

4.9.4

Applicable User Manual: v4.9

Major features:

Emission source module

A new Emission Source module is available. This module enhances the simulation of satellite testing by accurately modeling the UV and IR fluxes from UV/IR lamps and their absorption at various geometrical nodes of the model. This capability facilitates the preparation and optimization of physical tests, leading to more precise and effective evaluations.

This module is designed to fully replace the "Solar Lamp" specific item, whose outputs are generated by the Nodal Description module. Although the "Solar Lamp" specific item has been retained for compatibility reasons, it is highly recommended to use the Emission Source module now, as it offers at least the same capabilities and even more due to additional functionalities and fewer limitations. Additionally, this is a standalone module, which allows the generation of various dedicated output files such as .nwk, .h5 and files for ray visualization. The Emission Source module operates with a new specific item named "Point Source", which enables the placement of UV/IR lamps on the surfaces of the model.

Below is a table summarizing the differences between the capabilities of the "Solar Lamp" and the new "Emission Source" module:

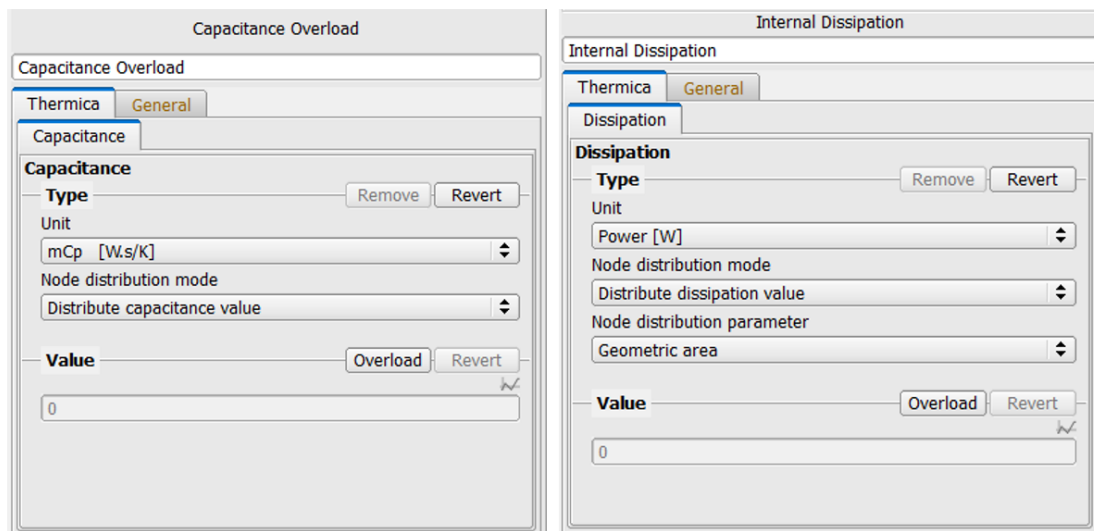
Feature	Solar Lamp specific item	Emission source module
Multiple lamp simulation	Not supported	Supported
Dual emission capability (UV & IR)	Either UV or IR	UV, IR or both UV and IR simultaneously
Parametric flux definition	Not available	Available in .nwk file
Versatile ray tracing	Ray emission in normal direction only	Ray emission in all directions (Lambert's law) or normal direction
3D ray visualization	Not available	Supported
Data Storage	fluxes in nwk file	fluxes in nwk file fluxes and couplings in h5 file
Time-Dependent emitted flux (user input)	Not available	Supported (only in the .nwk output, not in the emi.h5 file)

To learn more about this new module, refer to the Thermica user manual.

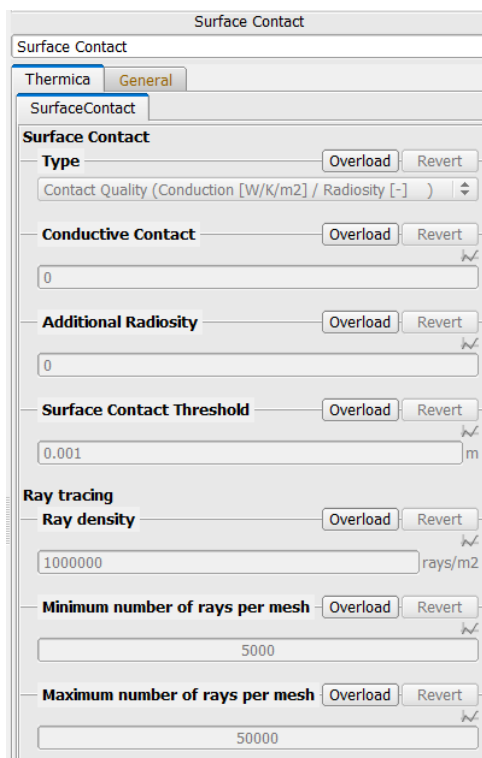
Minor features:

Specific item

- It is now possible to distribute the value of capacitance overload or internal dissipation to all selected nodes instead of duplicating it. For internal dissipation, an option is available to distribute the value in proportion to node geometric area or capacitance. For capacitance overload, the value is always distributed in proportion to node geometric area. See Thermica User Manual for more details.

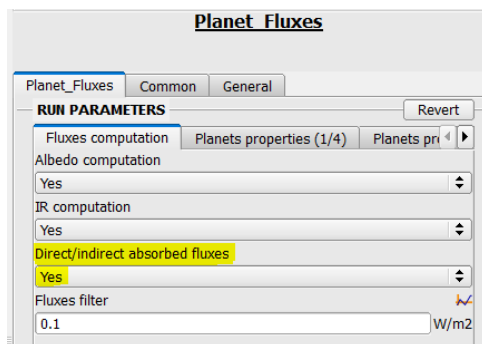


- Surface contact: it is now possible to choose the number of rays fired to calculate the contact area. Until version 4.9.3, a fixed number of rays was fired per mesh (50 rays in each direction), regardless of mesh size. From version 4.9.4, ray tracing is performed using an iso distribution law and a user specified ray density. The number of rays fired from each mesh is calculated from the density and the mesh area, but is nevertheless limited between a minimum and a maximum value, also chosen by the user.



Planet Fluxes module

- It is now possible to compute and export direct and indirect absorbed fluxes (albedo and infra-red fluxes). This option is available in the processing tab, by editing the Planet_Fluxes box.

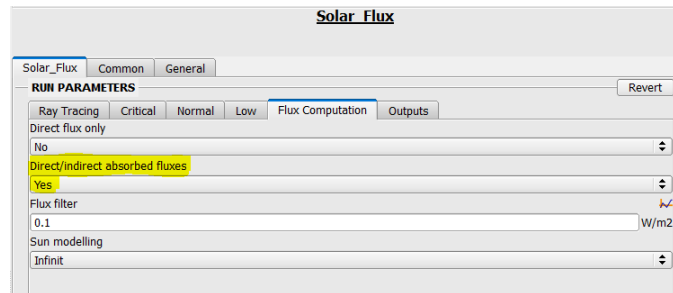


If set to yes, the direct and indirect absorbed planet fluxes are exported only to the h5 file, not to the nwk file. The direct/indirect albedo and infra-red fluxes are calculated only if the albedo and IR computation are enabled respectively.

- An option has been added to improve faraway planet fluxes computation results. This option is called "Exhaustive contribution from the Box". If set to "No", the legacy optimizations are used to filter the flux directions that have no contribution.

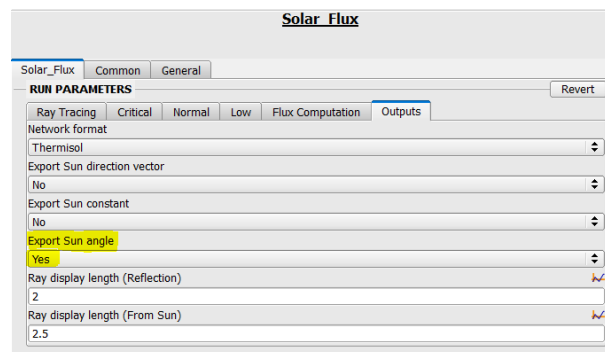
Solar Flux module

- It is now possible to compute and export direct and indirect absorbed fluxes. This option is available in the processing tab, by editing the Solar_Flux box.



If set to yes, the direct and indirect absorbed solar fluxes are exported only to the h5 file, not to the nwk file. The option “direct/indirect fluxes” is available only if the option “direct flux only” is set to no.

- It is also possible to export the sun angle value (angle between the normal of node and the sun direction vector) in the sf.nwk file. This option is available in the processing tab, by editing the Solar_Flux box.



If set to yes, it exports the sun angle in degrees for each node and at each computation time. It is stored in arrays named SANGXXX where XXX is the node number. In addition, a new entity "SA" is available to access the sun angle for each node at each time step of a transient computation performed by the solver Thermisol. The sun angle value can then be used as an entry of Thermisol in the dck file. Note that the sun angle is not calculated in eclipse and equals to -360.0°. The sun angle export is not supported for fast spin kinematic bodies (in that case, the angle equals to -360.0°).

Modifications:

- Fixed a bug in the calculation of surface contacts in a model containing moving bodies.
- Fixed a bug on extruded polygon cutters in a model containing moving bodies.

- Change default value for thermal expansion in the cavities specific item definition (cavity by sphere and cavity by rectangle)
- Fixed a ray-tracing bug in very specific cases where rays bounced off cutters instead of passing through them.
- Improved HDF5 ray storage performance.
- The limit on the number of Surface Contacts that can be applied to the same node has been raised from 10 to 100.
- Issue with thermostat defined for non-geometrical nodes fixed in Nodal description module.
- Updated the release (20041227) of the NRLMSISE-00 atmosphere model used in AeroFlux.
- Fixed the projection function used by AeroFlux for the calculation of the longitude and latitude inputs of the NRLMSISE-00 atmosphere model.
- Improved reemission rate precision for Quasi Monte-Carlo methods used in Radiation and Solar Flux modules.

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Modifications:

- Fixed a bug where changing the absorptivity value had an impact on Earth IR absorbed power.
- Improve the sphere discretization so that ray-tracing always gives the right results even when the voxels are very small.
- Eliminate some difference in results between Windows and Linux. When the remaining energy of a ray after a few bounces was exactly equal to the ray threshold, this generated small differences in the calculation of fluxes between Windows and Linux.
- Increased precision of geometrical position and normal export in nodal description output
- Fixed a bug that caused wrong nodes to be selected on a specific item after reopening the meshing.
- Fixed a bug that caused an internal dissipaton to be divided by 2 when it should not have been.
- Fixed bugs on conduction with volumes: the conduction calculation on cone was not correct, some GL were missing when using the simplified RCN method, GL on a sphere were not symmetrical with RCN method.

- It is now possible to deactivate the h5 output of Solar Flux module in the processing. This does not improve calculation time but it can save storage space.
- Defensive code added to prevent division by zero in the conduction module causing NaN values in Thermisol.

4.9.2P2

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Modifications:

- Fixed a bug in the calculation of surface contacts in a model containing moving bodies.
- Fixed a bug where changing the absorptivity value had an impact on Earth IR absorbed power.
- Fixed a bug on extruded polygon cutters in a model containing moving bodies.
- Change default value for thermal expansion in the cavities specific item definition (cavity by sphere and cavity by rectangle)
- Fixed a ray-tracing bug in very specific cases where rays bounced off cutters instead of passing through them.
- The limit on the number of Surface Contacts that can be applied to the same node has been raised from 10 to 100.
- Eliminate some difference in results between Windows and Linux. When the remaining energy of a ray after a few bounces was exactly equal to the ray threshold, this generated small differences in the calculation of fluxes between Windows and Linux.
- Issue with thermostat defined for non-geometrical nodes fixed in Nodal description module.

4.9.2P1

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Modifications:

- Increased precision of geometrical positions and normals export in nodal description output
- Improvement of the computation of GLs for spheres when using the simplified RCN method

4.9.2

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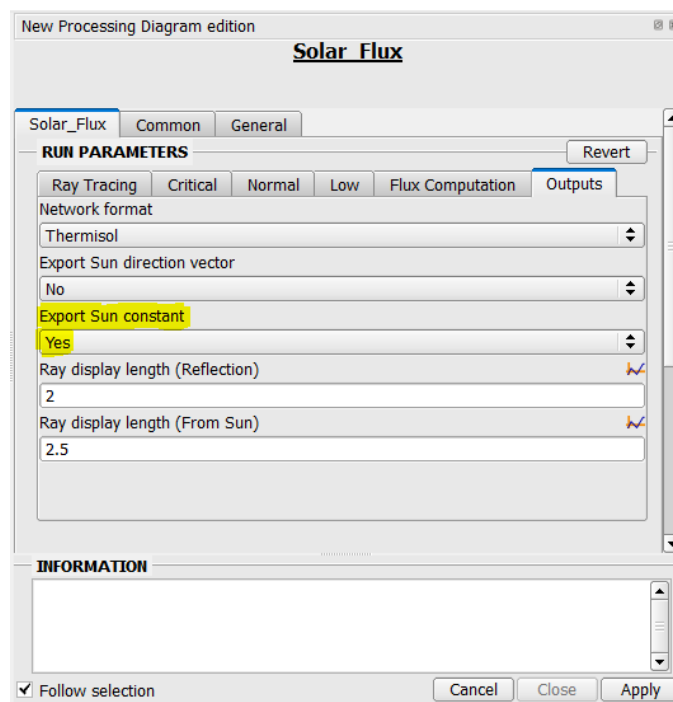
Major features:

- A new specific item called Solar Lamp is now available. It allows to model a source of UV or IR emission. See Thermica User Manual for more details.

Minor features:

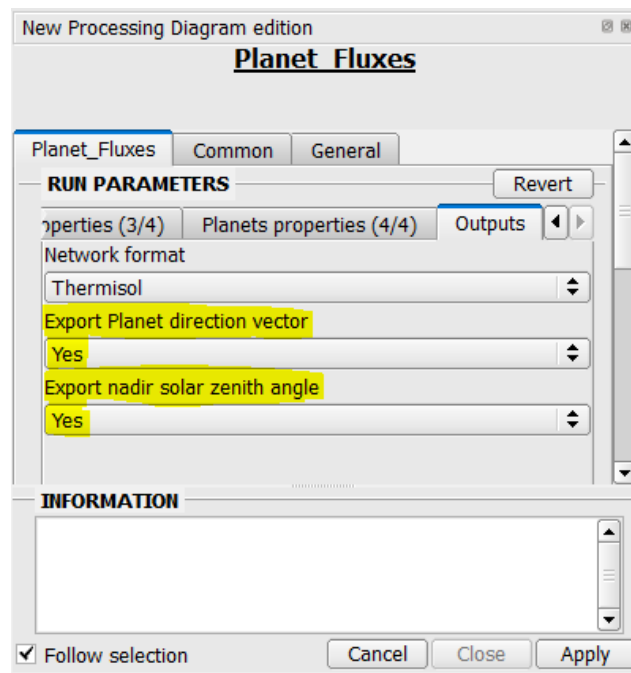
Solar Flux module

- It is now possible to export the Solar Constant value at each computation point in the .sf.nwk file. This option is available in the processing tab, by editing the Solar_Flux box. The Solar Constant value can then be used as an entry of Thermisol in the dck file.



Planet Fluxes module

- It is now possible to export the Solar Zenith Angle (SZA) value at each computation point in the .pf.nwk file. This option is available in the processing tab, by editing the Planet_Fluxes box. The SZA value can then be used as an entry of Thermisol in the dck file. The Solar Zenith Angle is defined as the angle between the Planet to Spacecraft vector and the Spacecraft to Sun vector. This option is available only for Thermisol output format.
- It is also possible to export the Planet direction vector at each computation point and for each active planet of the mission in the .pf.nwk file. This option is available in the processing tab, by editing the Planet_Fluxes box.

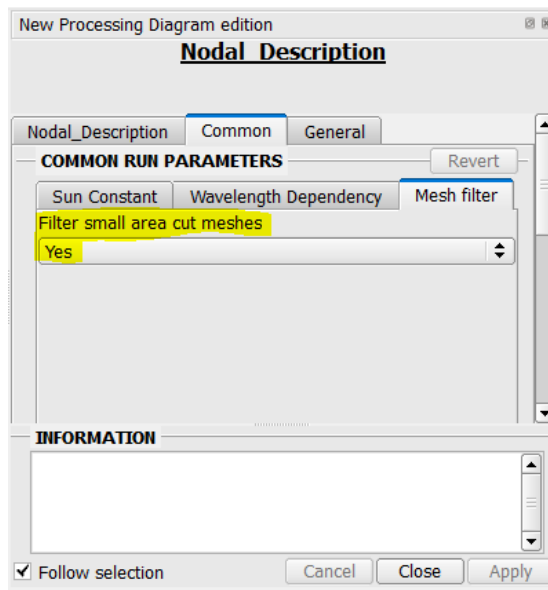


Nodal Description module

- Adding an option in Radiation module (in Outputs tab) to export geometrical positions and normal vectors (FX, FY, FZ, NX, NY, NZ) in H5 file. If option is activated it will create a new table in "Entries": "Thermal nodes positions". The option is de-activated by default and this additional table is not created, this ensure the retro-compatibility.

All modules

- An option is now available to disable the filtering of meshes partially cut by a cutter and whose resulting area is very small. By default, the filtering is activated to be compliant with the behavior of the previous versions. When the filtering is activated, a partially cut mesh is filtered when its resulting area is lower than 0.1% of the initial mesh area. In that case, the corresponding thermal node is not defined by Nodal Description. This option can be found in the common tab of each Thermica module.



Corrected issues:

Conduction

- Fixed the wrong calculation of couplings when using condensed nodes with simplified RCN.
- Fixed a bug on different conduction couplings depending on the node number using condensed nodes with simplified RCN.
- Fixed a bug concerning the management of thickness variable: if the thickness is a variable for one of two shapes in contact, the conductive coupling was not always calculated correctly.
- Fixed a buffer overrun when GL formula was very long.
- Fixed a crash of conduction module when 2 shapes were in T configuration and one was in distinct side nodes.

Other modules

- The number of digits after the decimal point of DATE50 has been increased to avoid a shift of the results with respect to the mission in the 3D view
- Fixed a crash of Convection module when cavity closure is out of the bounding box.
- Fixed a bug of Nodal Description module: NaN values were generated when exporting normal vector of condensed node.
- Fixed a bug on GV calculation when view factors are time dependent.
- Fixed a bug of Planet Fluxes module when loading a maps file with CRLF end of line on Linux. Planet Fluxes module now manages map files regardless of the end of line character.
- Fixed a bug of Nodal Description module when using a specific item (capacitance overload, internal dissipation, thermostat or heater) on a node with no coating activity. The geometric area is now used instead of radiative area which is zero in this case.

- The “Do not mesh” option is now working properly. This option removes the geometrical element at computation level.
- Fixed a wrong value of capacitance overload when the node has no coating activity.

4.9.1

Applicable User Manual: v4.9

Minor features:

Enclosure

- A list of enclosure numbers can now be defined for a shape. This feature is available for geometrical model created with Systema 4.9.1 or later. For previous versions, the model can be converted thanks to a python script (publicScripts/convertEnclosureInSysmdlFile.py – please refer to the user manual of the geometrical model for more details)

Corrected issues:

- Correction of capacitance calculation: the capacitance value was wrong when the thickness, density or specific heat was defined by a variable and the bulk material was not defined (manually specified properties).

4.9.0

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Minor features:

- The Planet Flux module provides now a maps output file if the output bullet “maps” is activated in the processing tab. This new output file provides maps of albedo and IR properties for one planet mission, with albedo and IR values computed from each latitude and longitude given in the input file, for every computational time. The .maps output file needs to have a .maps input file as a reference for computation. Thus, the maps output option shall be activated only if an input maps file is defined. The .maps output file is limited to 76 computation points.

Corrected issues:

- Correction of a syntax error generated by the Nodal description module when using sequences in the mission (coma and line break were missing in the table SEQNB)

- Capacitance overload were applied on nodes that did not exist (because the nodes were completely cut by a cutter). This led to an error when launching Thermisol. From version 4.9.0, a capacitance overload (or other specific items: Boundary condition, Internal dissipation, Thermostat, Heater, Linear coupling and Radiative coupling) are no longer taken into account if the node is not defined in the \$NODE paragraph (i.e. if the area or volume of the node is equal to zero).

4.8.3P3

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No modifications.

4.8.3P2

Applicable User Manual: v4.8

Corrected issues:

- Correction of surface contact calculation when using condensed nodes. The surface contact calculation could be wrong when only one part of a condensed node was involved in a surface contact specific item.

4.8.3P1

Applicable User Manual: v4.8

Corrected issues:

- The node surface values are now written with %.6E format in the nod.nwk file to avoid that the TSINK routine of Thermisol generates NAN values because of a lack of precision.
- Bug fix in the SDS/HDF5 library (h5 close on Windows)

4.8.3

Applicable User Manual: v4.8

Major features:

- Specific items can now be applied on nodes and not only on shapes in the Graphical User Interface. This feature is available for the following specific items: boundary condition, capacitance overload, internal dissipation, thermostat, heater, linear coupling and radiative coupling.

- The Heater specific item in Thermostat (or ON/OFF) mode can now be used with the THSTAT routine. Before the 4.8.3 release, only the THRMST routine was available.

Corrected issues:

Conduction

- Correction of conductive coupling calculation when using condensed nodes with RCN method. **Warning: it is strongly advised not to use node condensation between versions 4.7.1 and 4.8.3 (not included) for conduction computations.** A bug can lead to wrong conductive coupling values in this case.
- Correction of contact detection. Some contacts were detected between nodes that are not next to each other.
- Correction of conductive coupling calculation between two cylinders put end to end.

Convection

- Correction of a memory issue related to the number of voxels. The software will automatically reduce the number of voxels if the resulting one is too big.
- Correction of the beta value in Mac Adams correlation written in the gf.nwk file.

Specific items

- For heaters and thermostats, the dissipation power specified by the user is now distributed on application nodes in proportion of their area and not duplicated.
- Correction of several errors in the nod.nwk output file generated by Thermica when using Heater.
- Correction of a crash when using two heaters in Thermostat (or ON/OFF) mode.
- Correction of errors in the nod.nwk output file when using Thermostat with several objects selected for the control temperature.
- Correction of conductive coupling calculation with Simplified RCN method when using edge contact resistance.
- Correction of conductive coupling calculation with RCN method when using edge contact resistance (Sinda output format).
- Correction of errors (missing brackets) in the nod.nwk output file when using edge contact resistance with a material selected in the bulk tab.
- Correction of conductive coupling calculation when using surface contact with contact value type.
- Correction of a crash when using only 1 "average" sensor.

Enclosure

- Correction of error in the gr.nwk output file generated by the radiation module when using enclosures. GR values were written by enclosures but they were not sorted correctly.

Important information:

- In the 4.5.3 version of Thermisol the H5_DUMP function was obsolete even if the manual control of the store of the result was activated. The results were automatically stored in the h5 file for both automatic and manual control. This is no longer the case since the version 4.7.0: if the manual control is activated, the results are not stored automatically in the h5 file and the user must use the function H5_DUMP to store the results. It is recommended to place the call to the H5_DUMP function at the end of the \$VRESULTS paragraph of the .dck file

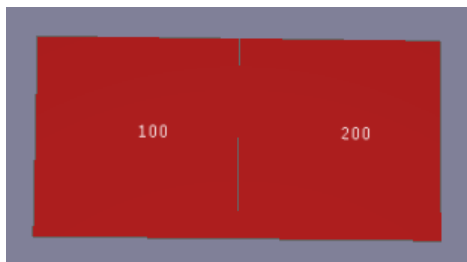
Conductive coupling calculation in Thermica

The following section describes how conductive couplings are calculated in Thermica. This section is divided into three parts. The first two deal with the conductive coupling calculation in basic configuration and T configuration respectively. The third part presents the general case.

1. CONDUCTIVE COUPLING IN BASIC CONFIGURATION

Model

Let's consider a model with 2 identical plates and 1 node per plate (100 and 200)



- Length: $L = 1\text{m}$
- Width: $l = 1\text{m}$
- Thickness : $t = 1\text{mm}$
- Conductivity: $\lambda = 100\text{ W/K/m}$

Conductive couplings

The conductive couplings generated by Thermica are as follows:

RCN method	Simplified RCN method
<pre># Couplings from node 100 GL(100, 100 E1) = 6.000E-001; GL(100, 100 E2) = 6.000E-001; GL(100, 100 E3) = 6.000E-001; GL(100, 100 E4) = 6.000E-001; GL(100 E1, 100 E3) = -2.000E-001; GL(100 E2, 100 E4) = -2.000E-001; # Couplings from node 200 GL(200, 200 E1) = 6.000E-001; GL(200, 200 E2) = 6.000E-001; GL(200, 200 E3) = 6.000E-001; GL(200, 200 E4) = 6.000E-001; GL(200 E1, 200 E3) = -2.000E-001; GL(200 E2, 200 E4) = -2.000E-001;</pre>	<pre>GL(100, 200) = 1.000E-001;</pre>

Detail of the calculation for the RCN method

For each node, Thermica generates node-edge conductive couplings and edge-edge conductive couplings in the gl.nwk output file. They are calculated as follows:

$$GL(0, E_1) = \lambda t \frac{6l_1}{l_2} = 100 \times 0.001 \times \frac{6 \times 1}{1} = 0.6$$

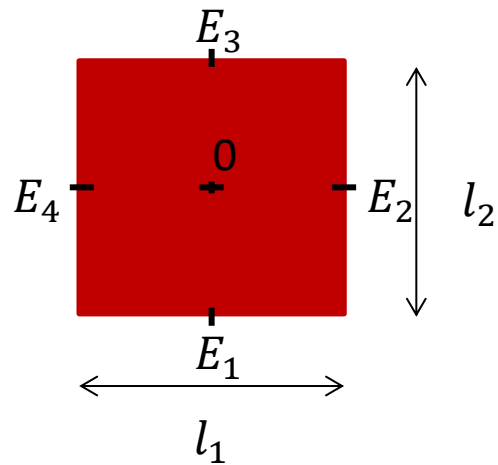
$$GL(0, E_2) = \lambda t \frac{6l_2}{l_1} = 0.6$$

$$GL(0, E_3) = \lambda t \frac{6l_1}{l_2} = 0.6$$

$$GL(0, E_4) = \lambda t \frac{6l_2}{l_1} = 0.6$$

$$GL(E_1, E_3) = -\lambda t \frac{2l_1}{l_2} = GL(E_3, E_1) = -0.2$$

$$GL(E_2, E_4) = -\lambda t \frac{2l_2}{l_1} = GL(E_4, E_2) = -0.2$$



Detail of the calculation for the Simplified RCN method

The simplified RCN method is derived from RCN. The couplings obtained by the RCN method are simplified by assuming piecewise linear temperature profile normal to each edge. **Thus the Simplified RCN method includes a RCN calculation to compute the $L(0, E_i)$ and $GL(E_i, E_j)$ of each node.** Then the Simplified RCN method calculates node-edge half-couplings for each edge of each node as follows:

$$GL_{half}(0, E_1) = GL(0, E_1) + \sum_{j \neq 1} \left(GL(E_1, E_j) \times \frac{E_1 E_j \cdot E_1 0 - (E_1 E_j \cdot A_1 B_1)^2 / A_1 B_1^2}{E_1 0 \cdot E_1 0 - (E_1 0 \cdot A_1 B_1)^2 / A_1 B_1^2} \right)$$

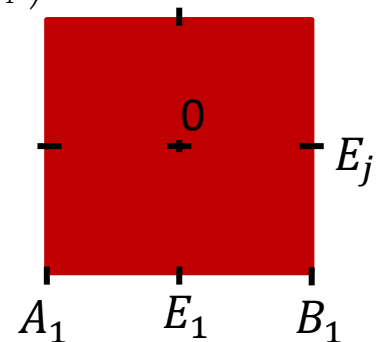
$$GL_{half}(0, E_1) = GL(0, E_1) + GL(E_1, E_3) \times \frac{0.5}{0.25} = 0.6 - 0.2 \times 2 = 0.2$$

In the same way :

$$GL_{half}(0, E_2) = 0.2$$

$$GL_{half}(0, E_3) = 0.2$$

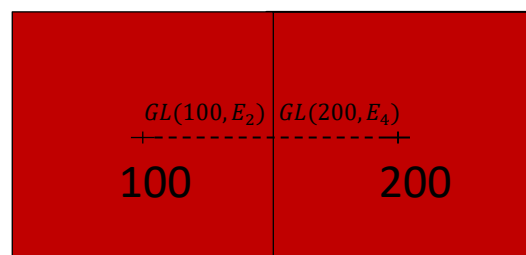
$$GL_{half}(0, E_4) = 0.2$$



Finally, node-edge half-couplings are associated in series to obtain the node-node couplings generated in the gl.nwk output file. Two node-edge half-couplings in series are equivalent to two conductances in series in an electrical circuit. Thus the resulting node-node coupling is equal to:

$$GL(100, 200) = \frac{GL_{half}(100, E_2) \times GL_{half}(200, E_4)}{GL_{half}(100, E_2) + GL_{half}(200, E_4)}$$

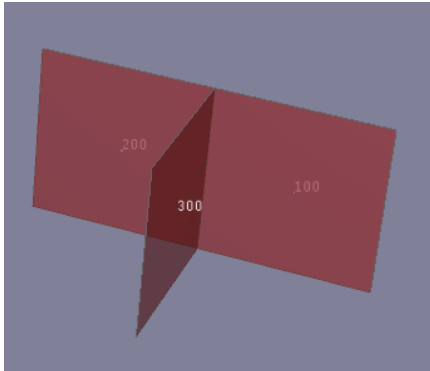
$$GL(100, 200) = \frac{0.04}{0.4} = 0.1$$



2. CONDUCTIVE COUPLING IN T CONFIGURATION

Model

Let's consider a model with 3 identical plates and 1 node per plate (100, 200 and 300)



- Length: $L = 1\text{m}$
- Width: $l = 1\text{m}$
- Thickness: $t = 1\text{mm}$
- Conductivity: $\lambda = 100\text{ W/K/m}$

Conductive couplings

The conductive couplings generated by Thermica are as follows:

RCN method	Simplified RCN method
<pre> # Couplings from node 100 GL(100, 100 E1) = 6.000E-001; GL(100, 100 E2) = 6.000E-001; GL(100, 100 E3) = 6.000E-001; GL(100, 100 E4) = 6.000E-001; GL(100 E1, 100 E3) = -2.000E-001; GL(100 E2, 100 E4) = -2.000E-001; # Couplings from node 200 GL(200, 200 E1) = 6.000E-001; GL(200, 200 E2) = 6.000E-001; GL(200, 200 E3) = 6.000E-001; GL(200, 200 E4) = 6.000E-001; GL(200 E1, 200 E3) = -2.000E-001; GL(200 E2, 200 E4) = -2.000E-001; # Couplings from node 300 GL(300, 300 E1) = 6.000E-001; GL(300, 300 E2) = 6.000E-001; GL(300, 300 E3) = 6.000E-001; GL(300, 300 E4) = 6.000E-001; GL(300 E1, 300 E3) = -2.000E-001; GL(300 E2, 300 E4) = -2.000E-001; </pre>	<pre> GL(100, 300) = 6.667E-002; GL(100, 200) = 6.667E-002; GL(200, 300) = 6.667E-002; </pre>

Detail of the calculation for the RCN method

For each node, Thermica generates node-edge conductive couplings and edge-edge conductive couplings in the gl.nwk output file. These couplings are the same as for the basic configuration because the plates are identical to the previous case:

$$GL(0, E_1) = \lambda t \frac{6l_1}{l_2} = 100 \times 0.001 \times \frac{6 \times 1}{1} = 0.6$$

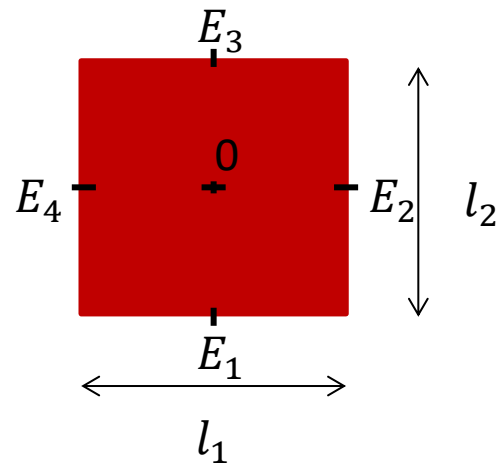
$$GL(0, E_2) = \lambda t \frac{6l_2}{l_1} = 0.6$$

$$GL(0, E_3) = \lambda t \frac{6l_1}{l_2} = 0.6$$

$$GL(0, E_4) = \lambda t \frac{6l_2}{l_1} = 0.6$$

$$GL(E_1, E_3) = -\lambda t \frac{2l_1}{l_2} = GL(E_3, E_1) = -0.2$$

$$GL(E_2, E_4) = -\lambda t \frac{2l_2}{l_1} = GL(E_4, E_2) = -0.2$$



Detail of the calculation for the Simplified RCN method

The node-edge half-couplings are therefore also the same as those of the basic configuration:

$$GL_{half}(0, E_1) = GL(0, E_1) + \sum_{j \neq 1} \left(GL(E_1, E_j) \times \frac{E_1 E_j \cdot E_1 0 - (E_1 E_j \cdot A_1 B_1)^2 / A_1 B_1^2}{E_1 0 \cdot E_1 0 - (E_1 0 \cdot A_1 B_1)^2 / A_1 B_1^2} \right)$$

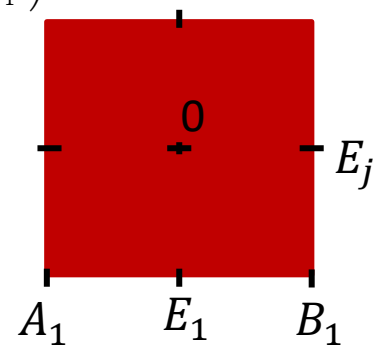
$$GL_{half}(0, E_1) = GL(0, E_1) + GL(E_1, E_3) \times \frac{0.5}{0.25} = 0.6 - 0.2 \times 2 = 0.2$$

In the same way :

$$GL_{half}(0, E_2) = 0.2$$

$$GL_{half}(0, E_3) = 0.2$$

$$GL_{half}(0, E_4) = 0.2$$



Finally, node-edge half-couplings are associated to obtain the node-node couplings generated in the gl.nwk output file. The transformation required to obtain the resulting node-node couplings is equivalent to the Star-Delta transformation for an electrical circuit. Node-edge half-couplings are in star (or T) configuration and the resulting node-node couplings should be in delta configuration. Thus, according to the Star-Delta transformation formula, the resulting node-node coupling is equal to:



$$GL(100,200) = \frac{GL_{half}(100, E_2) \times GL_{half}(200, E_4)}{GL_{half}(100, E_2) + GL_{half}(200, E_4) + GL_{half}(300, E_4)}$$

$$GL(100,200) = \frac{0.04}{0.6} = 0.066666$$

In the same way:

$$GL(100,300) = 0.066666$$

$$GL(200,300) = 0.066666$$

3. CONDUCTIVE COUPLING IN GENERAL CASE

Calculation of conductive couplings with the RCN method

- The couplings generated by Thermica in the gl.nwk file for a triangle are the following:

$$GL(0, E_1) = GL(0, E_2) = GL(0, E_3) = \lambda t \frac{24}{g_{12} + g_{13} + g_{23}}$$

$$GL(E_1, E_2) = GL(E_2, E_1) = \lambda t \left(g_{12} - \frac{8}{g_{12} + g_{13} + g_{23}} \right)$$

$$GL(E_1, E_3) = GL(E_3, E_1) = \lambda t \left(g_{13} - \frac{8}{g_{12} + g_{13} + g_{23}} \right)$$

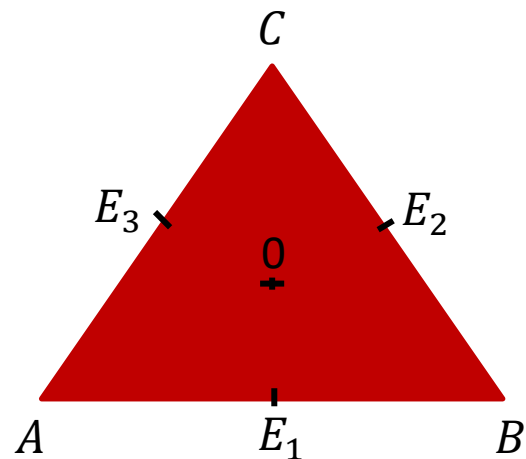
$$GL(E_2, E_3) = GL(E_3, E_2) = \lambda t \left(g_{23} - \frac{8}{g_{12} + g_{13} + g_{23}} \right)$$

where

$$g_{12} = \frac{AB^2 + BC^2 - AC^2}{2 \text{Area}}$$

$$g_{23} = \frac{AC^2 + BC^2 - AB^2}{2 \text{Area}}$$

$$g_{13} = \frac{AB^2 + AC^2 - BC^2}{2 \text{Area}}$$



- The couplings generated by Thermica in the gl.nwk file for a rectangle or a truncated cylinder (with 4 sides) are the following:

$$GL(0, E_1) = \lambda t \frac{6l_1}{l_2}$$

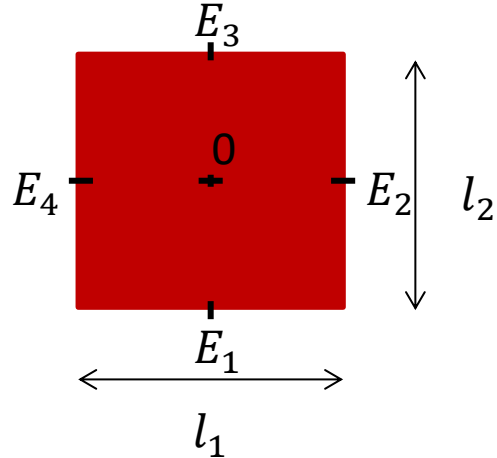
$$GL(0, E_2) = \lambda t \frac{6l_2}{l_1}$$

$$GL(0, E_3) = \lambda t \frac{6l_1}{l_2}$$

$$GL(0, E_4) = \lambda t \frac{6l_2}{l_1}$$

$$GL(E_1, E_3) = -\lambda t \frac{2l_1}{l_2} = GL(E_3, E_1)$$

$$GL(E_2, E_4) = -\lambda t \frac{2l_2}{l_1} = GL(E_4, E_2)$$

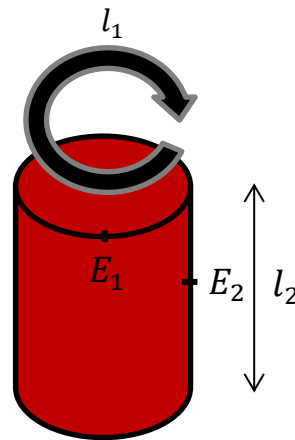


- The couplings generated by Thermica in the gl.nwk file for a cylinder are the following:

$$GL(0, E_1) = \lambda t \frac{6l_1}{l_2}$$

$$GL(0, E_2) = \lambda t \frac{6l_1}{l_1}$$

$$GL(E_1, E_2) = -\lambda t \frac{2l_1}{l_2}$$

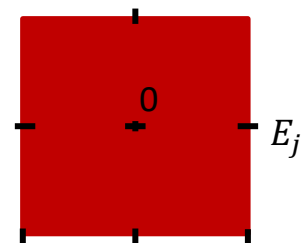


- For other shapes: the surface is sub-meshed in triangles, the conductive couplings are computed into each sub-triangle. The sub-meshed surface leads to a complex conductive network. The detailed conductive network is reduced back to original configuration.

Node-edge half-coupling calculation for the Simplified RCN method

In the general case, the node-edge half-couplings are calculated for each edge in each node as follows:

$$GL_{half}(0, E_i) = GL(0, E_i) + \sum_{j \neq i} \left(GL(E_i, E_j) \times \frac{E_i E_j \cdot E_1 0 - (E_i E_j \cdot A_i B_i)^2 / A_i B_i^2}{E_i 0 \cdot E_1 0 - (E_i 0 \cdot A_i B_i)^2 / A_i B_i^2} \right)$$

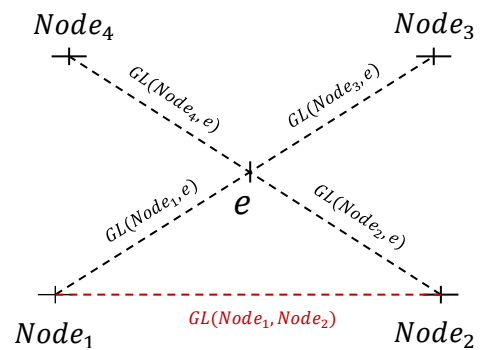


Association of node-edge half-couplings for the Simplified RCN method

In the general case, the node-edge half-couplings are associated as follows to obtain the resulting node-node couplings around an edge e:

$$GL(Node_1, Node_2) = \frac{GL_{half}(Node_1, e) \times GL_{half}(Node_2, e)}{\sum_{j \in N} GL_{half}(Node_j, e)}$$

where N is the number of nodes containing the edge e.



4.8.2

Applicable User Manual: v4.8

Major features:

- Convection: first release of the module (see User Manual for details)

Minor features:

- Conduction module: if the contact threshold value specified by the user is modified, the corrected value is now written in the .gl.nwk file. (Indeed, the value specified by the user can be locally modified in some critical cases like degenerate meshes)
- Conduction module: the Simplified RCN method is set as the default method of the Conduction Processing
- Nodal description module for Sinda output format: the capacitance value of zero-capacitance/arithmetic nodes is now written as -1.0.
- Nodal description module for Sinda output format: the capacitance value of boundary nodes is now written as 0.0 regardless of the volume, density, specific heat value of the node.
- MSC Version – MSC Sinda module: the single precision option is deleted. The double precision is the only precision option available.
- MSC Version – Skeleton module: the syntax used for running Steady State and Transient Sinda model is simplified.

For example, assuming Steady State solver is SNSOR, the syntax for running only this solver is now *SNSOR* instead of *SSANDTR('SNSOR',')*. In the same way, assuming Transient solver is SNDUFR, the syntax for running only this solver is now *SNDUFR* instead of *SSANDTR('', 'SNDUFR')*. However the syntax for running both types of solver has not changed: *SSANDTR('SNSOR', 'SNDUFR')*.

- Management of sensors with Linux version: backward RCN and average methods work.
- Management of sensors with Windows version: backward RCN and average methods are also available but average method works only under certain conditions (At least one sensor needs to be acknowledged as Edge contact - RCN backward). This issue will be solved in a future release.

4.8.1P1

Correction:

- Specific items referencing shapes are no longer referencing the node of the shapes but the shapes themselves. This modification was required so to set surface contacts involving shapes for which the nodal identification is condensed with other shapes (so previously all

shapes of the same node were concerned, now only the selected shapes – in case of condensation, unselected shapes then are excluding from the surface contact).

4.8.1

Major features:

- Nodes: New option to export normal vectors of nodes in nodal description
- Nodes: Export of sensors

Beta-released features:

- IR Camera: new module (for beta testing only)
- Convection: new module (for beta testing only)

Minor features:

- Nodes: Computation of capacitance activated even if bulk is not active
- Conduction: Simplified method - problem of division by zero in a specific case
- Solar Flux: export of solar vector in satellite frame as three additional vectors in the nwk output
- CPU optimization for loading sysset
- Memory optimization of radiation (free voxel structure just after ray-tracing)

4.8.0

Major features:

- Quasi-Monte-Carlo: The Radiative couplings and Solar flux modules have now the possibility to use a quasi-Monte-Carlo algorithm instead of the classical one. This new random number generation algorithm has better statistical convergence properties and will lead to an optimization of the ray-tracing accuracy
- Radiation: Automatic accuracy control loop based on the absolute symmetrization error. This option allows to specify a level of accuracy and let the software re-run new rays automatically
- Management of Phobos, Ganymede, Europa and Calisto

Minor features:

- Default conductivity and density properties set to zero
- Solar flux: Option to export the Sun direction vectors in a Thermisol array

- Radiation: Export of absolute symmetrization error in the log file ($Err_i = \sum_j |REF_{ij} - REF_{ij}^*|$) in addition to the already existing sum balance error ($Err_i = 1 - \sum_j REF_{ij}^*$)
- Addition of a new Heater specific item allowing to customize the heater type and control law
- Addition of a new *Area correction* option in the transverse couplings tab. This new option can be used to apply a corrective factor on the area of any transverse couplings and surface contact couplings
- Conduction: Addition of a “backward matrix” that may be used for temperature mapping applications using a backward RCN method
- Conduction: improvement of CPU time

Corrected issues:

- Radiation: Correction of a memory error when having a dynamic mission (moving bodies) and a too long mission name
- Planet fluxes: Correction of eclipses from a planet to another one (typically a Jupiter Sun eclipse on Ganymede)
- Nodal description: Correction of sequences table not written correctly in some cases (usually when an implicit default phase was applied at the end of a mission)
- Nodal description: Node status remains active in the case of no bulk and coating activities but having a surface contact
- Nodal description: Correction of surface contact filtering. The threshold value of contact surface has been set to 1.0e-8
- Nodal description: Correction of surface contact with unmeshed or inactive shapes
- Conduction: Correction of a crash on Windows when using resistance contacts.
- Conduction: Correction of simplified RCN on curved shapes
- Conduction: correction of contact resistance on shapes with distinct side nodes
- Conduction: output a warning for shapes with an active bulk but a null conductivity or thickness
- Conduction: wait for all errors to be raised before exiting program

4.7.1**Minor features:**

- Conduction: Parametric output available also for the simplified RCN method
- Radiation: GR values are written by enclosures

Corrected issues:

- Conduction: incorrect thickness in edge resistance contacts with double layers
- Conduction: forced contacts between triangles and circular edges leading to no coupling
- Crash due to surface contacts if too many element are selected
- External fluxes: problem of "box h5 not compatible" (bug introduced in 4.7.0)
- External fluxes: problem of computation when using enclosures
- Planet fluxes: possible error message when computing geo-coordinates using a map of properties
- Execution failure if enclosures and specific items are used

4.7.0**Major New features:**

- **Enclosures:** It is now possible to define an enclosure number onto geometrical elements and to specify on which enclosure the radiative enclosure shall be made. It is important to notice that enclosure 0 is the external part of the model, where external fluxes will be calculated. Enclosures above 1 are considered as internal ones and external fluxes will not apply to them
- **Parametric outputs:** All material properties and specific items specifications are exported as parameters into the TMM so to ease the parametric analysis at TMM level. Note that using the Thermisol output format, those are defined into the new Thermisol block \$GLOBAL so to avoid the repeat into each model or sub-model (see the Thermisol user's manual for more detail)
- **Mission sequences:** The timeline of mission sequences is now exported into the TMM so to be able to relay on them whenever dissipation profiles shall depend on the kinematic sequences

Minor features:

- Possibility to add more than one surface contact on the same node
- There was still a small inaccuracy of penumbra entry/exit computation compared to Systema's computation
- Export of planet fluxes nwk file whenever the Albedo was turned off
- Rather than choosing between radiative or geometrical area, the classical A nodal property remains always as the radiative area (as it has always been before). Now, for exporting the geometrical area, a new user nodal entity is created (if the option is activated). Besides, volumes may also be exported using a specific option (apply to volume shapes only).

Corrected issues:

- Thickness management on conductive couplings failed in specific cases
- Materials overloaded by variables were leading to inconsistent TMM
- Reversed option not taken into account for CAD shapes
- Problem of conformant contact management for volumes whenever the contact was a quadrangle wich was in fact a rectangle
- Dependent properties table exported into the TMM were written in the declaration order rather than sorted by its first entry

4.6.0**Major New features:**

- **Volume** management including:
 - Volume mesh management (volumes, external and internal layers)
 - Contact management (automatic merge of conformant contacts)
 - Conductive couplings export
- New **Aero-Thermal flux** module

Minor features:

- Meshing ratios has been changed to a set of values
- Check of superposition in solar flux leading to an error in a few cases
- Identification of edges for truncated spheres

4.5.3b**Corrected issues:**

- Simplified RCN on triangle-star configurations

4.5.3a**Corrected issues:**

- Sphere's contact detection for conduction
- Correction of flux computation using an input box.h5 file from a radiative couplings where transformation similitudes were identified
- Simplified RCN: Correction of linearity's direction hypothesis to the edge's normal

4.5.3

Minor features:

- Check of superposition in solar flux leading to an error in a few cases
- Identification of edges for truncated spheres

4.5.2

Minor features:

- Conduction: extension of forced contacts (between straight and curved edges) to unconfomant contacts

Corrected issues:

- Apparition of undesired GRWLB in output if no Gb output selected
- Conduction: problem of contact detections in some cases
- Management of badly conditioned sub-mesh of CAD geometries
- Surface contact with a value in W/K leading to uncorrect value

4.5.1b

Minor features:

- Addition of temperature dependent conductivity

Corrected issues:

- Fast-Spin on a sub-object leading to crash
- Cutters not moved with kinematics frames
- Finite Sun modelling with +X pointing the Sun not working

4.5.1a

Minor features:

- Addition of temperature dependent conductivity

Corrected issues:

- Planet flux returned unset values if the planet was too far away for being taken into account
- Management of condensation (shapes and edges) for conduction
- Management of contact resistances on multi-contact edges
- Penumbra coefficient was not correct for solar flux computation

- Finite Sun Modelling
- Solar flux on cut geometries
- Ray-Tracing problem on parabolas

4.5.1

Minor features:

- Addition of user's setting to adjust ray display length
- Addition of user's settings to set Sinda fluxes arrays
- Option to re-initialize the random seed for each node

Corrected issues:

- Material definitions in sub-models
- Radiative coupling with moving bodies
- Bulk activity management
- Conduction with reversed shape and unique activity
- Multi-coupling with Simplified conduction method
- 360° edge contact
- Sinda output of edges in conduction

4.5.0

Major New features:

- Wavelength Dependent Radiative computation
- Incident Angle Dependencies on thermo-optical properties
- Double Layer Bulk Management
- Simplified Conductive module
- New Edge definition and visualization

Minor features:

- Radiation report: Low space couplings
- Option to re-initialize the random seed for each node
- Parameterization of network outputs according to material definitions
- Shape superposition detection and management
- Fast-Spin on sub-parts

Corrected issues:

- Accuracy error of ray-tracing of tangent impact on curved surfaces
- Planet fluxes with property maps: correction of planet coordinates computation
- Planet fluxes: accuracy of sight angle computation
- Planet reference error when several planets are in the trajectory
- Thermostat: wrong formulation when applied on several nodes
- Conduction: crash with boolean or CAD geometries
- Surface contact with distinct side nodes

Suppressed options:

- Standard deviations removed

4.4.2**Meshing & Numbering:**

- Default numbering set as numbering with default values

Radiation:

- Correction of simulation time update

4.4.1

No change.

4.4.0

The version 4.4.0 of THERMICA is a major release. This version has now multi-threading possibilities and has improved its overall CPU Time.

Meshing & Numbering:

- Update of Meshing Library to handle more customizable numbering
- Distinct sides numbering are now available

Model library:

- Correction of antenna shape parameters

Mission library:

- Detection of kinematics similarities to improve the radiative couplings computation with new copy/skip functionalities to avoid re-computing similar computation points but ensuring a correct couplings interpolation at temperature computation level

- The fast-spin option is now restricted to the entire spacecraft (isolated fast-spin bodies are not supported anymore) in order to optimize all THERMICA computation modules.

Ray-Tracing library:

- Extension of the voxelization structure to handle more voxels with less memory
- Optimization of empty voxels management for a faster ray-tracing

Node:

- Correction of SINDA output
- Addition of a filtering coefficient in surface contact couplings
- Addition of a extra radiosity coefficient in surface contacts

Conduction:

- Correction of SINDA output
- Management of conductive plans for shapes with distinct sides numbering

Radiation:

- Multi-threading implementation
- Storage of ray path for ray-tracing visualization
- Optimization of matrix symmetrization process
- Optimization of dynamic cases by handling orbital position similarities
- Suppression of the fast-spin inner loop
- Deactivation of accuracy loop management (the 4.3.3 implementation is not conformant with the new optimized algorithm – it will be re-introduce on a later version)
- New storage of matrix in the h5 file (view factor after symmetrization correction / corrected symmetric radiative couplings)
- Correction of SINDA outputs

Solar Fluxes:

- Multi-threading implementation
- Storage of ray path for ray-tracing visualization
- Suppression of the fast-spin inner loop
- Optimization of algorithm for faster computation

4.3.3**Meshing & Numbering:**

- Update of Meshing Library to support non-geometrical elements

Ray-Tracing library:

- Correction of intersection's computation on non-planar shapes
- Correction of reflection problem on negative surfaces

Nodal Description:

- Handling of new non-geometrical elements (properties overloading, non-geometrical nodes, dissipations, heater, couplings, surface conduction)

Conduction:

- Management of Edge Resistance Contacts
- Use of analytical results on conformant rectangles
- Correction on spheres
- Correction of a memory problem

Radiation:

- Accuracy loop management
- Output of Standard Deviation summary tables
- Fully condensed ray-tracing management

Solar flux:

- Upgrade of Ray-Tracing following the Radiation module evolutions

4.3.2**Meshing & Numbering:**

- Correction of cone mesh when 'diameter1 = 0'

Geometrical library:

- Correction of areas for parabolas, cones and shapes truncated by prisms

Ray-Tracing library:

- Correction of surfaces / voxels associations
- Correction of ray-tracing through boolean shapes
- Correction of specular reflection
- Optimization of voxels management – better CPU time performances

Nodal Description:

- Export of FX, FY and FZ new nodal properties (THERMISOL / ESATAN format)
- New parameter to set a main model name different than the mission name

Conduction:

- Correction of "full sphere" management (no coupling exported)

- Optimization for conformant triangles rectangles and cylinders
- Export of FX, FY and FZ new nodal properties (THERMISOL / ESATAN format) for Edge nodes
- Edge Area's definition: Length x Thickness (previously only the length was output with a negative sign)

Radiation:

- Correction of standard deviation export in the SINDA language (incorrect comment symbol)
- Correction of time dependant GR export (THERMISOL / ESATAN format): keyword \$ARRAYS missing
- Correction of inactive impingements budget
- Optimization of algorithm: computation based on nodal entities rather than mesh ones
- New parameter to control overall filtered couplings
- New presentation of view and Gebhart factors in the gb.txt output file
- New tables output in the log file: REF budgets sorted by inaccuracy and Inactive impingements

Planet fluxes:

- Correction of IR flux on both side active shapes

Solar flux:

- Correction of indirect contributions
- New input: radiation "box.h5" – optimize the computation of solar flux for shapes that don't

4.3.1

Meshing & Numbering:

- **The mesh increment is applied from the second mesh**

This means that the first mesh has the same number that the shape itself. This behaviour is compatible with the v3 and was necessary for the full SYSEXP compatibility.

WARNING: A numbering set with previous versions 4.3.0 or 4.2.3 is changed.

Common librairies:

- **Error message when the meshing is not attached to the mission**

This error is specified at the beginning of a THERMICA process

- **Load of complex kinematics**

This follows the framework evolutions

- **Compression of H5 files**

A compression equivalent to a zip is made on the results. It optimizes the disk memory especially for sparse results (like the big matrix from the radiation module).

General functionalities:

➤ **Output of Esatan-compatible nwk files**

In addition to the THERMISOL format and the SINDA/G one.

➤ **Possibility to specify time tables of nwk output as “common” or “separated”**

To have only one time table for all time dependant phenomena or dedicated tables (in the case the user wants to use different orbit discretization).

Sinda/G interface:

➤ First official version integrating this functionalities

Nodal Description:

➤ **Values of Alpha & Epsilon not correct for shapes with both sides active**

Corrected

Planet Fluxes:

➤ **Possibility of specifying maps of planet properties**

Now it's in the v4 !

➤ **Day & Night temperatures of planets**

Easy way of specifying a temperature variation on the planet.

Conduction:

➤ **Problem of couplings between cylinders and disks**

Problem of edges correspondences corrected

4.3.0

Meshing & Numbering:

➤ **Possibility of defining meshing ratios in a & b directions**

➤ **Numbering: Negative increment allowed**

➤ **Numbering: Increments in a & B directions**

Generalities:

➤ **Handling of boolean shapes**

Except for the conduction module

➤ **Criticality of the ray-tracing**

Instead of specifying the number of rays at process level for all mesh, possibility to specify 3 categories of criticality.

- **New output in the H5 file: fluxes (W/m²)**

Conduction:

- **New computation process: The RCN method**

Available from this version. Will however require some further optimizations and evolutions for boolean shapes compatibility