

Comparing the Long-term Evolution of the Space Debris Environment with DELTA, LEGEND and SDM

C. Martin, J.- C. Liou, A. Rossi

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Introduction

- To compare the results of different models for a common reference scenario
 - SDM 3.0 (developed for ESA at ISTI/ CNR in Italy)
 - DELTA 2.0 (developed for ESA at QinetiQ in the UK)
 - LEGEND (developed at NASA/ JSC in the USA)
- Inter- Agency Space Debris Co- ordination Committee
 - Effort initiated several years ago to compare the results of evolution models available in member organisations
 - To achieve this a common set of input data and a common simulation scenario was identified and agreed

Study Description

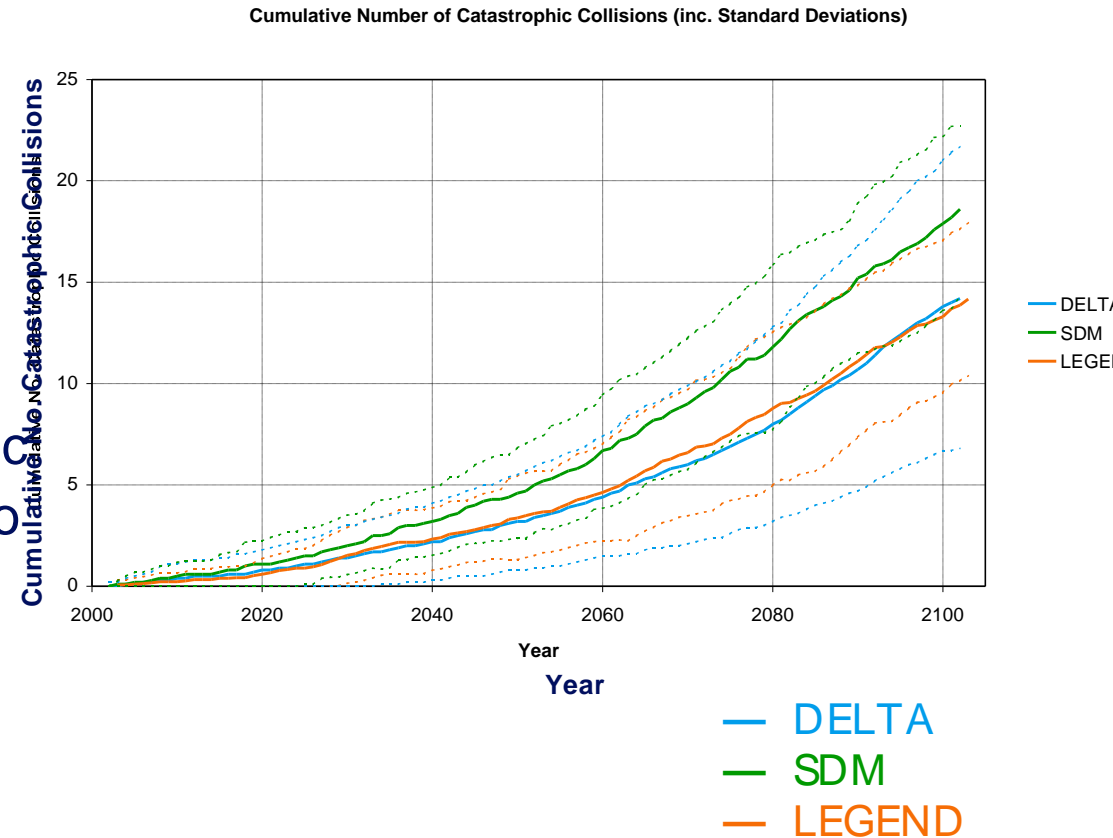
- Projection period 100 years (2002 – 2102)
- Payload operational lifetime 7 years
- Rocket body operational lifetime 0 years
- Initial environment ≥ 1 cm Snapshot 1- Jan- 02
- Projected launch traffic 8 year cycle IADC Baseline 2002
- Projected explosion traffic 8 year cycle
- Explosion prevention Complete prevention from 2012
- Non- fragmentation sources Ignored
- Projected solar activity F10.7 data
- Minimum collision target mass 50 kg; ≥ 10 cm in LEGEND
- Altitude resolution 50 km (200 – 2,000 km)

Comparing the Models

- Each model has an implementation of the NASA Break-up Model for explosions and collisions
 - A recent IADC comparison shows good agreement between models
- Different collision prediction algorithms
 - LEGEND uses pair-wise collision prediction, treating each object individually
 - DELTA only models catastrophic collisions
- Different orbit propagators
- SDM uses mass as main physical quantity, object size / area is derived for reporting purposes in this study

Catastrophic Collisions

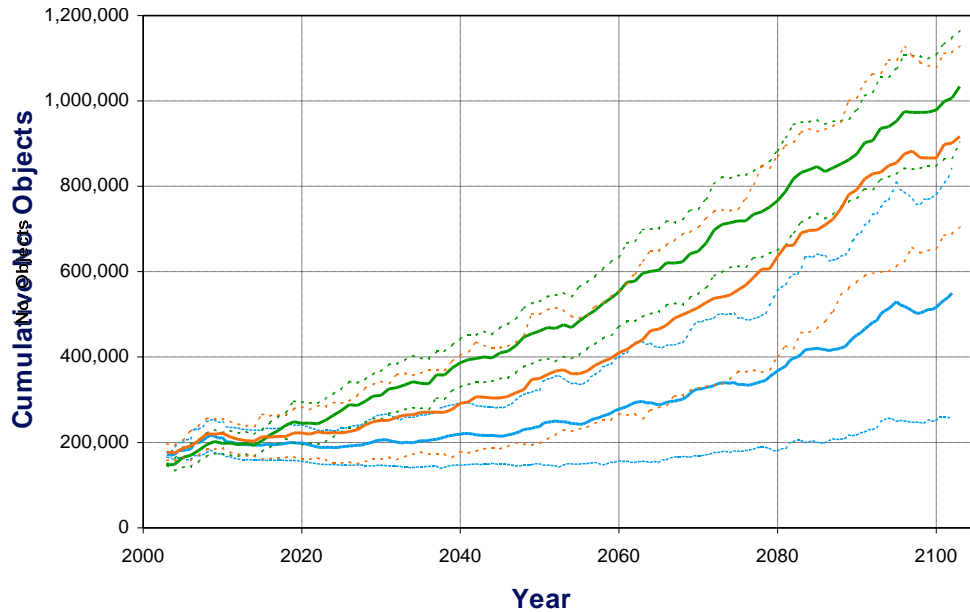
- Good agreement
 - In the absolute number of catastrophic collisions
 - In the trend of the cumulative number of catastrophic collisions
- Distribution of catastrophic collisions with altitude also shows a good comparison
 - Most collisions occur at ~ 800 km and ~ 1,000 km
 - Smaller number (~ 2 – 3) occur at ~ 1,400 km



Number of Objects in LEO

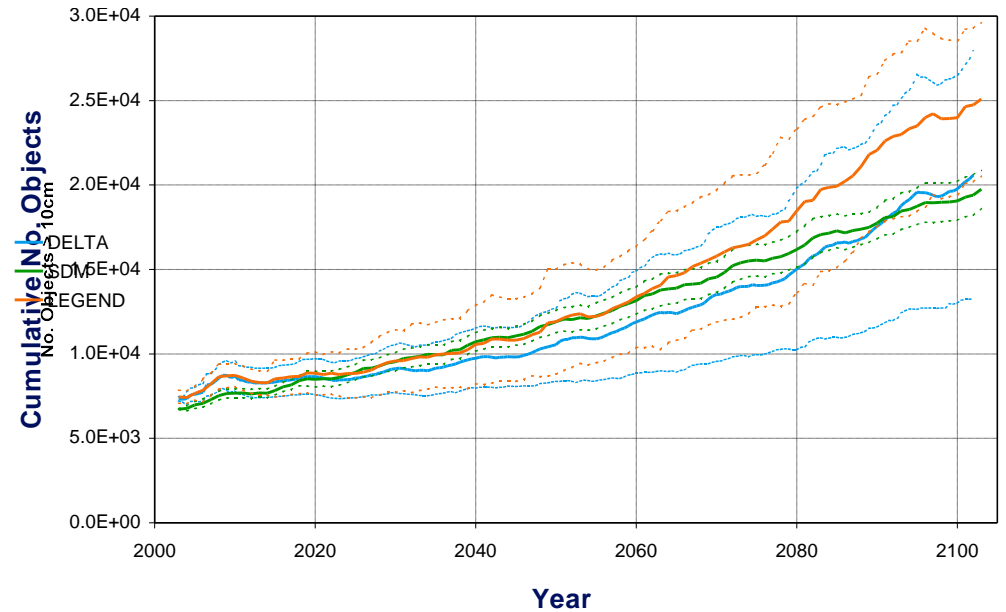
1 cm

Number of Objects > 1 cm in LEO (inc. Standard Deviations)



10 cm

Number of Objects > 10 cm in LEO (inc. Standard Deviations)



— DELTA — SDM — LEGEND

Number of Objects in LEO

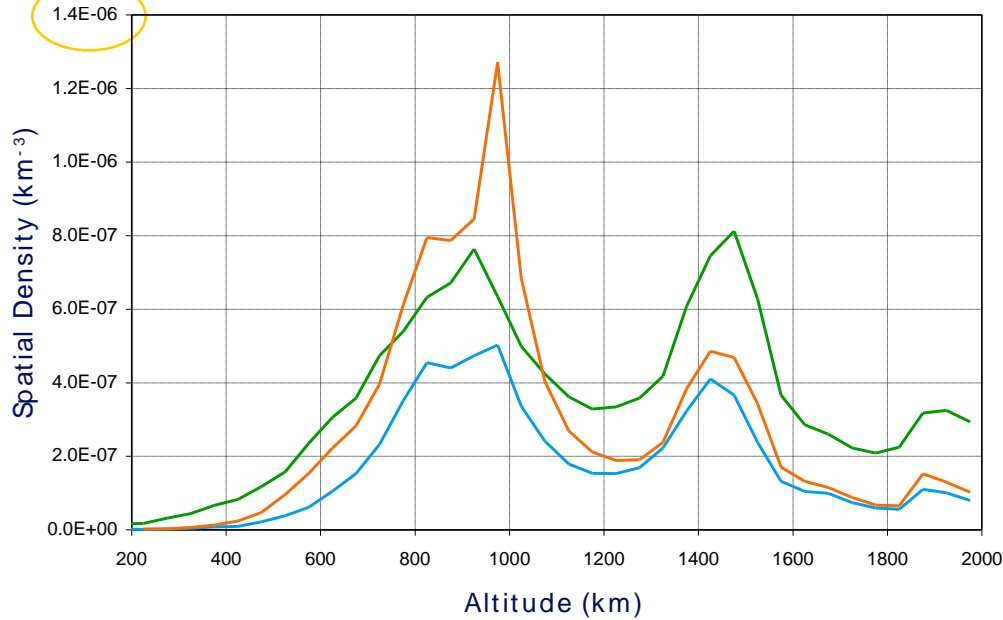
- DELTA is predicting fewer objects ≥ 1 cm
 - On average $\sim 40 - 45\%$ fewer than LEGEND & SDM after 100 yrs
 - But, DELTA is predicting an equivalent number of catastrophic collisions (source of objects after 2012)
 - Attributable to collision prediction algorithm
 - DELTA does not model “damaging” collisions
 - DELTA is not predicting collisions between large intact objects
- Better agreement in the number of objects ≥ 10 cm
 - Differences due to the different masses of objects involved in collisions in each of the models

Spatial Density v. Altitude ≥ 1 cm

In year 2052

Spatial Density of Objects > 1 cm in LEO (2052)

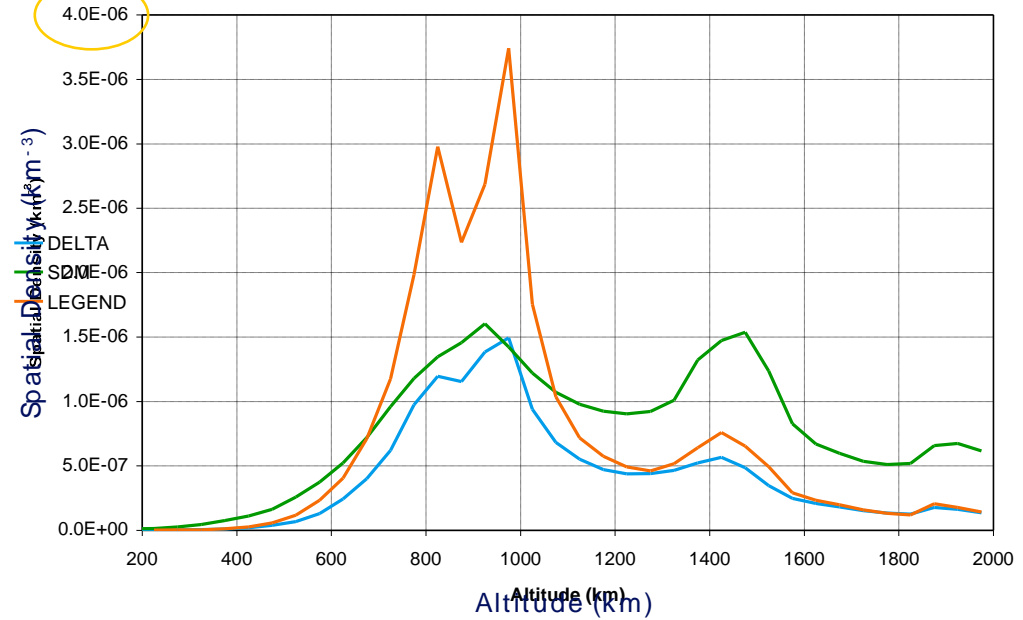
1.4×10^{-6}



In year 2102

Spatial Density of Objects > 1 cm in LEO (2102)

4.0×10^{-6}



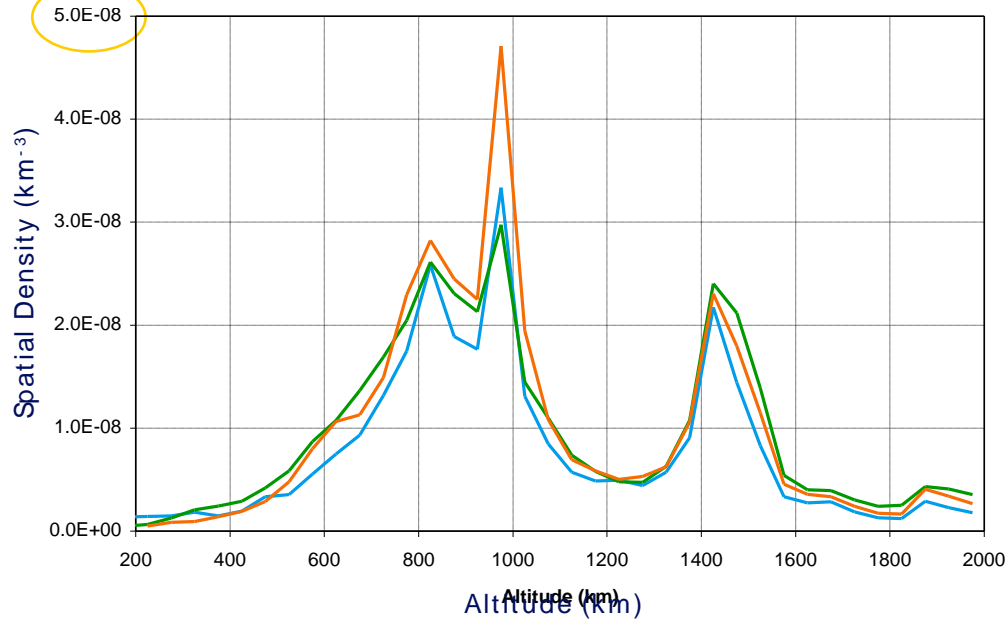
— DELTA — SDM — LEGEND

Spatial Density v. Altitude ≥ 10 cm

In year 2052

Spatial Density of Objects > 10 cm in LEO (2052)

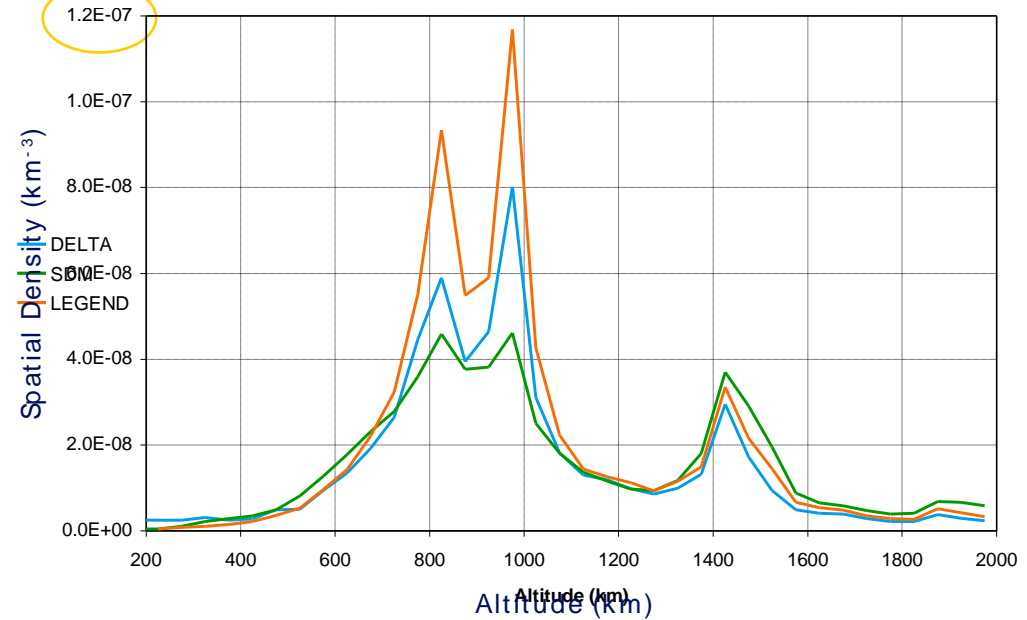
5.0×10^{-8}



In year 2102

Spatial Density of Objects > 10 cm in LEO (2102)

1.2×10^{-7}



— DELTA — SDM — LEGEND

Spatial Density of Objects in LEO

- Spatial density peaks correspond to the altitudes of predicted collision events
- Derivation of object size from mass in SDM
 - Objects “lighter” than those of equivalent size in other models
 - Therefore, expect SDM spatial density levels to be reduced at altitudes where atmospheric drag is important
- Low DELTA spatial densities for objects ≥ 1 cm corresponds to the lower number of centimetre-sized objects predicted

Spatial Density of Objects in LEO

- SDM shows no peak in the spatial density of objects ≥ 1 cm at 800 km altitude
 - Not due to the number of predicted collisions at this altitude
 - SDM predicts a similar number of events to the other models
 - Not a result only of the derivation of object size from mass for reporting purposes
 - Attributable partly to atmospheric drag model
- Peaks in the spatial density of objects ≥ 10 cm show good correspondence between all the models

Summary

- Comparison made between SDM 3.0, DELTA 2.0 and LEGEND for a common reference scenario
 - Comparison between models, not agreed prediction of future evolution of debris environment
- Overall, very good agreement between model predictions
- Differences observed considered to be principally due to
 - Collision prediction algorithms
 - Orbit propagation