# Appendix P

Development of an automated thermal model correlation tool

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Abstract

A generally essential part in the development of a spacecraft is the implementation of a thermal model for the temperature predictions during the operation phase. In order to achieve a good accuracy of the assessed temperatures, the thermal model has to be correlated with measurements from predetermined thermal tests. Currently this correlation is only possible in a manual way at Airbus DS GmbH. As this manual method is often a time consuming process, a new method for solving this problem is currently under development. With this newly developed MATLAB® tool (TAUMEL = Tool for AUtomated Model correlation using Equation Linearization) it will be possible to correlate restricted thermal models from ESATAN-TMS automatically. The first master thesis regarding this automated approach was finished in December 2013, whose outcome will be presented. Because of the promising potential of this new correlation method, Airbus DS in Bremen is currently working within the frame of a second master thesis. The current status will be presented as well.
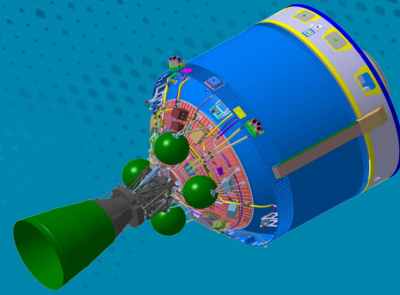
Development of an automated thermal model correlation tool
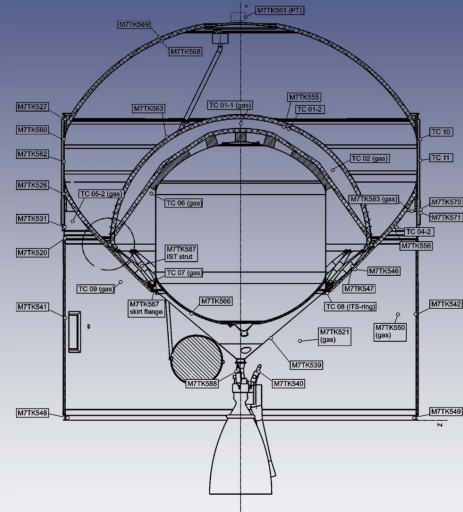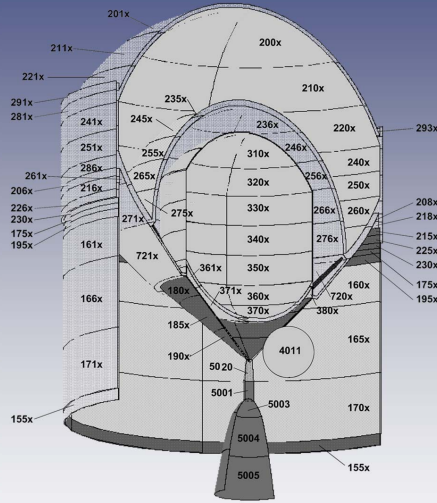
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Date: 14.10.2014

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Fundamentals
Test vs. TMM

$$\begin{bmatrix} T_{model,1} \\ \vdots \\ T_{model,n} \end{bmatrix}_c = [T_{model}]_c \quad \xleftarrow[\text{(mean absolute deviation)}]{\text{comparison criterion}} \quad [T_{test}] = \begin{bmatrix} T_{test,1} \\ \vdots \\ T_{test,n} \end{bmatrix}$$

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Fundamentals
Parametric correlation

$$C_i \frac{dT_i}{dt} = \sum_{\substack{i=1 \\ j \neq i}}^{N} GL_{ij} PL_{ij} (T_j - T_i) + \sigma \sum_{\substack{i=1 \\ j \neq i}}^{N} GR_{ij} PR_{ij} (T_j^4 - T_i^4) + \dot{Q}_i$$

Uncertainties:

❑ Heat conduction ($GL_{ij} = \lambda_i \frac{A_{ij}}{d_{ij}}$): $\lambda: \pm 20\%$

❑ Heat radiation ($GR_{ij} = A_i \varphi_{ij} \varepsilon_i \alpha_j$): $\varepsilon, \alpha: \pm 20\%$

❑ Convection (GF) excluded in the current development stage

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Motivation
state of the art

❑ Currently: manual correlation at Airbus DS

    ❑ Time consuming (months)

    ❑ Limited number of parameters/calculations

❑ Very challenging schedule in A5ME

➔ **Automated correlation necessary!**
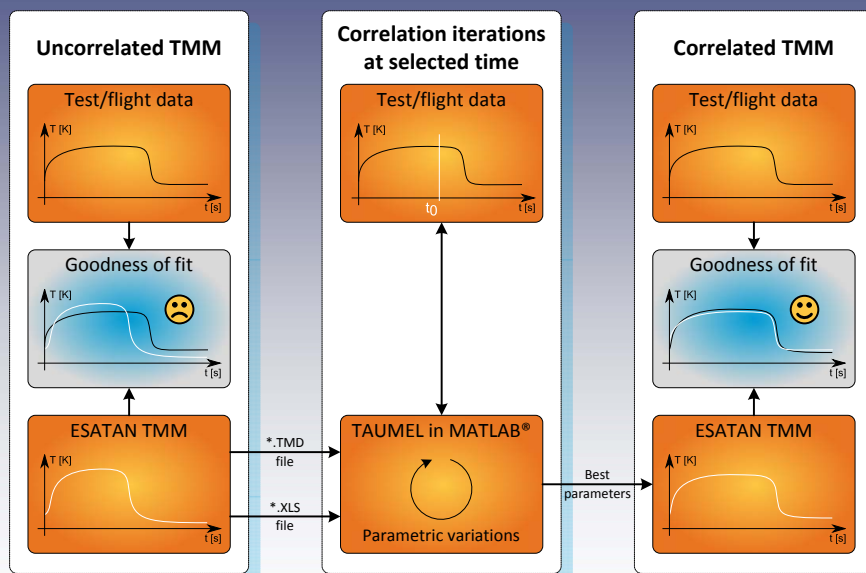
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Introducing a new approach
The idea

TAUMEL: Tool for AUtomated Model correlation using Equation Linearization)

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Current GUI in MATLAB®

Results
Academic test case vs. reality

	Small models (15-150 nodes)	**ESC-A (~1800 nodes)**
MAD uncorrelated	14.5K	19.6K
MAD correlated	0.8K	14.8K
$\dfrac{\text{runs}}{\text{hour}}$	500000 - 60000	13000 - 4500

FAST !

Conclusion

Current state of the tool

- ❑ Reading TMD-files from ESATAN-TMS into MATLAB®
- ❑ Excellent correlation for academic cases (vacuum test)
- ❑ Only small models in an acceptable time due to
  exponentially increasing number of parameter cases

Open problems

- ❑ Selection of quasi steady state
- ❑ Fluid connected nodes / convection
- ❑ Temperature depending boundary conditions

Essential for correlation of "real" models!

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Outlook
Planning for further development

- ❑ Open problem treatment
- ❑ Implementation of intelligent numerical parameter solver
  - ❑ Simulated annealing
  - ❑ Threshold accepting
  - ❑ Genetic algorithm
- ❑ Validation of the method
- ❑ Application to projects (A5ME)

Second master thesis
currently running

Third thesis/internship
planned for 2015

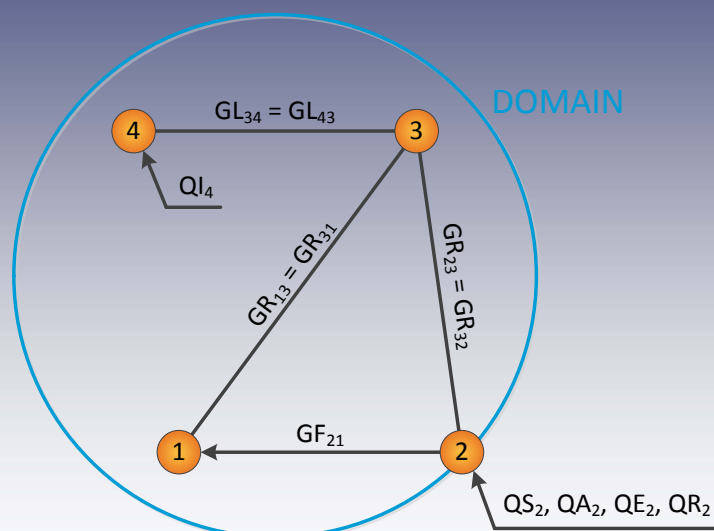14.10.2014   10 / 11

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Appendix: Mean absolute deviation

$$MAD = \frac{1}{n}\sum_{i=1}^{n}\left|T_{test,i} - T_{model,i}\right|$$

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Appendix: Parameter combinations

Case	Parameter 1	2	3		Case	Parameter 1	2	3
1	0.9	0.9	0.9		15	1.0	1.0	1.1
2	0.9	0.9	1.0		16	1.0	1.1	0.9
3	0.9	0.9	1.1		17	1.0	1.1	1.0
4	0.9	1.0	0.9		18	1.0	1.1	1.1
5	0.9	1.0	1.0		19	1.1	0.9	0.9
6	0.9	1.0	1.1		20	1.1	0.9	1.0
7	0.9	1.1	0.9		21	1.1	0.9	1.1
8	0.9	1.1	1.0		22	1.1	1.0	0.9
9	0.9	1.1	1.1		23	1.1	1.0	1.0
10	1.0	0.9	0.9		24	1.1	1.0	1.1
11	1.0	0.9	1.0		25	1.1	1.1	0.9
12	1.0	0.9	1.1		26	1.1	1.1	1.0
13	1.0	1.0	0.9		27	1.1	1.1	1.1
14	1.0	1.0	1.0					

```
1  $REAL
2  #----------------------------------------------------------
3  # Array of correlation parameters calculated with TAUMEL
4  #----------------------------------------------------------
5  Corr_Par(2,7) =
6    1.000000, 1.200000,
7    2.000000, 1.200000,
8    3.000000, 1.200000,
9    4.000000, 1.000000,
10   5.000000, 0.800000,
11   101.000000, 1.000000,
12   102.000000, 1.000000;
```

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Appendix: New approach in MATLAB®
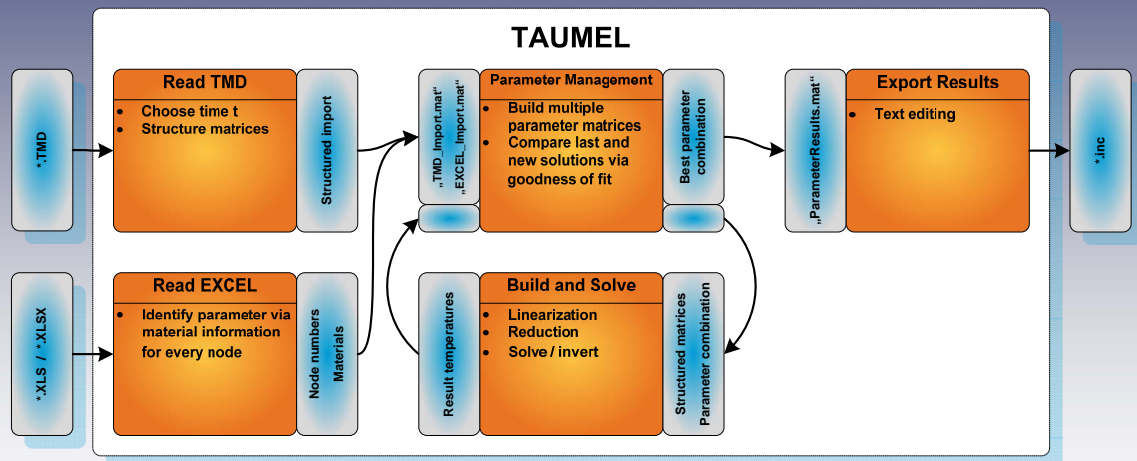
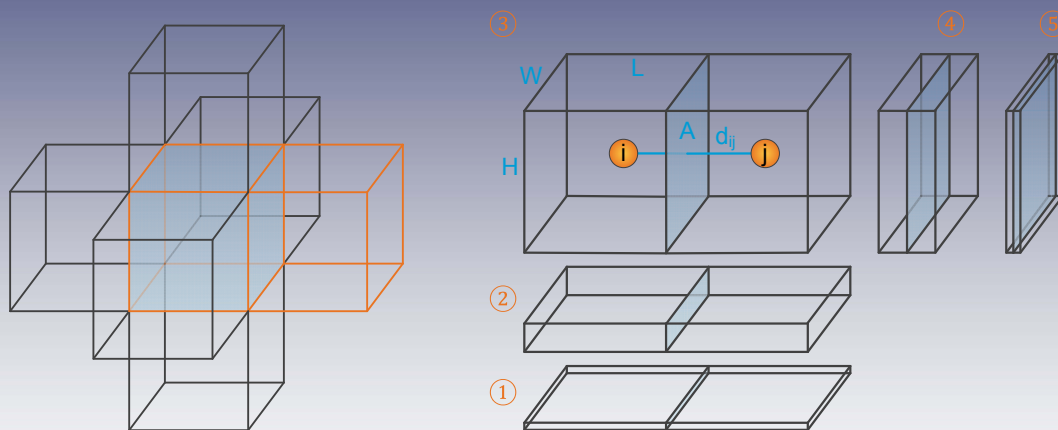Appendix: Problematic of material depending parameter building