DEDRA: A Modular In-Situ Detector for Monitoring Sub-Millimetric Space Debris

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Introduction

In light of the new ESA space debris mitigation requirements and further emphasis on pre-mission risk assessment, mission planners rely on models like MASTER or ORDEM to give accurate simulations of the debris environment. Unfortunately, these have significant discrepancies in the sub-millimetric realm.

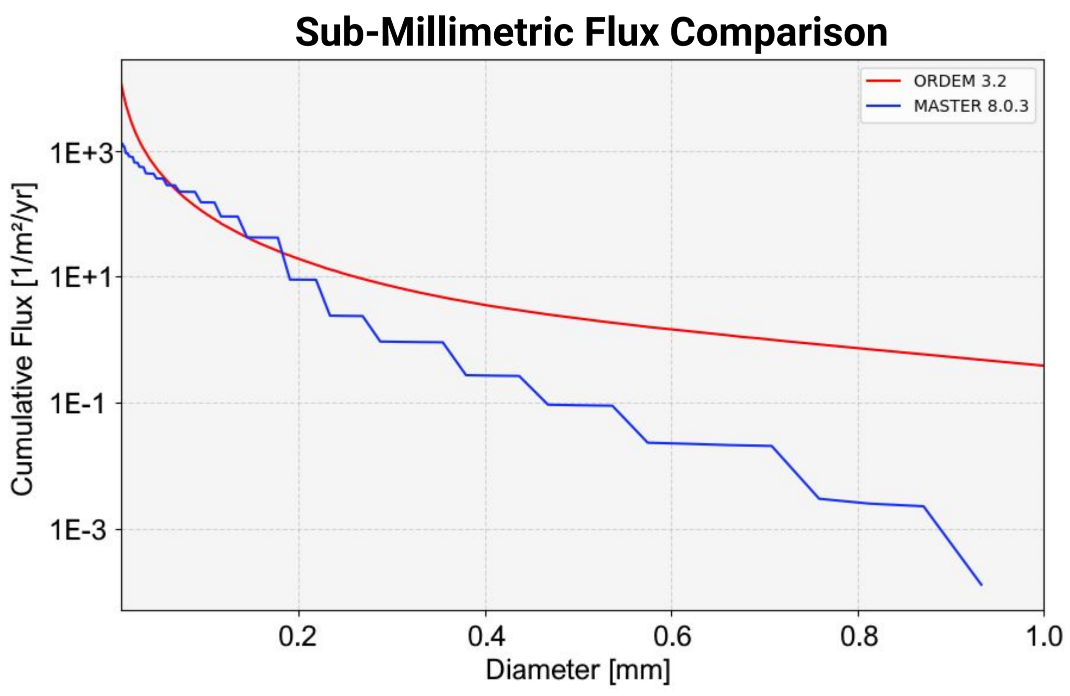

Figure 1: Difference in Sub-millimetric Flux in a 600 km SSO between MASTER 8.0.3 and ORDEM 3.2

While objects larger than 10cm can be reliably tracked from the ground, subcentimeter space debris can only be detected in-situ or by examining space-exposed surfaces returned from orbit. Although past validation of debris models relied on such surfaces, they only recorded impacts from 1984 to 2002 and covered a limited range of altitudes and inclinations [1]. In-situ detection methods have not been widely implemented yet, but missions like DEBIE and APID/ADLER have demonstrated the feasibility of such sensors [2,3].

Performance Simulations

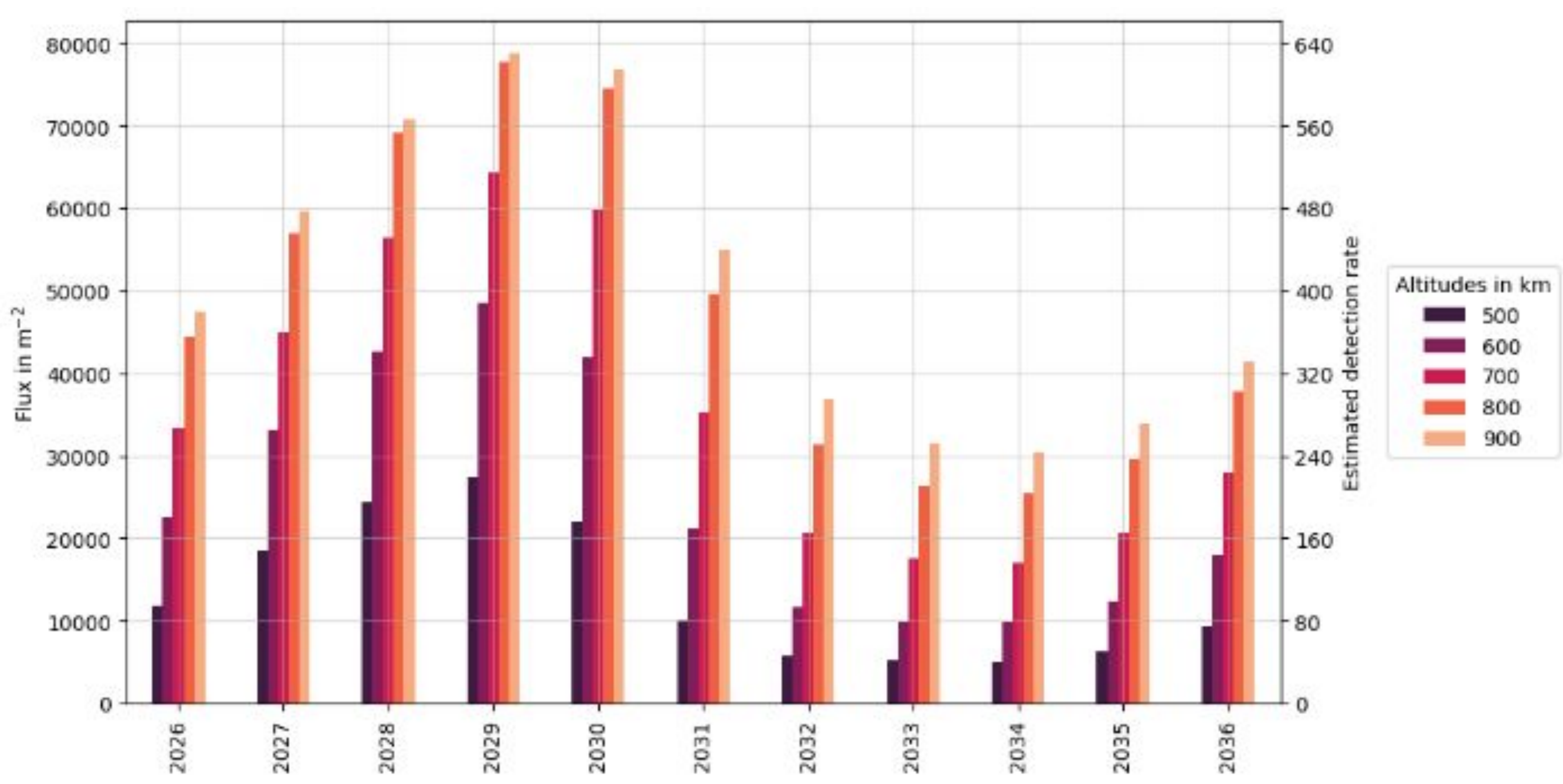

Figure 2: Variability of modelled sub-millimetric debris flux and estimated detection rates throughout a 11-year period for selected altitudes in SSO (ORDEM 3.2.0).

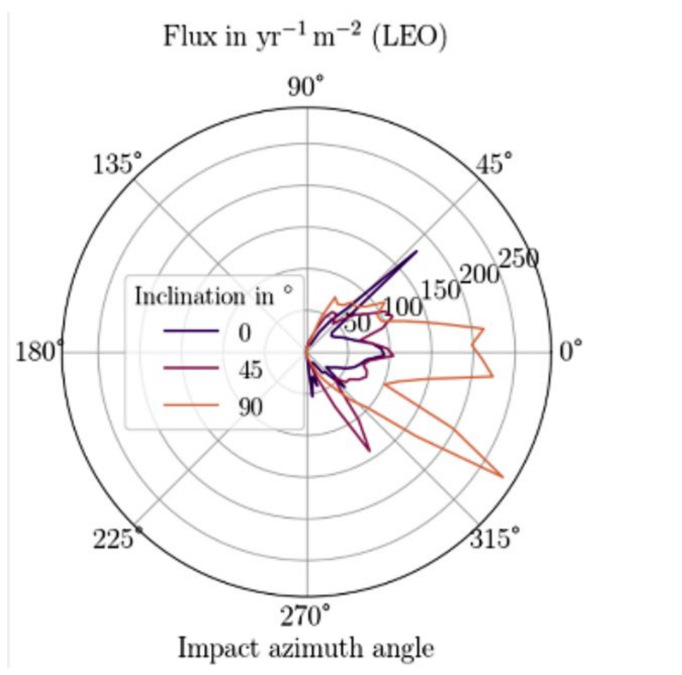

Figure 3: Variability of modelled sub-millimetric debris flux impact angle throughout a 11-year period for different orbital inclinations in LEO (MASTER 8.0.3)

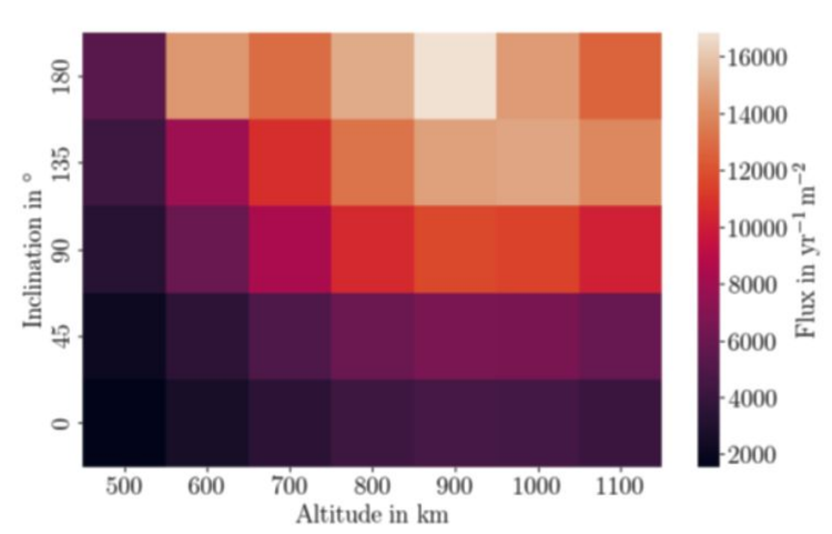

Figure 4: Heatmap of the total modelled sub-millimeter debris flux (11-year-average) in LEO for selected altitudes and inclinations (MASTER 8.0.3).

References

[1] Horstmann, A. et al. *Flux Comparison of Master-8 and Ordem 3.1 Modelled Space Debris Population*, in Proceedings of the 8th European Conference on Space Debris (virtual), 20–23 April 2021, ESA/ESOC, Darmstadt, Germany

[2] Schwanethal, J. et al. *Analysis of impact data from the debie (Debris In-Orbit Evaluator) sensor in polar low earth orbit* in: Proceedings of the 4th European Conference on Space Debris, 18-20 April 2005, ESA/ESOC, Darmstadt, Germany.

[3] Groemer, G. *ADLER-1 In-situ Space Debris Measurements,* Presentation at MASTER Modelling Workshop, ESA, 2021.

[4] Senger, R. (2008) *Data handling and evaluation for autonomous experiments in interplanetary missions*. Planetary and space science Vol.56, p.1057-1059

Debris Density Retrieval and Analysis (DEDRA)

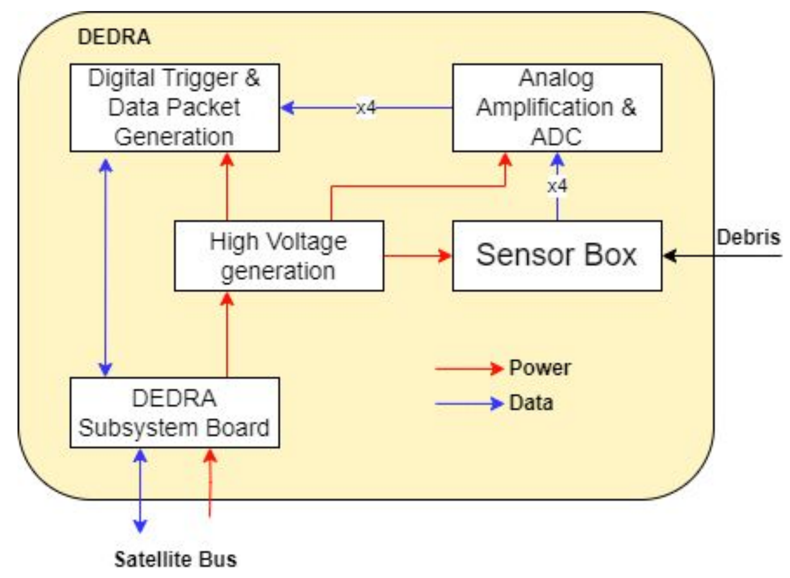

Figure 5: Schematic of the DEDRA sensor architecture

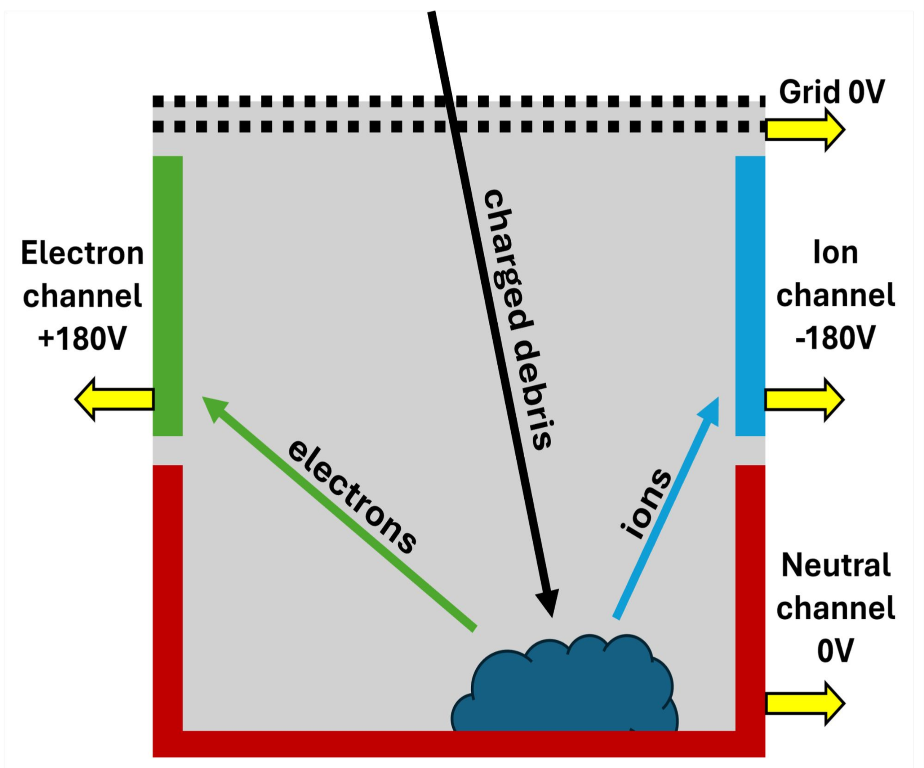

Figure 6: Simplified schematic of the DEDRA sensor box

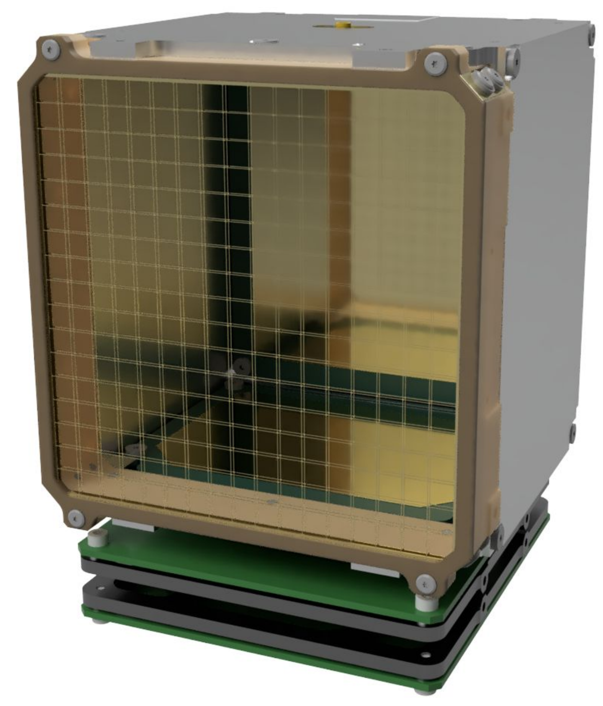

Figure 7: Rendering of the DEDRA CAD model

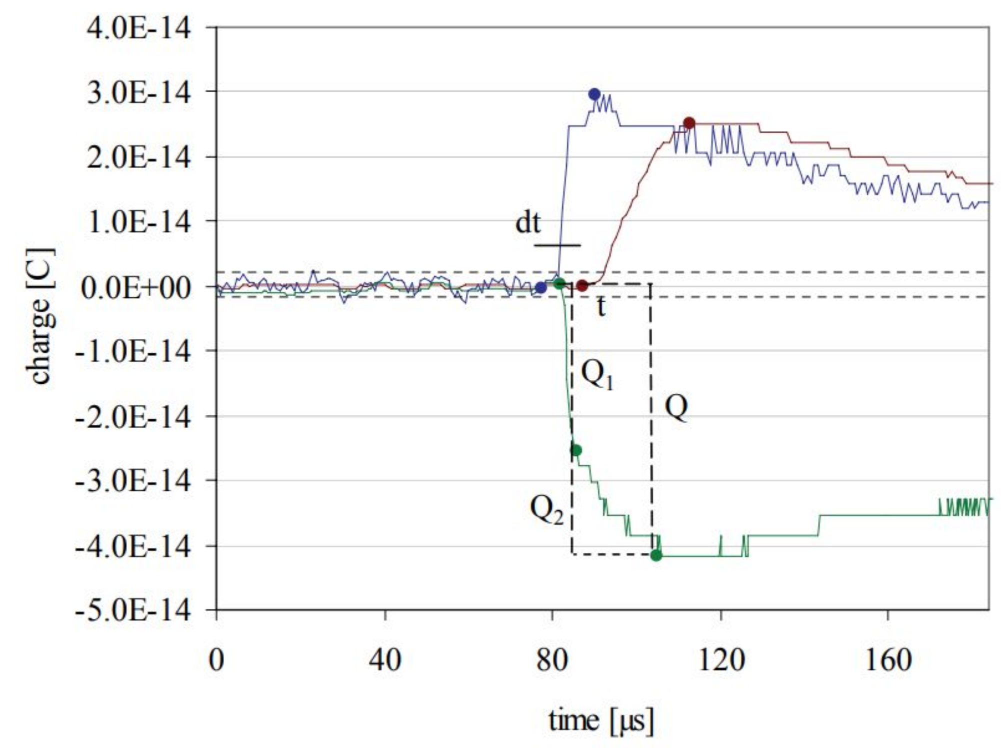

Figure 8: charge curve from exemplary impact during the Munich Dust Counter (MDC) calibration campaign [4]

Sensor Characteristics:

- Particle Mass:	10^{-15} to 10^{-10} kg
- Mass Resolution:	2×10^{-15} kg
- Velocity:	7 to 30 km/s
- Velocity Resolution:	1 km/s
- Power Consumption	3.7 W
- Size	1U (Box only)

Challenges

- The upcoming IOD mission will show the effectiveness of the sensor's noise mitigation measures against both atmospheric interference, which largely affected DEDRA's predecessor MDC on BremSat, and periodic solar noise
- Although we expect best scientific results at 1000 km, the initial injection altitude is practically limited due to the 5 years LEO clearance requirement
- Calibration of this sensor remains a challenge as the impact ionization cannot be properly simulated. The use of machine learning algorithms helps us find correlations in the signals and particle characteristics. These are currently being trained on old MDC calibration datasets
- Once the concept of this sensor has been proven, many more must be flown to get optimal statistical significance in different orbits

Acknowledgements

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