NASA's Orbital Debris Environment Model
ORDEM 3.0

Implications for Measurements and Modeling

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WG 1-2 Joint Meeting

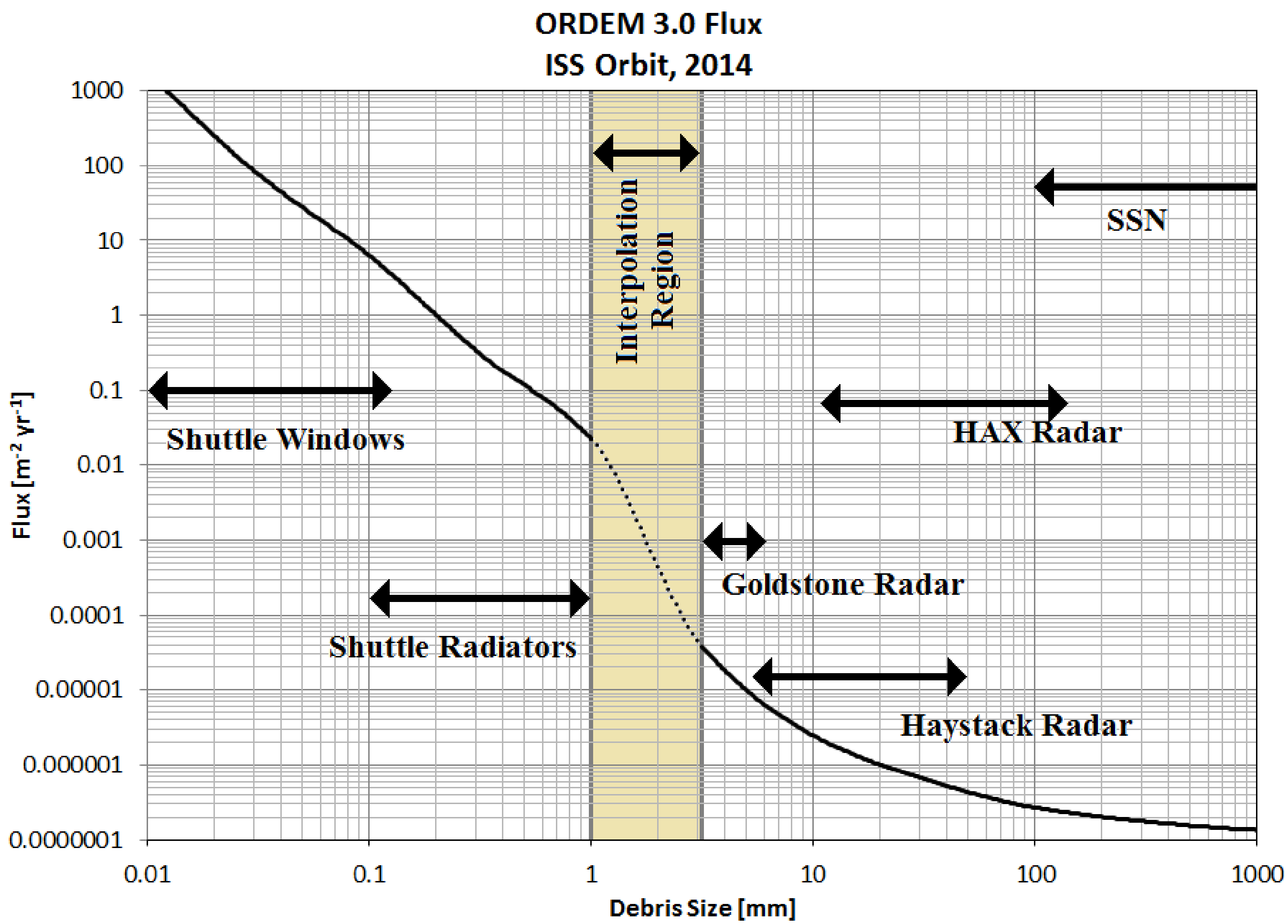
ORDEM 3.0

- **An engineering model is a tool (primarily) for spacecraft designers and users to understand the long-term risks of debris collisions**
- **ORDEM 3.0 represents NASA's best estimate of the current and near future orbital debris environment.**
  - The environment is dynamic and must be updated periodically.
- **ORDEM 3.0 has significant new capabilities**
  - Uncertainties
  - Material density categories
  - Model extended to GEO
  - Can easily calculate flux for satellites in highly elliptical orbit

ORDEM Flow
Creating the Current Environment

- **Initial environment created using database of known space activity and tools such as the NASA Standard Breakup Model & PROP3D**
- **Environment dominating events such as the Chinese ASAT (~850 km) and the Iridium/COSMOS collision (~775 km) were modeled separately as were a few unique populations**
- **Material distributions derived from analysis of residue in impact features from returned spacecraft surfaces and from ground impact tests**
- **Initial environment fit to measurement data using Maximum Likelihood Estimator to create final "Current" debris environment**
  - Weighting factors derived from the fitting routine are used to project into the future

Data and Size Regimes



- **Small particle populations are fit separately from large particle populations**

ORDEM Flow
Projecting Into the Future – Debris > 1 mm

- **LEGEND used to propagate the "Current" environment into the future**
- **When LEGEND creates new future debris (such as through collision or explosion) the same weighting values that were used to fit historical size distributions are applied to debris production in the future**
- **Launch rate, solar activity, and explosion rate are independent inputs into the model**
- **Probability of future debris producing collisions is calculated based on spatial density and cross sectional area of orbiting objects**
- **120 Monte Carlo future environments are created**
- **Reported future environment is the average of the 120 possible future environments**

ORDEM Flow
Projecting Into the Future – Debris < 1 mm

- **LEGEND used to characterize the population of intact objects**
- **The surface degradation model "creates" particles with zero delta-velocity at different sizes and material types proportional to the area of the parent body**
- **These debris are propagated under solar radiation pressure and atmospheric drag to compute flux on *in situ* surfaces**
- **Damage equations (based on empirical tests) are used to estimate distribution in feature size (e.g., crater diameter)**
- **Production rates at the parent bodies adjusted to match data**
- **Assumptions**
  - Production rate only a function of area of parent, not broken down by type of parent or orbit family
  - No "feedback" assumed such as would be expected from ejecta due to small collisions

ORDEM 3.0 vs. ORDEM2000

Parameter	ORDEM2000	ORDEM 3.0
Spacecraft & telescope/radar analysis modes	Yes	Yes
Time range	1991 to 2030	2010 to 2035
Altitude range with minimum debris size	200 to 2000 km (>10 μm) (LEO)	200 to 38,000 km (>10 μm) (LEO to GTO) 34,000 to 38,000 km (>10 cm) (GEO)
Orbit types	Circular (radial velocity ignored)	Circular to highly elliptical
Model populations divided by type & material density	No	Intacts Low-density (<2 g/cc) – e.g., plastic Medium-density (2-6 g/cc) – e.g., aluminum High-density (>6 g/cc) – e.g., steel RORSAT NaK coolant droplets (0.9 g/cc)
Special model populations	No	Yes (ASAT, Iridium/Cosmos, Snapshot, Transit)
Model cumulative size thresholds (*fiducial points*)	10 μm, 100 μm, 1 mm, 1 cm , 10 cm, 1 m	10 μm, 31.6 μm, 100 μm, 316 μm, 1 mm, 3.16 mm, 1 cm, 3.16 cm, 10 cm, 31.6 cm, 1 m
Flux uncertainties	No	Yes
Meteoroids	No	No*

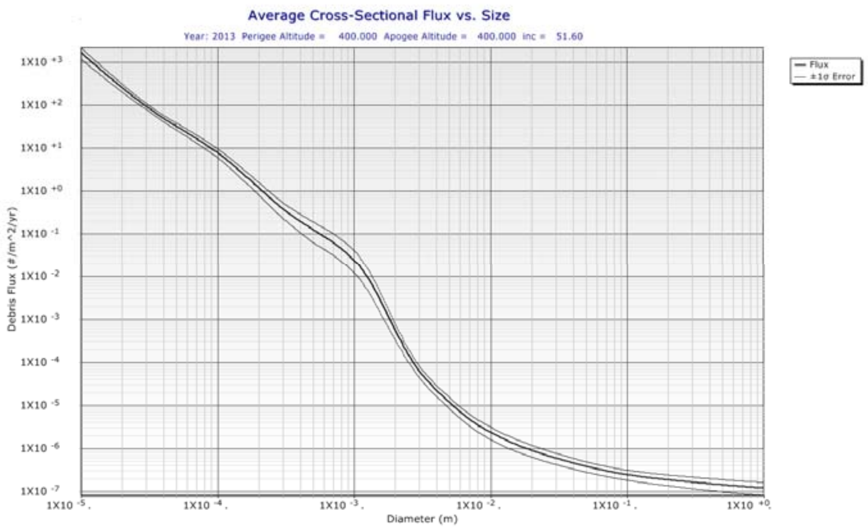
*** a separate meteoroid environment model (MEM) is available from NASA's Meteoroid Environment Office**

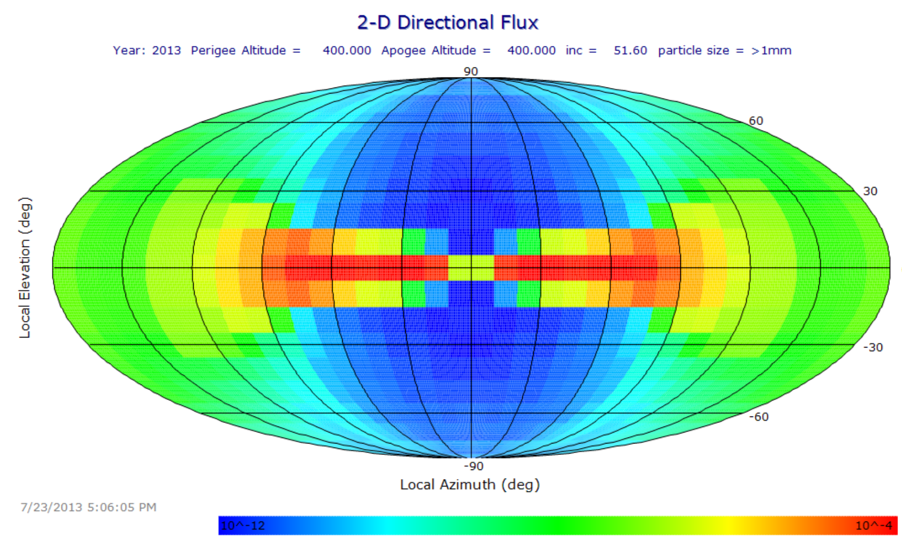
ORDEM 3.0 Datasets and Supporting Models

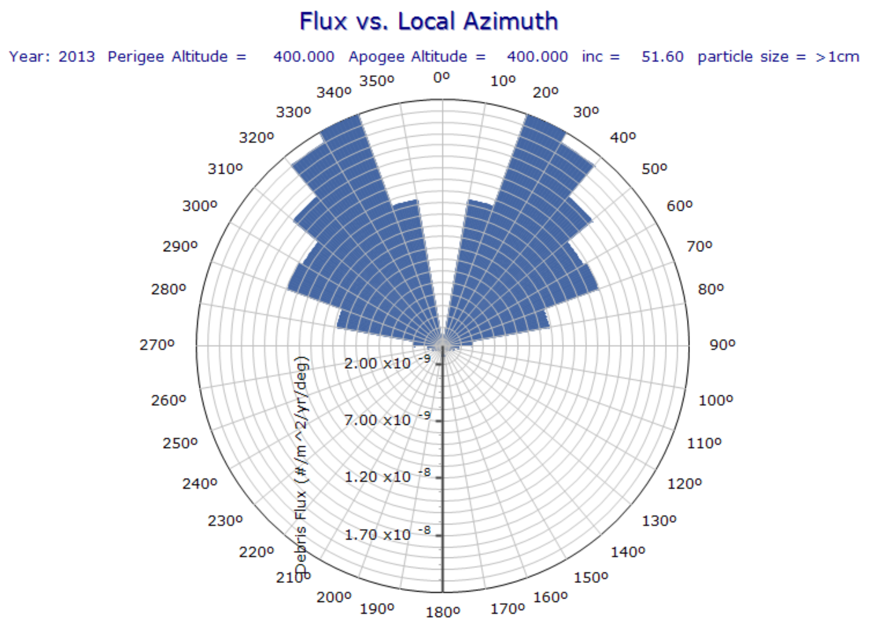
Observational Data	**Role**	**Region/Size**
SSN catalog (radars, telescopes)	Intacts & large fragments	LEO > 10 cm, GEO > 70 cm
HAX (radar)	Statistical populations	LEO > 3 cm
Haystack (radar)	Statistical populations	LEO > 5.5 mm
Goldstone (radar)	Statistical populations	LEO > 3 mm
STS windows & radiators (returned surfaces)	Statistical populations	10 μm $<$LEO $\leq$ 1 mm
MODEST (telescope)	GEO data set	GEO > 30 cm

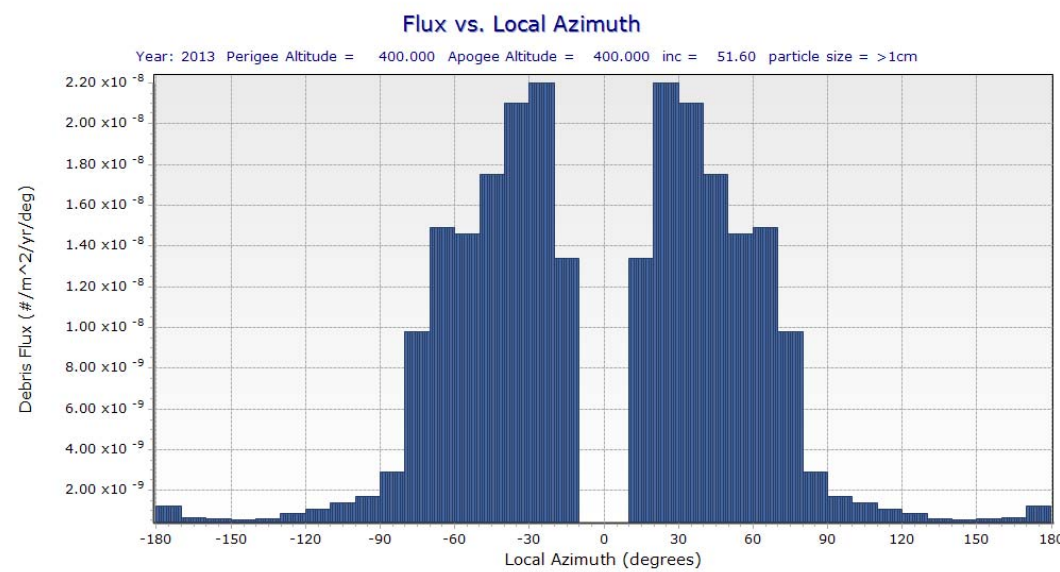
- Note that the US Space Shuttle is no longer an active data source

Graphical Output Options for Spacecraft Mode

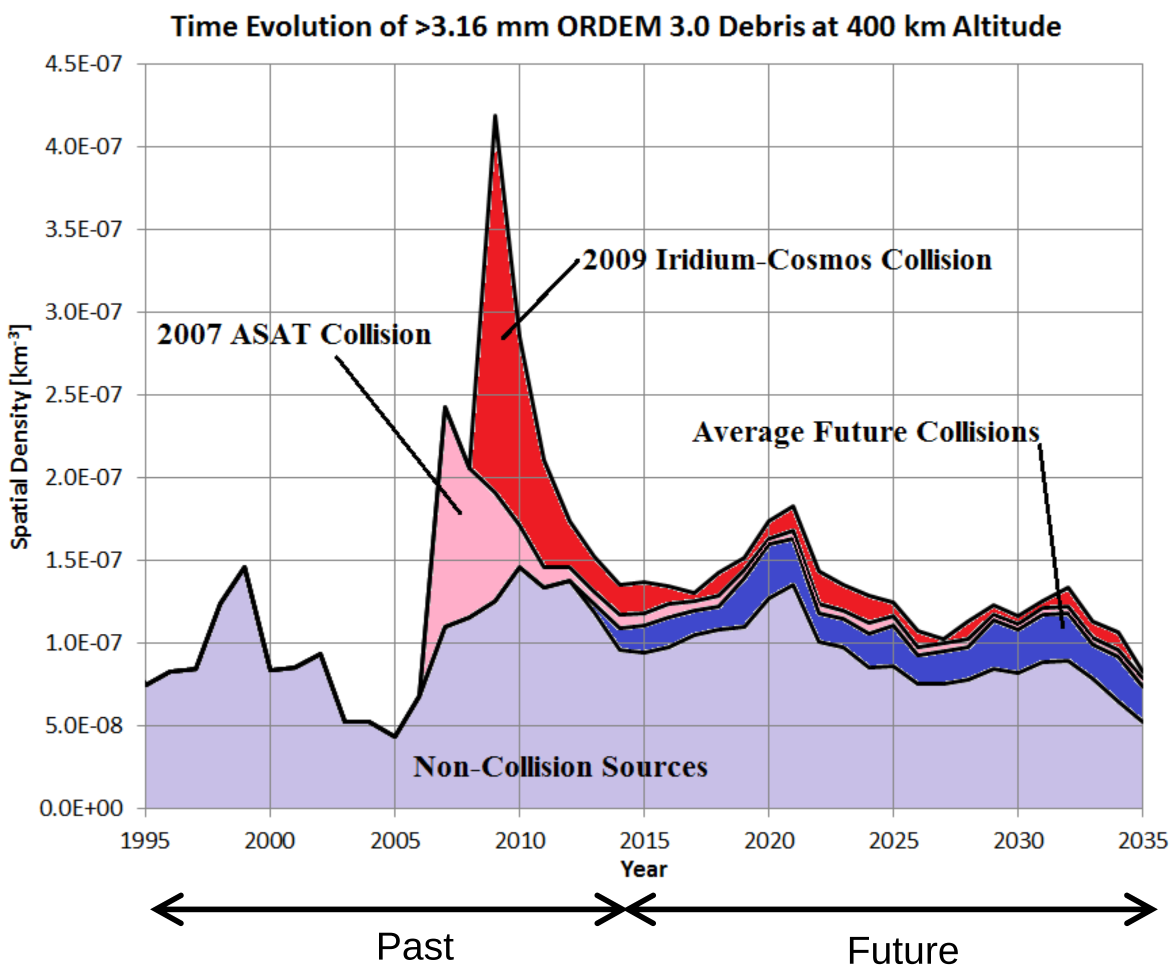








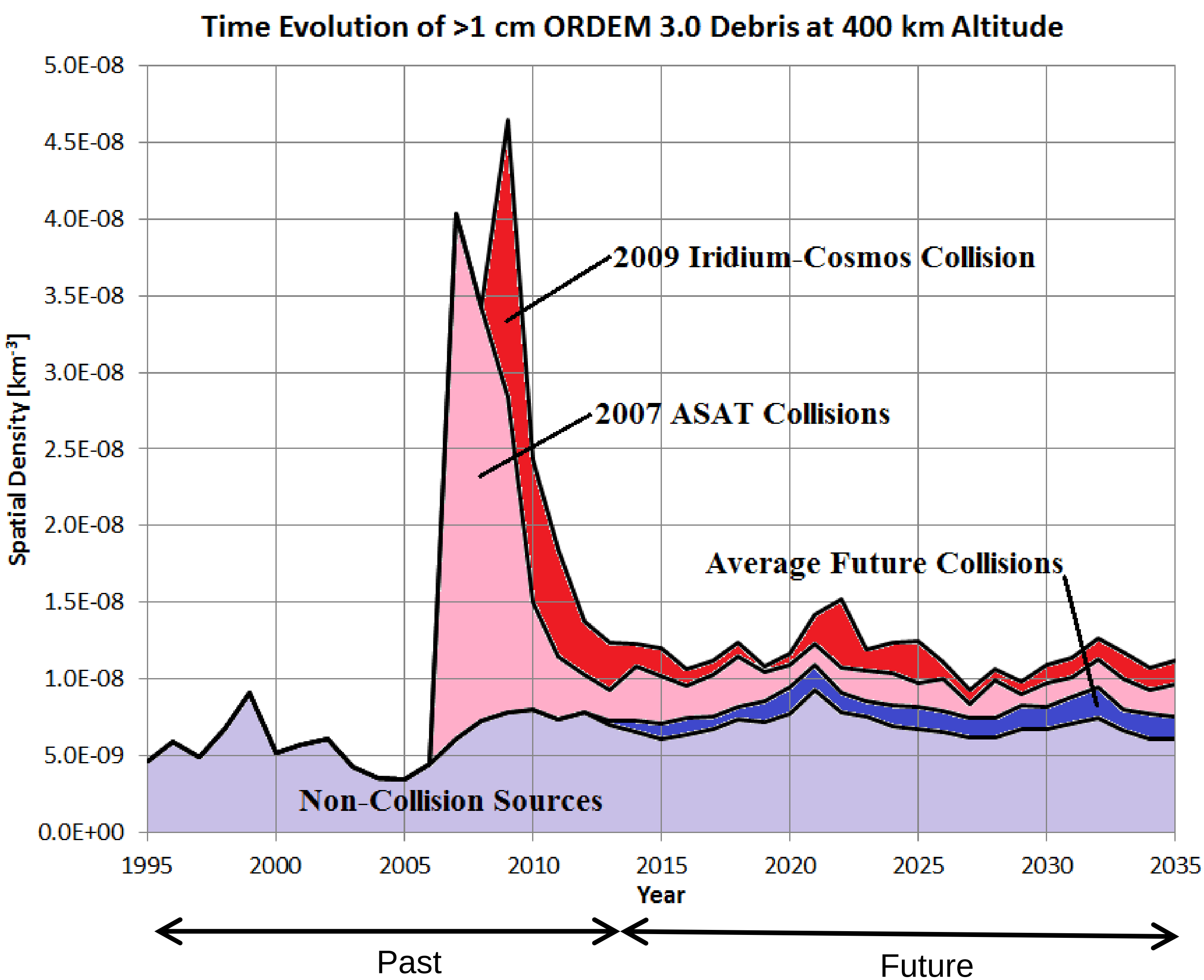
Past Environment vs. Future Risk; > 3 mm



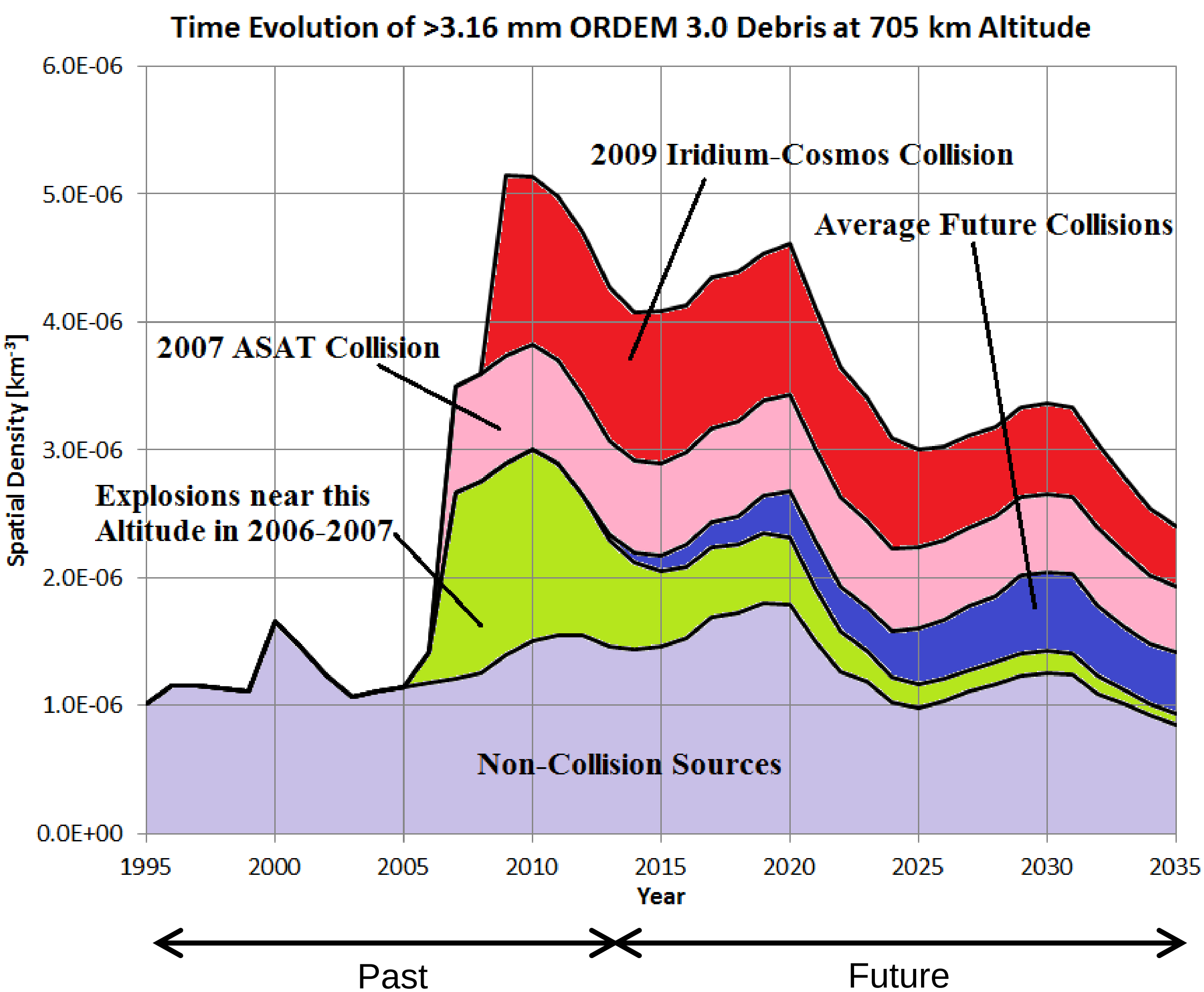
- **Predicted spatial density in the future is somewhat higher than pre-2007 measured values even though the contribution from the two collisions has dropped to very low levels.**
- **Part of the increase is due to averaging 120 different future "realities."**
  - Each future Monte Carlo environment has 0, 1, 2, or more future collisions or explosions at "random" times.
- **The future level is an accurate representation of the risk to ISS.**

Note: Public release version will not produce data prior to 2010

Past Environment vs. Future Risk; > 1 cm



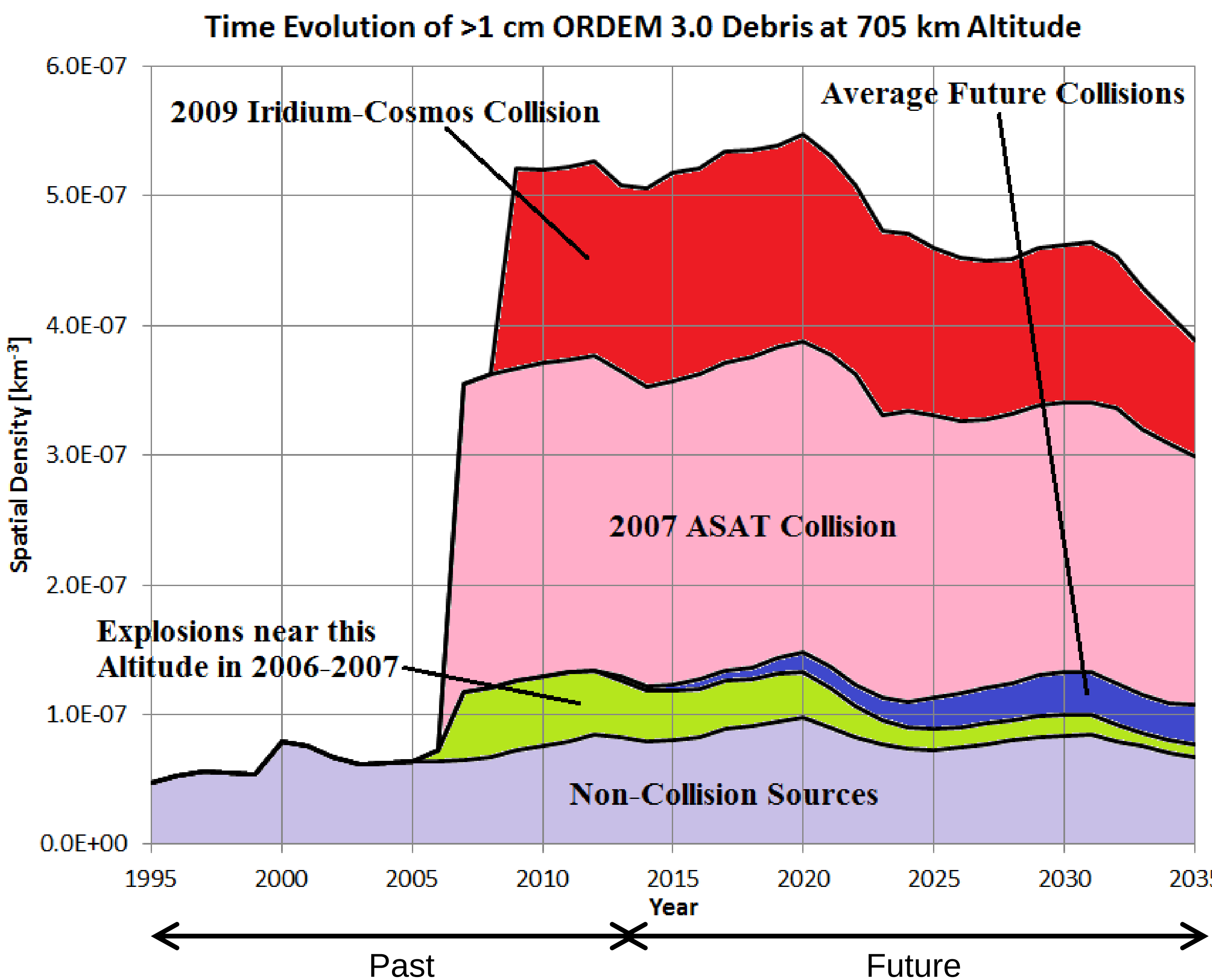
Future Population > 3 mm



- **Effects of explosions and collisions are not as transient at this altitude**

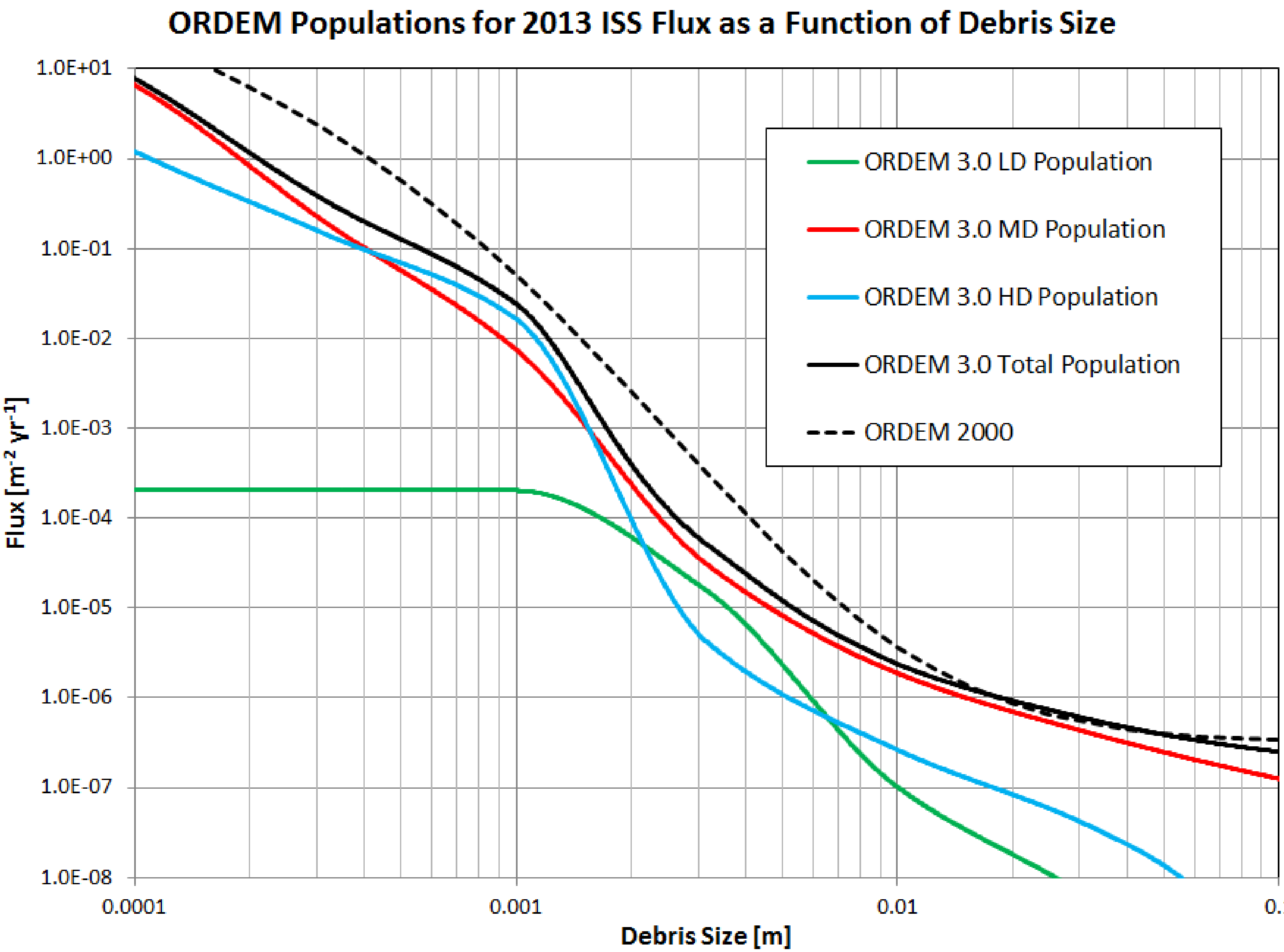
- **Spatial density at this altitude will remain much higher than pre-2006 levels for many years.**

Future Population > 1 cm



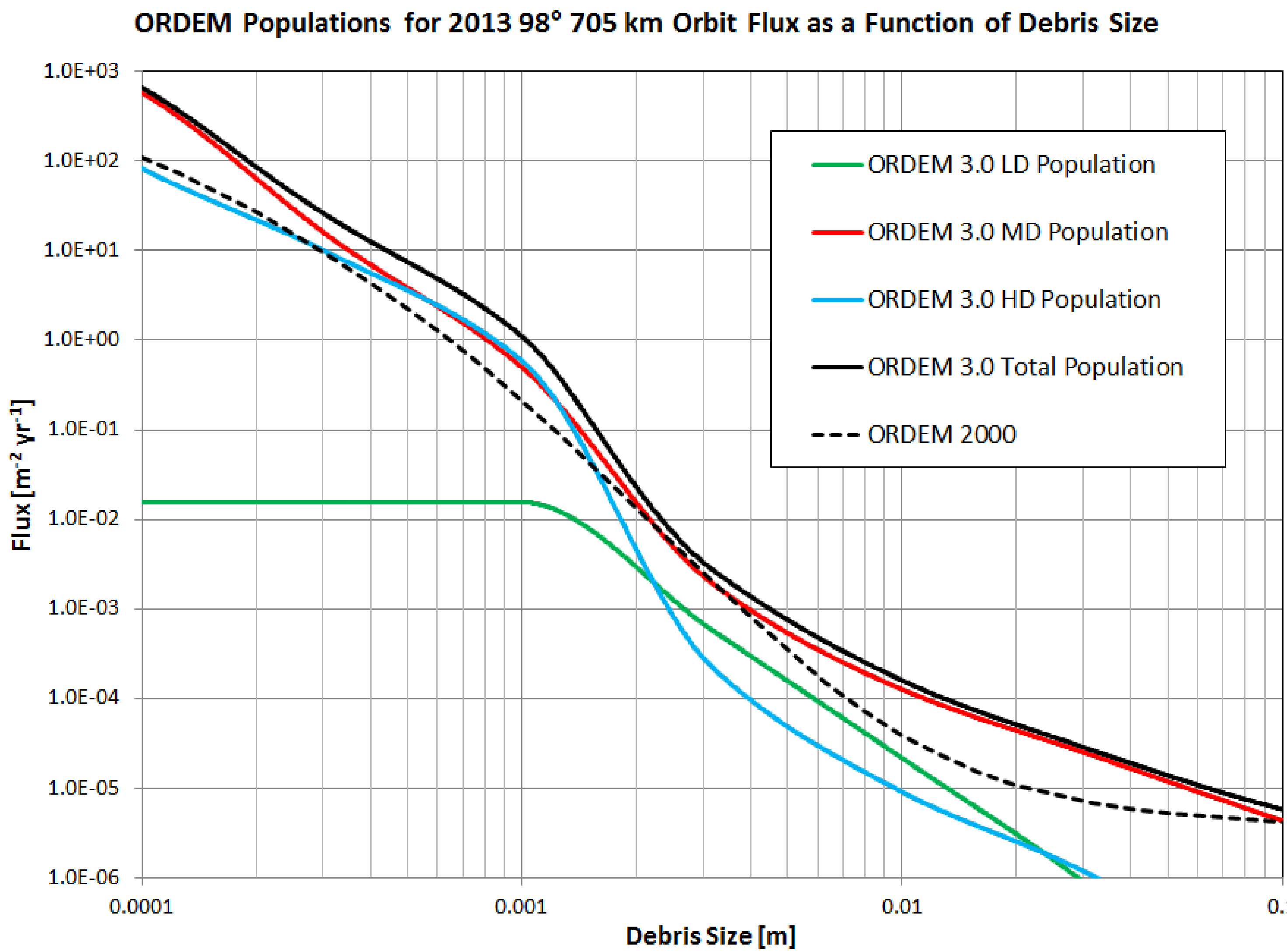
ORDEM Flux for ISS 400km

Material Distributions - ISS

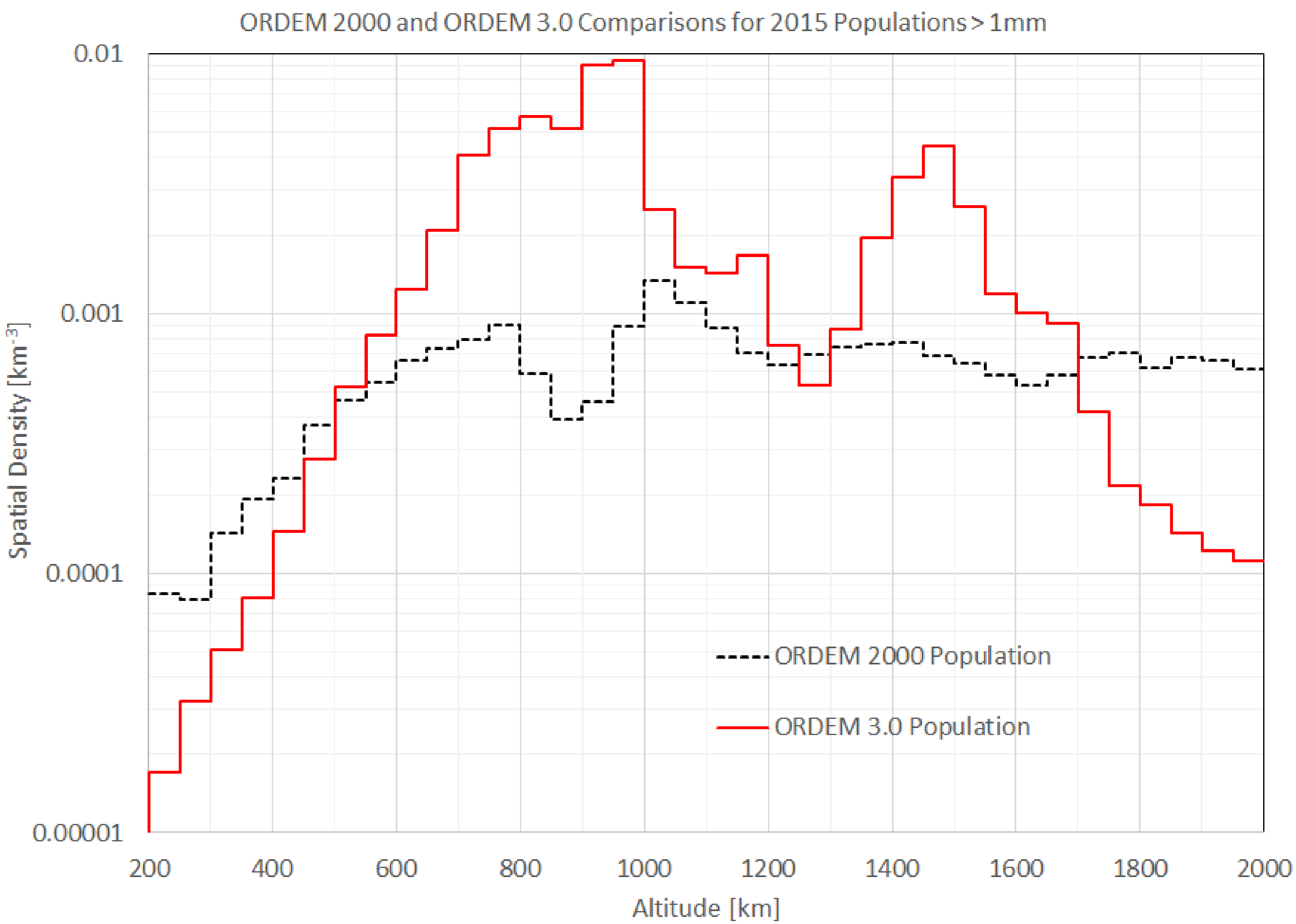


ORDEM Flux for A-Train 705km

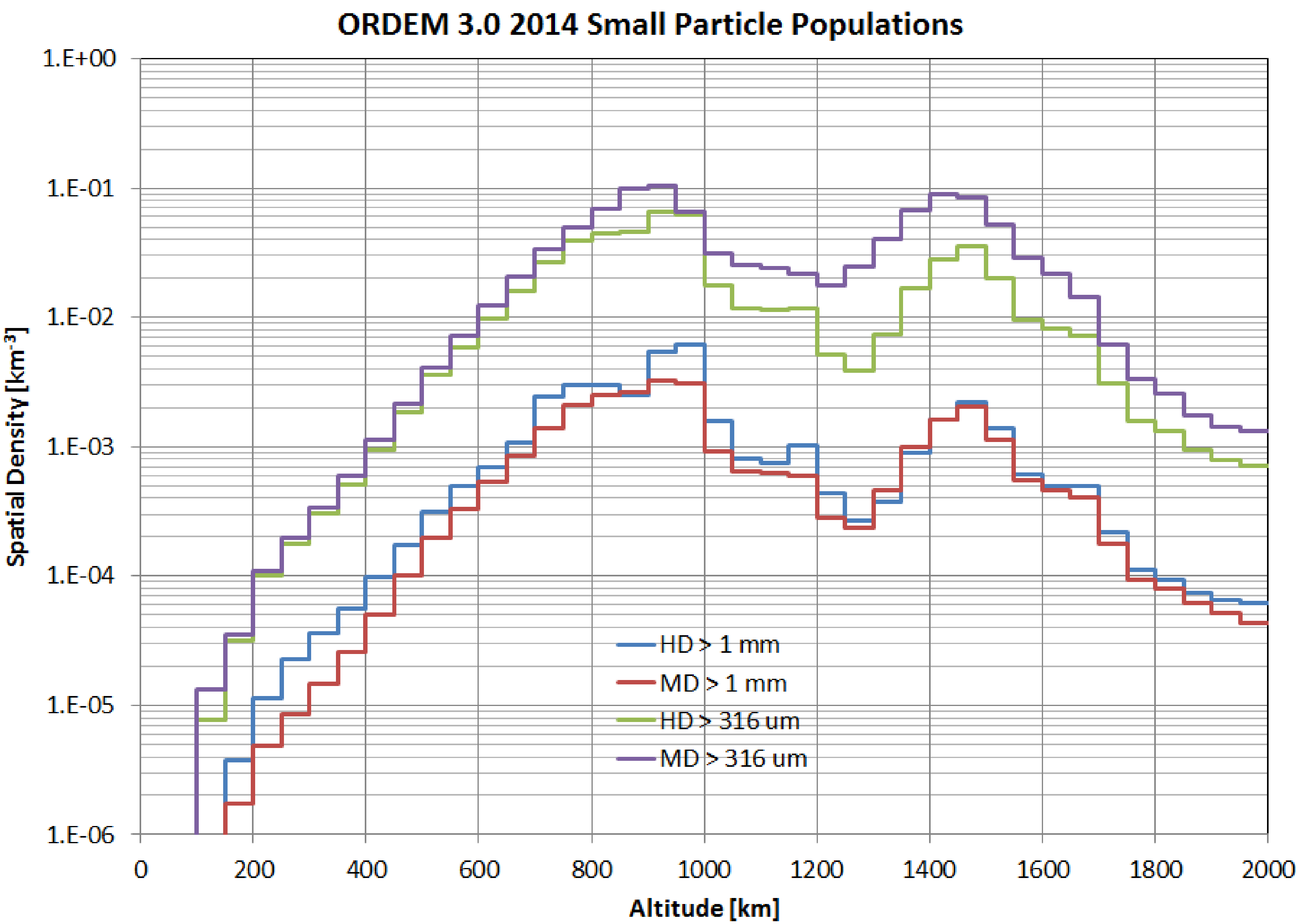
Material Distribution – A-Train



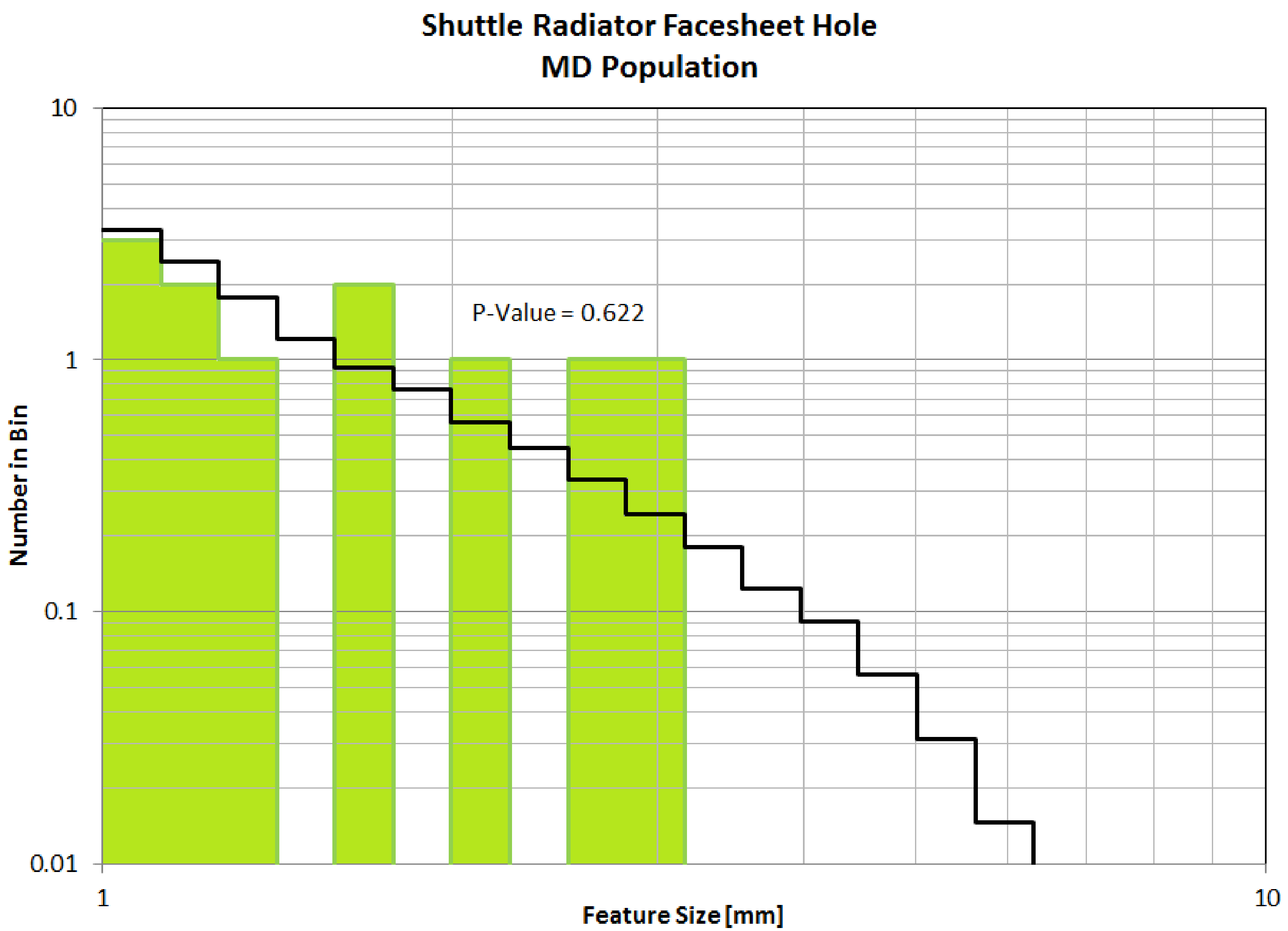
ORDEM 2000 and ORDEM 3.0



Small Particle Population



STS Radiator Data



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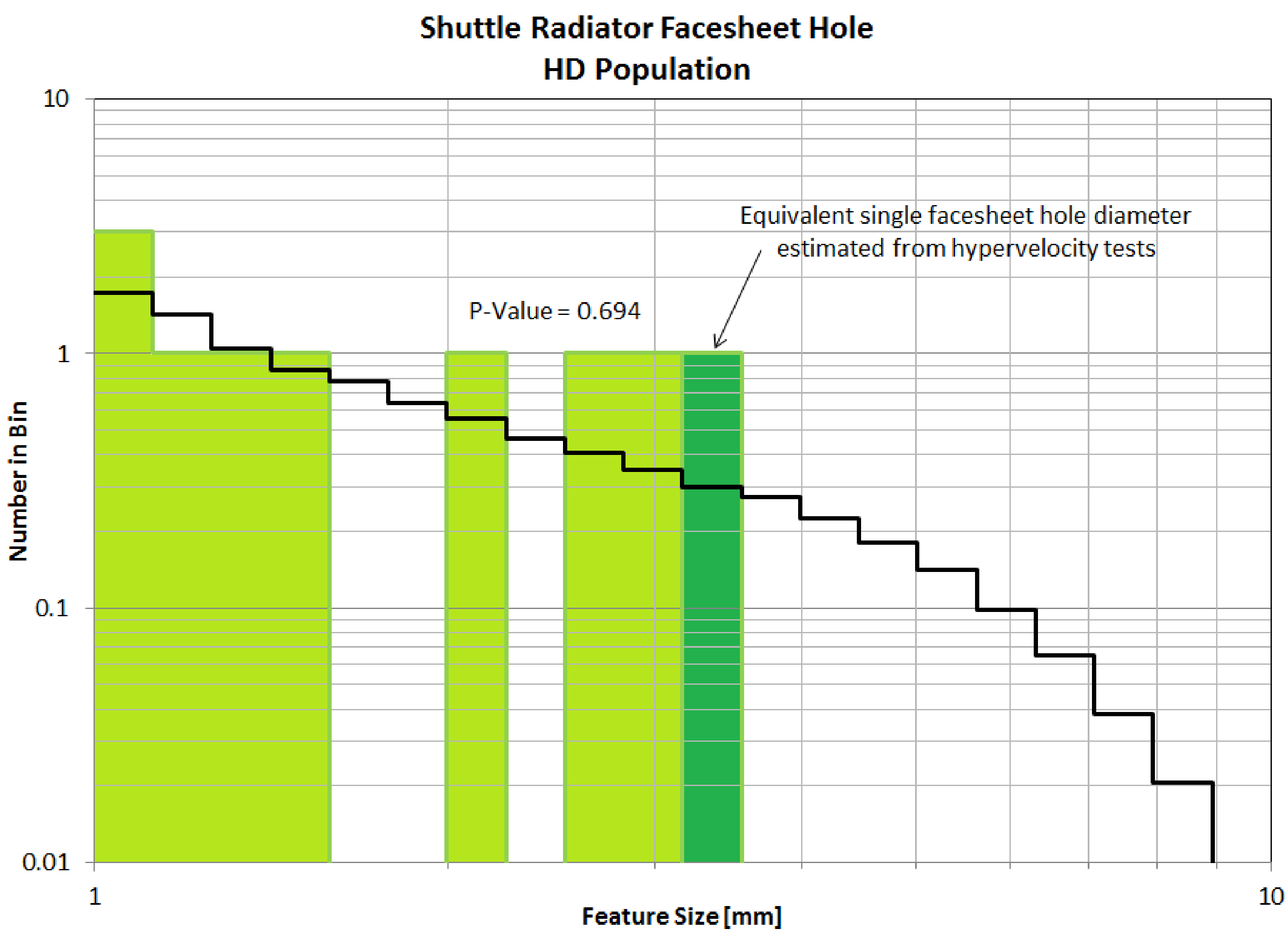
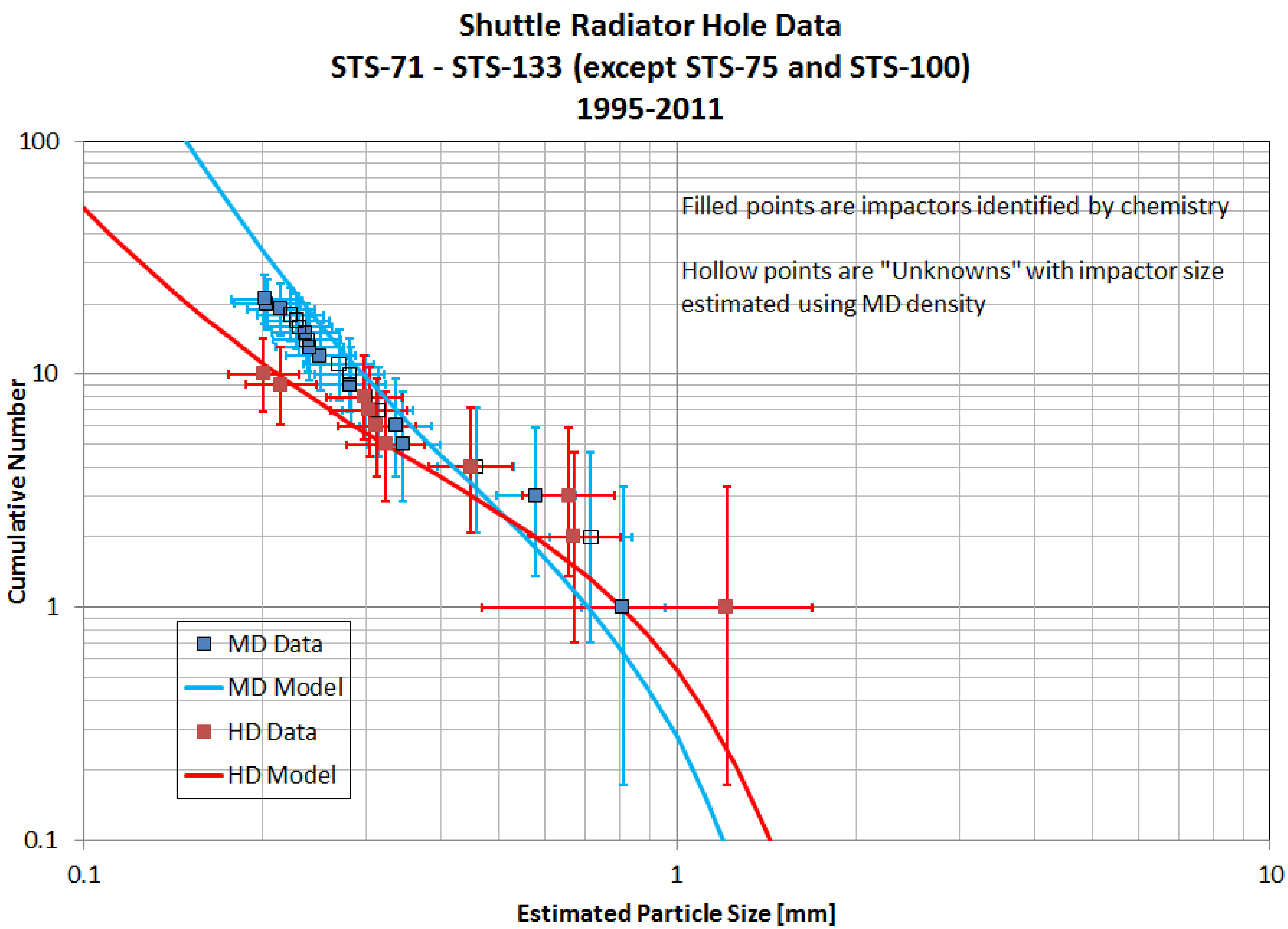


STS Radiator Data



Conclusions

- **The ORDEM model has allowed us to separate the risk from different material density categories of debris**
  - HD populations dominate the risk to all classes of spacecraft
  - HD populations drive down the critical size
- **Model and measurement limitations make it difficult to understand what is happening at higher altitudes for the 1 mm population**
  - Elliptical vs circular orbits
  - Sources? Production processes?
- **Our best data set of populations <1 mm is no longer available**
- **We need new and improved instruments to measure the <1 mm environment**
  - Collecting areas as large as possible (Shuttle Radiators ~100 m^2)
  - Measure particle sizes up to and larger than 1 mm
  - Distinguish material densities (especially HD vs MD)
  - Measure orbit parameters (especially inclination and eccentricity)
  - Measure at higher altitudes (e.g., sun-synchronous altitudes)