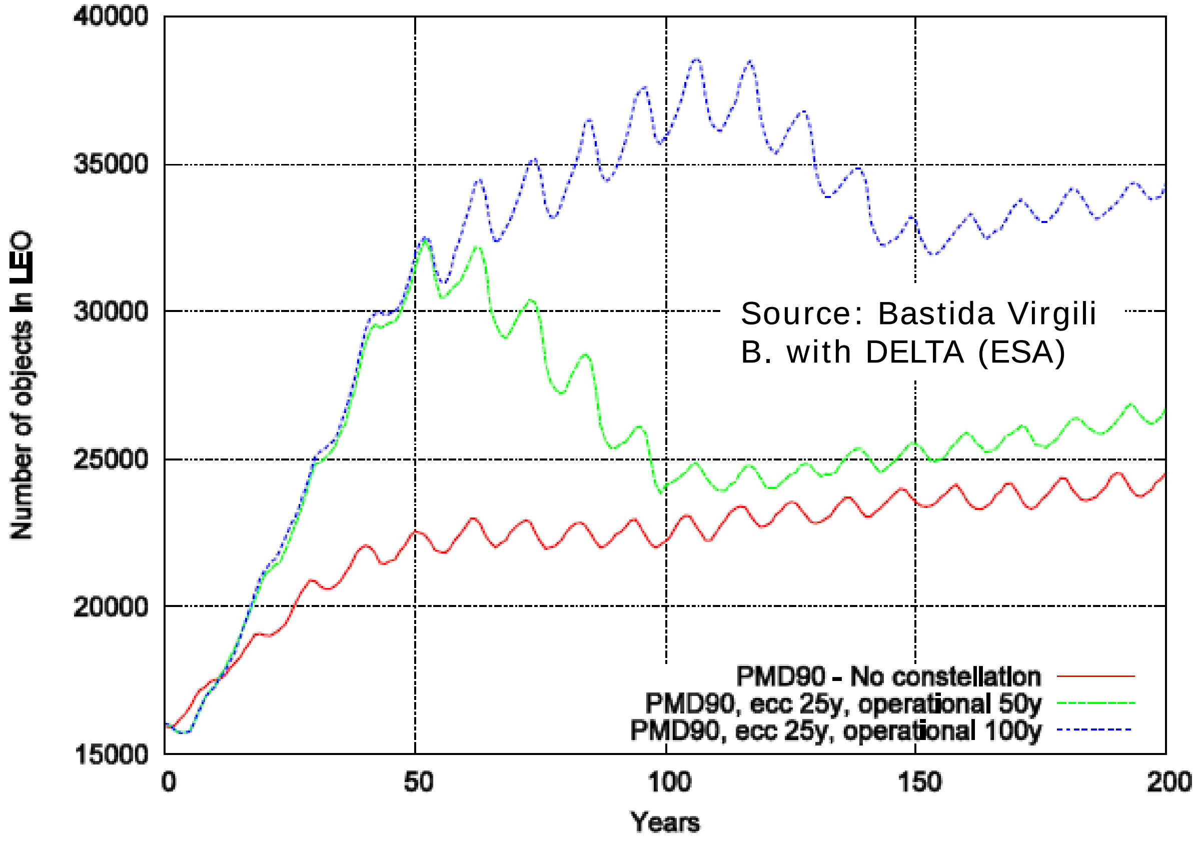
Name	Orbit height [km]	Total / Active members	EoL Strategy	Compliance estimate (worst case)
Orbcomm OG1	820/740	35 / 25	None observed	20% (6%)
Orbcomm OG2	710/650	6 / 6	Orbit lowering	-
Iridium	778	95 / 68	Orbit lowering	19% (5%)
Globalstar GFG	1414	60 / 14	Orbit raising	20% (15%)
Globalstar GSG	1414	24 / 24	Orbit raising	-
Gonets D	1420	11 / 1	None observed	0% (0%)
Gonets M	1502	13 / 12	None observed	0% (0%)



Source: Lemmens S. with DISCOS (ESA)

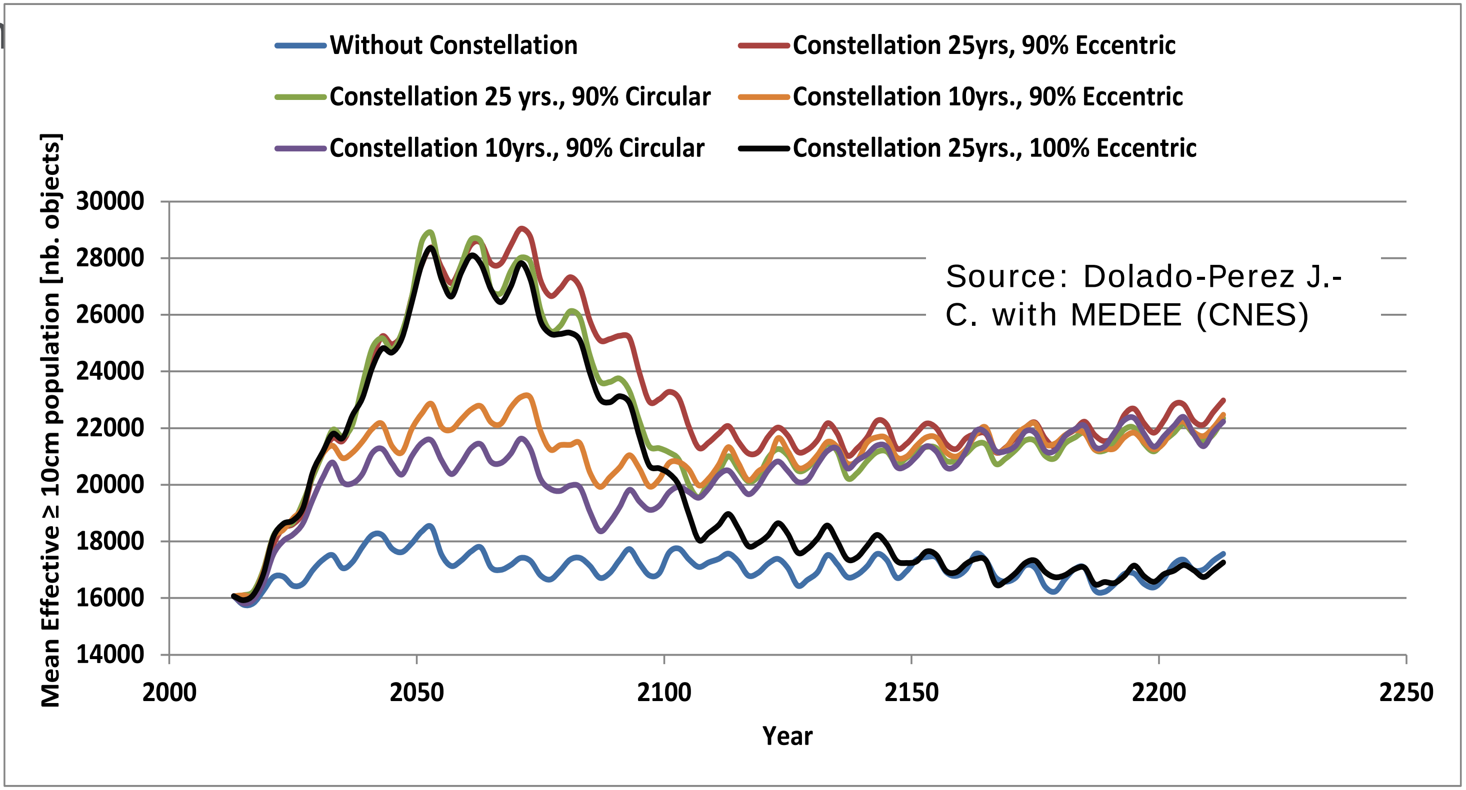
Mission Duration

- Increasing the mission duration to 100 years impacts the growth rate in the equilibrium phase (depending on the PMD rate)
- The final offset is a function of the PMD rate and the duration



Orbital Lifetime Reduction

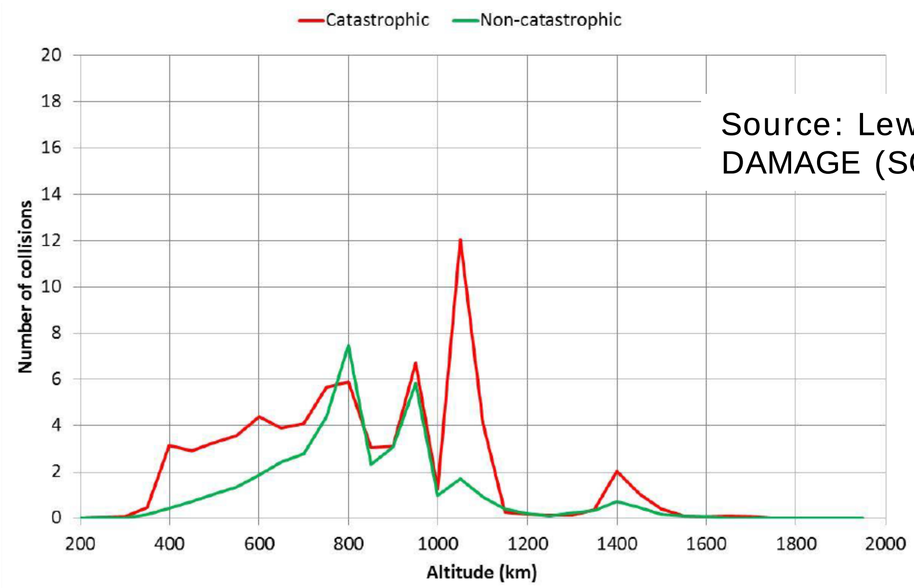
- A further orbital lifetime reduction to below 25 years can influence object numbers during operations, but has no long-term effect
- The disposal orbit (eccentric / circular) has no significant impact on



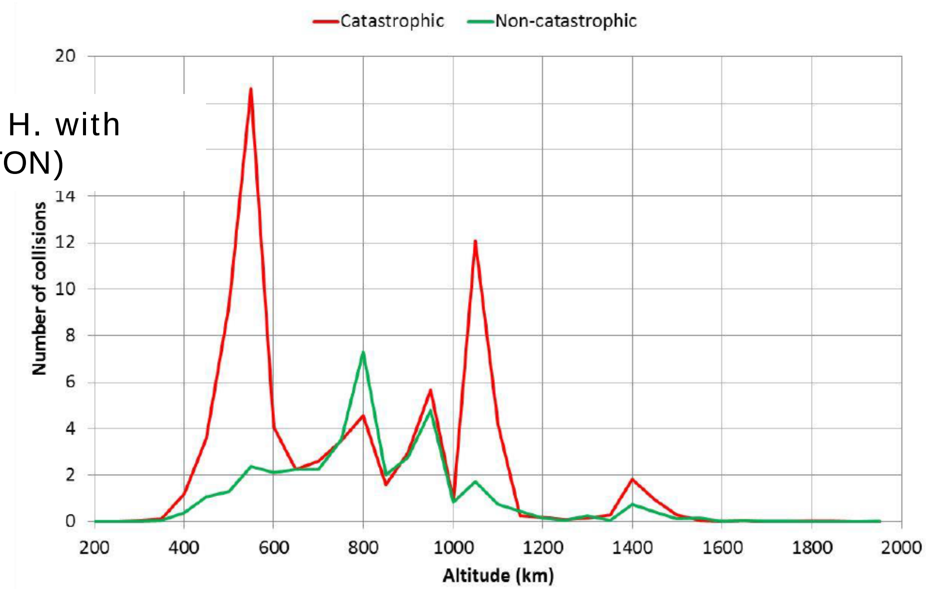
Disposal Orbit (1/2)

- Eccentric disposal orbits will distribute more uniformly the collision risk in altitudes below the constellation

Eccentric disposal orbits



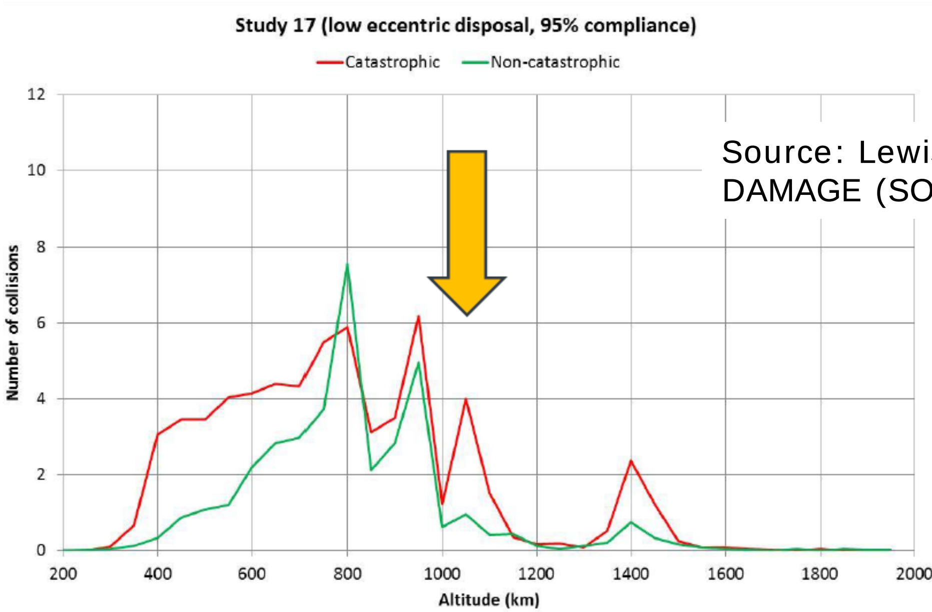
Circular disposal orbits



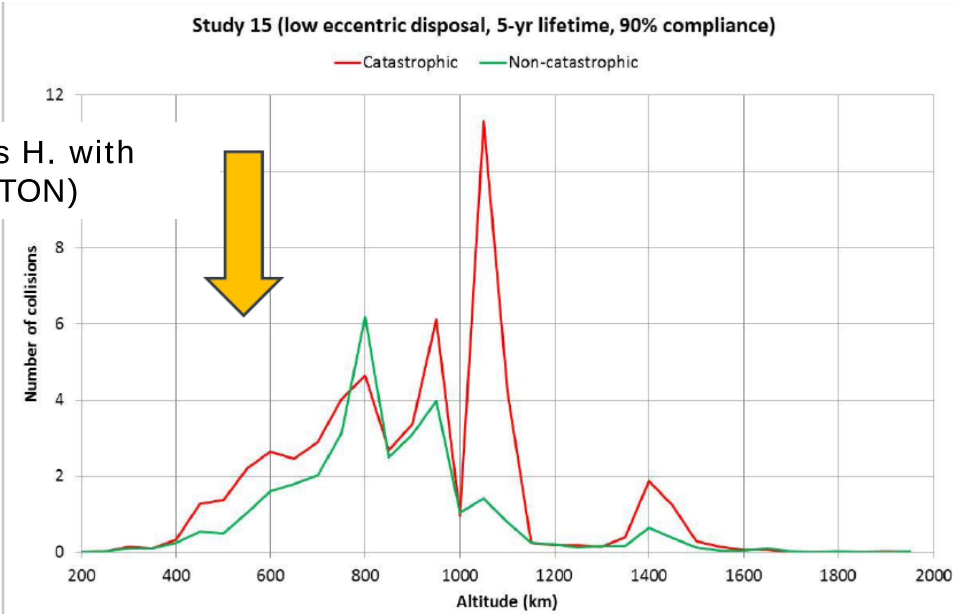
Source: Lewis H. with DAMAGE (SOTON)

Disposal Orbit (2/2)

- An even lower post mission disposal lifetime further improves the situation for space traffic below the constellation
- A better PMD rate improves the situation in the constellation altitude (driver for long-term effects!)

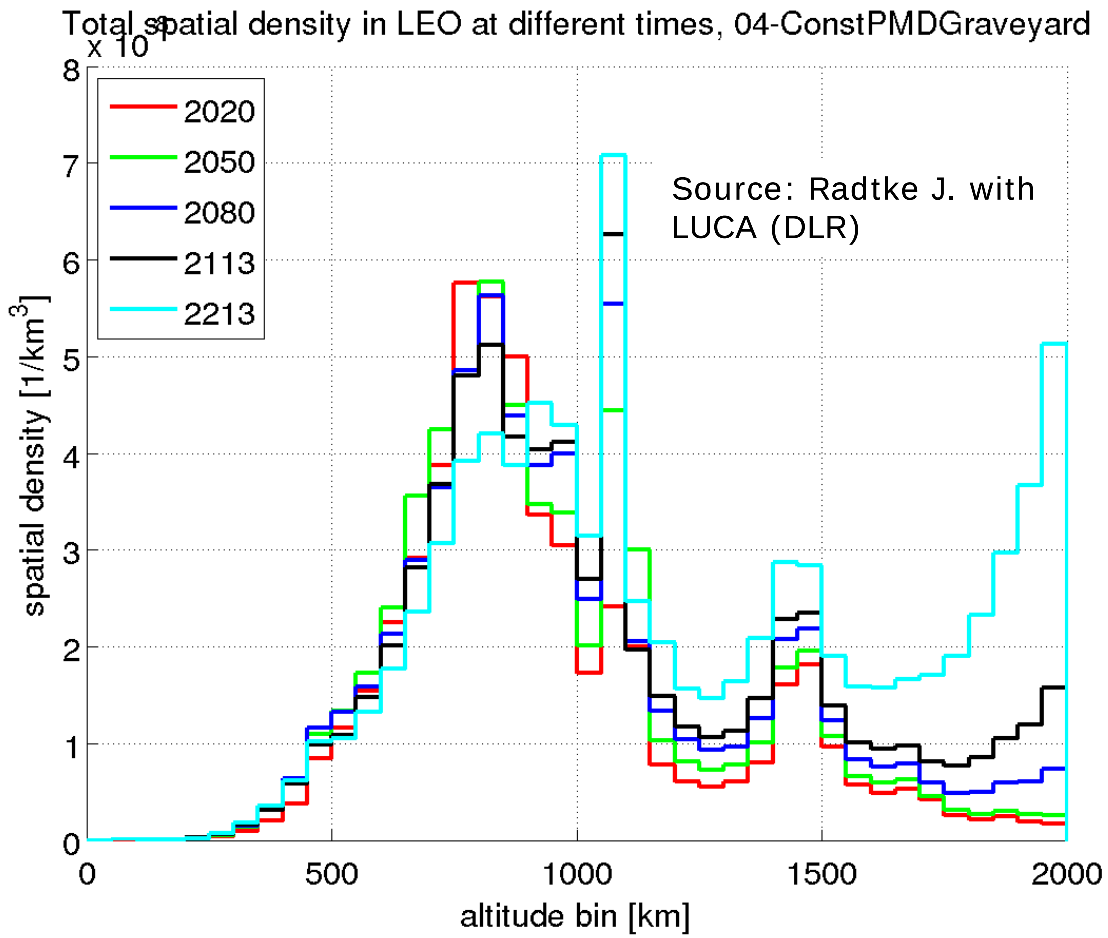


Source: Lewis H. with DAMAGE (SOTON)



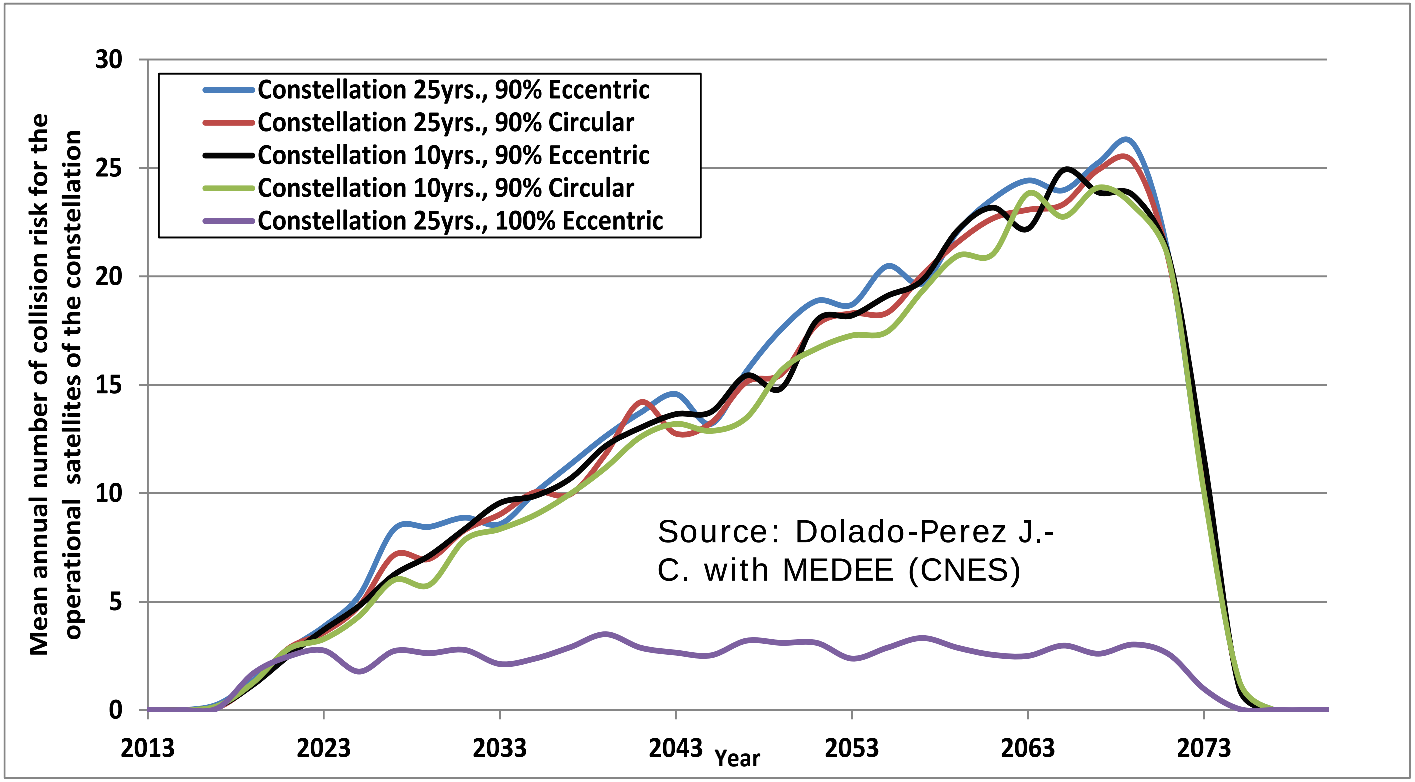
Re-Orbiting

- Re-orbiting to > 2000km leads to (in the absence of atmospheric decay) a contamination of all altitudes above the constellation



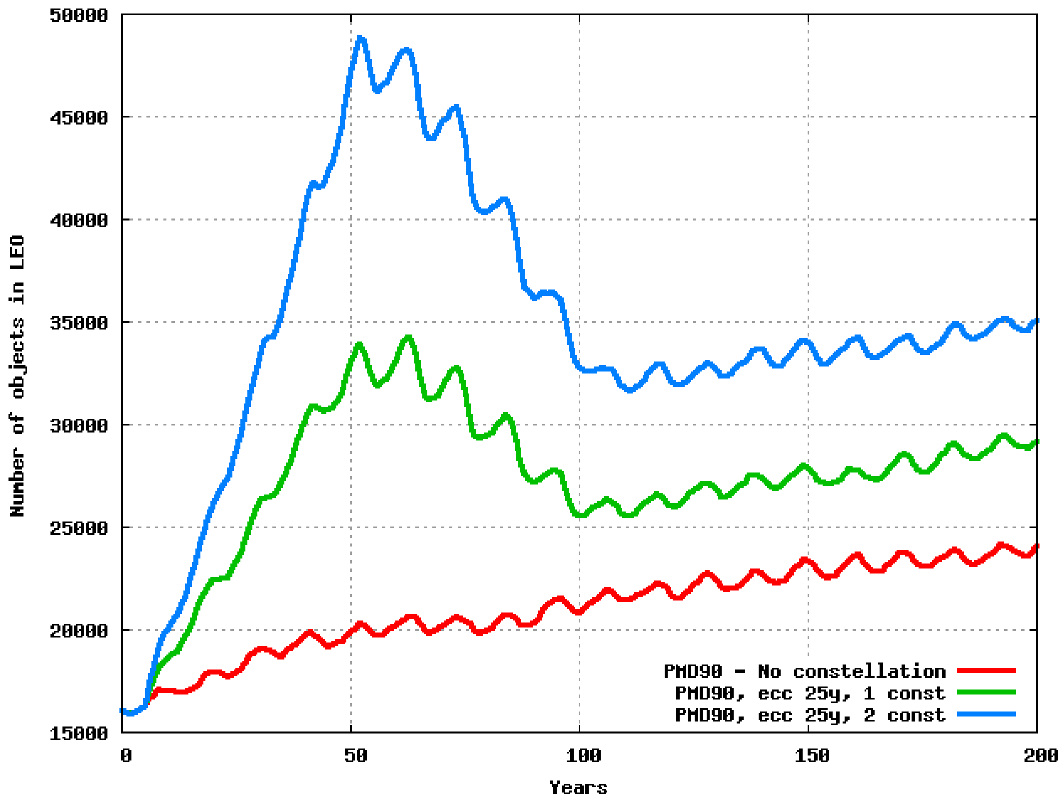
Collision Avoidance

- Collision Avoidance efforts for the constellation satellites can grow by a factor of 6 over the constellation lifetime
- In absolute terms, the constellation may have to handle between 2,000 and 140,000 close approach alerts (JSpOC alert crit.) per year



Multiple Constellations

- Can the findings for a single constellation be transferred to multiple constellations?
- Test: Duplication of the population at 1200km altitude
- Object number also double – Approach is generic



Source: Bastida Virgili B. with DELTA (ESA)

Conclusions

- The operation of a mega constellation means a step increase in launch traffic. The impact can be analysed in a generic manner
- The level of adherence to the post mission disposal guidelines is the absolute key driver for the environmental impact
- This does not only concern the satellites, but also the upper-stages used (ignored in this study)
- Historical behaviour (of all objects) in this regard shows that post mission disposal is a technological and operational challenge in reality
- The mission duration will drive the environmental level in combination with the post mission disposal rate
- Impact of the disposal on lower altitude can be mitigated to some degree (eccentric disposal, lower post mission lifetime)
- Operational efforts in terms of collision avoidance are very high
- The impact of the behaviour of the background on the observed trends needs to be analysed