ExoOps: an analysis tool for electric propulsion powered missions

Orekit Day Presentation
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Our vision & mission

Our mission
Delivering agility to small satellites

→ Reduce launch costs

→ Enhance launch flexibility

→ Improve picture resolution, coverage, link performance

→ Increase satellites lifespan

→ Reduce space pollution

Our vision
From propulsion to in-orbit servicing

First deliveries ***2020***

PROPULSION

Electric propulsion systems for 10-100kg satellites.

Mission software to design, optimise and operate propulsion manoeuvres.

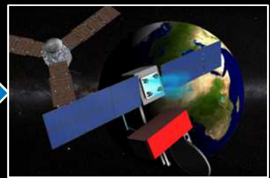
2022

PROXIMITY OPERATION

Proximity operation technologies for space surveillance and debris managelent.

2025

ON-ORBIT SERVICING



On-orbit inspection, delivery & assembly of spacecraft.

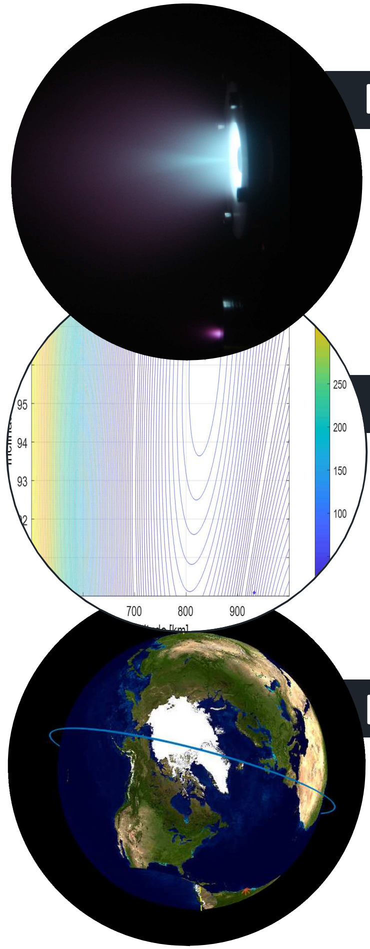
Exotrail Today

Massy, France

15 people
Electric propulsion systems

Toulouse, France

4 engineers + 3 interns
Mission software



ExoMG™ Hall Effect Thrusters for small satellites

Modular
Affordable
High thrust

ExoMS Mission Study for the space industry

Responsiveness
Understand the impact of propulsion
Study new use cases & trade-offs

ExoOps™ Mission Software for propulsion

Cloud-based, user-friendly
Propulsion mission design
AOCS Operation

ExoOps™ Mission Design

Understand the impact of propulsion

Parametrical analysis for
Phase 0 / A / B / C Mission Design

Broad range of missions:
Altitude change – Inclination correction – Local Time Phasing – Anomaly phasing – Station keeping – Deorbitation – Collision Avoidance – GEO relocation - …

Broad range of results:
ΔV – Mission Duration – Power Consumption – Fuel used – Thrust & Attitude sequence – …

Comparing different solutions

Compare the impact of different propulsion technologies on your system and your mission

Optimize launch strategies

Trade-off between rideshare + electric propulsion & dedicated launchers becomes easy with our software.

Analyze quickly the impact of various launch scenarios on your orbital deployment timing and your costs.

Cloud-based, easy-to-use software

Cloud-based software
Local data storage possible
Easy-to-use, even for non experts
Periodic license: no very large one-off fee
SaaS model: regular updates included

ExoOps™ Mission Design

Cloud-based software
Java-based back-end
Javascript-based front end

Analytical computation

For Phase 0 / A

Based on validated literature

Validated against Celestlab toolbox

Validated against numerical propagation models

OREKIT-based numerical propagation

For Phase B / C

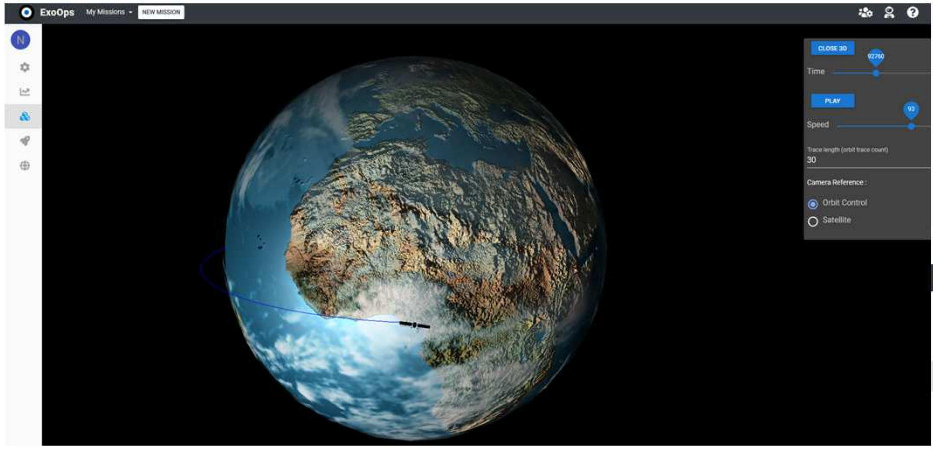
Event-based propagation and mission planning

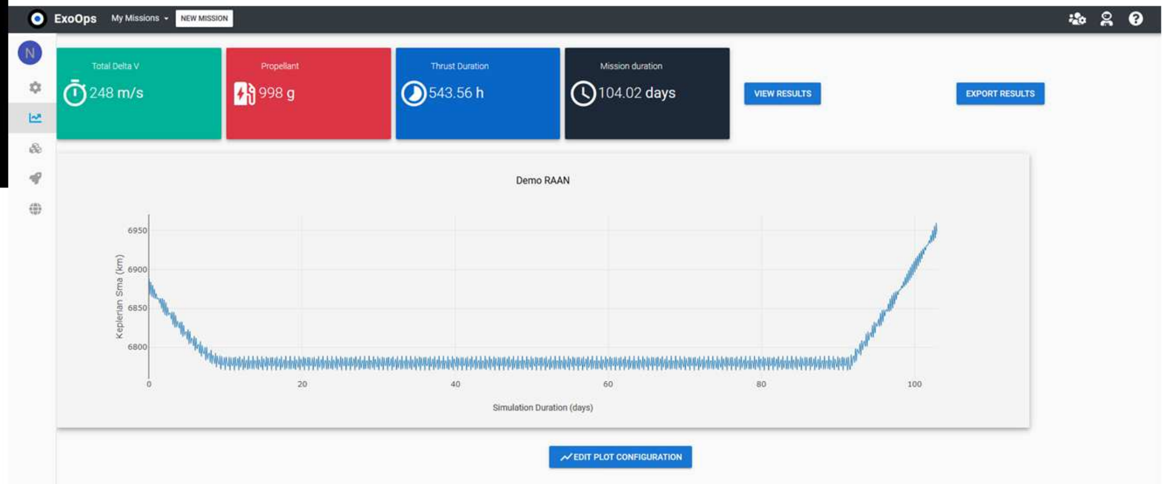
Full modeling of perturbations: Earth potential, atmospheric drag, third-body, etc.

Power generation and depletion

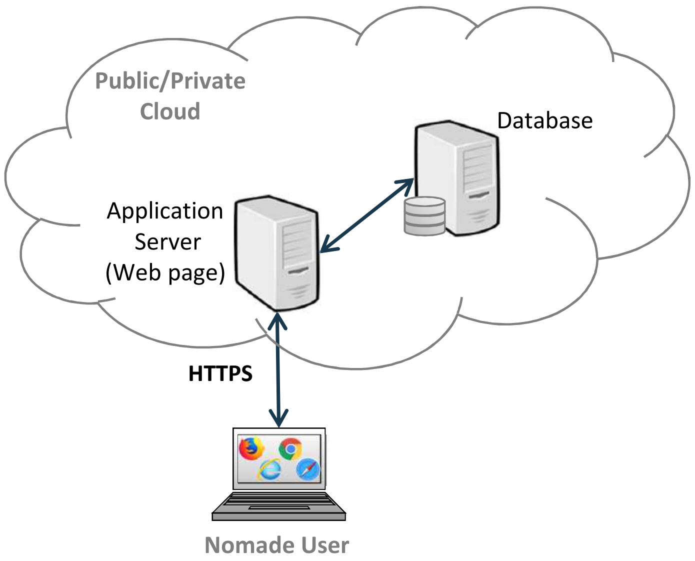
AOCS inputs and commands

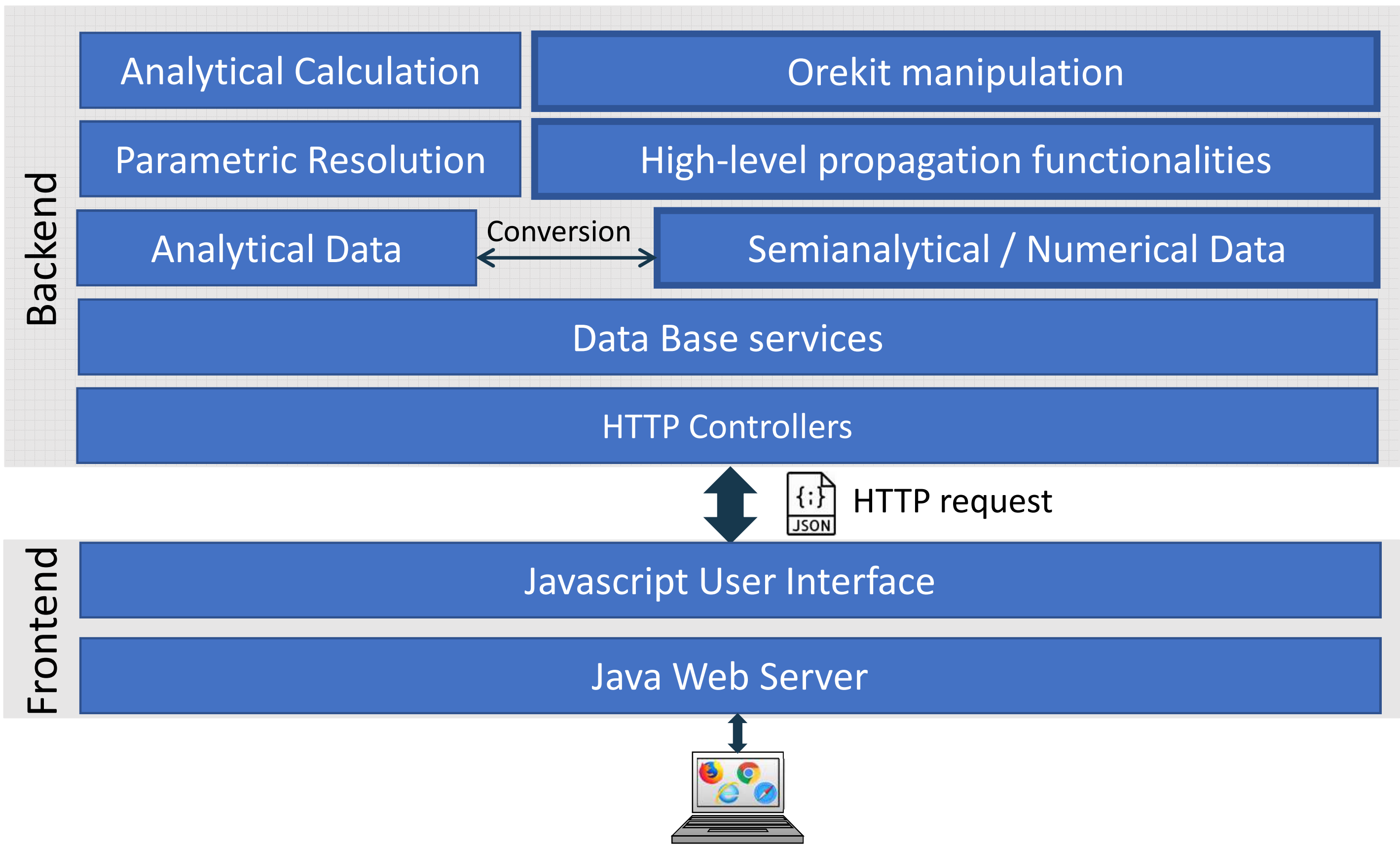
ExoOps™ Mission Design





ExoOps™ Architecture





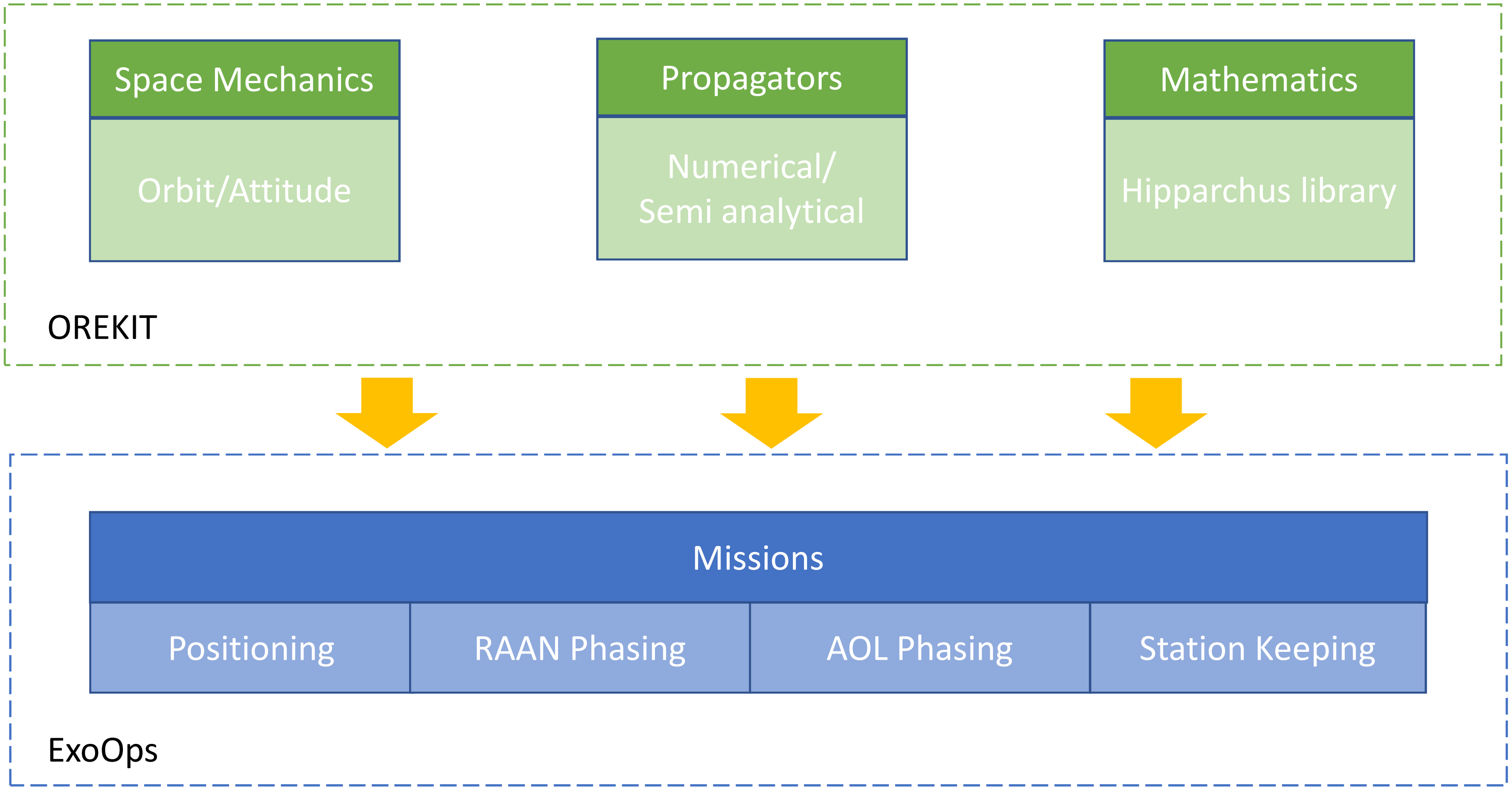
Why Orekit?

A few reasons behind our choice

- Longstanding open-source project
- High profile users from both the academic and industrial worlds
- Developers/users interaction
- Thoroughly validated
- Orekit day...☺

Orekit in ExoOps

How does it help us achieving our goal



Low-Thrust Maneuvers with Orekit

Enhancing Orekit for continuous maneuvers' design

OREKIT

`ConstantThrustManeuver`

- Fixed Direction in SAT frame
- Start/Stop with Date Detectors
- No available model for DSST

→

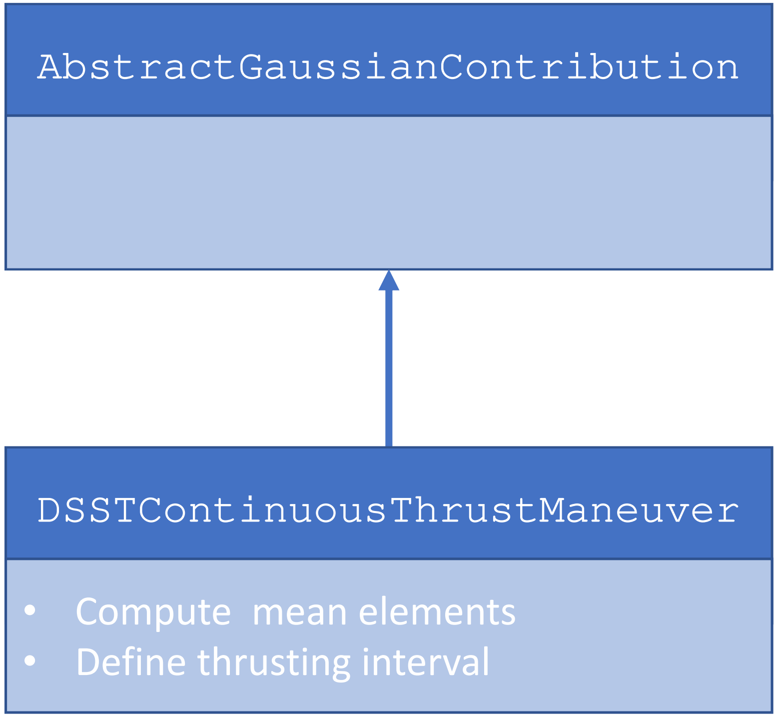
ExoOps

`ConstantBurn`

- Arbitrary direction in any frame
- Any detector can be used as trigger
- Added DSST low-thrust model

Low-Thrust Maneuvers with Orekit

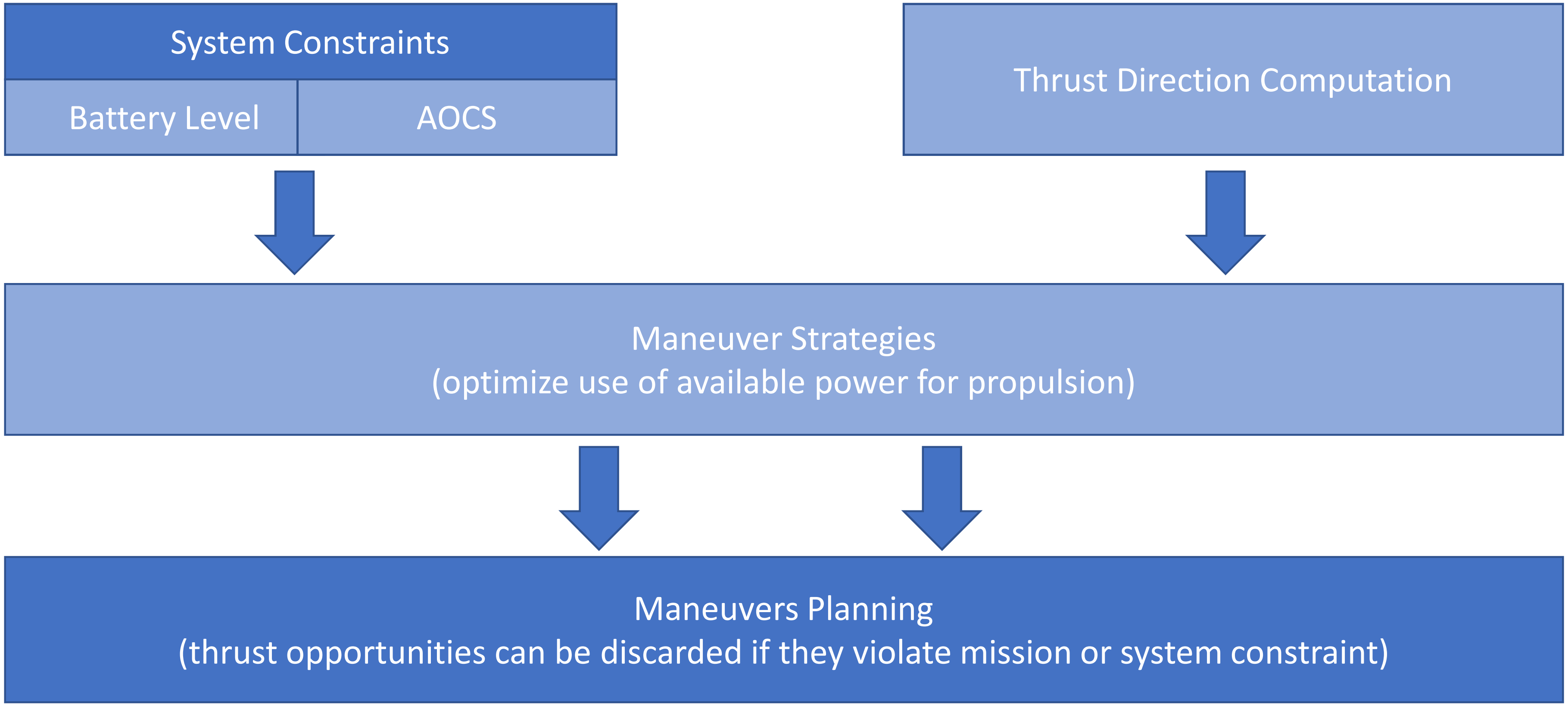
A low-thrust module for the DSST propagator



- Validated against numerical propagation
- Possibility of simulating satellite’s duty cycle
- Allows for fast estimation of maneuver cost
- Allows for fast dynamics propagation when computing optimized maneuvers

System Engineering with Orekit

Taking into account system-level constraints for maneuver planning



Technical issues and workarounds

A few tips from our experience

- Osculating to mean elements conversion
  - Needs: convert osculating to mean elements to check maneuver convergence or compute control
  - Issues: slow and convergence sometimes fails,
  - Workaround: for detectors, use a mean step computed in a step handler. Customize DSST conversion.

Technical issues and workarounds

A few tips from our experience

- Osculating to mean elements conversion
  - Needs: in detectors to stop the maneuver or to output ephemerides,
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  - Workaround: for detectors, use a mean step computed in a step handler. Customize DSST conversion.

- System constraints defined by detectors
  - Needs: stop the propulsion when an event occurs (e.g. low battery),
  - Issues: the detector stay at 0 when the event occurs,
  - Workaround: introduce a noise term to make the value vary.

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- Additional states in simulation's output
  - Needs: useful infos for the user (e.g. battery charge, power collected by SAs),
  - Issues: the evaluation of additional states "offline" might give unexpected results,
  - Workaround: investigation on-going.

Perspectives

Exchanging with the Orekit community

- Low thrust layer improvements
- Constrained Optimization in Hipparchus (NLP and TPBVP)
- Spacecraft and system modelling
- Augmented robustness of osculating to mean conversion and in detectors

Thanks for your attention!

Credits for Icons: Freepik from Flaticon