MASTER Modelling Workshop 2021: use of MASTER on the risk assessment process at Airbus

DEFENCE AND SPACE

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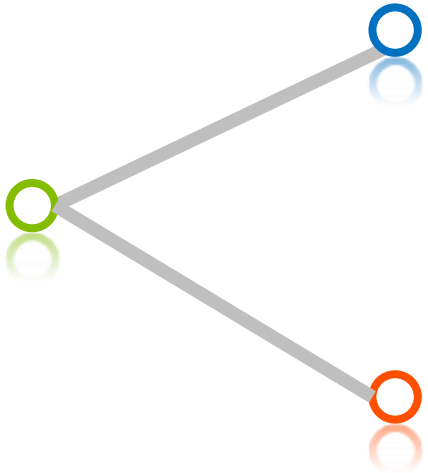
How MASTER will be used



How MASTER is used today at ADS

Comparison between M2009 and M8

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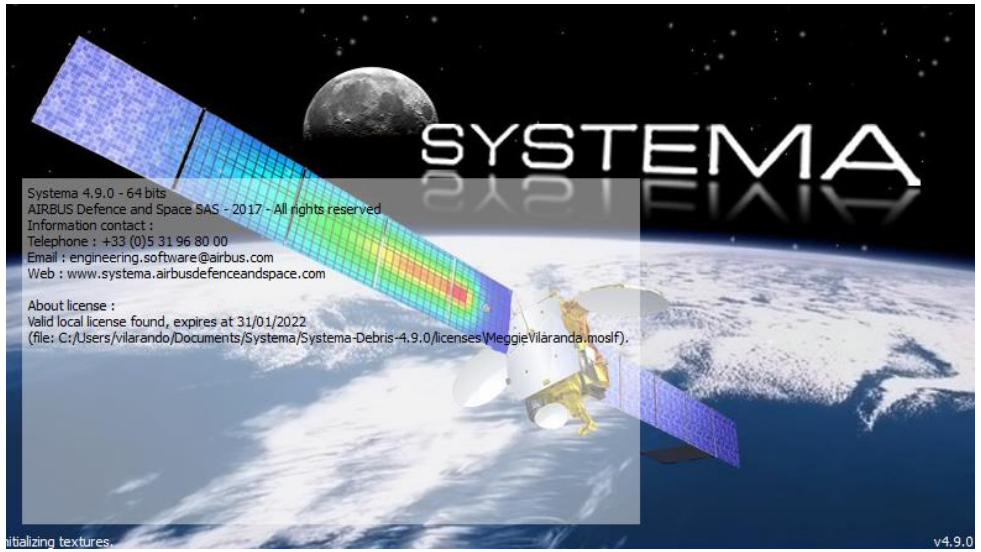
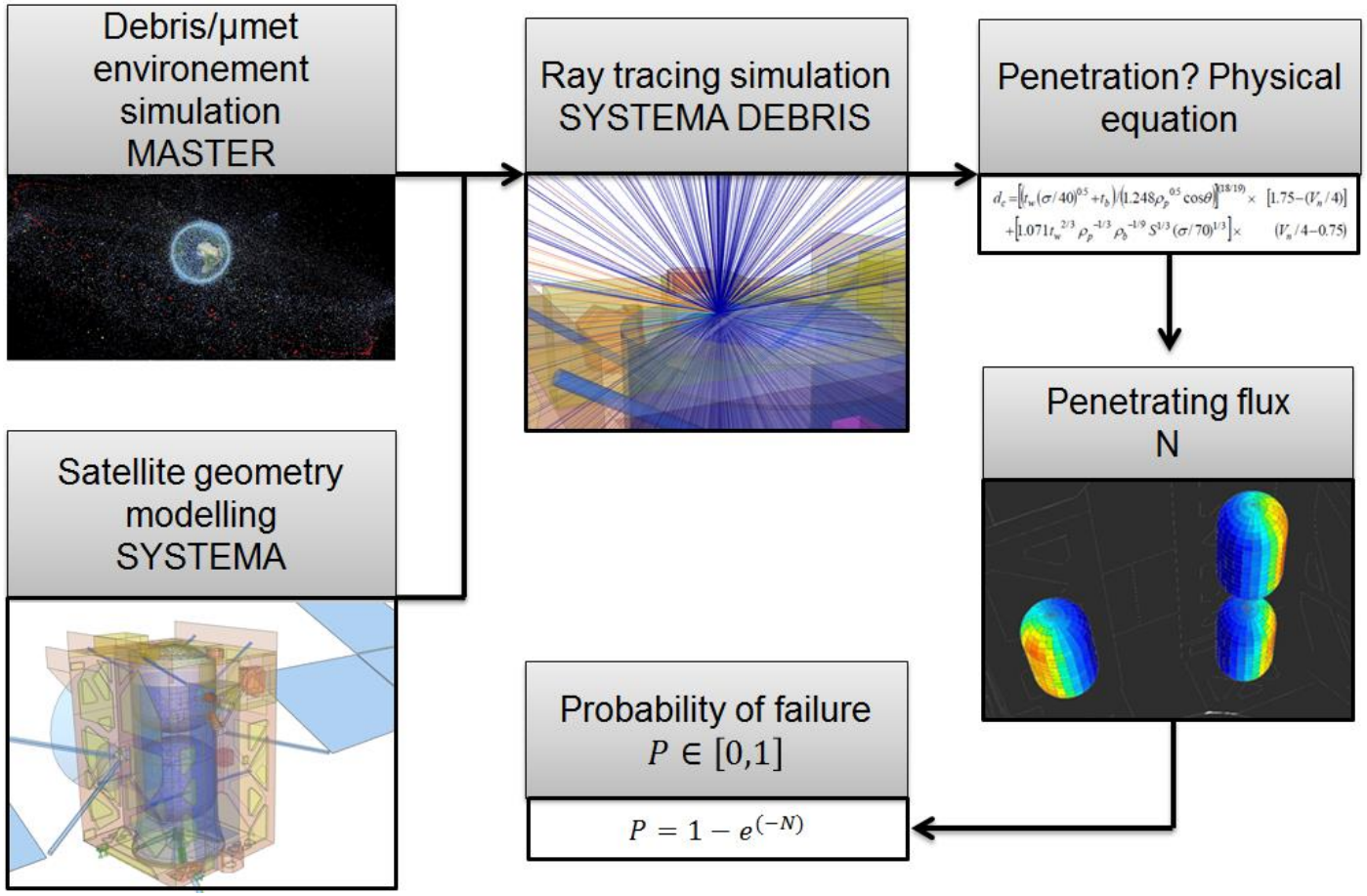
How MASTER is used today

MASTER on the risk assessment process





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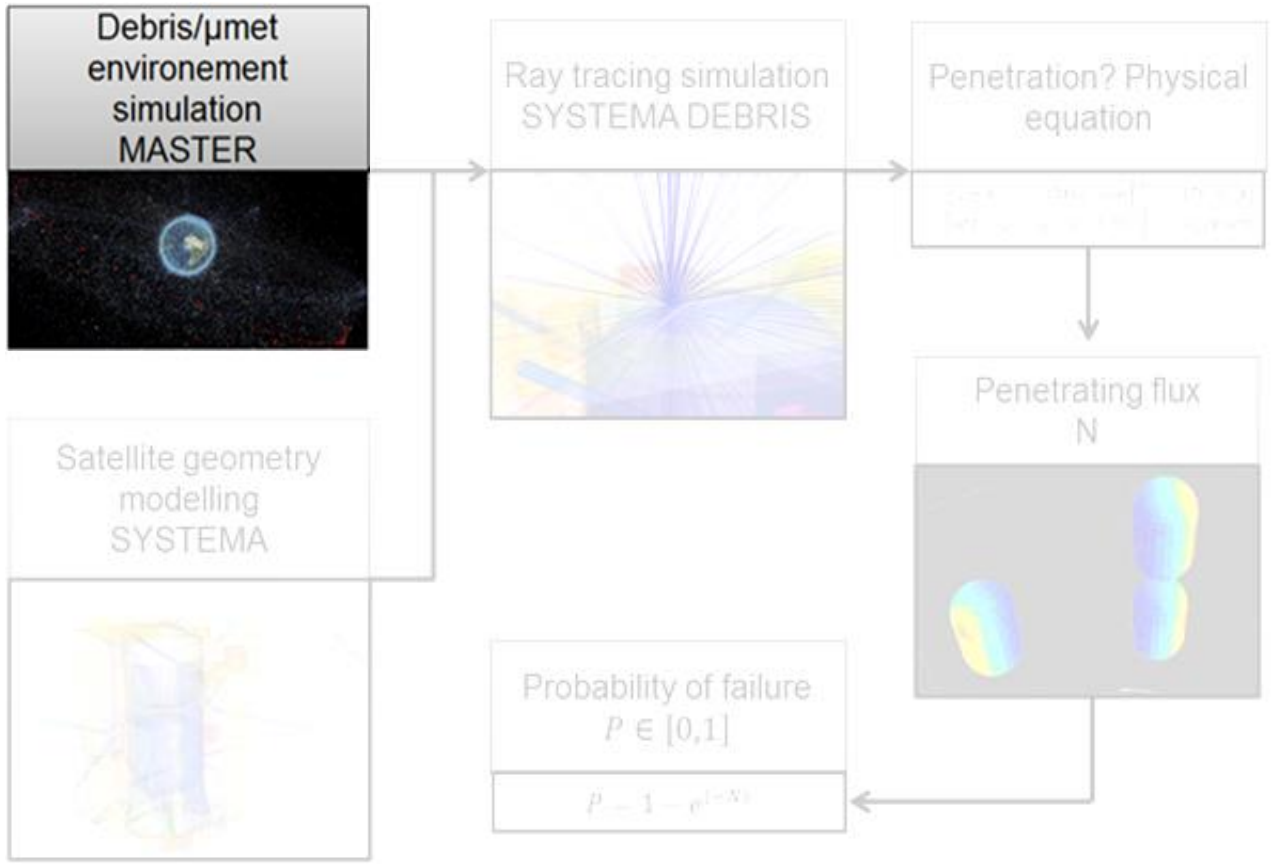
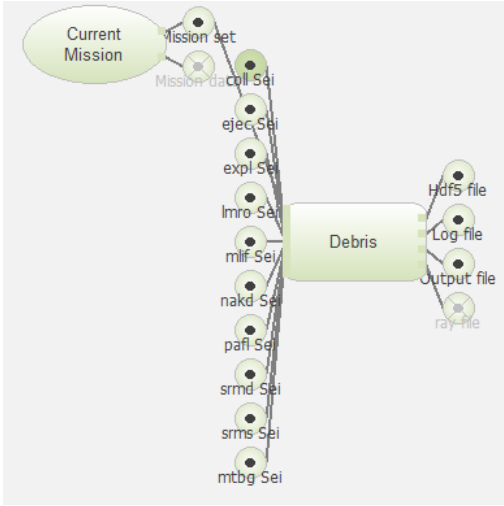
Environment



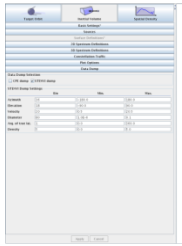


STENVI format is the input of Systema-Debris

Various type of environment can be used:

- Detailed environment
- Simplified isotropic environment

Direct output from MASTER



MASTER 2009

Created from others environment models

Diameter [m]	Fluence [m⁻²]		
	Interplanetary / IMEM	Jovian / JMEM	TOTAL
1.00E-07	3.44E+05	1.39E+04	3.58E+05
3.00E-07	8.01E+04	9.68E+03	8.98E+04
6.00E-07	3.85E+04	2.79E+03	4.13E+04
1.00E-06	2.18E+04	9.68E+02	2.28E+04
2.00E-06	7.98E+03	2.85E+02	8.26E+03
5.00E-06	2.28E+03	8.25E+01	2.36E+03
1.00E-05	9.10E+02	2.47E+01	9.35E+02
3.00E-05	2.50E+02	1.84E+00	2.52E+02
1.00E-04	1.48E+01	6.01E-02	1.48E+01
3.00E-04	1.37E+00	2.55E-03	1.38E+00
1.00E-03	8.93E-03	1.79E-04	9.11E-03
1.00E-02	1.09E-06	6.22E-06	7.30E-06

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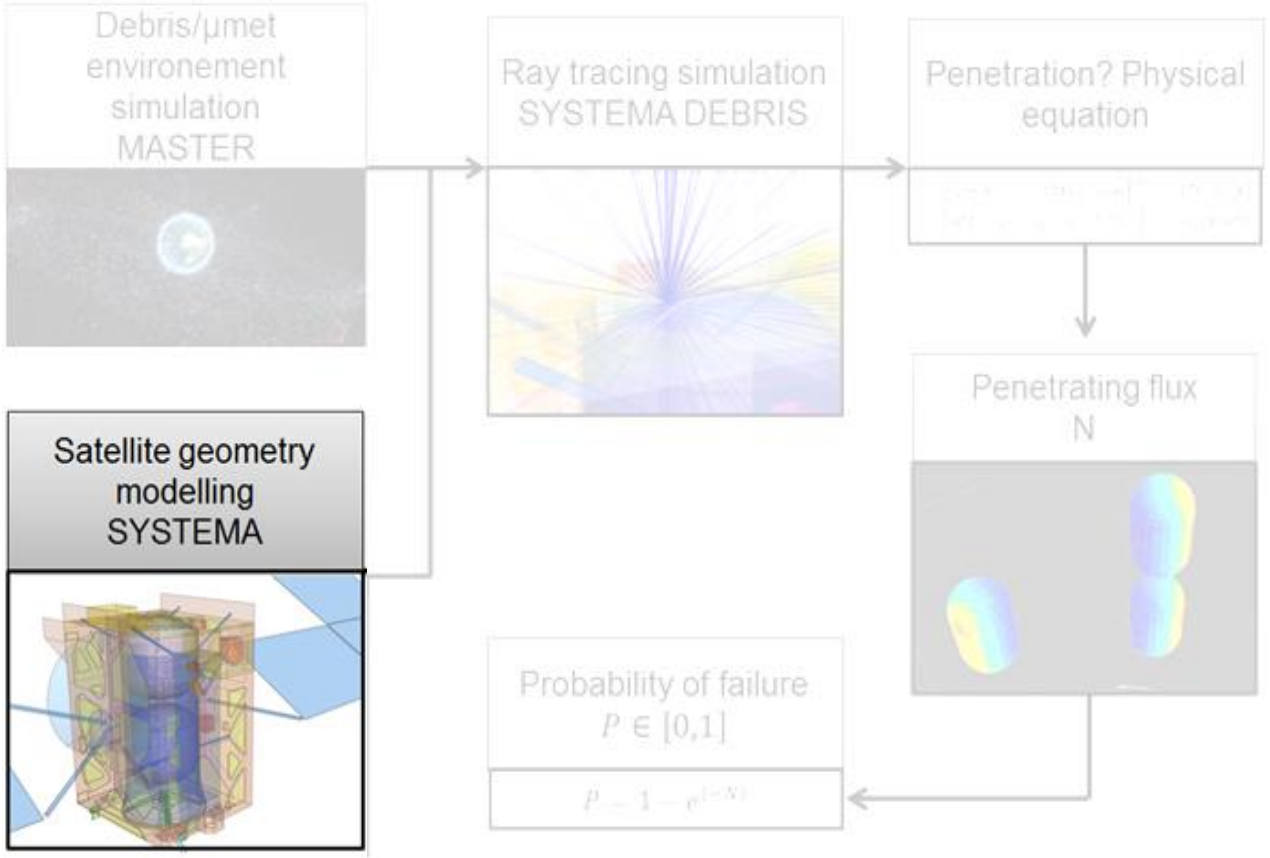
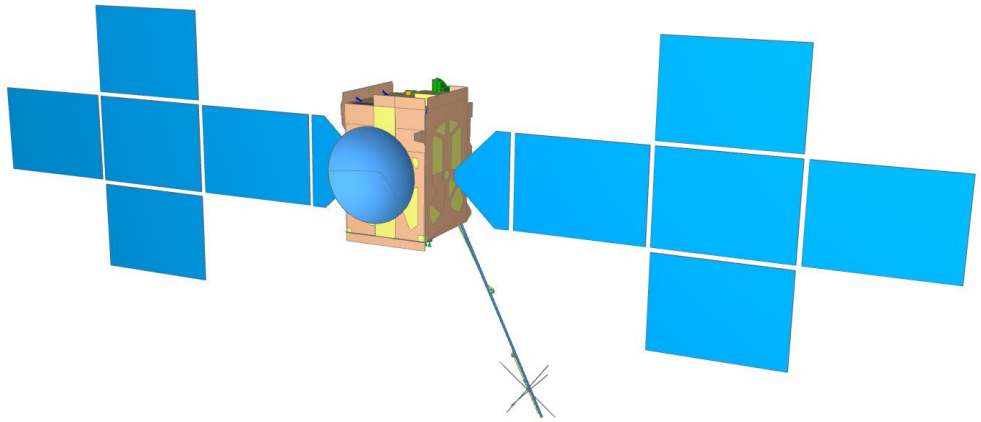
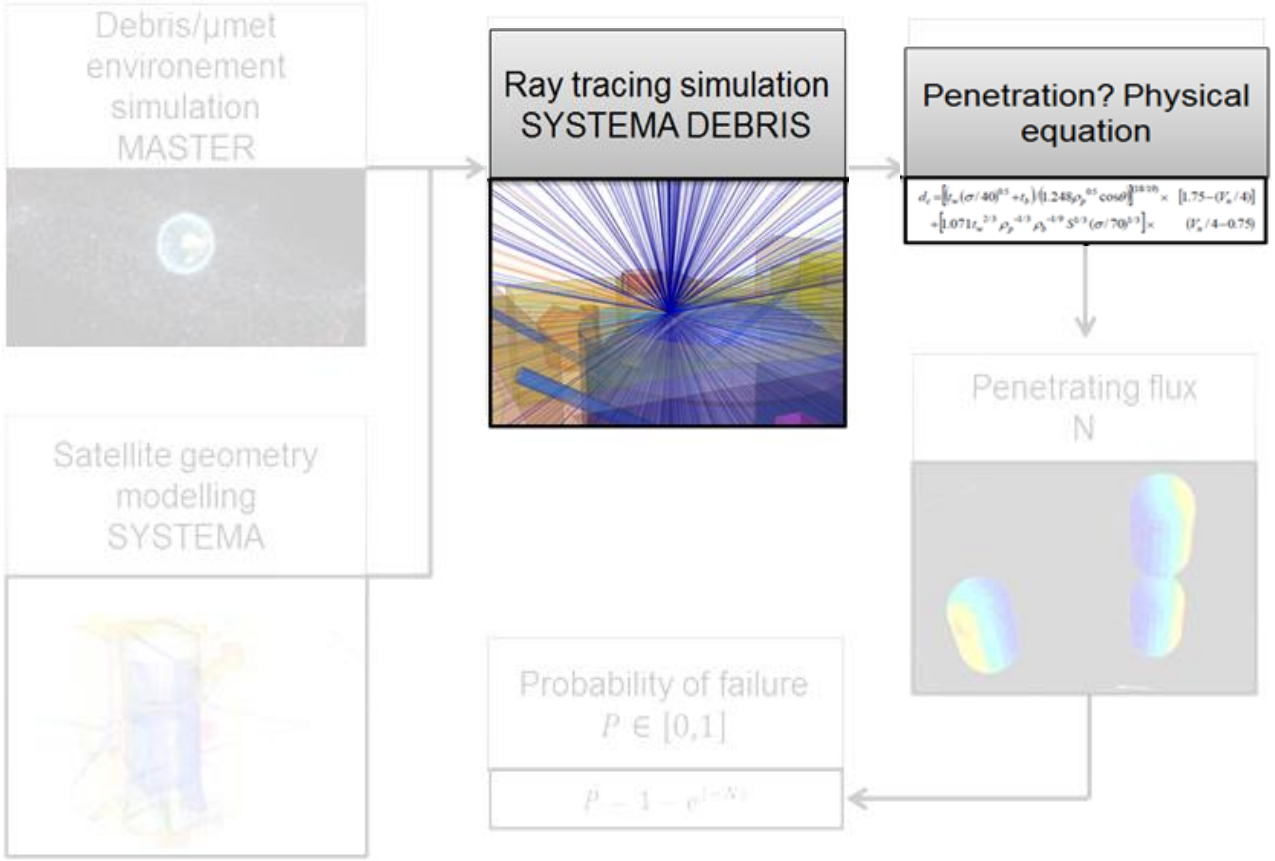
Satellite geometry



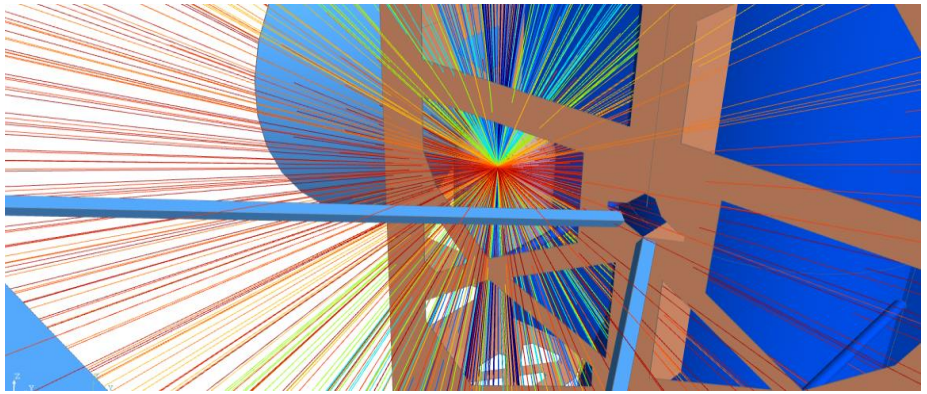
Generation of a realistic satellite model



Ray tracing - Ballistic equations

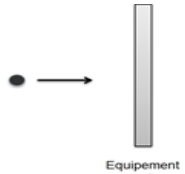


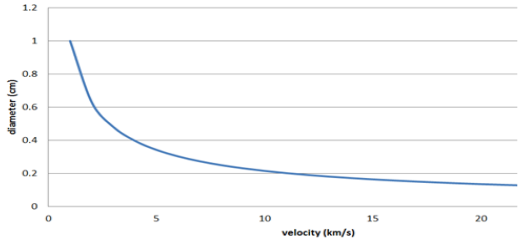
Backward ray tracing as support to physical equation



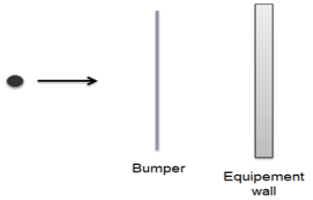
Physical equation

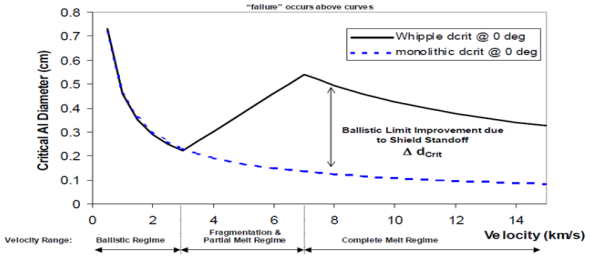
1 wall → Christiansen "single wall equation"





2 wall → Modified Cours-Palais/Christiansen equation





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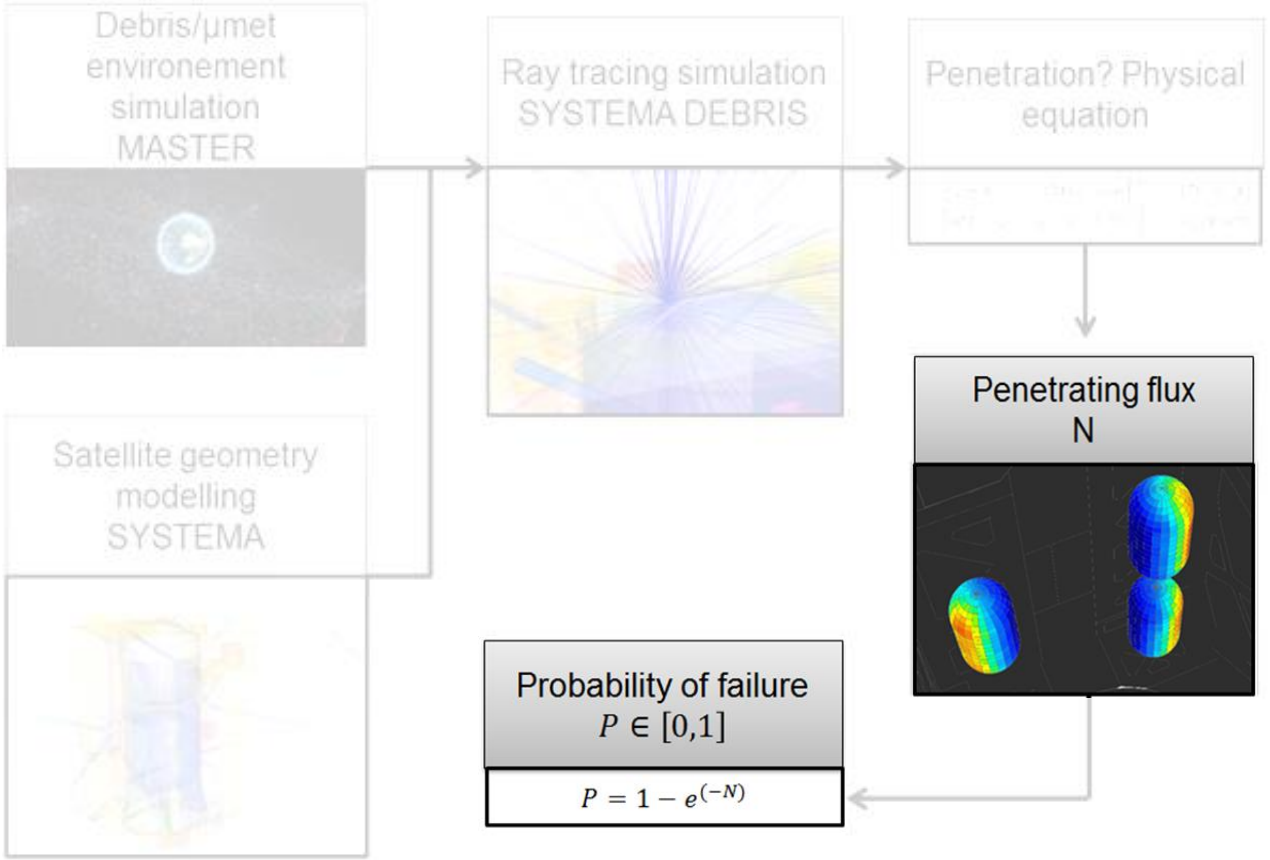
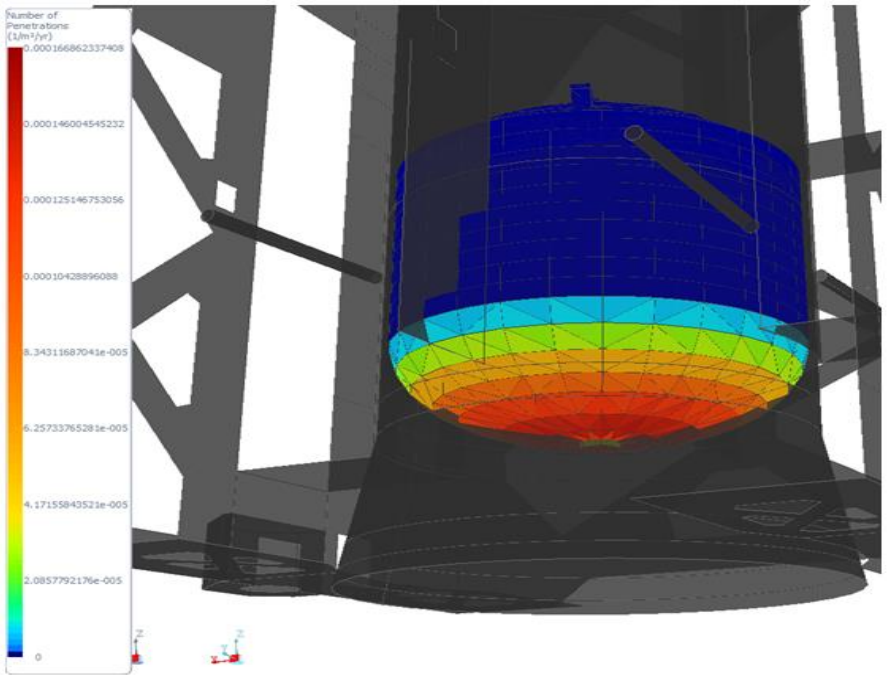
Penetrating flux - Probability of failure



Penetration flux



Probability of failure

From the penetrating flux, the probability of (no) penetration can be computed using a Poison law.

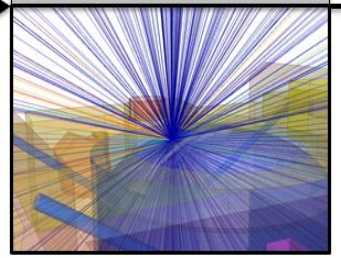
How MASTER will be used

Connexion Systema-Debris/MASTER

Risk assessment process

Debris/µmet environement simulation MASTER

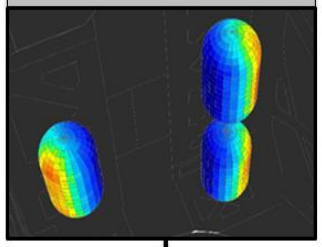
Ray tracing simulation SYSTEMA DEBRIS



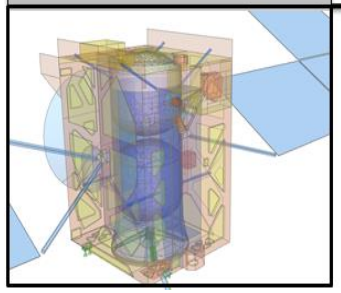
Penetration? Physical equation

$$d_c = \left[t_w(\sigma/40)^{0.5} + t_b\right]\left(1.248\rho_p^{0.5}\cos\theta\right)^{2/3} \times \left[1.75-(V_n/4)\right] + \left[1.071 t_w^{2/3}\rho_p^{-1/3}\rho_b^{-1/9}S^{1/3}(\sigma/70)^{1/3}\right] \times \left(V_n/4-0.75\right)$$

Penetrating flux N



Satellite geometry modelling SYSTEMA



Probability of failure $P \in [0,1]$

$$P = 1 - e^{(-N)}$$

✖ Times

Trajectory:

Mission around Earth: x2
- orbit transfer
- orbit mission

} 2 MASTER outputs

Interplanetary mission: x1 isotropic environment.

Kinematic:

Geostationary spacecraft: x1

Earth observation spacecraft: x$N_{pointing}$

Calculation for a set of representative pointing

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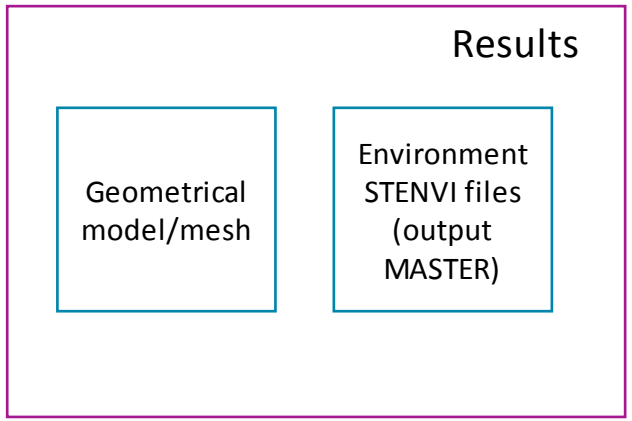
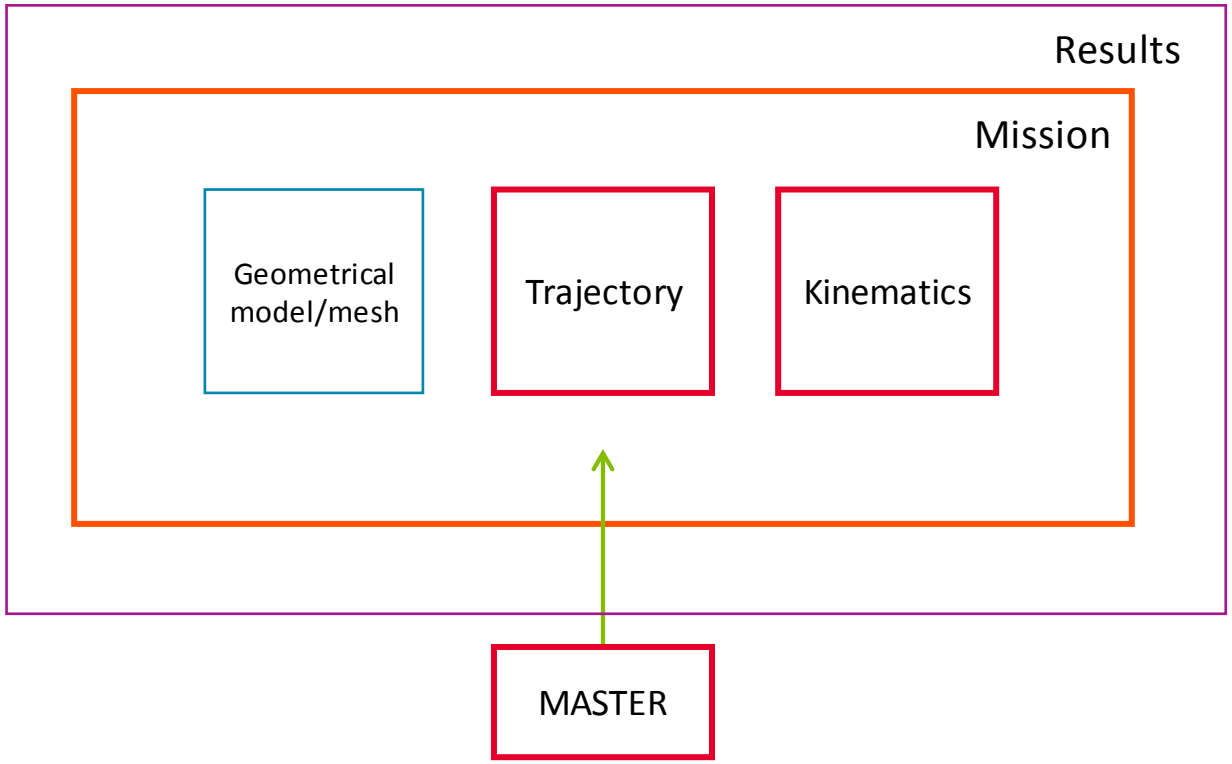
Connexion Systema-Debris/MASTER

Now



Possible Future



How connect MASTER to Debris?
Call N times MASTER and read N times the STENVI?

Systema-Debris 1D tool

Environments:

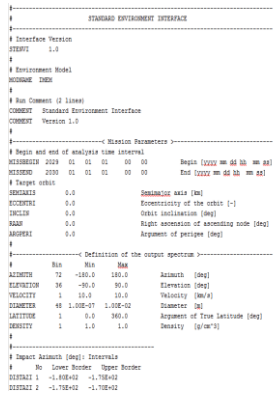
- MASTER STENVI outputs → ✓ OK. STENVI compatible with Systema
- Environment from other tools like ORDEM or MEM3 → ✖ STENVI not a standard for all tools → Converter between formats.
- Tables Flux vs diameter/mass from specification document → ✖ → Converter between table and STENVI.

Table

Diameter [m]	Fluence [m^{-2}]		
	Interplanetary / IMEM	Jovian / JMEM	TOTAL
1.00E-07	3.44E+05	1.39E+04	3.58E+05
3.00E-07	8.01E+04	9.68E+03	8.98E+04
6.00E-07	3.85E+04	2.79E+03	4.13E+04
1.00E-06	2.18E+04	9.68E+02	2.28E+04
2.00E-06	7.98E+03	2.85E+02	8.26E+03
5.00E-06	2.28E+03	8.25E+01	2.36E+03
1.00E-05	9.10E+02	2.47E+01	9.35E+02
3.00E-05	2.50E+02	1.84E+00	2.52E+02
1.00E-04	1.48E+01	6.01E-02	1.48E+01
3.00E-04	1.37E+00	2.55E-03	1.38E+00
1.00E-03	8.93E-03	1.79E-04	9.11E-03
1.00E-02	1.09E-06	6.22E-06	7.30E-06

Conversion

STENVI format



Tool to:

- Generate STENVI from a table and vice versa
- display STENVI
- Interrogation of STENVI

Comparison between M2009 and M8

Comparison between M2009 and M8

A study has been performed by Airbus DS for CNES in 2020.

The aim of this study was :

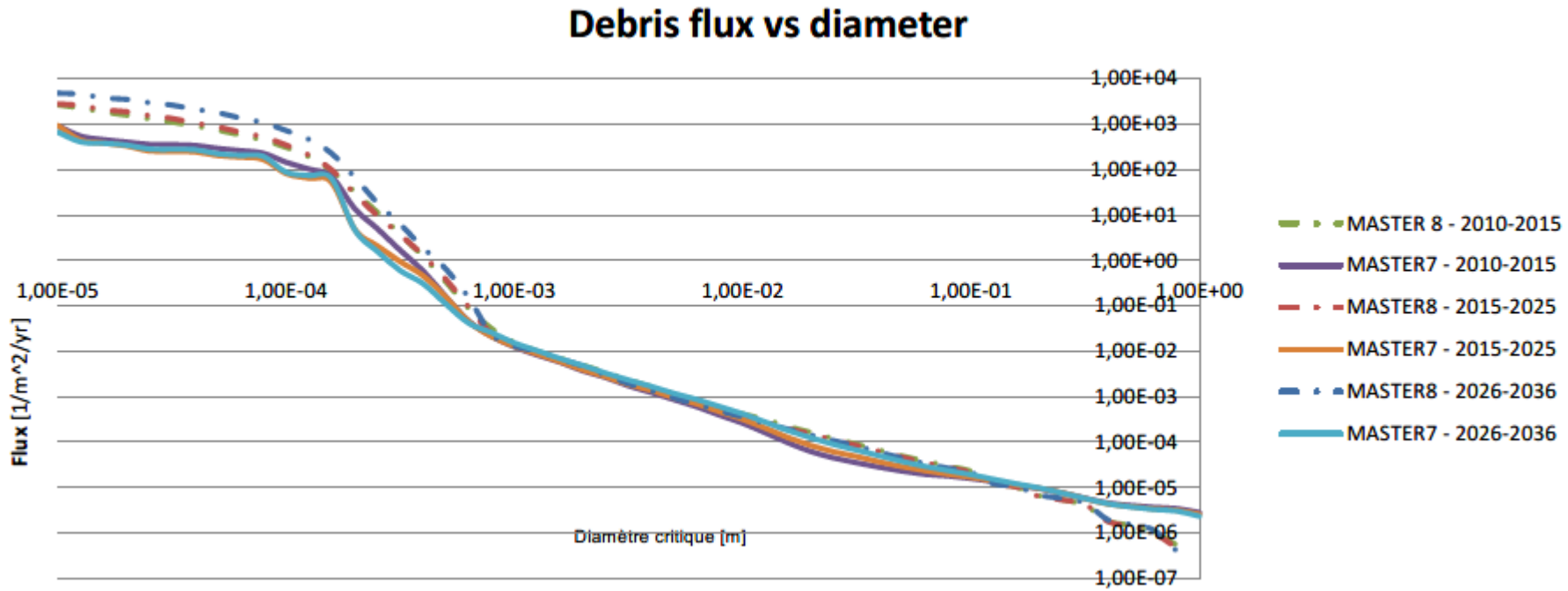
- quantify the impact of the new Debris environment model MASTER-8 on the spacecraft reliability,
- check if current S/C designs are adequate or need to be reinforced (with additional shielding for example).

The study was made:

- At 800km.
- Only on the debris population.
- For 3 epoch to catch the evolution of the time → 2010-2015 (the referent epoch)
  → 2015-2025
  → 2026-2036

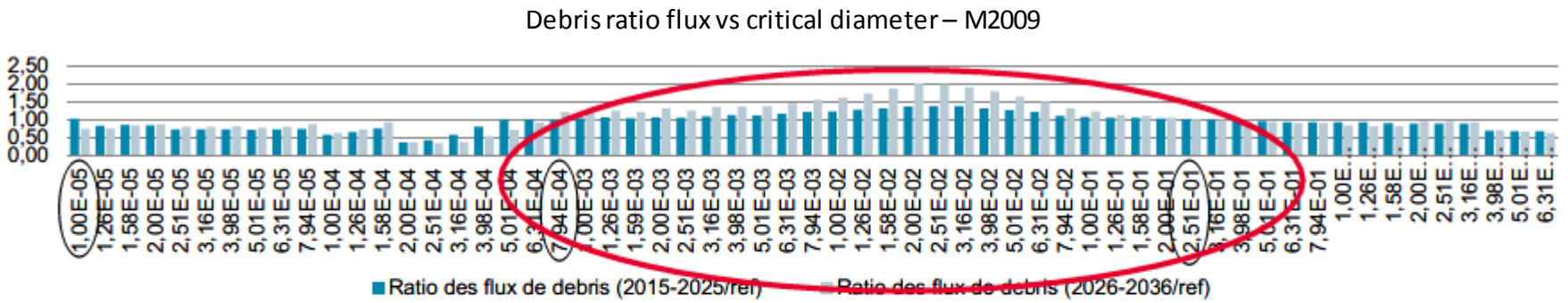
The first step was to compare the two environment predicted by MASTER 2009 and MASTER8, than to see the impact on the S/C critical impacts and the mission reliability.

Comparison between M2009 and M8

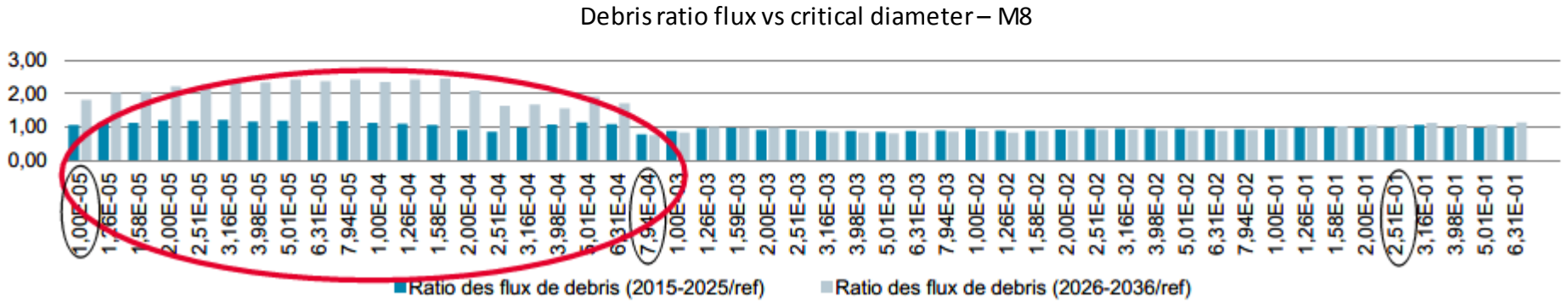


→ At 800km, for the small particles under 0.6mm, the number of particles predicted by M8 are superior of the M2009 flux over the time.

Comparison between M2009 and M8



→ M2009: Increase over time of the flux between 0.8mm and 0.25m.



→ M8: Increase over time of the flux for particles below 0.8mm.

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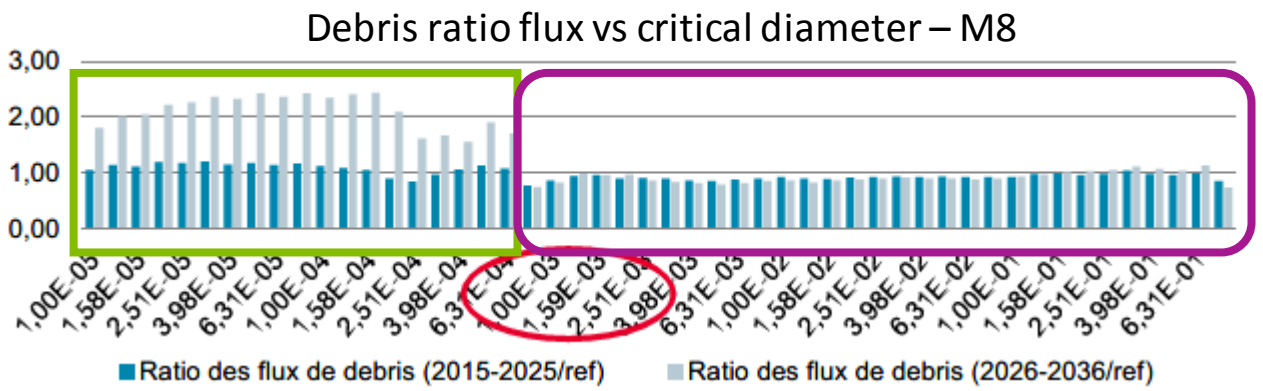
Comparison between M2009 and M8



On M8, the particles that increase over time are most of the time not critical for the sensitive part of the S/C.

On M8, the number of critical particles for the sensitive part of a S/C stay **stable or reduce** over time.

→ Impact on the number of penetrations on two S/C of the study: reduction of the number of penetration over time.

Comparison between M2009 and M8

- At 800km, the number of small particles predicted by M8 are superior of the M2009 flux over the time.
- The range where the number of particles increase over time in not the same for M2009 and M8.
- The number of no critical particles for a S/C **increase** over time.
- the number of critical particles for a S/C stay **stable or reduce** over time.

This led to a surprising stability of S/C critical impacts in the future with M8 **at 800km**. This stability is not consistent with the current trend for constant and strong increase of the space traffic.

Summary

- Today, the STENVI files are the input of Systema-Debris.
- Tomorrow, we would like to connect MASTER to Systema-Debris.
- Some points on the connection between MASTER and Systema-Debris are still open.
- Systema-Debris is flexible, it can adapt it STENVI reader to be in line with a possible evolution of a new STENVI format (inclusion of uncertainty, binning ...).
- A more exhaustive investigation on the debris M8 model need to be performed at other orbits.

Thank you

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