Appendix S

ESATAN Thermal Modelling Suite
Product Developments and Demonstration

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(ITP Engines UK Ltd, United Kingdom)

Abstract

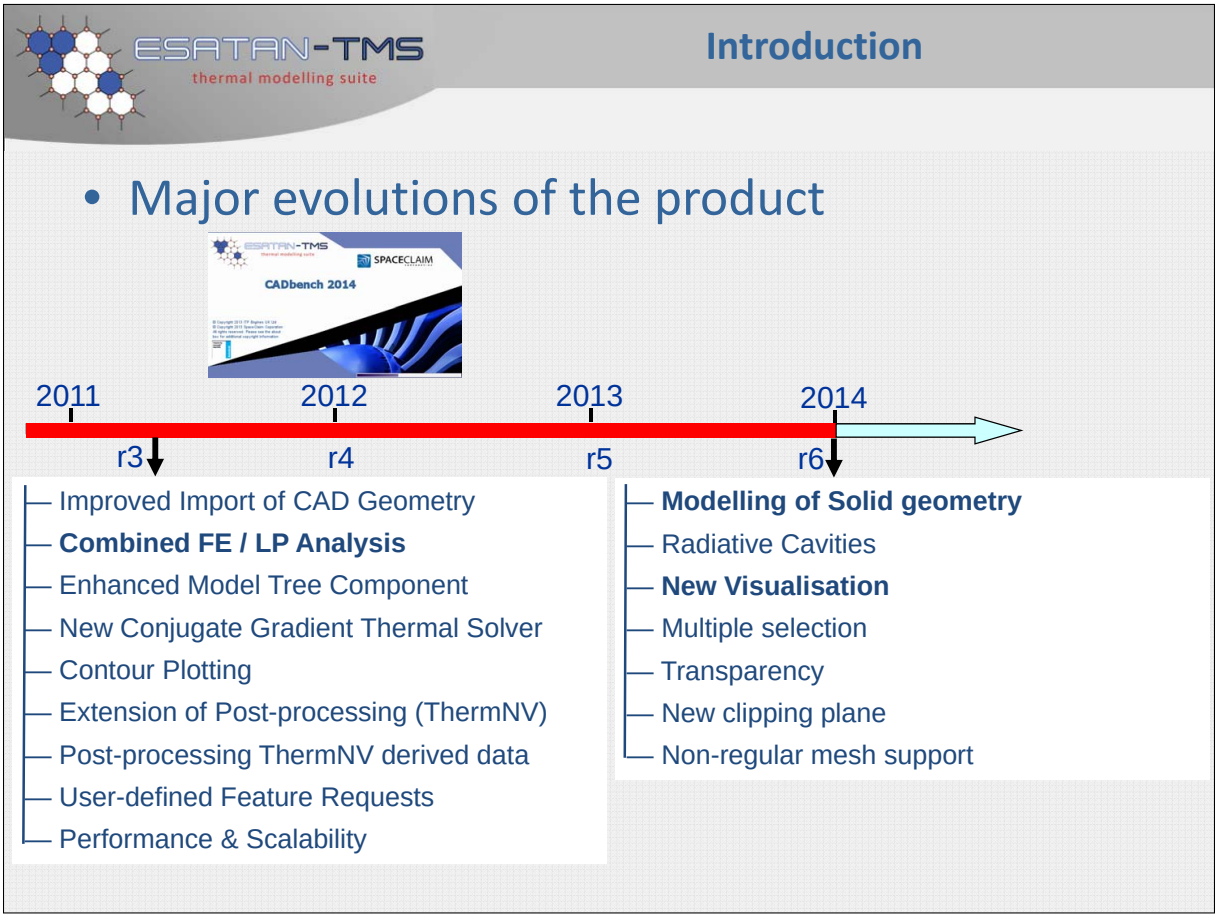
Product Developments

ESATAN-TMS provides the Engineer with a complete and powerful integrated thermal modelling environment. Version r6 was released at the end of last year and saw a significant evolution in its modelling capability. 3D solid geometry can now be modelled, performing ray-tracing on solid surfaces and allowing selection of either lumped parameter or finite element thermal analysis on the solid structure. With ESATAN-TMS r7 the focus of work of this release has been on a number of areas, including a tighter integration between Workbench and ESATAN, improvements to the layout of the user interface and general improvements directly raised by our customers.
This presentation outlines the new features to be included in the next release of ESATAN-TMS.

Thermal Modelling Demonstration

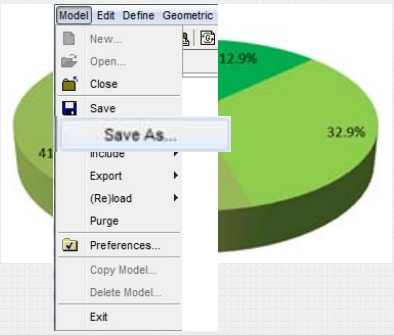
A demonstration of the new features included in ESATAN-TMS r7 will be given, building a thermal model to demonstrate the new functionality.

ESATAN-TMS
thermal modelling suite
ESATAN-TMS
Product Overview
Chris Kirtley
28th European Thermal & ECLS Software Workshop
ESA/Estec, Noordwijk, the Netherlands


ESATAN-TMS
thermal modelling suite
Introduction
• Major evolutions of the product
CADbench 2014
2011
2012
2013
2014
r3
r4
r5
r6
Improved Import of CAD Geometry
Combined FE / LP Analysis
Enhanced Model Tree Component
New Conjugate Gradient Thermal Solver
Contour Plotting
Extension of Post-processing (ThermNV)
Post-processing ThermNV derived data
User-defined Feature Requests
Performance & Scalability
Modelling of Solid geometry
Radiative Cavities
New Visualisation
Multiple selection
Transparency
New clipping plane
Non-regular mesh support

Introduction

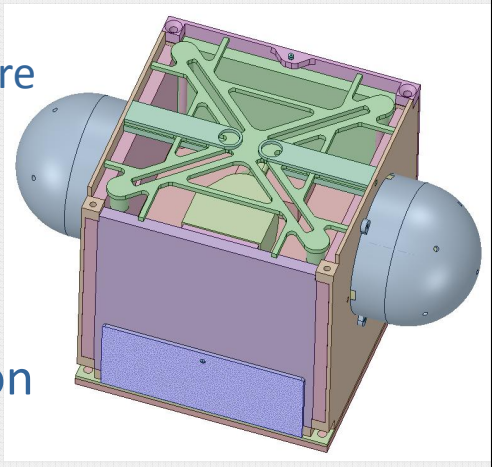
- User survey performed at the end of 2013
  - Feedback on how we are doing
    - Product functionality
    - Quality of user support
    - **What's important to you**



- Continued **major investment** on the product
- Focusing on points you raised
- Now finalising release for the end of the year

Contents

- Presentation of ESATAN-TMS development status
  - Model import from CAD
  - Further thermal integration
  - Improved user interface
  - Modelling time & temperature dependency
  - Model definition
  - Simplified user input
- Followed by a demonstration



ESATAN-TMS thermal modelling suite

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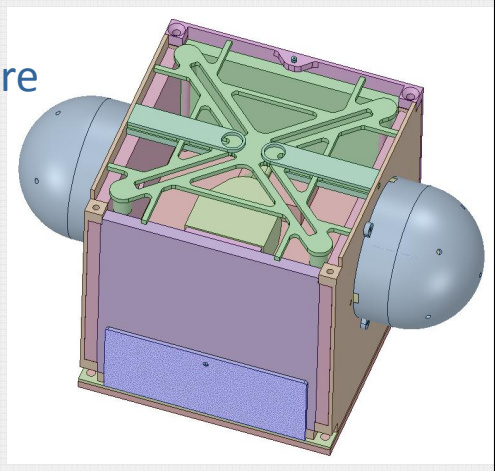
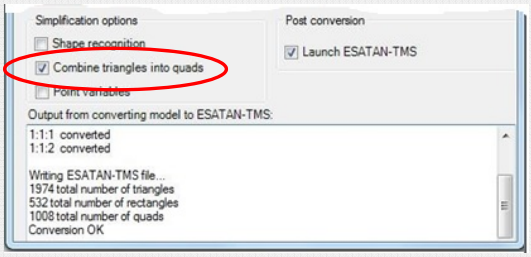
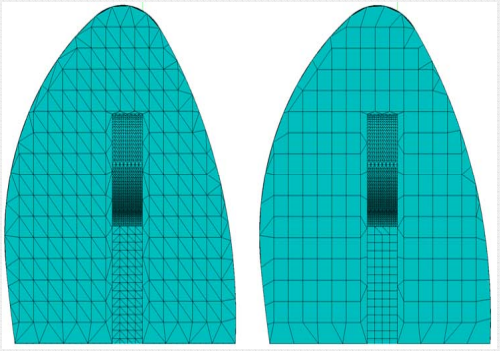


ESATAN-TMS thermal modelling suite

Model Import from CAD

- CADbench 2014 development
  - User feedback on conversion of CAD models
  - Handle more cases recognising primitives
  - Option to merge triangular element into quads
    - Merge triangles which are planar within a tolerance





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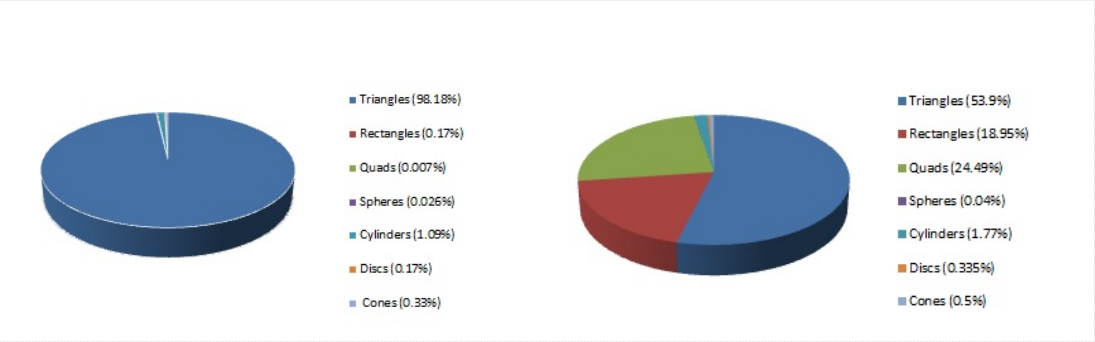
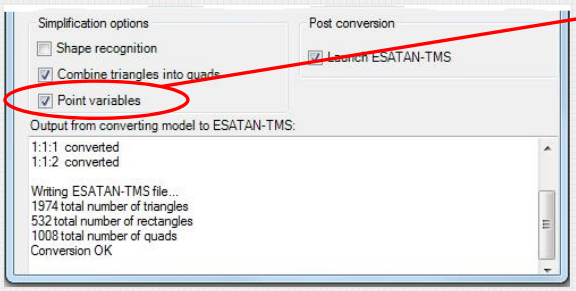
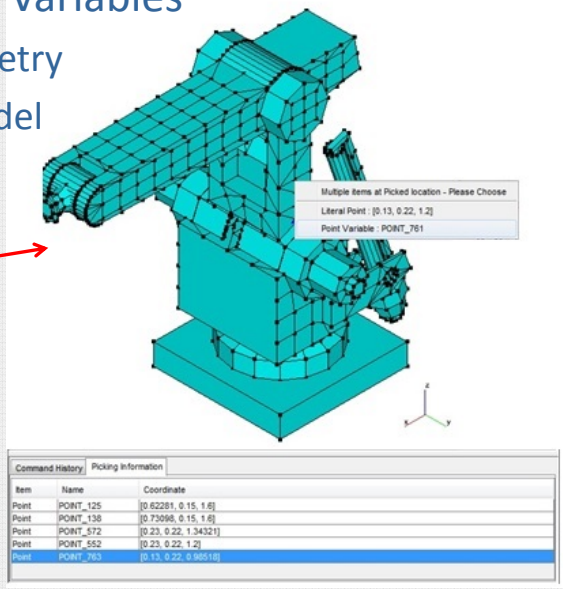


ESATAN-TMS thermal modelling suite

Model Import from CAD

- CADbench 2014 development
  - Option to generate Point Variables
    - Dynamic binding of geometry
    - Literal points reduces model complexity





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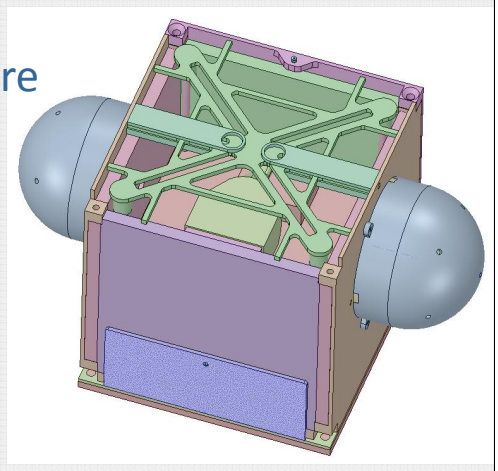
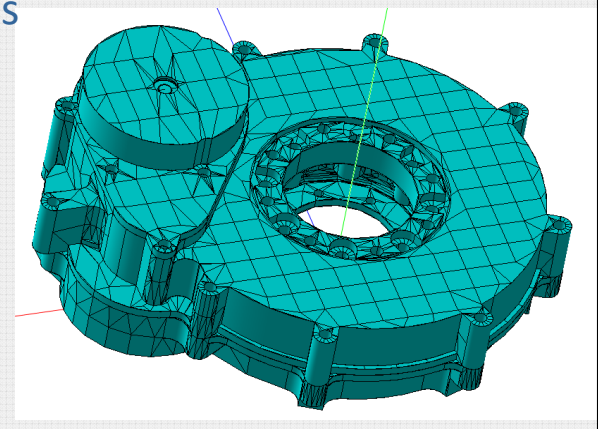
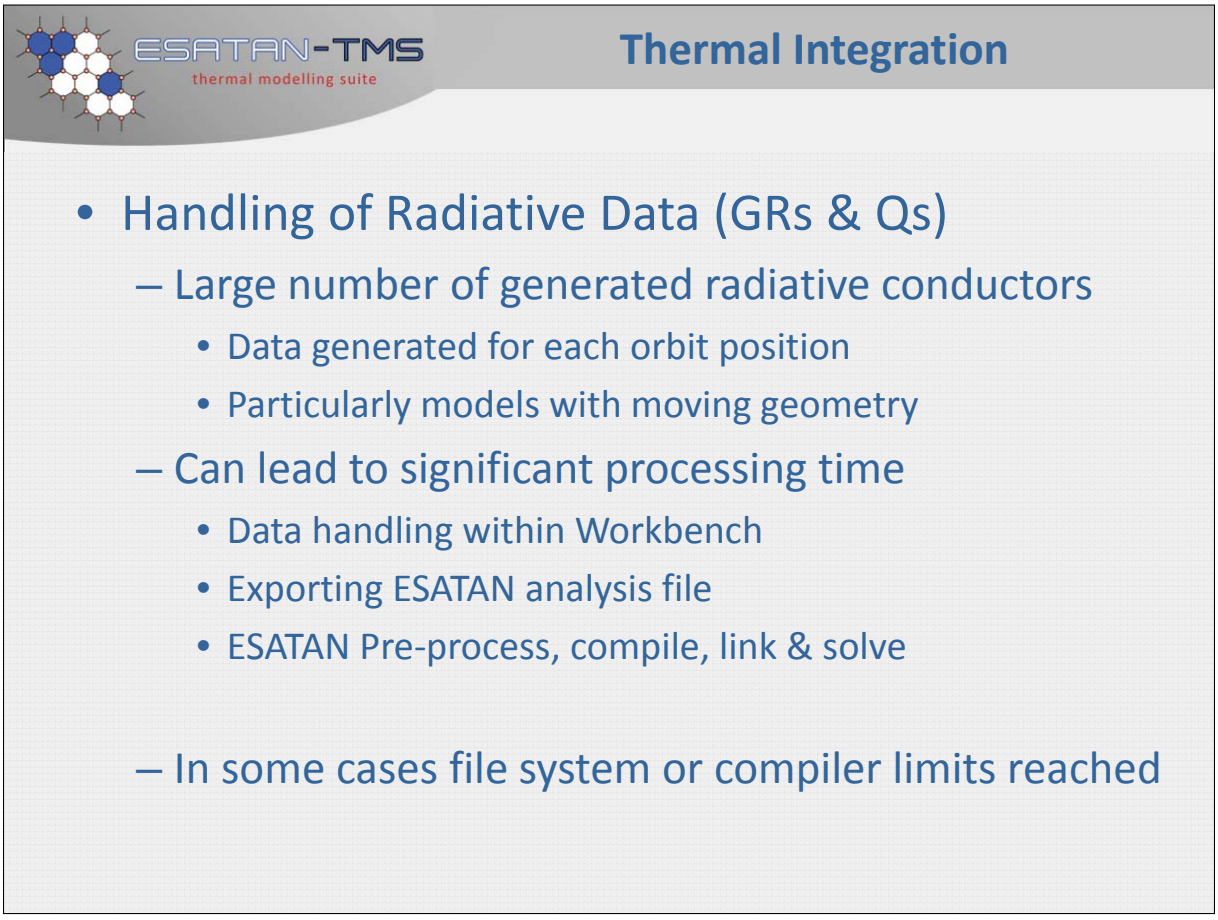


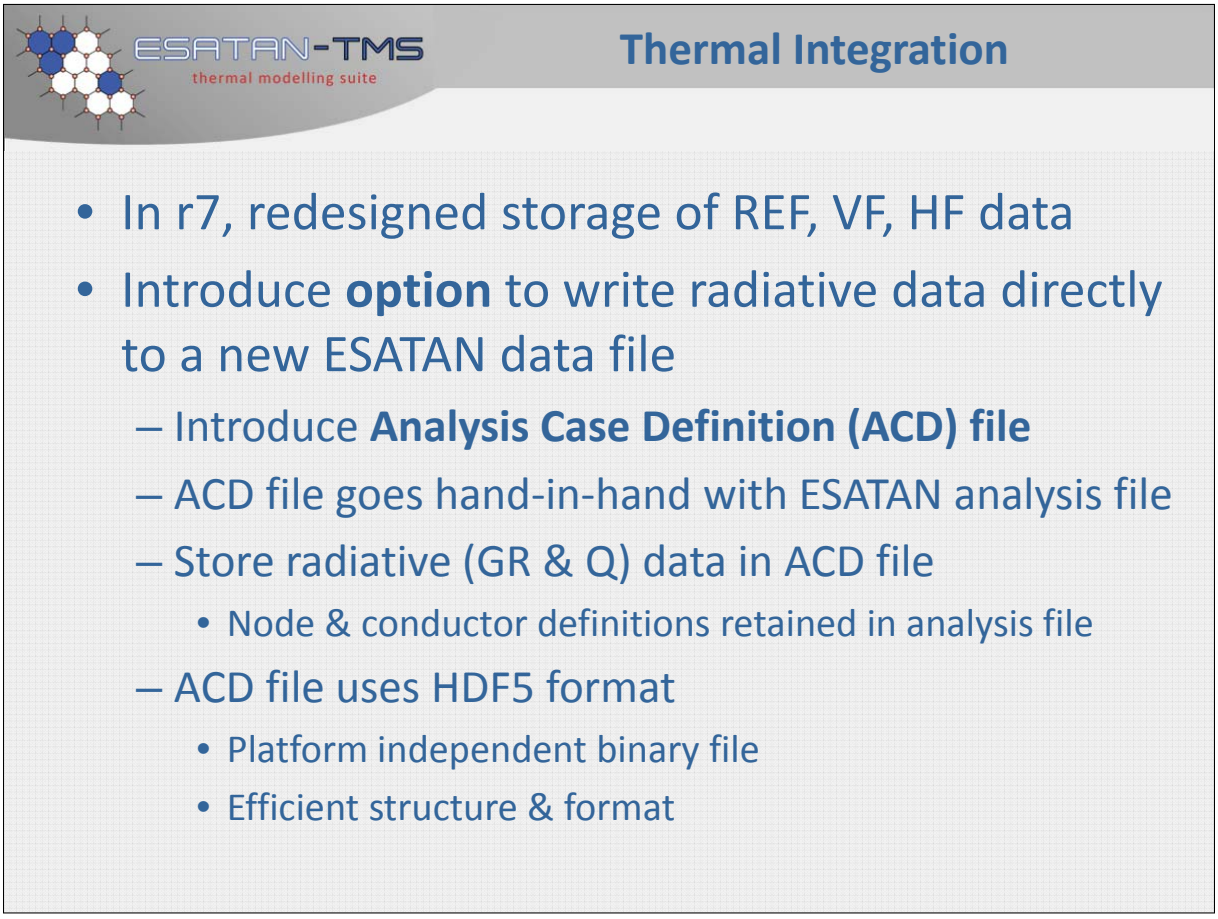
ESATAN-TMS thermal modelling suite

Thermal Integration

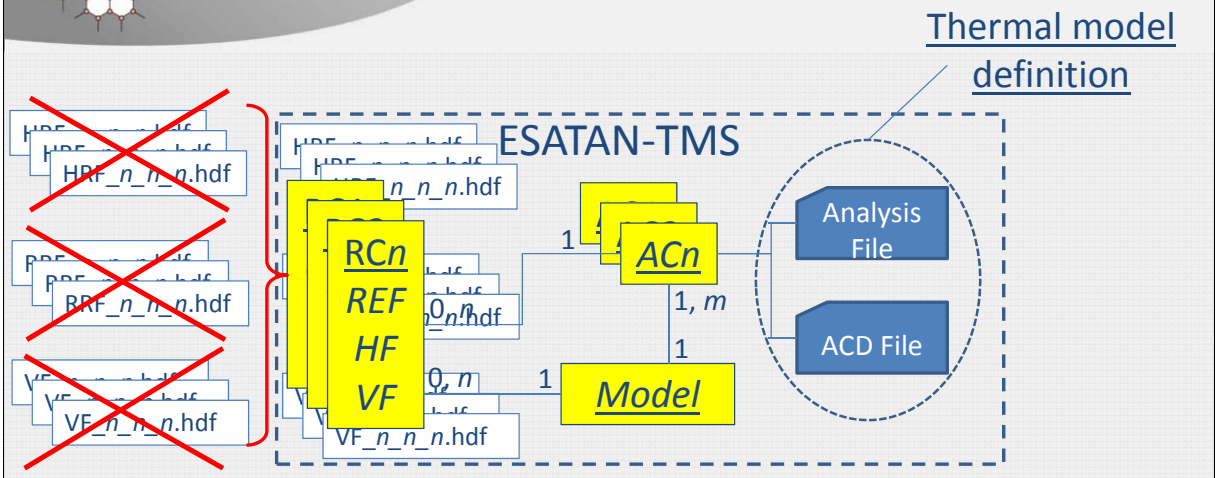
- Vision of an **fully integrated thermal modelling environment**
  - High-level thermal modelling through Workbench
  - Simplified interface, less error prone
  - Easier validation
  - More efficient
  - Availability of data
  - Consistency of data & concepts throughout




ESATAN-TMS
thermal modelling suite
Thermal Integration
• Handling of Radiative Data (GRs & Qs)
– Large number of generated radiative conductors
• Data generated for each orbit position
• Particularly models with moving geometry
– Can lead to significant processing time
• Data handling within Workbench
• Exporting ESATAN analysis file
• ESATAN Pre-process, compile, link & solve
– In some cases file system or compiler limits reached


ESATAN-TMS
thermal modelling suite
Thermal Integration
• In r7, redesigned storage of REF, VF, HF data
• Introduce **option** to write radiative data directly to a new ESATAN data file
– Introduce **Analysis Case Definition (ACD) file**
– ACD file goes hand-in-hand with ESATAN analysis file
– Store radiative (GR & Q) data in ACD file
• Node & conductor definitions retained in analysis file
– ACD file uses HDF5 format
• Platform independent binary file
• Efficient structure & format

Thermal Integration



- **Significantly reduced** the number of associated files
- New ACD file contains the radiative data, previously in
  - Arrays (storing QS, QE & QA data)
  - QAVERG, QCYCLC and RCYCLC subroutines

Thermal Integration

- Reduced ESATAN analysis file size

Data Moved to ACD File

```
$ARRAYS
 $REAL
  SU3507(5) = # SOLAR absorbed
   0.000000, 0.000000, 0.000000, 4.371837E-006, 0.005033;
  AL3507(5) = # ALBEDO absorbed
   0.056816, 0.049021, 0.031292, 0.001038, 0.000000;
  PL3507(5) = # PLANET absorbed
   0.116959, 0.135201, 0.219413, 0.361704, 0.493029;

  GR00003UI(5) = # GR(3507, 3509)
   3.379200E-007, 0.000000, 2.252800E-007, 3.942400E-007, 0.000000;
```

QS, QE & QA arrays generated **for each radiative face** & a GR array **for every radiative conductor**

```
$SUBROUTINES
      SUBROUTINE QCYCLC LANG = MORTRAN
        .
        QS3507 = INTCYC(TIMEM, ORBTIM, SU3507, 1, PERIOD, 0.0D0)
        QA3507 = INTCYC(TIMEM, ORBTIM, AL3507, 1, PERIOD, 0.0D0)
        QE3507 = INTCYC(TIMEM, ORBTIM, PL3507, 1, PERIOD, 0.0D0)
        .
      END
      SUBROUTINE RCYCLC LANG = MORTRAN
       .
       GR(3507, 3508) = INTCYC(TIMEM, ORBTIM, GR00003UH, 1, PERIOD, 0.0D0)
       GR(3507, 3509) = INTCYC(TIMEM, ORBTIM, GR00003UI, 1, PERIOD, 0.0D0)
       GR(3507, 3510) = INTCYC(TIMEM, ORBTIM, GR00003UJ, 1, PERIOD, 0.0D0)
       .
       END
```

Interpolation of heat flux & radiative conductance arrays

ESATAN-TMS thermal modelling suite

Thermal Integration

- ACD data is automatically read by the solution
  - Static heat flux read at the start of the analysis
  - Transient heat flux & conductance
    - Read in $VARIABLES1
    - Data only read into memory as required
    - Efficient interpolation of data
- Reminder, a full ESATAN analysis file can be generated if required

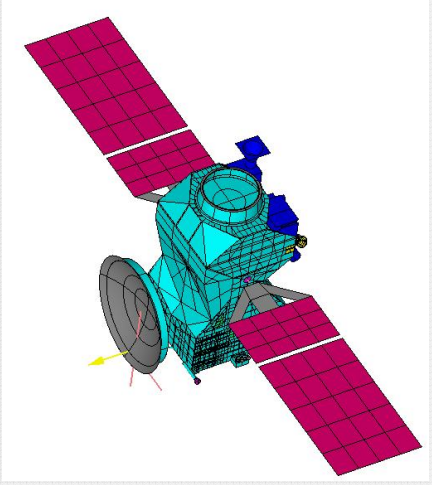
ESATAN-TMS thermal modelling suite

Thermal Integration

- Leads to **improved performance, reduced overall file size** & **reduction in memory**
- Example science model provided by OHB

Generated File Size (Mb)			
Data File	ESATAN-TMS		Δ (%)
	r6	r7	
Analysis File / ACD File	40	18	55%
MDB file	39	6	85%
Pre-processor log file	40	13	68%
Fortran file	15	6	60%
Model executable	18	5	72%
Total	**152**	**48**	**68%**

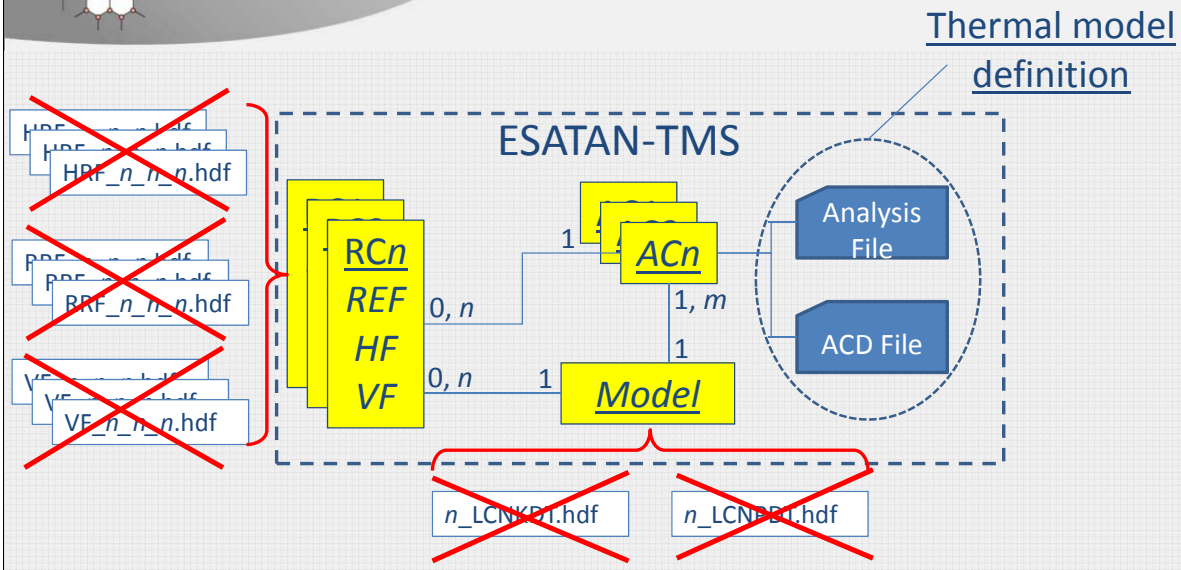
Performance (s)			
Process	ESATAN-TMS		Δ (%)
	r6	r7	
Pre-process	204	18	91%
Solution	133	67	50%
Total	**337**	**85**	**75%**



Thermal Integration

- In r7, handling of linear conductor data improved
  - Redesigned data storage within Workbench
  - Now store **all linear conductor data**
    - Previously stored only the LP conductors
    - Now store FE conductors and conductors generated from Contact Zones and User-Defined Conductors
  - Automatically calculate linear conductors on export to ESATAN, **only if they are out of date**

Thermal Integration

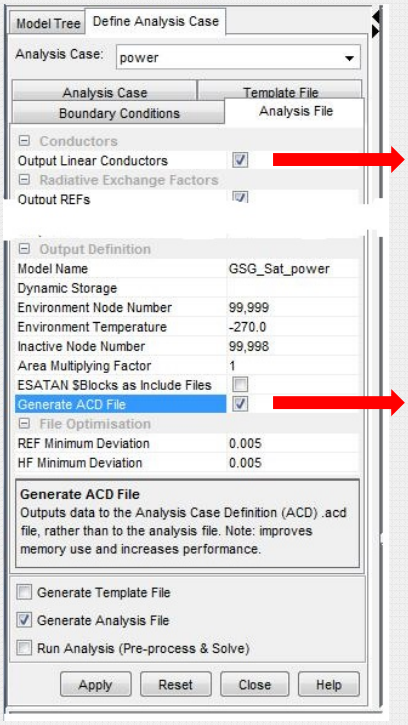


- Reduce the number of associated files
  - Linear conductors stored with the overall model data
- Now **store all conductor data**

ESATAN-TMS thermal modelling suite

Thermal Integration

Workbench GUI Changes



- Select to output **all linear conductors** (default)
- "Calculate Conductors" option removed
- **Option** to generate radiative data in Analysis Case Definition file (default)

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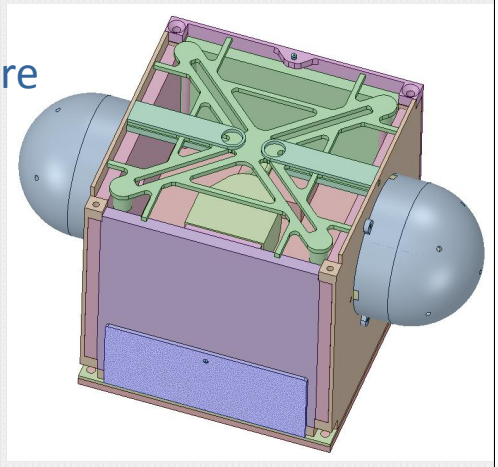
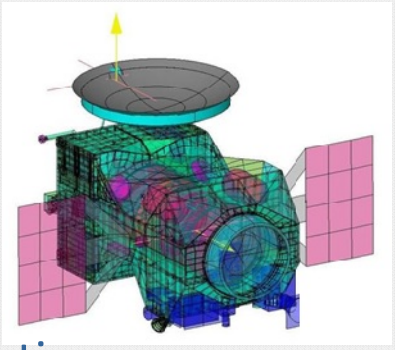


ESATAN-TMS thermal modelling suite

Improved User Interface

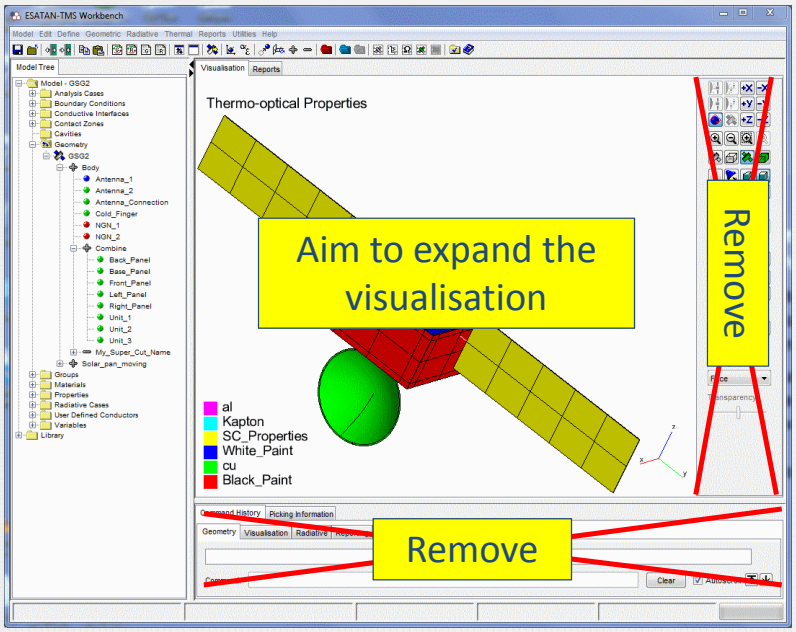
- ESATAN-TMS r6 saw a new visualisation
  - New visualisation technology
  - Take advantage of hardware
  - New functionality
    - Multiple selection, transparency & revised cutting plane



- Continue to build on this foundation
  - Improved user interface
  - More interactive model build
  - Pre- and post-processing of model data

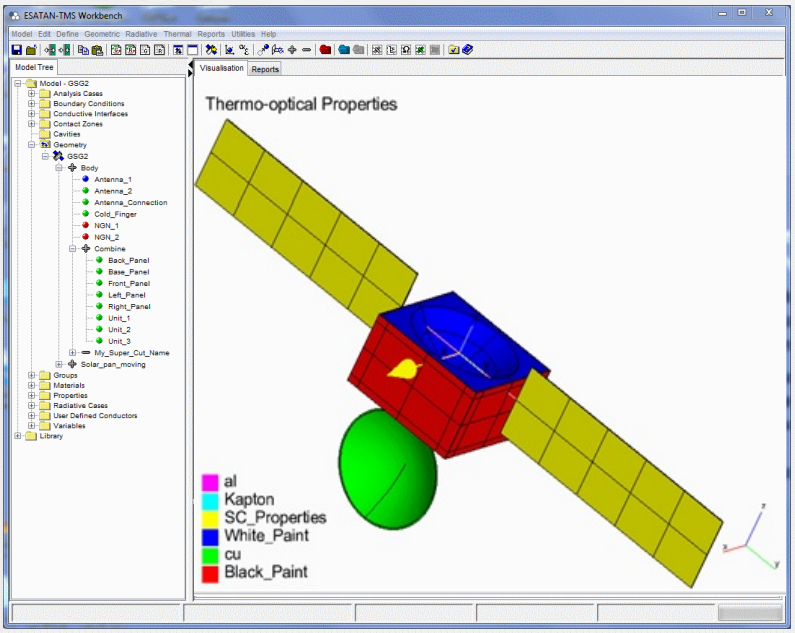
ESATAN-TMS thermal modelling suite

Improved User Interface



ESATAN-TMS thermal modelling suite

Improved User Interface

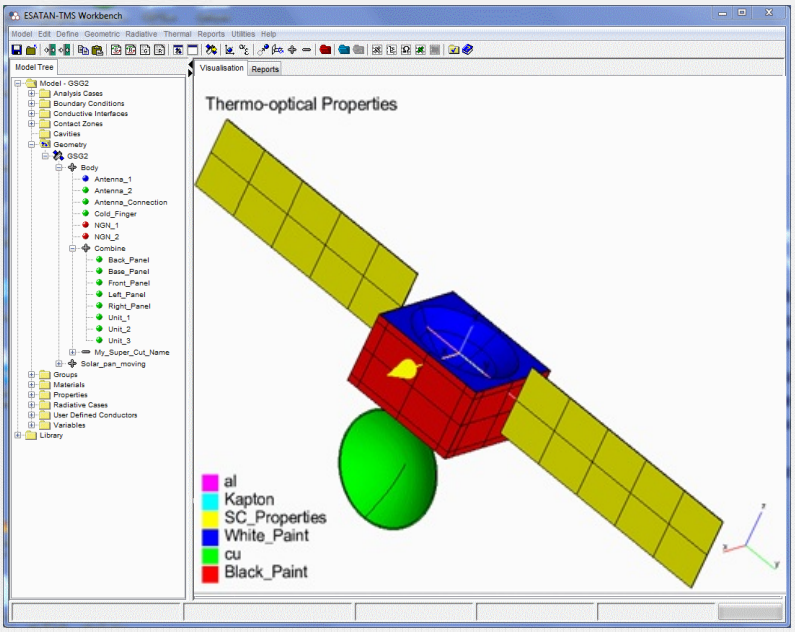


In r7 redesigned,

- Report Symbols
- Delete Environment
- Clipping Plane
- Include Model
- Custom Menu
- Report Case Results
- Process Conductor Interfaces
- Assembly
- Define Variables
- Cut / Combine
- Reporting Tab

ESATAN-TMS thermal modelling suite

Improved User Interface



In r7 redesigned,

- Report Symbols
- Delete Environment
- **Clipping Plane**
- Include Model
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- **Process Conductor Interfaces**
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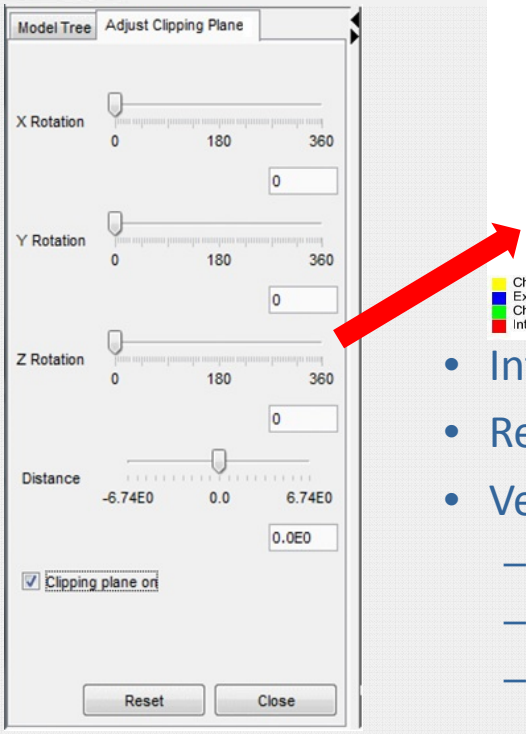
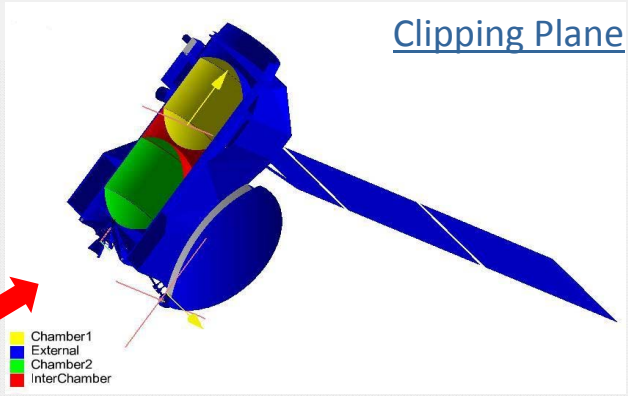
- Cut / Combine
- **Reporting Tab**

Improved User Interface

Clipping Plane

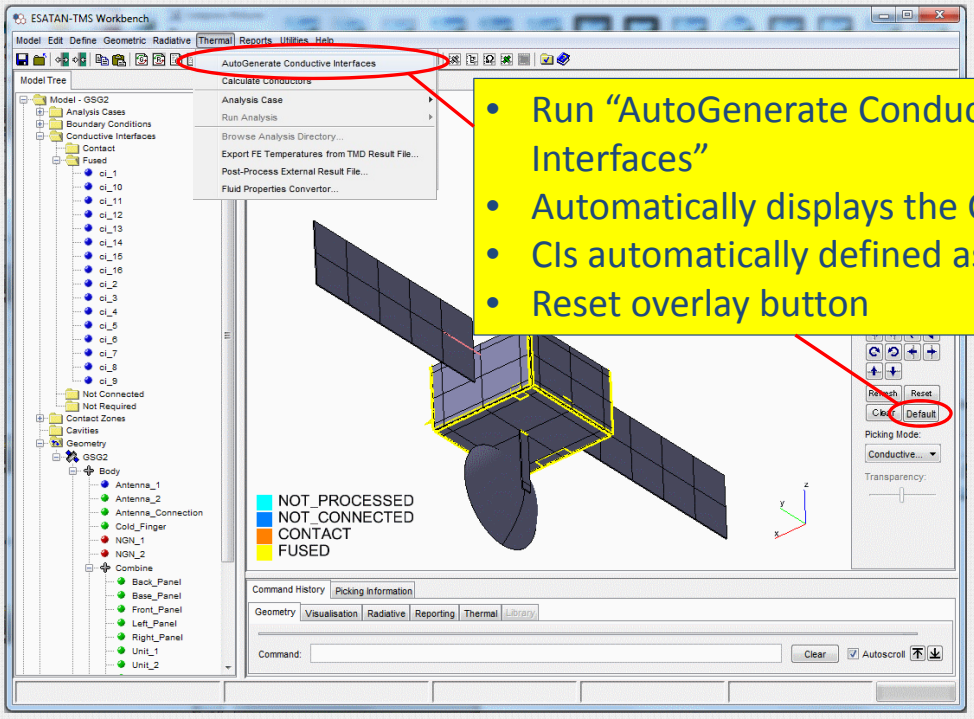




- Introduced in ESATAN-TMS r6
- Redesign to a vertical dialog
- Very useful modelling tool
  - Inspect internal geometry
  - Visualise Radiative Cavities
  - Display internal results

Improved User Interface

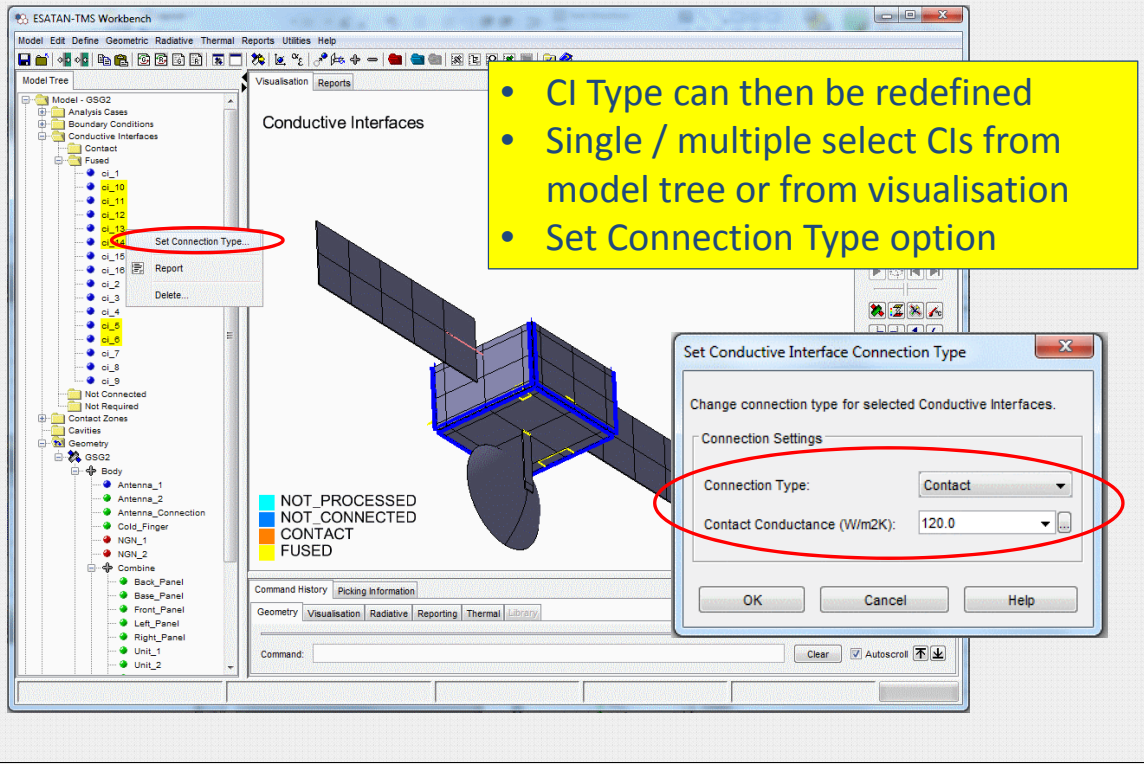
Process Conductive Interfaces



- Run “AutoGenerate Conductive Interfaces”
- Automatically displays the CI overlay
- CIs automatically defined as Fused
- Reset overlay button

Improved User Interface

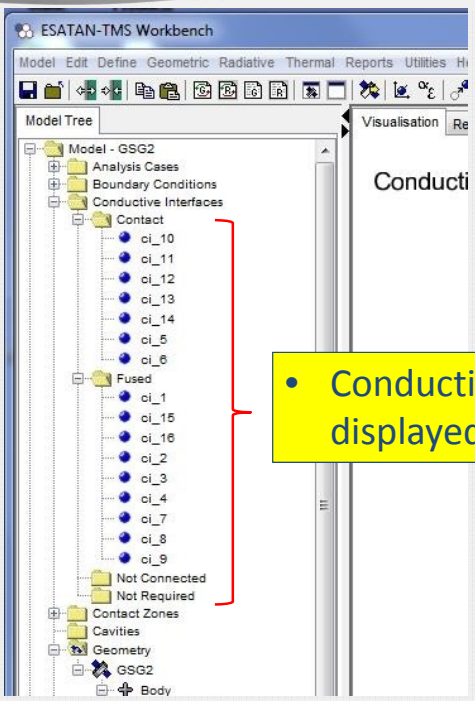
Process Conductive Interfaces



- CI Type can then be redefined
- Single / multiple select CIs from model tree or from visualisation
- Set Connection Type option

Improved User Interface

Process Conductive Interfaces

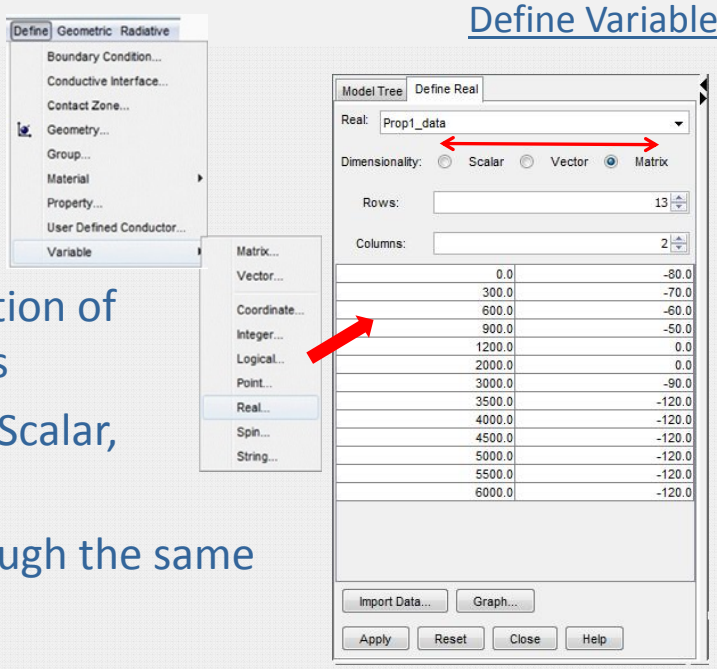


- Conductive Interfaces now displayed by type on model tree

Improved User Interface

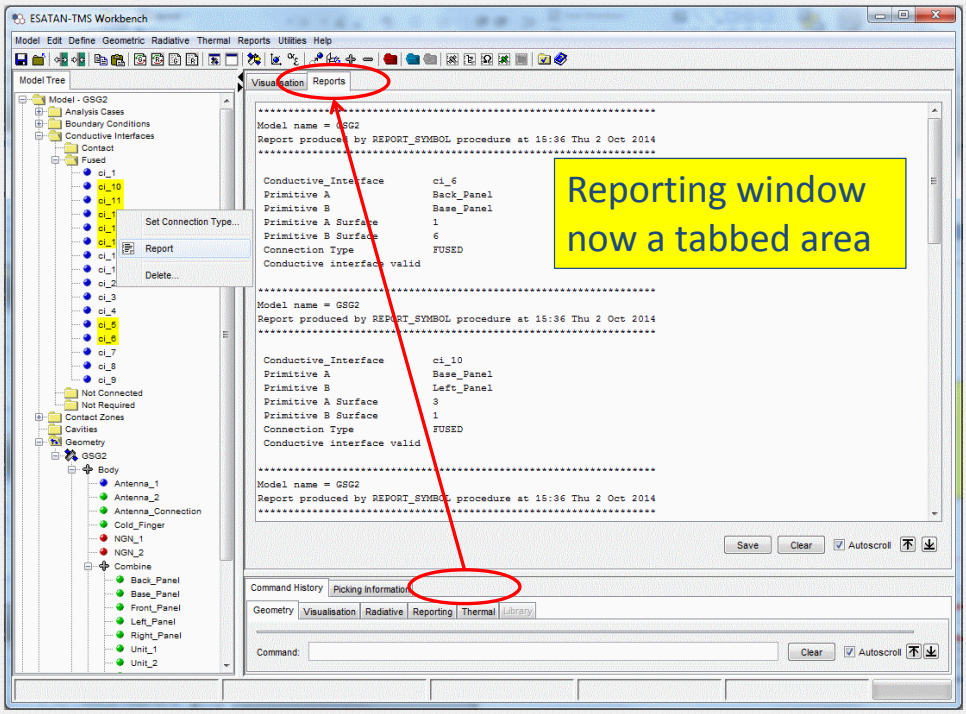
Define Variables

- Interface for definition of basic variable types
- Same interface for Scalar, Vector and Matrix
- Edit definition through the same dialog



Improved User Interface

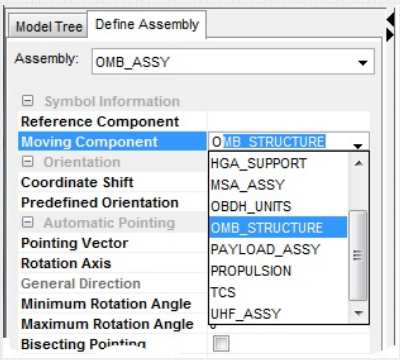
Reporting Tab



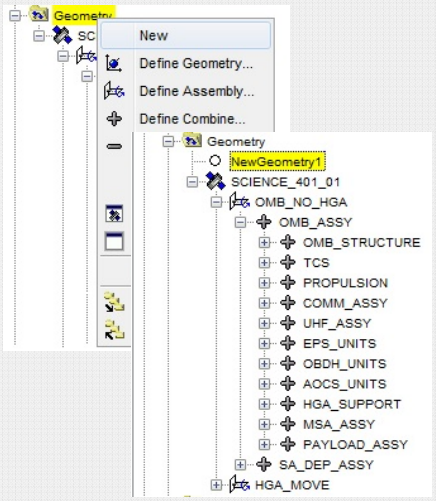
Improved User Interface

Other Items

- Auto-completion on dialogs



- Geometry New Command



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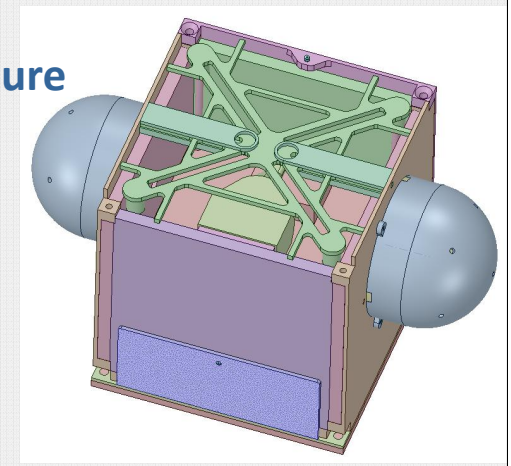
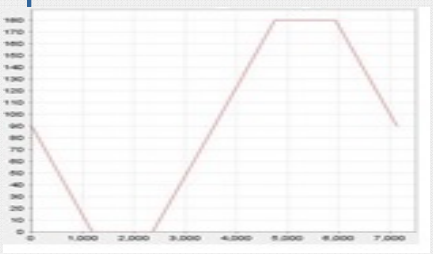


Time & Temperature Dependency

- Model time or temperature dependent properties in Workbench
  - Define Property
    - Time, temperature or time-cyclic
    - Plot profile



  - Additional support provided in ESATAN-TMS r7
    - Time or temperature dependent
      - All components of User-Defined Conductors
      - Conductance of Contact Conductor Interfaces
      - Capacitance of Non-Geometric Thermal Nodes
      - Shell through emissivity & conductance

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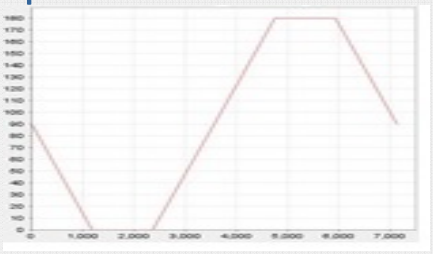
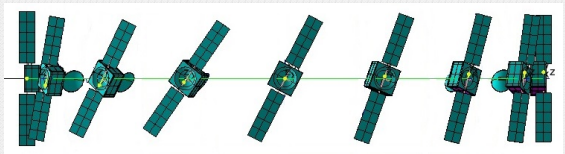
    - Plot profile

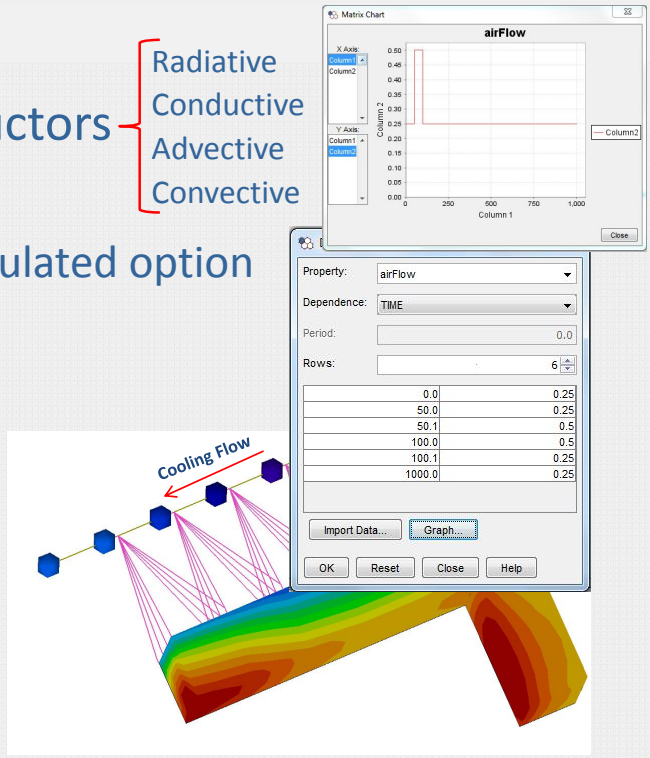


  - Additional support provided in ESATAN-TMS r7
    - Time dependent
      - Assembly pointing
      - Environment temperature



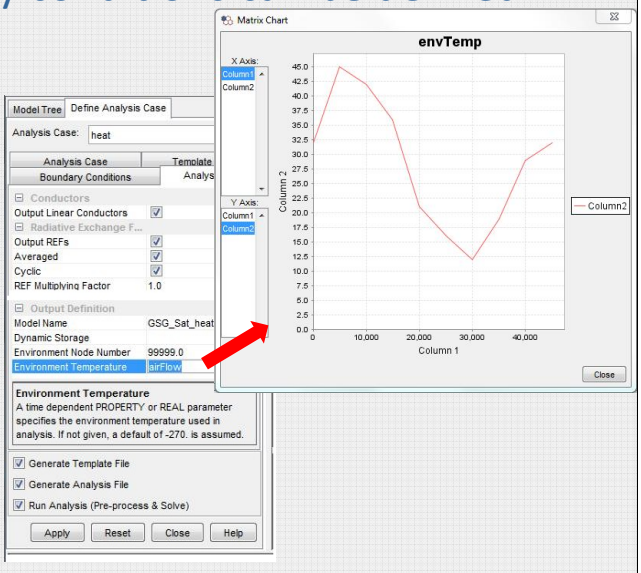
Time & Temperature Dependency

- User-Defined Conductors
  - Radiative
  - Conductive
  - Advective
  - Convective
  - – Conductance value
  - – Components of Calculated option
    - Advective, $\dot{m}$ & *Cp*
    - Radiative, ε & *REF*
    - Conductive, *k*
    - Convective, *h*



Time & Temperature Dependency

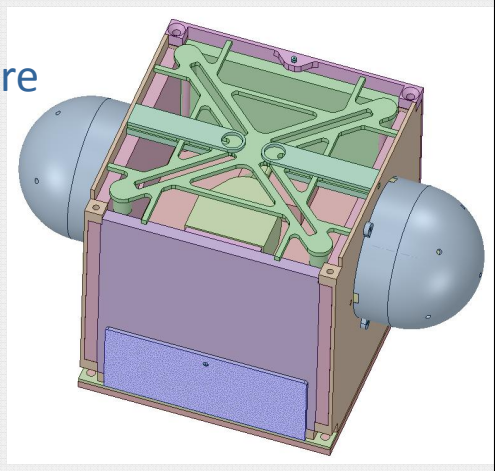
- Environment temperature boundary condition
  - – As for other boundary conditions can be defined time dependent



ESATAN-TMS thermal modelling suite

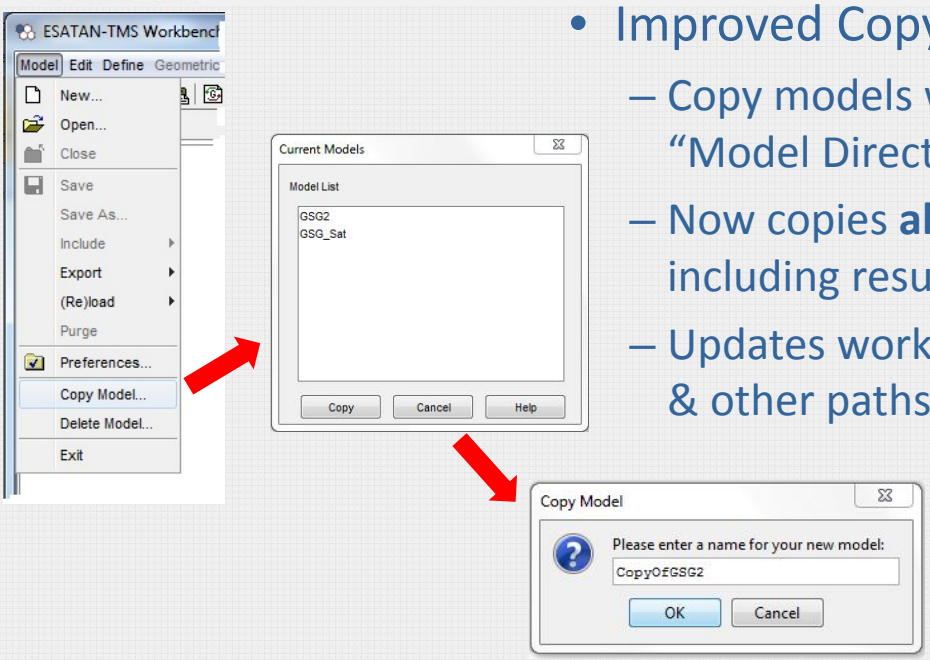
Contents

- Presentation of ESATAN-TMS development status
  - Model import from CAD
  - Further thermal integration
  - Improved user interface
  - Modelling time & temperature dependency
  - **Model definition**
  - Simplified user input



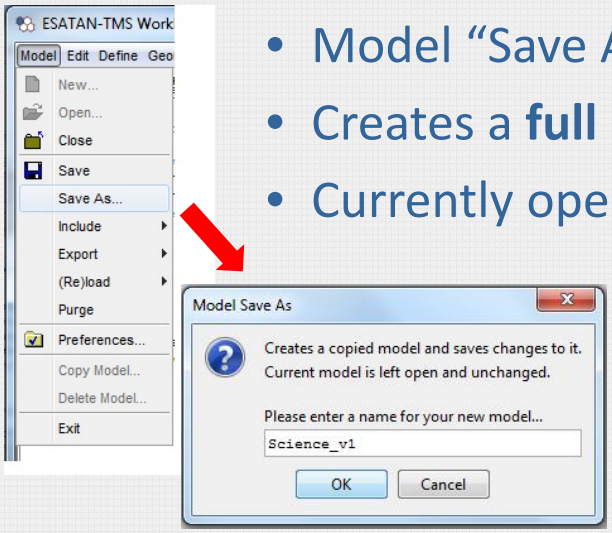
ESATAN-TMS thermal modelling suite

Model Definition



- Improved Copy Model
  - Copy models within the “Model Directory”
  - Now copies **all data**, including result data
  - Updates working directory & other paths

Model Definition

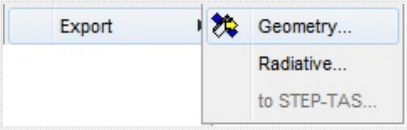


- Model “Save As” option now provided
- Creates a **full** back-up of the model
- Currently open model not changed

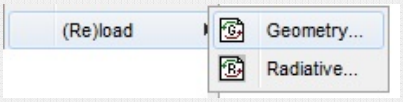
- Version control of the model
- High-priority from the user survey 2013

Model Definition

- Export complete model definition
  - **Implementation being finalised**
  - Extended Model Export
    - Export Model option
    - Export Thermal option



  - Extended Model Import
    - (Re)load Model option
    - (Re)load Thermal option



ESATAN-TMS thermal modelling suite

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- Presentation of ESATAN-TMS development status
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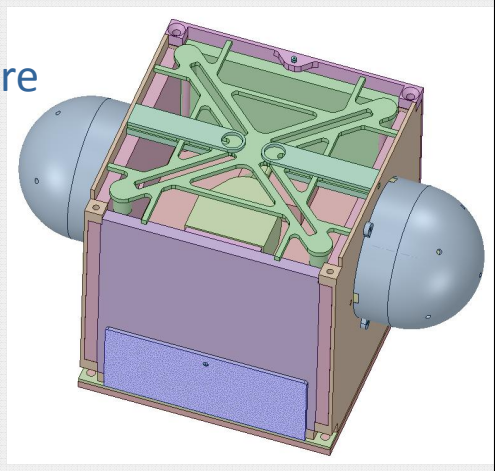
  - **Simplified user input**

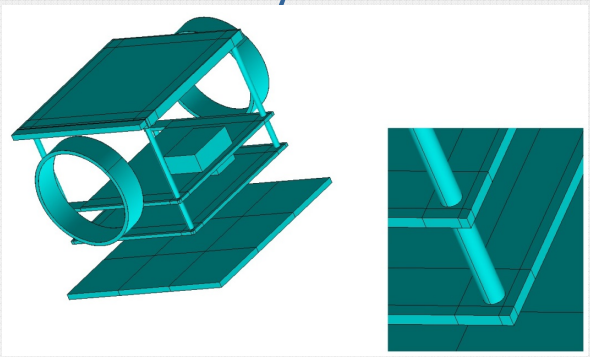


ESATAN-TMS thermal modelling suite

Simplified User Input

- Definition of Real Vectors directly as literal values
  - non-regular mesh

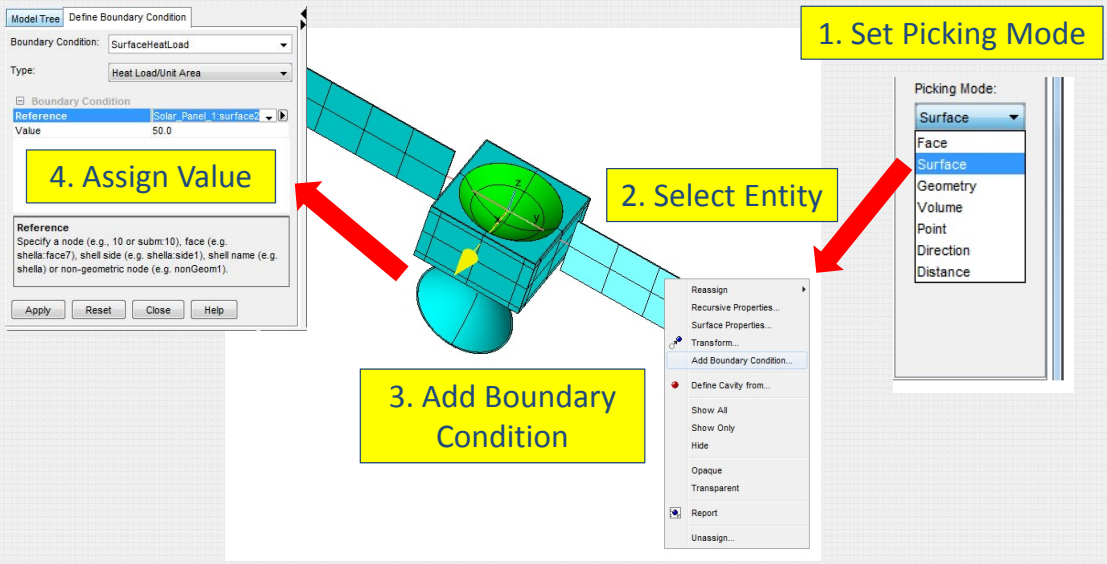
Mesh	
Faces along Direction 1	12.0
Faces along Direction 2	1.0
Ratio in Direction 1	1.0
Ratio in Direction 2	1.0
Mesh Positions in Direction 1	{0.1, 0.3, 0.7}
Mesh Positions in Direction 2	0.2, 0.35, 0.55, 0.9



  - night-side temperature
  - orbit true anomaly
  - waveband frequency array

Simplified User Input

- Assignment of BCs directly onto selected entities in the visualisation

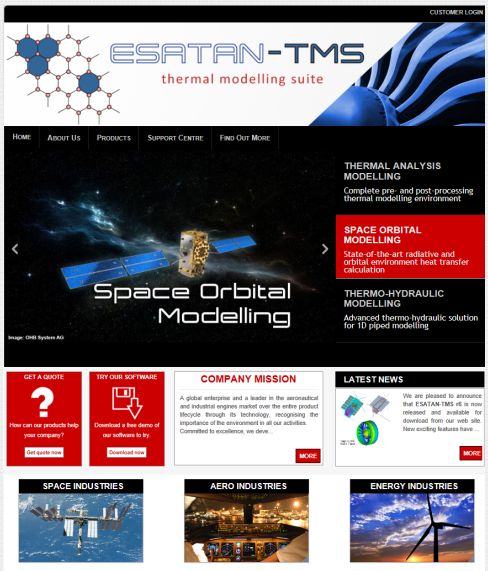


Conclusion

- ESATAN-TMS r7 **release at the end of the year**
- Continued **major investment** on the product
- Focus on input from **user survey 2013**
  - Improved thermal modelling environment
  - Time & temperature dependency
  - Control of model data
  - Improved performance
  - Simplified input
  - Improved visualisation

Product Support

- New web site, self help, short videos, …



- Extended Getting Started Guide
- Training courses at ITP
  - Nov 2014 Beginner
  - Jan 2015 Advanced
- On-site training on request
- Thermal consultancy

Product Support

- Maintenance & bug fixing of the product
  - General bug fixing, including STEP-TAS Import/Export
- Obtain feedback on priorities, both immediate and future requirements
  - Web report system
  - Customer visits
  - User survey
- … and the support team are here!

ESATAN-TMS
thermal modelling suite

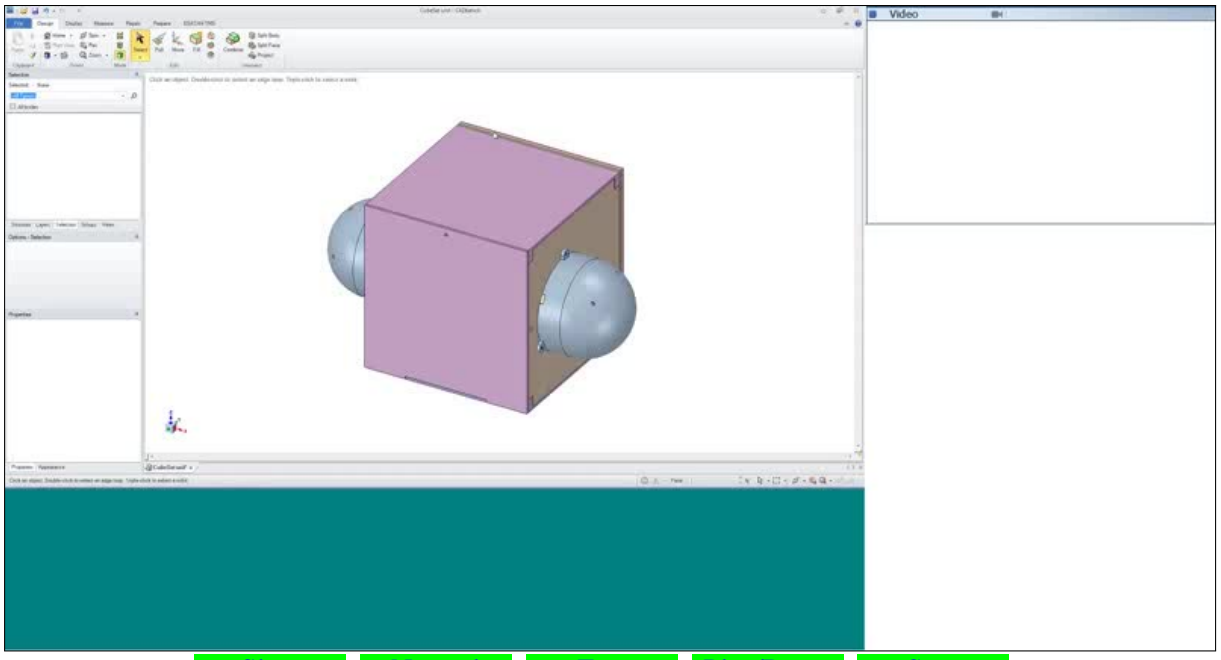
Thank You

Questions following the demonstration

ESATAN-TMS
thermal modelling suite

New Functionality (Summary)

- CAD Conversion
  - Shape recognition
  - Merge triangles
  - Option to generate Point Variables
- Thermal Integration
  - New Analysis Case Definition file
  - Control of output of all conductors
  - Automatically calculate conductors
  - Calculate conductors if out of date
- Redesign of dialogs
- Process Conductive Interfaces
- Reporting Tab
- Geometry New command
- Auto-completion on dialogs
- Extension of time & temperature dependency support
- Extended Copy Model
- Model Save As
- Export Complete Model Definition
- Define Vectors directly using literal values



Slow Normal Fast Play/Pause Stop