Appendix G

THERMICA – THERMISOL

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Abstract

Process Control

Presentation of the new functionalities & outputs dedicated to control the convergence of the simulations.

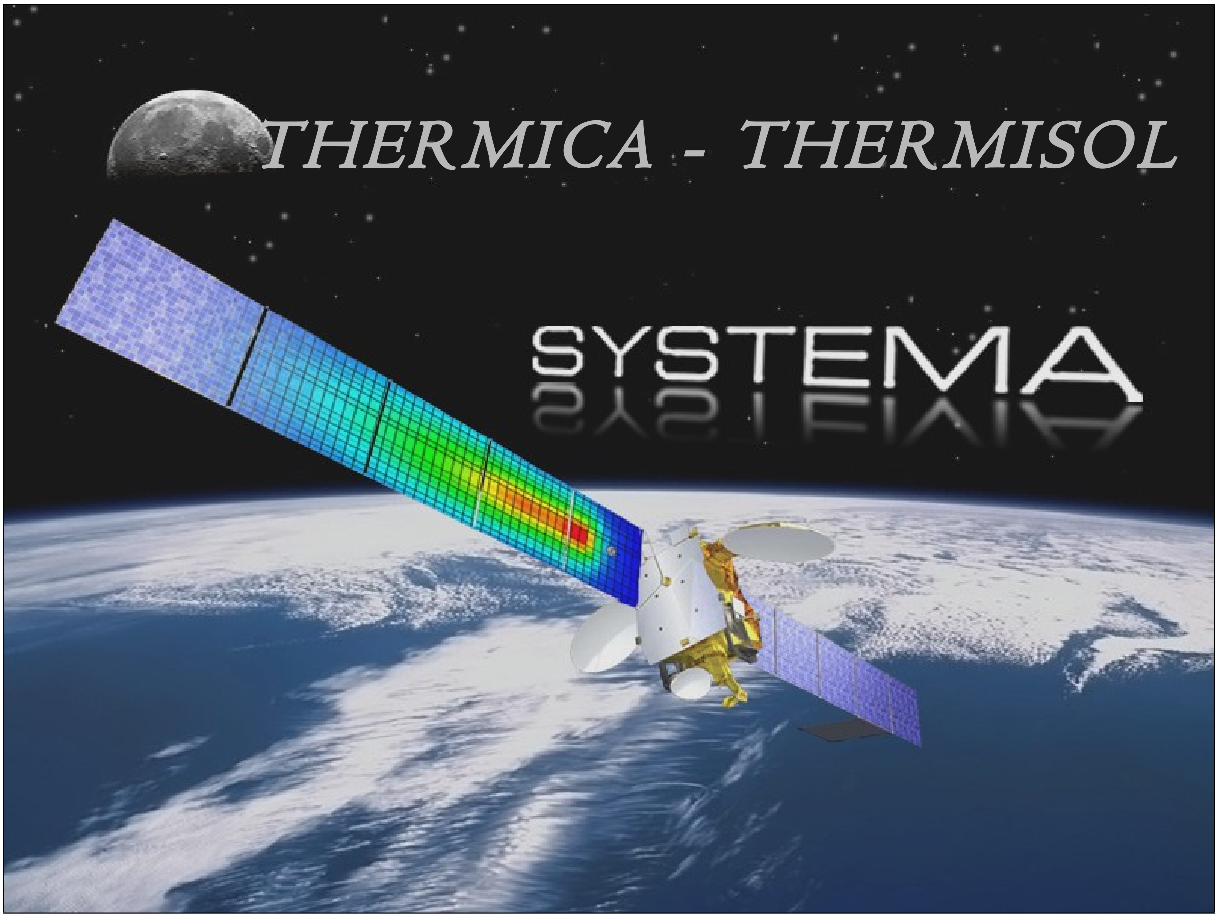
- New summary tables in log files for Ray-Tracing algorithms
- New accuracy loops in the Radiation & Solar Flux modules
- Extended data in the THERMISOL process control file
- New error definitions in THERMISOL

THERMISOL to ESATAN converter

THERMISOL is based on the ESATAN language and more than 95% of the commonly used syntax is supported by both software. THERMISOL now offers additional advanced functionalities and also more users friendly syntax (free format, real format automatic adaptation, easy Mortran data access . . .). To ensure the compatibility, a converter translates a THERMISOL input file and re-formats it in order to be 100% compliant with both software.

Latest Validations & Performances Tests

The v4 is now completely mature to be integrated into production processes.
This is a short presentation of process integrations and results based on industrial cases.



Versions

- V 4.3.1
  - November 2008

Presented at the 2008 ECLS Workshop, ESTEC

- V 4.3.2
  - May 2009

Presented at the 2009 THERMICA Workshop, Toulouse

- V 4.3.3
  - December 2009

Next release

Model & Mission Parameterization
Non-Geometrical Model Completion
Advanced Process Control
Automatic Ray-Tracing Accuracy Control
Advanced Mortran Syntax
THERMISOL – ESATAN converter

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SYSTEMA
Content
Process Control
More information to control convergence parameters in THERMICA and THERMISOL
New Ray-Tracing Accuracy Loops
THERMISOL: New Mortran Easy Syntax
Mortran Implicit Calls: Parametric Mortran Access
Mortran Macros: Allows multi-affectation and multi-modification
THERMISOL to ESATAN converter
Reformat the input file in order to be 100% compatible with both solver
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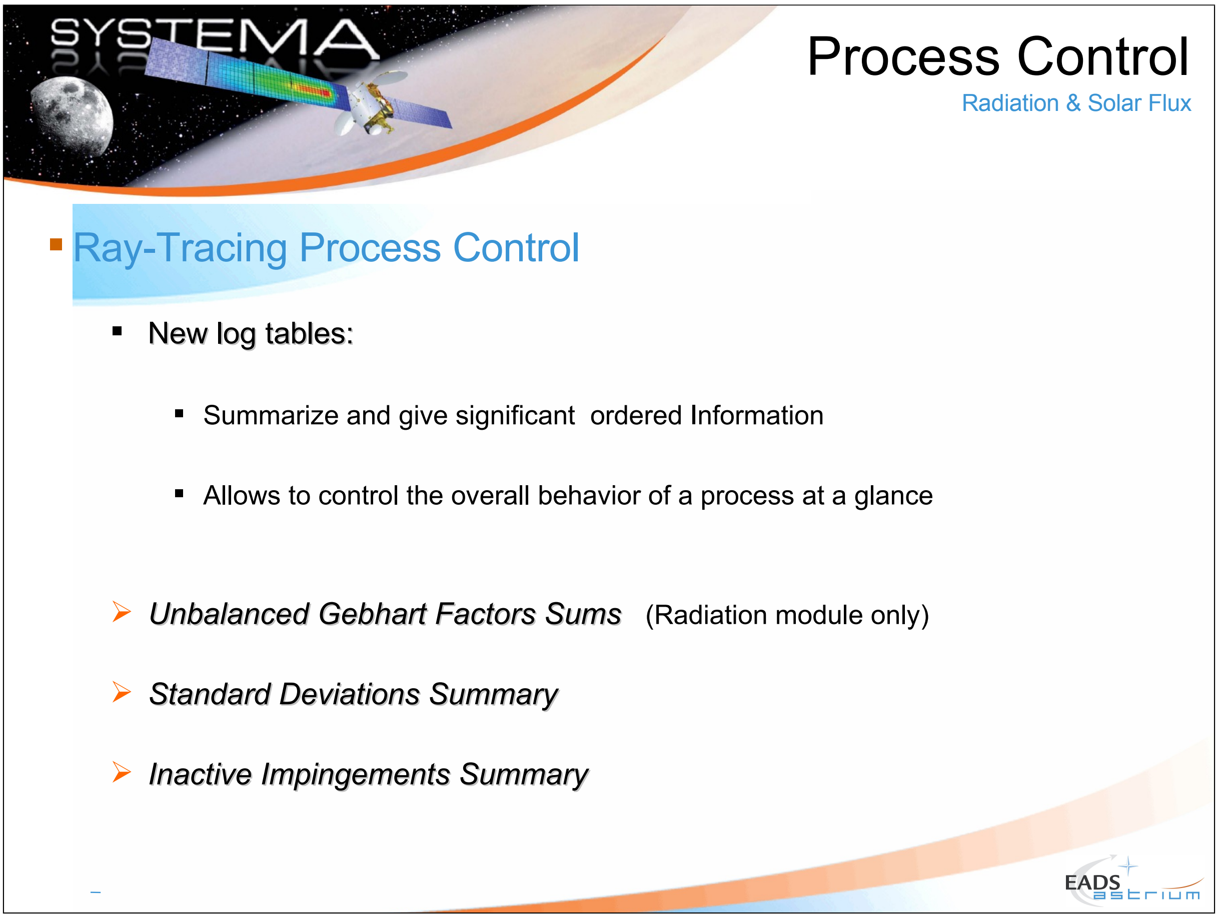
SYSTEMA
Process Control
Radiation & Solar Flux
Ray-Tracing Process Control
New log tables:
Summarize and give significant ordered Information
Allows to control the overall behavior of a process at a glance
Unbalanced Gebhart Factors Sums (Radiation module only)
Standard Deviations Summary
Inactive Impingements Summary
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Process Control

Radiation & Solar Flux

REF Sums

Initially the REF sums are equal to 1.0

But when computing the GR, the REF are modified

in order to get the symmetrization:

$$GR_{ij} = \varepsilon_i .\ S_i .\ REF_{ij} = \varepsilon_j .\ S_j .\ REF_{ji}$$

This table summarizes the symmetrizations that lead

to REF sums different than 1.0

Customized levels of unbalanced REF sums

Unbalanced nodes

Percentage of error

Accurate Nodes

IR Gebhart Factor Budget :

REF (IR) sum : error above 10 % :

Emission Node	Rays Emitted	VF sum	Error
99	10000	0.8383	16.2 %
247	20000	1.147	14.7 %

REF (IR) sum : error between 5 % and 10 %:

Emission Node	Rays Emitted	VF sum	Error
279	20000	1.099	9.87 %
280	20000	1.074	7.36 %
138	10000	0.9274	7.26 %
13	10000	1.057	5.73 %

REF (IR) sum : error between 1 % and 5 %:

Emission Node	Rays Emitted	VF sum	Error
133	10000	1.038	3.84 %
58	10000	1.038	3.79 %
3	10000	1.034	3.35 %
53	10000	1.028	2.83 %
275	20000	1.028	2.75 %
35	10000	1.022	2.23 %
90	10000	1.02	2 %
248	20000	1.019	1.9 %
97	20000	1.019	1.89 %
55	10000	1.015	1.5 %
230	10000	1.012	1.25 %
96	20000	1.011	1.06 %
252	20000	1.01	1.03 %

Number of REF (IR) bellow 1 % of error: 377 (91.7 %)

Process Control

Radiation & Solar Flux

New Accuracy Loops

- A new accuracy control has been developed in the 4.3.3

It allows the user to specify a target accuracy to be reached

The application then automatically loops and adjusts the number of ray

- This version is based on the 2 aspects:

- Maximum Standard Deviation (theoretical ray-tracing error)
- Maximum REF unbalance (empirical ray-tracing error)

Process Control

THERMISOL

THERMISOL: Convergence Control File

- Dynamically written file
- More information than before
- Frequency of update controlled by new parameter: CSV_FREQ

Steady-state run : SOLVIT

LOOPCT	RELXCC	NRLXCC	ENBALA	ENBALR	ENBALT	DAMPT	VTEMPERATURE
10	1.25E+01	421001 (E3000OS)	7.79E+03	3.87E-01	5.51E+04	1.8759	10
50	9.96E-01	345102 (E3000OS)	2.58E+01	1.28E-03	2.03E+02	1.7104	10
100	4.76E-01	1640031 (E3000OS)	1.23E+01	6.13E-04	2.54E+02	1.948	10
150	5.89E-03	1640021 (E3000OS)	3.09E-01	1.53E-05	4.96E+00	1.8614	2
200	1.79E-04	1640011 (E3000OS)	7.84E-03	3.90E-07	5.69E-02	1.7643	1
216	9.52E-05	1640035 (E3000OS)	4.01E-03	1.99E-07	7.42E-02	1.9243	1

Evolution of convergence evolution

Damping Factors

$VTEMPERATURE optimization

Evolution of energetic balances

Process Control

THERMISOL

- Transient run

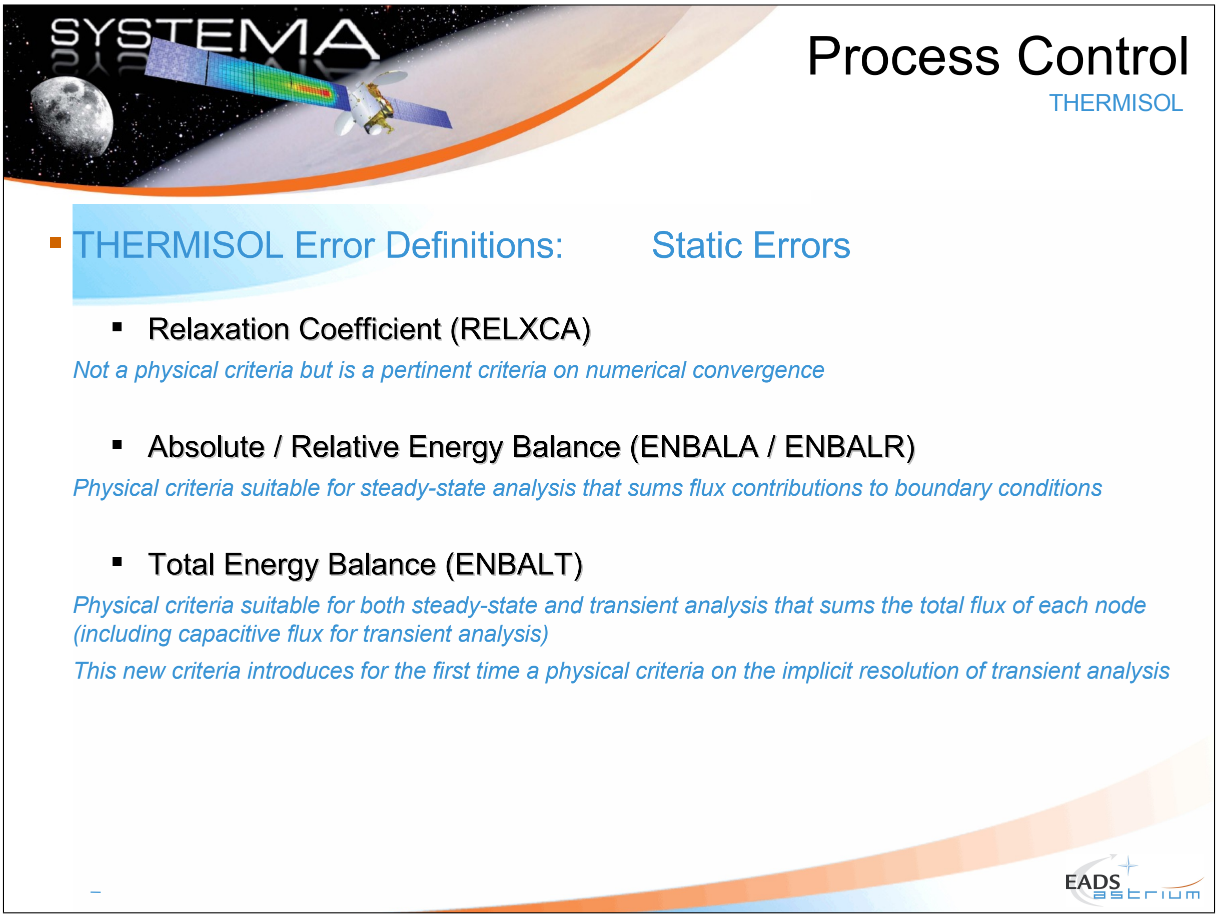
% TIME	TIMEN	DTIMEU	LOOPCT	RELXCC	NRLXCC	ENBALT	MAX ERROR	NERRMAX	% BELOW 1.000e-01
1.62%	180	30	165	9.57E-07	22077 (ATLID_IF)	2.03E-03	3.02E+00	21160 (ATLID_IF)	88.39%
3.24%	360	30	153	9.58E-07	22077 (ATLID_IF)	-5.36E-04	2.63E+00	21160 (ATLID_IF)	88.66%
4.86%	540	30	150	9.99E-07	22077 (ATLID_IF)	-4.39E-04	2.29E+00	21160 (ATLID_IF)	88.86%
6.36%	706.018	16.018	97	9.73E-07	22077 (ATLID_IF)	-1.45E-04	5.62E-01	21160 (ATLID_IF)	93.49%
7.85%	872.036	30	190	-9.96E-07	21211 (ATLID_IF)	-4.50E-03	1.66E+00	21160 (ATLID_IF)	89.73%
9.47%	1052.036	30	145	-9.75E-07	21211 (ATLID_IF)	-1.62E-03	1.45E+00	21160 (ATLID_IF)	89.87%
11.36%	1262.036	30	145	9.79E-07	21211 (ATLID_IF)	2.71E-03	1.23E+00	21160 (ATLID_IF)	90.34%
12.94%	1437.525	30	139	-9.50E-07	22077 (ATLID_IF)	3.97E-04	1.16E+00	21160 (ATLID_IF)	90.74%
14.62%	1623.891	18.183	100	9.51E-07	22077 (ATLID_IF)	-4.75E-04	5.43E-01	22079 (ATLID_IF)	93.76%
16.51%	1833.891	30	129	-9.95E-07	22077 (ATLID_IF)	7.75E-04	7.57E-01	22079 (ATLID_IF)	92.68%
18.15%	2016.168	30	125	-9.87E-07	22041 (ATLID_IF)	-1.09E-03	6.25E-01	22079 (ATLID_IF)	93.56%
19.93%	2213.479	30	128	9.59E-07	21211 (ATLID_IF)	1.96E-03	5.29E-01	22079 (ATLID_IF)	93.96%
21.61%	2399.913	30	142	9.75E-07	22077 (ATLID_IF)	1.32E-03	4.39E-01	22079 (ATLID_IF)	94.70%
23.32%	2590.436	30	137	-9.98E-07	22077 (ATLID_IF)	-7.32E-04	5.49E-01	22079 (ATLID_IF)	93.96%
25.44%	2825.925	30	117	-9.90E-07	22077 (ATLID_IF)	6.98E-06	3.33E-01	22079 (ATLID_IF)	95.64%

Transient Total Heat Balance

Time Data

Error (in K) related to Time Discretisation

Implicit Convergence Parameters


SYSTEMA
Process Control
THERMISOL
THERMISOL Error Definitions: Static Errors
Relaxation Coefficient (RELXCA)
Not a physical criteria but is a pertinent criteria on numerical convergence
Absolute / Relative Energy Balance (ENBALA / ENBALR)
Physical criteria suitable for steady-state analysis that sums flux contributions to boundary conditions
Total Energy Balance (ENBALT)
Physical criteria suitable for both steady-state and transient analysis that sums the total flux of each node (including capacitive flux for transient analysis)
This new criteria introduces for the first time a physical criteria on the implicit resolution of transient analysis
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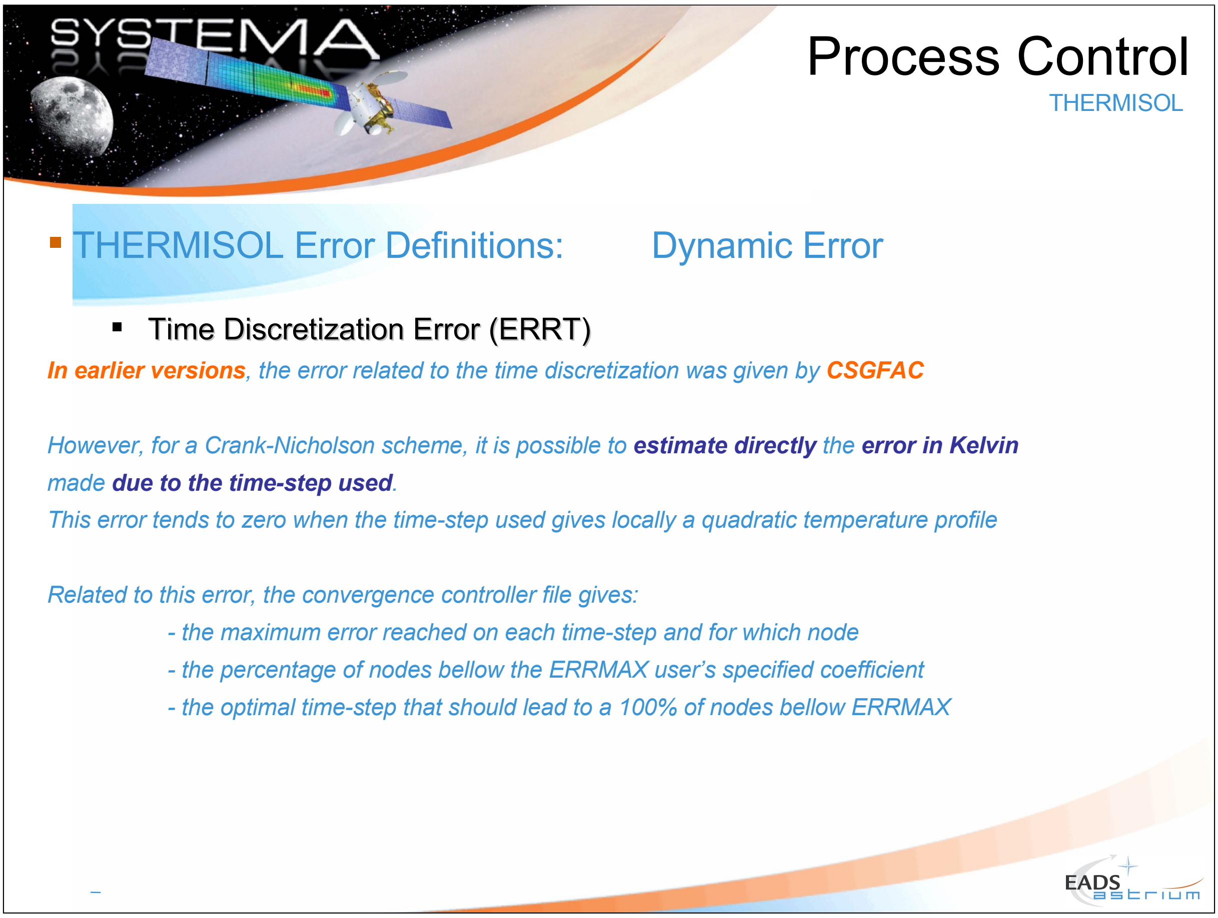
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Process Control
THERMISOL
THERMISOL Error Definitions: Dynamic Error
Time Discretization Error (ERRT)
In earlier versions, the error related to the time discretization was given by CSGFAC
However, for a Crank-Nicholson scheme, it is possible to estimate directly the error in Kelvin made due to the time-step used.
This error tends to zero when the time-step used gives locally a quadratic temperature profile
Related to this error, the convergence controller file gives:
- the maximum error reached on each time-step and for which node
- the percentage of nodes bellow the ERRMAX user's specified coefficient
- the optimal time-step that should lead to a 100% of nodes bellow ERRMAX
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THERMISOL

New THERMISOL to ESATAN converter

- **THERMISOL was originally developed on the ESATAN v8 language**

Since, THERMISOL has included more ESATAN functionalities in order to maximize the compatibility

More than 95% of usual syntax is strictly the same.

If a specific functionality is not implemented in THERMISOL, it can be added on demand – if you need it, just ask for it !

- **THERMISOL evolutions**

THERMISOL has also developed new functionalities and advanced features

generally developed in order to speed-up the computation, increase the accuracy of the temperature integration, or to give more sense on the keywords used.

- **This converter produces an input file 100% compatible with both ESATAN and THERMISOL**

All the modifications are reported into a log file

In a few cases, the log notifies that a modification has to be checked or manually performed

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THERMISOL

ESATAN converter

THERMISOL executive blocs

- THERMISOL is compatible with the 2 executive blocs definitions
  - Classical mode: $VARIABLES1 / $VARIABLES2
  - Complete mode: $VTEMPERATURE / $VTIME / $VRESULT
- The converter translate the complete mode to the classical one

The new input file produced can be re-run into THERMISOL to check the convergence quality using the classical mode

!

If tem ture dependencies are significant, the time-step will probably need to be decreased to get the sam ergence quality

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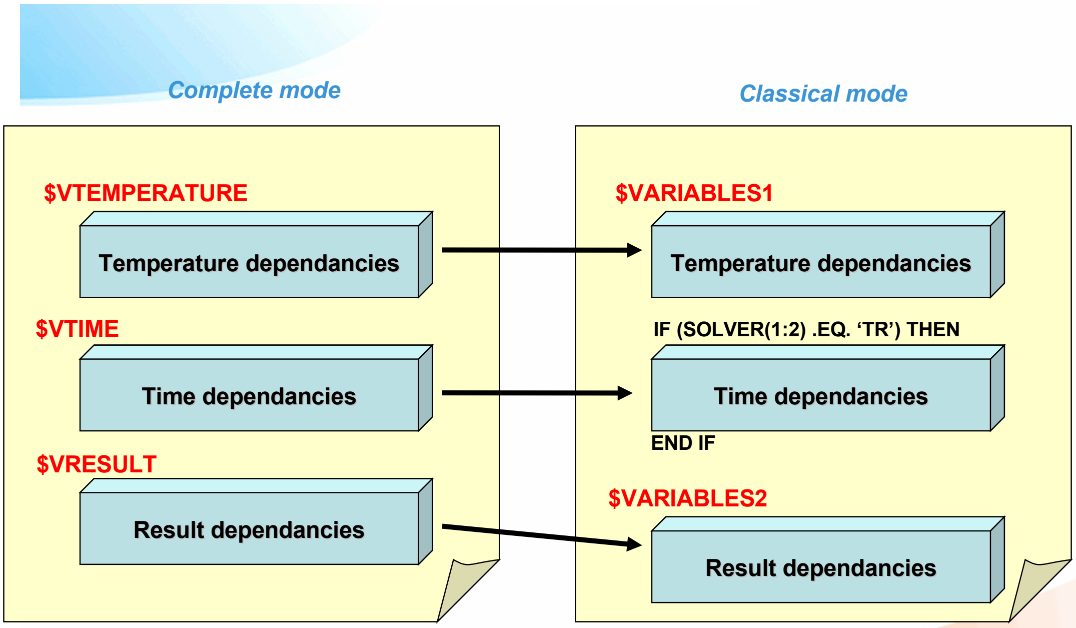
THERMISOL

ESATAN converter



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THERMISOL

ESATAN converter

- Syntax corrections
  - Free format

The THERMISOL preprocessor can read free format (even if the Fortran created is written in a pure Fortran77 using fixed format)

The converter positions every Mortran line at the 6th column

  - Real formats

The THERMISOL preprocessor automatically detects real's formats and write a correct Fortran to prevent from random behaviors at subroutine calls

The converter re-write all reals in double precision format to avoid inconsistencies

  - Implicit declaration loops

THERMISOL accepts both the ESATAN syntax and the FORTRAN syntax

The converter translate FORTRAN loops to the ESATAN syntax

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THERMISOL

ESATAN converter

Syntax translations

- Specific THERMISOL keywords

Specific options, like the H5 output controls or advanced accuracy management, are commented

- THERMISOL Mortran Data Access

Quick data access are converted as follow

N xxxx	*INTNOD(CURRENT, xxxx)*
N:model:xxxx	*INTNOD(model, xxxx)*
N variable	*INTNOD(CURRENT, variable)*
NS xxxx = 'B'	*CALL STATST('Nxxxx','B')*

Warning: some THERMISOL NS statements (using variable) cannot be automatically converted
The log file gives explicitly the eventual manual modifications to be performed

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THERMISOL

ESATAN converter

Syntax advanced translations (1/2)

- THERMISOL Implicit Mortran Data Access

In THERMISOL, it is possible to implicitly reference a node or a coupling using variables and/or formulas

```
$INITIAL
  DO INODE = 1, 6
    C:INODE = 8.43e-01* A:INODE
    C:(INODE + 760) = 9.52e-01* A:(INODE+760)
    C:SUBMOD1:INODE = 8.43e-01* A:SUBMOD1:INODE
    GL(INODE, INODE+760) = 0.25
  END DO
```

Nodal implicit references are converted in pure ESATAN format using the INTNOD function
Coupling implicit references cannot be automatically translated

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THERMISOL

ESATAN converter

Syntax advanced translations (2/2)

- THERMISOL Mortran Macros

In many cases, it is very convenient to modify at once the property of a group of nodes or couplings (for which a loop could not be suitable)

C:'group definition' = ...

GL(xxx, 'group definition') *= ...

The converter expends this Mortran Macro to as many lines as required

Every Mortran Macro using a nodal entity can be converted to ESATAN.
However, for couplings, if the first node reference is not explicit, the conversion cannot be automatically performed

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Conclusion

- The v4 is now getting **very mature** and is **fully validated**
- Thanks to the SYSTEMA framework, it offers a **very powerful and efficient process** into a **user friendly environment**
- The computation processes have been **greatly improved** giving much more control on the results convergence
- It is now time to switch to this software generation in industrial production

It will **significantly improved** the user's processes and quality

We will give all the **necessary support** to adapt the processes

by either helping the coding of user's software or interfaces modification or by also taking into account some user's constraints directly into our software suite.

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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 tunes. 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.
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 :
Automatic time-step adjustment