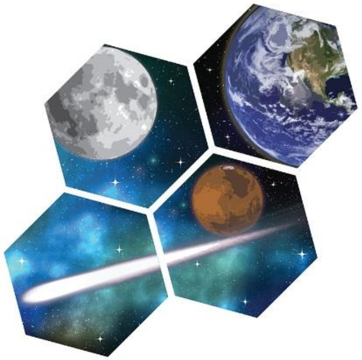
National Aeronautics and Space Administration

Orbital Debris Engineering Model (ORDEM) 3.1 Development and Validation

M. Matney and A. Manis

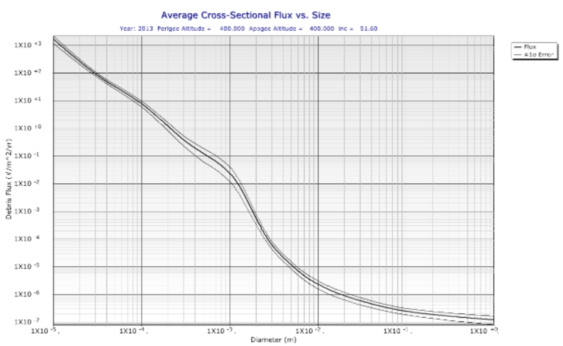
NASA Orbital Debris Program Office

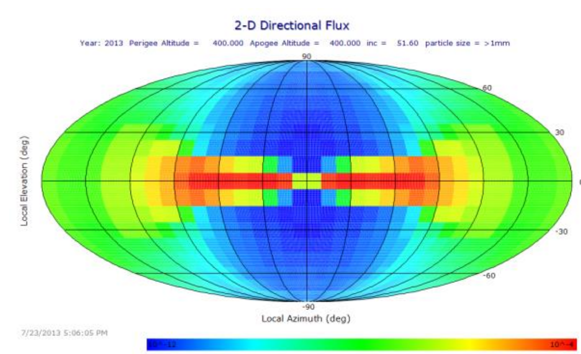


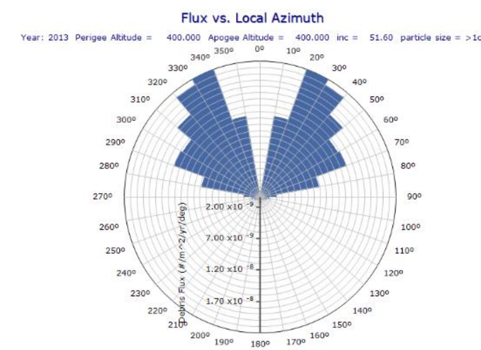
First MASTER Modelling Workshop
2 March 2021

ORDEM – A Mission Support Tool

- **Satellite designers and operators use the Orbital Debris Engineering Model (ORDEM) to estimate the orbital debris impact risks on their vehicles in Earth orbit**
  - ORDEM provides information on debris impact rate as a function of size, material density, impact speed, and direction along mission orbit







- **ORDEM 3.0 (2013) represented NASA's best estimate (at the time) of the current and near future orbital debris environment**

- **Since the orbital debris environment is dynamic, ORDEM must be updated periodically to better reflect reality**

ORDEM Modeling Approach

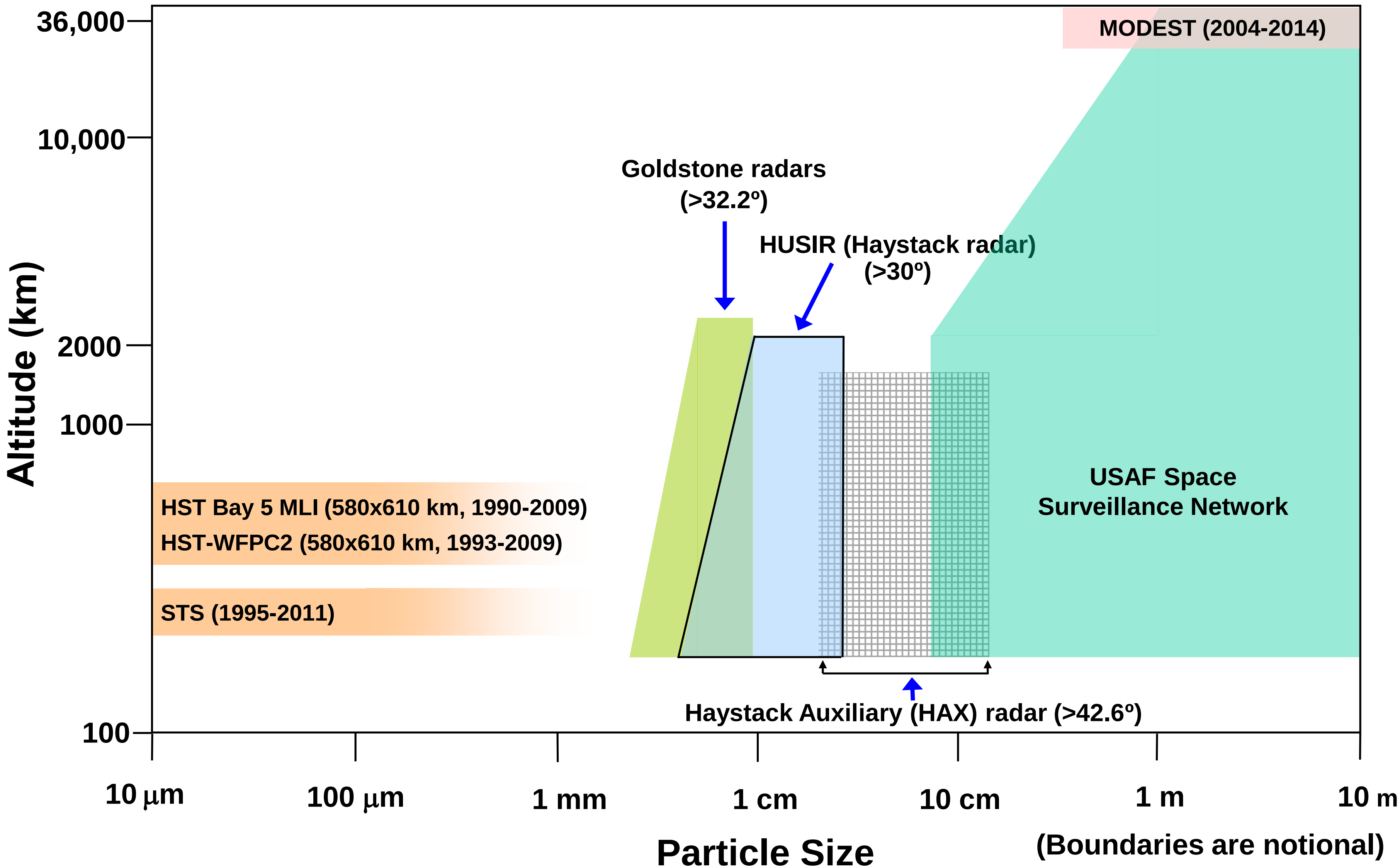
- **Data-driven approach uses measurement data to inform model population estimates**
  - Simulated debris populations are scaled using available measurement data
    - Remote measurements (radar and optical)
    - Returned surfaces (STS windows & radiators)
  - Measurements are indirect (RCS vs. size & material, Range & Range Rate vs. orbital elements, Feature size vs. debris size)
  - Incomplete, sparse samples (STS < ~600 km, radars cannot observe all inclinations, observations not continuous or available for future)
- **Initial model population estimates are based on historical model and data information**
  - Future launch traffic, surface degradation, breakups (explosions, random collisions), atmospheric drag
- **Data-adjusted model provides population estimates where and when we cannot observe**

*Note: Size = characteristic length

History of ORDEM

Year	Model	Notes
1996	ORDEM96	Analytical, using a set of equations to describe debris populations in 6 inclination bands and 2 eccentricity families in low Earth orbit (LEO)
2001	ORDEM2000	Numerical, debris populations were derived from measurement data, using a finite element model to describe the environment in LEO
2013	ORDEM 3.0	Numerical, using more data to derive debris populations, material density distribution and uncertainties were included in model predictions from LEO to GEO
2019	ORDEM 3.1	No changes to model architecture, but debris populations updated with more recent measurement data

Debris Measurement Coverage

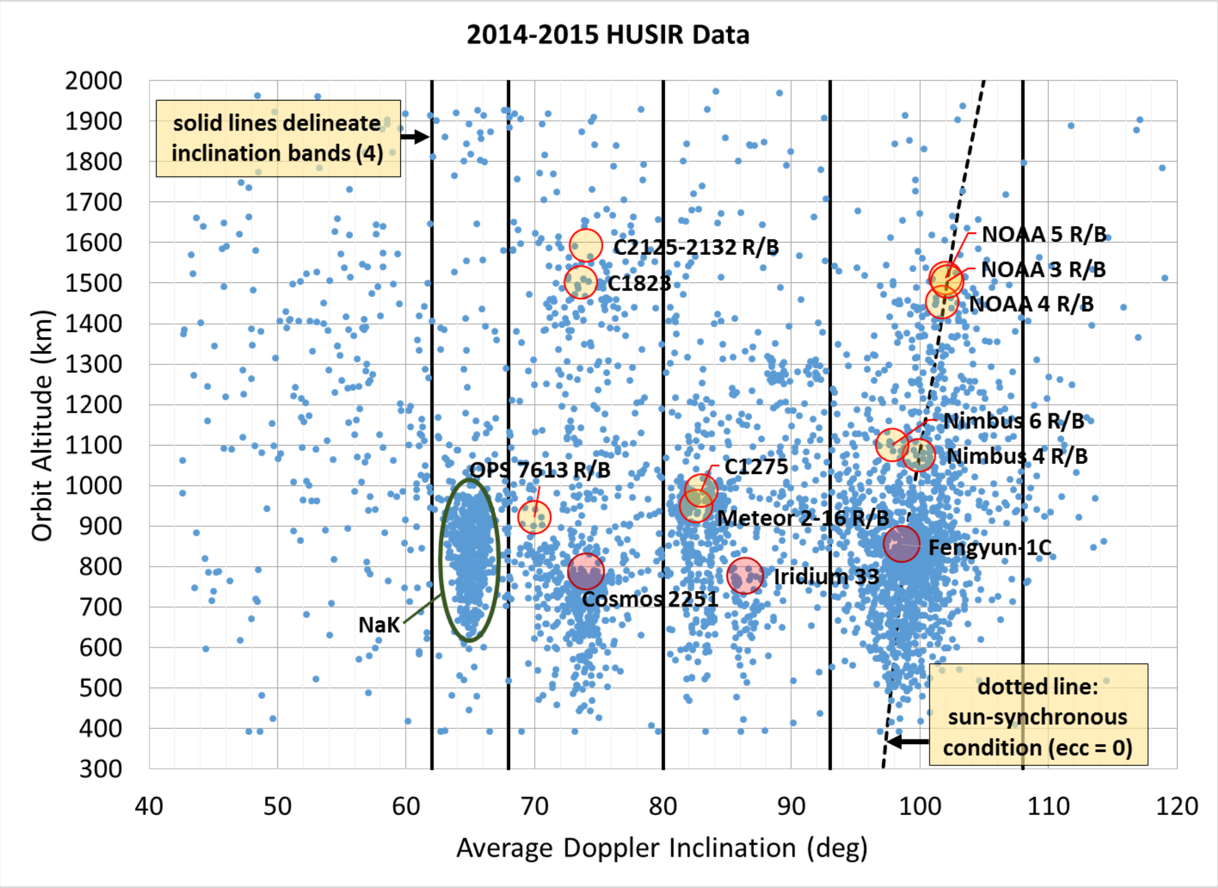


Data Sources – Model Build and Validation

Data Source	Source Type	Orbit Region	Detection Size Range (approximate)	Calendar Year(s): Model Build	Calendar Year(s): Model Validation
STS windows, excluding cargo bay windows	*in situ*	LEO	10 – 300 µm	1995-2011	N/A
STS radiators	*in situ*	LEO	300 µm – 1 mm	1995-2011	N/A
HST Bay 5 MLI cover	*in situ*	LEO	10 – 300 µm	N/A	1990-2009
HST WFPC-2 radiator	*in situ*	LEO	50 – 300 µm	N/A	1993-2009
HUSIR, 75˚E	Radar	LEO	>5.5 mm	2007*, 2009*, 2013-2015	2016-2017
HUSIR, 20˚S	Radar	LEO	>2 cm	2015	N/A
Goldstone	Radar	LEO	2 – 8 mm	N/A	2016-2017
SSN	Radar, Optical	LEO, GEO	>10 cm (LEO), >1 m (GEO)	1957-2015	2016
MODEST (UCTs and CT debris)	Optical	GEO	>30 cm	2004-2009	2013-2014

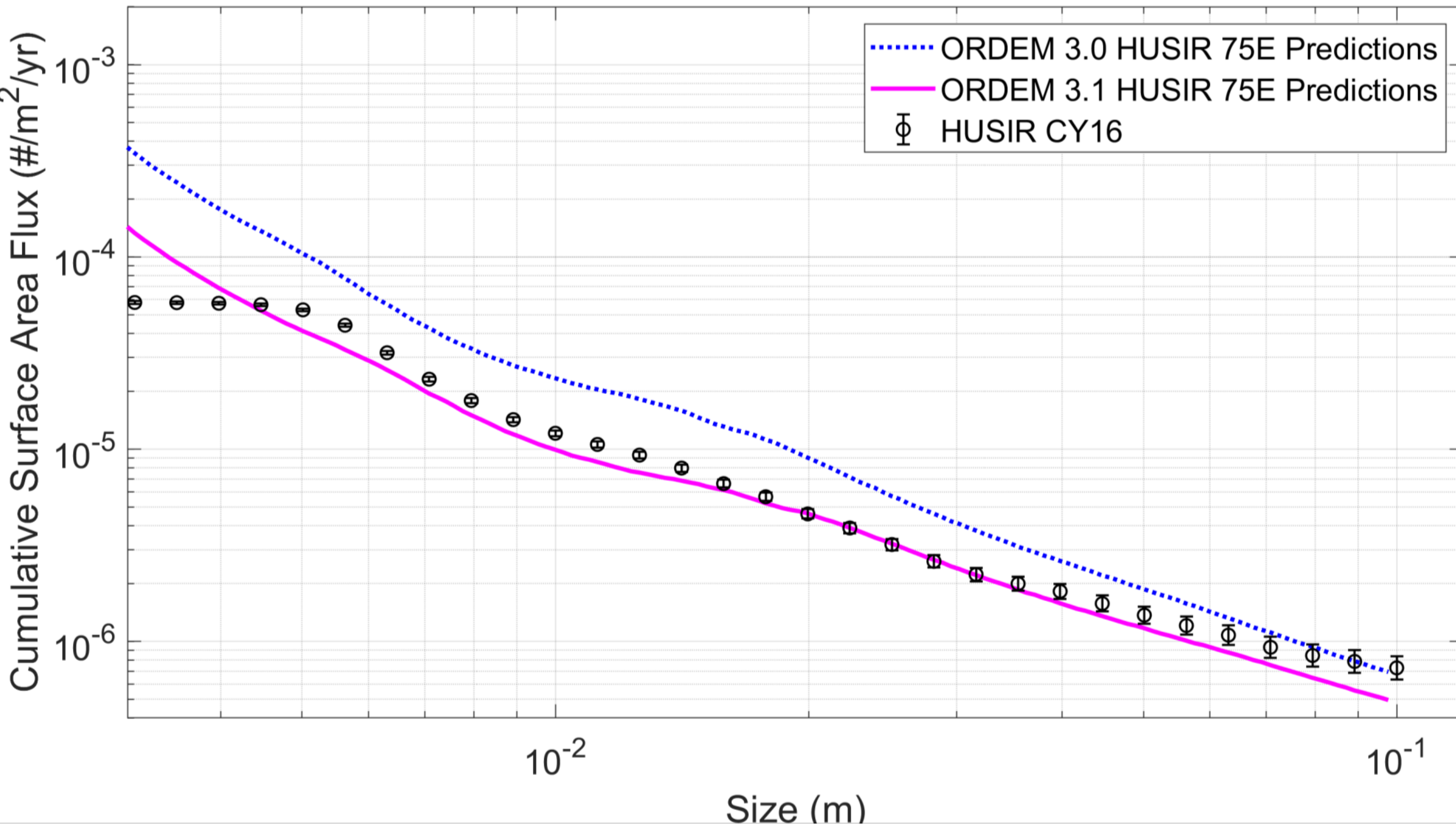
* Datasets used for characterization of large breakups (Fengyun-1C [FY-1C], Iridium 33, and Cosmos 2251). Data from special Haystack observation campaigns around the time of the event were used.

Radar-Based Populations: Special Breakups

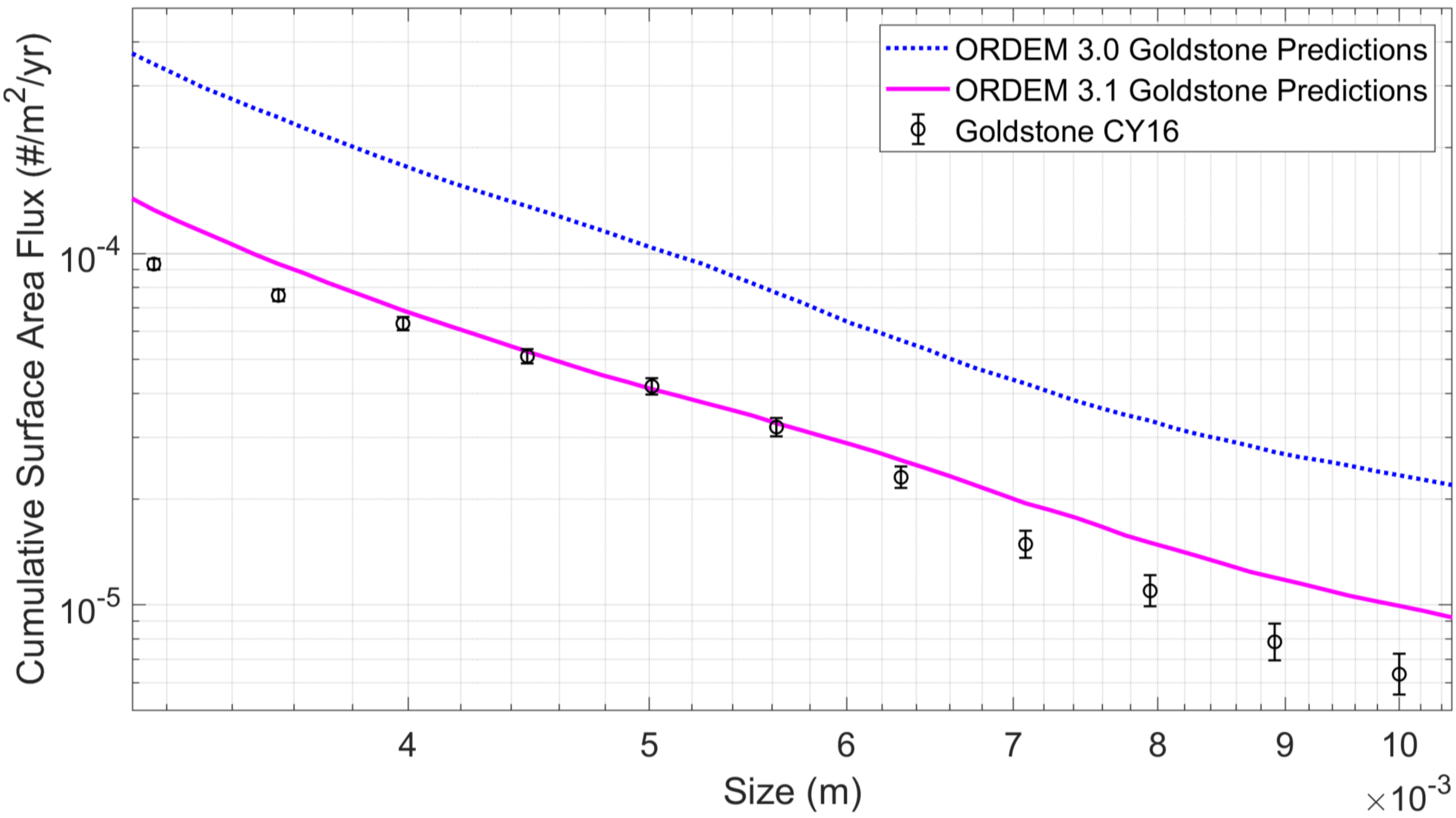


- **Several major breakups observed by HUSIR to have different size and orbit distributions than previously modeled**
  - Iridium-33/Cosmos-2251 collision cloud
  - Fengyun-1C collision cloud
  - 10 major breakups
  - NaK Population
- **Initial breakup conditions empirically adjusted to match measured clouds**
  - Increase of area-to-mass ratios of small debris from collisions most significant factor

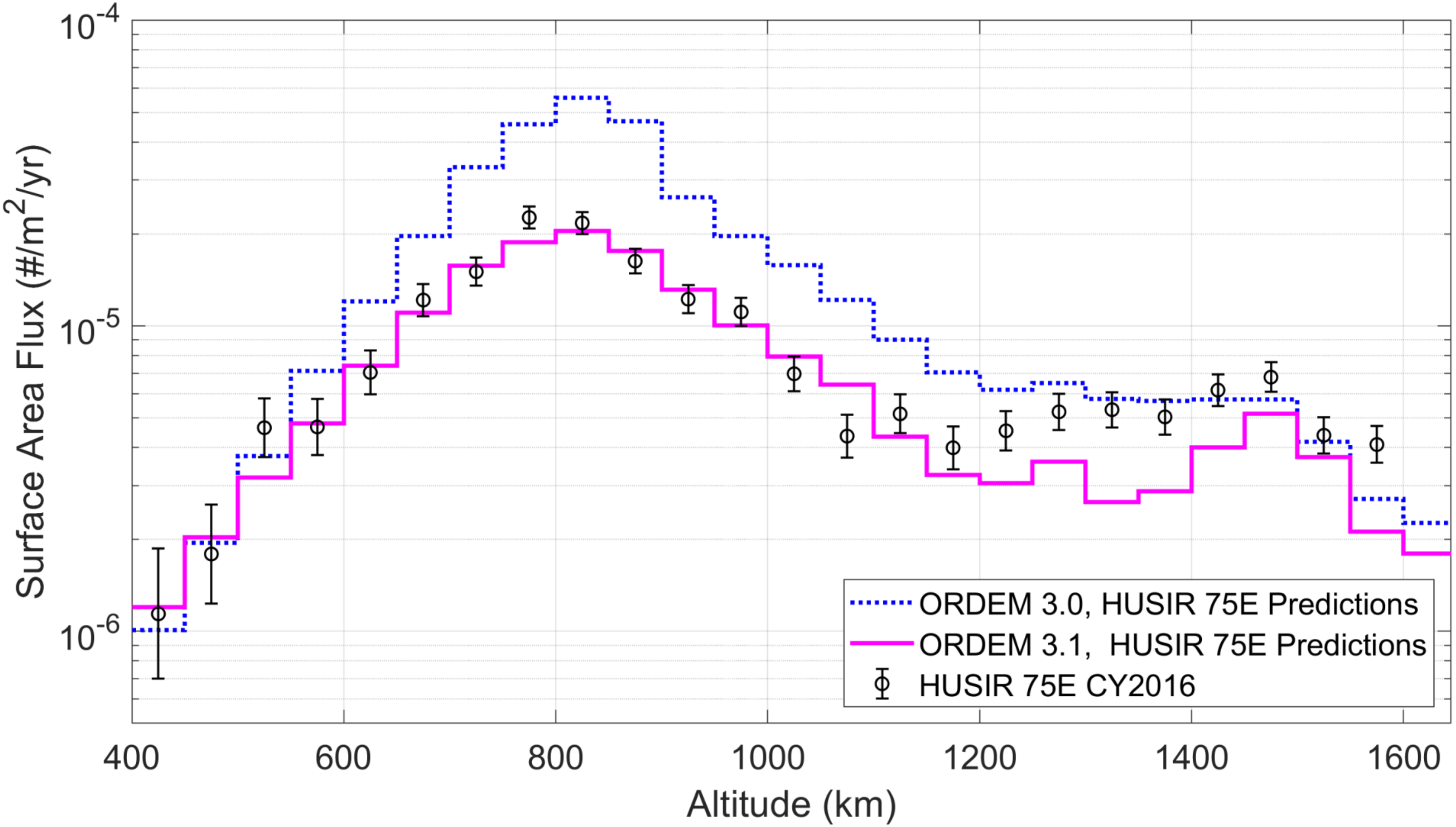
Validation: HUSIR 75ºE CY16, Cumulative Flux vs. Size, 400-1000 km Altitude



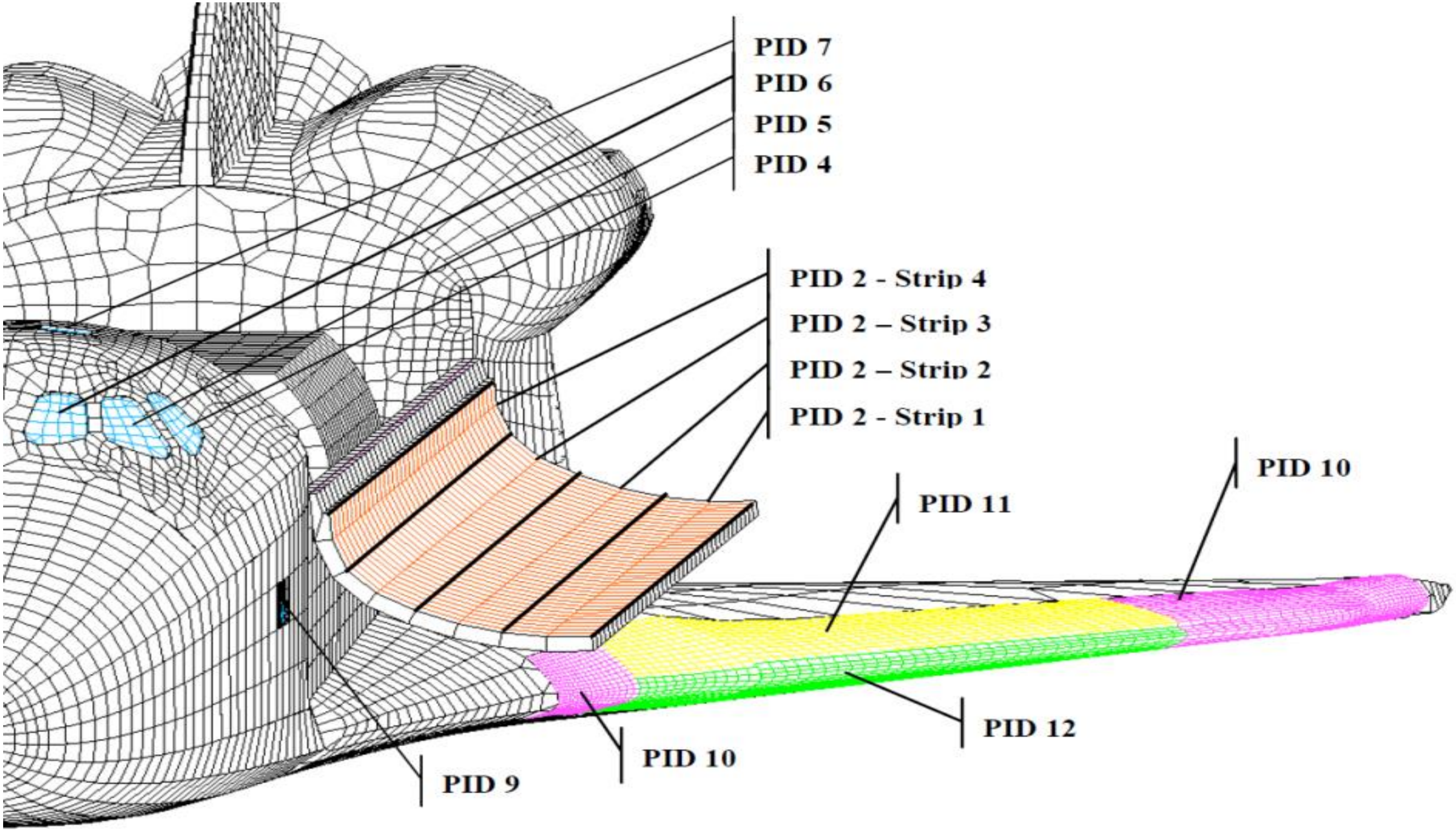
Validation: Goldstone CY2016, Cumulative Flux vs. Size, 400-1000 km Altitude



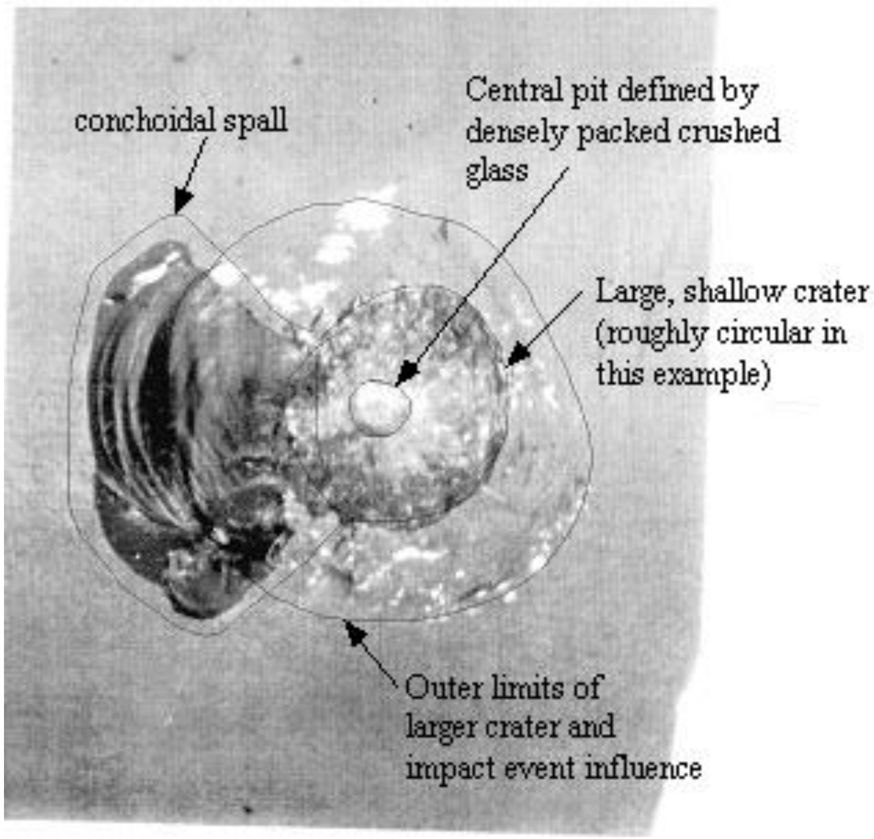
Validation: HUSIR 75ºE CY2016, Surface Area Flux vs. Altitude, ≥1 cm

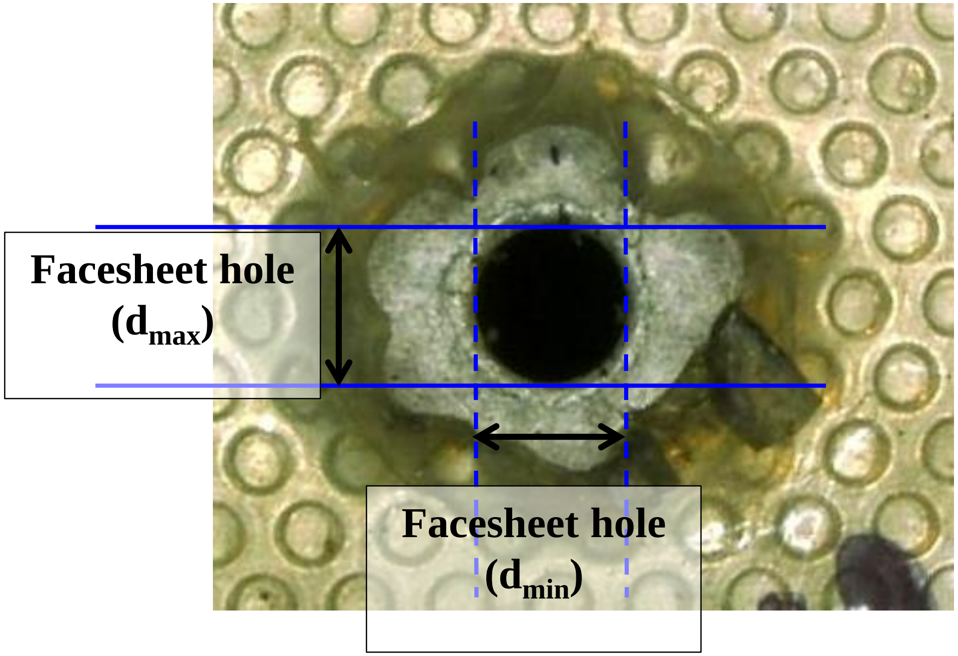


Degradation Population: STS Windows and Radiators



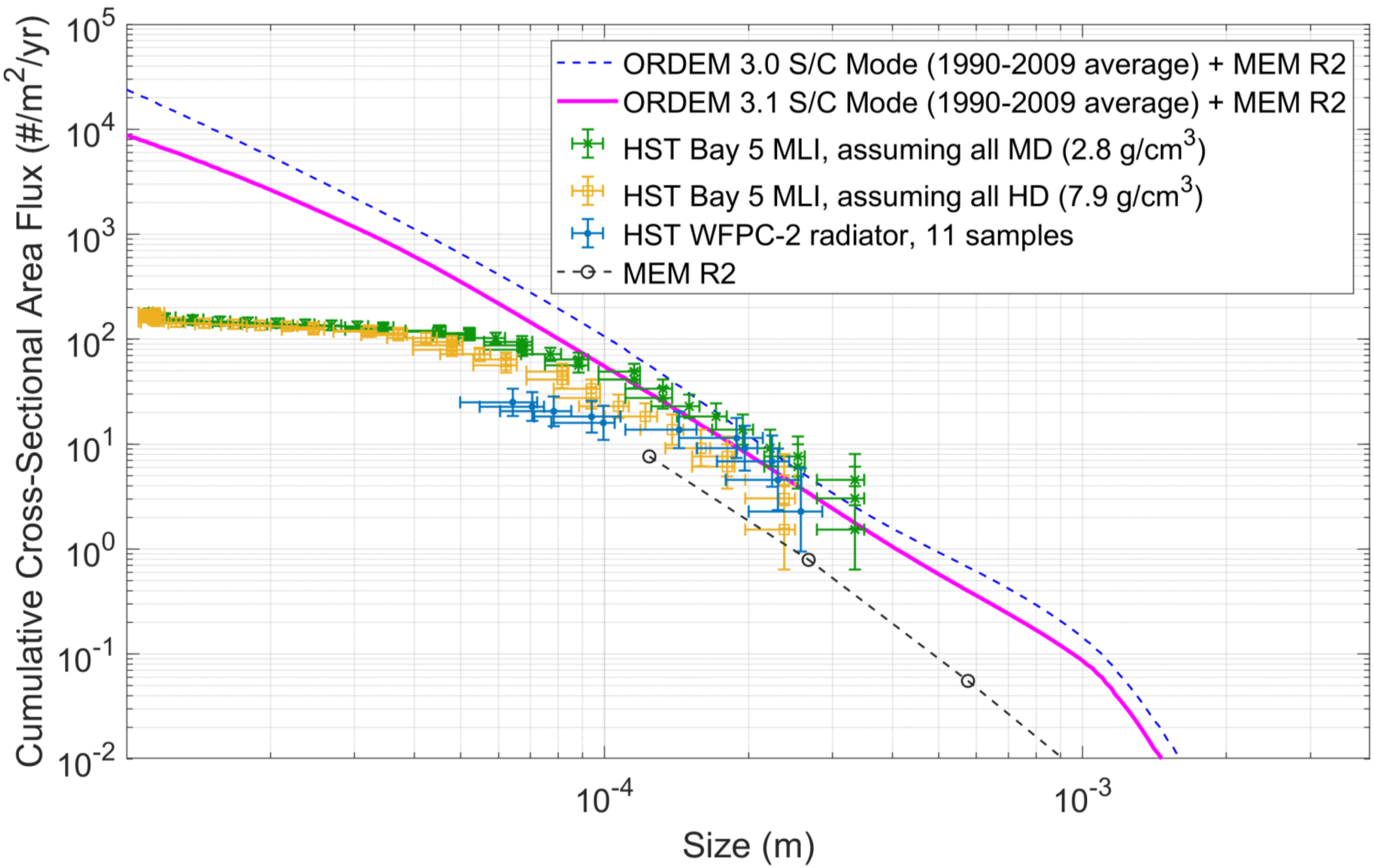
Degradation Population: STS Window and Radiator Craters



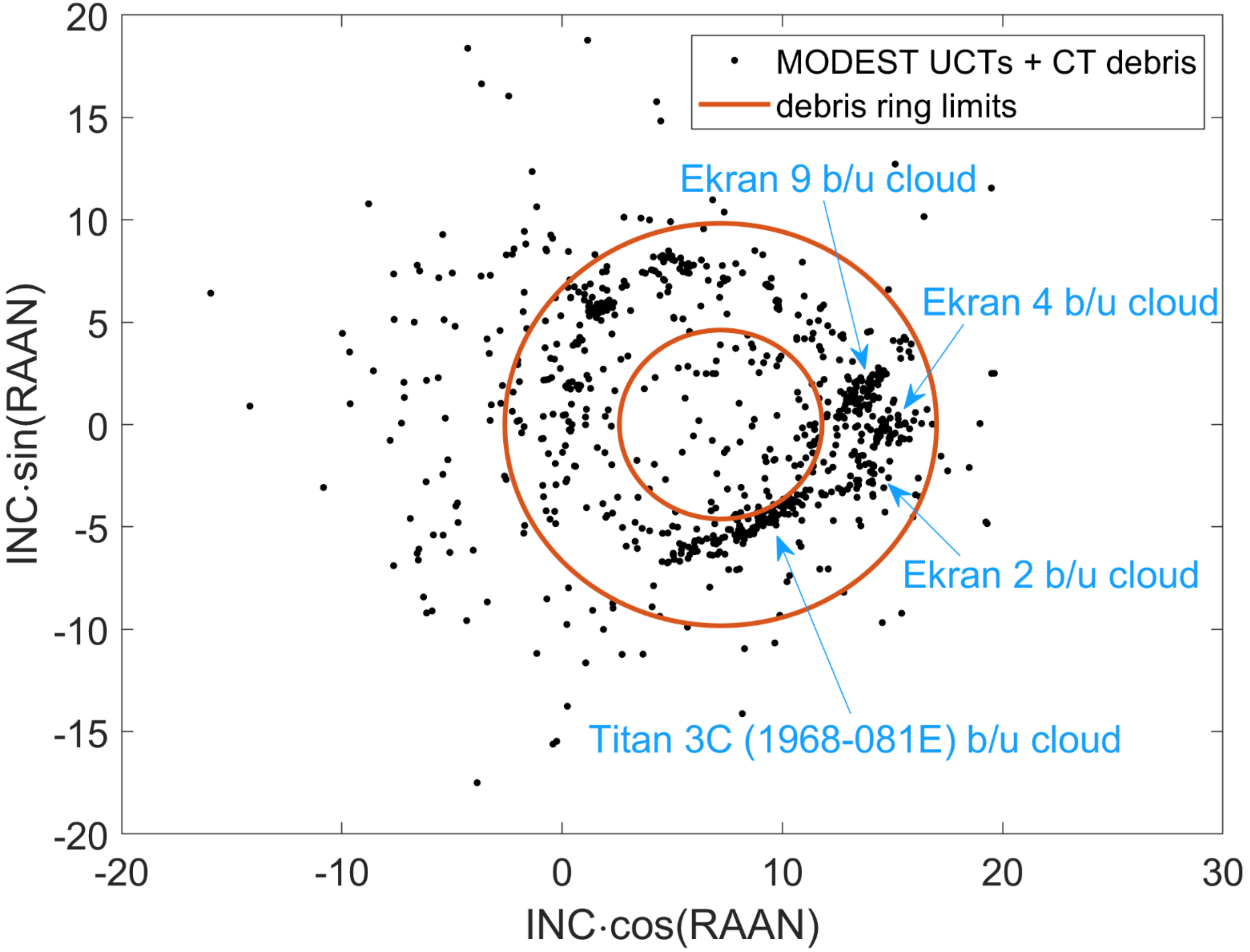


Degradation Validation: Cumulative Flux vs. Size

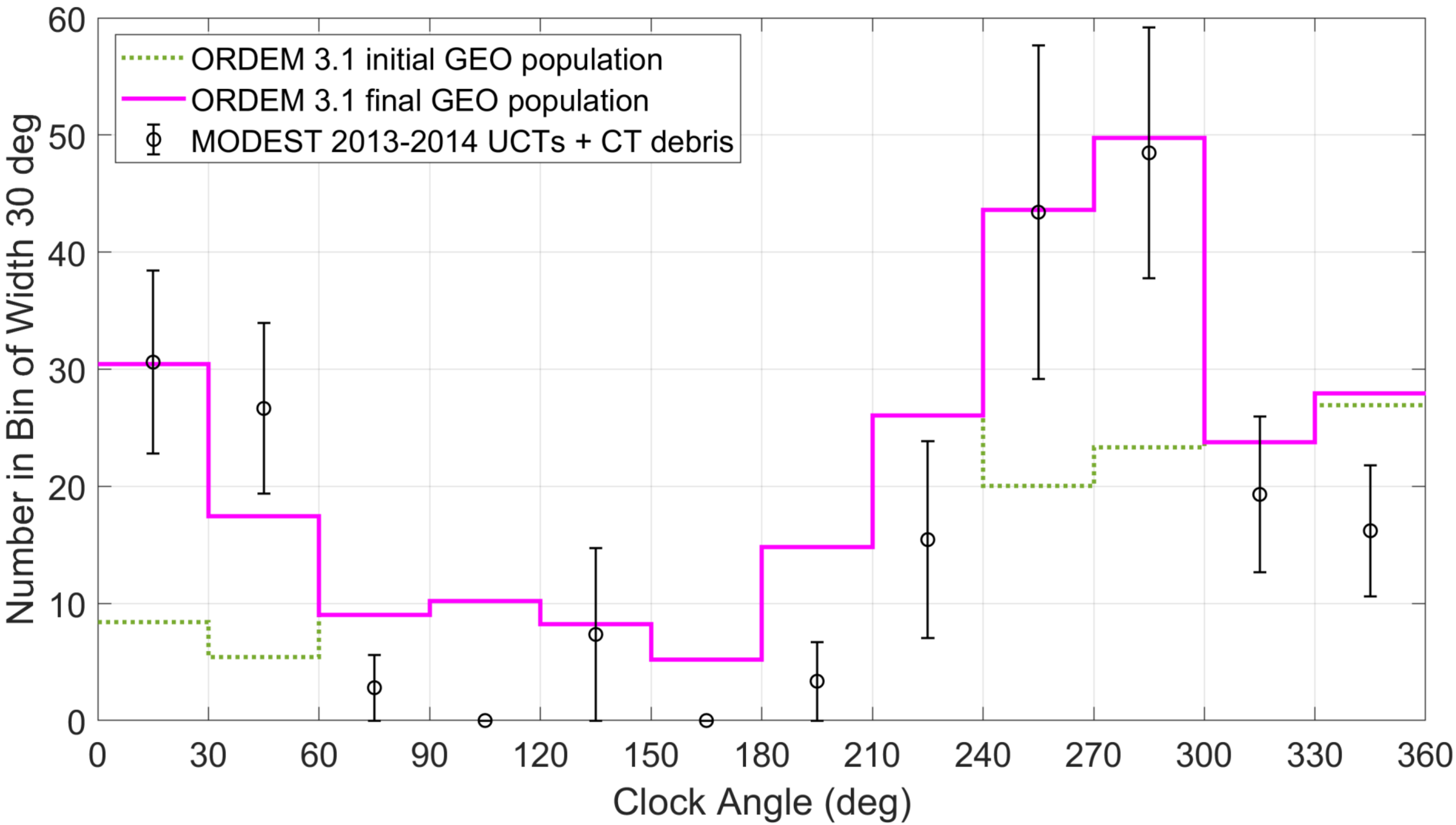
- **New data sources available for validation of the small particle population: HST Bay 5 MLI and WFPC-2 radiator**



GEO Population



GEO Validation: Clock Angle Distribution



Summary

- **ORDEM 3.1 is in final stages of review**
  - Does not change the overall architecture from ORDEM 3.0, but has updated populations and future projections

- **It incorporates the latest available data and data analysis techniques**
  - Adjustments in major breakups to reflect evolution of the clouds through the most recent solar cycle
  - New analysis to take into account STS directional and altitude influences
  - Expanded GEO data and analysis techniques

- **Validation indicates good agreement between model and independent data sets**

- **Generally, overall fluxes for the current environment are somewhat lower than those predicted by ORDEM 3.0**