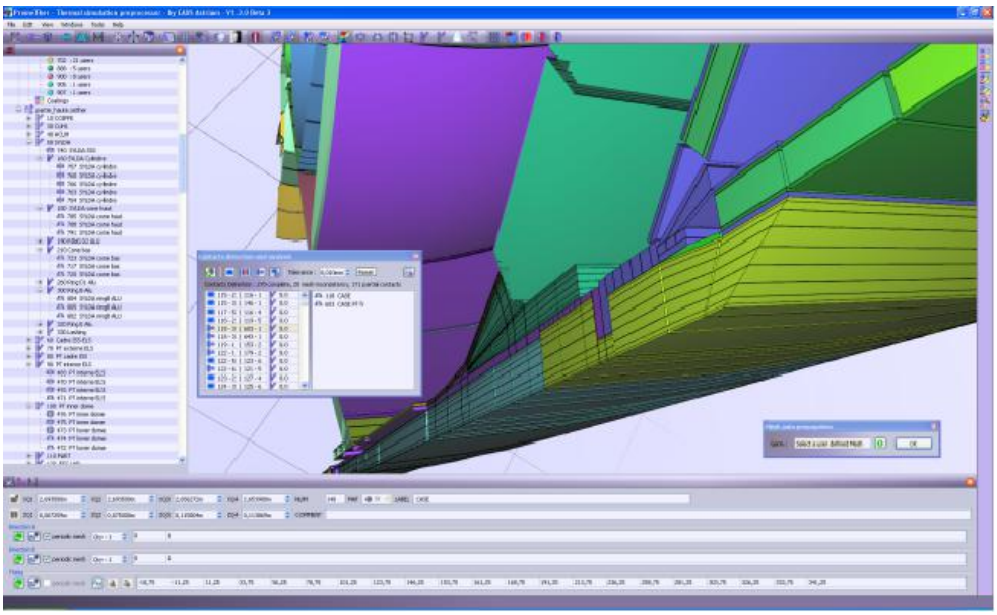
Appendix E

A Thermal Analysis Pre-processor

Laurent Bauer
(Astrium Space Transportation, France)

Abstract

Promether is a thermal analysis pre-processor.
Its basic function is to create, from a 3D solid representation, the thermal models (conductive and radiative) that will be sent to the thermal solvers.
Promether has an internal contact recognition engine that allows an automated creation of the conductive couplings. The engine also supports extraction of surface models (cavities) to prepare the radiative model. By using Promether, both conductive and radiative models derive from a same and unique reference, ensuring consistency. The nodal model can be written in different file formats, enabling compatibility with different solvers.
Promether is a white-box software, thermal analysts oriented: the 3D graphical user interface continuously helps engineers to "see inside" their models. Using 3D metaphors to represent information (material, coatings ...), the visual feedbacks helps the users and increase models confidence and reliability. Numerous quality checks are also continuously performed in background.



Promether

A Thermal Analysis Pre-processor

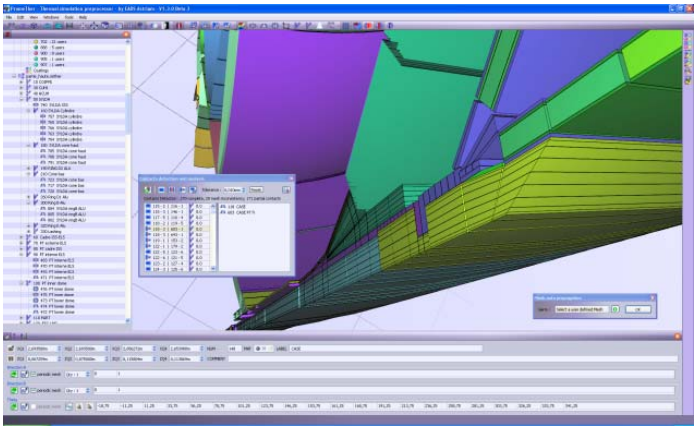
Laurent Bauer, Astrium Space Transportation

laurent.bauer//at//astrium.eads.net

26th annual European Workshop on Thermal and ECLS Software

20 and 21 November 2012

ESTEC, Noordwijk, the Netherlands



Abstract

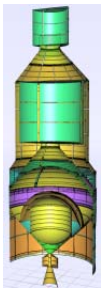
Promether is a thermal analysis pre-processor in charge of creating a conductive model and entries for radiative simulation. Both models are derived from one unique 3D volume model, thus ensuring consistency.

An internal contact recognition engine widely automates the creation of the conductive couplings. The engine also supports extraction of surface models (cavities) to prepare the radiative model. The nodal model can be written in different file formats, enabling compatibility with different solvers: Promether is solver-agnostic.

The application is thermal analysts oriented: the 3D graphical user interface continuously helps engineers to “see inside” their models. Using 3D metaphors to represent information (material, coatings…), the visual feedbacks helps the users and increase models confidence and reliability. Numerous quality checks are also continuously performed in background.

This software has been developed by Astrium Space Transportation in the frame of a self-funded improvement project, with a particular attention brought to Ariane 5 Middle Life Evolution studies. It is the result of a tight cooperation between the Methods & Tools department with the Thermal Engineering department.

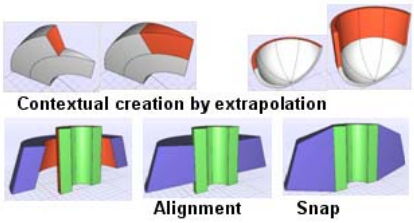
Visualization and interaction



Promether is built upon an interactive 3D visualization engine supporting large assemblies. It seamlessly supports models with over 50 000 nodes on a standard desktop PC.

Geometry construction

Promether has a volume modeller. It handles simple primitives like cone, sphere, cylinder or cube. Geometries are assembled in a tree. Many functions help the user to quickly define the geometry using contextual creation, extrapolation, aligning or snapping.

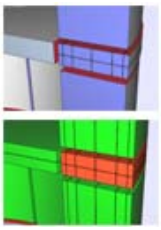


Promether core: the contact engine

Promether's originality comes from an internal component called "contact engine". This invisible component continuously provides adjacency properties between faces and edges. Contacts will be used for many purposes. The geometric model quality can first be inspected by displaying neighbor geometries. Mesh subdivisions can be propagated to neighbors. A model of external surfaces can be extracted. Interface conductive couplings are also automatically identified.

Contacts might be planar, cylindrical, conical or spherical. The recognition engine handles positions, orientations and mesh definition. Identified contacts might be complete, partial or complete with different meshes.

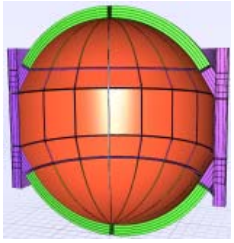
Mesh definition and propagation



The volume model is refined using meshing functions defined by arithmetic, geometric or symmetric ratio. Once defined, a mesh can be propagated to neighbour geometries through faces in contact. This propagation is applied in all possible directions and recursively repeated.

Modifications of geometry and mesh are interactively updated providing constant visual feedback to the user.

Cavities extraction: the surface model



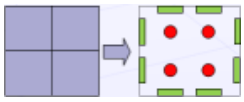
A surface model is extracted from the volume model. A "seed algorithm" starts from an external face, and searches adjacent external faces. This leads to the extraction of topologically closed set of faces for well-formed models (complete contacts). For singular cases, cavities can also be user-defined. In both cases, quality controls run in background and signal broken rules like missing thermo-optical properties or forgotten cavities (external faces that not yet belong to any cavity).

Together with thermo-optical properties, the surface model is exported to feed a radiative simulation.

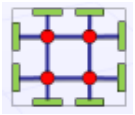
Conductive model creation

The conductive nodal model is directly computed from the volume model. It is composed of capacitive nodes and conductive couplings.

The nodes capacity, form factors – geometrical contribution to the conductance –, volumes and center of gravity are computed for each subdivision of the geometry. Additionally, arithmetic nodes with area and center of gravity are computed for each external facet.

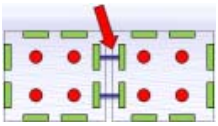


Conductive couplings are automatically generated between nodes that belong to the same geometry:
capacitive - capacitive and capacitive-arithmetic.

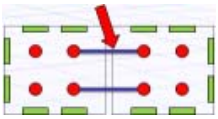


Interface couplings

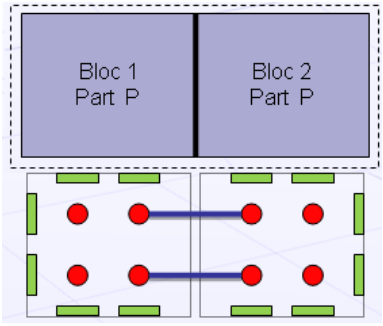
Once an interface resistivity is defined on a contact face, interface couplings are automatically computed between fronting facets.



If a zero resistivity is applied, couplings are generated between fronting capacitive nodes. Corresponding arithmetic nodes are removed.



In addition, coupling generation takes into account a part concept. A part is an assembly of geometric primitives. It must be considered as a real life part: a homogeneous bloc of matter. For part internal interfaces, Promether directly chooses capacitive-capacitive couplings and removes arithmetic nodes.



To sum up, user's task is reduced to interface resistivity definition. The rest of the geometry-based conductive model is computed automatically.

Modifications and updates

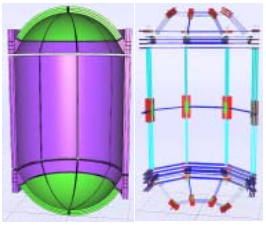
The nodal model is continuously updated and available whenever needed.

Since both radiative and conductive models derive from the same reference, modifications that preserve the model definition will update both radiative and conductive model and ensure consistency. This might be especially important for nodes numbering consistency.

The Thermal Mathematical Model

The thermal mathematical model is described in memory. Writing this information in a specific format is a simple implementation task. It makes this pre-processor potentially compatible with any kind of thermal solver. Promether is solver-agnostic.

The thermal mathematical model is continuously updated and can be 3D visualized at any time. This increases the confidence in the software and obviously the models reliability.



A user oriented and thermal analyst oriented software

The software is developed according to modern software standards. A special attention was paid on user ergonomics and interaction design:

- 100% Undo-redo capabilities
- Interactive visualization
- Real time updates
- Continuous quality checks
- Visual feedbacks: colorizing by material, thermo-optical properties, red lights for broken quality rules…

In general, interaction has been developed to ease user's activities and maximize automation. Users get rid of boring and error prone tasks and refocuses on thermal engineering: fine-tune a more representative model or try, test and design more technical solutions. This feature finally increases the interest of engineers for daily works.

PromeTher

Thermal Pre-processor

Laurent Bauer - 20th Nov. 2012

TA34 - Process Methods & Tools

All the space you need

ASTRIUM
AN EADS COMPANY

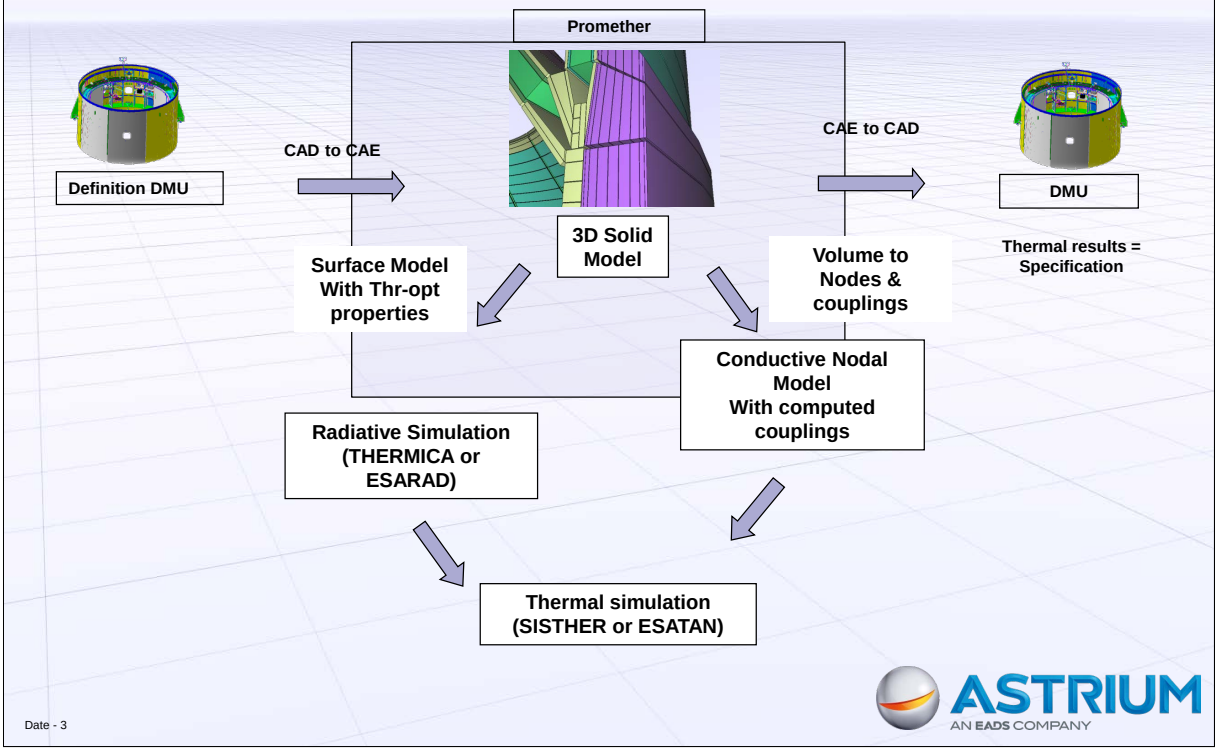
Content

- Global process with Promether
- Promether core : 3D model & contact engine
- Conductive nodal model
- Entries for radiative model
- Overview of other tool features
- Futures

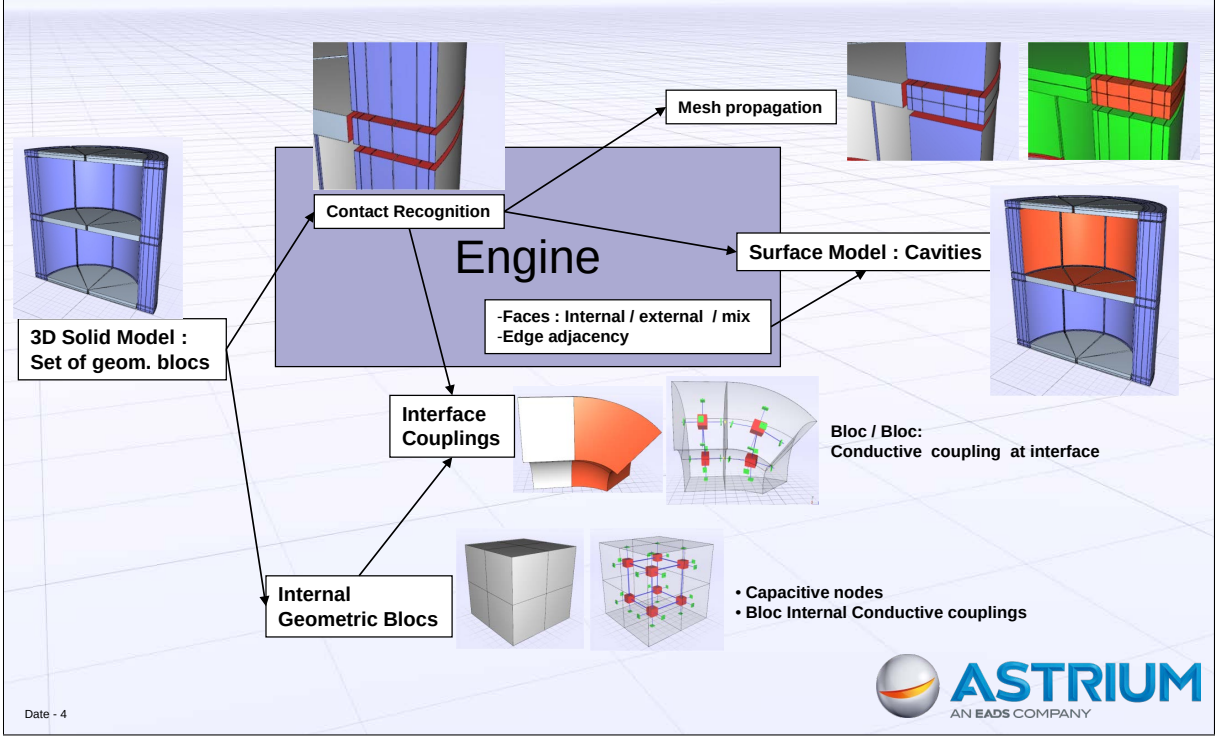
Date - 2

ASTRIUM
AN EADS COMPANY

Process Overview



Promether core : Geometric Model and Contact engine



Contact engine features:

Works in background

Recognition between :

- Different types of Geometrical Blocs
- With different position and orientation
- Different geometric definition
- Different meshes

Contacts Types :

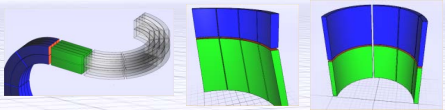
- Complete
- Partial
- Complete with different meshes
- No over-detection

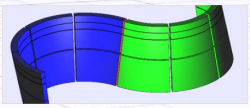
Test Suite :

- 213 unary test cases

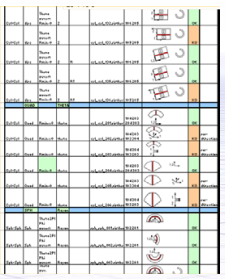
Default Precision

- 1E-05 m.
- Customizable

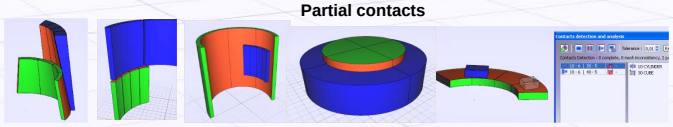




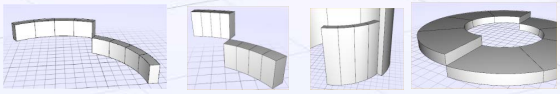
Complete



Partial contacts



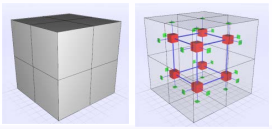
No over detection



Date - 5

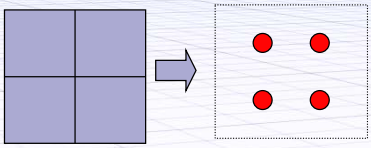
ASTRIUM AN EADS COMPANY

Conductive Nodal Model Geometrical Bloc : Internal

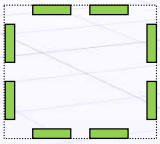


Full automatic generation of :

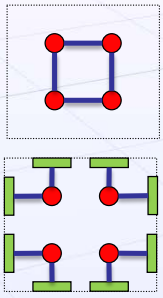
- Capacitive Nodes



- Arithmetic nodes on external faces



- Couplings : Blocs Internal :
  - capacitive / capacitive
  - capacitive / arithmetic

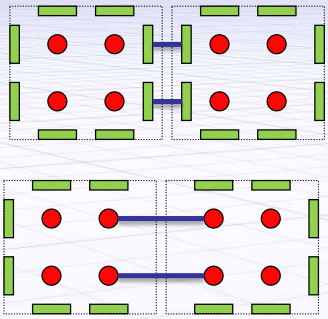


Date - 6

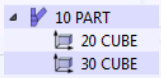
ASTRIUM AN EADS COMPANY

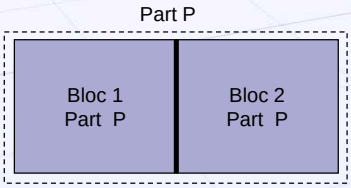
Conductive Nodal Model
Bloc – Bloc Interface

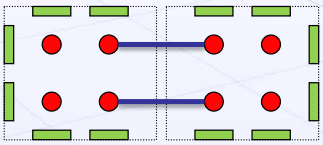
- Couplings : Blocs External
  - arithmetic / arithmetic
    - User defines interface R/GL
    - Engines creates couplings between fronting arithmetic nodes
  - If RI=0 (User Defined)
    - No arithmetic node generation
    - Capa/Capa Coupling creation



Bloc External, Part Internal
- Automatically RI=0





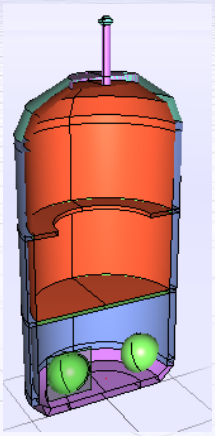


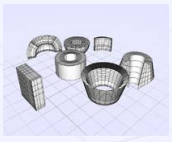
Date - 7

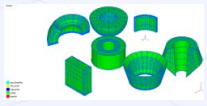
ASTRIUM AN EADS COMPANY

Cavities :
Surface Model + thermo-optical properties

- Automated creation
  - “Seed” (propagation from ~) algorithm
- Manual creation :
  - Selection by face
  - Assemble cavities
  - Activate/ Inactivate
- Quality : Checks / Warnings
- Thr-Optical Properties :
  - emissivity, absorptivity
  - From pointed coating object
- Export
  - Esarad
  - Pegase: bridge to Thermica V3
  - Thermica V4 is planned



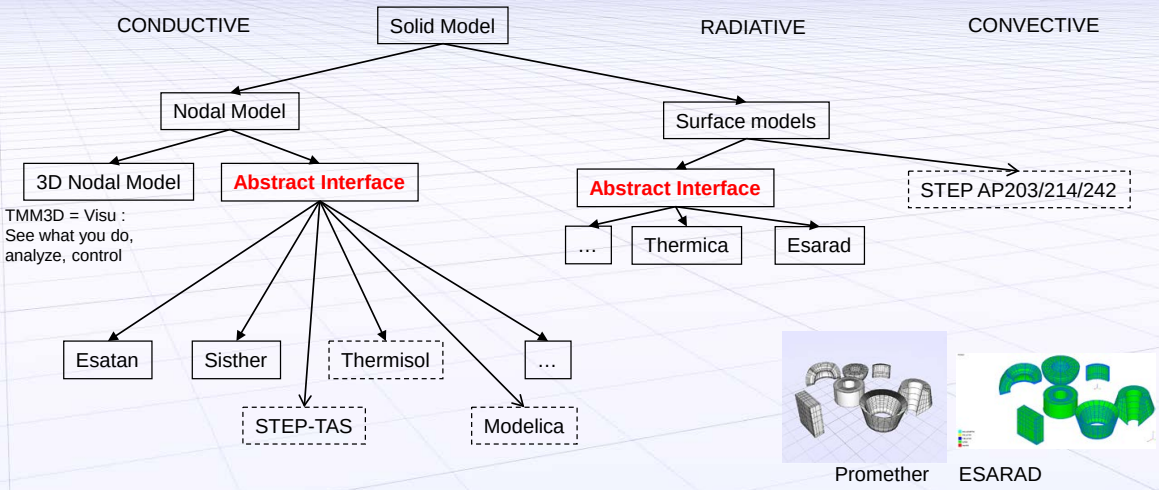




Date - 8

ASTRIUM AN EADS COMPANY

Promether architecture
Multi-format, Multi-solver



Models derived from a single and shared reference
Ensure consistency between Models (node numbering)
Export in the desired format => Solver interchangeability

Date - 9

ASTRIUM AN EADS COMPANY

Other features :
Model quality / Generalized checks

RULES
- **RMin < Rmax**
- **Cones vertices defined in the trigonometric orientation**
- **Unique Identifier is Unique !**
- **Cannot export Cavity without coatings**

WARNINGS

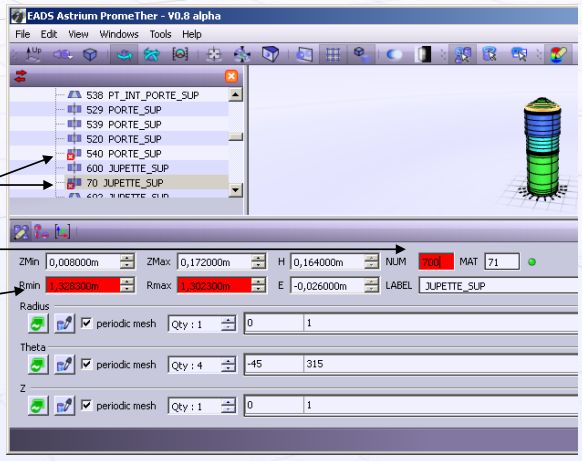
Warning, the cavity contains faces without coating

Visual feedbacks
- **Visual identification of Inconsistent objects**
  - **In 3D**
  - **In Data Tree**
  - **In object editor**

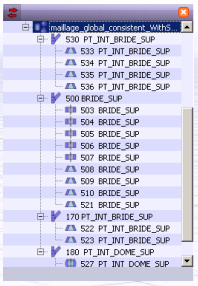
Inconsistent objects are identified in the tree

Num already exists

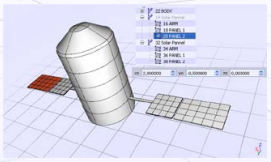
Inconsistent values : Rmin > Rmax

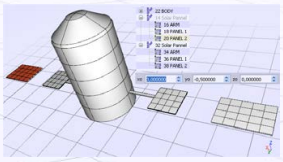


Other features



- Assembly Tree
  - Assembly
    - Part
      Geometric bloc
      Nodes
  - Instances
    - Modify once
    - Propagate where used





- Import Export :
  - assembly of files/models
- Work in progress:
  - User defined conductive couplings
  - Non geometrical nodes

Date - 11

ASTRIUM AN EADS COMPANY

Demo

- Large Model support
- Geometric Model creation :
  - Using “contextual modeling” features
  - Assembly tree
- Mesh
  - Definition
  - Propagation
- Conductive Nodal Model Creation
  - User defined interface resistivity : 0 and Not 0
  - Part internal interfaces (matter continuity)
- Cavity creation
  - Automated, manual
  - Quality checks

12

ASTRIUM AN EADS COMPANY

Promether future

- We continue
- We believe that the future is in collaboration
  - See “open innovation”
- Co-development ?
  - Co-funding, R&D project
  - Private, academics, consortium…
- Open to discussion, proposition
- Contact : laurent.bauer // at // astrium.eads.net

Date - 13

ASTRIUM
AN EADS COMPANY