Appendix K

THERMICA Suite - Complete thermal analysis package

Timothée Soriano
(EADS Astrium, France)

THERMICA Suite

Complete thermal analysis package

Timothée SORIANO, ASTRIUM Satellites

21st European Workshop on Thermal and ECLS Software
30 October 2007

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THERMICA V4

21st Thermal and ECLS Software Workshop

Content

- THERMICA
  - A SYSTEMA V4 Plug-In Application
  - New Conduction Module
- THERMISOL
  - Linked to SYSTEMA v4
  - Recent evolutions
  - Recent projects
- POSTHER
  - A post-processing tool for THERMISOL

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THERMICA

A SYSTEMA V4 Plug-In Application

- Input Model =
  - SYSTEMA v4 geometry
    - Easy model creation
  - + THERMICA properties
    - Inheritance of properties
    - Use of materials
    - New meshing and numbering concepts
  - + SYSTEMA v4 trajectory
    - Interplanetary mission taken into account
  - + SYSTEMA v4 kinematics
    - Easy kinematics creation

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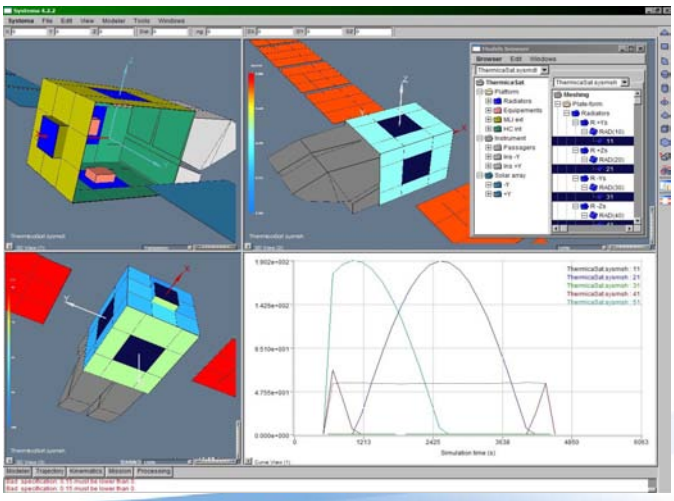
THERMICA

A SYSTEMA V4 Plug-In Application

- Pre and Post-Processing features



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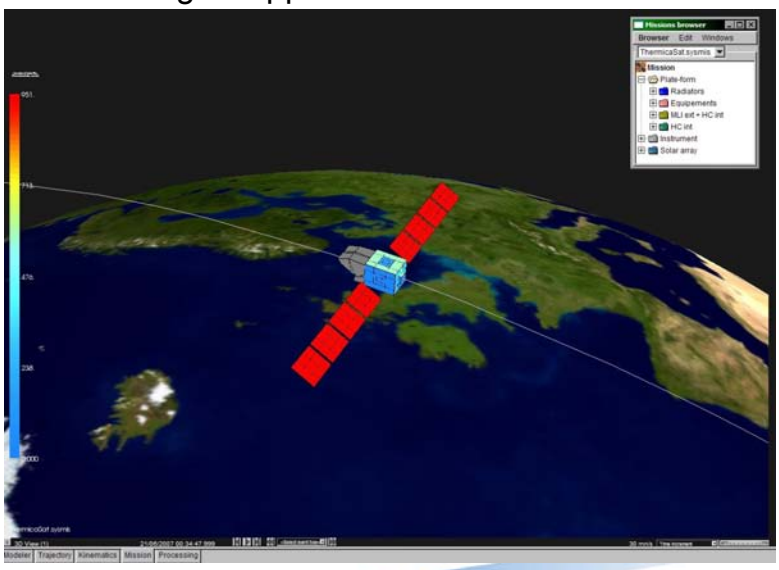
A SYSTEMA V4 Plug-In Application



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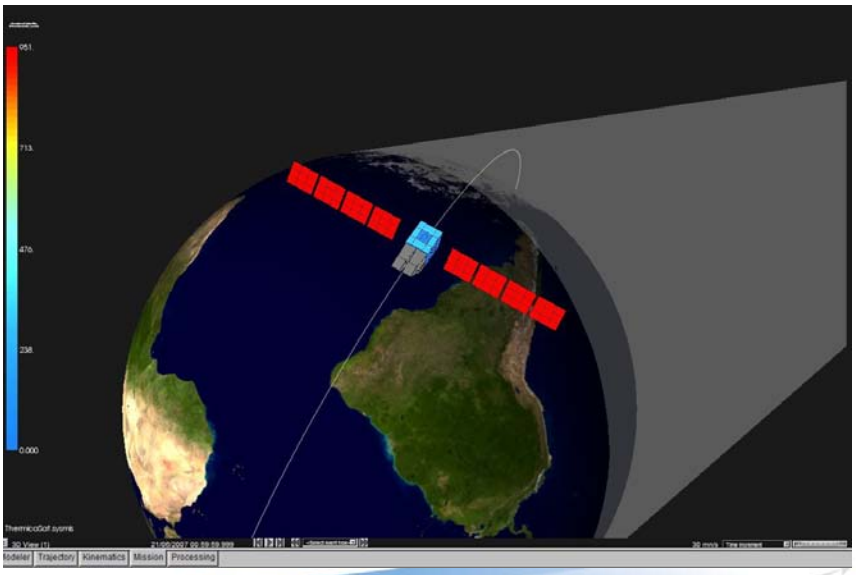

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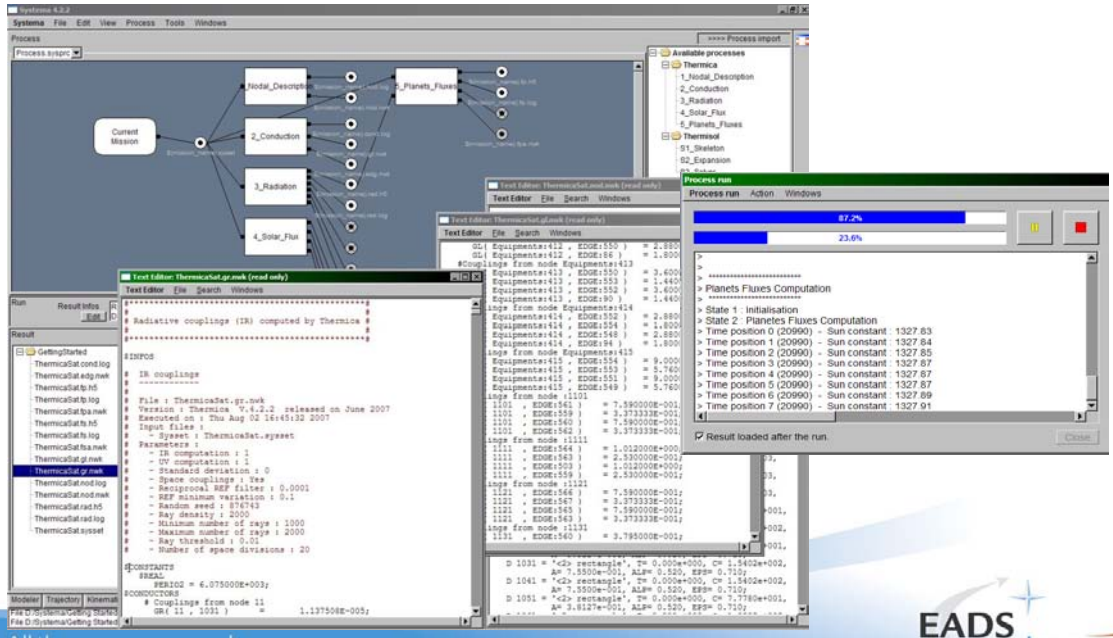
A SYSTEMA V4 Plug-In Application



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THERMICA

A SYSTEMA V4 Plug-In Application

- Open for New Evolutions
  - SYSTEMA V4 platform allows new possibilities to THERMICA
    - Planet Properties
    - Mission Sequences
    - Boolean Shapes
    - New Ray Display
    - … Dual Geometry/Schematic representation

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THERMICA
New Conduction module

- Context
  - History
    - Conduction was added by hand
    - Automatic generation of conductors using empirical formulas
    - Finite Elements method
  - Need for an updated method
    - For non-conformance management (without lose of accuracy)
    - For boolean shapes (to come next year)

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THERMICA
New Conduction module

- Why a new method is needed
  - Finite elements methods are good using a fine mesh…

  … usually much finer than a mesh designed for radiation

  … and we need one set of variables for both radiation and conduction

  - When searching to update the actual finite element method…

  … limitations where found to the FEM

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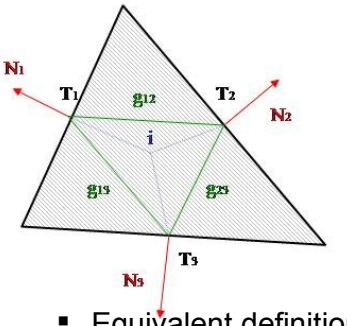
THERMICA

New Conduction module

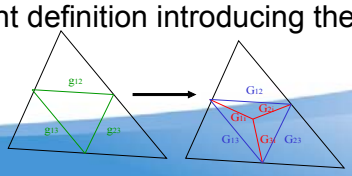
- Review of the Finite Element approach
  - Computation of Edge Couplings using the Fourier's law



$$\int_C e\lambda \nabla T.n \; ds = 0$$

$$\rightarrow \quad q_k = -e.l_k.\lambda.\nabla T.N_k$$

  - Equivalent definition introducing the shape centre



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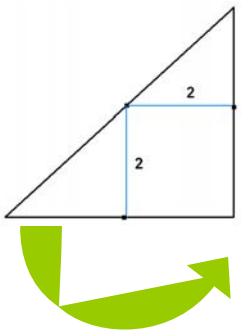
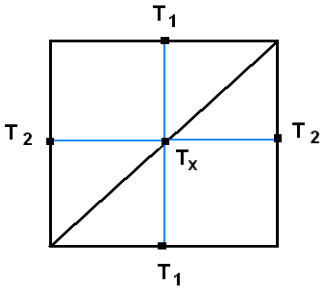
THERMICA

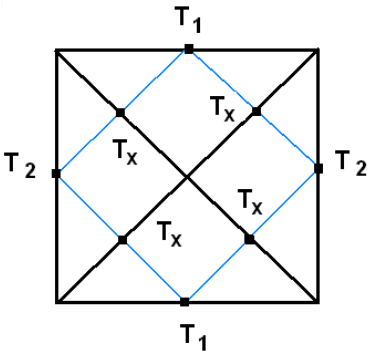
New Conduction module

- Flux computation using the FEM
  - On a non-linear temperature field, calculation of the flux through a border vary depending on the mesh

Because of the piecewise linear temperature prof







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New Conduction module

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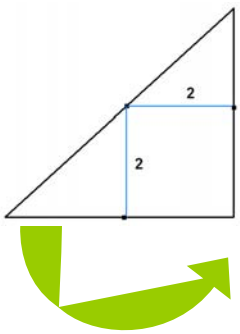

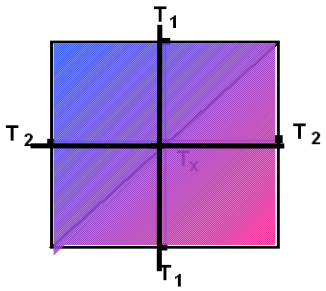

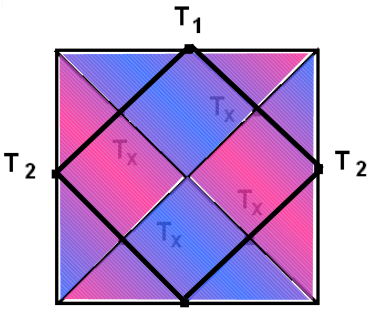

$$Q_2 = GL \cdot \left(\frac{T_1 - T_2}{2}\right) \qquad Q_2' = 2.GL \cdot \left(\frac{T_1 - T_2}{2}\right)$$

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THERMICA

New Conduction module

- The New Module was designed so
  - It is independent from the mesh
  - It guaranties a good flux through edges
  - It has a surface node representing the mean temperature of the surface
  - It can manage non-conformance without approximations
  - It can deal with boolean shapes
- This was given by a **Volume Element** approach

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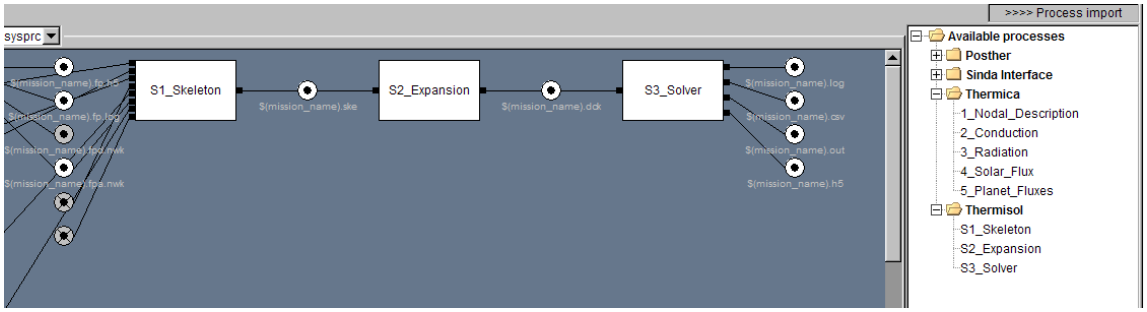
THERMISOL

A SYSTEMA V4 Plug-In Application

- Composed of the three classical modules



- SYSTEMA Post-Processing features are also available

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THERMISOL

Recent Evolutions

- Use of “Constants” and “Locals” paragraphs
  - The “Locals” definitions can be used in the entire Input File
    - No more restricted to declaration paragraphs
    - Do not create GENMOR code (for automatic updates)
    - Cannot be changed
    - **Guaranty a full double precision compatibility**
  - The “Constants” definitions are unchanged from previous version
    - Can be used in the entire input file
    - Generate a GENMOR code for automatic updates
    - Can be updated by the user
    - **Guaranty a full double precision compatibility**

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THERMISOL
Recent Evolutions

- Use of “Variables1” and “Variables2”
  - Status has not always be cleared
    - Does V1 should be called at each iteration of one transient step
    - If V1 is called at the beginning of one time-step and V2 at the end, since the time-steps are solved one after the other, what really makes the difference…
  - But some needs where clearly defined
    - Temperature dependant coefficients, when resolving the implicit part of one time-step, should be updated as the temperature evolutes
    - Time dependant phenomena should be only updated when time varies
- …So, in Thermisol, the scope of V1 and V2 was re-defined as
  - Variables1: Temperature dependant code
  - Variables2: Time dependant code

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THERMISOL
Recent Evolutions

- Variables 1 and 2 optimisations
  - The clear definition of V1 and V2 allows advanced optimizations for more accurate and faster convergence
- Example of call sequence using a Crank-Nicholson scheme

At $t = t^0$
- Update of time dependencies at t^0 (V2 call)
- Update of temperature dependences (V1 call)

→ Evaluation of φ^0

t^n → t^{n+1}

- Update of temperature dependences (V1 call)
  - ♦ *Explicit resolution*
- Update of time dependencies at t^{n+1} (V2 call)
  - ♦ *Implicit resolution loops*
    - Update of temperature dependences (V1 call)
    - → Evaluation of φ^{n+1}
    - Computation of temperatures

$$C . (T^{n+1} – T^n) = \Delta t . (\varphi^n + \varphi^{n+1}) / 2$$

Call to V2 not at the end but at the middle of one time step

Calls to V1 to update temperature data

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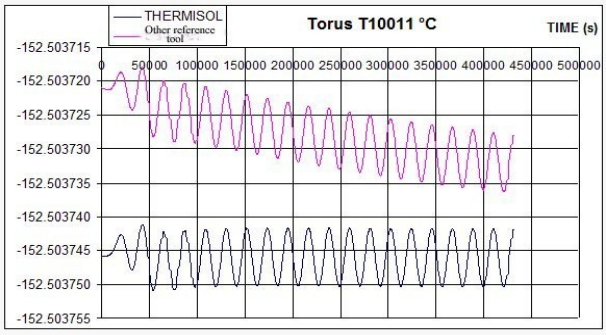
THERMISOL
Recent Projects

- GAIA
  - Steady-State convergence reached micro-Kelvin



  - … but at first, it needed more than 40.000 iterations
  - With the newly V1 optimisations, it converged in less than 2.000 iterations

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THERMISOL
Recent Projects

- COMS
  - Ability to manage very large models
    - Newly updates of Thermisol suppress limitations on the number of variables to be used or on the number of variable couplings
    - On the COMS projects, tests were made using more than a million variables and more than a million variable couplings

Thanks to more extensive use on different projects
THERMISOL evolutes to converge faster and more accurately

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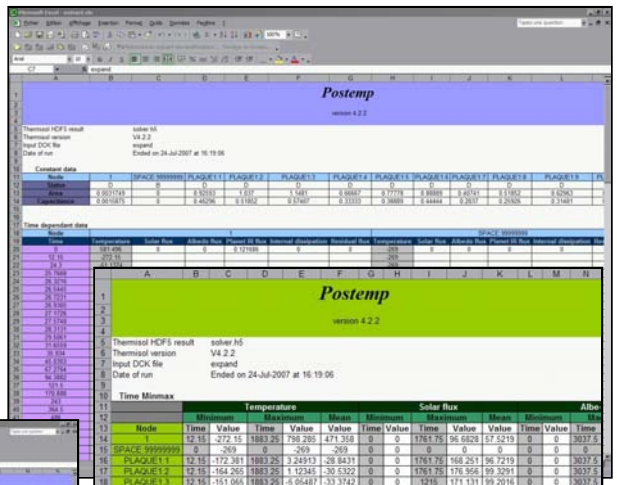
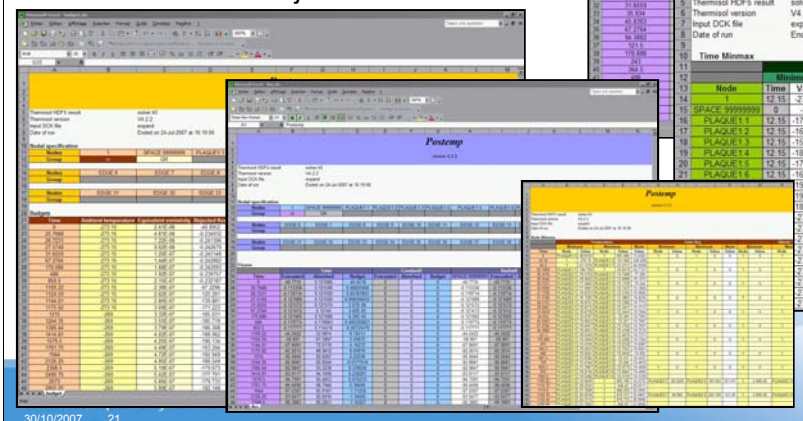
POSTHER

Post-Processing Tool for Thermal Results

- Generates Excel files
  - Extracts data from results
  - Performs Min/Max analysis over nodes
  - Performs Min/Max analysis over times
  - Gives Flux balances
  - Exports Ambient Temperature, Equivalent emissivity, Rejected flux and Thermal rejection





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THERMICA

THERMISOL

Visit our new Web site:

http://www.systema.astrium.eads.net

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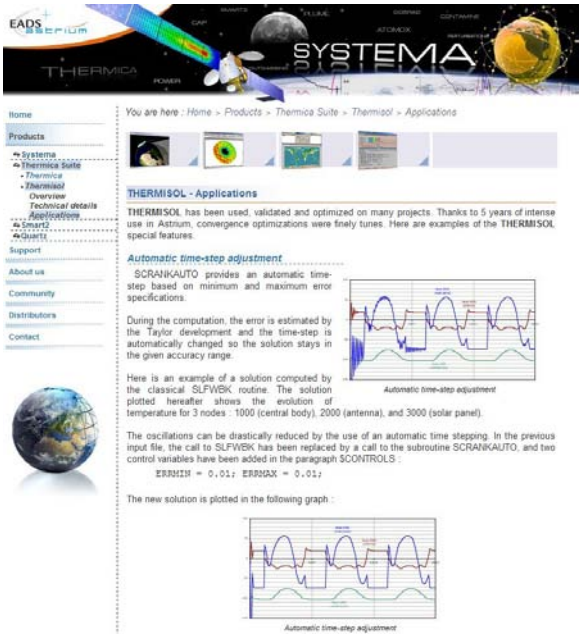

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