MIRAD

Micro-particle impact related attitude disturbances

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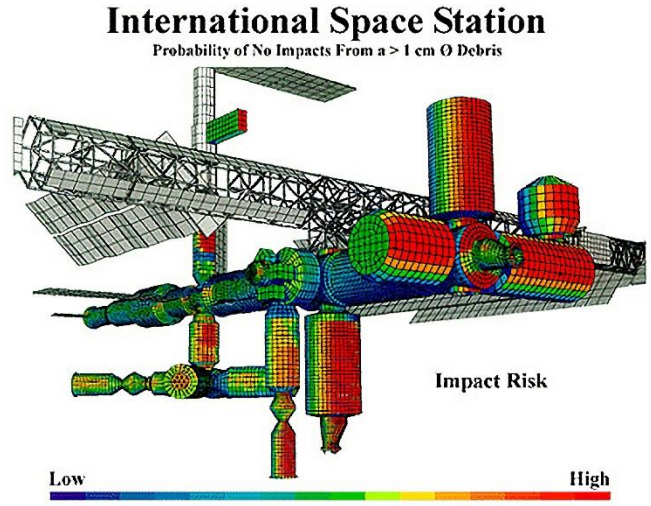
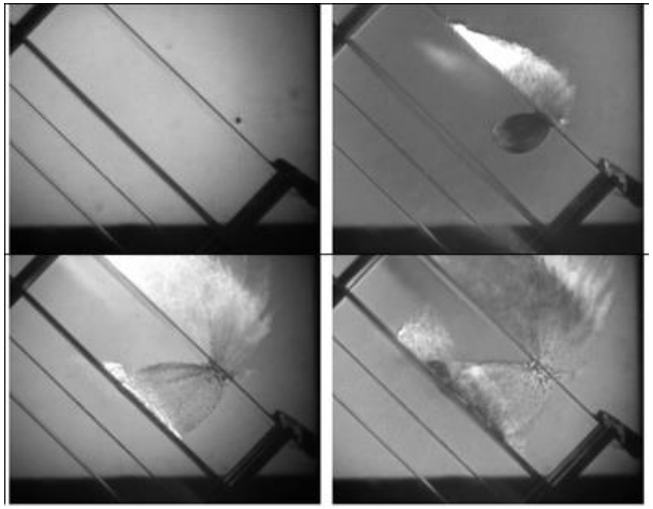
Microparticles pose a significant risk to space missions

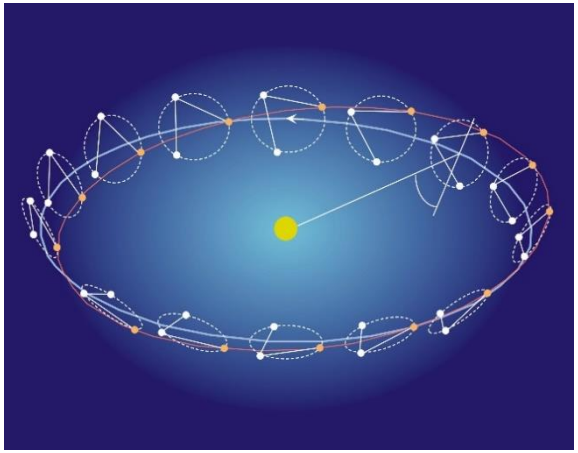
https://commons.wikimedia.org/wiki/File:ISS_impact_risk.jpg



https://www.lisamission.org/fr/multimedia/image/lisa-spacecraft-and-gravitational-waves



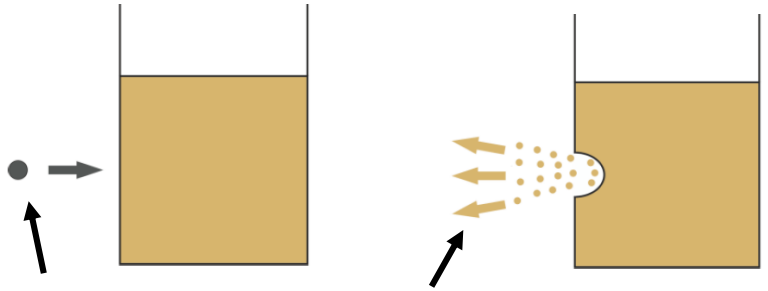
https://www.esa.int/ESA_Multimedia/Images/2013/04/Hypervelocity_Impacts#.XfZ8xT39QA4.link



http://web.mit.edu/klmitch/classes/8.224/project/c_clarke/orbit163sc.jpg

Attitude disturbance due to microparticle impacts are poorly understood

https://www.esa.int/ESA_Multimedia/Images/2013/04/Hypervelocity_Impact#.XfZ7WPIftvg.link



$$\vec{P}_{Particle} + \vec{P}_{Ejecta} = \vec{P}_{Total}$$

Momentum enhancement:

$$\beta = \frac{\vec{P}_{total}}{\vec{P}_{Particle}}$$

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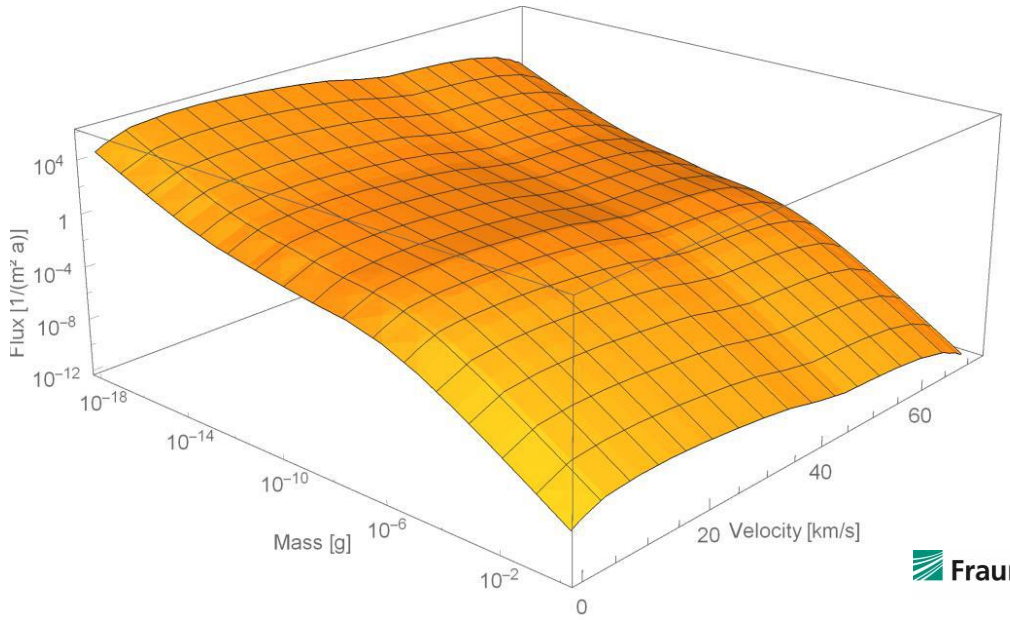
The goal is to develop an engineering tool to predict attitude disturbance from an impact

- **Develop a momentum transfer model** based on hypervelocity impact experiments.

- **Extend the IOTA framework** to handle **closed-loop control** and replace the current momentum transfer model with the **newly developed, improved momentum transfer model**.

- To **validate** the software we are **using operational data from** three ESA satellites, **Lisa Pathfinder, GAIA and Sentinel-1A.** Finally, we are going to **apply the software to the LISA design to assess the influence** of the microparticle environment **on the mission**.

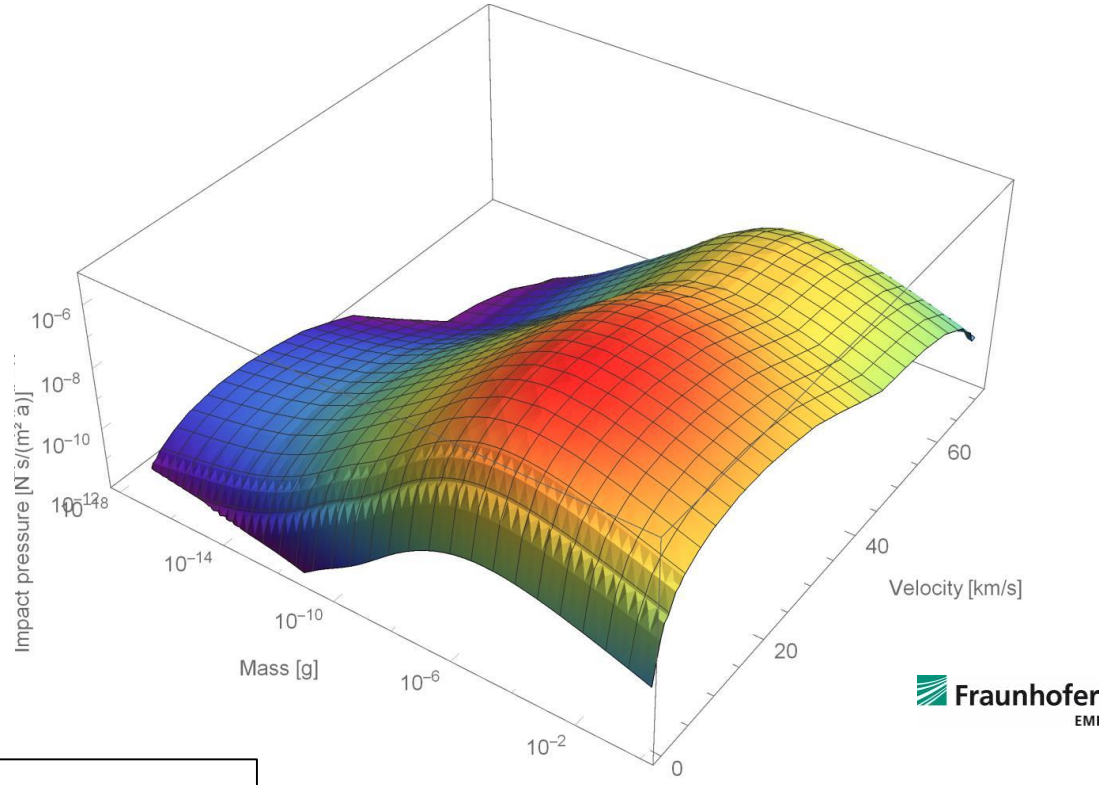
Relevant Particle Sizes



Fraunhofer EMI

Impact count or probability	Particle momentum	Average impact velocity $\bar{v}$	Particle size at $\bar{v}$ (2.5 g/cm³)	Particle size at 7 km/s (2.7 g/cm³)
1 per day	0.0086 mN·s	20.4 km/s	0.069 mm	0.096 mm
1 per year	2.34 mN·s	21.9 km/s	0.43 mm	0.62 mm
1 per 10 years	15.0 mN·s	22.2 km/s	0.80 mm	1.15 mm
5% in 10 years	152 mN·s	22.3 km/s	1.73 mm	2.49 mm
1% in 10 years	529 mN·s	22.4 km/s	2.62 mm	3.77 mm

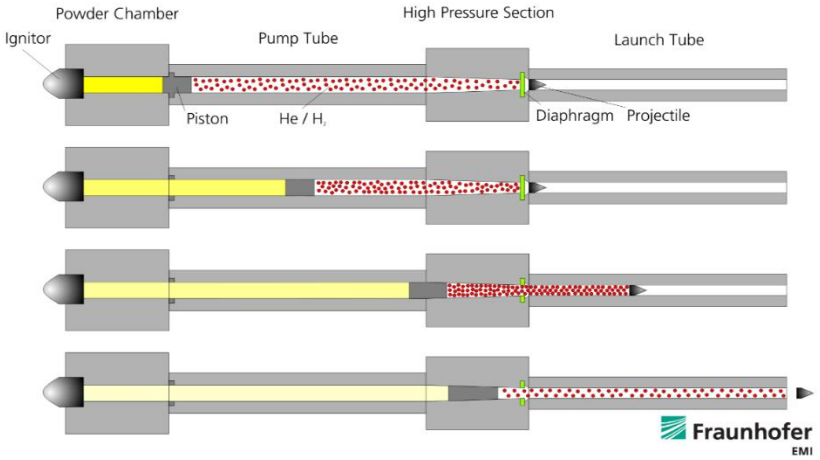
Reasonable worst case particles determined via an abundance approach

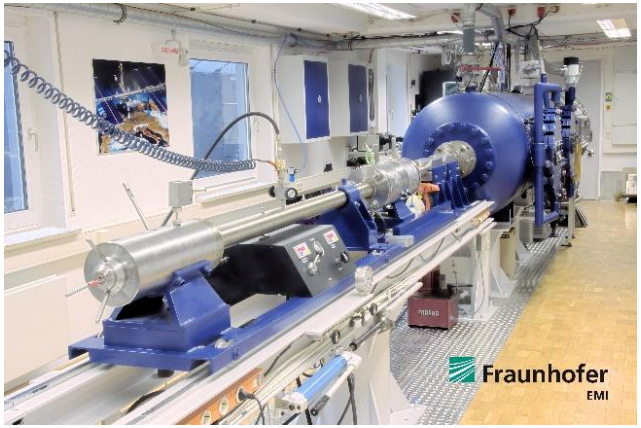


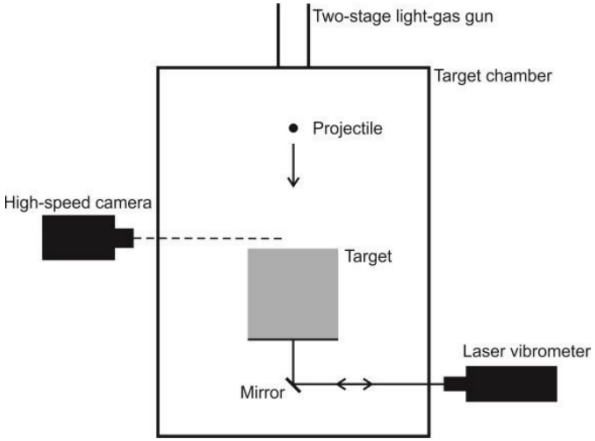
Peak in distribution:
$m = 6.4 \cdot 10^{-6}\ g$ and $v = 18\ km/s$

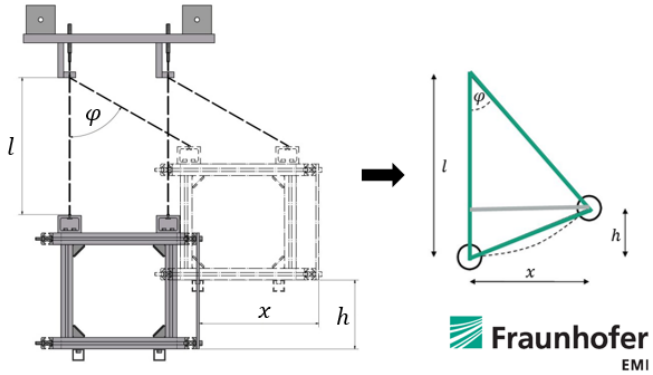
Corresponding momentum:
$P = 0.115\ mN \cdot s$
(0.23 mm aluminum sphere at 7 km/s)

Experiments performed with a two-stage light-gas gun and ballistic pendulum

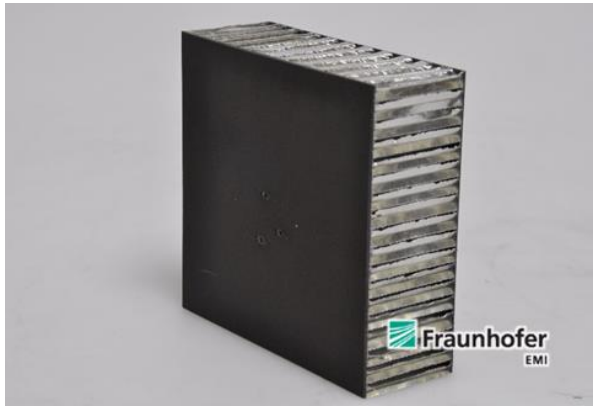






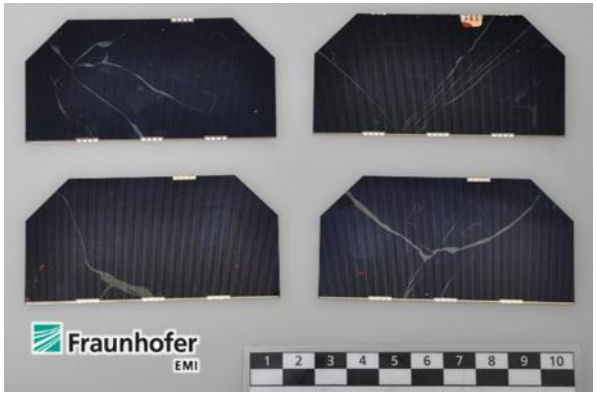


Realistic spacecraft surface materials are used as targets

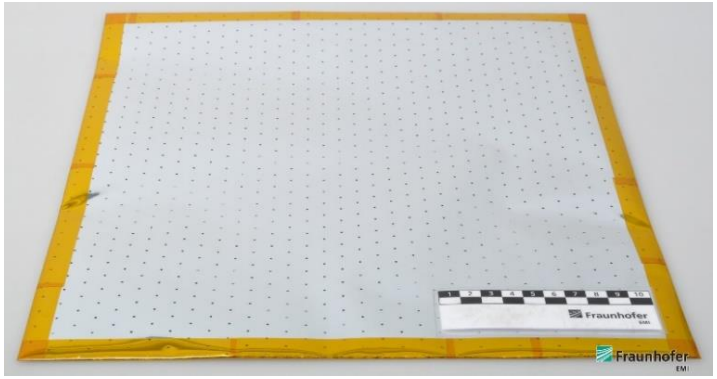


Standard CFRP Honeycomb Sandwich Panel

CFRP honeycomb sandwich panel with thick face sheets.

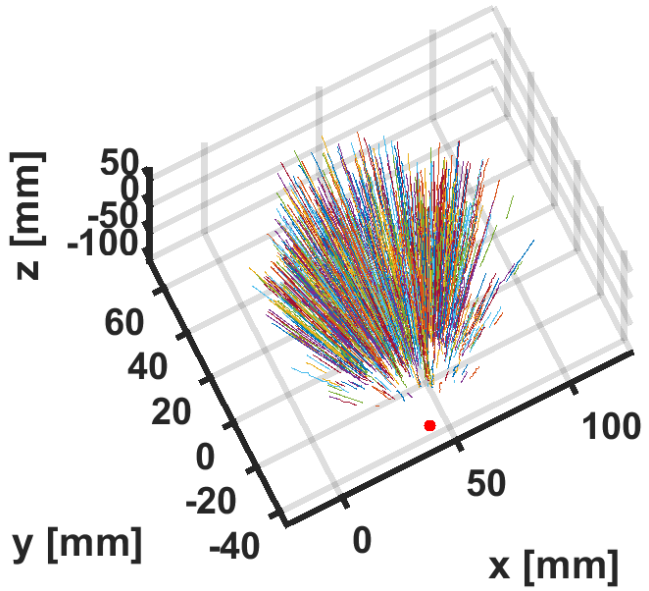


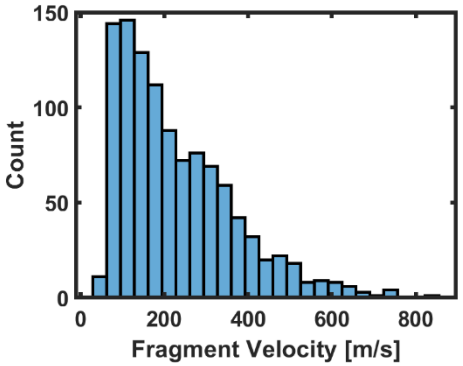
Solar cells (mounted on structural panel)

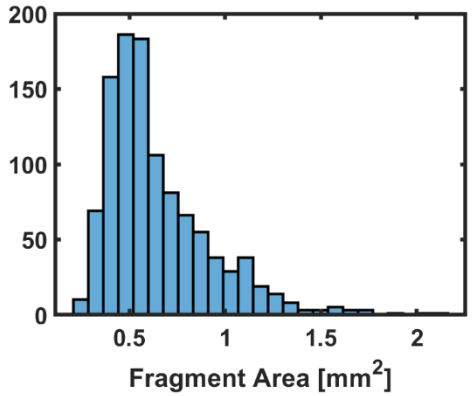


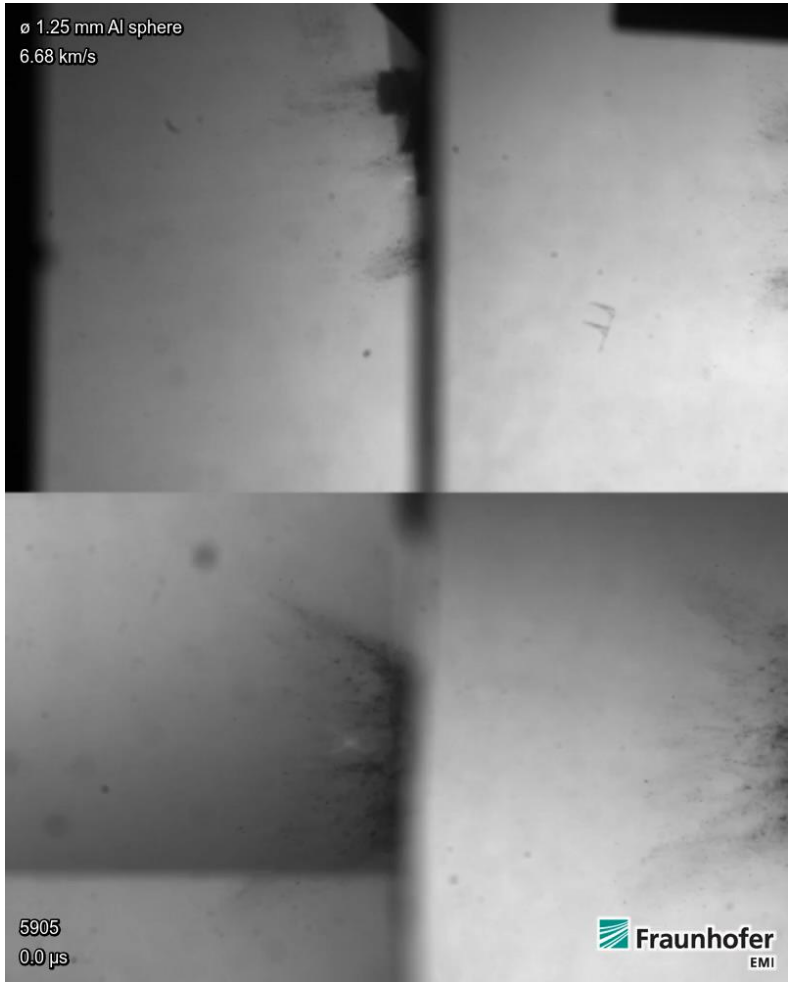
MLI (mounted on structural panel)

Optical fragment tracking is used to measure the ejecta velocity and size distribution







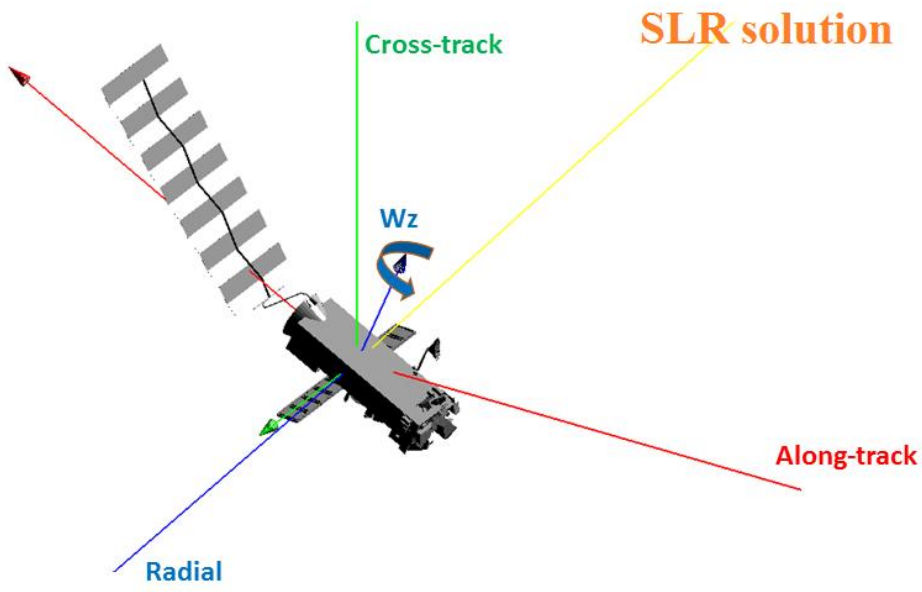


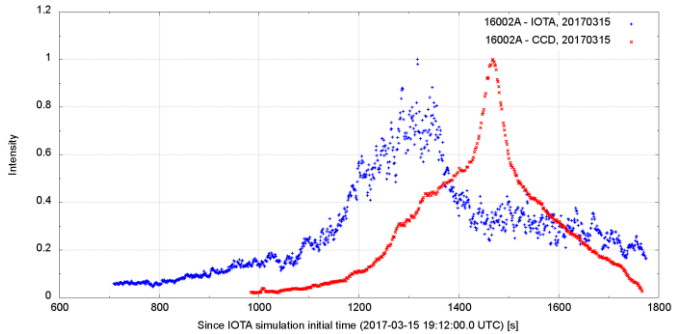
Momentum transfer model developed

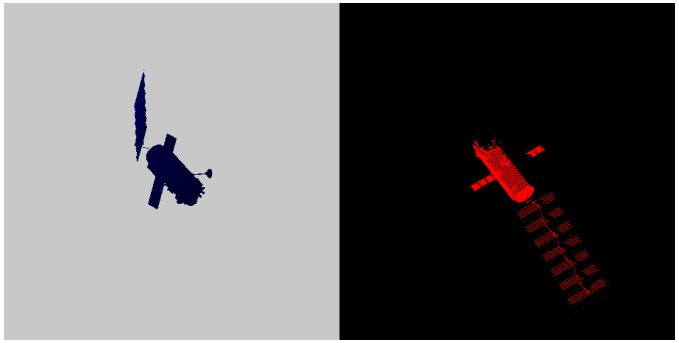
Ejected fragment momentum based on experimental data

- Size
- Velocity
- Momentum
- Angle

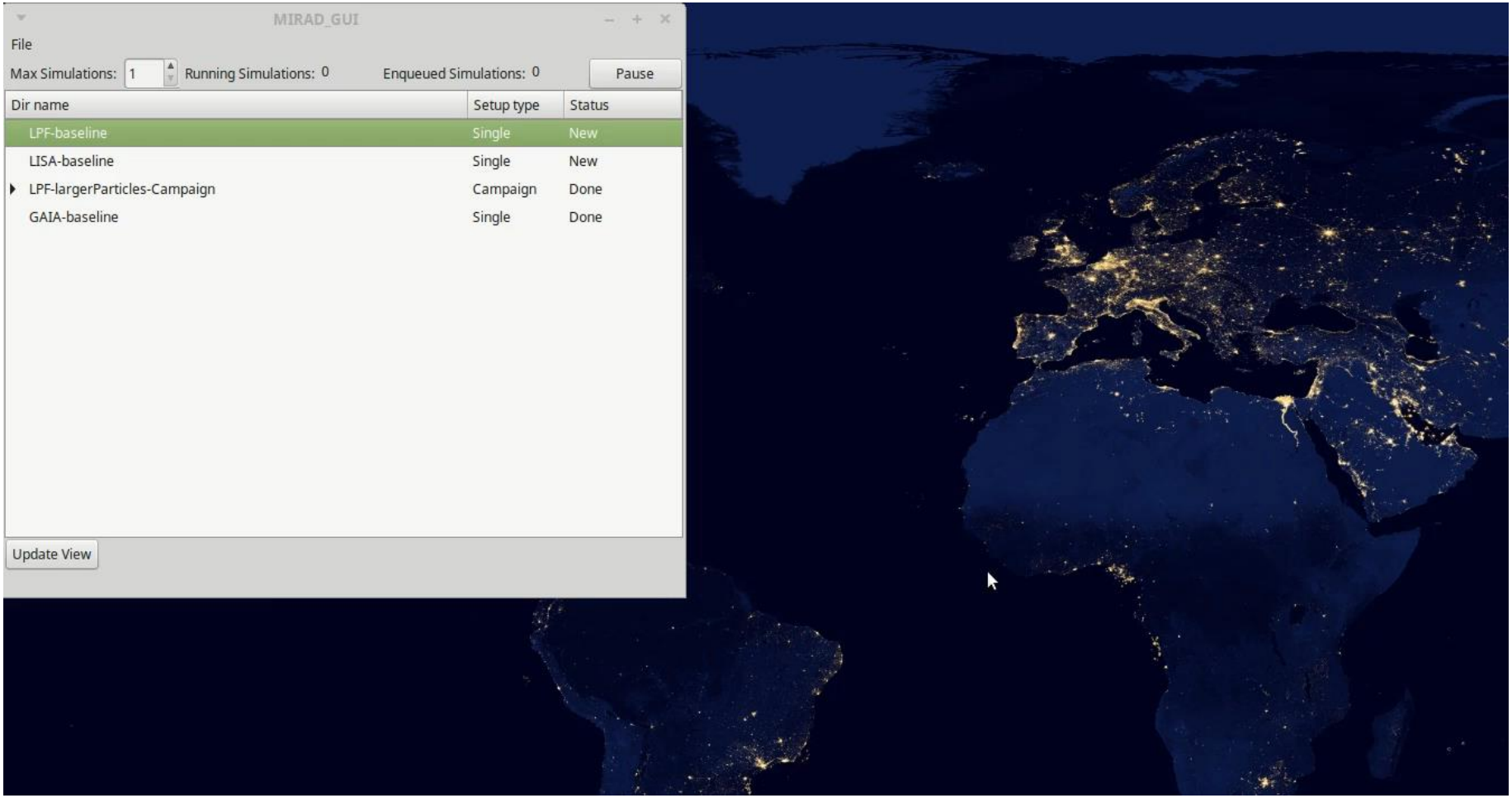
Extension of the IOTA framework



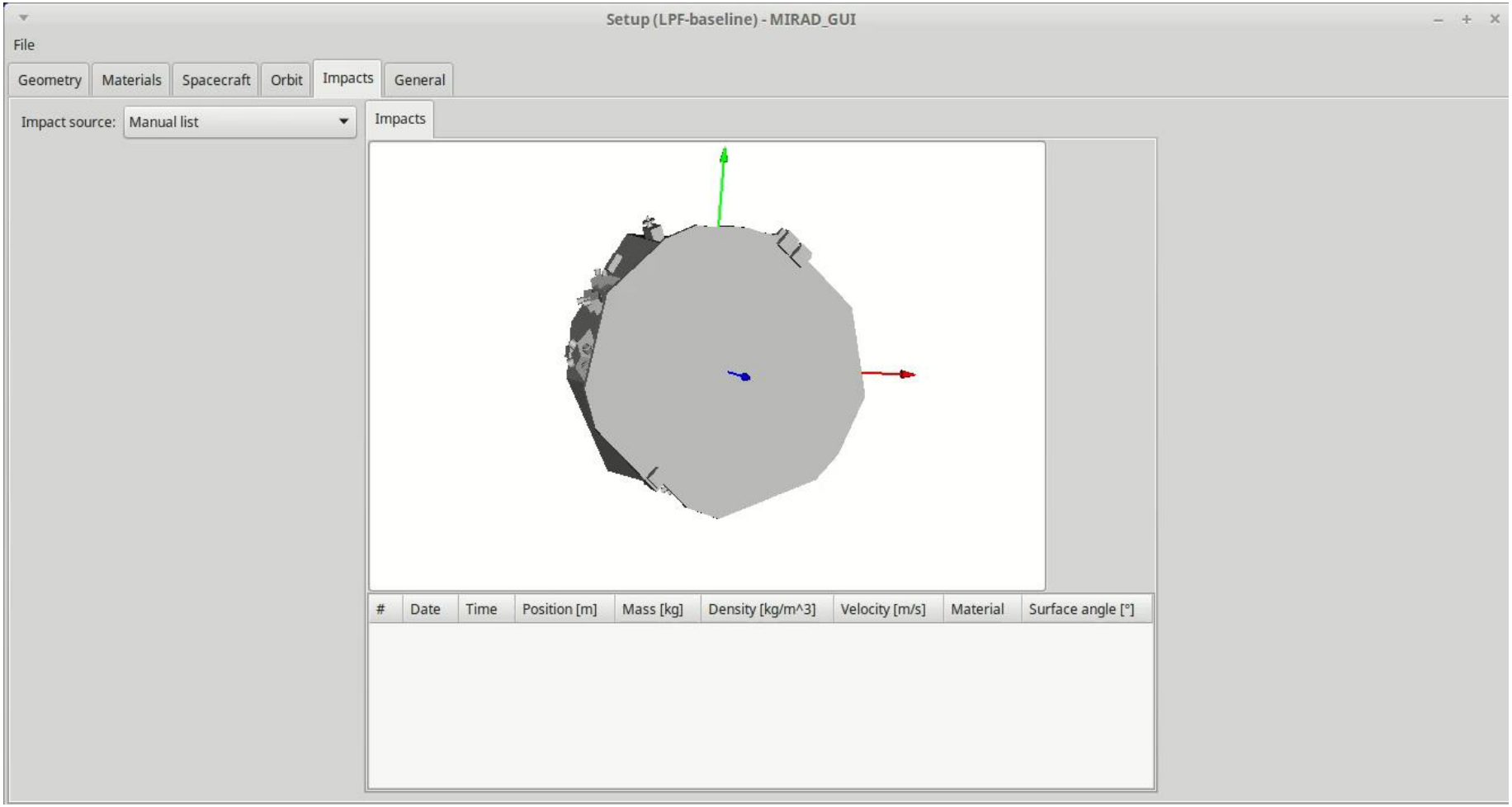




Setting up a simulation



Sampling impactors from the microparticle environment

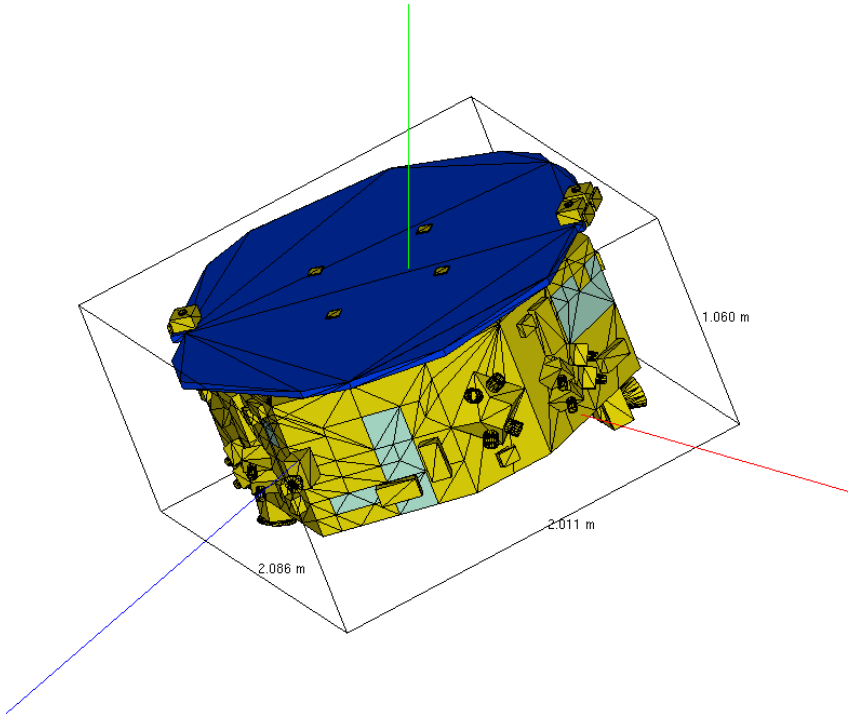


Validation case: Lisa Pathfinder

Input:

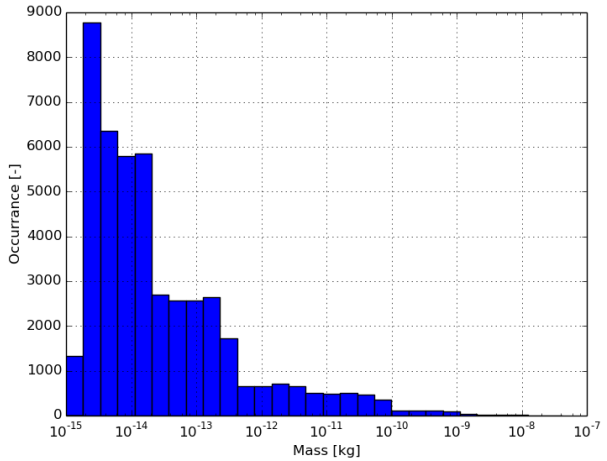
- SPICE kernel
- STENVI
- Mass, CoM, MoI
- Generic AOCS properties

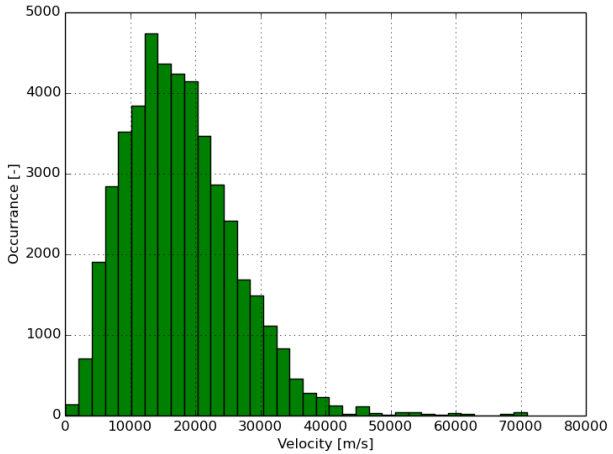
- Impact in the campaign set to occur 60 sec after simulation start

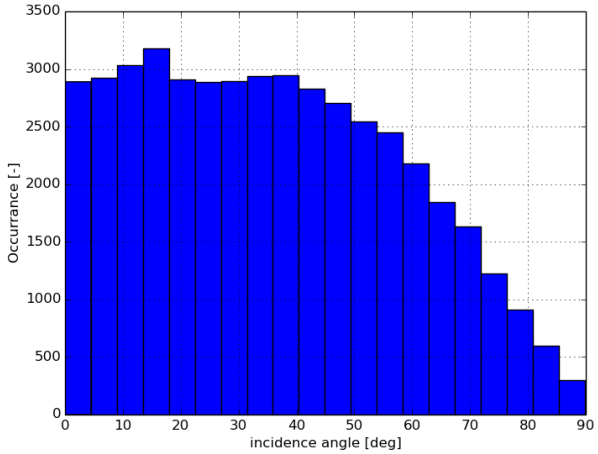


Validation case: Lisa Pathfinder

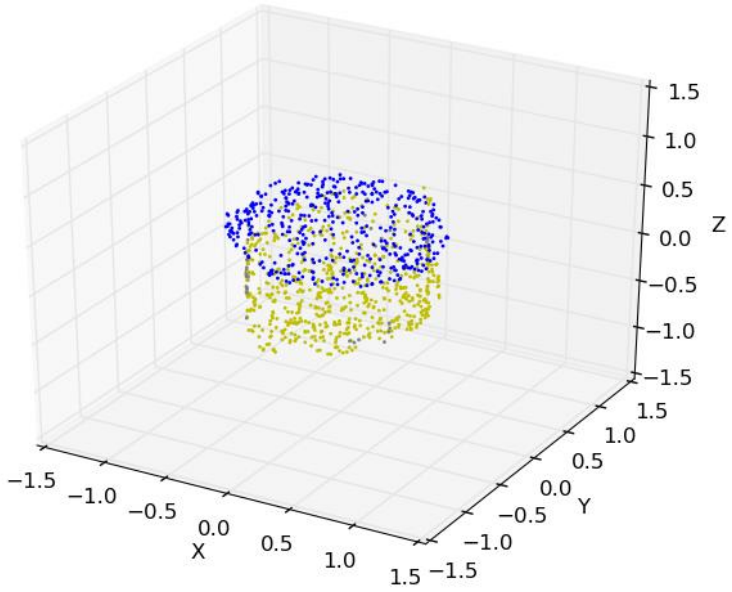
45,821 impacts sampled:



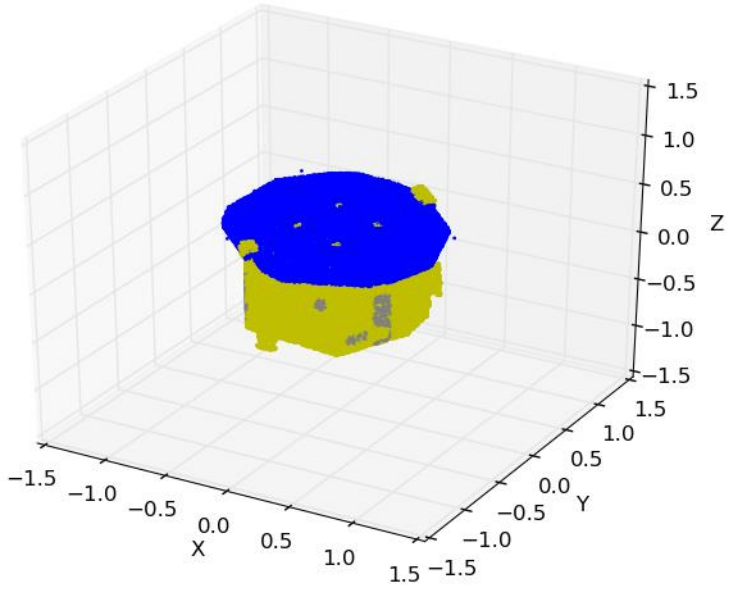




Validation case: Lisa Pathfinder

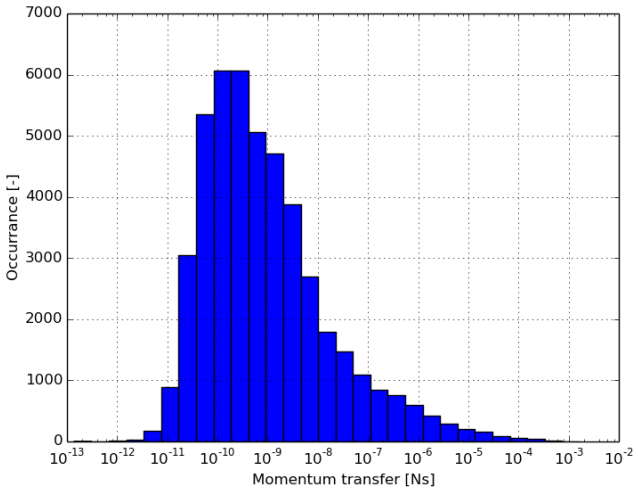


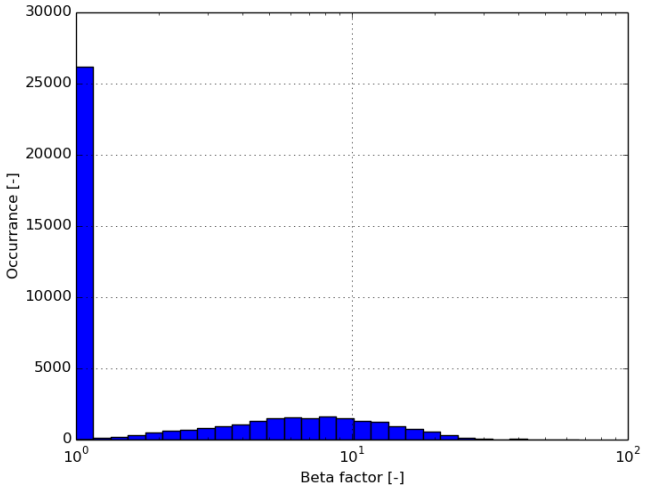
2000 impact locations

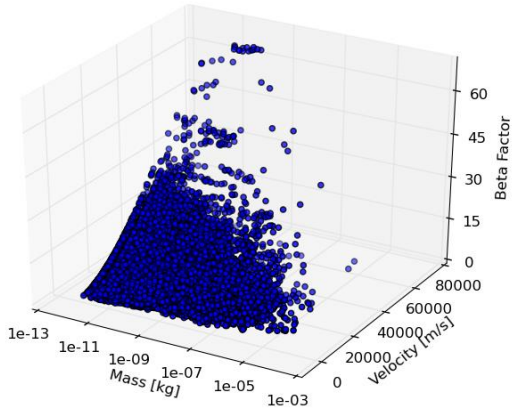


45821 impact locations

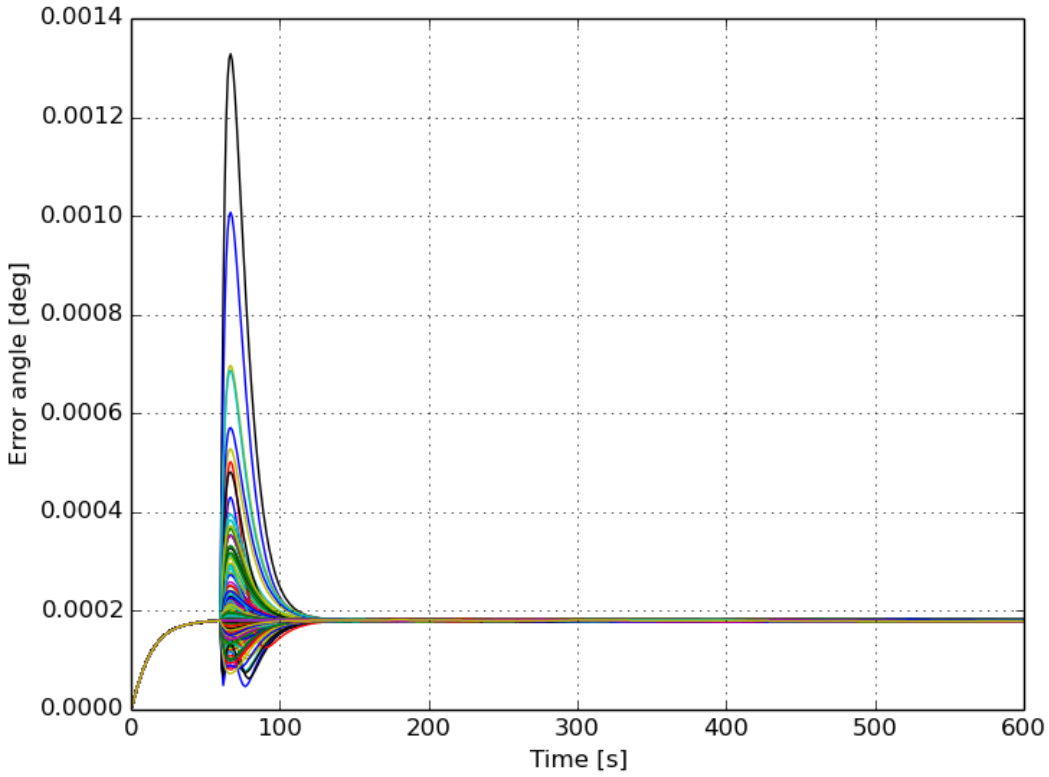
Validation case: Lisa Pathfinder





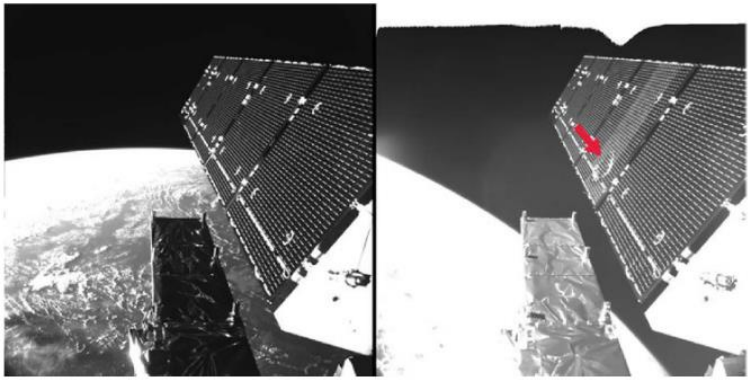


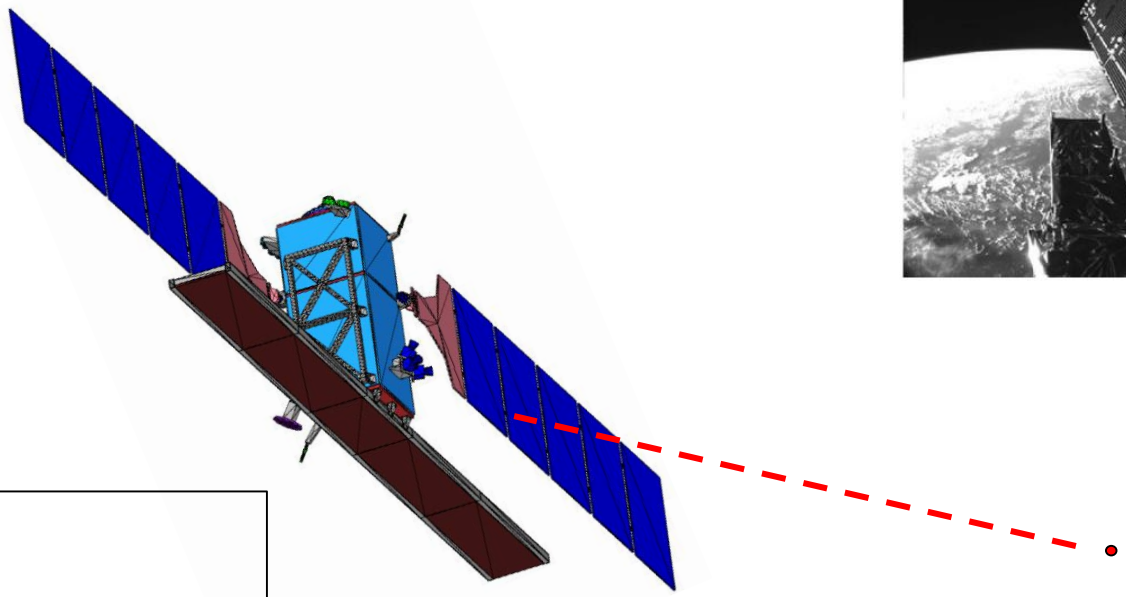
Validation case: Lisa Pathfinder

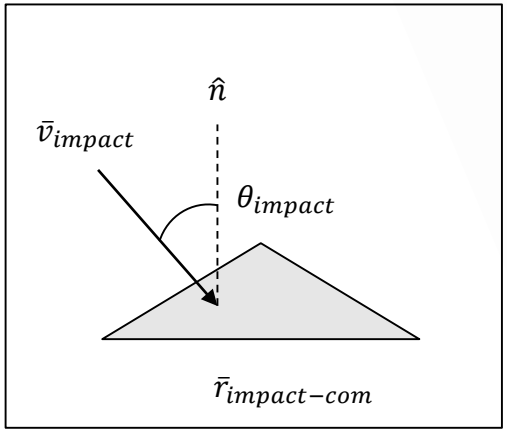


Validation case: Sentinel-1A

https://www.esa.int/ESA_Multimedia/Images/2016/08/Sentinel-1_impact#.XfZ6KTevX3c.link







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Thank you for listening!

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