Achievements in Space Flight Dynamics

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14TH OF DECEMBER, 2018

AGENDA

- Main components of a Flight Dynamics Software (FDS)
- Orekit open source space dynamics library
- Neosat FDS application for SpaceBus Neo electric satellites
- Space debris collision avoidance movie using simulations with Orekit library

MAIN COMPONENTS OF A FLIGHT DYNAMICS SOFTWARE (FDS)

1

Flight Dynamics Software (FDS)

What is a Flight Dynamics Software in a Space system?

- A ground segment operational software used to control a satellite in orbit
  - Determine the orbit (GNSS and/or ground stations measurements)
  - Predict the orbit & orbital events (orbit propagation & detectors)
  - Plan the orbital maneuvers & monitor the propulsion system

When is it used?

- During all the phases of a satellite lifetime
  - Launch & Early Orbit Phase (beginning of life)
  - Station Keeping (operational phase)
  - Disposal (end of life)

Who uses it?

- Operators
  - Everyday survey and control of the satellite
  - Occasional help from experts in case of issue or emergency

ROMANIA

OREKIT OPEN SOURCE SPACE DYNAMICS LIBRARY

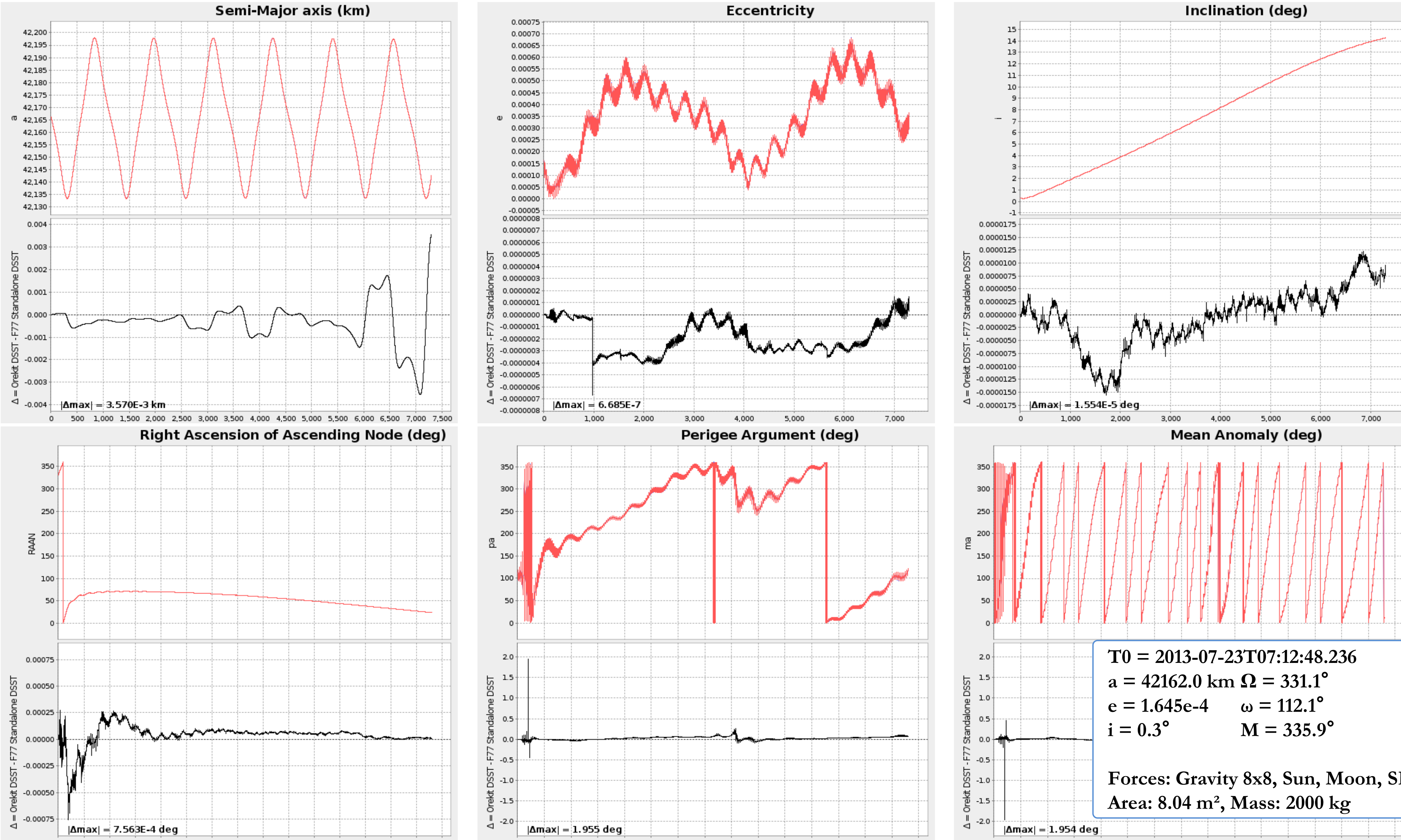
2

About OREKIT library and main features

- Open source space dynamics library that provides accurate and efficient low level components for the development of flight dynamics applications, implemented in Java (https://www.orekit.org)
- Main features:
  - Propagation
    - Analytical propagation models
    - Numerical propagator with customizable force models (central attraction, gravity models, atmospheric drag, third body attraction, radiation pressure with eclipses, tides, multiple maneuvers)
    - Semi-analytical propagation model (DSST) with customizable force models, implemented by CS ROMANIA and CS SI as ESA project
  - Maneuvers - Impulse maneuvers, continuous maneuvers
  - Attitude - Predefined laws such as nadir pointing, yaw compensation, inertial
  - Spacecraft - Cartesian, elliptical Keplerian, circular and equinoctial parameters, Two-Line Elements and transparent conversion between parameters
  - Use of Hipparchus (https://hipparchus.org), a Java a library of low level, lightweight and self-contained mathematics and statistics components

Orekit DSST – semi-analytical propagator (ESA project)

➔ Validation against Standalone DSST software provided by Paul Cefola (Draper Labs)

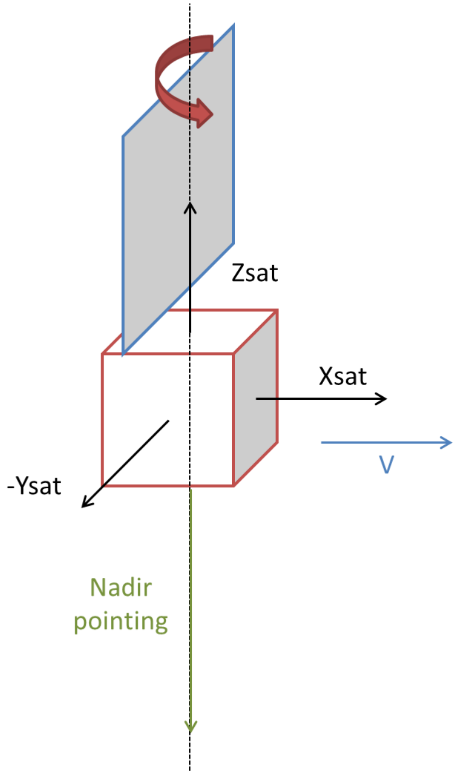


T0 = 2013-07-23T07:12:48.236
a = 42162.0 km Ω = 331.1°
e = 1.645e-4 ω = 112.1°
i = 0.3° M = 335.9°

Forces: Gravity 8x8, Sun, Moon, SRP
Area: 8.04 m², Mass: 2000 kg

Orekit DSST – handling of periodic attitudes

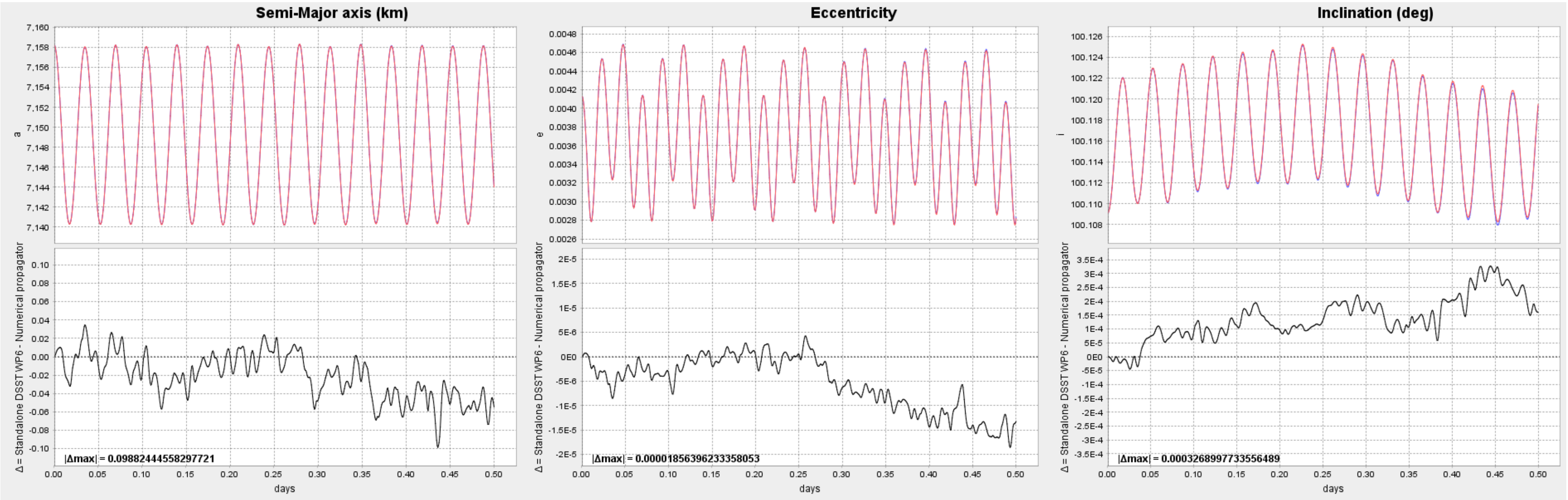
- Validation strategy for attitude handling – implement DSST attitude modelling and use of Orekit's numerical propagator as a reference
- Various cases of spacecraft shape, surface, and attitude law
- Example: observation satellite
  - Box + Solar arrays: Mass: 1000 kg
  - Box: 1.0 x 1.0 x 1.0 m
  - Solar arrays: 5 m²
  - Attitude law: Nadir Pointing

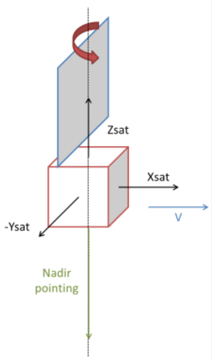


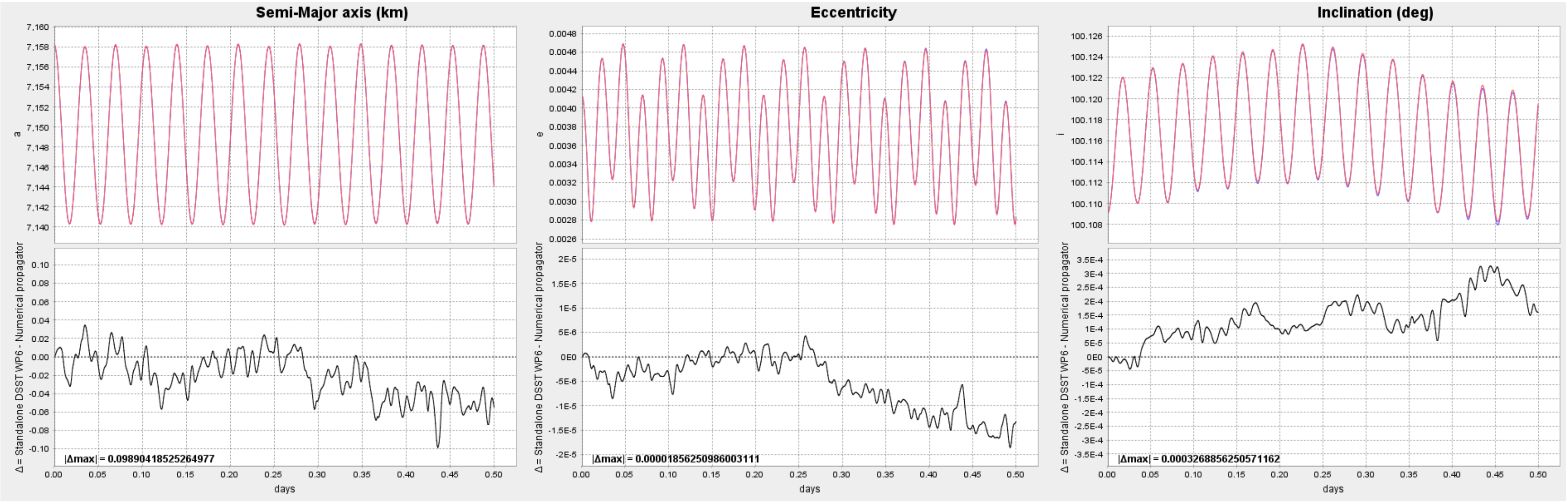
T0 = 2013-07-23T06:46:23.312
a = 7149.2 km Ω = 285.5°
e = 3.652e-3 ω = 6.4°
i = 100.1° M = 353.8°
apogee alt. = 797.2 km
perigee alt. = 745.0 km

Forces: Gravity **50x50**, Drag, **Sun**, **Moon**

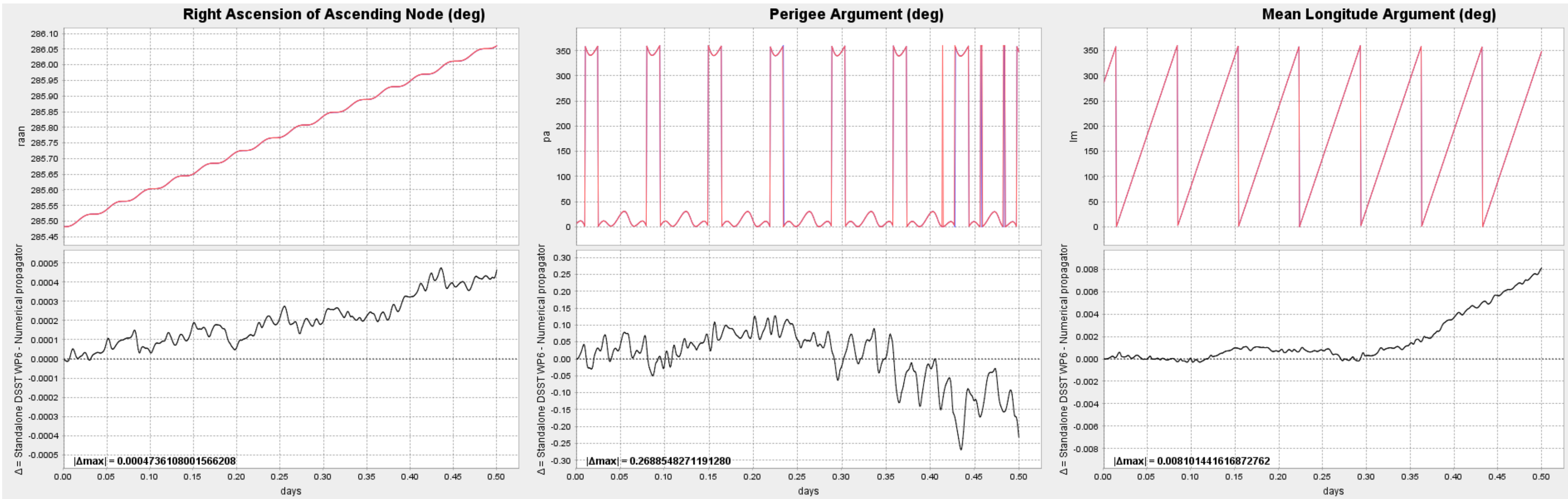
Orekit DSST – handling attitudes of an observation satellite (1/2)

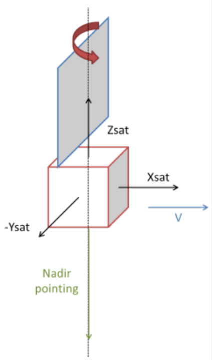


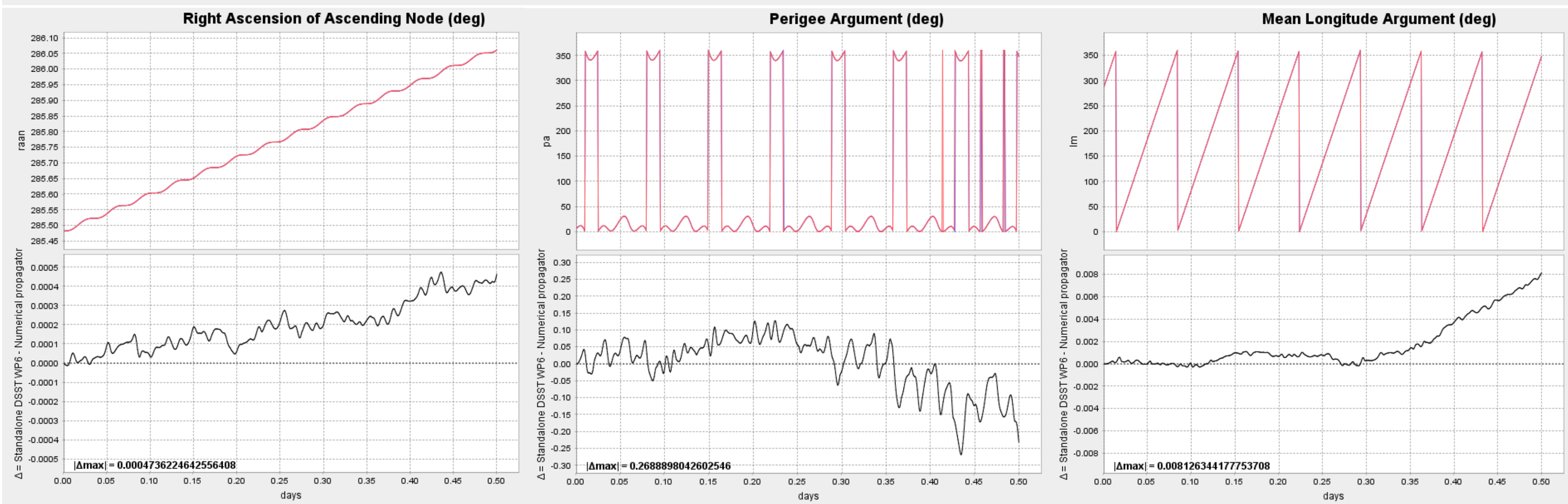




Orekit DSST – handling attitudes of an observation satellite (2/2)







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NEOSAT FDS FOR SPACEBUS NEO ELECTRICAL GEOSTATIONARY SATELLITES

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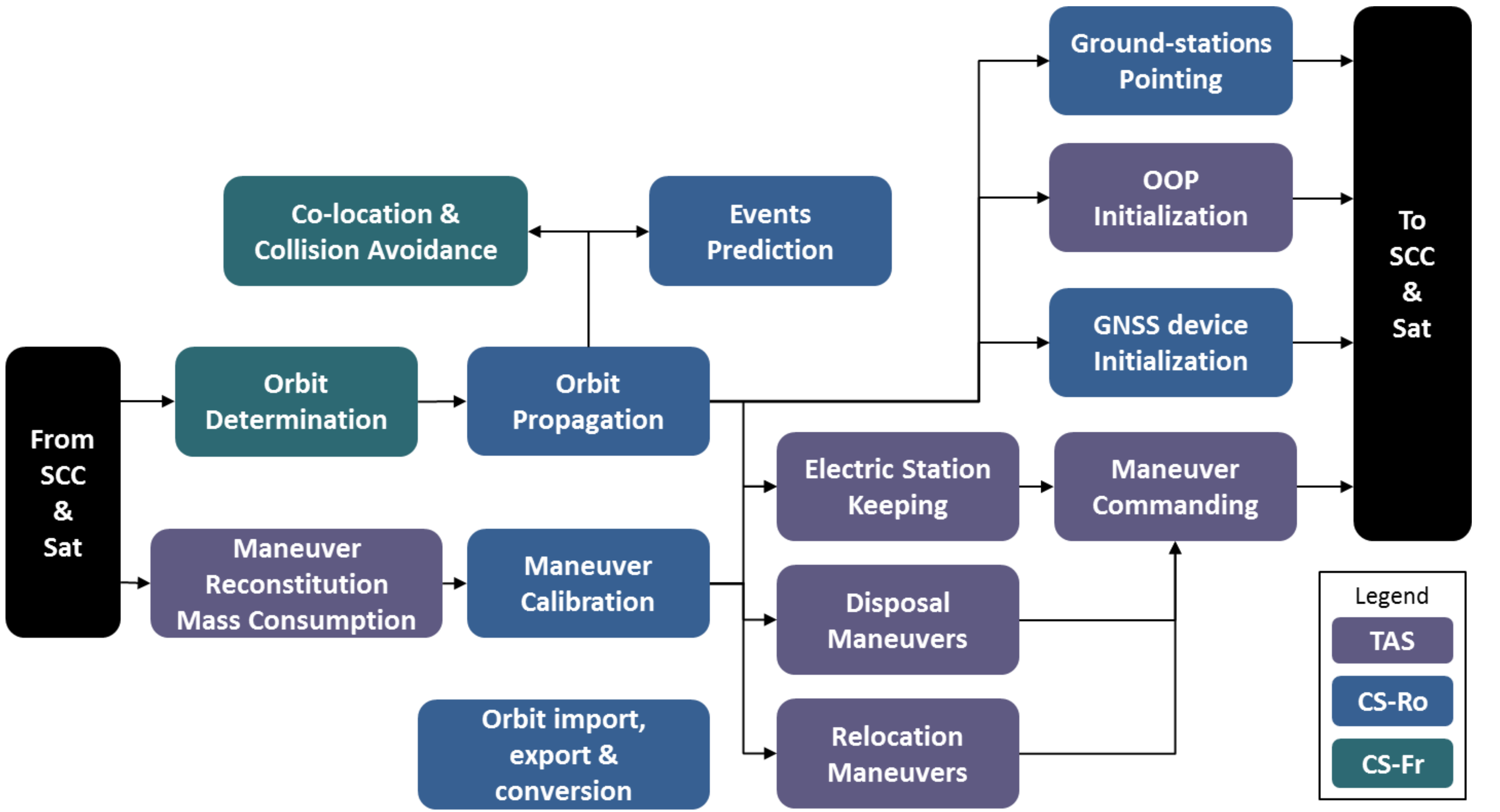
Neosat FDS Project (1/2)

- Neosat - part of ESA's Advanced Research in Telecommunications Systems (ARTES) program
- Context and Challenges
  - Development of an infrastructure for the integration with Satellite Control Center (SCC) system
  - Combining FDS modules with Electrical station keeping, Relocation maneuvers, De-orbitation maneuvers and Maneuver reconstruction modules
- SpaceBus Neo electrical geostationary telecommunication satellites
  - Payload capacity: up to 2000 kg, in the range of 20kW
  - Mass at launch: from 3 to 6 tons

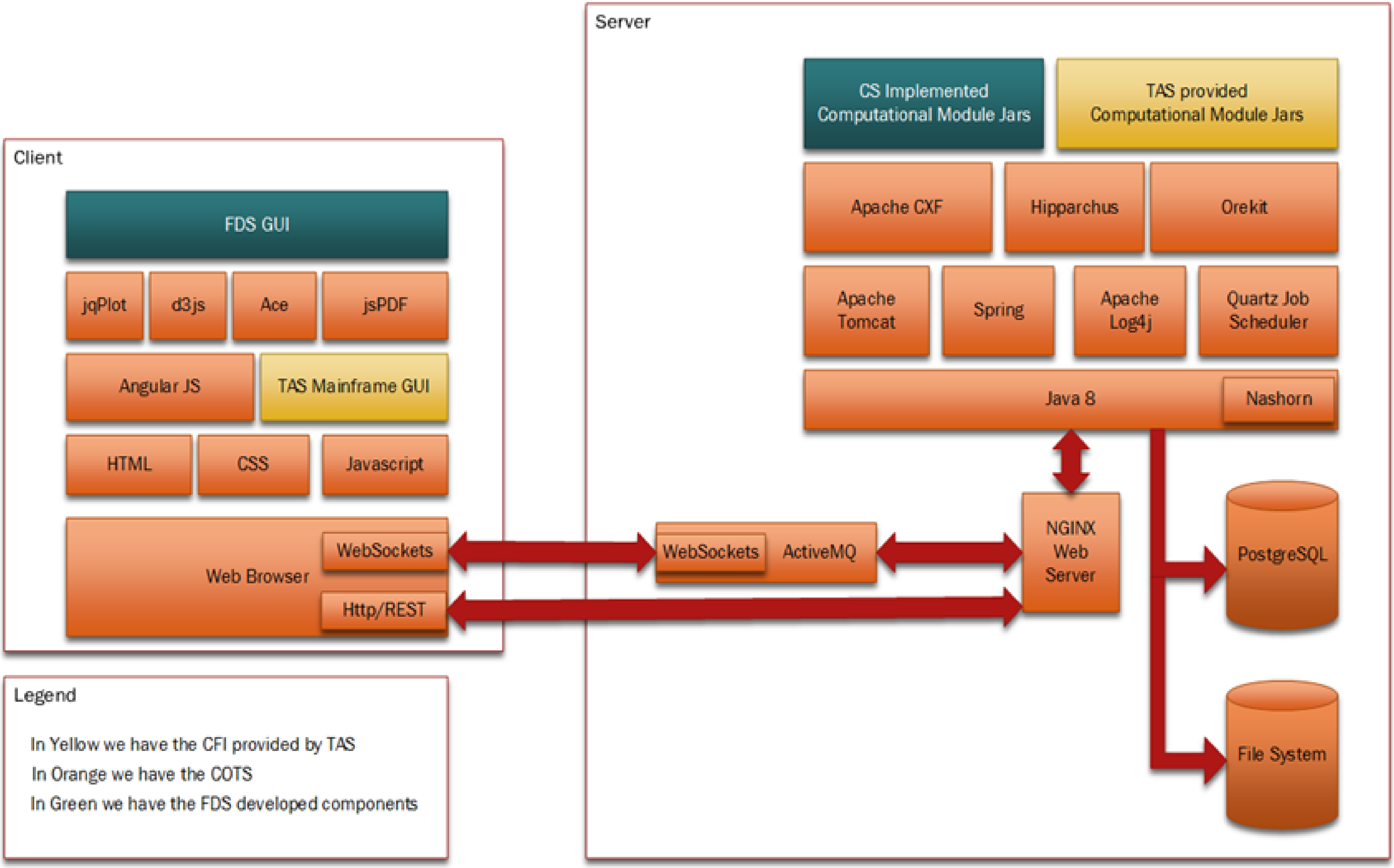
Neosat FDS Project (2/2)

- **Neosat project objective:**
  - Implementation of a Flight Dynamics Software (FDS) set of modules designed to perform the orbital control of a geostationary satellite during On Orbit Control (OOC), relocation and deorbitation phases
- **Neosat project organization:**
  - ESA – Head of Neosat Program, final customer
  - Thales Alenia Space (TAS) – designer and integrator of SpaceBus Neo, customer of Neosat FDS
  - CS ROMANIA – Prime Contractor of TAS, in charge with FDS management, design, development and validation
  - CS France – Sub-contractor, provides expertise in flight dynamics
- **Contributions of CS ROMANIA**
  - Implementation of FDS modules:
    - Orbit propagation including maneuvers,
    - Orbital events prediction (including interferences computation),
    - Ground antenna pointing,
    - Orbit import, conversions and export,
    - GNSS receiver initialization,
    - Software infrastructure for integration with SCC
- **Client Benefits**
  - High precision Flight Dynamics Software modules
  - Integration with Satellite Control Center
  - Use of Orekit open-source space dynamics library

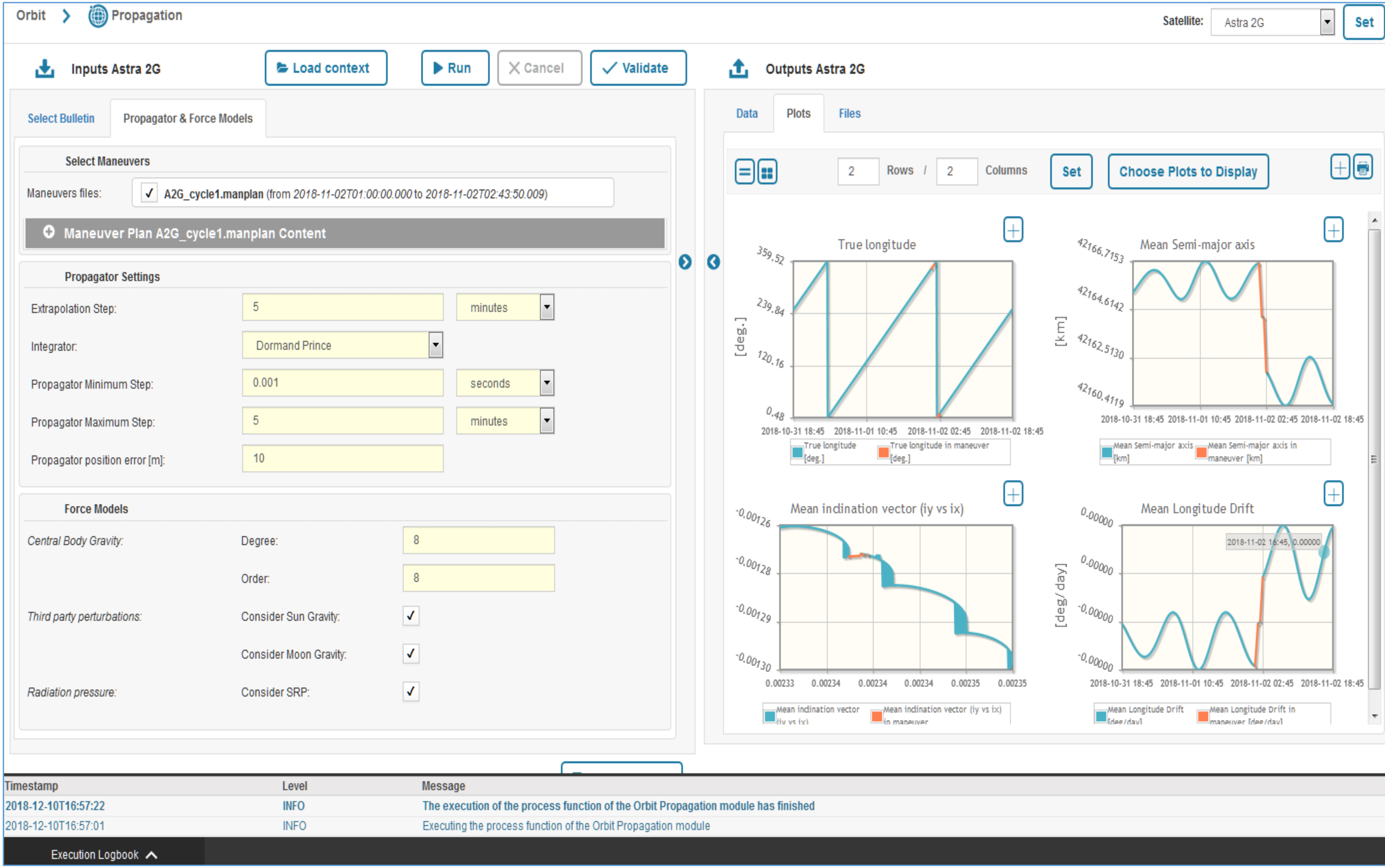
Neosat FDS Flight Dynamics Modules



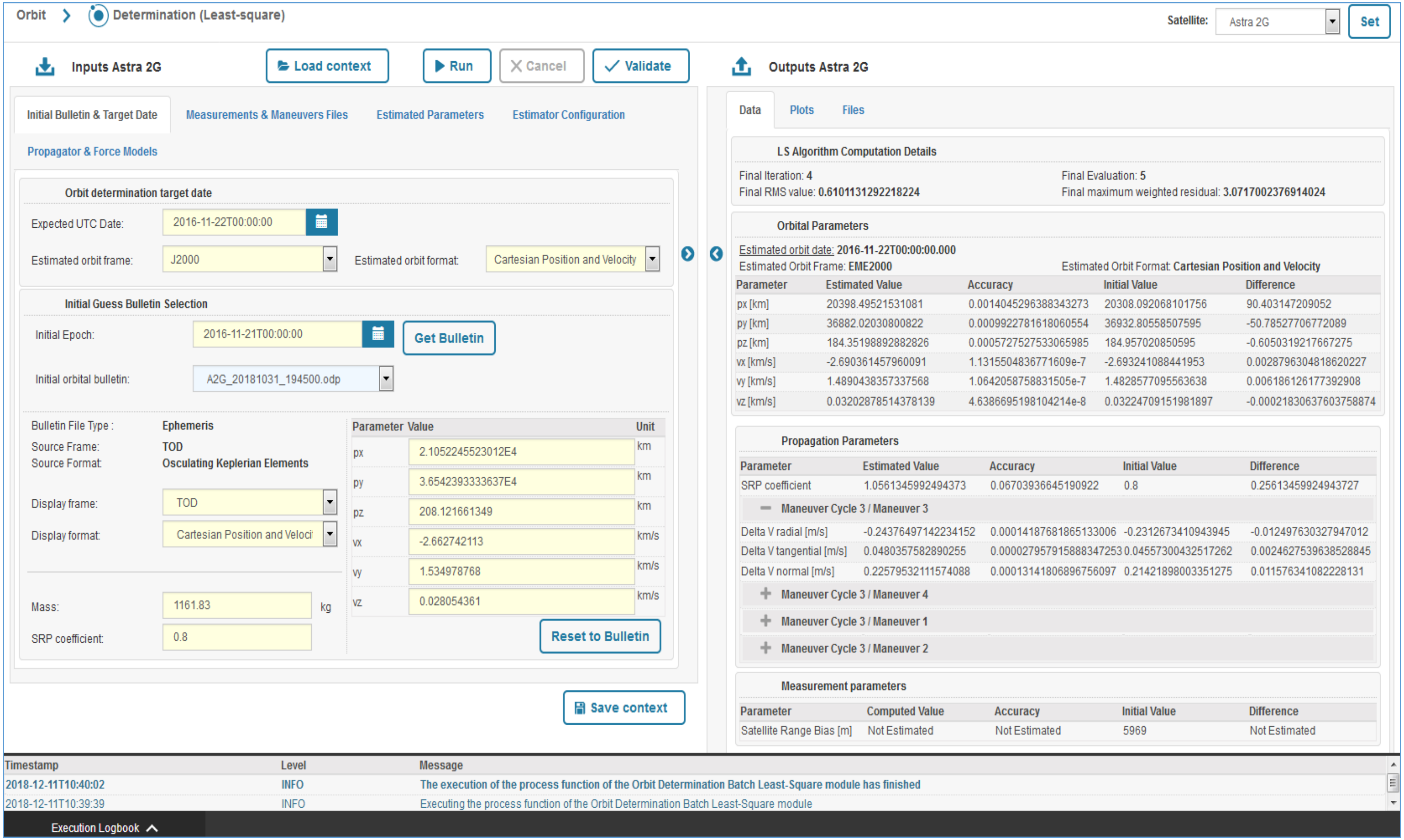
Neosat FDS Technology Stack



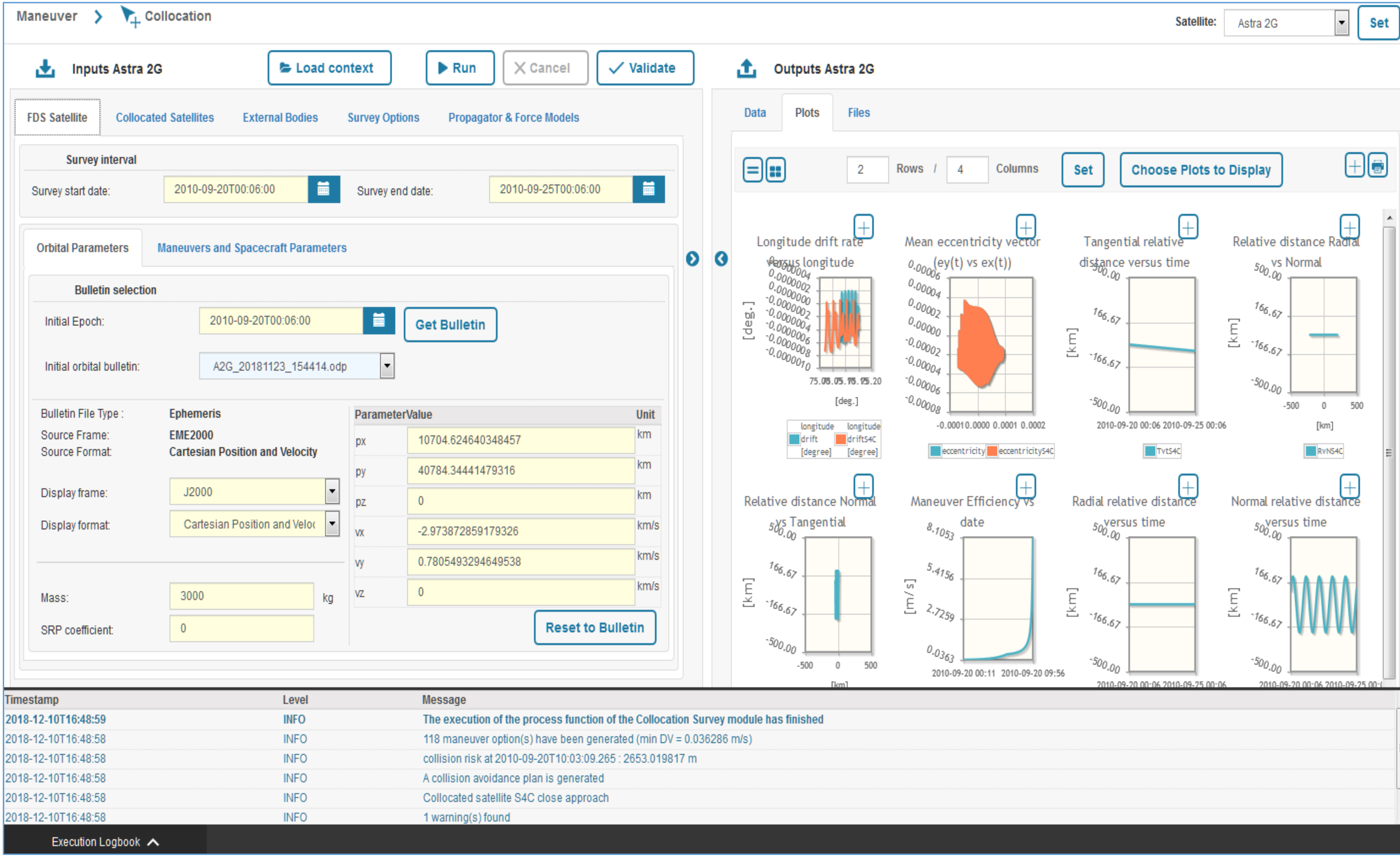
Neosat FDS Example – Orbit Propagation



Neosat FDS Example – Orbit Determination



Neosat FDS Example – Collocation and collision avoidance



SPACE DEBRIS COLLISION AVOIDANCE MOVIE USING OREKIT LIBRARY

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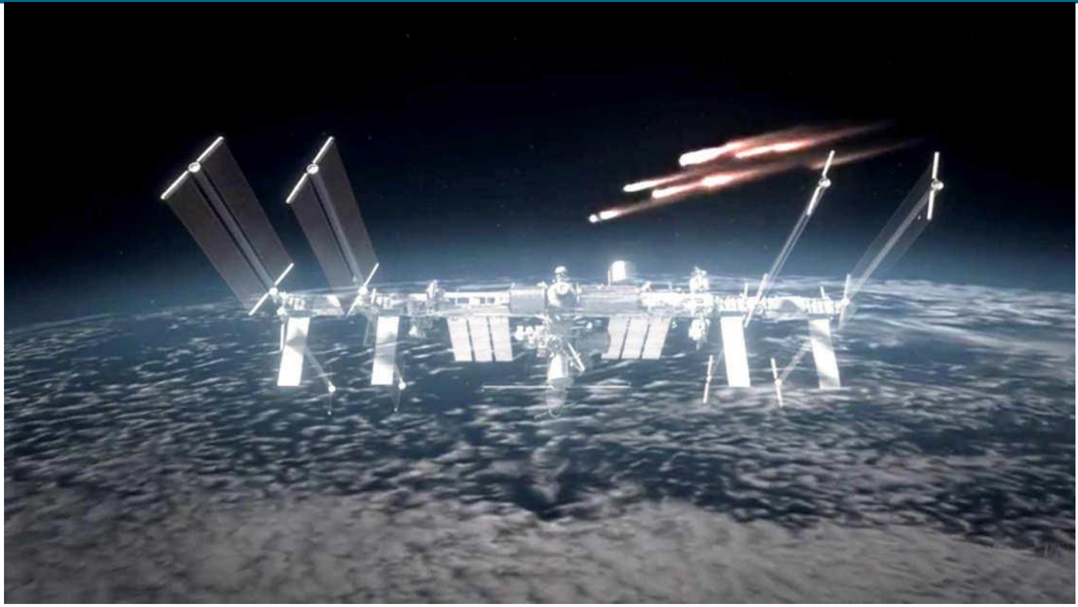

SPACE DEBRIS MOVIE – TECHNICAL DATA

- Stereoscopic 3D Space debris movie developed in 2017 for ESA's Space Debris Office by ONiRIXEL with support from CS OREKIT team for Flight Dynamics and Attitude simulation

- In order to display realistic positions and attitude requested by ESA, physical simulation was required for Earth orbiting objects. This simulation was based on OREKIT, that was directly interfaced with Blender Open-Source 3D animation software, to provide accurately realistic simulations for more than 15 000 objects

- Attitude is handled using a few predefined modes, depending on the debris category:
  - Active spacecraft use controlled attitude depending on their orbit
  - Other objects use tumbling mode with random initial attitude and angular velocity
  - Solar arrays attitude is also computed with respect to the body attitude to ensure a proper orientation with respect to lighting in the movie scenes

- Orbit and attitude are propagated using a variable step numerical propagator

- Very realistic simulation, movie available on the net (YouTube, Google+) in both 2D & 3D

ENJOY THE MOVIE!