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Space Trajectory Analysis (STA)

An Astrodynamics software suite

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Introduction(1)

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- STA stands for “Space Trajectory Analysis”
- The STA project is an educational software project concerned with the development of a software suite able to mimic a portion of the functionalities of the COTS Satellite Tool Kit (STK)
- This new Space Trajectory Analysis (STA) tool shall provide a framework for education in astrodynamics at University level
- The software kit shall support the analysis phase of a space mission, including concept and requirements definition

Introduction(2)

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- STA project is an original idea of the Technical Directorate of ESA (TEC-ECM). It was born in Aug 2005
- Technical University of Delft in Netherlands supports this development by partnershipping with ESA and leading the software development
- STA development is based on open source, state of the art, astrodynamics routines
- One of the main STA requirement is that it shall be compatible with tools used at ESA like MATLAB, ASTOS, DCAP, SCILAB, etc
- STA design and development shall follow ESA standards (ECSS)

STA functionalities (1)

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- The ability to simulate for a range of trajectories including:
  - Ascent, Re-entry, Descent and landing trajectories
  - Orbits around planets and moons
  - Interplanetary trajectories
  - Rendezvous trajectories
  - Spacecraft constellations
- The ability to provide calculations in the field of:
  - Spacecraft tracking
  - Attitude analysis
  - Visibility analysis
  - Close-approach analysis
  - Orbit determination
  - Position and velocity of solar system bodies

STA functionalities (2)

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- The ability to allow the user to define the problem to be solved using a space scenario consisting of a given group of space “objects” in a given “scenario”
- The ability to show results in 2D, 3D environment containing the scenario elements and the resulting trajectory(ies)
- The ability to show the results to the user in the form of plots and reports and to allow the user to decide on the content and type of these
- The ability to import and export the results of the calculations to 3rd party products, such as MATLAB, ASTOS
- It shall run on Win, MACOSX, Linux

Celestia as a 3D engine for STA

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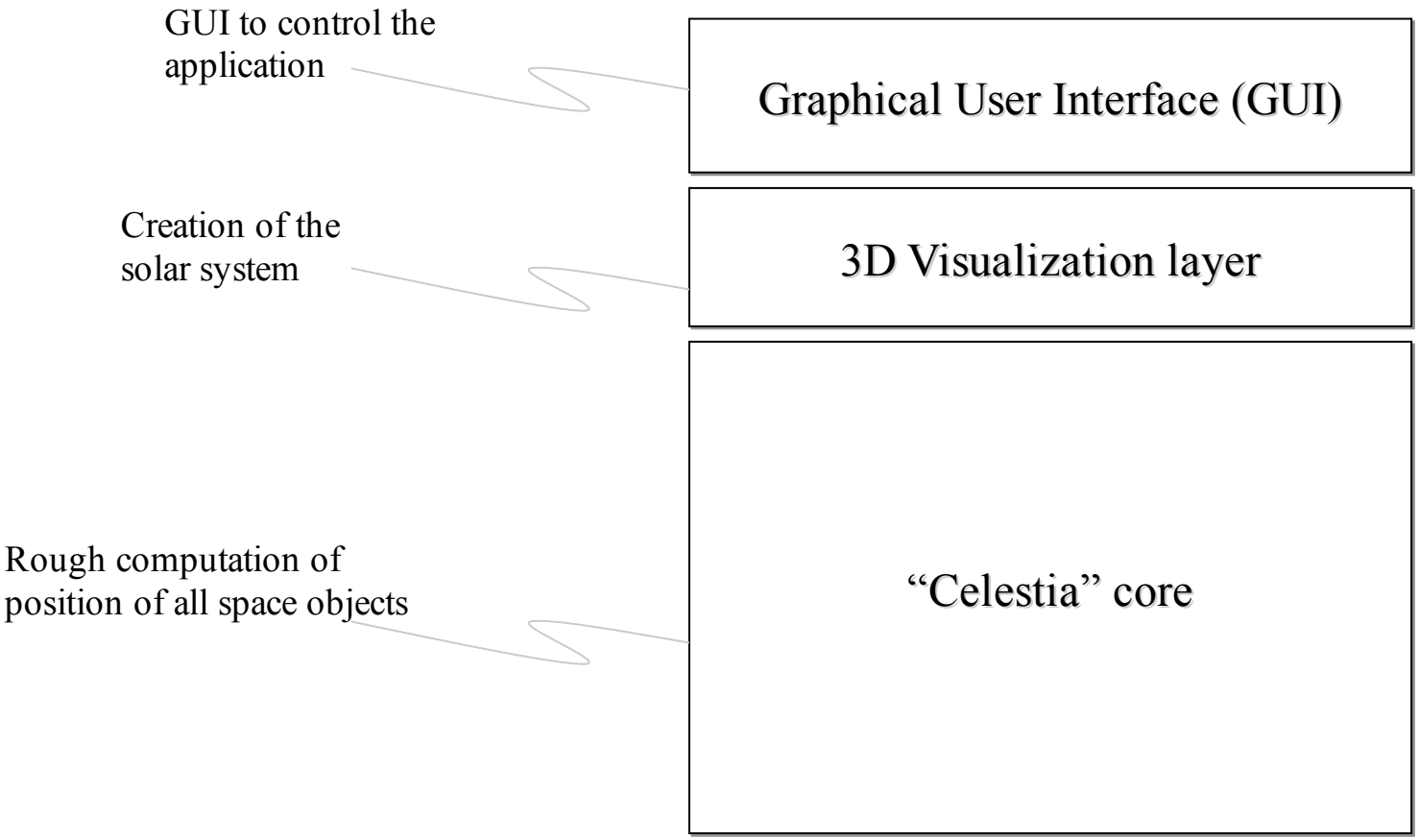
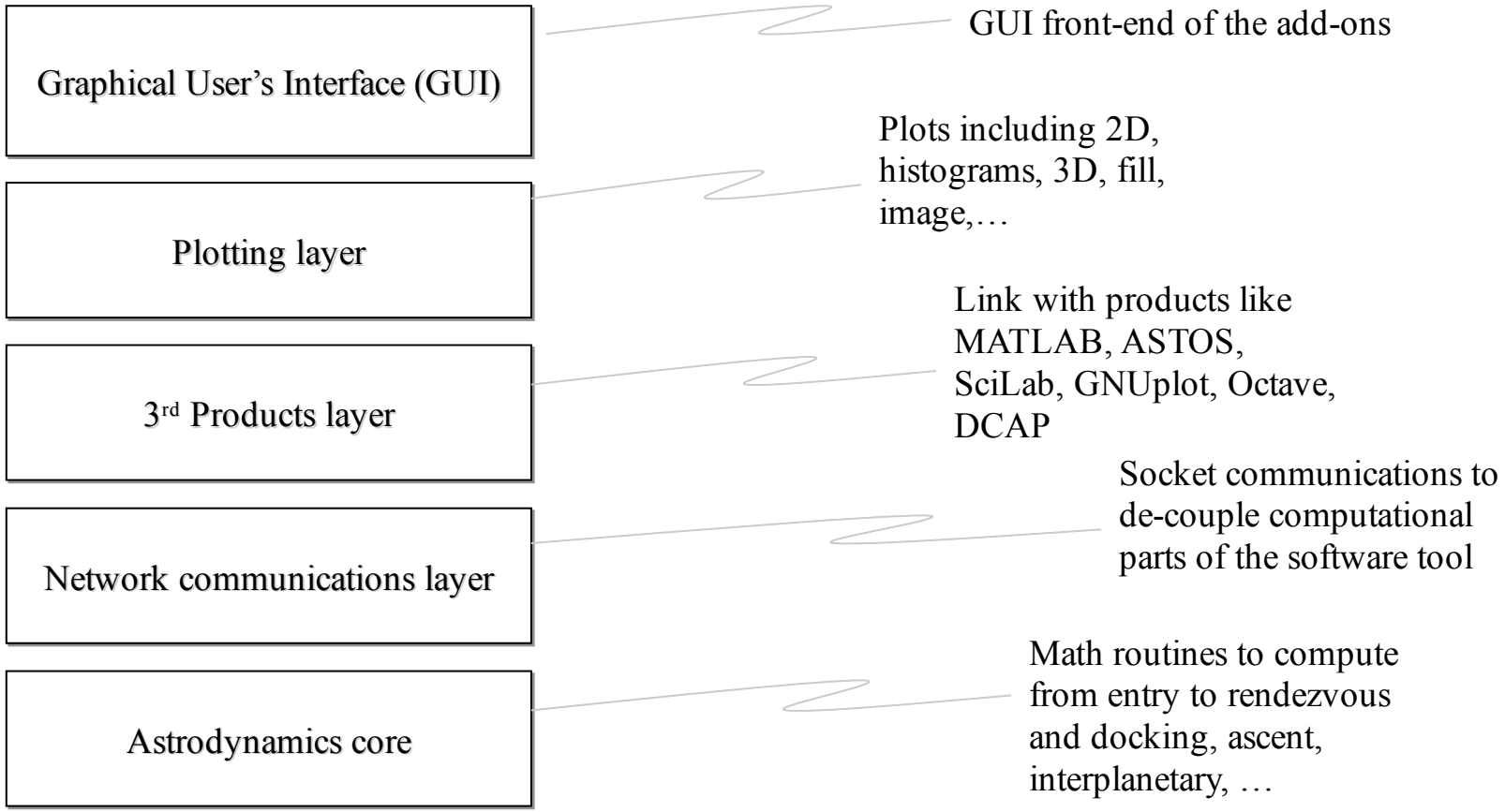
- Celestia is 3D planetarium software which allows a user to fly among celestial bodies
- Allows a user to travel throughout the solar system, to any of over 100,000 stars, or even beyond the galaxy
- It is able to handle 3D visuals in an efficient manner
- Celestia does not use a space scenario, nor does it handle 2D visuals
- It is open source and supported by an active community for maintenance and upgrades

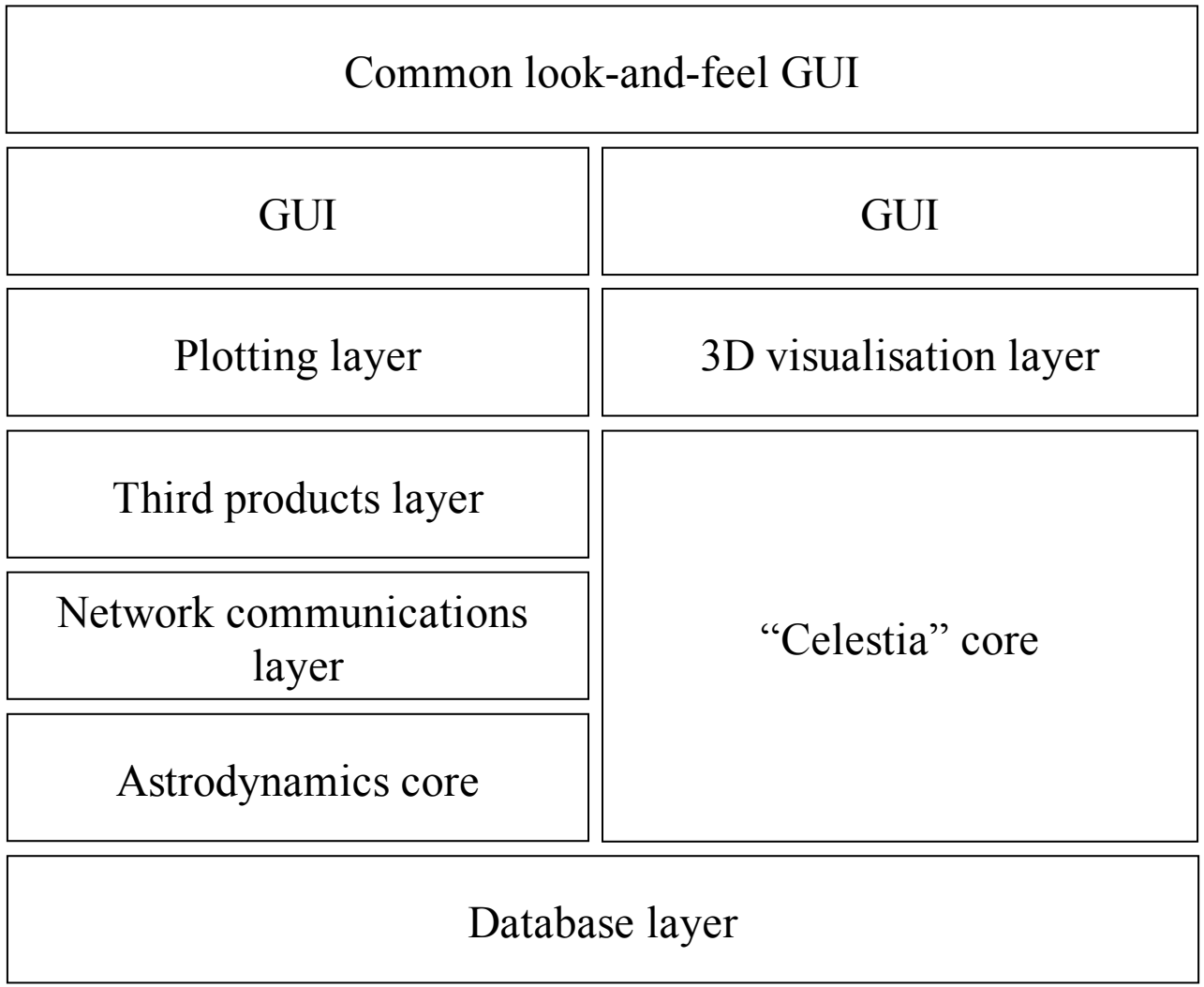
Present Blocks in Celestia



Future Building Blocks: STA



STA building blocks



STA building blocks (2)

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- STA 3D graphics engine is based on “Celestia”
- Most elementary astrodynamics building blocks already exist (orbit propagation routines, coverage analysis, analysis modules, etc)
- Interfaces between the already existing pieces need are being developed, and validated
- A graphical User Interface is well underway

STA Views

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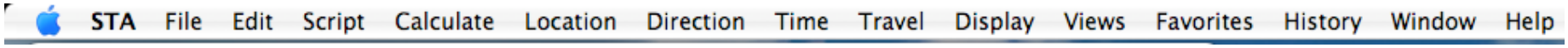
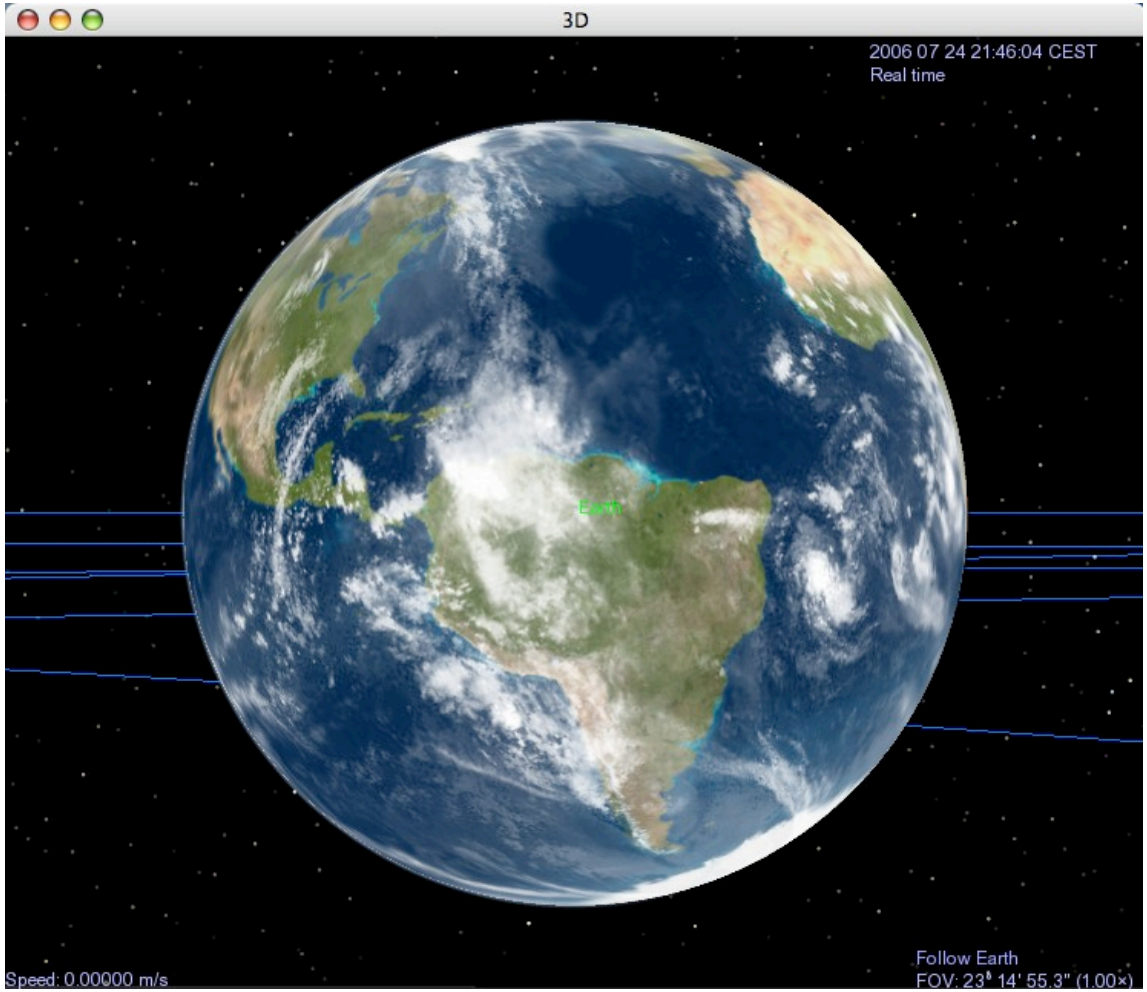
STA Menu



STA 3D view



STA Splash Window

STA application icon

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Interplanetary module

An STA module to analyse interplanetary trajectories

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Interplanetary module: Functional Requirements

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- It shall be able to simulate interplanetary spacecraft trajectories
- It shall be able to incorporate 6 planetary swing-by's in the simulation of an interplanetary trajectory
- It shall be able to incorporate impulsive and finite spacecraft maneuvers into the interplanetary trajectory simulation
- It shall be able to simulate interplanetary trajectories having as destination:
  - A planet or a planet's moon
  - An asteroid or comet
  - A Lagrange point
- It shall be able to use three methods to solve for the interplanetary trajectory problem, which are:
  - Lambert targeting
  - Numerical propagation
  - Optimisation

Interplanetary Module: GUI(1)

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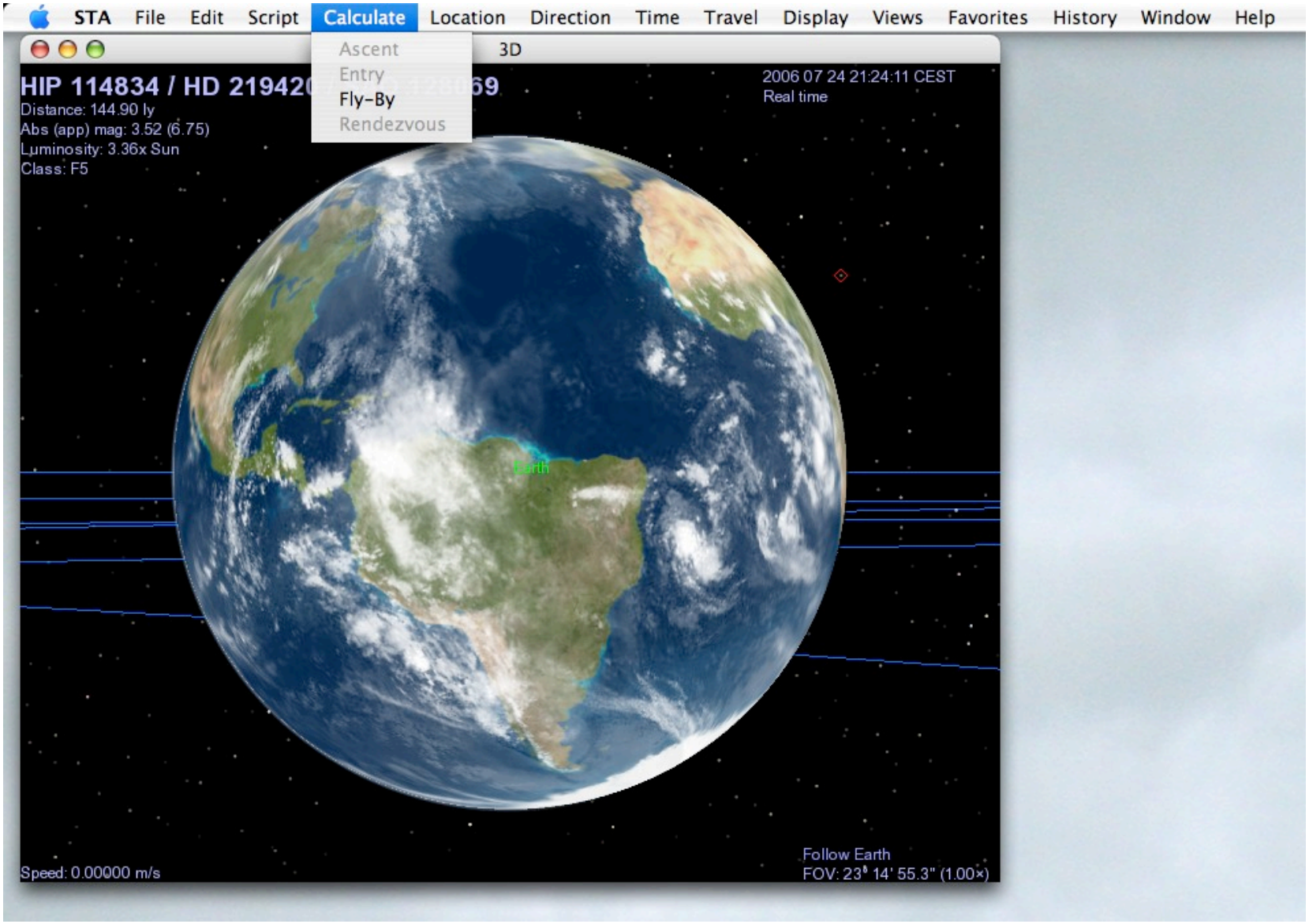

Interplanetary Module: GUI(2)

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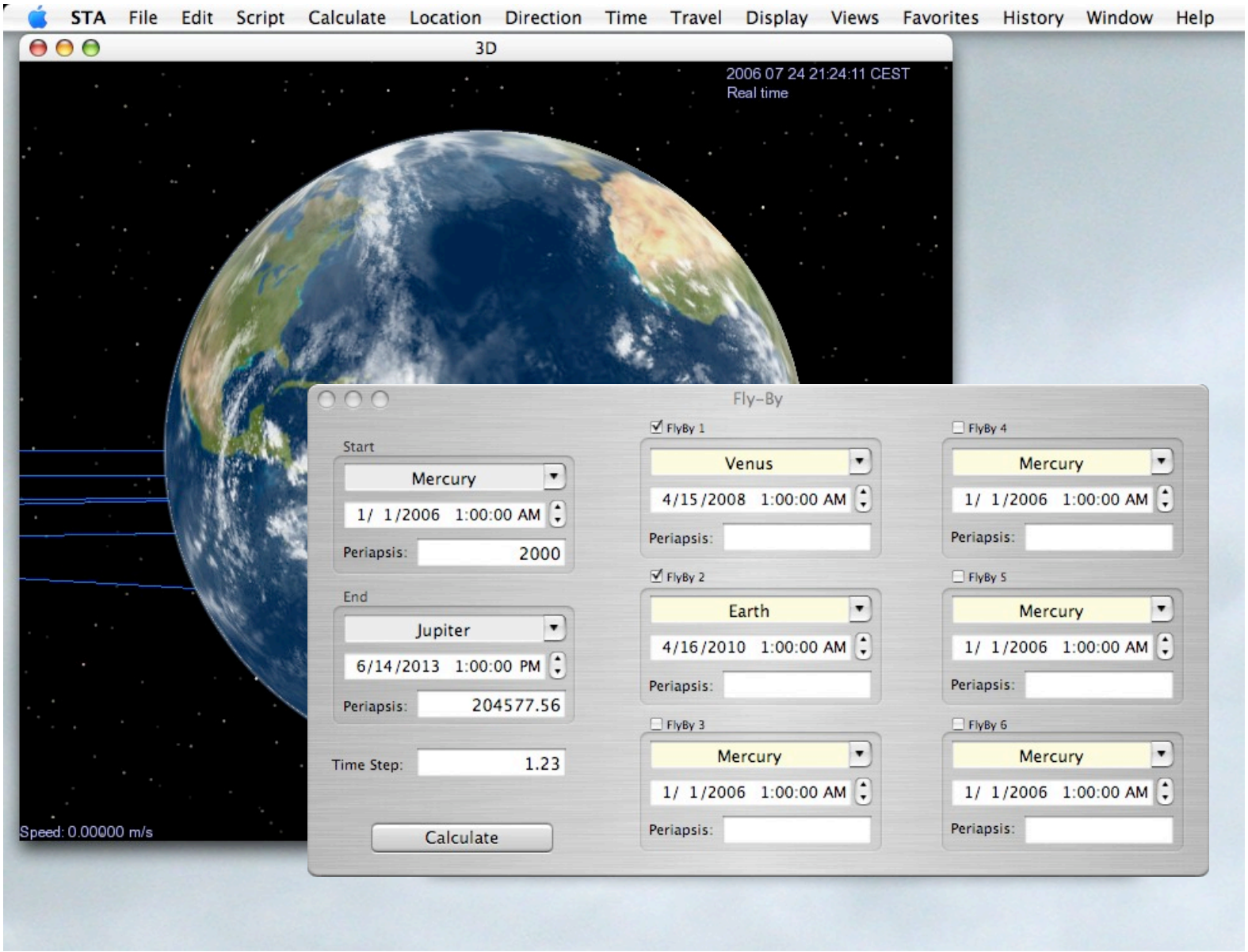

Interplanetary module: Input

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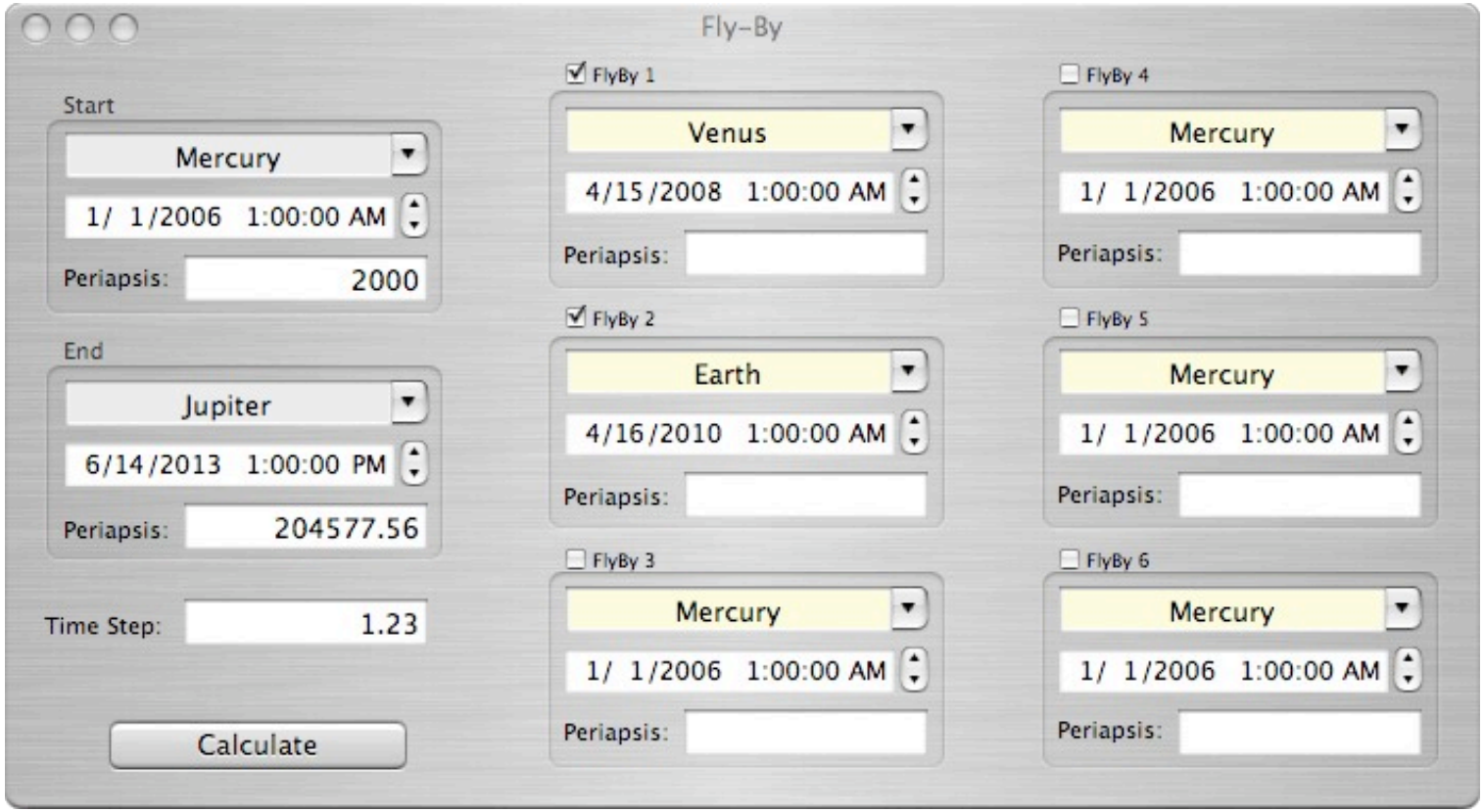
- **Input:**



Interplanetary module: Calculations

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- Ability to calculate conic section between planets using the Lambert targeting technique
  - Calculation of conic section from planet center to planet center in a specified time
- Ability to calculate the required velocity impulse at each of the planets
- Ability to optimise the results using a Genetic algorithm
  - Optimisation wrt required velocity impulse and/or transfer time
  - Optimization work is still in progress…

Interplanetary module: Output

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- Generation of a report containing
  - Input
  - Keplerian elements of all conic sections
  - Required velocity impulse
  - State vector wrt time
- Generation of a “Celestia” type *.xyz file to plot the spacecraft trajectory

Interplanetary module: Improvements

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- Finish the optimisation routines
- Include multiple revolutions in Lambert routine
- Include finite spacecraft maneuvers
- Include Moon's, asteroids, comets and Lagrange points as targets
- Include Numerical integration technique

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ExoMars Example

Mission to Mars

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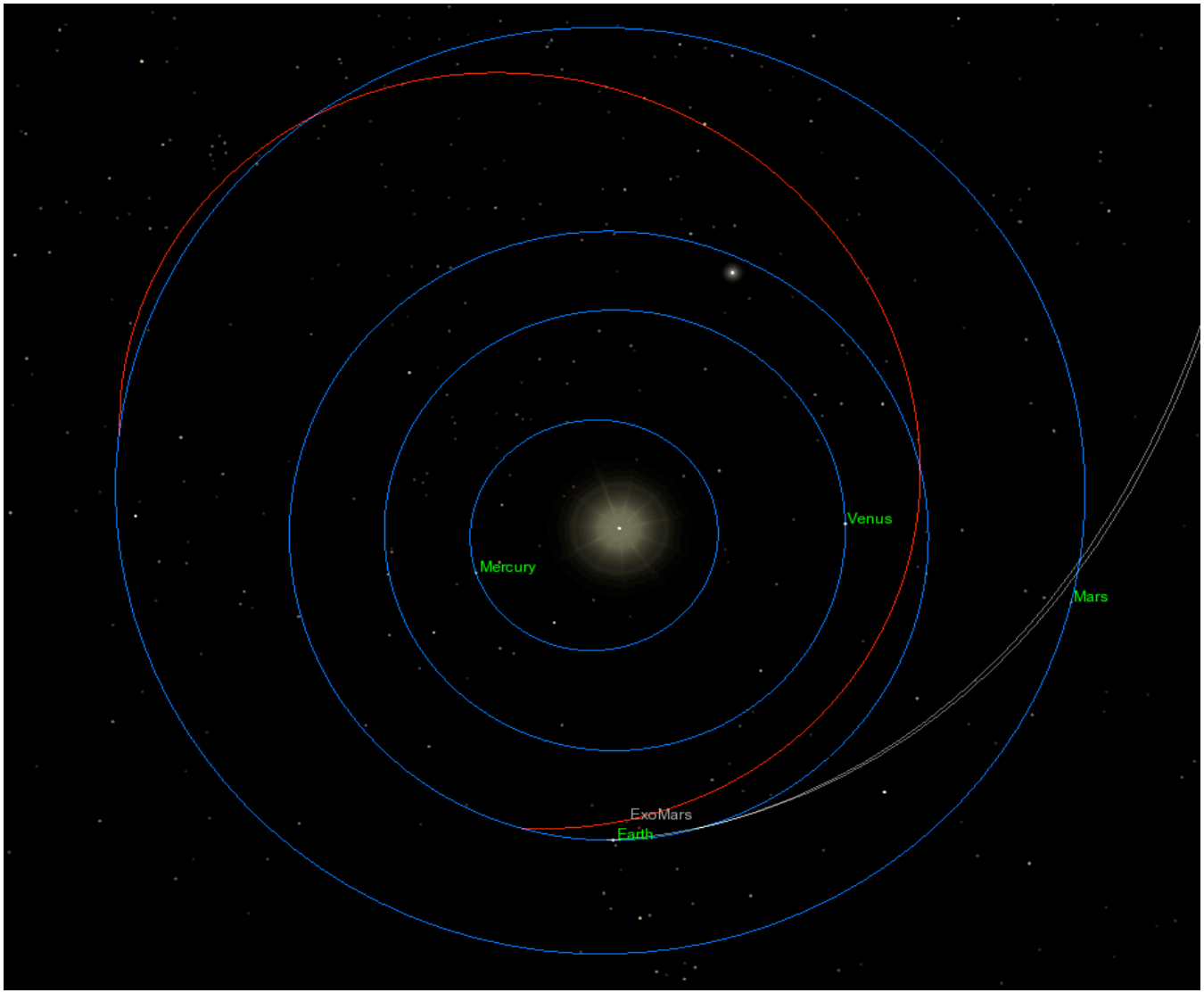
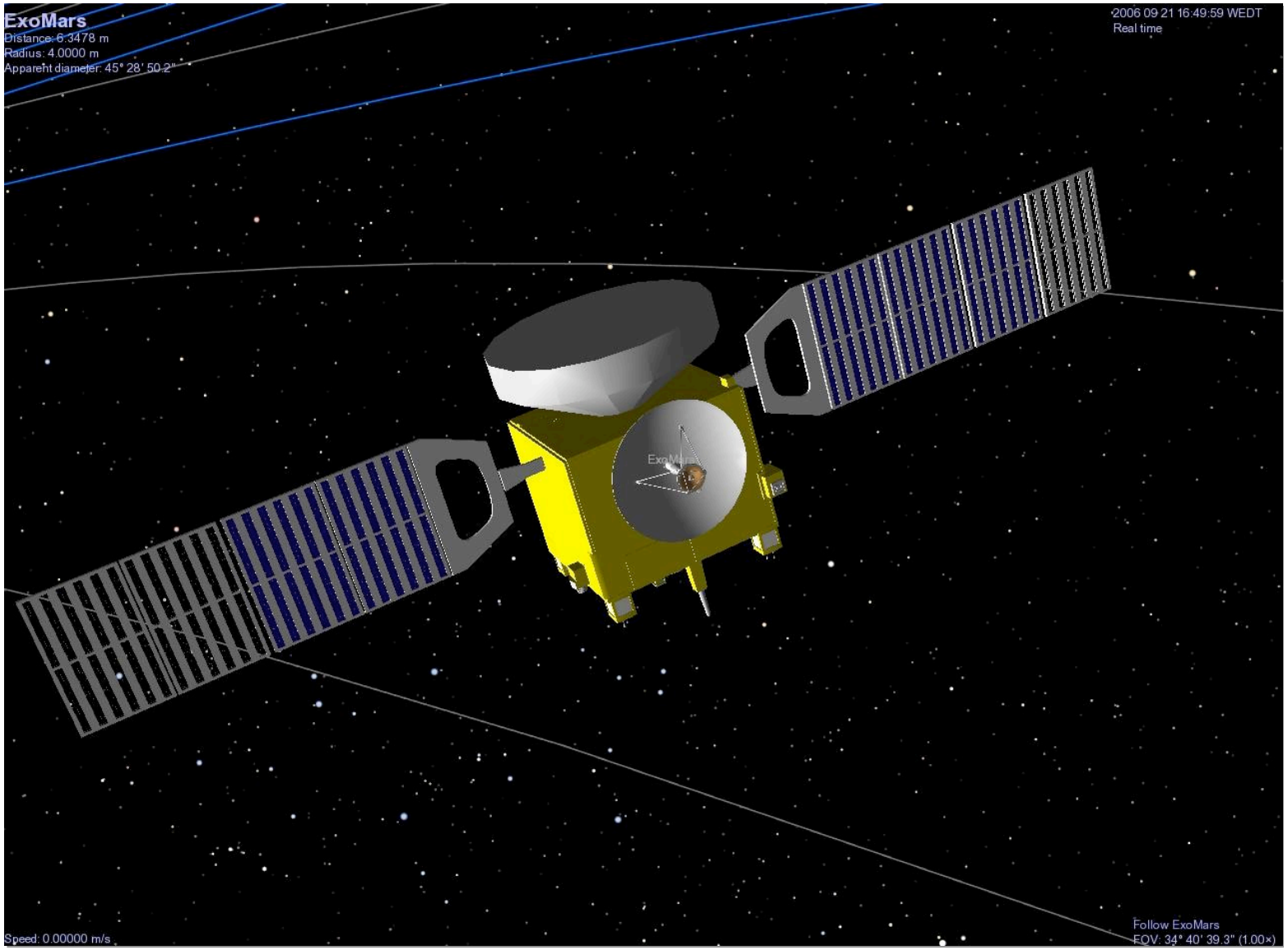
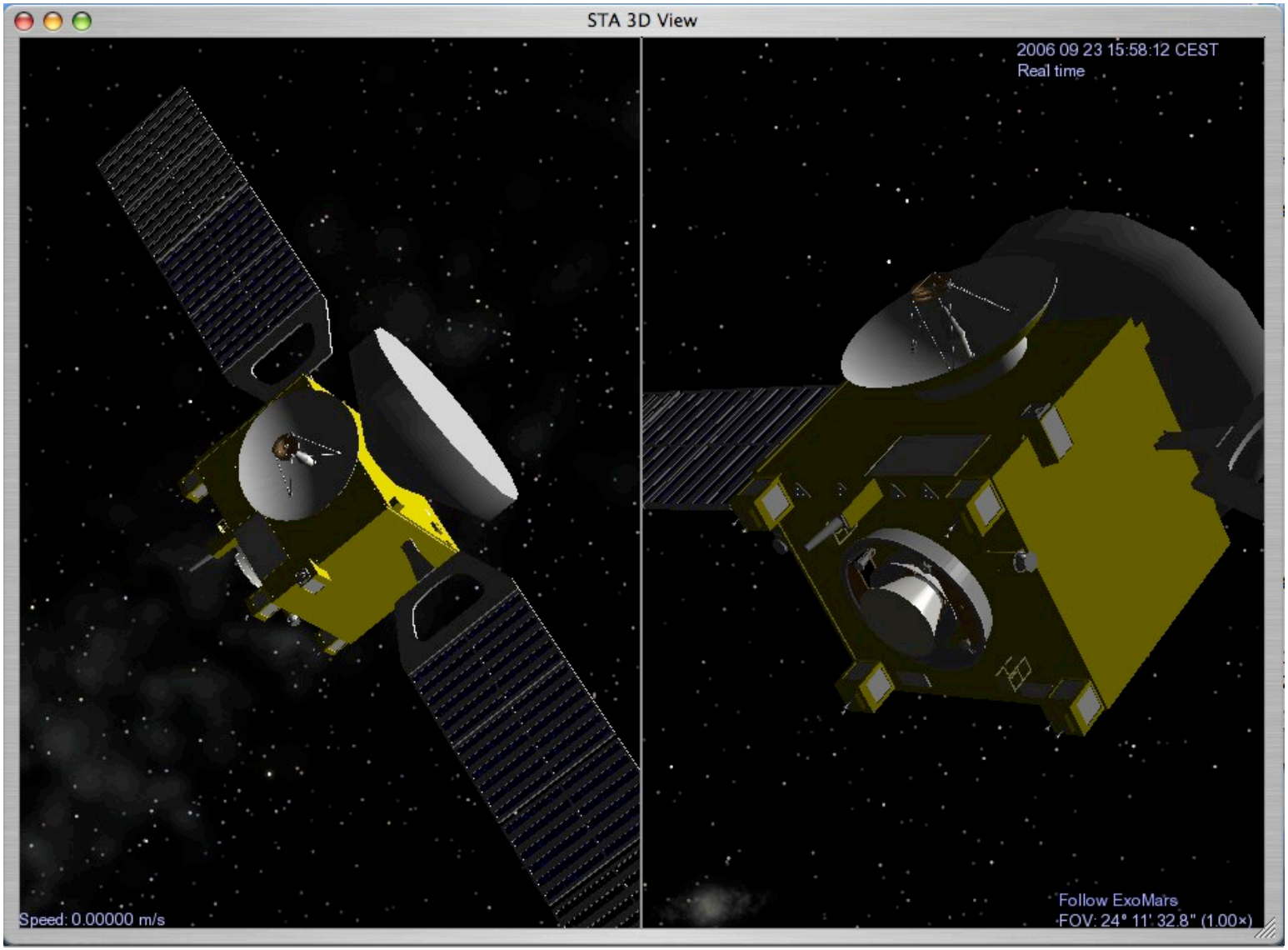
Resulting trajectory within Celestia



Model

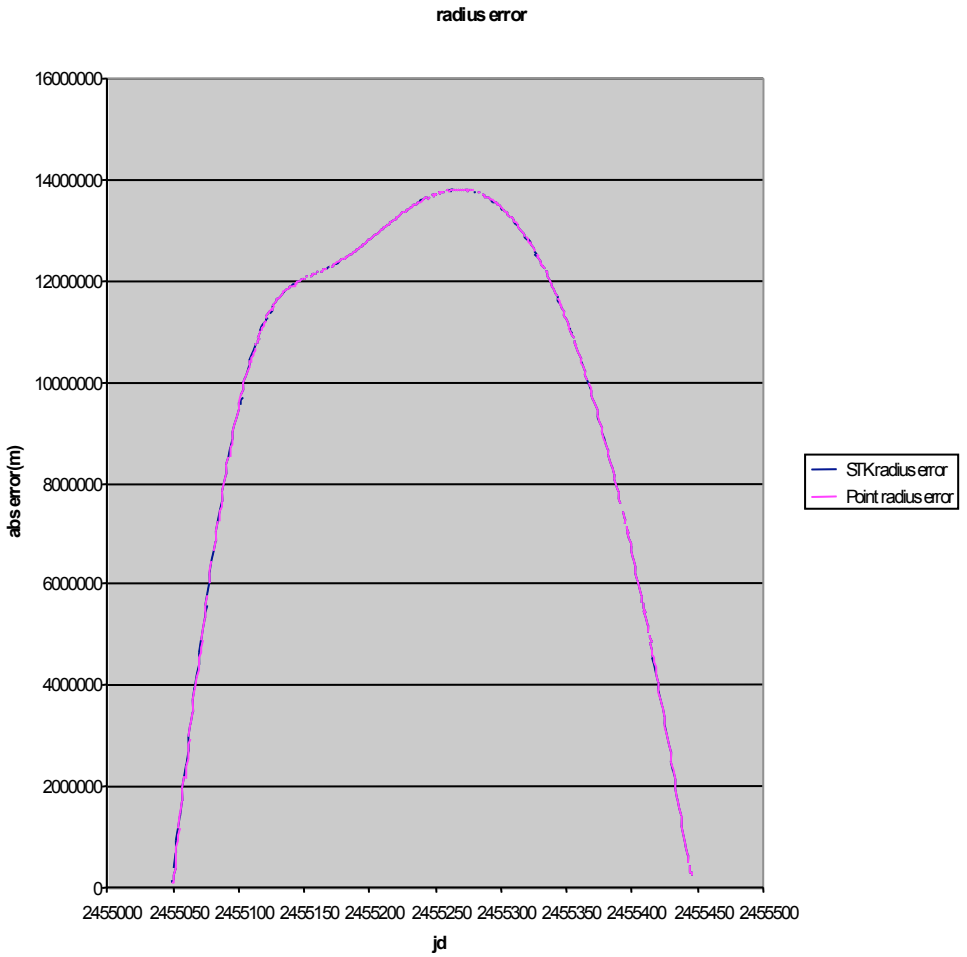

ExoMars
Distance: 6.3478 m
Radius: 4.0000 m
Appareht diameter: 45° 28' 50.2"
2006 09 21 16:49:59 WEDT
Real time
Speed: 0.00000 m/s
Follow ExoMars
FOV: 34° 40' 39.3" (1.00×)

3D View: ExoMars



Lambert routines validation

- Compare the calculated state vector with results from COTS like STK or POINT
- Largest error is 14000 km for a conic section
- Error is 0.005% of total chord length between Earth and Mars



Future

How to proceed ?

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- Improve the interplanetary module with optimization techniques
- Extend the functionalities of the STA tool to other missions like:
  - Rendezvous
  - Atmopsheric fligth
- Incorporate the concept of space “scenario” within the tool

Thank you for your attendance:

Any Questions?