Appendix M

Thermal Model Reduction with Stochastic Optimisation

Matteo Gorlani
(Blue Group, Italy)

THERMAL MODEL REDUCTION WITH STOCHASTIC OPTIMISATION

Matteo Gorlani
Blue Engineering, Torino, Italy
Maurizio Rossi
Galileo Avionica, Firenze

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Topics

- Introduction
- **Galileo Avionica** IRES N2 Instrument
- Stochastic Model Reduction
- **Blue Group** P.ANA.MA software
- Conclusions

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Introduction (1/3)

DETAILED THERMAL MODELS

INSTRUMENTS MAIN CHARACTERISTICS

- Small dimensions
- Very different levels of external heat fluxes
- Materials with low heat conductance
- Internal cavities, sensors and equipments with very different thermal requirements
- Very different levels of termperatures within the whole instrument

DETAILED MODELS

Introduction (2/3)

REDUCTION OF THERMAL MODELS

WHY A THERMAL REDUCED MODEL:

- Thermal analysis at higher level
- Coupled thermal analysis with S/C

THE PROCESS OF MODEL REDUCTION

The reduction of the Detailed Thermal Mathematical Model (DTMM) with its sets of nodes, conductors, dissipations and heat loads, is the process of deriving from these sets the smallest "reduced" ones, which, once organised in the Reduced Thermal Mathematical Model (RTMM), provide the minimum deviations of results between the two TMM's.

Introduction (3/3)

REDUCTION OF THERMAL MODELS

REQUIREMENTS FOR THE THERMAL REDUCED MODEL

- sufficient representation of thermal behaviour of sensor
- sufficient representation of main performances of sensor
- sufficient representation of thermal exchange with S/C and environment

MAIN STEPS OF MODEL REDUCTION PROCESS

- Definition of reduction approach/comparison between DTMM and RTMM
- Definition of thermal cases for the validation of the RTMM
- Definition of criteria for admissible deviations between DTMM and RTMM

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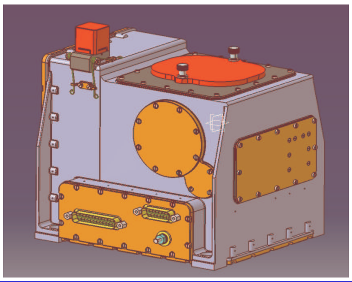
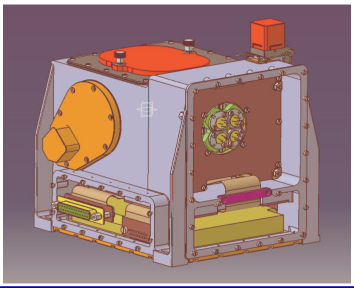
The IRES N2 Instrument (1/2)

GALILEO AVIONICA two-axis infrared horizon sensor for accurate measurement of pitch and roll attitude angles wrt the Earth disk centre

- A main aluminium housing body supporting the internal H/W.
- four feet on a supporting structure, providing conductive sink

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The IRES N2 Instrument (2/2)

SENSOR INTERNAL H/W

The sensor is essentially constituted of the following major components:

- I/R telescope for localization of the Earth disk
- Scan mirror, with relevant driving system
- Optical Sensors
- Electronics package

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Stochastic Model Reduction (1/6)

REDUCTION APPROACH FOR CRITICAL ITEMS

Thermal Requirements Applicable Also To The RTMM

- sensors
- printed circuit boards
- scan mirror assembly

Maintain one to one correspondence to the critical items

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Stochastic Model Reduction (2/6)

REDUCTION APPROACH FOR I/F's and STRUCTURE

Heat Exchange with the S/C from DTMM Applicable To The RTMM

- representative of thermal I/F's with the external environment
- representative of thermal I/F's with the internal environment
- structural parts shall be as simple as possible
- external configuration shall be as simple as possible

DTMM reduced to 15 nodes (about 20%)

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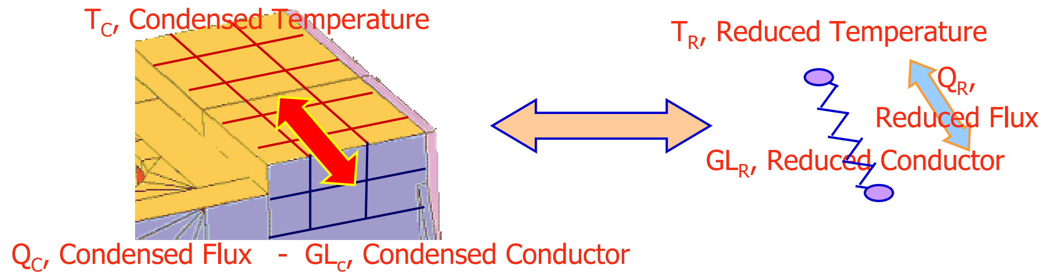
Stochastic Model Reduction (3/6)

CONDENSED AND REDUCED MODEL



T_{Ci} = **averaged Temperature of condensed node i**

Q_{Cij} = **heat flux between condensed nodes i and j**

$GL_{Ci,j} = Q_{Ci,j} / (T_{ci} - T_{cj})$ **condensed linear conductor between i and j**

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Stochastic Model Reduction (4/6)

REDUCTION APPROACH – VERIFICATION CRITERIA

RTMM defined in S/S worst cases:

- Cold Case
- Hot Case

Validation parameters:

Temperature Deviation $\Delta T_i = T_{Ci} - T_{Ri}$

Global Temperature Deviation $\Delta T = (\Sigma \Delta T_i^2)^{1/2}$

MAX $\Delta T_i < 2$ °C

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Stochastic Model Reduction (5/6)

FULL STOCHASTIC SCAN

- Guess Solution for GL_R from $GL_{C(HOT)}$ and $GL_{C(COLD)}$
- Full stochastic analysis (search for the most influencing GL's and improve the guess solution):
- ΔT_i , ΔT calculated for each case

Best case stored

Influence of $GL_{Ri,j}$ on ΔT evaluated

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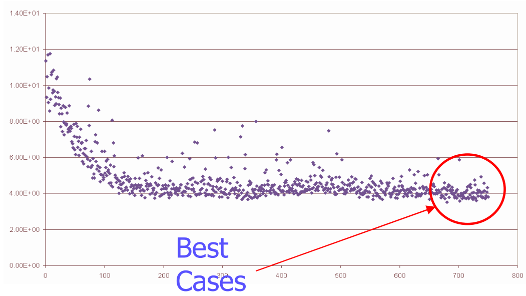
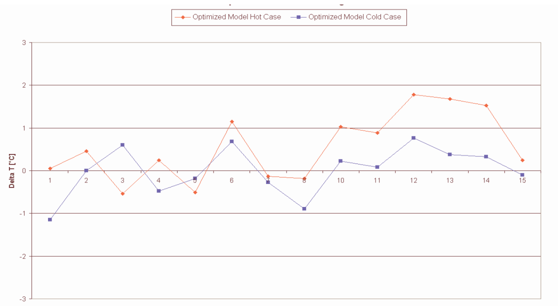
Stochastic Model Reduction (6/6)

STOCHASTIC OPTIMISATION





- **Critical items: ±1.2 °C**
- **Remaining nodes: ± 2°C**

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P.ANA.MA software (1/2)

Parametric ANAlysis MAnager by BLUE GROUP

- Definition of variations of Parameters
- Editing of ASCII files for parameters definition in models
- Management of remote analysis
- Full factorial analysis with stochastic method
- Stochastic optimisation
- Gradient and genetic optimisation under development

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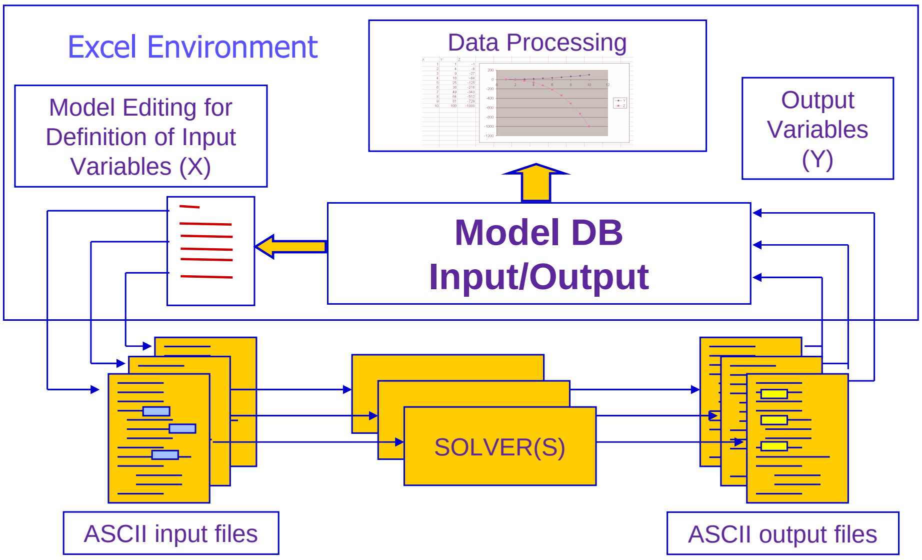
P.ANA.MA software (2/2)



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Conclusions

The model reduction based on:

- Calculation of condensed conductors
- Full stochastic scan for determination of influencing GLs
- Stochastic optimisation DTMM/RTMM correlation

Useful for fast reduction of thermal models of sensors:

- Provide good convergence to RTMM/DTMM correlation required
- Provide intuitive thermal network
    - Positive GLs
    - GLs between adiacent nodes
- RTMM/DTMM correlation accounts for different thermal cases

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