

Appendix K

THERMICA Suite - Complete thermal analysis package

Timothée Soriano
(EADS Astrium, France)

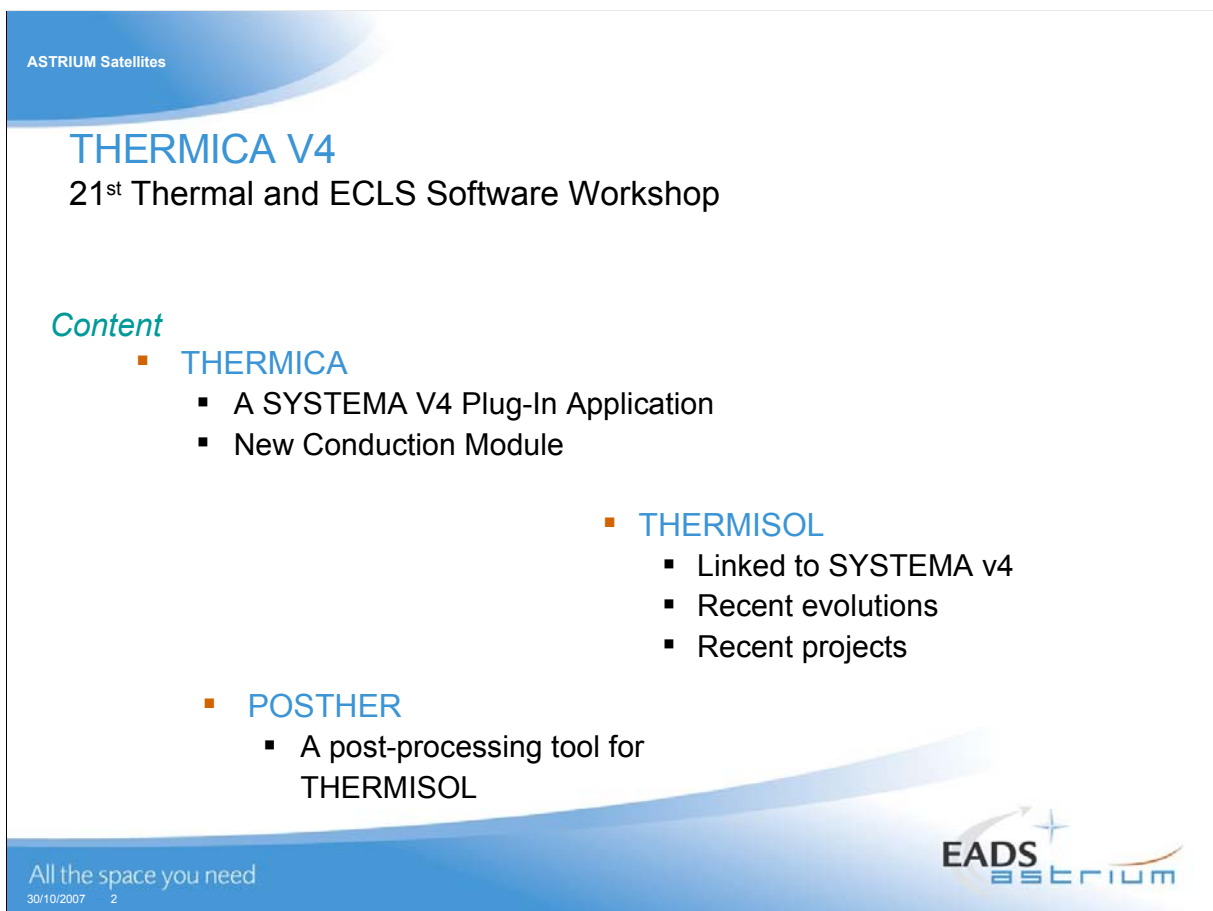


THERMICA Suite
Complete thermal analysis package

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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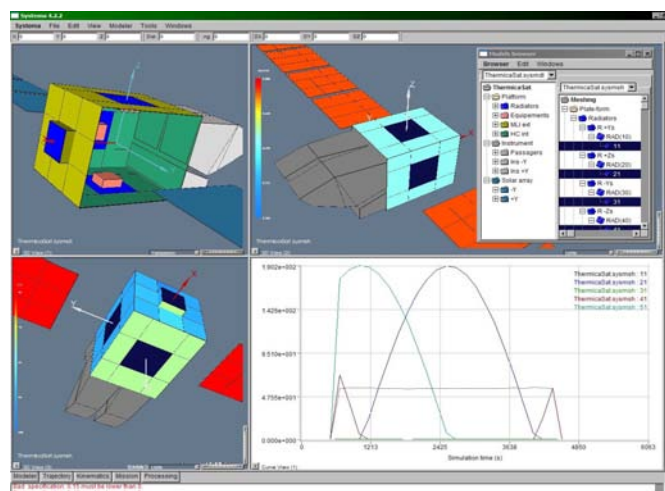


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THERMICA

A SYSTEMA V4 Plug-In Application

- **Pre and Post-Processing features**



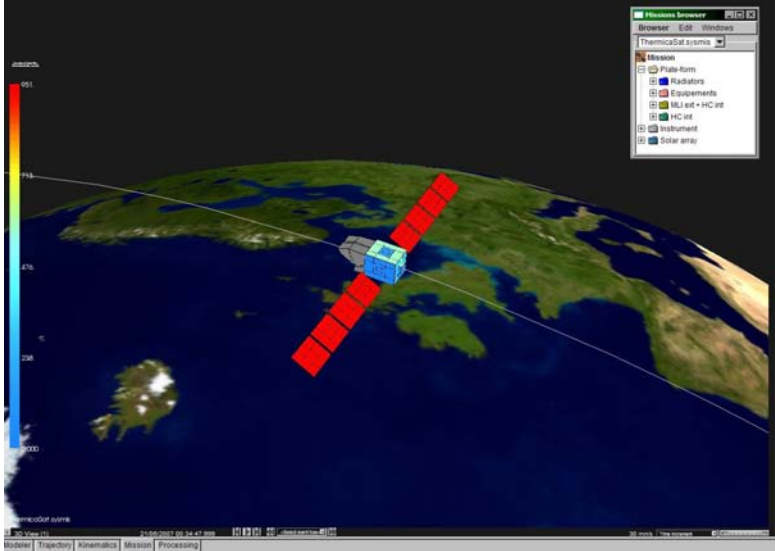
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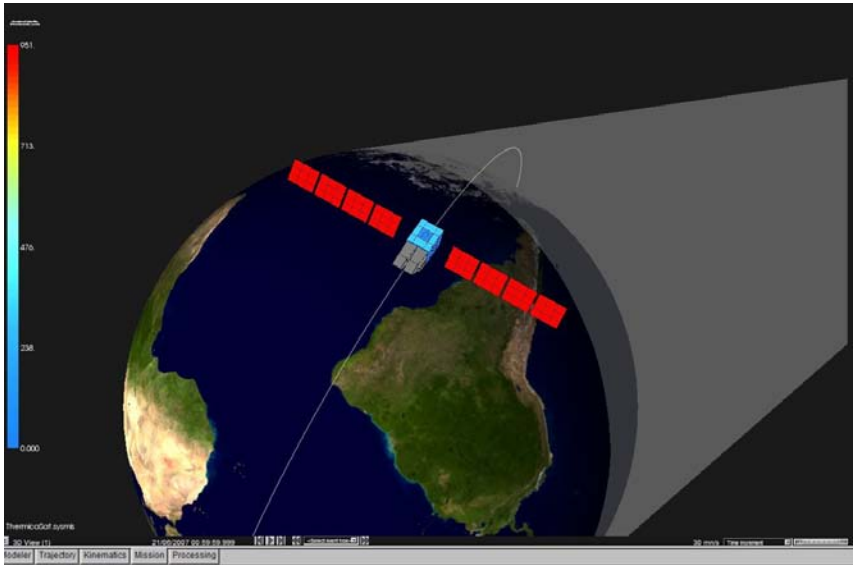
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A SYSTEMA V4 Plug-In Application



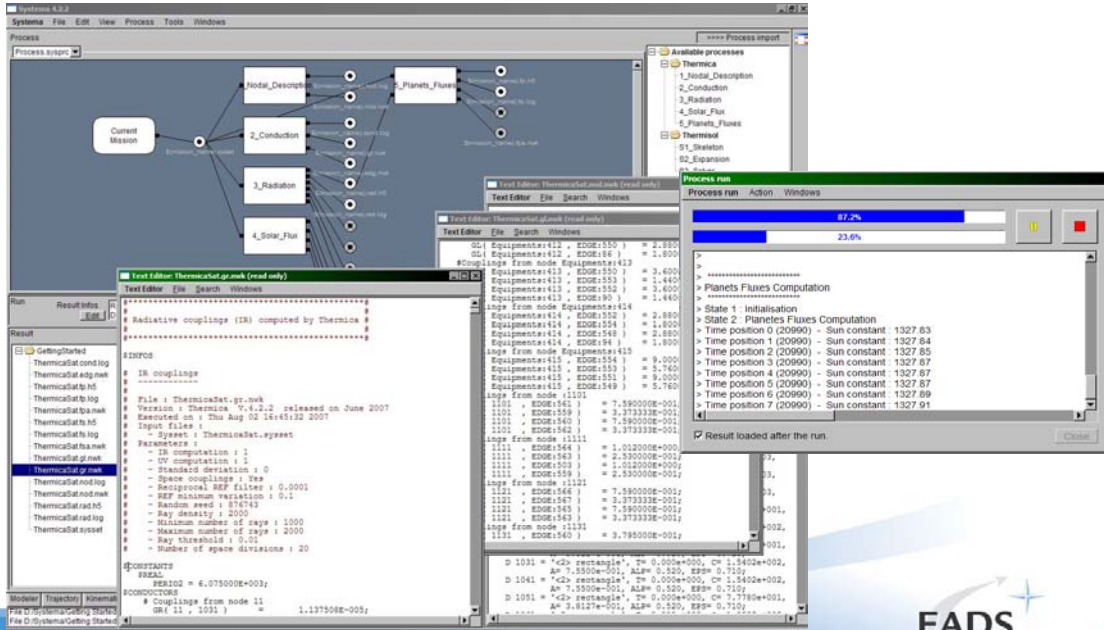
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THERMICA

A SYSTEMA V4 Plug-In Application



The screenshot displays the THERMICA software interface within the SYSTEMA V4 environment. The main window shows a process flow diagram with nodes like 'Current Mission', '2_Conduction', '3_Radiation', and '4_Solar_Flux'. A 'Process run' window is open, showing progress bars for 'Thermica' (87.2%) and 'Thermosol' (23.6%). A 'Text Editor' window displays code for 'ThermicaSat.gr.nmk', including parameters and simulation settings. The bottom left corner features the text 'All the space you need' and the date '30/10/2007'.

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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

The bottom left corner features the text 'All the space you need' and the date '30/10/2007'.

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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

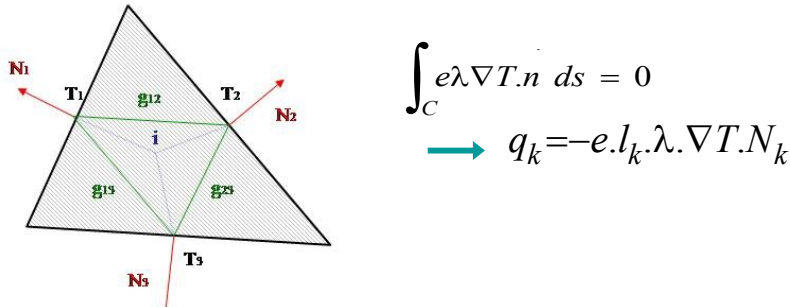
- **Why a new method is needed**
 - Finite elements methods are good using a fine mesh...
... usually much finer than a mesh designed for radiation
... and we need one set of variables for both radiation and conduction
 - When searching to update the actual finite element method...
... limitations where found to the FEM

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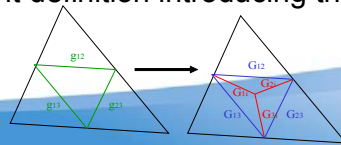
THERMICA

New Conduction module

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



- Equivalent definition introducing the shape centre

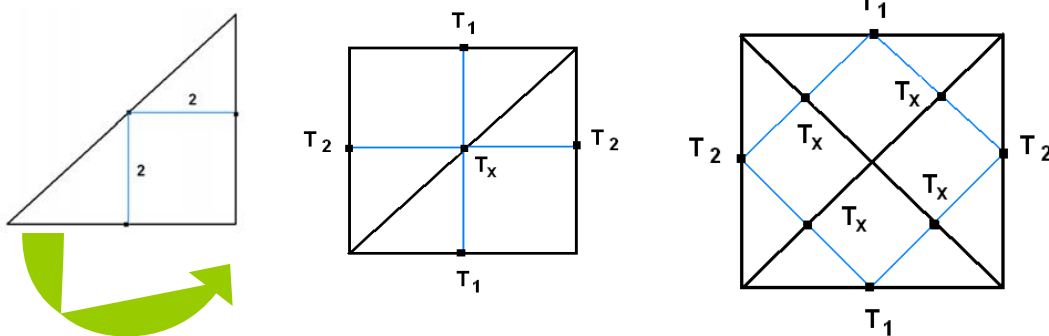


THERMICA

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



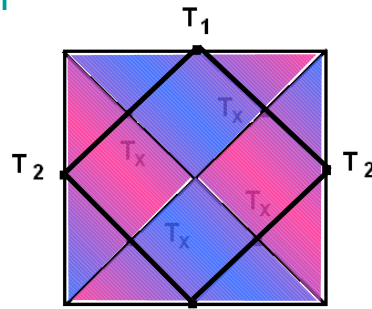
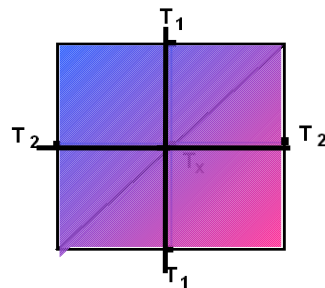
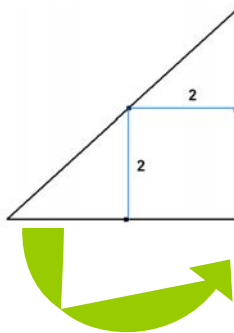
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THERMICA

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



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

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

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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 evolves
 - 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

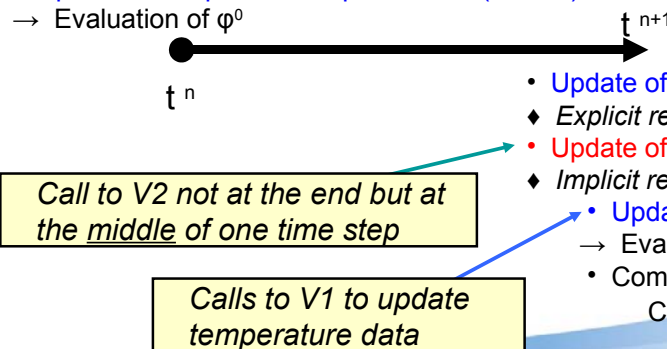
Recent Evolutions

- 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


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

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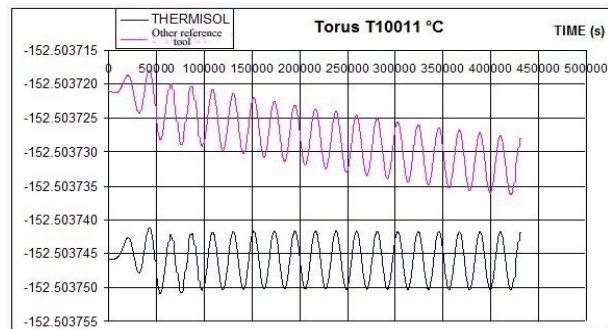
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THERMISOL

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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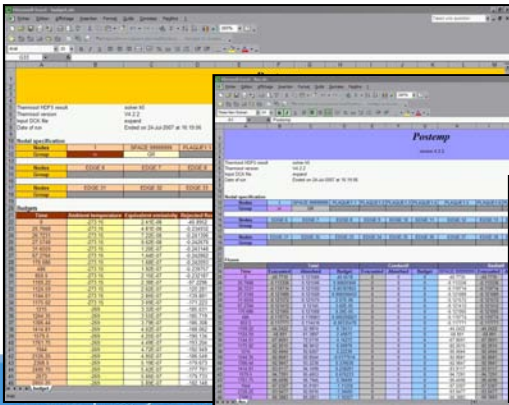
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POSTHER

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



Postemp version 4.2.2

Thermal HCF result solver h5
Thermal version V4.2.2
Input DOK file expand
Date of run Ended on 24-Jul-2007 at 16:19:06

Node	SPACE	PLAQUET1	PLAQUET2	PLAQUET3	PLAQUET4	PLAQUET5	PLAQUET6	PLAQUET7	PLAQUET8	PLAQUET9	PLAQUET10	PLAQUET11
Area	0.0001741	0	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002

Time Minimax

Time	Value	Time	Value	Time	Value	Time	Value	Time	Value	Time	Value	Time	Value
12.15	472.15	1883.25	798.265	471.358	0	1761.75	96.6828	57.5219	0	0	0	0	3037.5

Thermal HCF result solver h5
Thermal version V4.2.2
Input DOK file expand
Date of run Ended on 24-Jul-2007 at 16:19:06

Node	Time	Value	Time	Value	Time	Value	Time	Value	Time	Value	Time	Value
1	12.15	472.15	1883.25	798.265	471.358	0	1761.75	96.6828	57.5219	0	0	3037.5



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THERMICA THERMISOL

Visit our new Web site:
<http://www.systema.astrium.eads.net>

Contact:
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THERMISOL - Applications

THERMISOL has been used, validated and optimized on many projects. Thanks to 5 years of intense use in Astrium, convergence optimizations were finely tuned. Here are examples of the THERMISOL special features.

Automatic time-step adjustment

SCRANKAUTO provides an automatic time-step based on minimum and maximum error specifications.

During the computation, the error is estimated by the Taylor development and the time-step is automatically changed so the solution stays in the given accuracy range.

Here is an example of a solution computed by the classical SLFWBK routine. The solution plotted hereafter shows the evolution of temperature for 3 nodes : 1000 (central body), 2000 (antenna), and 3000 (solar panel).

The oscillations can be drastically reduced by the use of an automatic time stepping. In the previous input file, the call to SLFWBK has been replaced by a call to the subroutine SCRANKAUTO, and two control variables have been added in the paragraph \$CONTROLS:

ERRMIN = 0.01; ERRMAX = 0.01;

The new solution is plotted in the following graph:

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