A cloud-based space debris mitigation tool

ESA Clean Space Industry Days, 16-19 Oct. 2023, ESTEC

Re CAE

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Content

01 Space situation

Rocket launches since Sputnik I

~6400

Number of satellites in orbit

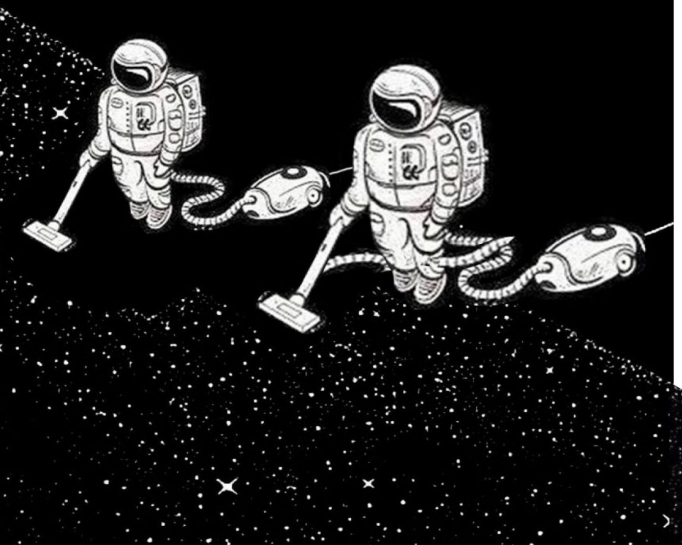
~10000

Number of space debris

~140 million

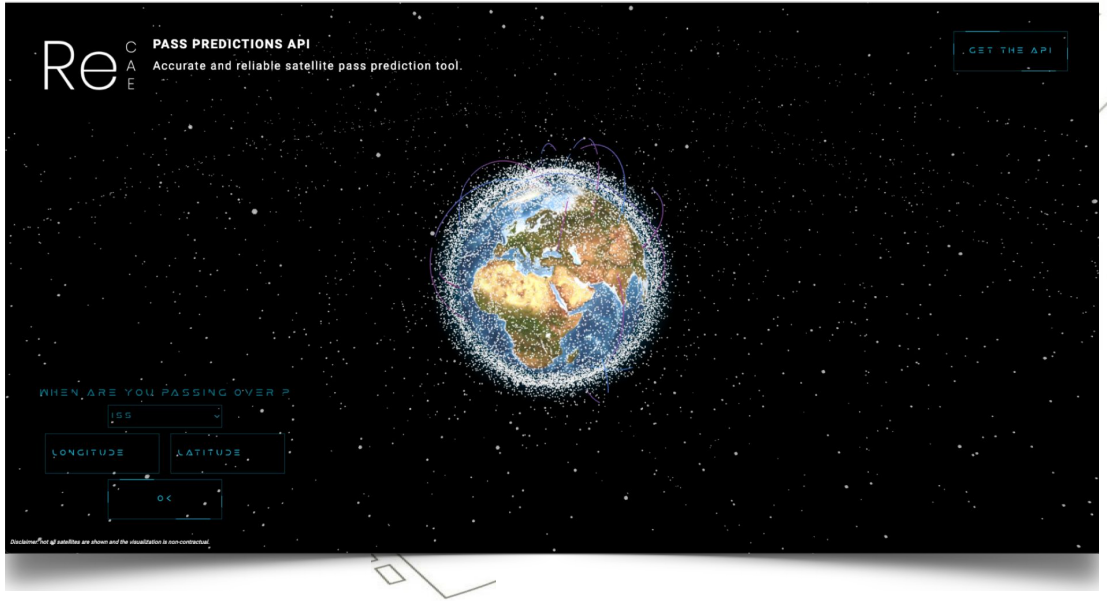
*Source: ESA's Space Debris Office

02 Our mission



To catalyze the achievement of the **Zero Debris goal** on a global scale.

Reconstructing a cleaner cosmos by providing accessible space solutions.



Precise orbital forecasts

In-depth spacecraft assessments

Comprehensive cloud-based platform

03
Our Solution

Preventing debris formation through extensive life, end-of-life & re-entry predictions

Exo-atmospheric flight

Re•Propagate

- State propagation
- Attitude propagation
- Pass predictions
- Uncertainty quantification
- Collision risk assessment

Endo-atmospheric flight

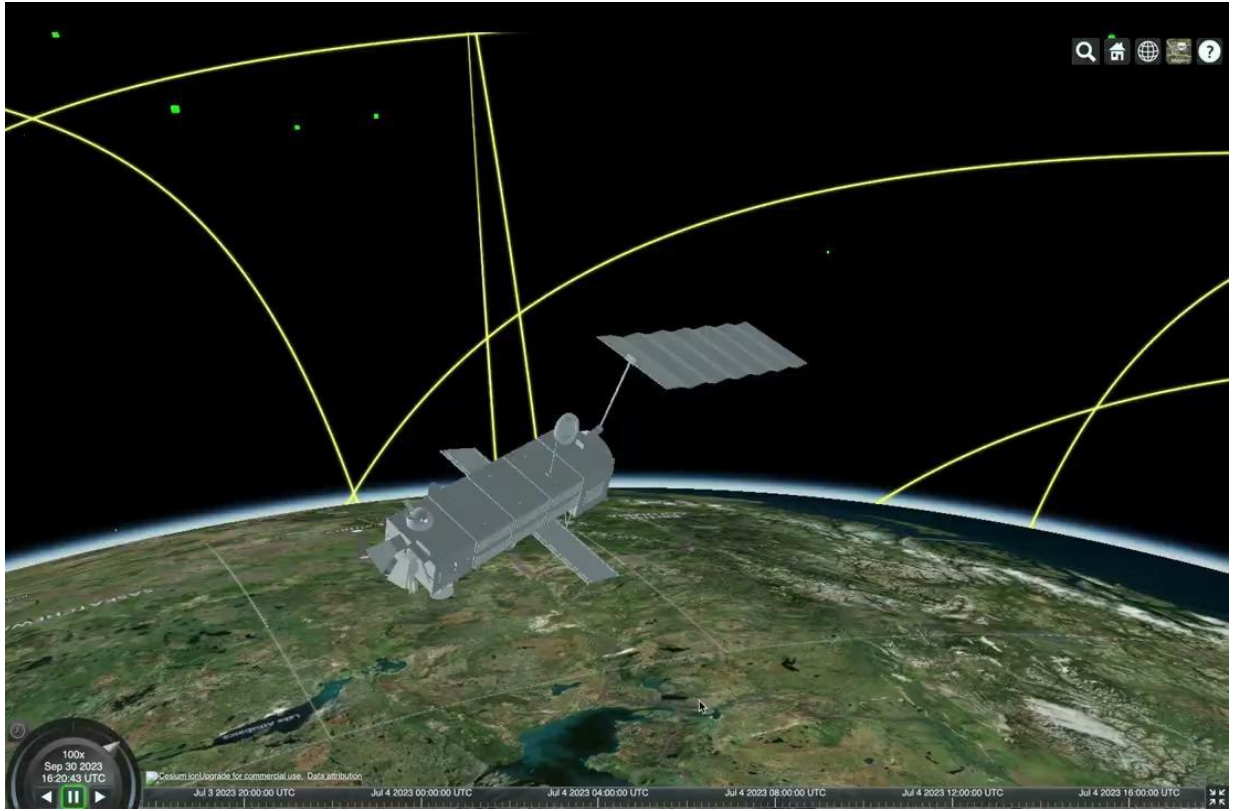
Re•Entry

- 6 d.o.f. trajectory
- Low-fidelity ablation
- Heat flux & aerodynamic coefficient calculator

Re•CFD

- Hypersonic flow
- 3D heat diffusion

03 Building blocks



Special perturbations

Attitude propagation

Covariance estimation

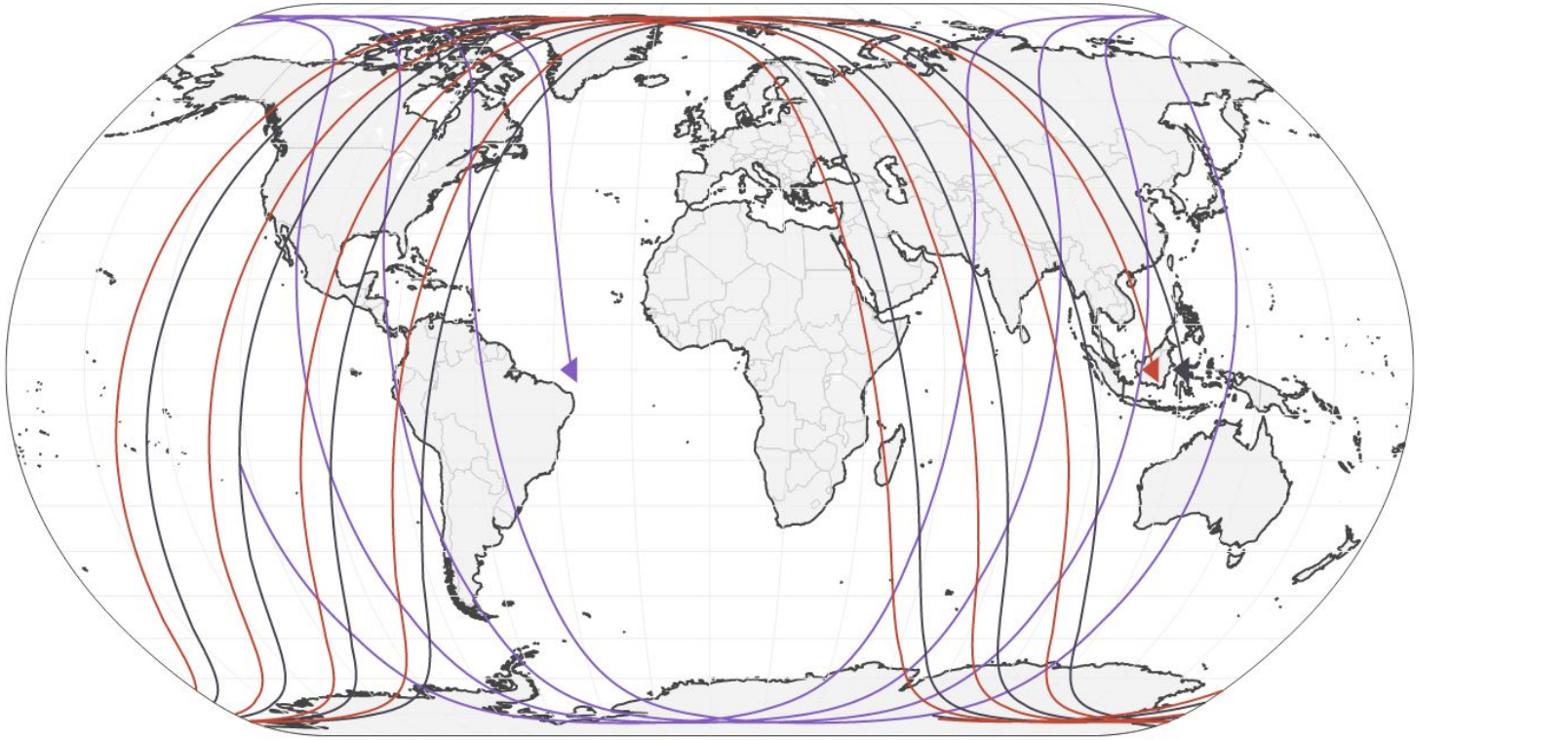
Massive simulations

Near-instant results

Re•Propagate

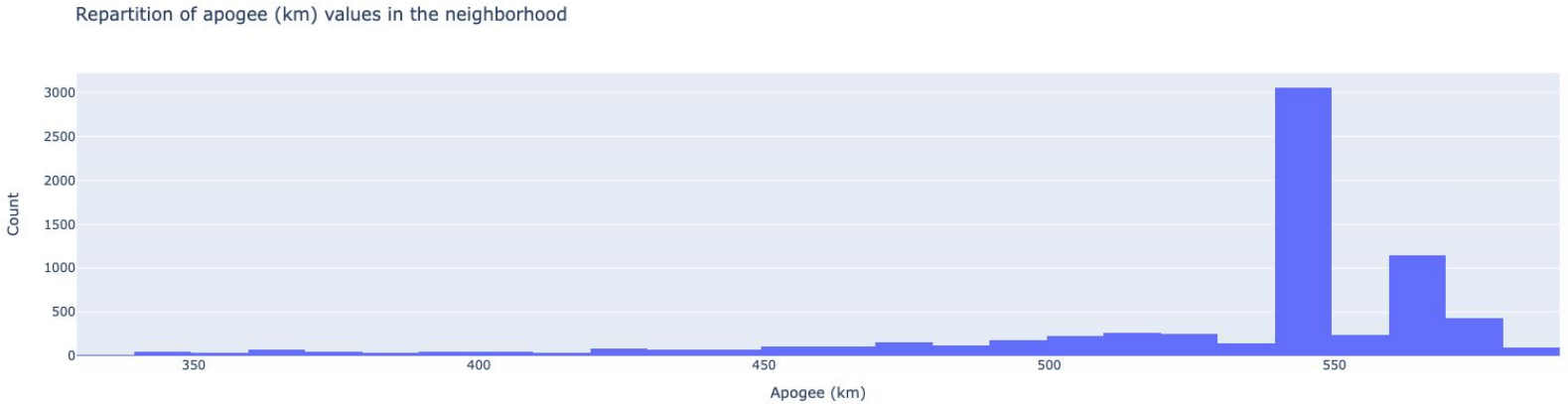
Service Demo

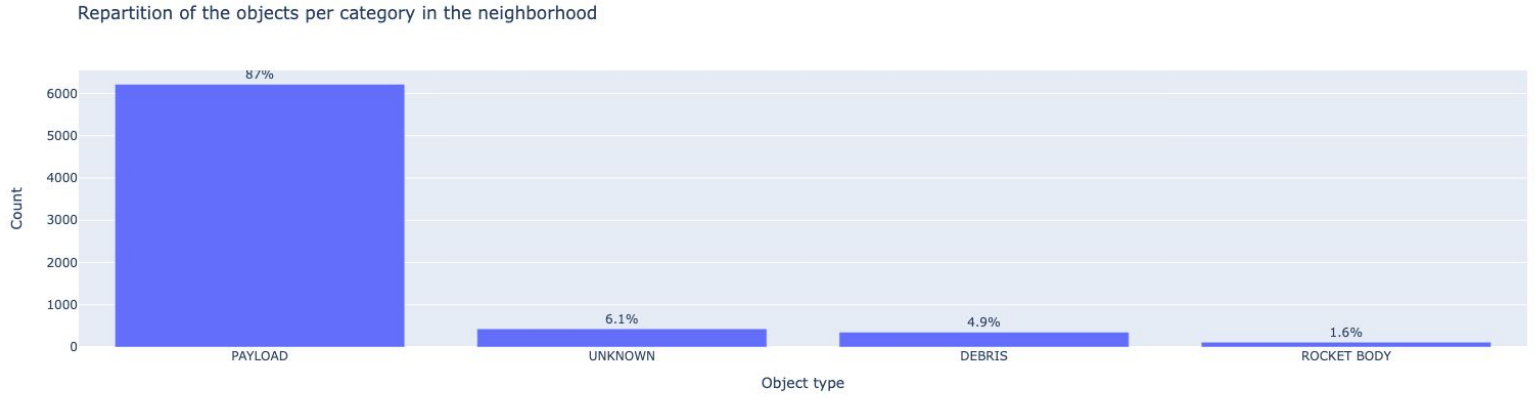
Company X satellites groundtracks as of 2023-10-03



Service Demo

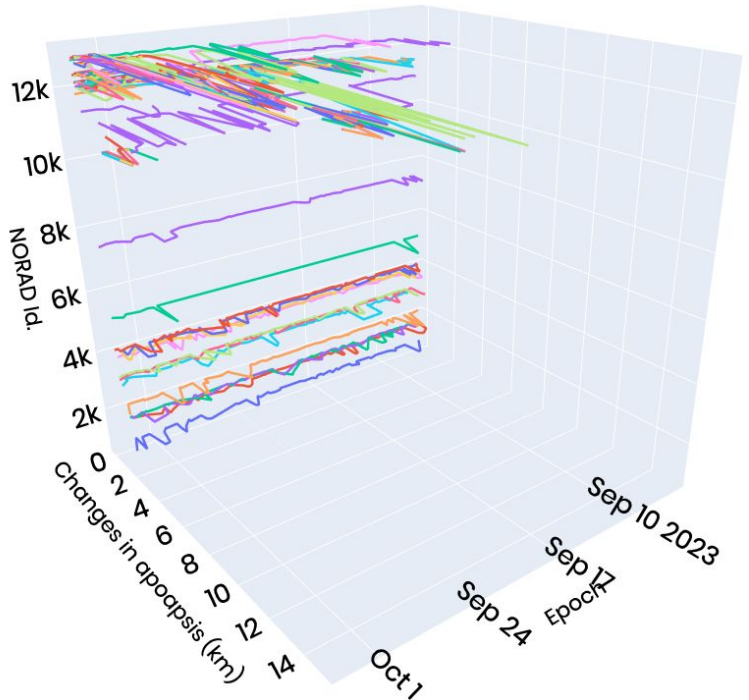
~7000 neighbors, mostly in the 540 - 570km apogee band





Service Demo

Apoapsis (km) changes over epoch for possible maneuvering neighbors
Percentage of neighbors maneuvering over the last month ~ 3%.



Looking at anomalous apogee changes over the past month, a conservative estimate of the number of maneuvering neighbors is 3%.

Collision Risk Demo

Data from 21/09

SAT 2: two possible collisions around 30/09 - 01/10.

Neighbor NORAD Id	Approx. miss distance	Approx. UTC TCA	Estimated probability of collision
ABCDE	~4km	2023-09-30T19:14:01	3.704770e-04
XYZTW	~3km	2023-09-29T23:59:01	8.828505e-07

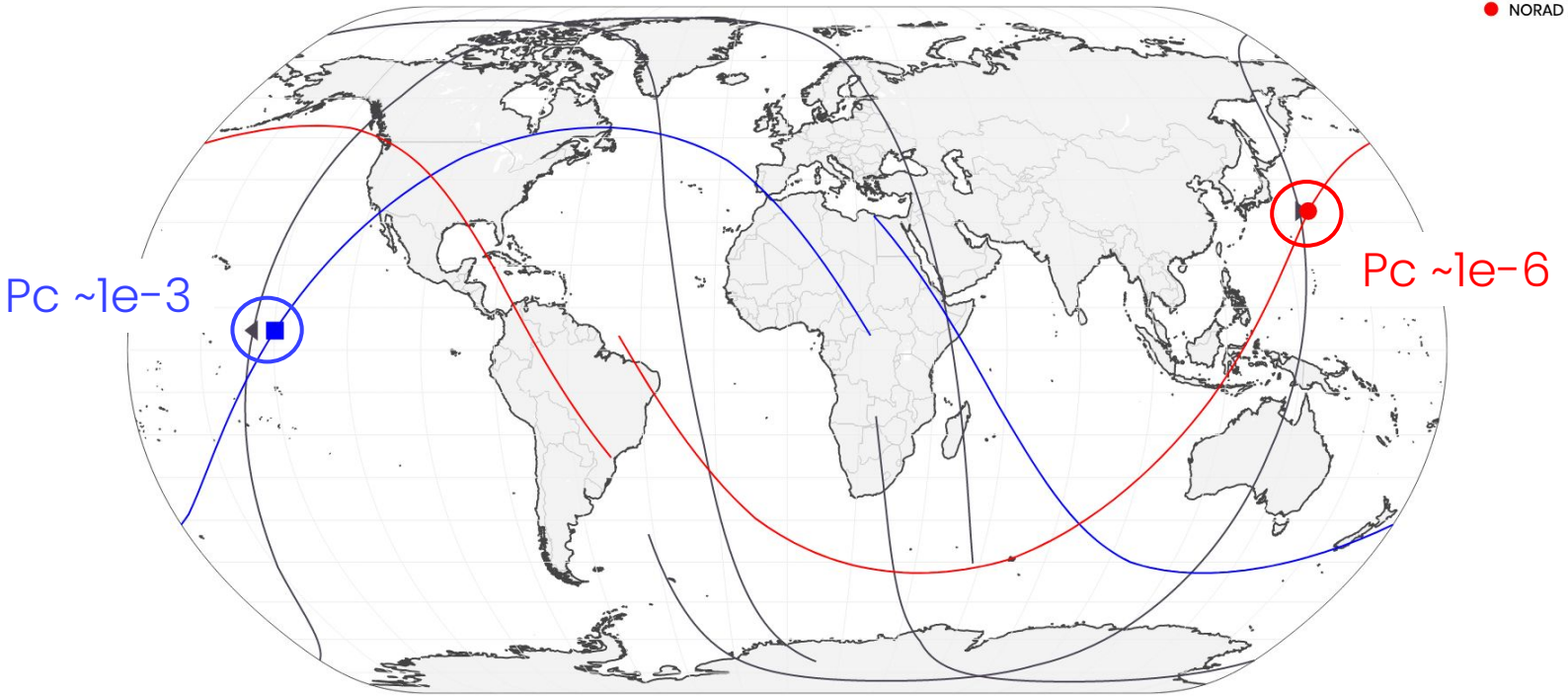
SAT 3: one possible collision around 27/09 (highly improbable).

Neighbor NORAD Id	Approx. miss distance	Approx. UTC TCA	Estimated probability of collision
RRTPO	~4.9km	2023-09-27T07:42:57	0.0

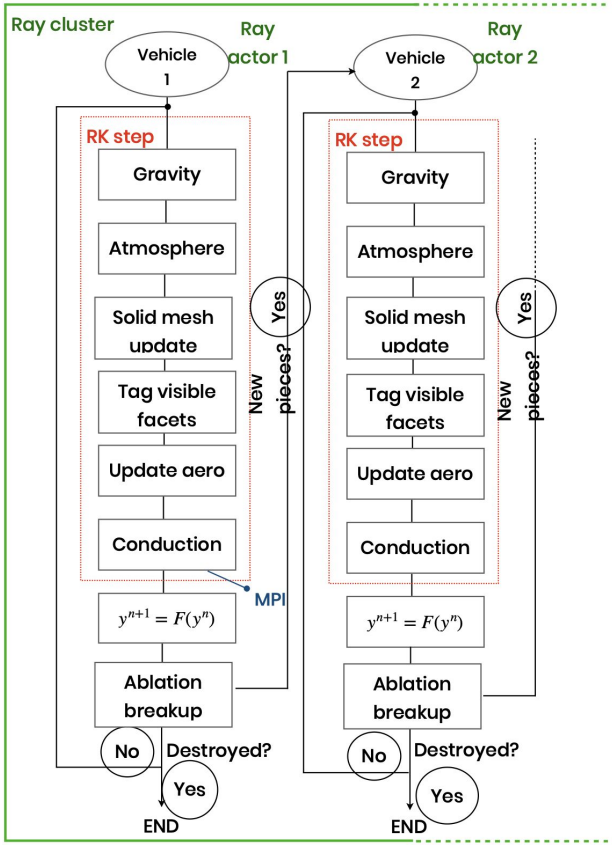
Collision Risk Demo

Estimation with data from September 21st

SAT 2: two possible collisions around 30/09 - 01/10.

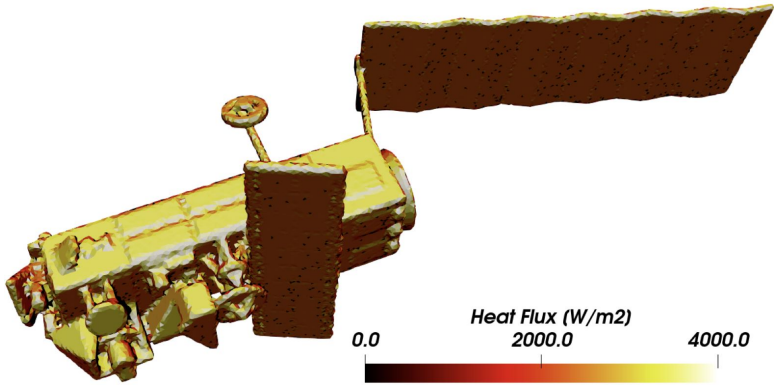


Re•Entry

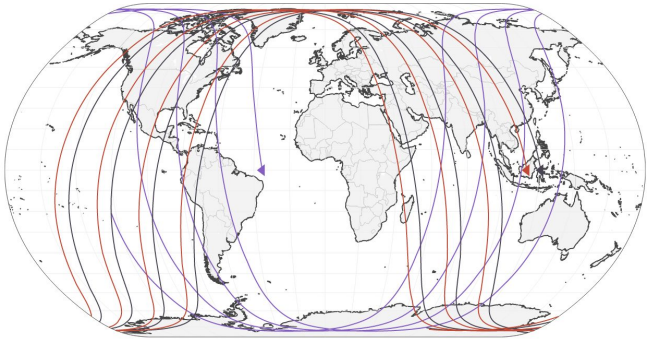


Models:

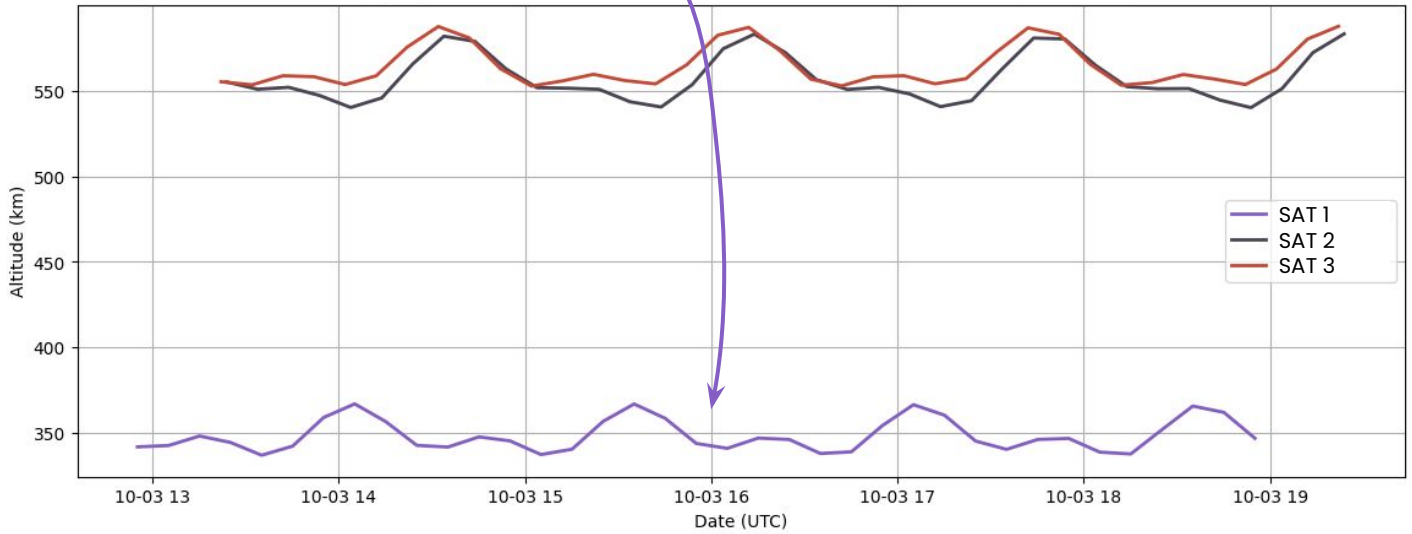
1. influence of the planet - XGM 2019e
2. Aerodynamic forces & moments - MSIS v2 from NRL
3. Evolution & integrity of a vehicle



Service Demo

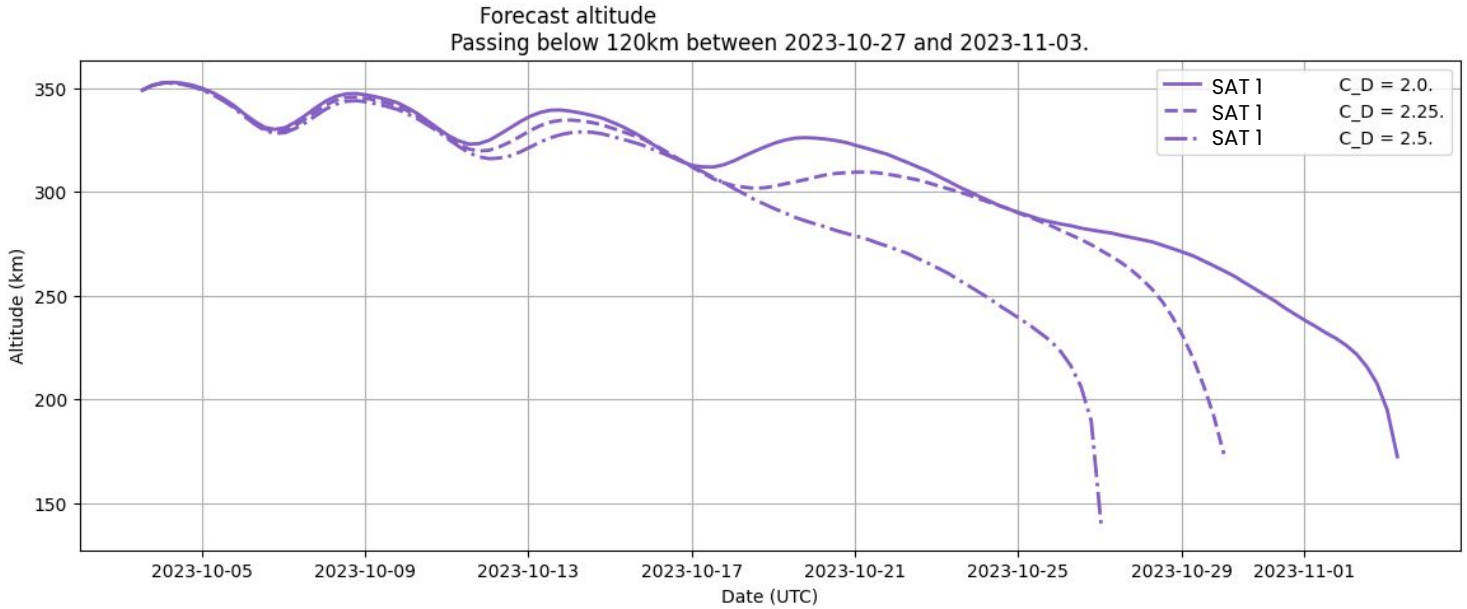


SAT 1 is markedly below its nominal orbit

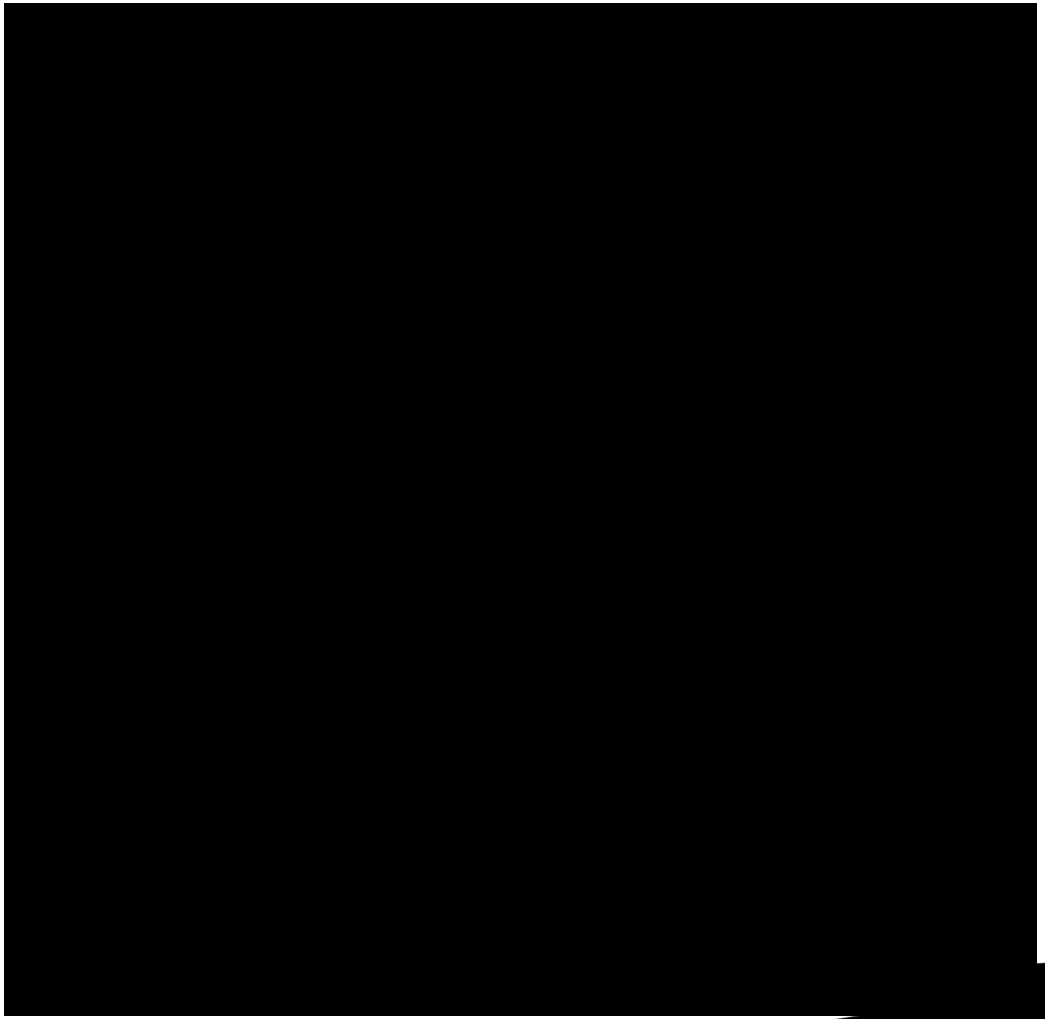


Service Demo

Estimates with average flow-facing cross-section of SAT 1



⇒ With SAT 1 shape and attitude feed = improved predictions for reentry dates and coordinates.



Spacecraft oriented

Ablative materials

Structural elasticity and plasticity

Physics-drive breakup

Ground impact footprint

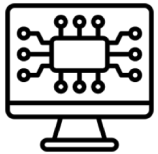
Re•Entry

Re•CFD

- ❏ High-fidelity multi-physics simulation code
- ❏ Leverages simple irregular Cartesian meshes and Immersed Boundary Condition* (IBC) paradigm

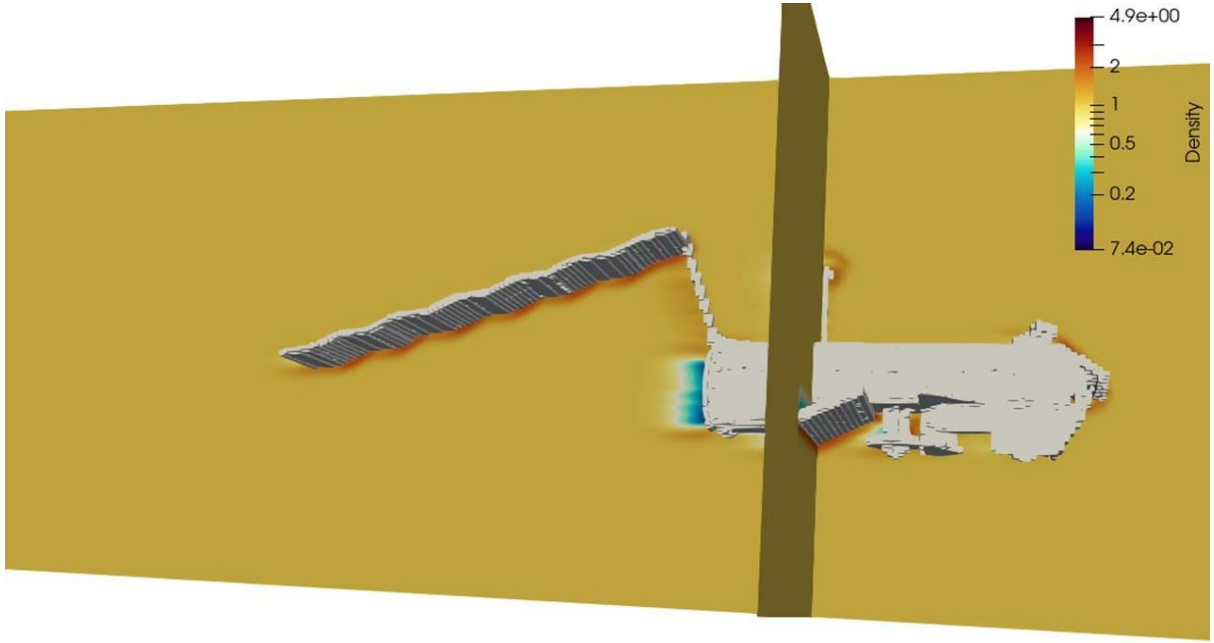
Fast rasterization algorithm, video games rendering technique

Massively parallel migratable tasks-based algorithm



Non-oscillatory reconstruction method

*Bridel-Bertomeu T., Computers & Fluids 2021, 10.1016/j.compfluid.2020.104794



Reliable design aid

Meshless computer games-like technology

Massively scalable

Aerothermal multi-physics

Ablative material

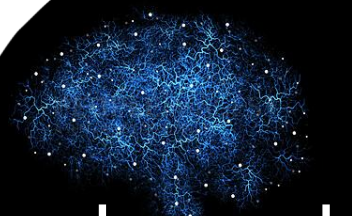
Re•CFD

Empowering self-driving satellites

Automated orbital decisions

Neural-network enhanced re-entry models

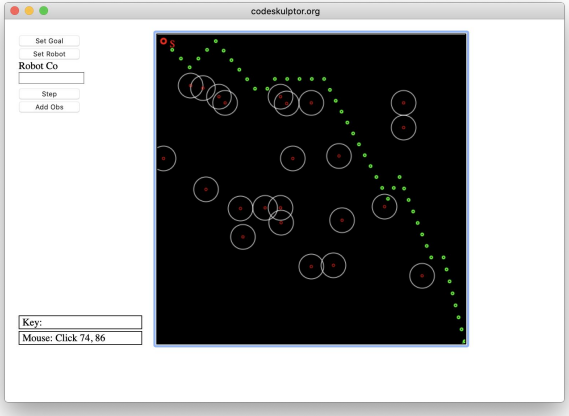
Autonomous controlled re-entry system



04 AI-on-board

RNN for enhanced orbital predictions

+ In-depth research about long-term material evolution when in space.



RL-based NN for collision avoidance

GAN-based synthetic reentry data generation

CNN-based atmospheric reentry simulations

+ Study of PINN-enhanced results

04 AI-on-board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