MMOD modelling in an industrial context:

The use and application of MASTER

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Overview:

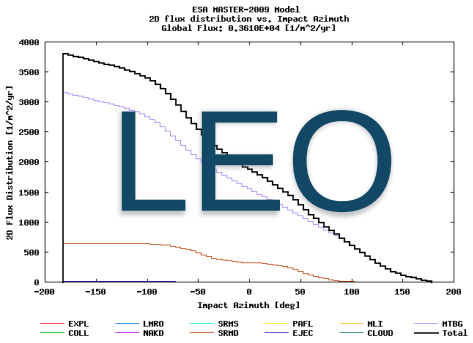
I. **MMOD Assessment process by OHB:**
   1. Project needs
   2. General MMOD Analysis process
   3. Detailed MMOD Analysis methodology

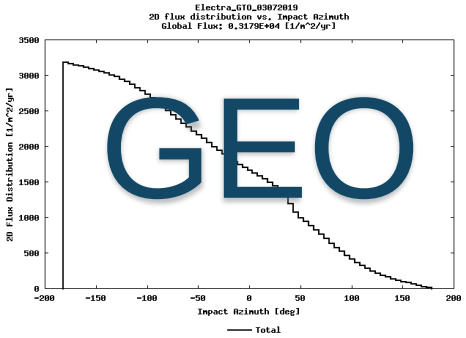
II. **MMOD Modelling**
   1. Master use and comparison M2009 vs M8 outcome
   2. Connection to Systema (stenvi files)

III. **Conclusion: open discussion**
   1. MM models change? Why? [Results are weirder in new MASTER]
   2. New Stenvi file format?

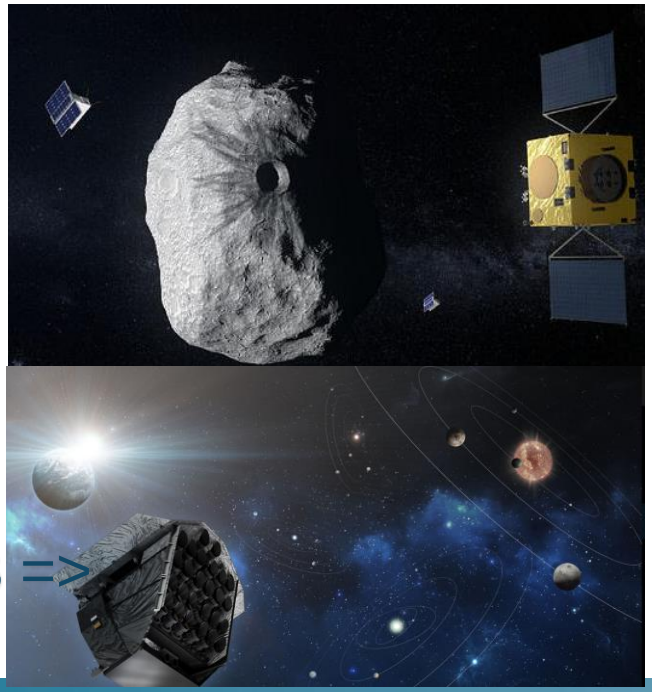
Project needs:

- OHB variety of missions: LEO, MEO, GEO, Exploration. Needs to study several MMOD environment and not only one type
  - LEO: 2 Observation satellites + CO2M
  - MEO: Galileo first generation satellites
  - GEO: Telecommunication satellites (H2SAT, Electra –orbit raising-) + Scientific (MTG)
  - Exploration: Plato, HERA





Exploration

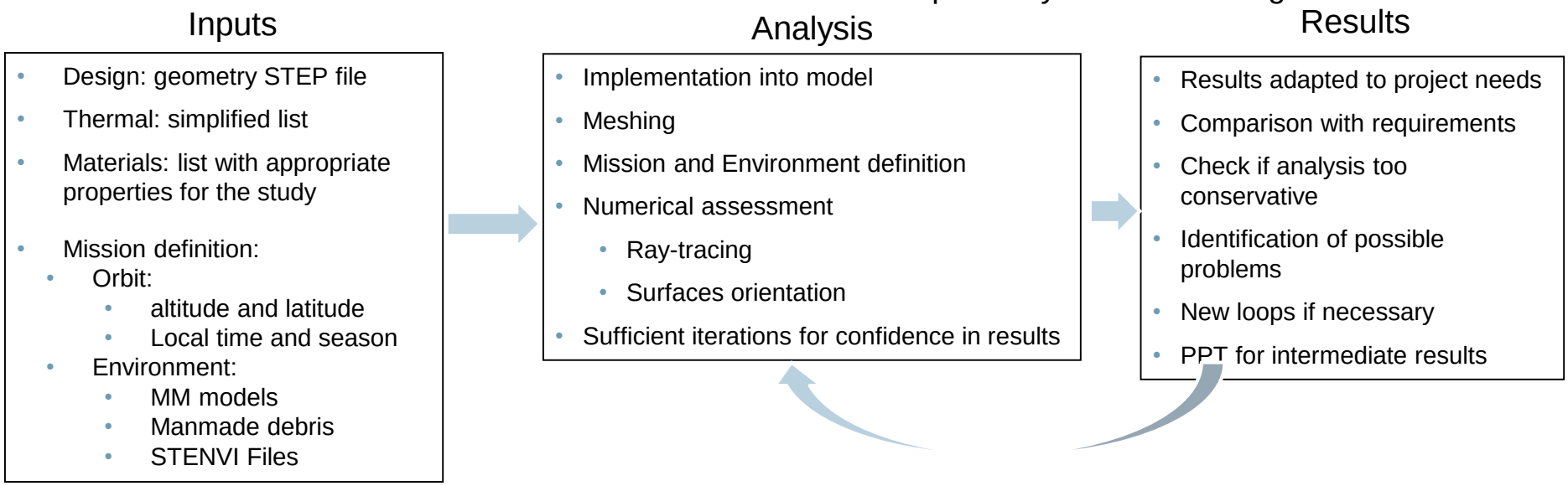


- Project have specific needs for units or the whole satellite, to assess the PNF

Lagrange L3 =>

MMOD Analysis process:

- Goal: check if the design is correct with regard of the studied subject
- These types of environment analysis interact with several disciplines:
  - Design
  - Thermal
  - Materials
  - Mission definition (orbit + Environment)
- Interactions in two directions:
  - Defining the analysis
  - Flowing the outputs to the impacted subsystems
  - Loop if analysis show a design flow



MMOD Analysis Methodology

- Depending on the project state: PDR or CDR, we go more in details if needed
- Simplified process at early satellites stages: « MASTER + EXCEL »
  - Define Environnement with MASTER
  - Load MASTER ouput file in our own Excel tool
  - Make a first assessement for surfaces, for different BLEs, at different angles
  - Provide a first PNP
- Detailed assessment at advanced stages: “MASTER + SYSTEMA”
  - Defining the the meteoroids and orbital debris (M/OD) flux model from MASTER
  - Simplifying the spacecraft geometry within Systema
  - Computation of equipment vulnerability
    - Identifying structures and elements within the model
    - Defining the material parameters
    - Choosing the correct equations
  - Evaluating the Probability of No Penetration (PNP)

MMOD modelling: MASTER use and comparison

Comparison between M2009 and M8

- Target orbit

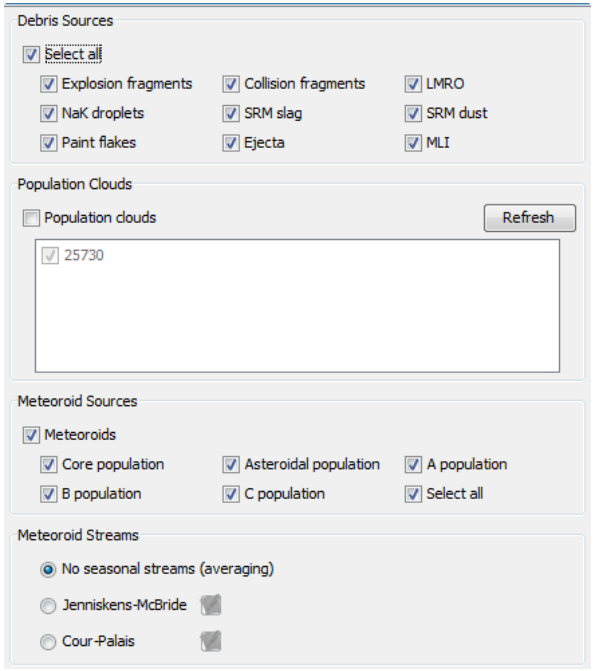
Target orbits (Singly Averaged Elements)

Prop.	Start epoch	End epoch	SMA	ECC	INC	RAAN	AoP
☐	2025 11 03 00	2026 03 23 00	42103.0	0.002	0.0	171.8	273.7

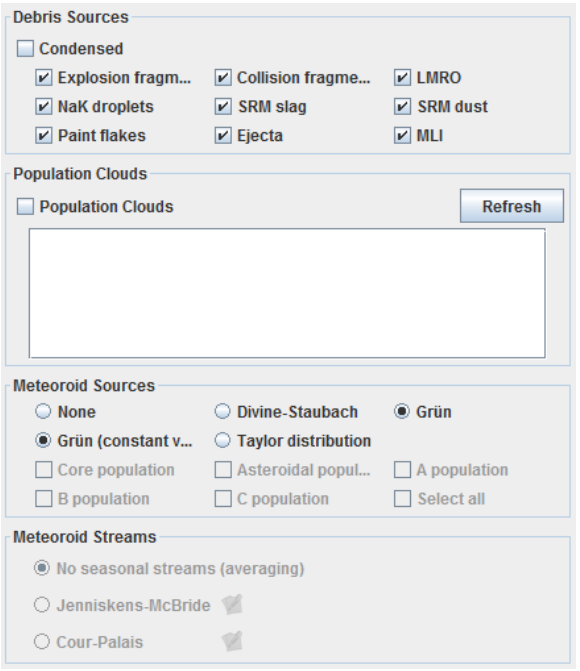
- Performed for:
  - MASTER 2009
  - MASTER 8
    - Grün model – Grün distribution
    - Grün model – Taylor distribution
    - Divine-Staubach model (Grün distribution)
    - Divine-Staubach model (Taylor distribution)

First Comparison Analysis

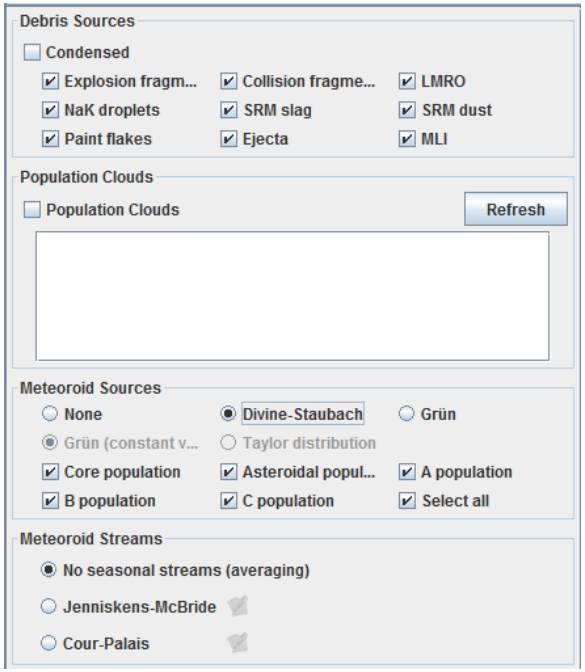
Master 2009



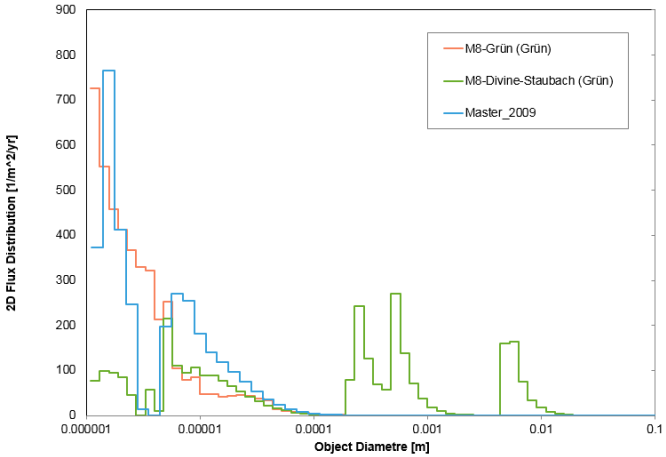
Master 8 Grün – Grün

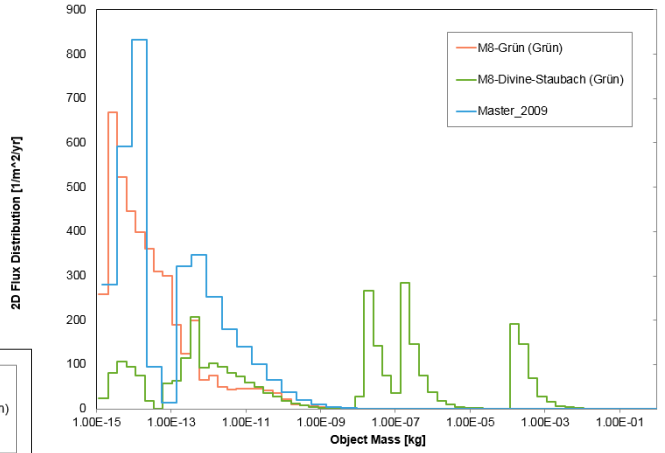


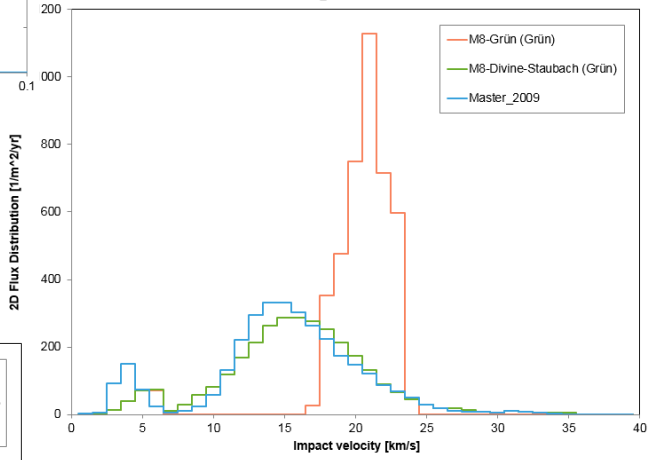
Master 8 Divine-Staubach (Grün option)

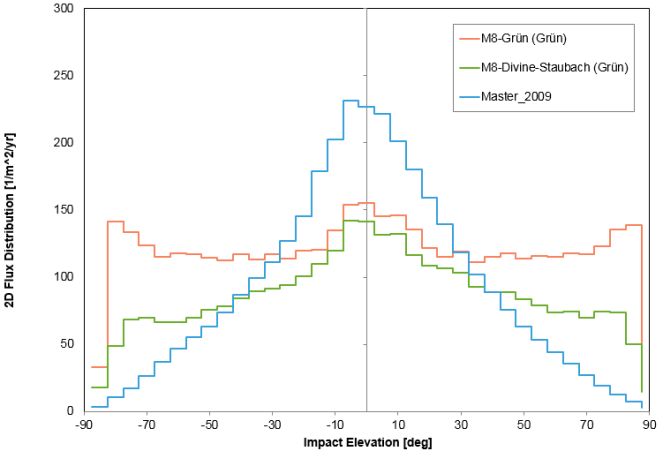


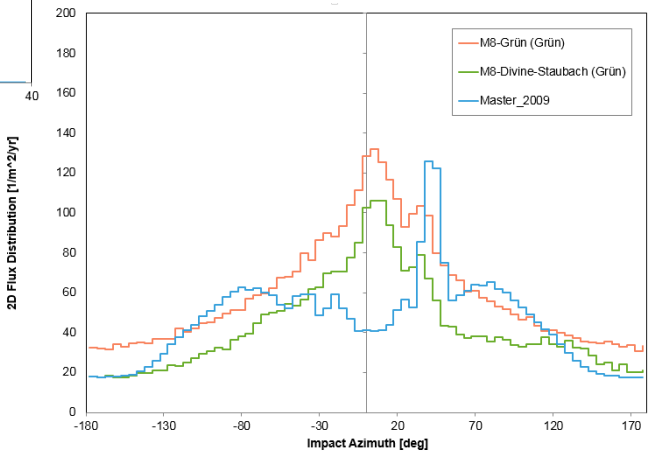
MMOD modelling in an industrial context (OHB)





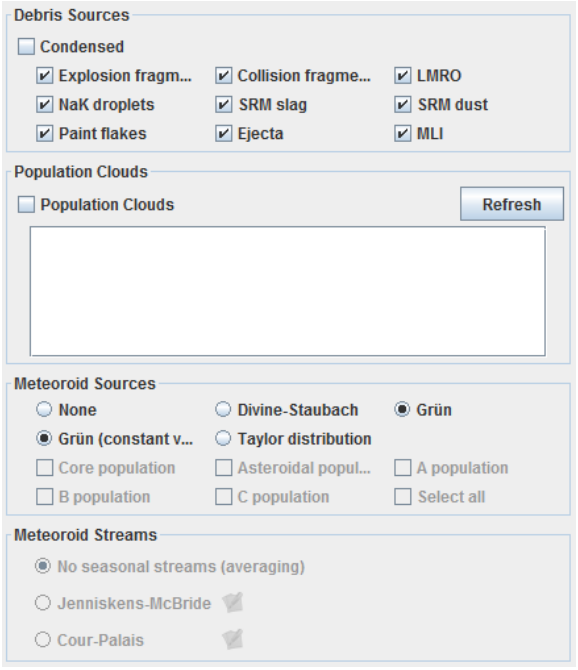




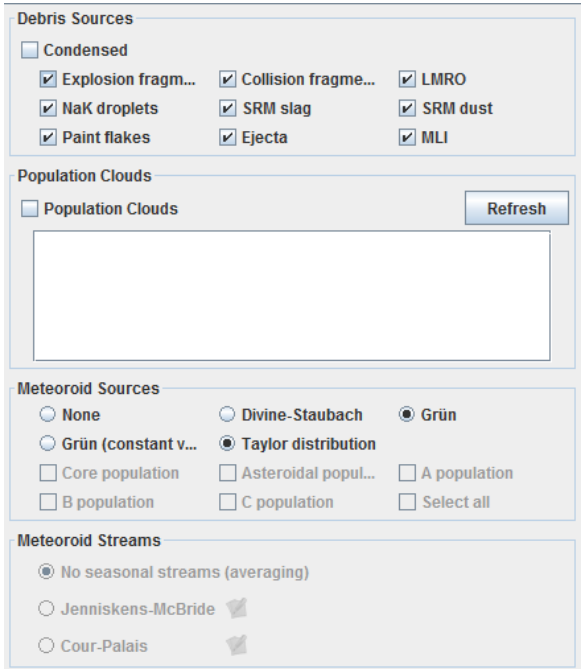


Suggestions of change from ESOC

Master 8
Grün – Grün



Master 8
Grün – Taylor



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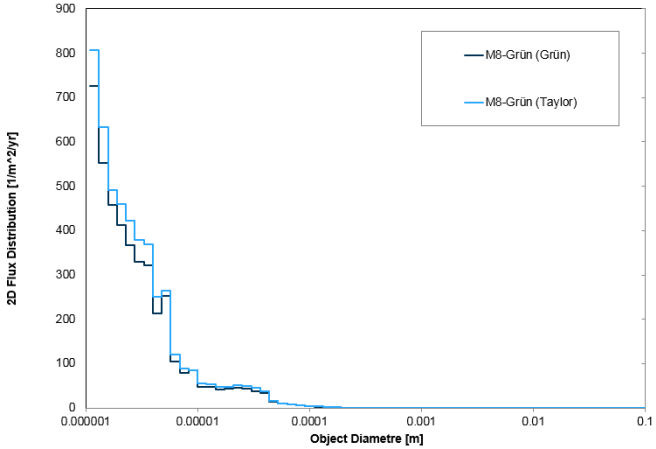
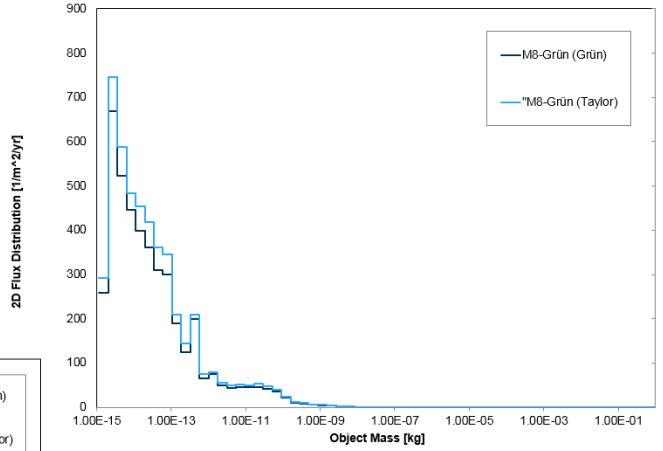
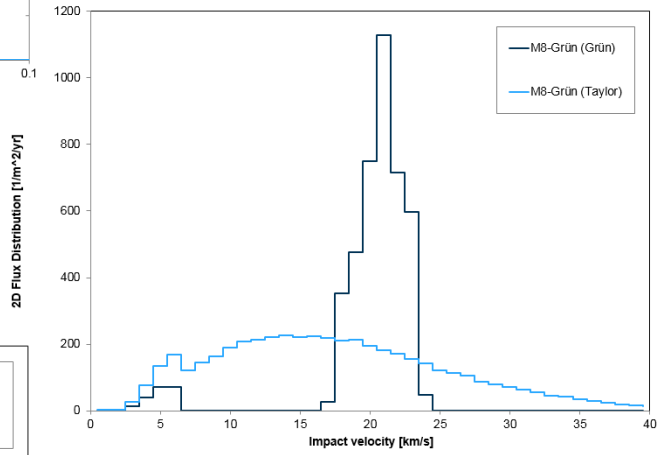
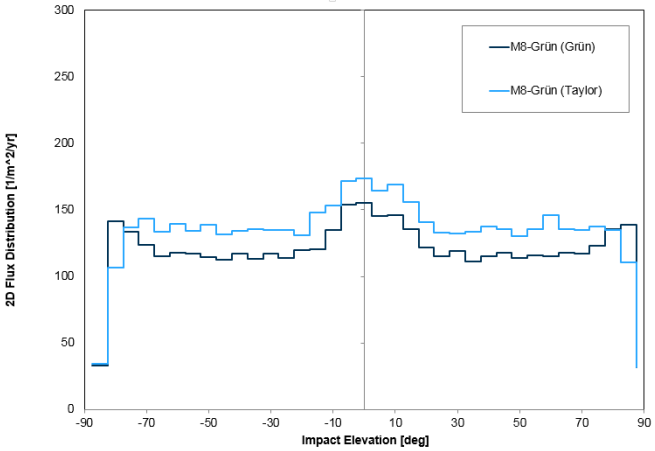
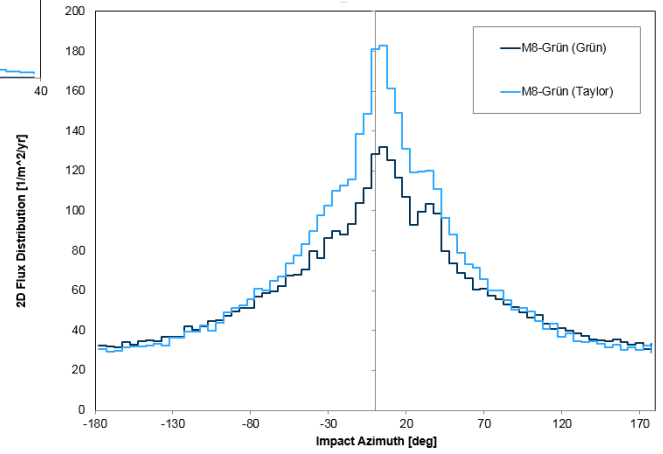




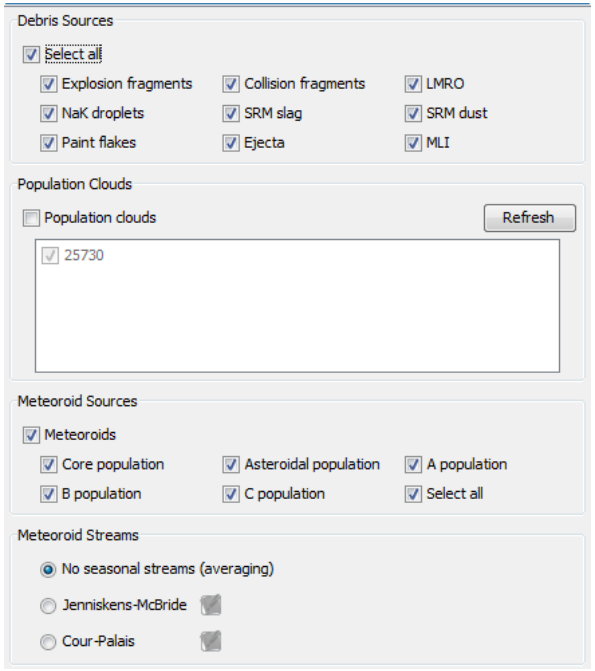






Second Comparison Analysis

Master 2009



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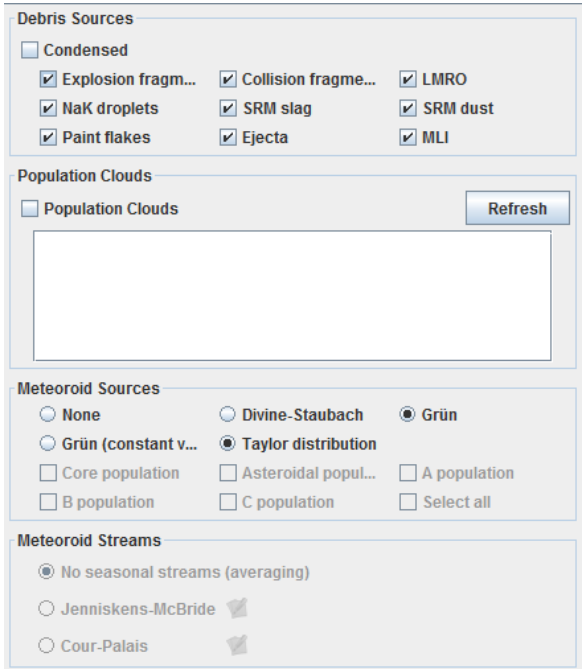

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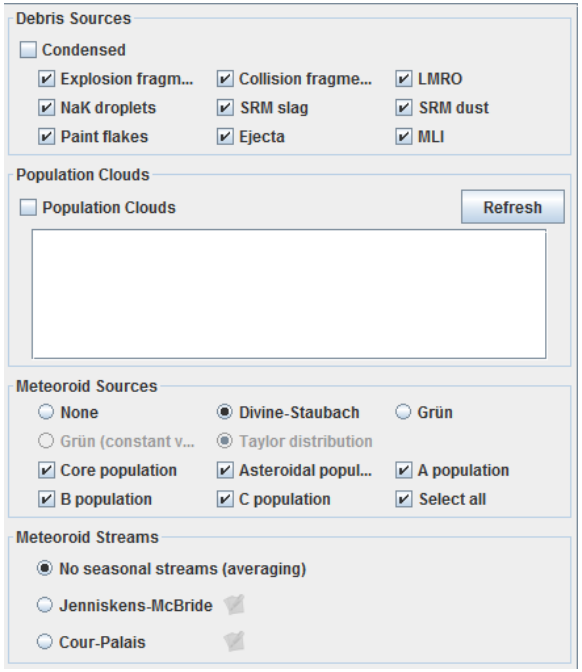

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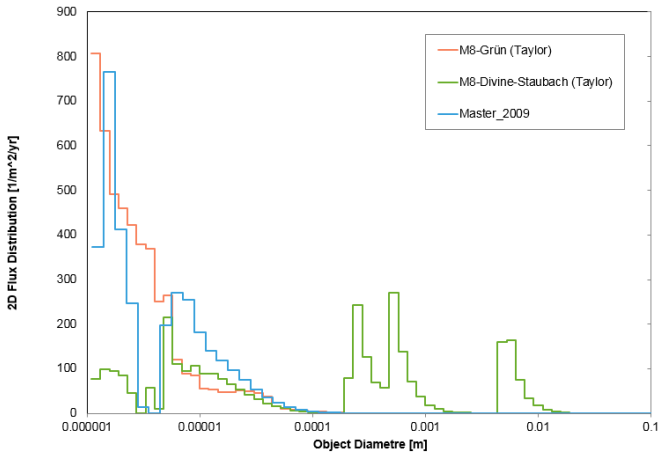
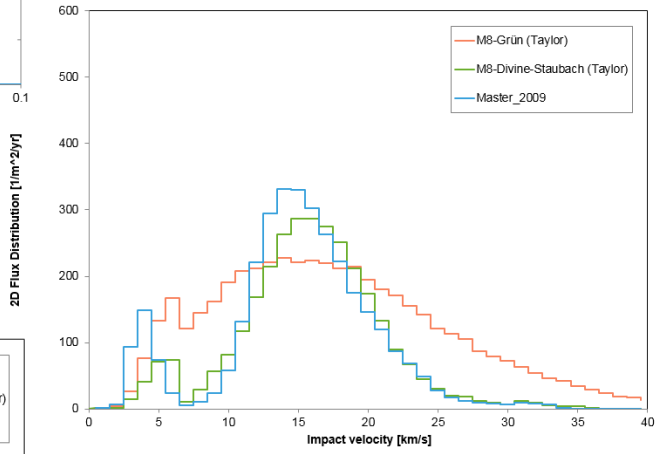
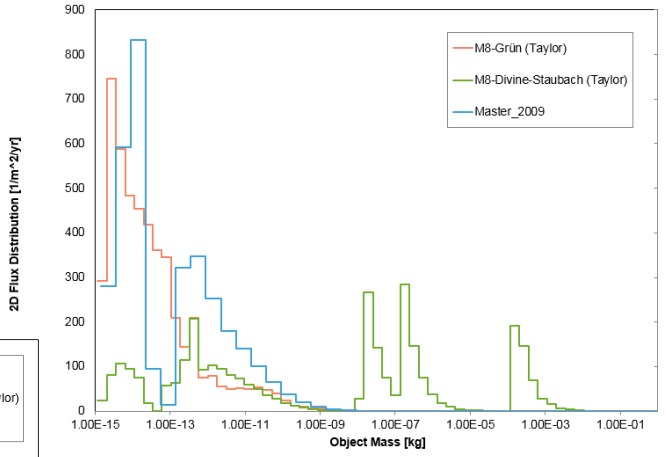
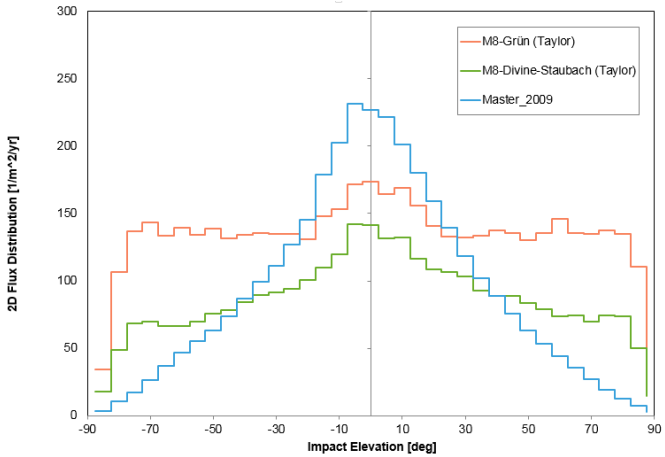
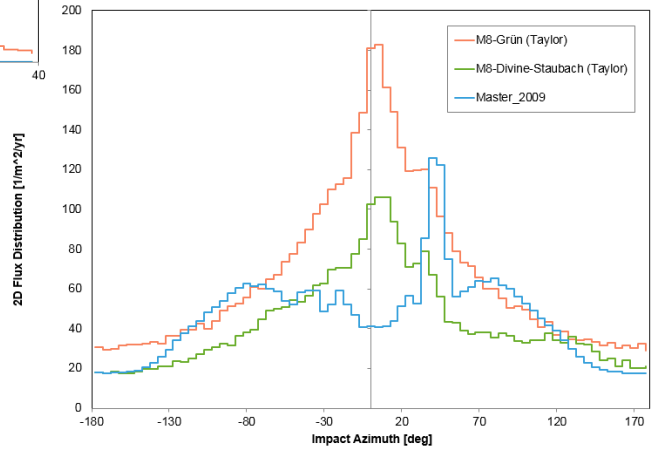


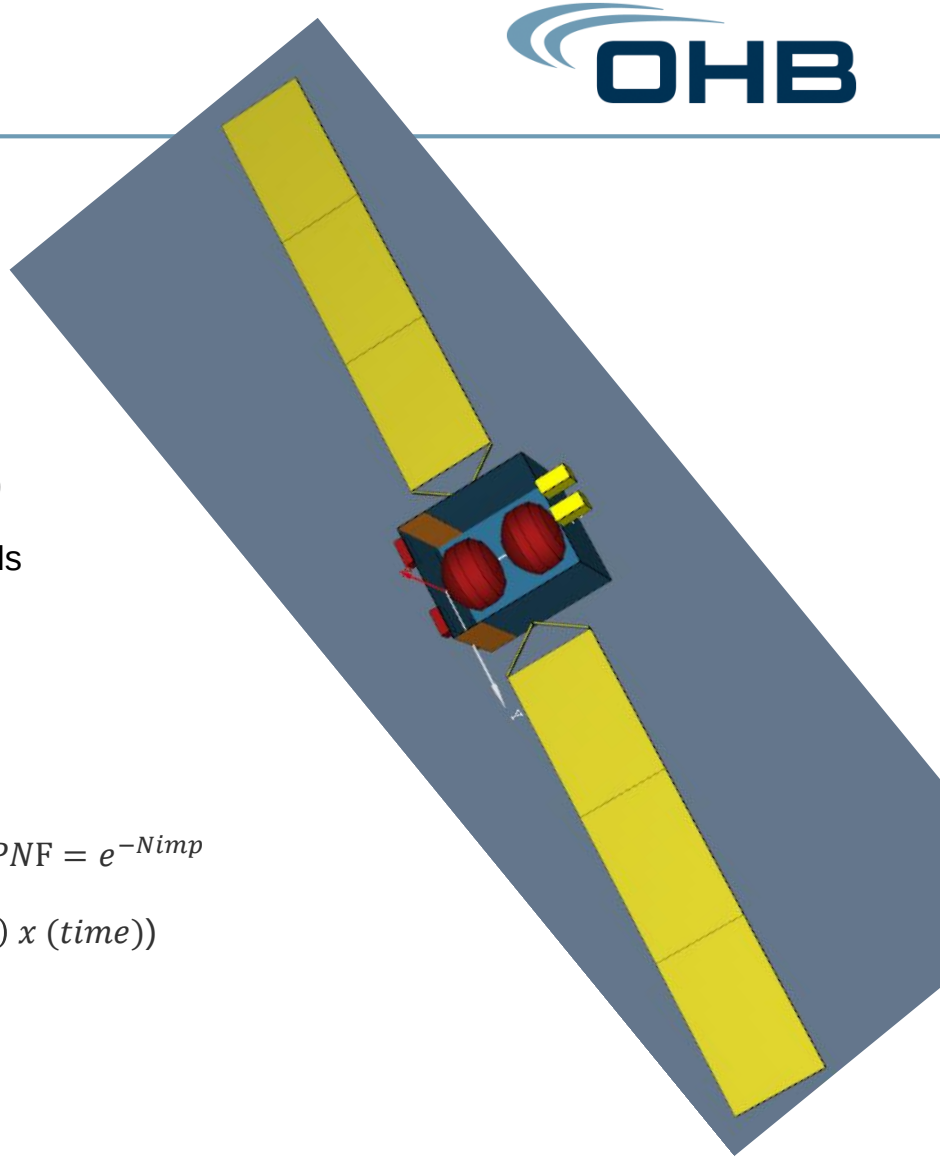








Impact risk assessment



Risk of failure assessed by using:

- Spacecraft information (geometry, trajectory…)
- Ballistic limit equations (stablishing the failure criteria)
- Directional collision fluxes derived from MMOD models

Measure of risk : Poisson statistics relations

$$P_{imp} = 1 - e^{-Nimp} \quad \rightarrow \quad PNF = e^{-Nimp}$$

$$(N_{imp} = (flux)\ x\ (area)\ x\ (time))$$

- Link with MASTER?

Link with MASTER: Stenvi files

- First difficulty: how to define the BIN?

#--------------------< Definition of the output spectrum >----------------------

#	Bin	Min	Max	
AZIMUTH	18	-180.0	180.0	Azimuth [deg]
ELEVATION	18	-90.0	90.0	Elevation [deg]
VELOCITY	2	0.5	20.5	Velocity [km/s]
DIAMETER	40	0.1E-04	0.1E+02	Diameter [m]
LATITUDE	1	0.0	360.0	Argument of True Latitude [deg]
DENSITY	200	0.0	5.0	Density [g/cm^3]

- How the link with the “different years scenarios” is performed?
- Stenvi only provides Lower border and Uppers Borders, averaged in time
- Some information are lost afterwards in the simulation (exact distribution according to the particles sizes)

Conclusion: open discussions

Micrometeoroids and Debris assessment

- The **use of MASTER 2009 is recommended** until the MASTER 8 Divine-Staubach model patch is released and a more **exhaustive investigation on the Grün model** has been performed
  - An **exchange with ESA/ESOC** about the MASTER new version investigation was performed
  - The use of Grün model with **Taylor distribution is recommended**
- **Why change of the MM models? Not stable in new MASTER**
- Use of new orbits such as Lagrange Points, exploration… **How reliable is the tool? Limitations?**

Link with Systema: STENVI files, open for discussions

- Some questions remains open: different years scenarios, averaged values, information lost later