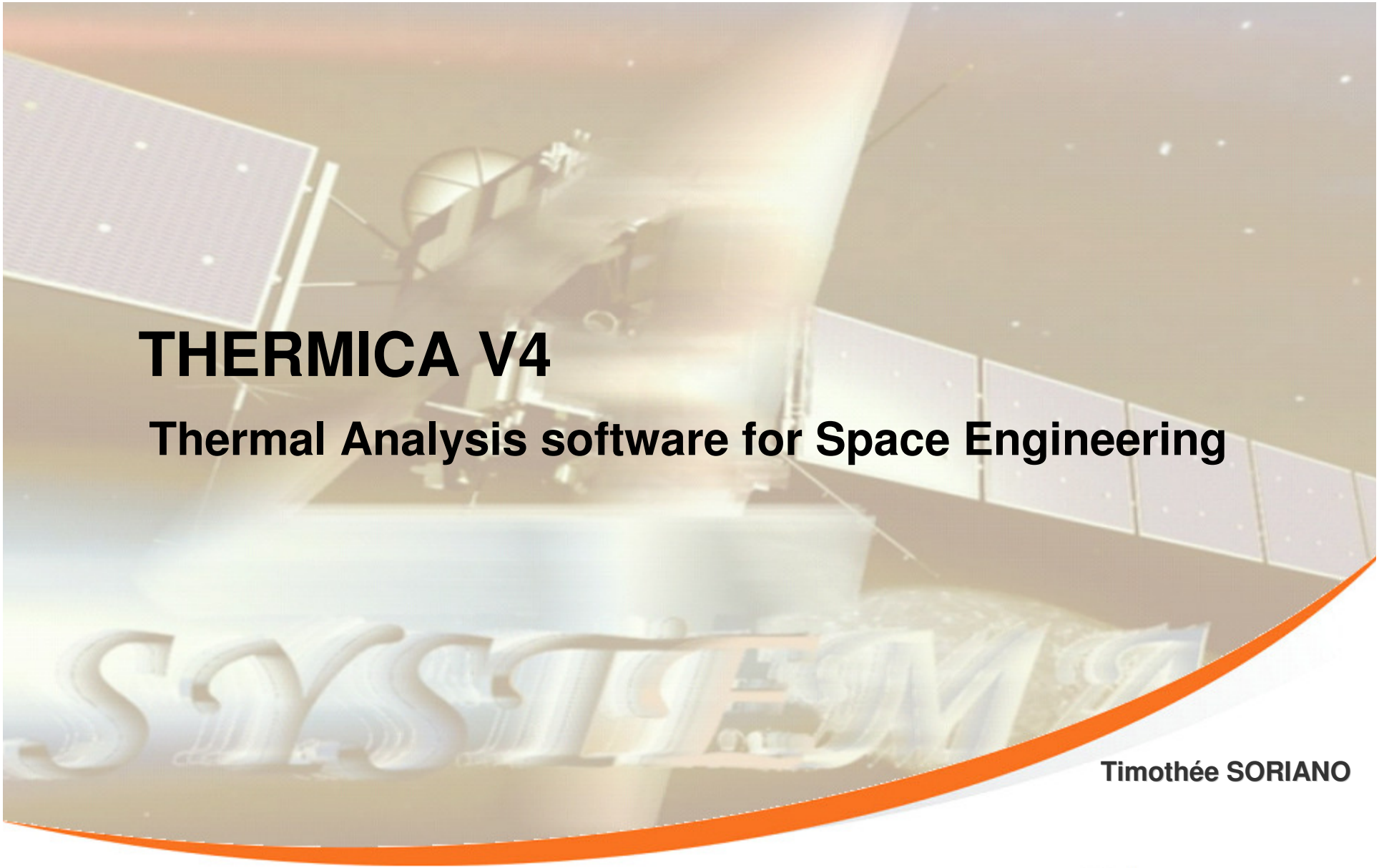

THERMICA V4

Thermal Analysis software for Space Engineering

Timothée SORIANO

All the space you need

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THERMICA V4

18th Annual Thermal and Fluids Analysis Workshop

Content

- Introduction
- The SYSTEMA V4 environment
  - Modeler
  - Trajectory
  - Kinematics
  - Processing
- The THERMICA Application
  - Nodal description
  - Radiation
  - Solar fluxes
  - Planet fluxes
  - Conduction
- SINDA/G Interface
- Post-processing
- What's coming next

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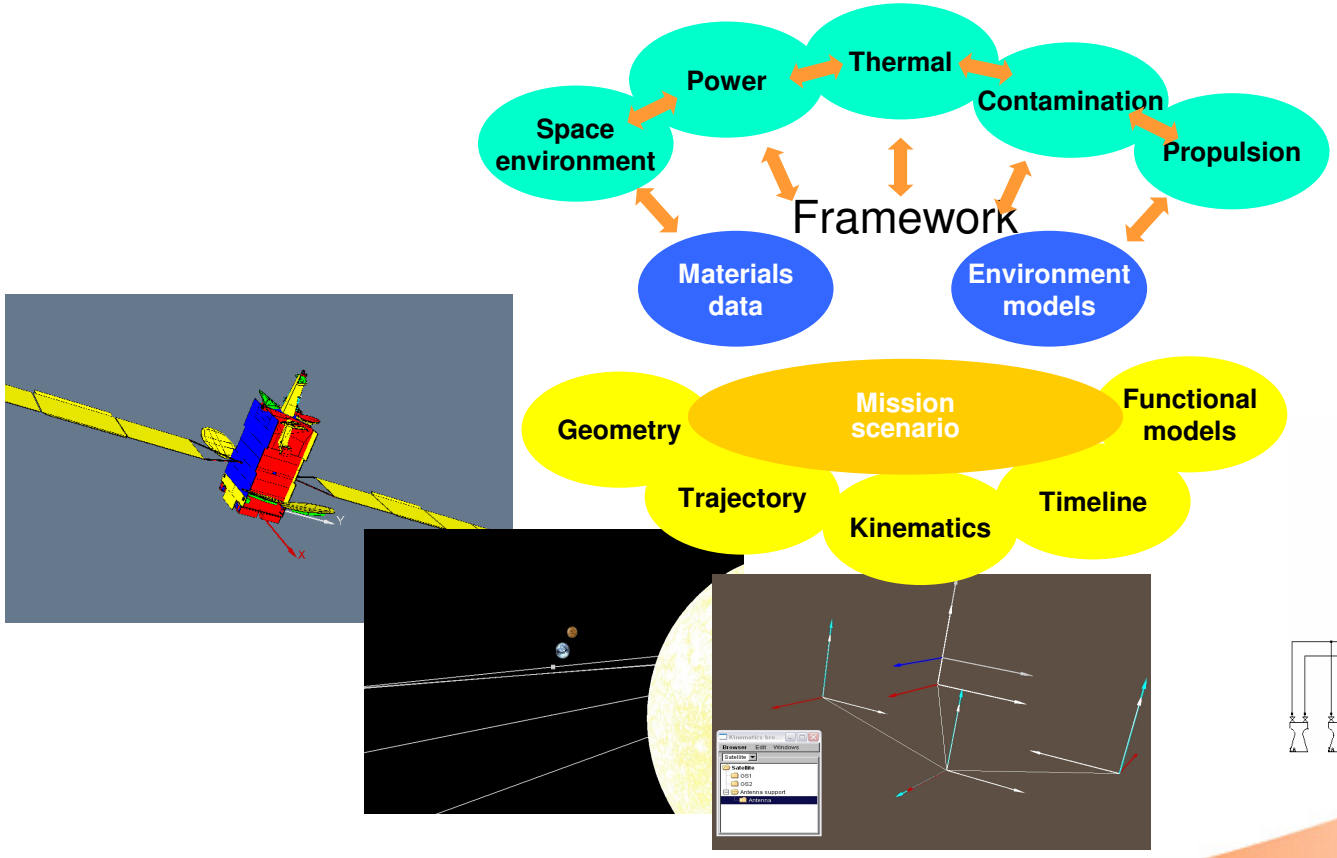
SYSTEMA Environment

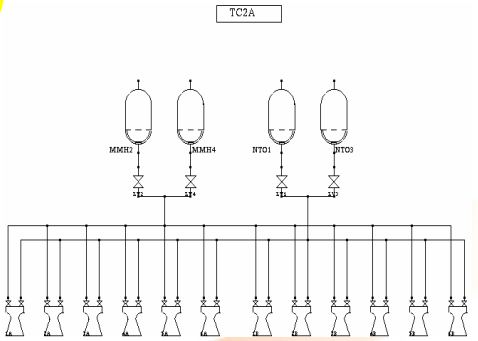
Overview

- Description
  - SYSTEMA permits satellite system analyses with detailed applications intended for specialists (thermal, AOCS, power …)
  - SYSTEMA embeds applications requiring: a 3D surface model of the spacecraft, the spacecraft mission, space environment models.
- History
  - System analysis software development with ESA and CNES for more than 15 years
  - Software distribution (THERMICA, DOSRAD …) for more than 10 years
- THERMICA
  - First tool in Europe to propose Monte-Carlo ray tracing for REF, Sun and Planet fluxes (1988)
  - Became a complete thermal analysis software

SYSTEMA: an interdisciplinary tool suite

Overview





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SYSTEMA V4

A New Environment for Space Applications

- Goals of the New Environment
  - Gathering a large set of applications
    - ✓Common geometry description, compatibility between applications
    - ✓Common definition of trajectory, pointing and kinematics
    - ✓Common use of visualization and pre / post processing tools
    - ✓Integration of the applications based on a functional description
- Main principles
  - PC / Unix native
    - ✓compliant with the standard engineer tools
  - Fully interactive
    - ✓up to date framework capabilities
  - Based on standard formats for interface
    - ✓Step, XML, HDF5
  - CAD & FEM interface
    - ✓for efficient model generation
  - Open for evolutions
    - ✓Applications are plug-in packages

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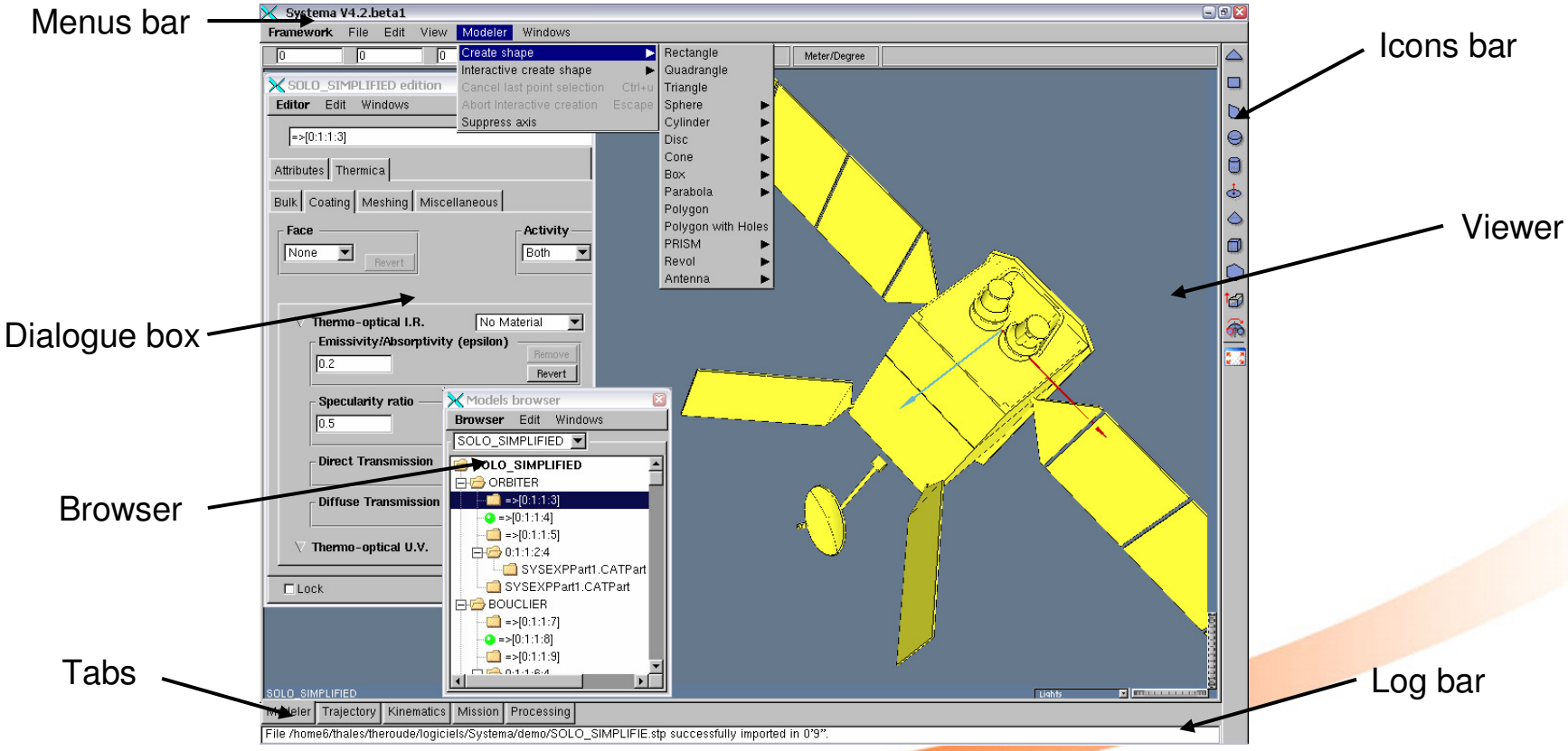
SYSTEMA Framework

Main concepts

- The user interacts with a desktop where he can access to all the data (geometry, trajectory, kinematics, mission…) in parallel



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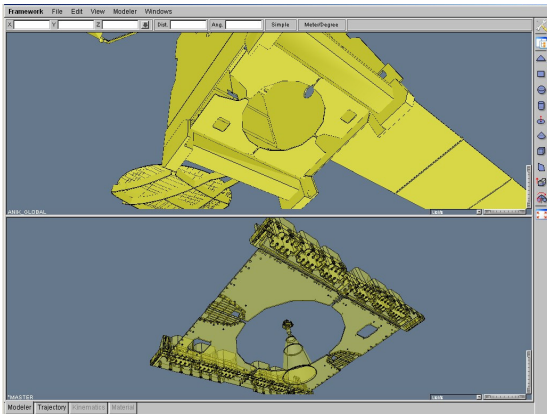
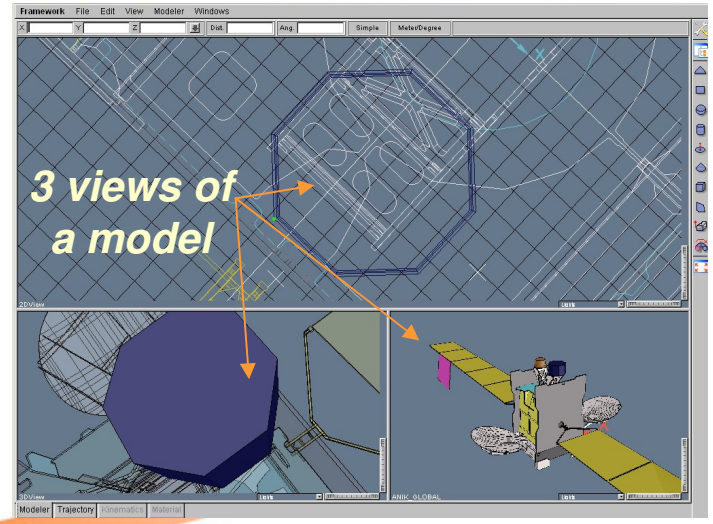
SYSTEMA V4

3D Modeler: Setting the Geometry

- Advanced Visualization Features
  - Easy 3D Manipulation
    - ✓Standard mouse zoon, pan rotate actions
    - ✓Fill ‘all’ or ‘only selected’
    - ✓Multi representations (wire frame, solid…)
    - ✓Transparency & Lights orientation management



  - Multi-viewers and Models Management
    - ✓Creation/Deletion, Resizing/Masking
    - ✓Simultaneous point of view over a model
    - ✓Several models can be opened
    - ✓They can share viewports



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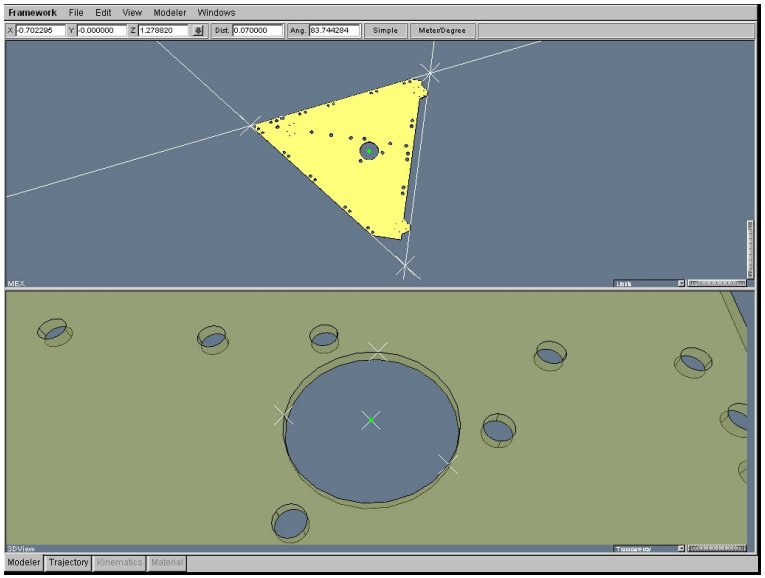
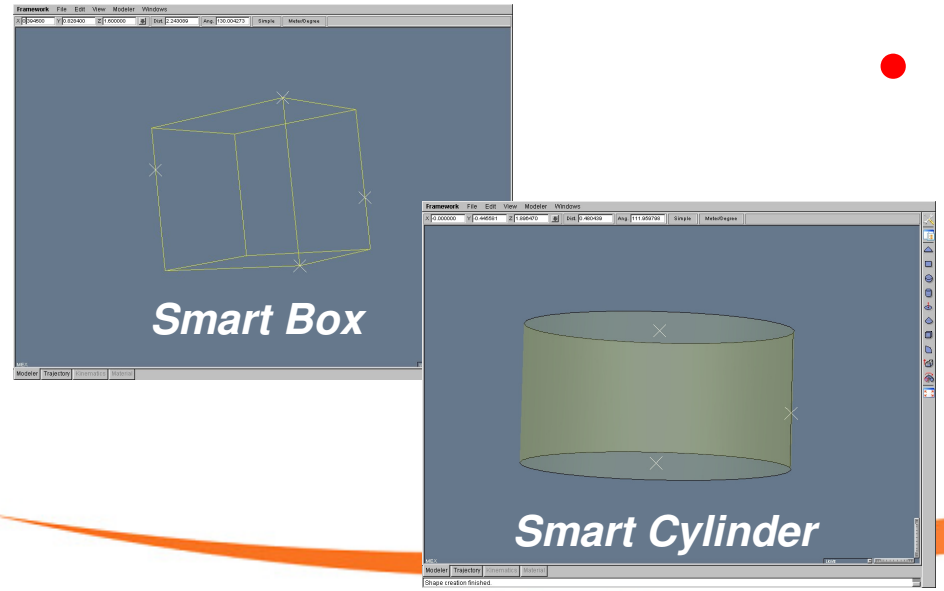
SYSTEMA V4

3D Modeler: Setting the Geometry (2)



- Multi way point construction
  - 3D direct selection
  - Manual edition
  - Virtual point using Helps items
    - ✓ Grids
    - ✓ Lines to create intersection points
    - ✓ Curve centre with 3 points
    - ✓ Middle of a segment



- Quick shape construction
  - Step-by-step interactive construction
    - ✓ by picking points
  - Smart construction points
    - ✓ height and width computed with projections if necessary

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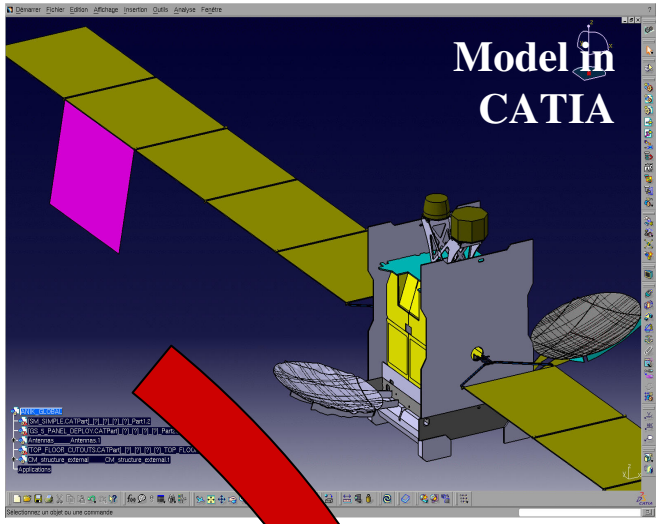
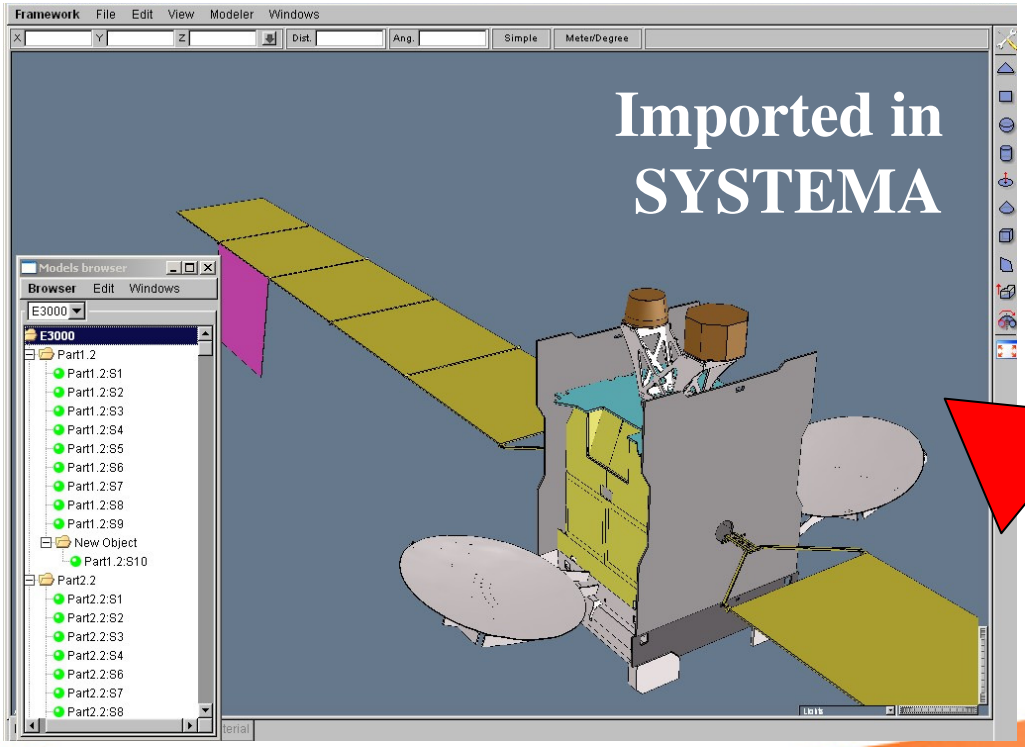
3D Modeler: Setting the Geometry (3)

- Import from CAD
  - CAD Geometry is used as a layer





STEP-AP203 Files

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SYSTEMA V4

3D Modeler: Completing the Geometry

- Easy settings of the properties
  - Inheritance management
  - Material management
  - Definitions of “Activity” and “Side”

- Meshing & Numbering independent from the geometry
  - Meshing/Numbering provided by applications
  - Multi-meshing support for one model
  - Improved Numbering management

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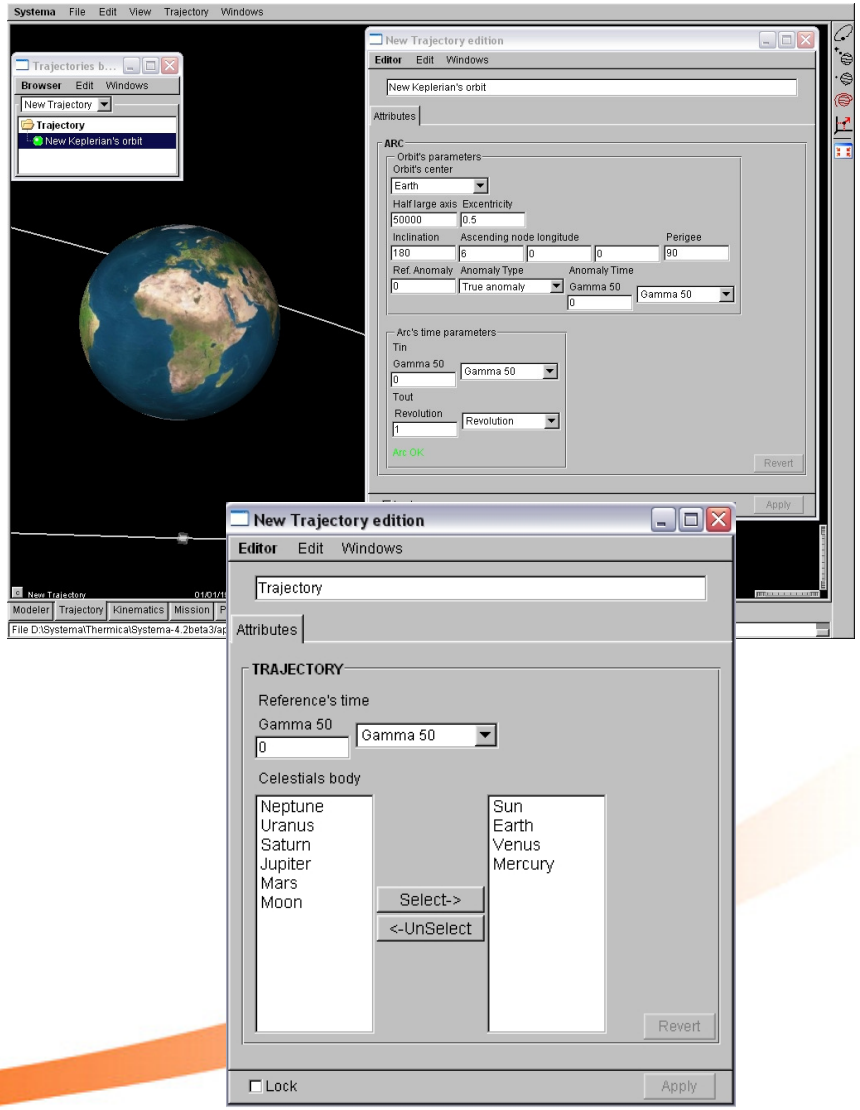
SYSTEMA V4

Trajectory

- Customization of the trajectory
  - Management of the Sun, Solar System planets and Moon
    - ✓Real ephemerids
  - Creation of arcs
    - ✓Keplerian
    - ✓Sun synchronous
    - ✓Geo synchronous
    - ✓Transfer orbits
  - Import of any trajectory
    - ✓Using a simple file with definition of Time, Speed and Positions
  - Advanced 3D visualizations
    - ✓Zoom, rotate, pan
    - ✓Variable time scale
    - ✓Play / Stop



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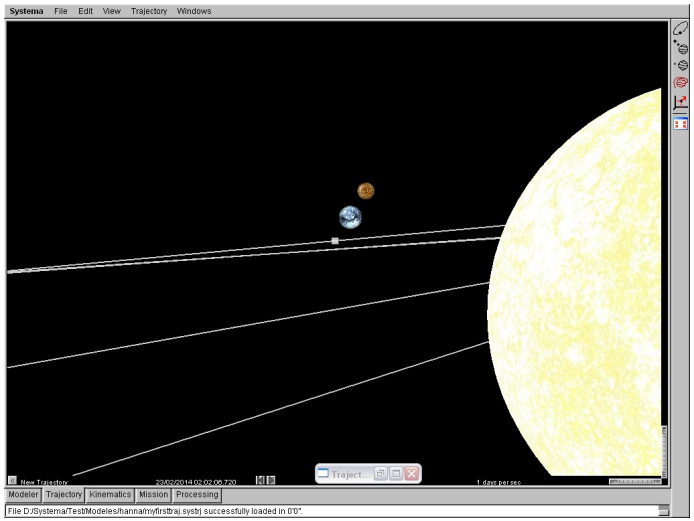
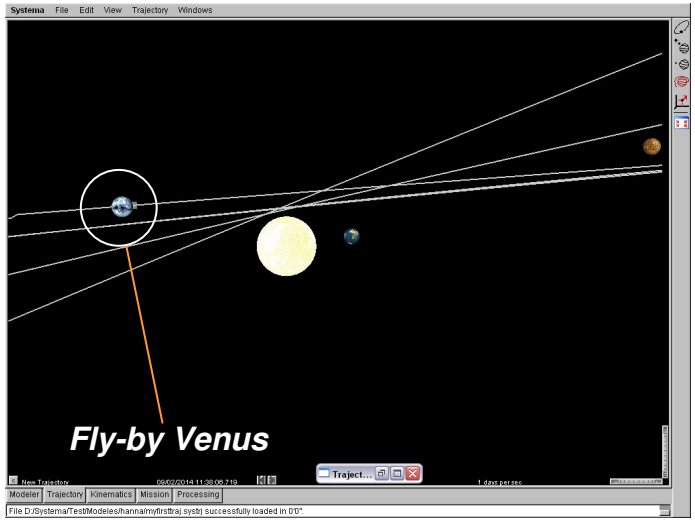
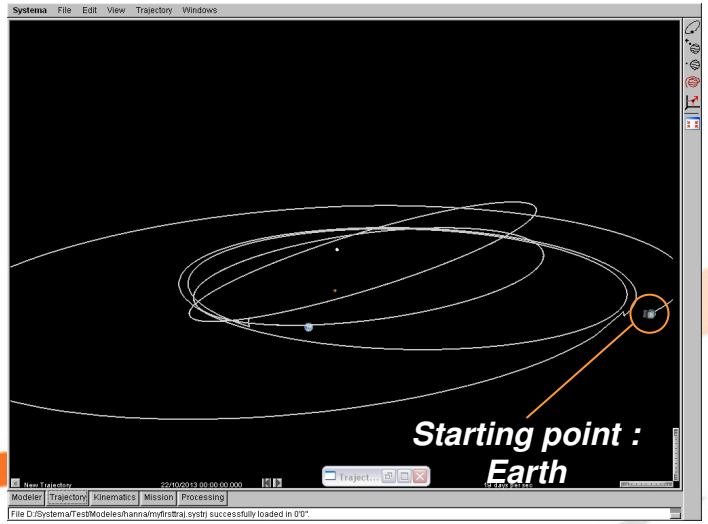
SYSTEMA Trajectory

Interplanetary mission

- 3D visualization of the trajectory
  - The user can play/stop the trajectory
  - Variable time scale
  - Zoom / Pan / Rotate interactivity







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SYSTEMA V4

Kinematics

- Independent from the geometry
  - ➢ Tree of rigid bodies linked by
    - ✓Pivot connection

1 degree of freedom

    - ✓Ball pivot

2 degrees of freedom

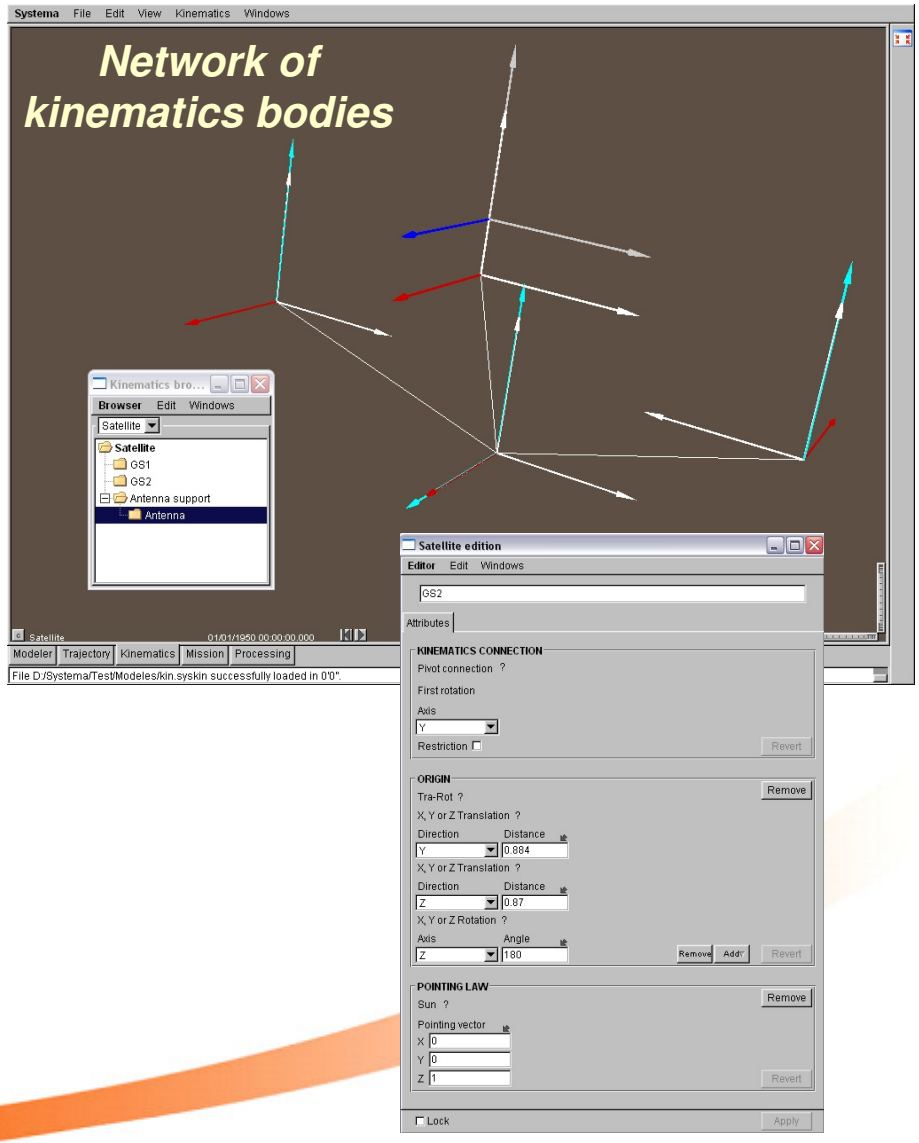
    - ✓Ball joint

3 degrees of freedom

  - ➢ Definition of laws
    - ✓Pointing

Sun, Planet, velocity, orbital momentum…

    - ✓Spin around axis
    - ✓…
    - ✓Possibility of combining laws
    - ✓Fast-moving option available



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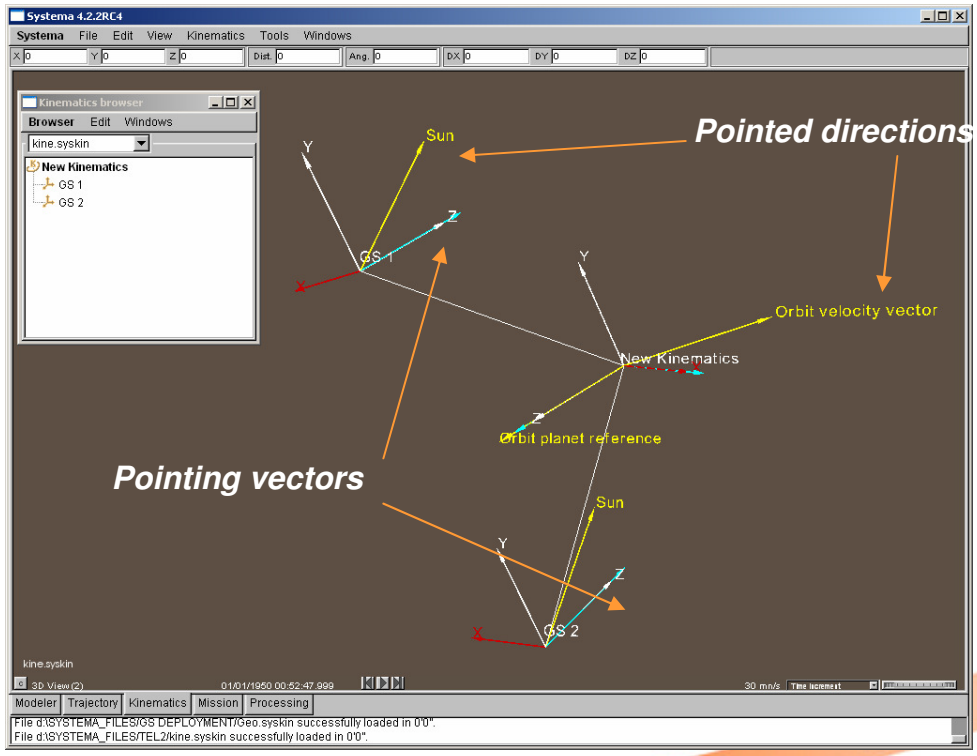
SYSTEMA V4

Kinematics

- Visualisation of the kinematics of bodies
- Animation for pointing validation



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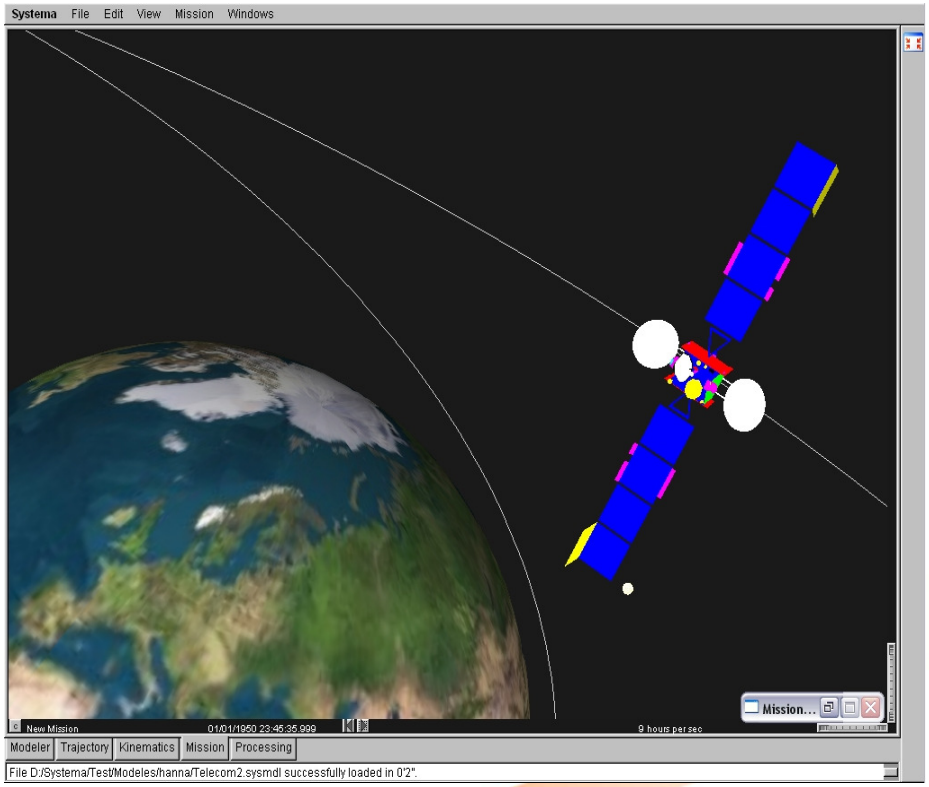
SYSTEMA V4

Mission

- Build your Mission
  - Gather all data
    - ✓Geometry
    - ✓Trajectory
    - ✓Kinematics
    - ✓Link the model / kinematics
  - Set computation points

- Advanced 3D features
  - Planets and Sun
    - ✓Light effects



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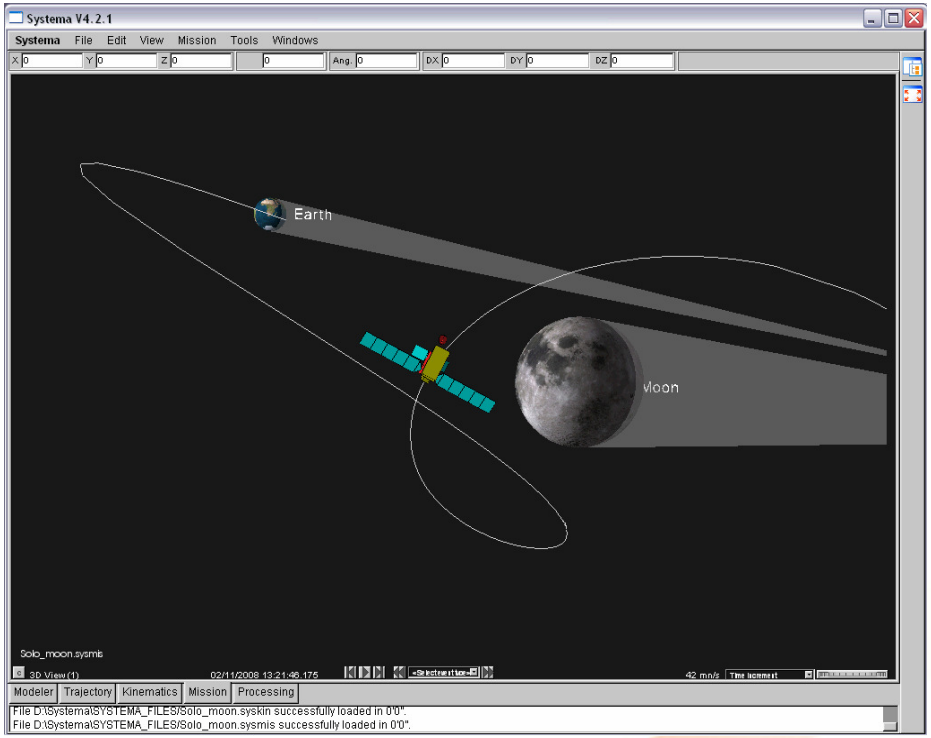
Mission

- 3D animation taking into account
  - Planet orbits
  - Spacecraft trajectory
  - Moving bodies



- Possibility of exporting video
  - Available in a near future

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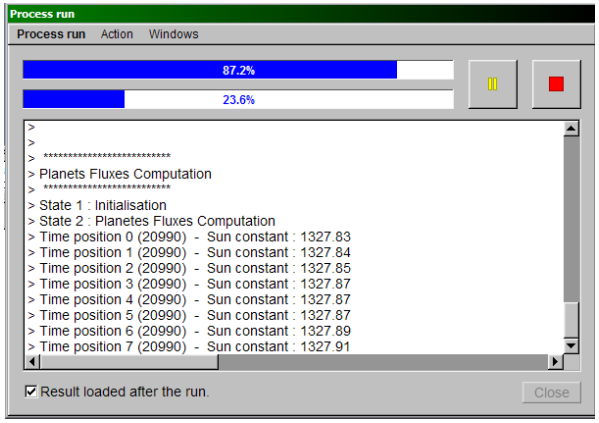
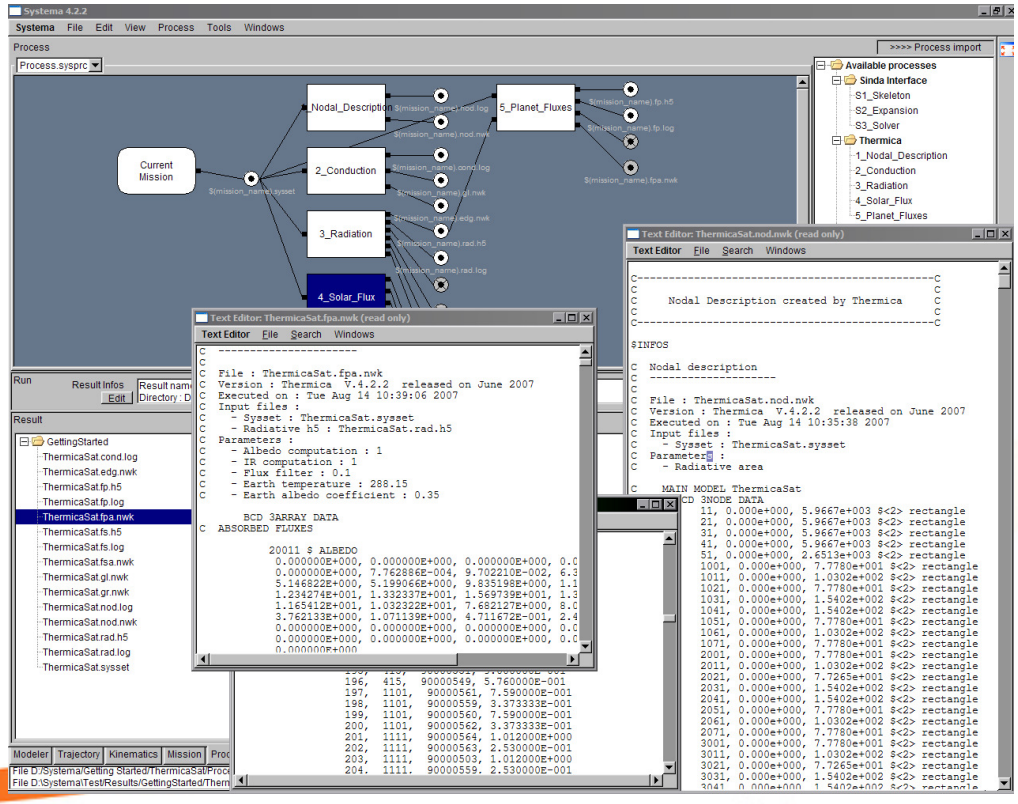
Processing

- Interactive processing
  - Sets the applications and their properties, their input/output files…
  - A processing schematics created
  - Any mission can be chosen from this module
  - Results management





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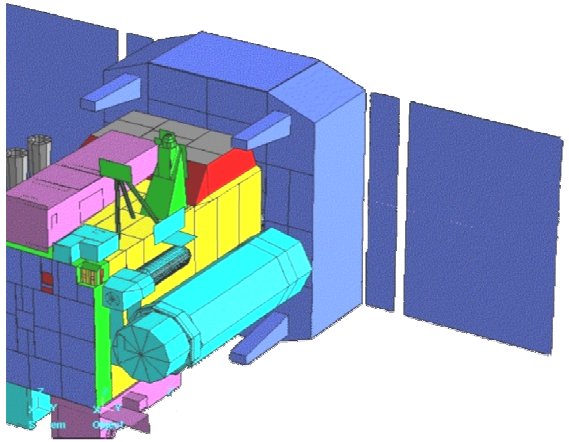
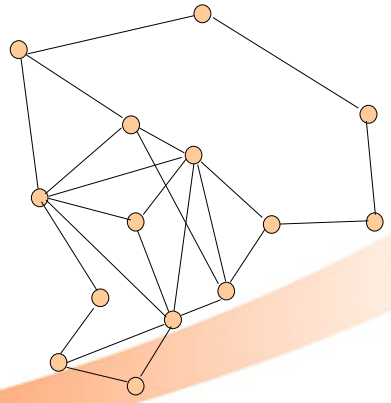
Nodal description

- Nodal method
  - Transformation of the geometrical problem into a network of nodes linked by radiation, conduction and with external conditions



$$\sum_j GL_{i,j}\left(T_j - T_i\right) + \sigma \sum_j GR_{i,j}\left(T_j^4 - T_i^4\right) + P_i = MCp_i \frac{dT_i}{dt}$$



  - Allows the use of a powerful temperature solver
    - ✓Additional modelling can be added to the network (non-geometrical nodes, heat controls, fluid loops…)

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THERMICA V4

Radiation module

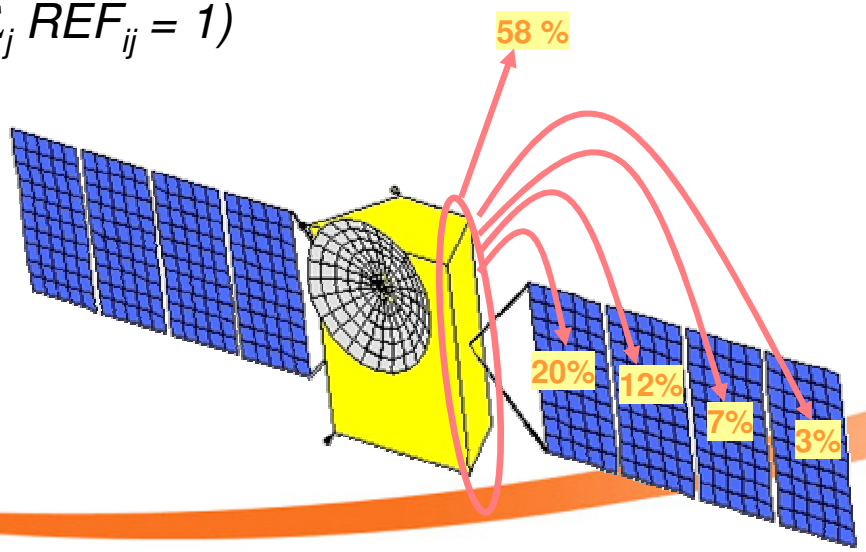
- Distribution of the Energy transmitted by a node

$$E_i = \varepsilon_i S_i \sigma T_i^4 = \left(\Sigma_j REF_{ij} \right) \varepsilon_i S_i \sigma T_i^4$$

WHICH energy is transferred

HOW the energy is transferred

- REF = Radiative Exchange Factor
  Proportion of energy transferred from i to j
  ($\Sigma_j REF_{ij} = 1$)



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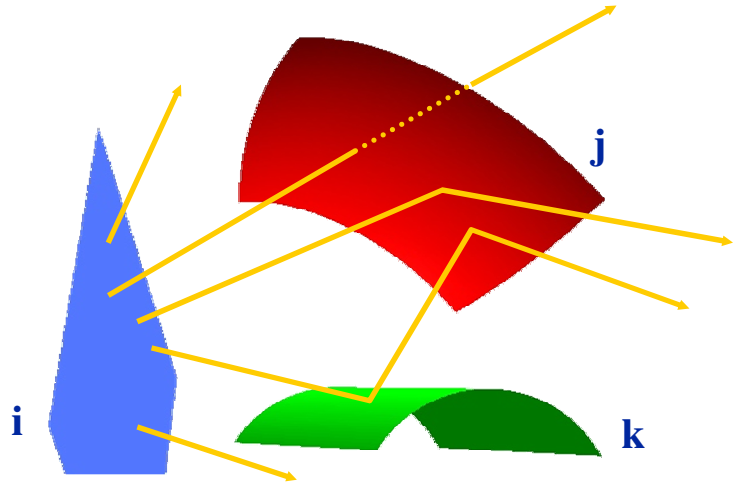
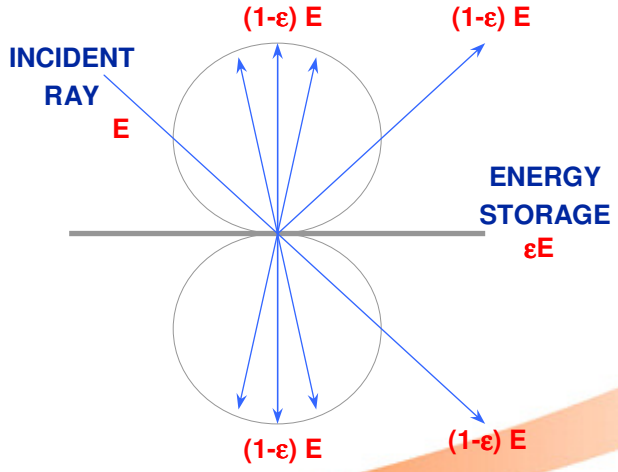
Radiation module (2)

- Monte-Carlo Ray Tracing
  - Accounts for the true geometrical shapes
  - Manages specular and diffusive reflection, transmission and refraction
  - Manages multi-reflection into the model
  - Handle shading effects





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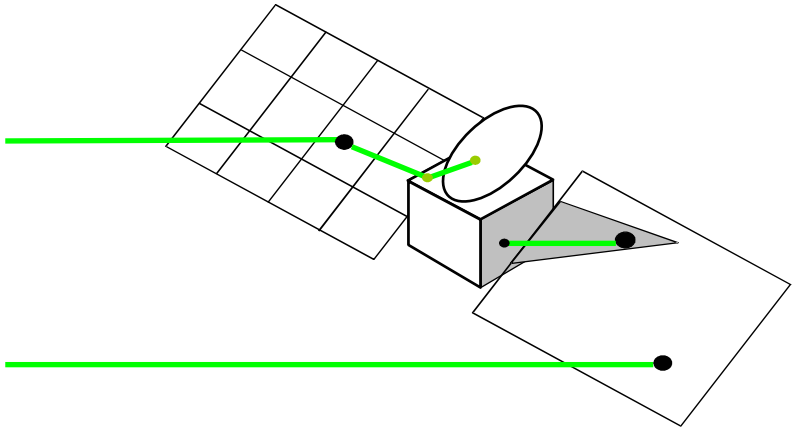
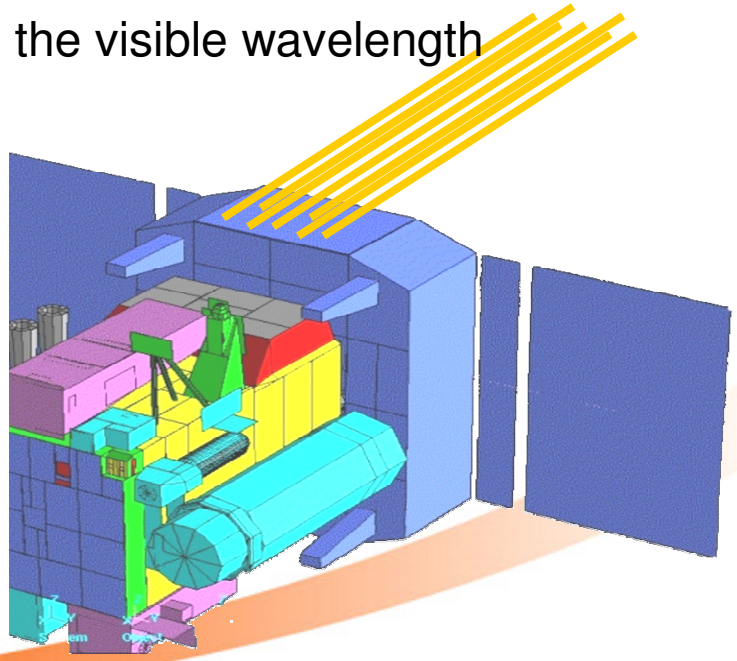
Solar fluxes computation

- A ray-tracing based computation
  - Search for highlight parts of the spacecraft
  - Takes into account planet penumbra effects
  - Propagate the sun incoming flux
    - ✓Use the thermo-optical properties in the visible wavelength





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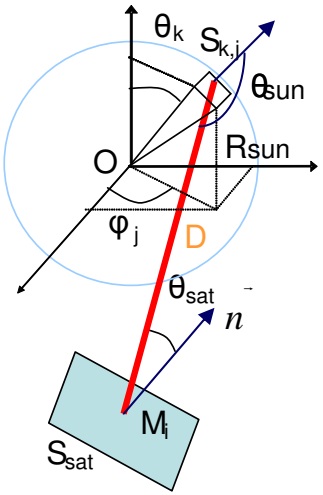
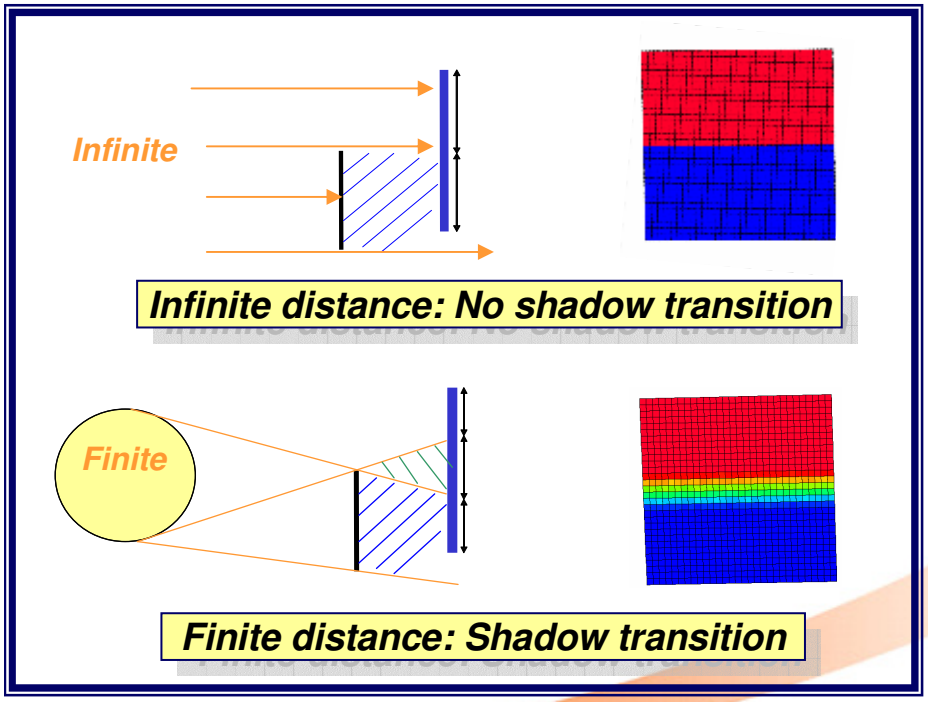
Solar fluxes computation (2)

- Possibility of modelling a Sun at a finite distance



Numerical Integration of Sun at finite distance



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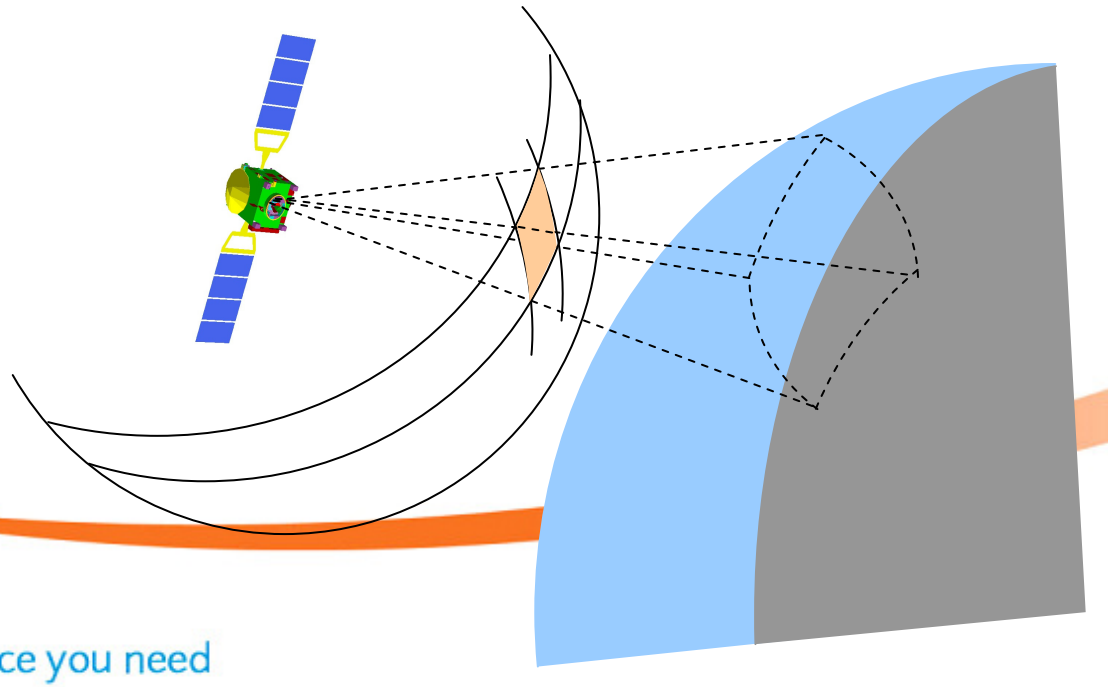
Planet fluxes computation

- Based on the Radiation computation
  - A virtual sphere located at infinity is meshed
  - Exchange factors are evaluated between each surface and each sphere element
  - Radial projection of the sphere mesh to the planet
  - On-ground light ratio is computed for projected meshes



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Conduction modelling

- Conduction problem
  - Usually requires a fine mesh for accuracy
    - ✓But we have to solve the temperature on one nodal network used for radiation, external fluxes and conduction
  - Need a temperature gradient
    - ✓But radiative meshes are supposed to be isothermal
- Implemented method
  - Based on finite elements and Fourier's law integration
  - Manages all SYSTEMA shapes
  - Insure compatibility between radiation and conduction
    - ✓Uses edge nodes to get temperature gradient

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THERMICA V4
SINDA/G Interface

- THERMICA outputs results in SINDA/G language

- A specific interface
  - Manages all the network files created
  - Automatically generates a Sinda/G input file
    - ✓Customization of options, control parameters, solution routines

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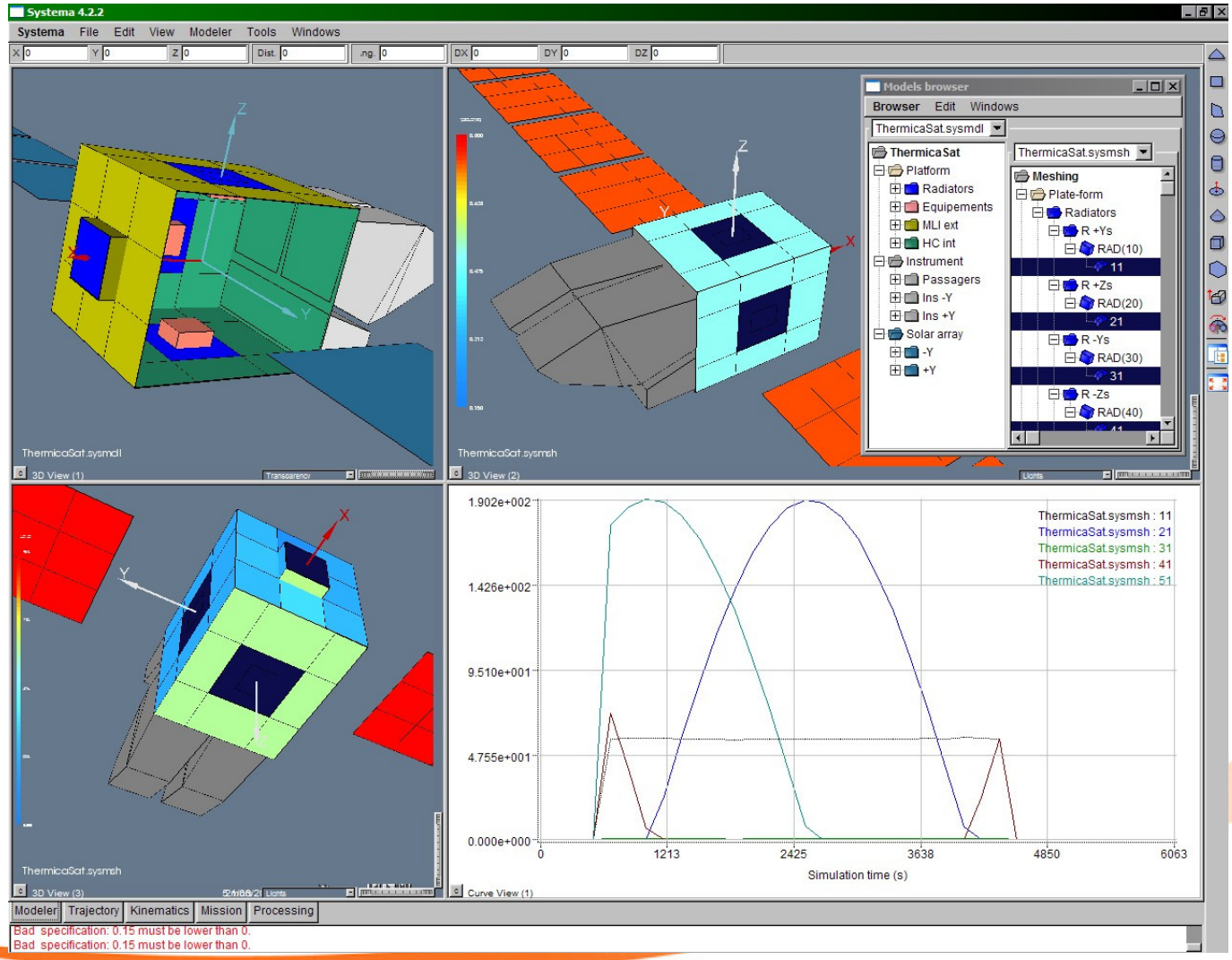
Post-processing: Screenshots (1)



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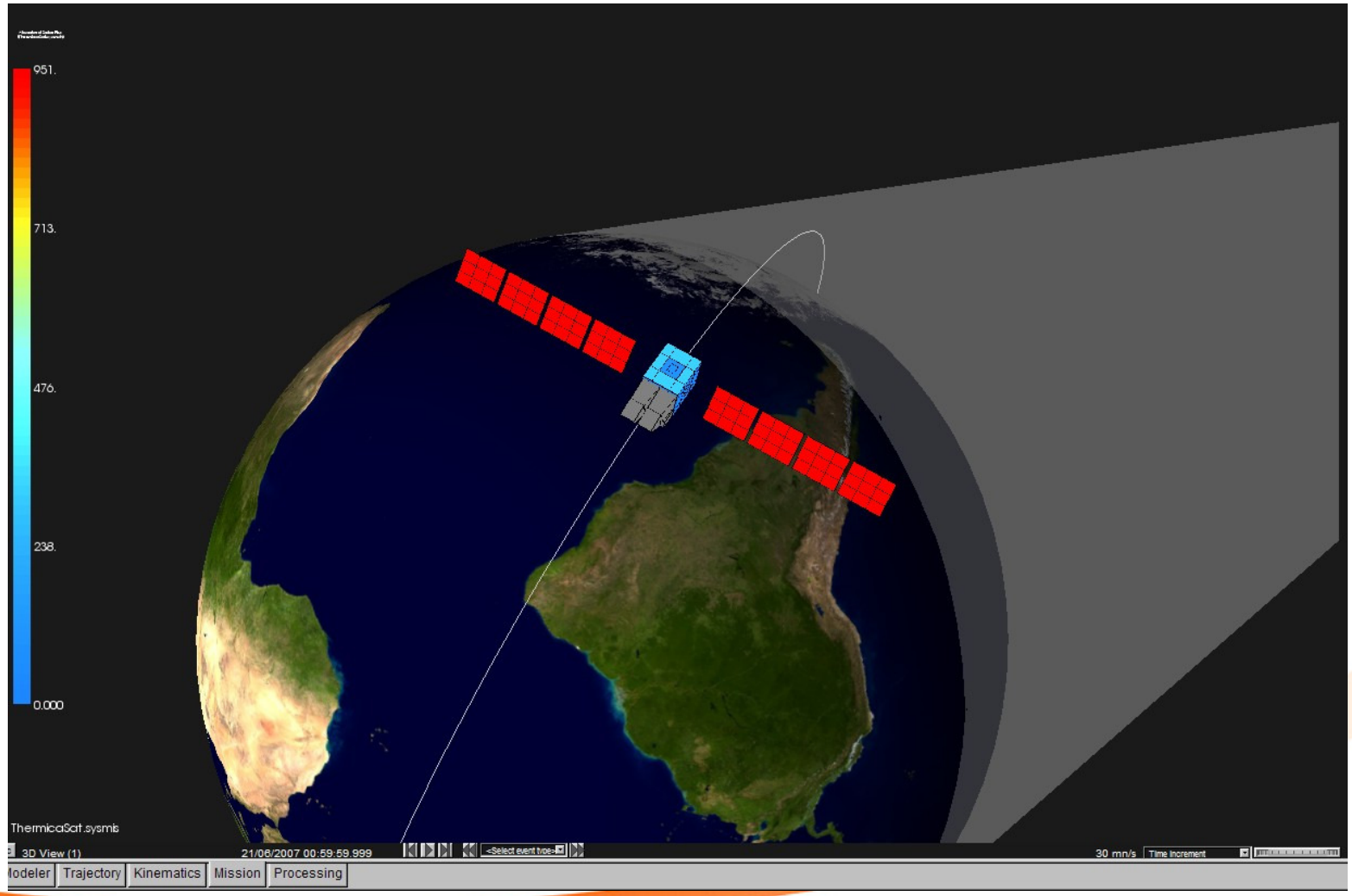
Post-processing: Screenshots (2)



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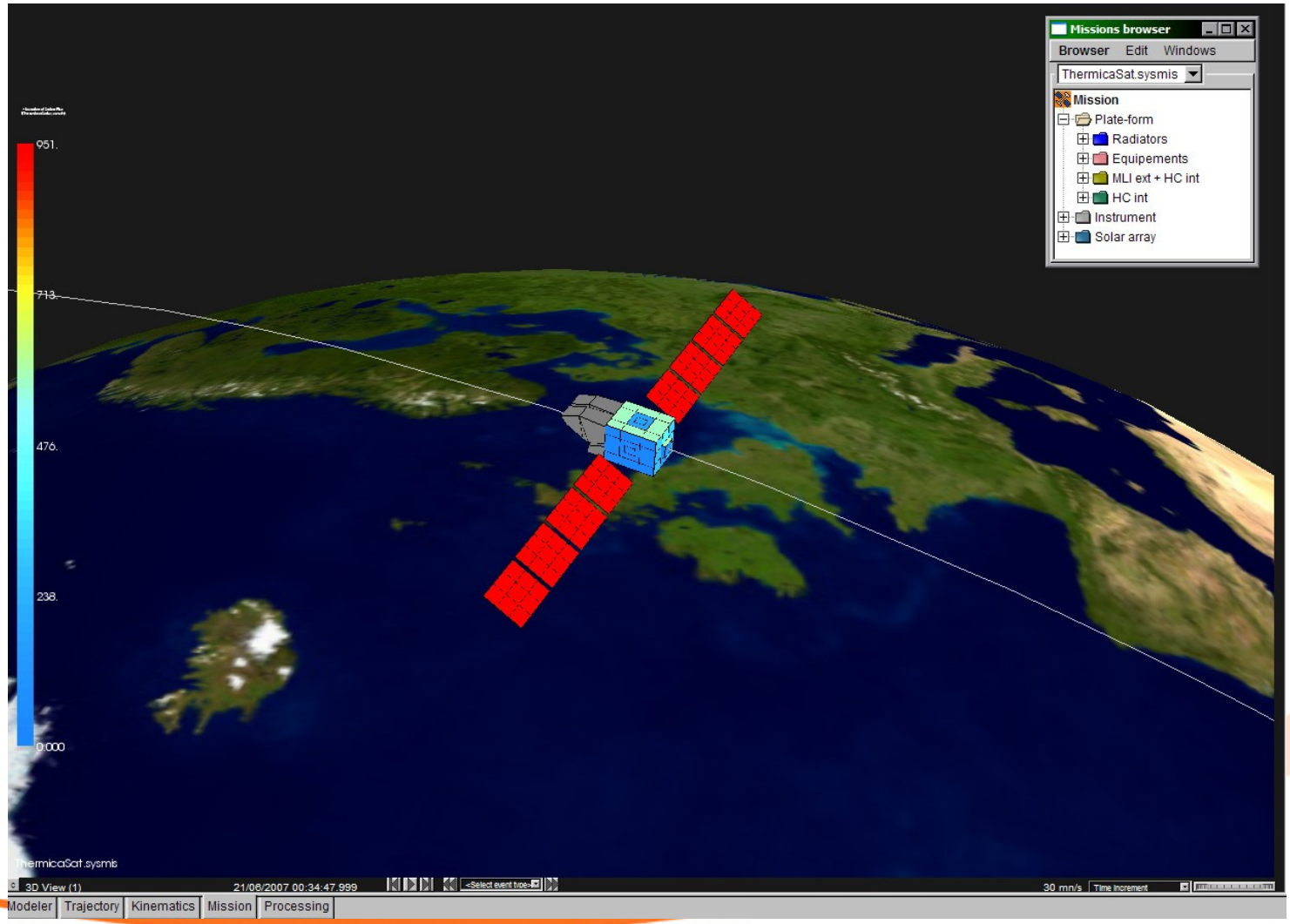
Post-processing: Screenshots (3)



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THERMICA V4

What's coming next

- New GUI Environment (QT)
  - Even more interactivity
  - Advanced viewport management
  - Improved visualization post-processing features
- Boolean cuts
  - Available in the model builder and for all application modules
    - ✓Advanced radiation module
    - ✓Completely new conduction module
- Conduction module
  - Powerful volume elements based module
    - ✓Even more accurate
    - ✓Handle boolean shapes and non-conformance

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THERMICA V4 is Now Available

- For more information
  - http://www.systema.astrium.eads.net
  - http://www.sinda.com

- THERMICA class
  - On Tuesday morning and afternoon, room 113