# Introduction to SINAS

7th February 2012

# Introduction to SINAS (1)

- SINAS is a S/W tool for mapping thermal node temperatures (e.g. ESATAN results) onto a Finite Element (FE) mesh (e.g. NASTRAN model)
  - Typically used to prepare temperature load data for thermo-elastic analysis
  - Other applications of SINAS are also possible e.g. automatic conductor generation
- Project was initiated by structures section at ESA circa 1985
  - Developed by Dutch Space (formerly Fokker) under a series of ESA contracts
  - Last development contract was 1998
  - IPR handed to ESA in 2004
- Freely available on TEC-MTV exchange portal http://exchange.esa.int

# Introduction to SINAS (2)

- When preparing a thermo-elastic analysis usual inputs are:
  - Geometrical Mathematical Model (GMM) for radiative calculations (e.g. ESATAN-TMS)
  - Thermal Mathematical Model (TMM) for temperature computation (e.g. ESATAN)
  - Structural FE model adapted for thermo-elastic analysis (e.g. NASTRAN)

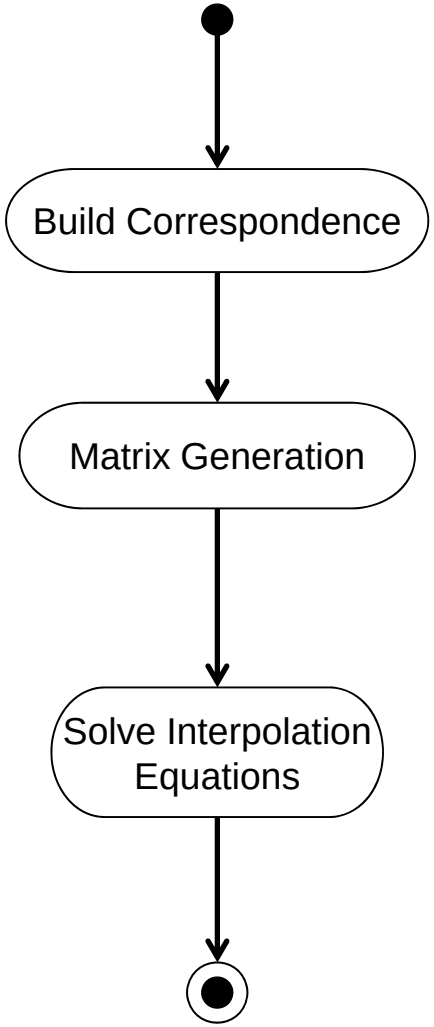
- Objective is to map TMM results (at lumped parameter nodes) to FEM model grid points but there are challenges:
  - GMM and FE model almost always use different geometry (FE uses much finer mesh)
  - Not all nodes in TMM are modeled in GMM (e.g. purely conductive nodes)
  - Specific H/W usually missing in FE model (e.g. MLI)
  - Equipment often modelled as lumped (point) masses in FE model

- Purpose of SINAS is to help overcome these challenges and enable a high quality mapping of lumped parameter temperatures onto FE mesh

# SINAS Functionality

- Functionality to build *overlap* (mapping) between thermal nodes and FE mesh
  - MSC Patran add-in (written in PCL) to aid the overlapping process
  - Automated overlap where thermal and structural geometry are (almost) coincident
  - Manual overlap supported for:
    - non-coincident thermal and structural geometry
    - thermal nodes with no geometric representation (conductive nodes)
- Any thermal lumped parameter code is supported (ESATAN, SINDA etc.)
  - User provides temperatures in SINAS format (convertors provided for ESATAN .csv)
- Supported FEM codes are MSC NASTRAN, ASKA:
  - Generates FE nodal temperature loads (NASTRAN TEMP cards)
  - Generates element temperature loads for transverse temperature gradients such as honeycomb panels (e.g. NASTRAN TEMPP1)

# The SINAS Method in 3 Steps



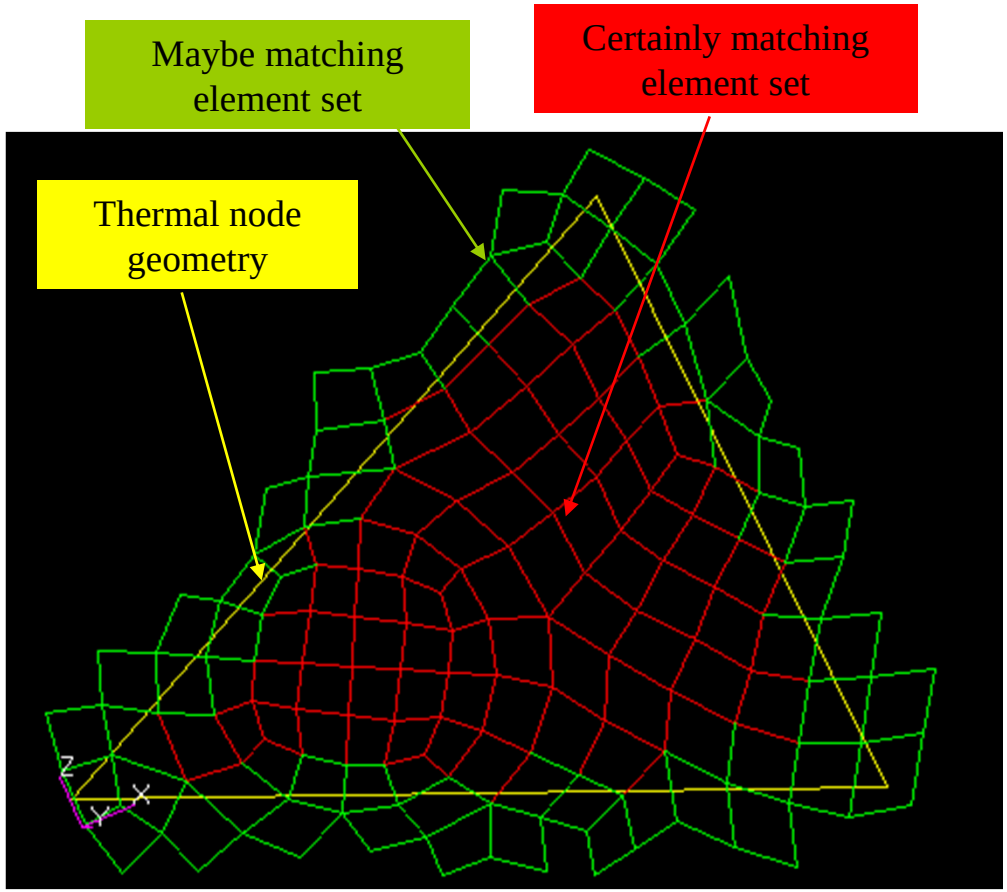

MSC Patran GUI

Command line / batch modules in conjunction with FE model

Command line / batch module

# SINAS Method: Step 1 : Correspondence building

- Build correspondence / mapping between:
  - Lumped parameter thermal nodes
  - Structural finite elements
- Using MSC.PATRAN GUI
- Automatic overlap detection



# SINAS Method: Step 2 – Matrix Generation

- **Next step is to mathematically link thermal nodes and FE nodes using *Prescribed Average Temperature Method*:**
  - **Weighted average temperature of FE nodes of elements overlapping a thermal node is equal to the thermal node temperature**
- **FE shape functions are used to obtain weighting coefficients:**

$$T^t_j = \sum_i a_i T^f_i \quad \Longrightarrow \quad \boldsymbol{T^t = A\,T^f}$$

$$1 = \sum_i a_i$$

constraint matrix

$T_i^f$ = FE node temperature

$T_j^t$ = Thermal Node Temperature

a = weighting coefficient

- **Derive conduction matrix from structural FE mesh**
  - **Replace structural materials with thermal ones (e.g. MAT1 with MAT4)**
  - **Use FE tool (NASTRAN or ASKA) to generate conduction matrix**

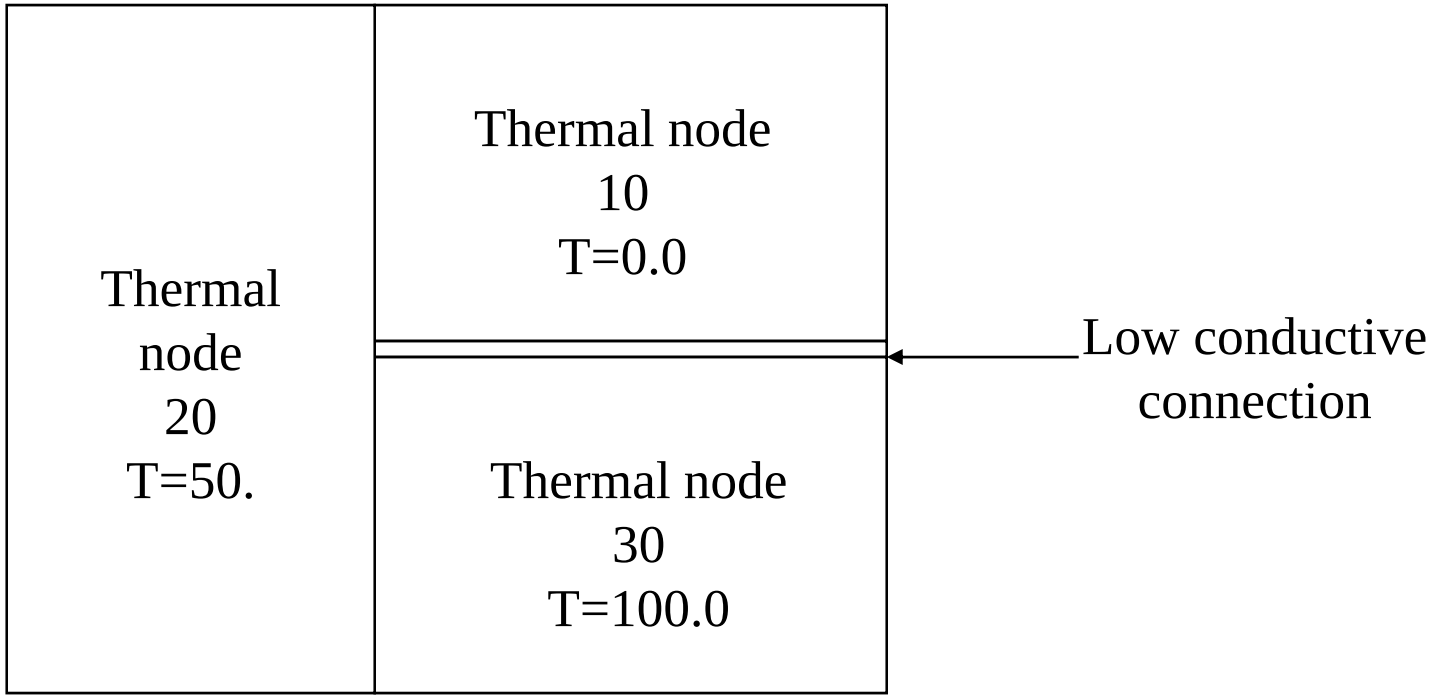
# SINAS Method: Step 3 – Solve Interpolation Equations

- **Assemble the following partitioned system of interpolation equations**
  - **Thermal node temperatures put in vector form: $T^t$**
  - **Solve the system of interpolation equations for: $T^f$**

$$\begin{bmatrix} C & A^T \\ A & 0 \end{bmatrix} \begin{Bmatrix} T^f \\ q \end{Bmatrix} = \begin{Bmatrix} 0 \\ T^t \end{Bmatrix}$$

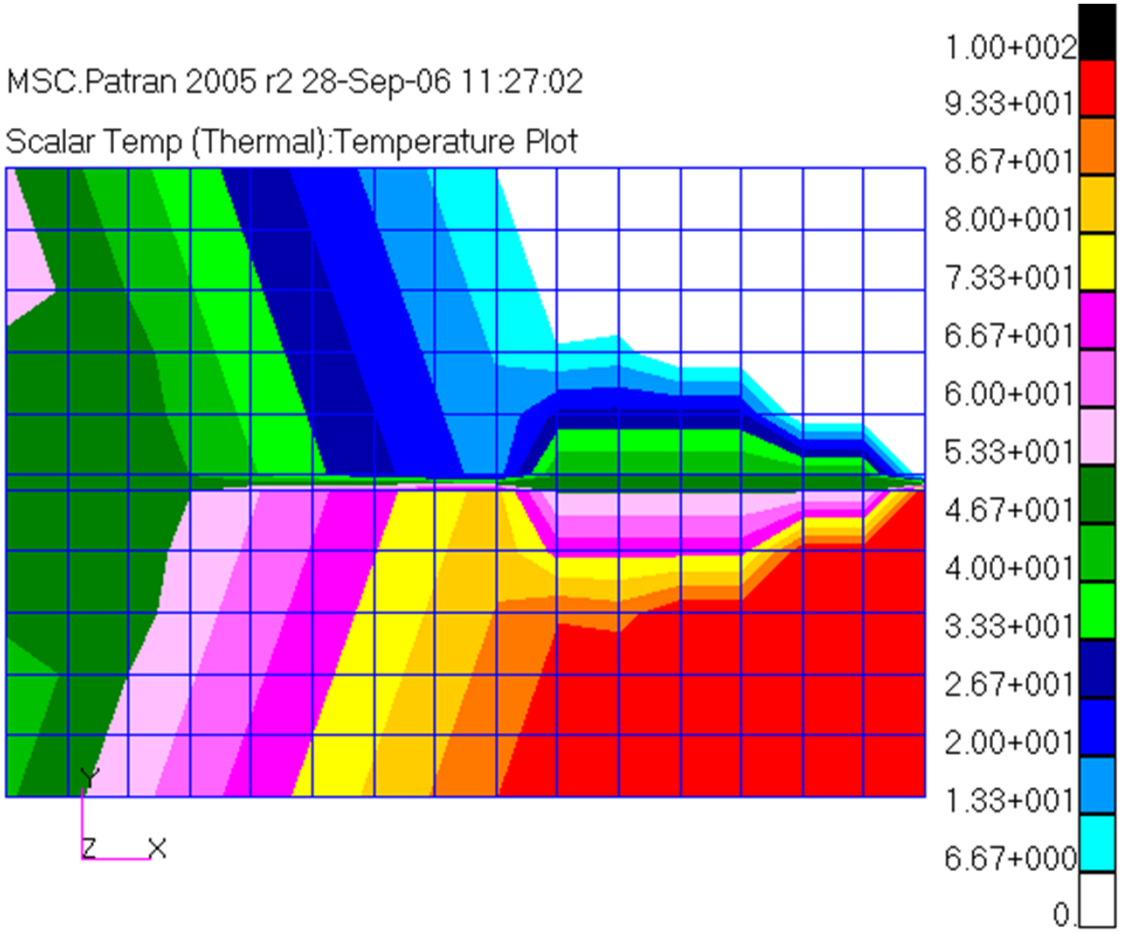
Conduction matrix derived from structural model

# SINAS Simple Example (1)



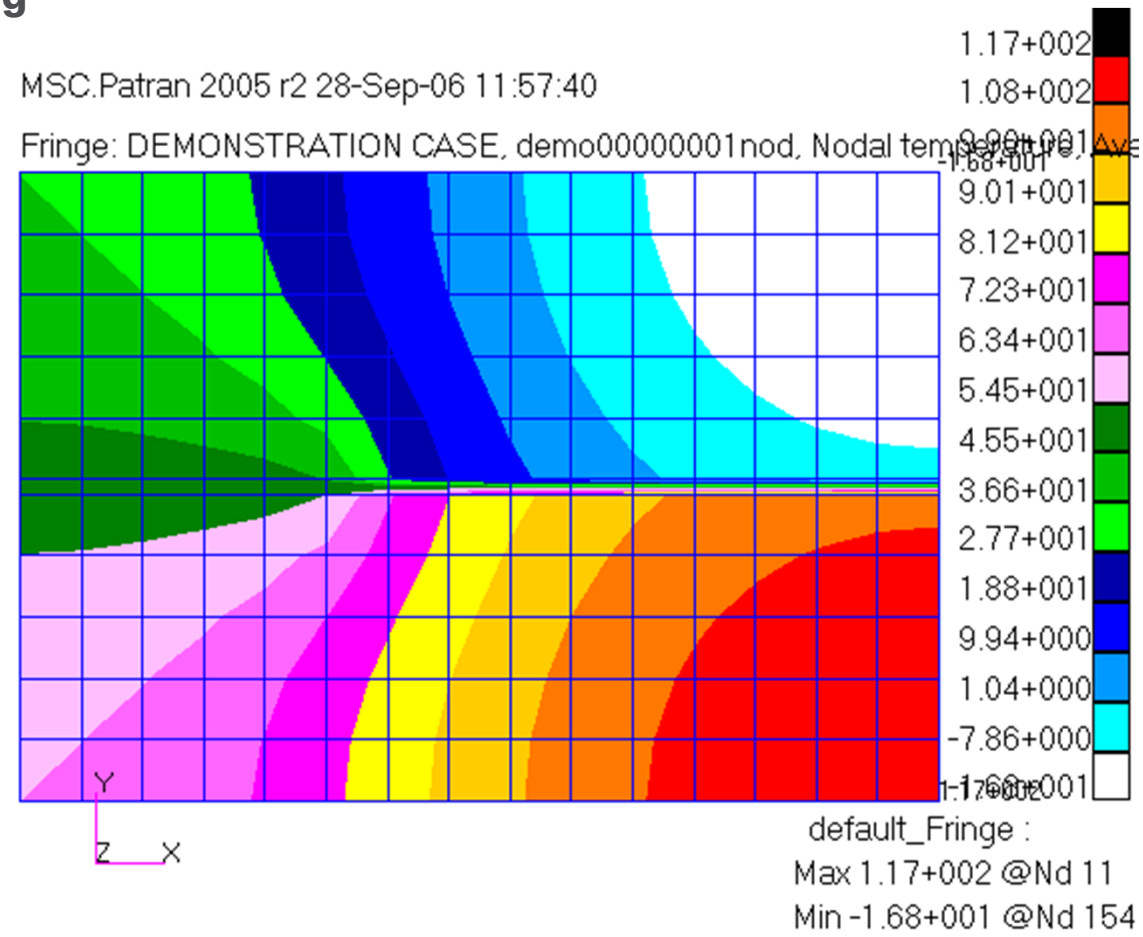
# SINAS Simple Example (2)

**Purely geometrical interpolation of TLP temperatures on FE mesh**



# SINAS Simple Example (3) : SINAS Results

- Contours of SINAS results show temperatures consistent with thermal model
- Use of conductive FE model for interpolation provides better mapping



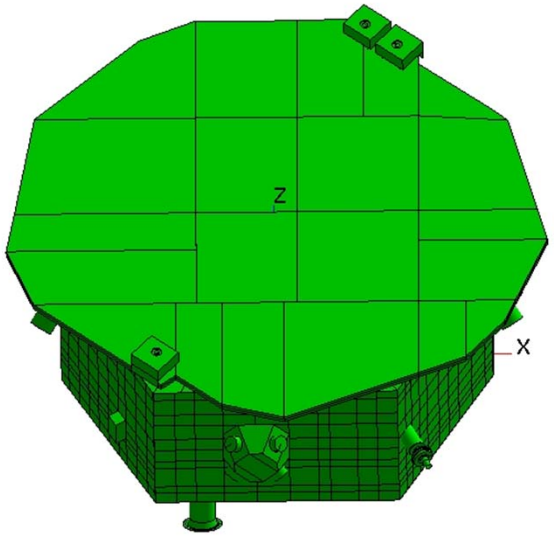
# ESTEC In-house SINAS Competence

- **Thermal Analysis and Verification Section (TEC-MTV) has experience using SINAS on real projects**
  - **Knowledge of all major space thermal tools (ESATAN-TMS, Thermal Desktop/SINDA, Thermica)**
  - **Patran experience for building correspondence between thermal and structural models**
  - **Experience using converting structural FE model to conductive thermal model for mapping**
  - **Experience with NASTRAN Thermal and NASTRAN for thermo-elastic analysis**

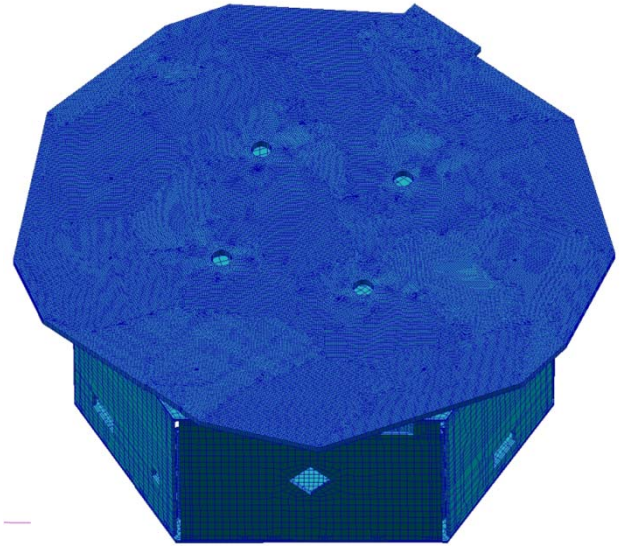
- **TEC-MTV has used SINAS on several projects:**
  - **GAIA optical bench**
  - **LISA Pathfinder full S/C model (ESA ESTEC)**
  - **EXPERT**

# Application Example: LISA Pathfinder

- SINAS has been used for LPF model twice in 2006 and 2009
- Combined SCM and LTP Thermal Model – approx 10,000 thermal nodes
- Full S/C structural FE model – approx 400,000 nodes, 500,000 elements




Thermal Model



FE Model

# Application Example: LISA Pathfinder

- **Thermal model results mapped onto FE model – temperatures shown in Patran**