



Orbit.m

Orbit Maintenance & Propulsion Sizing Tool

In the Spirit of the Open Source Cube-Sat Workshop (OSCW), 12 – 13 December 2020



Why should orbit maintenance analysis be fast?

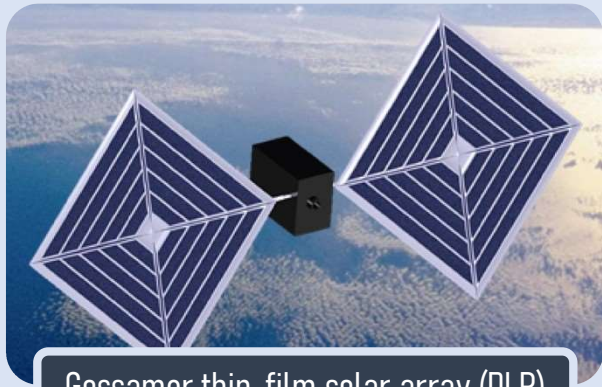
How can orbit maintenance analysis be faster?

What does OrbitM offer to your analysis?

Why should orbit maintenance analysis be fast?

Agile development → agile requirements; requiring frequent mission life comparisons between multiple structures.

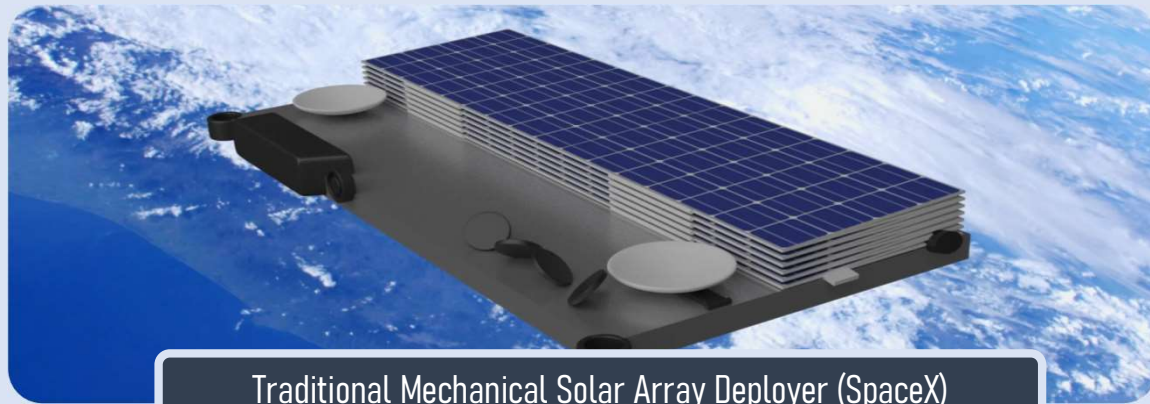
Drag Effects on Different Solar Array Types



Gossamer thin-film solar array (DLR)

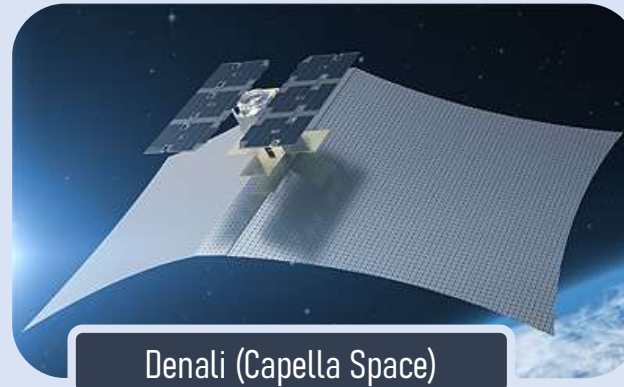


S2TEP Small Sat Bus (DLR)

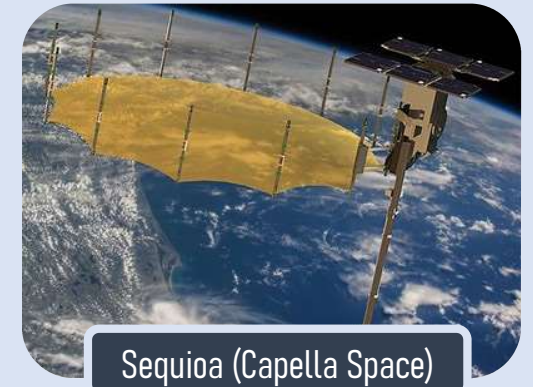


Traditional Mechanical Solar Array Deployer (SpaceX)

Drag Effects on Different Antenna Reflectors



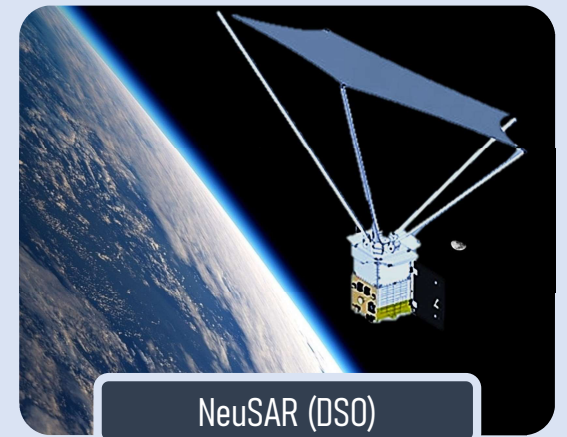
Denali (Capella Space)



Sequoia (Capella Space)



TeLEOS-2 (DSO)



NeuSAR (DSO)

How can orbit maintenance analysis be faster?

Commercial astrodynamics software like STK and GMAT can compute with high precision the orbit state vectors at any point in time, but that may be too much work for a simplified orbit lifetime analysis... (and not everyone has access to STK!)

Scenario1 - STK 10 - [Satellite1 : Basic Orbit]

File Edit View Insert Analysis Satellite Utilities Window Help

Search

Object Brow... Basic

- Orbit
- Attitude
- Pass Break
- Mass
- Eclipse Bodies
- Reference
- Ground Ellipses
- Description
- 2D Graphics
- Attributes

Propagator: Astrogator Central Body: Earth

Propagator: Earth HPOP Default v10

Stopping Conditions

On	Name	Sequence	User Comment	Description
<input checked="" type="checkbox"/>	Duration	STOP	Stop after a specified duration	Stop after a specified duration

Trip: 43200 sec Criterion:

Tolerance: 1e-008 sec Repeat Count: 1

Max Trip Times: 10000

User Calc Object: Edit Constraints:

Timeline

11 D

Sc

Scenario1 - Earth (-88.36661, -105.58477) 11 Dec 2020 04:00:00.000 Time Step: 60.00 s

Create the scenario, the satellite object, AstroGator parameters, set the automatic thrust sequences, setup automatic optimisation for thrust vectors, set the custom calculated orbit decay limit, and finally propagate for 30 minutes!

Automatic Sequence Browser

Name	User Comment
Stop	Stops Running the Sequence
OrbitM	OrbitMaintain

Automatic Sequence Properties

Maneuver Type: Impulsive

Attitude Engine

Attitude Control: Thrust Vector

Thrust Axes: VNC(Earth)

Cartesian Spherical

X (Velocity): 0 km/sec Azimuth: 0 deg

Y (Normal): 0 km/sec Elevation: 0 deg

Z (Co-Normal): 0 km/sec Magnitude: 0 km/sec

Allow Negative Spherical Magnitude

Initial: -Not Set- Final: -Not Set-

Results... OK Help

JUST TOO MUCH WORK!!!

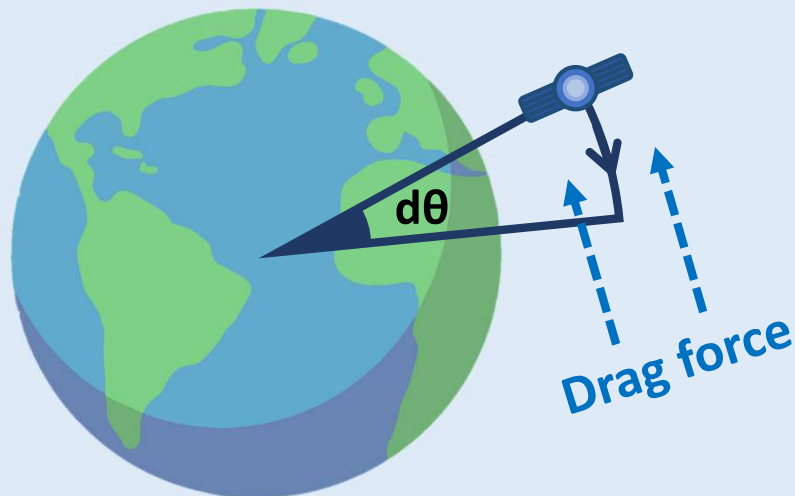
How can orbit maintenance analysis be faster?

Key Idea: You only need the altitude to compute the decay rate, no need for all 6 state vectors with high precision orbit propagation, and definitely no need for such a complicated series of steps!

Starting from some high school physics... let's see how we can characterise energy loss in orbit...

Total Orbital Energy

$$U = KE + GPE = \left(-\frac{GM_E m}{2R} \right)$$



Let's differentiate with R

Radial Derivative

$$\frac{dU}{dR} = \frac{GM_E m}{2R^2}$$

Let's revisit first principles of "energy and work done"

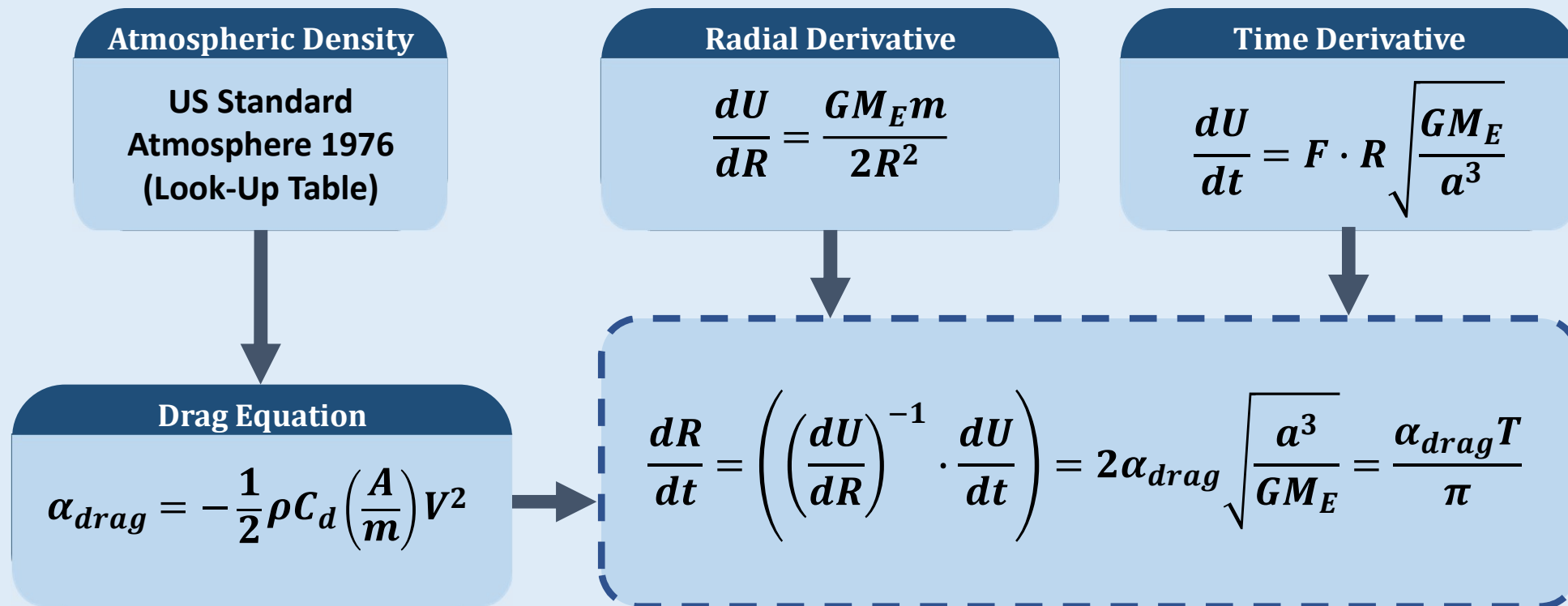
Time Derivative

$$\frac{dU}{dt} = F \frac{ds}{dt} = F \cdot R \cdot \frac{d\theta}{dt} = F \cdot R \sqrt{\frac{GM_E}{a^3}}$$

Drag
Radius
Mean Motion

How can orbit maintenance analysis be faster?

Now, we can actually already derive the orbit decay rate easily!



$$T = 2\pi \sqrt{\frac{a^3}{GM_E}} \rightarrow \text{Kepler's Third Law (Circular Orbits)}$$

How can orbit maintenance analysis be faster?

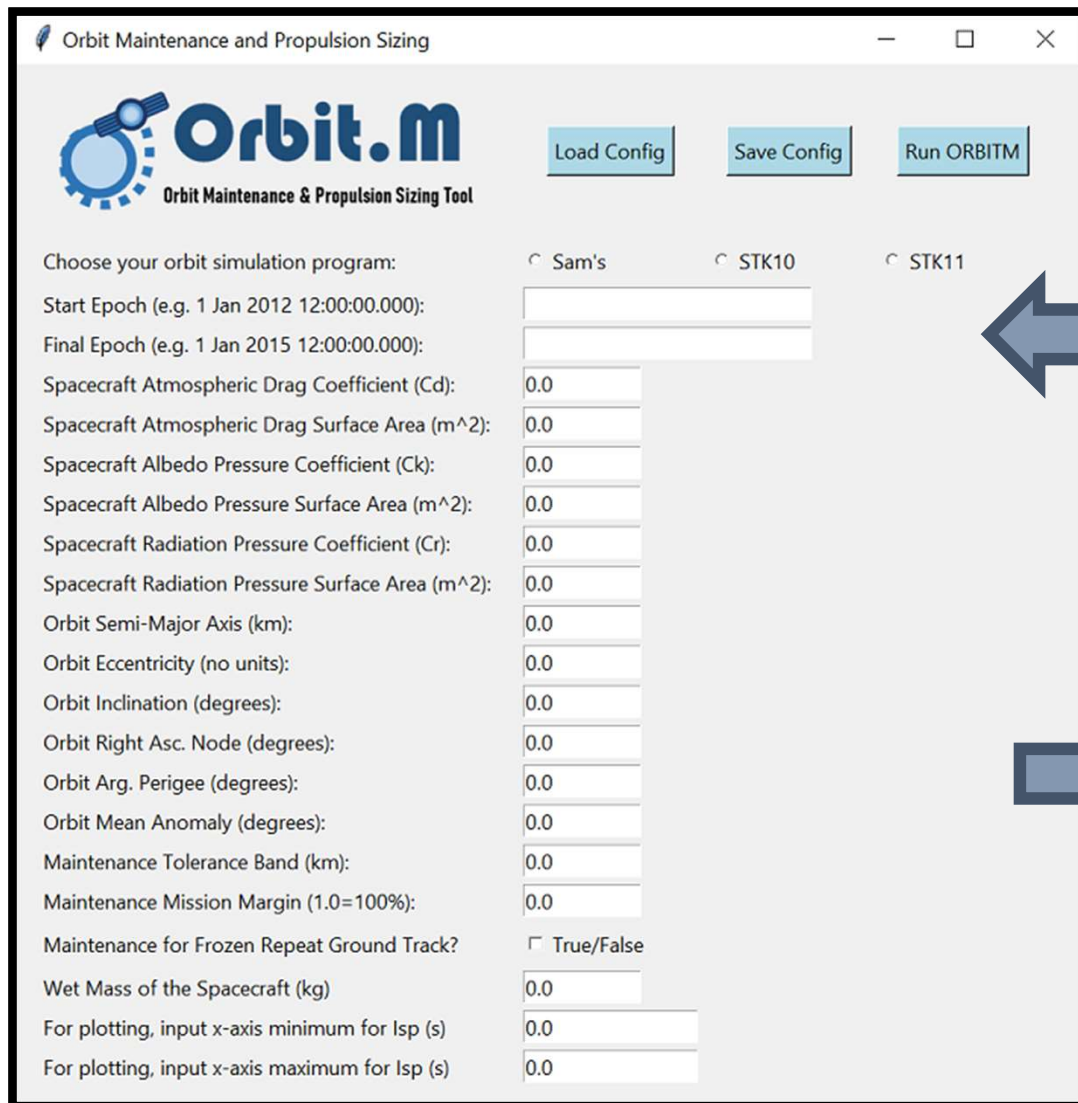
Now, we can actually already derive the orbit decay rate easily!

$$\frac{dR}{dt} = \frac{\alpha_{drag} T}{\pi}$$

In other words, the rate at which the orbit decays can be solved in closed-form without any full orbit propagation of orbit states!

The decay rate = product of the drag deceleration and the Keplerian period, divided by Pi!

What does OrbitM offer to your analysis?



Orbit Maintenance and Propulsion Sizing

Orbit.M
Orbit Maintenance & Propulsion Sizing Tool

Load Config Save Config Run ORBITM

Choose your orbit simulation program: Sam's STK10 STK11

Start Epoch (e.g. 1 Jan 2012 12:00:00.000):

Final Epoch (e.g. 1 Jan 2015 12:00:00.000):

Spacecraft Atmospheric Drag Coefficient (Cd): 0.0

Spacecraft Atmospheric Drag Surface Area (m²): 0.0

Spacecraft Albedo Pressure Coefficient (Ck): 0.0

Spacecraft Albedo Pressure Surface Area (m²): 0.0

Spacecraft Radiation Pressure Coefficient (Cr): 0.0

Spacecraft Radiation Pressure Surface Area (m²): 0.0

Orbit Semi-Major Axis (km): 0.0

Orbit Eccentricity (no units): 0.0

Orbit Inclination (degrees): 0.0

Orbit Right Asc. Node (degrees): 0.0

Orbit Arg. Perigee (degrees): 0.0

Orbit Mean Anomaly (degrees): 0.0

Maintenance Tolerance Band (km): 0.0

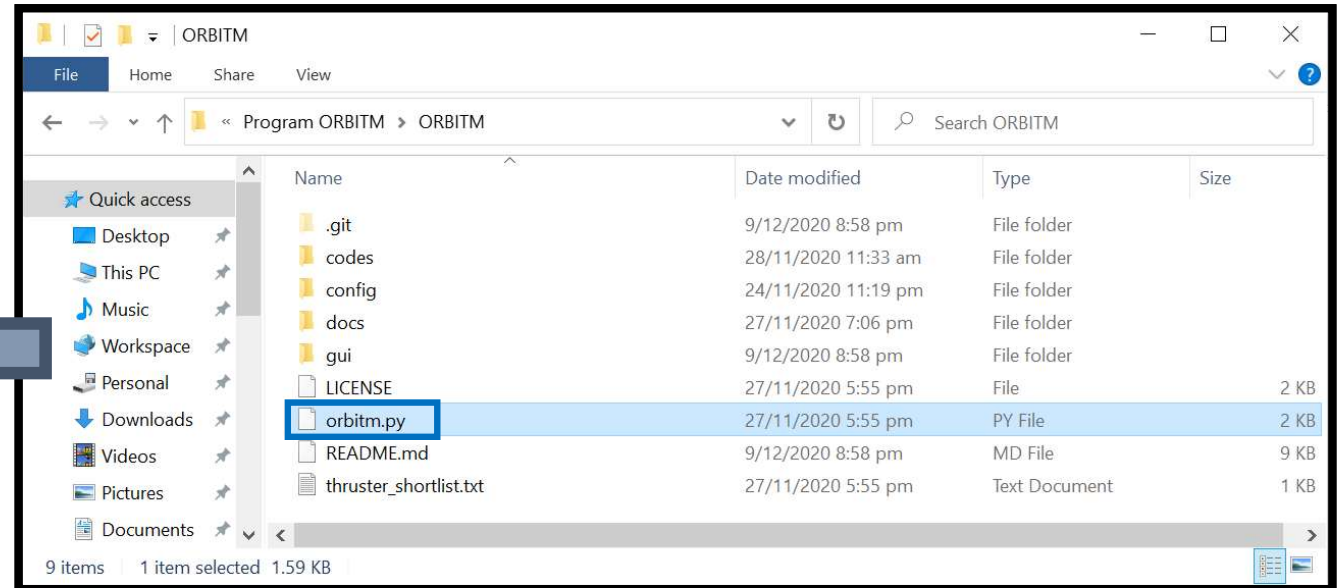
Maintenance Mission Margin (1.0=100%): 0.0

Maintenance for Frozen Repeat Ground Track? True/False

Wet Mass of the Spacecraft (kg): 0.0

For plotting, input x-axis minimum for Isp (s): 0.0

For plotting, input x-axis maximum for Isp (s): 0.0

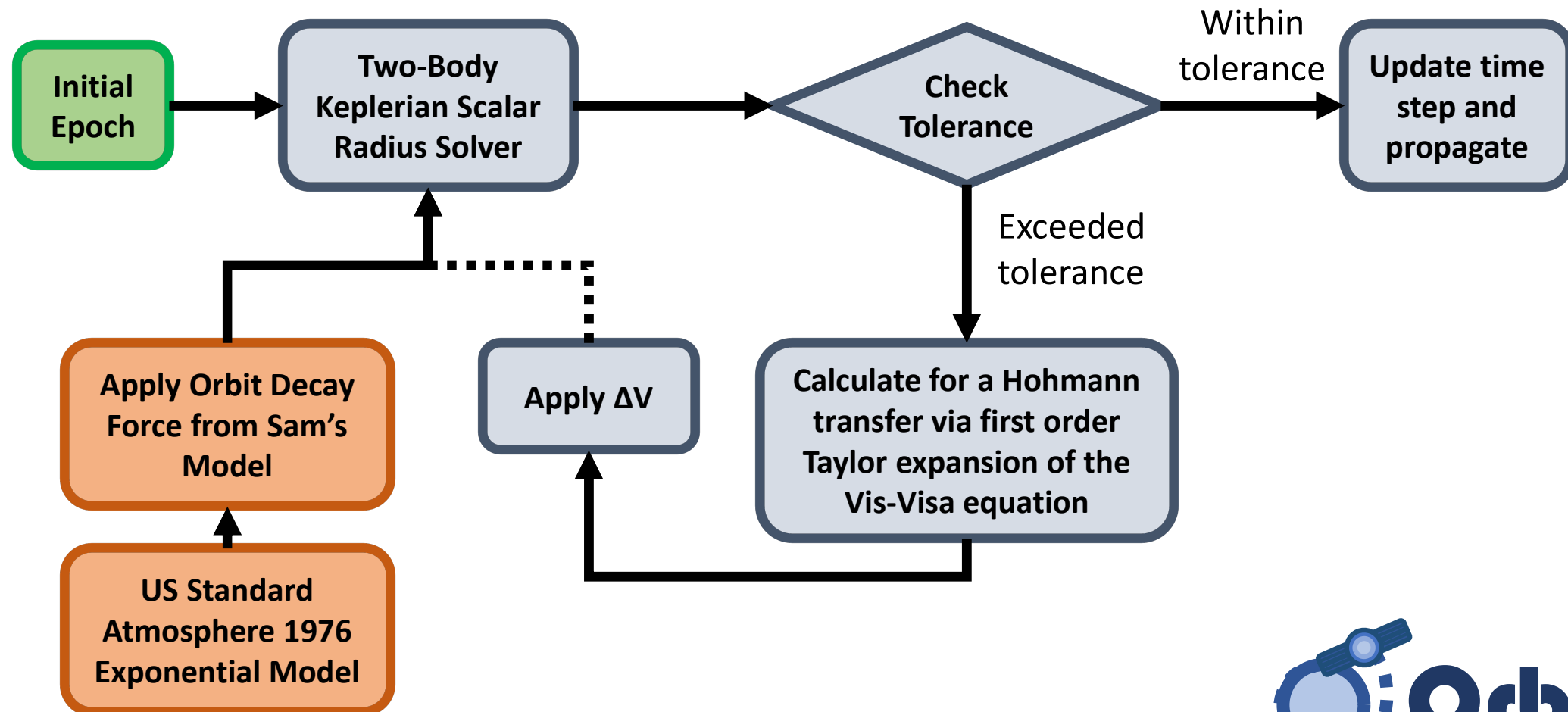


- Choose your orbit simulator.
- Specify your mission duration.
- Specify your spacecraft and orbit parameters.
- Specify your mission tolerances and margins.

Outputs a propulsion sizing chart and a ΔV report.

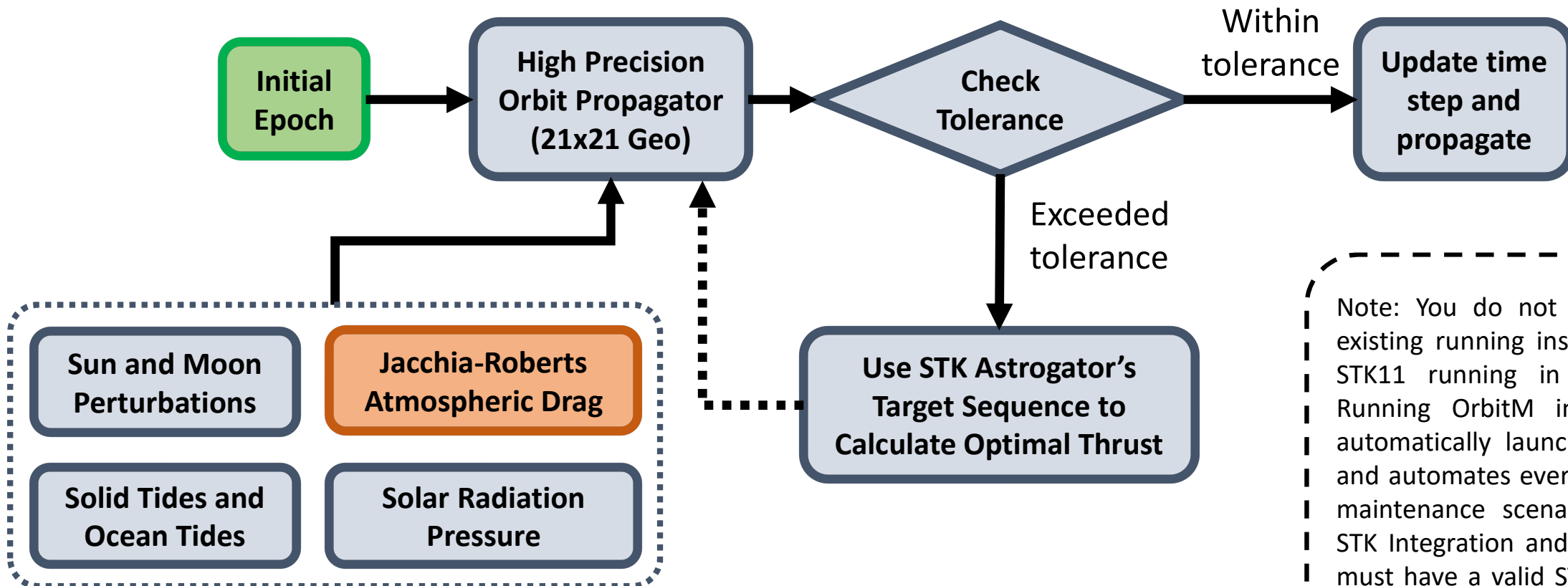
What does OrbitM offer to your analysis?

Sam's (Fast) Computation



What does OrbitM offer to your analysis?

STK's (Precise) Computation



Note: You do not need to have an existing running instance of STK10 or STK11 running in the background. Running OrbitM in the STK mode automatically launches STK, the GUI, and automates every step of the orbit maintenance scenario for you using STK Integration and STK Connect. You must have a valid STK Integration and Astrogator license!



What does OrbitM offer to your analysis?

Orbit Maintenance Scheduling Report

```
1 Maintain.ThrustApo 8 Jan 2012 03:45:24.438158324 0.13666080028002783
2 Maintain.ThrustPeri 8 Jan 2012 04:33:35.359392809 0.13666080028002783
3 Maintain.ThrustApo 16 Jan 2012 23:46:19.843702020 0.13666080028002783
4 Maintain.ThrustPeri 17 Jan 2012 00:33:44.859483133 0.13666080028002783
```

... ..

```
293 Maintain.ThrustApo 22 Dec 2014 05:13:52.359890580 0.13666080028002783
294 Maintain.ThrustPeri 22 Dec 2014 06:01:07.847235188 0.13666080028002783
295 Maintain.ThrustApo 30 Dec 2014 14:04:11.517531291 0.13666080028002783
296 Maintain.ThrustPeri 30 Dec 2014 14:52:41.602837637 0.13666080028002783
```

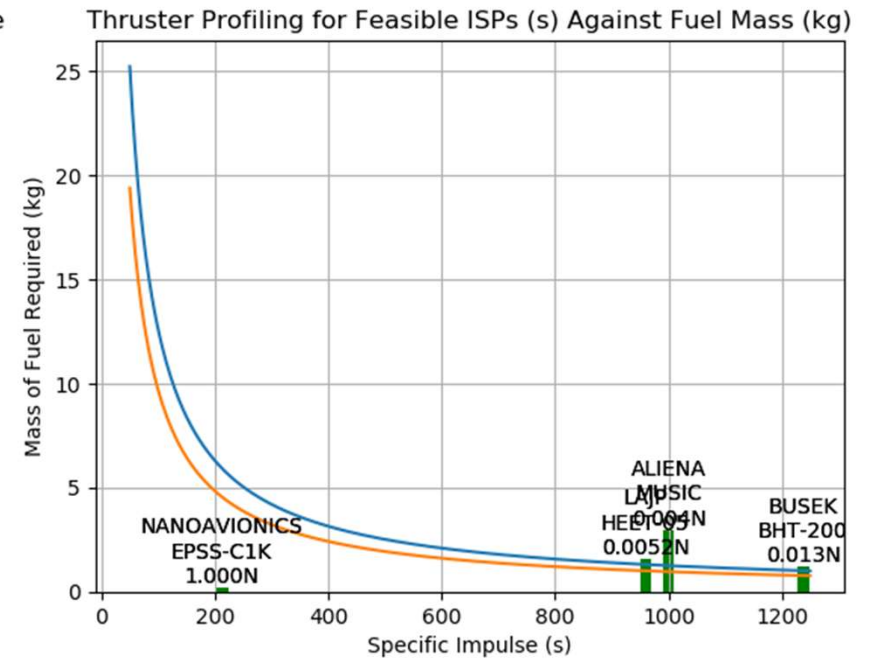
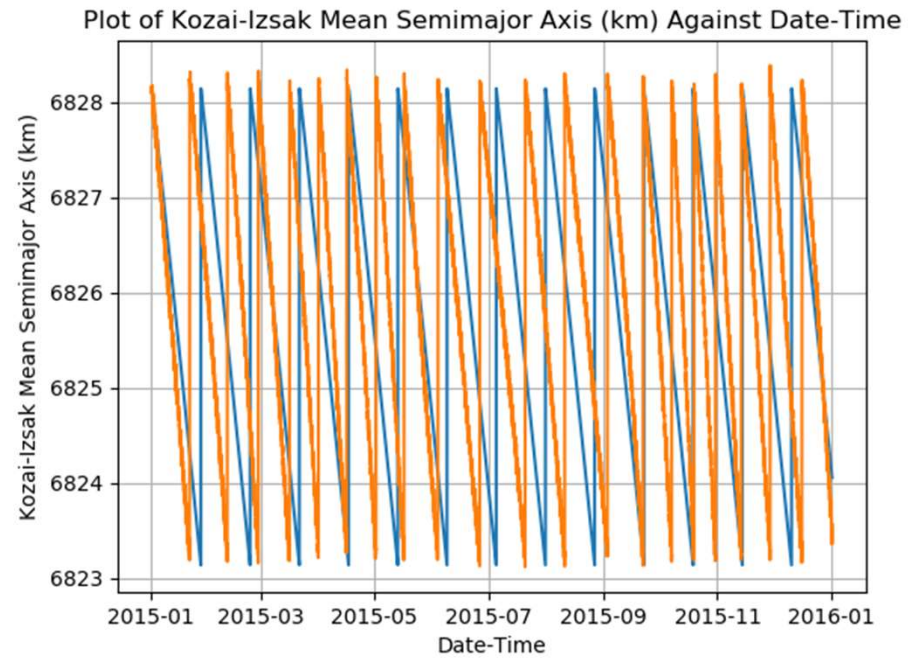
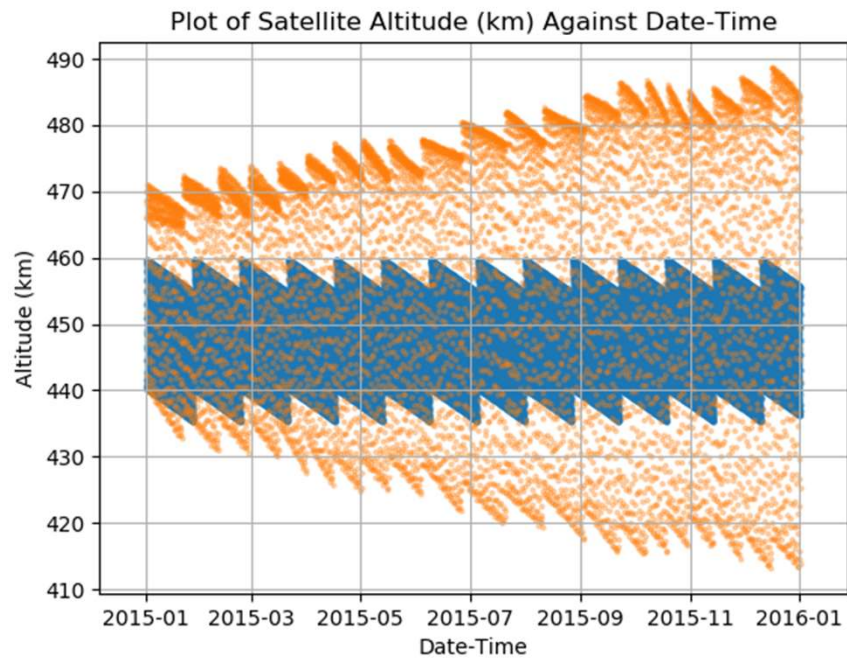
Number

Thrust Location

Time of Impulsive Thrust

Delta-V

What does OrbitM offer to your analysis?

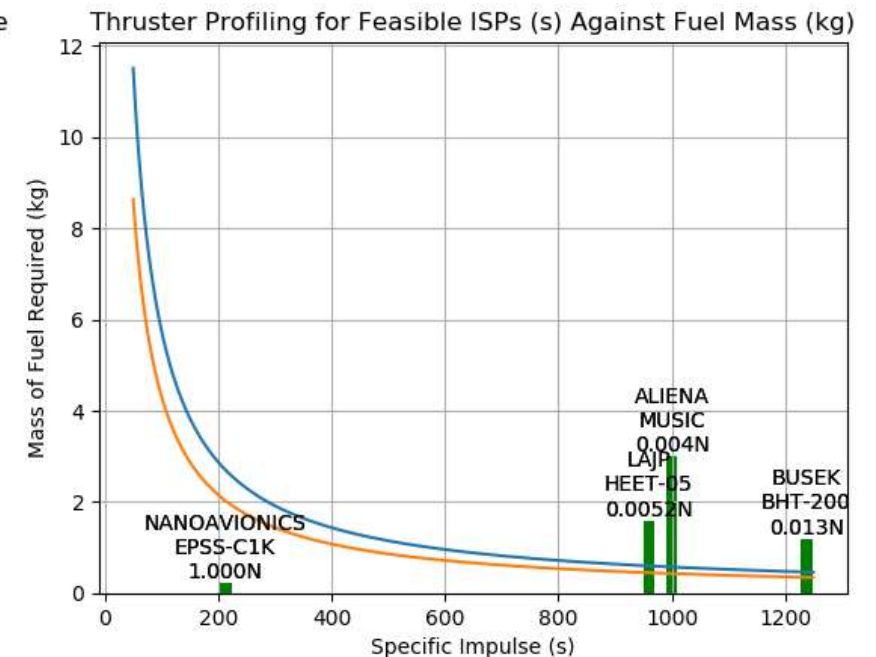
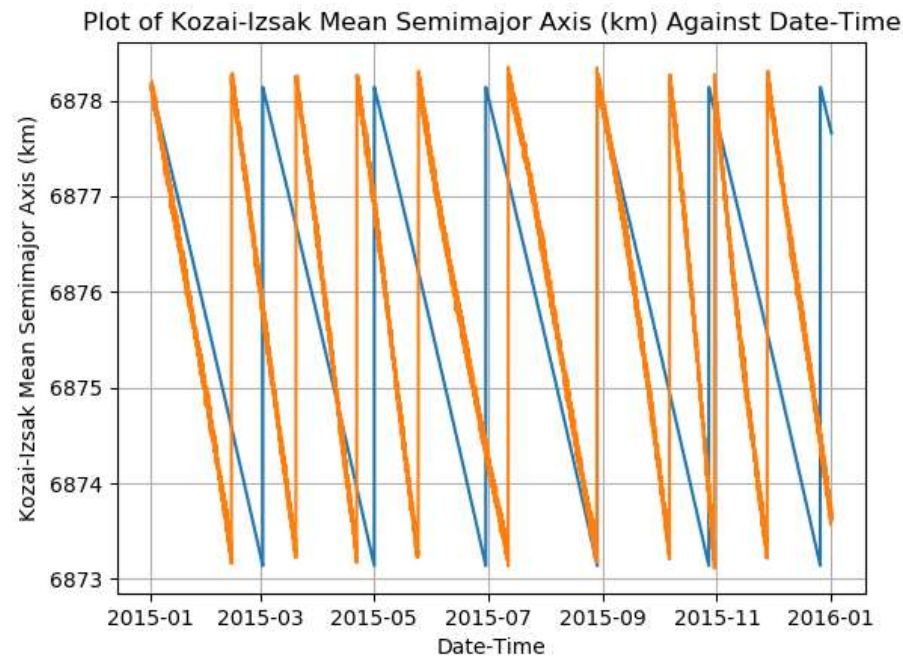
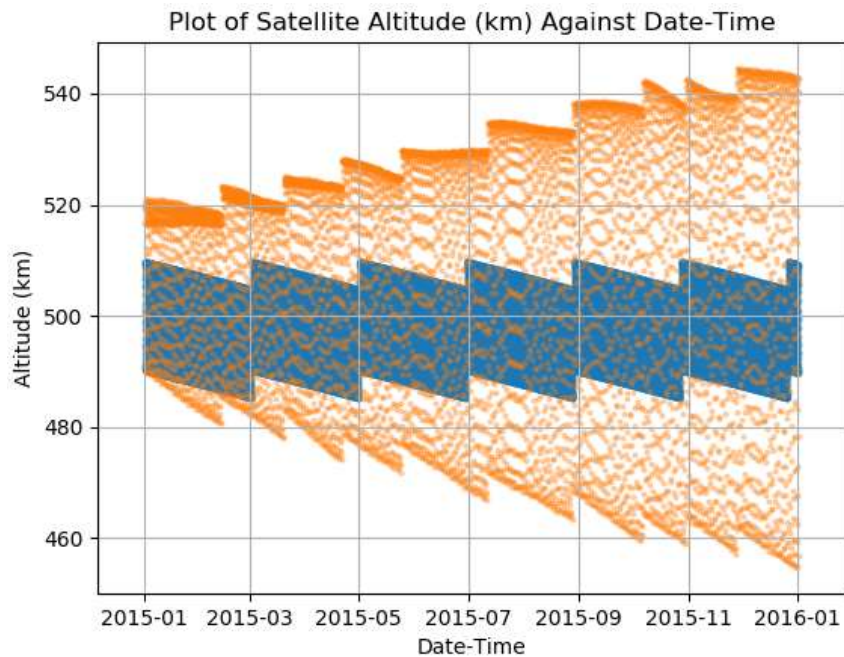


Circular Orbit @ 450km Mean Altitude

$C_d = 2.3$; Mass = 170kg; Area $\sim 2.5m^2$

- Sam's (Fast) Solver
- STK10 AstroGator (HPOP)

What does OrbitM offer to your analysis?

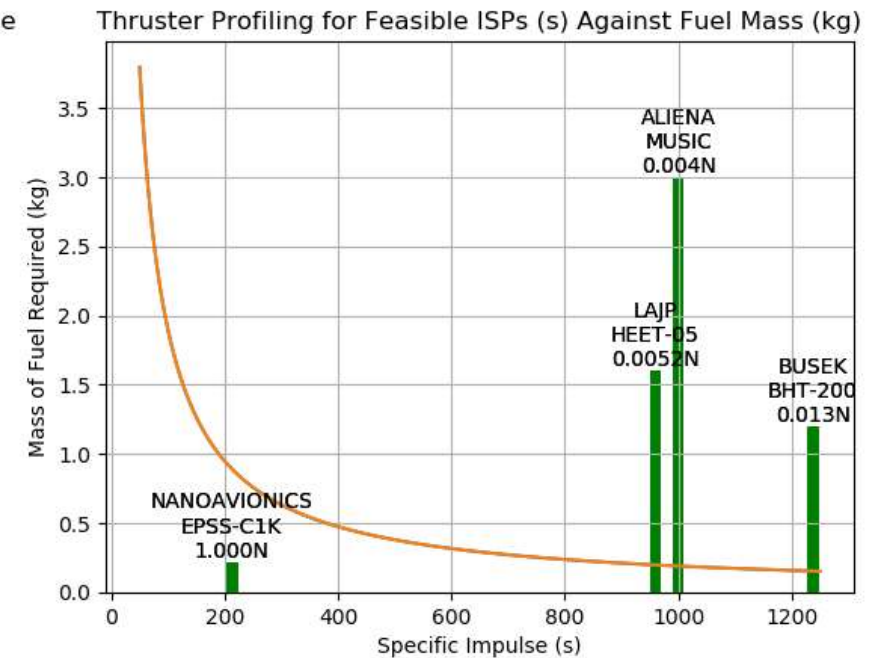
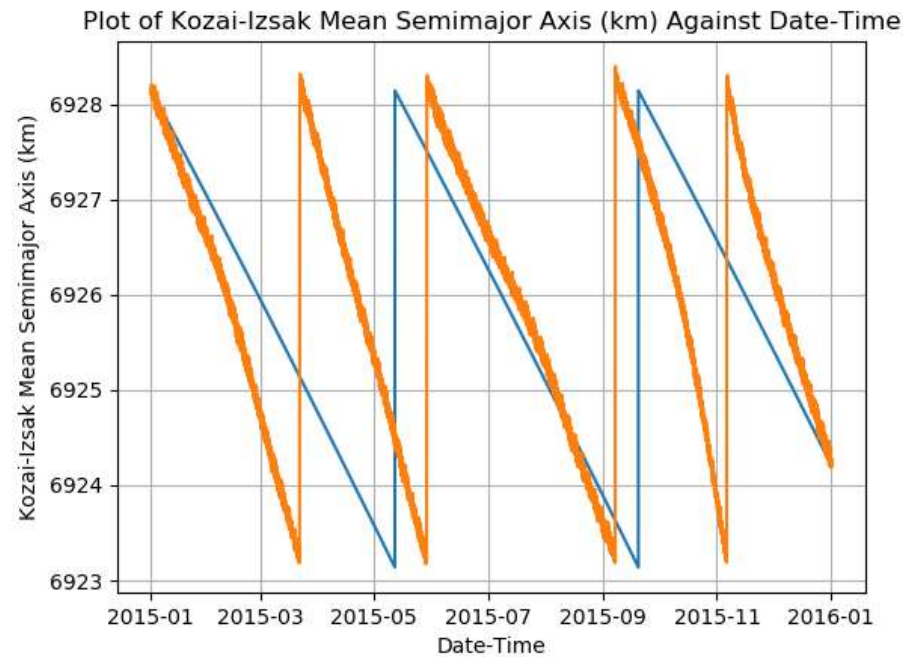
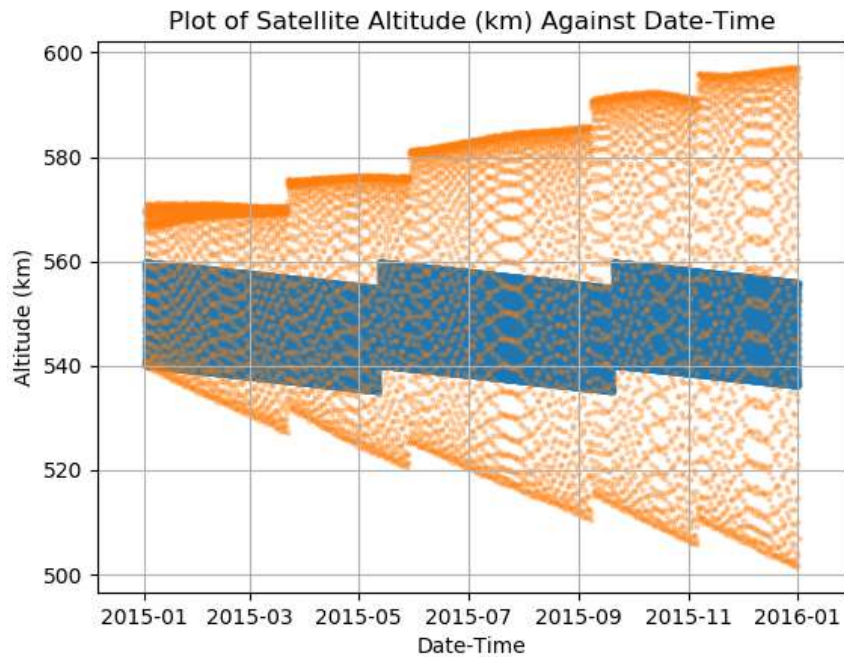


Circular Orbit @ 500km Mean Altitude

$C_d = 2.3$; Mass = 170kg; Area $\sim 2.5\text{m}^2$

- Sam's (Fast) Solver
- STK10 AstroGator (HPOP)

What does OrbitM offer to your analysis?



Circular Orbit @ 550km Mean Altitude

$C_d = 2.3$; Mass = 170kg; Area $\sim 2.5\text{m}^2$

- Sam's (Fast) Solver
- STK10 AstroGator (HPOP)

Summary and Conclusion

Orbit.M is a Python-based orbit maintenance simulator, which helps you size your mission lifetime quickly!

Orbit.M can also help you determine if your short-listed propulsion units are suitable for your mission.

Orbit.M is most useful, if your satellite design has many physical iterations with changing area-to-mass.

Orbit.M is also looking for collaborators versed in GMAT (since STK is not free!)



- [1] Larson, W.J. and Wertz, J.R. (1999). "Space Mission Analysis and Design, 3rd Edition"
- [2] Chao, C.C. (2005). "Applied Orbit Perturbation and Maintenance", American Institute of Aeronautics and Astronautics.
- [3] Low, S. Y. W., & Chia, Y. X. (2018). "Assessment of Orbit Maintenance Strategies for Small Satellites", 32nd Annual AIAA/USU Conference on Small Satellites, Logan, Utah, Utah State University, USA.

**** Please cite [3] if you found OrbitM useful!***