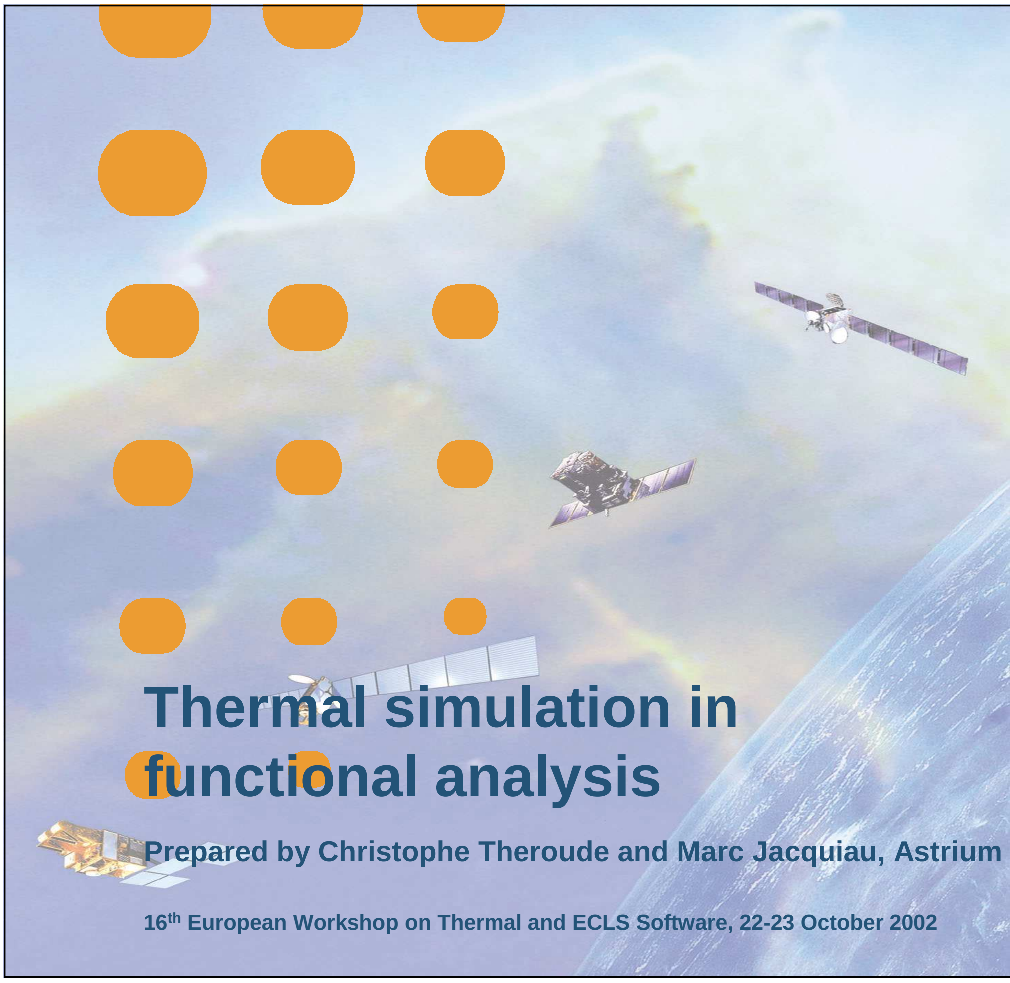

Thermal simulation in functional analysis

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Introduction

- **Besides the classical geometrical approaches used to model the thermal behaviour of spacecraft, there is also a need to perform simpler analysis :**
  - →Development of a tool adapted to perform preliminary thermal design
- **Moreover, a geometrical approach doesn't fit the modelling needs for sub-system performances analysis like Power, Propulsion, etc. :**
  - →Development of *functional* tools to perform Power and Propulsion analysis
- **The chosen approach is to describe the problem with a set of differential equations that are solved by a numerical solver**
  - The model can be coupled with a geometrical simulation to compute flux, radiative coupling, etc

Software concepts

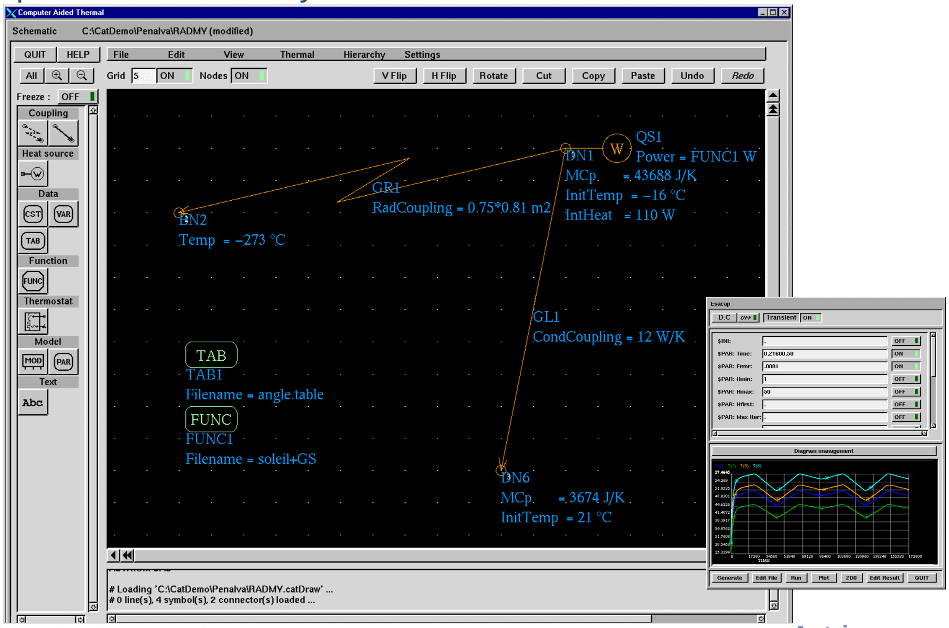
- **These software are organised under the same basis :**
- **They are based on an common toolkit aimed to describe and solve the problems that can be modelled with a network of equations**
- **Each component of the network is described by a mathematical model of its behaviour**
- **The model can support different types of node : thermal, fluid, control, electric**
- **Each tool is integrated in a same graphical interface :**
  - Schematic editor
  - Visualisation tool (text editor, 2D plot visualisation)
  - Post-processing : interface with Excel

Tools description

- **CAT**
  Conception d'Architecture Thermique in French
  - For thermal pre-dimensioning adapted for small models
  - Easy to use and easy to understand
- **CAP**
  Computer Aided Propulsion
  - For quick design of propulsion systems
  - Detailed performances analysis of propulsion systems
  - Exploitation of in-orbit data
  - Ventilation and venting analysis
- **POWER**
  - For quick design of power systems
  - Detailed performances analysis of power systems

CAT

- **CAT : a software tool for thermal preliminary design (pré-dimensionnement)**
  - Use of the schematic approach
  - Automatic link to Esacap solver : stationnary & transient routines
  - Post-processing :
    - Quick 2D curves
    - Excel file
    - 2D0 Systema file
    - Results on scheme



CAT

- **Suited to a small number of nodes (up to 40 – 50)**
- **Easy to use**
- **An alternative approach between Excel-based tools and detailed analysis software**
  - A key for software harmonisation inside Astrium
  - Typical users :
    - system engineers
    - thermal analysts (quick preliminary design)

Power & Propulsion : coupling with thermal tools

- **For some problems it is necessary to perform a coupling between the functional analysis tools and other tools like Systema/Thermica or ESATAN**

In particular for :

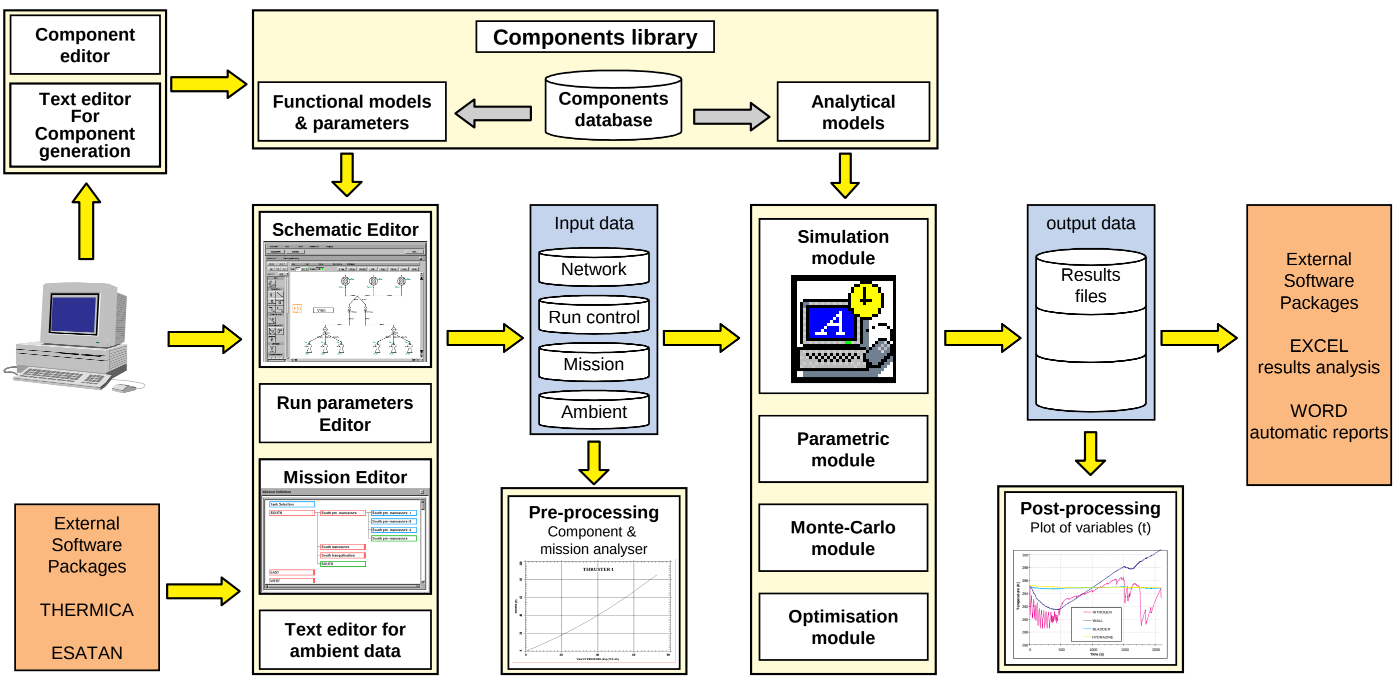
- **Power analysis to compute the :**
  - Solar flux during the mission
  - Radiative coupling between surfaces when there is a strong coupling between power performances and thermal environment (e.g. battery temperature)

  →Application : Power system performances analysis

- **Propulsion analysis when there is a strong coupling between the thermal environment and the fluid behaviour**

  →Application : hydrazine temperature calculation on Ariane 5

Power & Propulsion : Software architecture



Power : Power systems analysis

- **Power uses different models to define a PSS architecture**
  - solar arrays (with definition of thermal fluxes on orbit)
  - battery
  - regulation elements
  - electrical elements : resistance, diode, capacitance, …
  - thermal elements : conductive coupling, radiating coupling,…

  - Use of the mission module of **Thermica** and geometry to define the environment of the solar arrays (thermal)

- **Typical outputs of the software :**
  - current and voltage values at each node of the network
  - all the parameters specified by the models

Power – Interface with Thermica

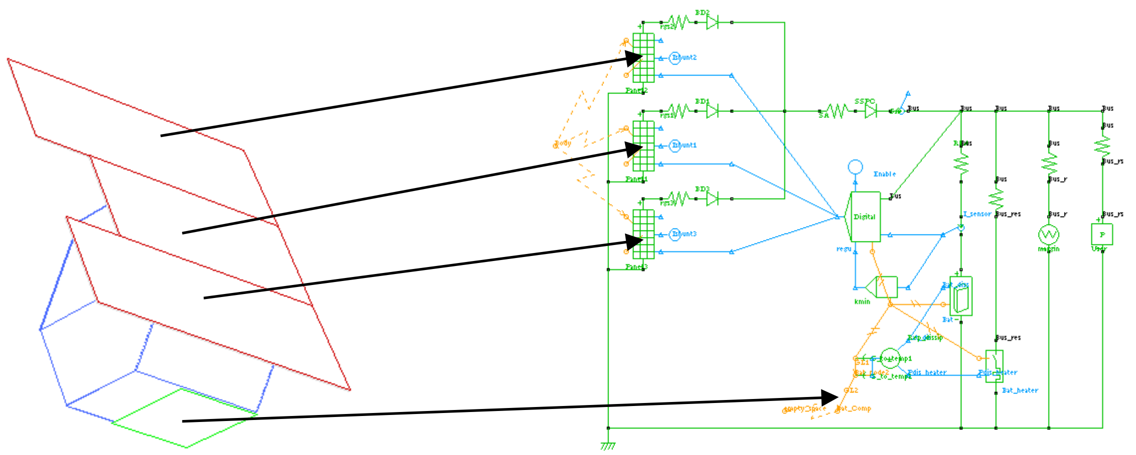
- **Evaluation of power sub-system performances requires the knowledge of the solar fluxes on the solar panels**
  - For any missions, the solar fluxes cannot be easily computed and require a geometrical description of the spacecraft, its mission and pointing
  - Moreover, for a detailed analysis, thermal and power behaviour are strongly coupled
    - E.g. the solar cell performances depend on the solar panel temperature and the solar panel temperature depends on the power converted in the solar cell

- **Need to implement an analysis tool coupling the power and thermal aspects**

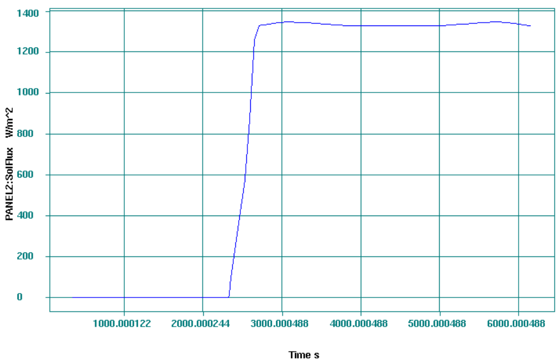
- **Well interfaced with Thermica for an easy use**

Interface between Thermica and Power

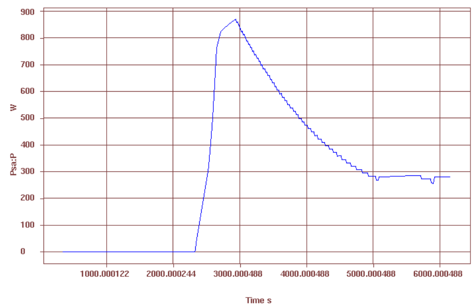
- The tool allows to manage a correspondence between the geometrical objects and the network components



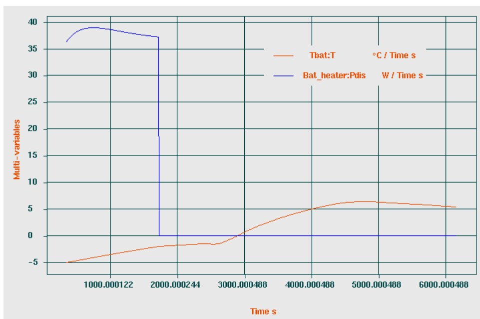
Power : Examples of results



Solar flux along the orbit



Total power from SA



Battery temperature and heater power

CAP : Propulsion systems analysis

- **CAP uses different models to define the propulsion system**
  - Thrusters (monopropellant, bipropellant, cold gas…) and nozzles
  - Tank (blow down and pressurised)
  - Vanes
  - Pipes

  - Interfaced with ESATAN to handle coupled thermal / fluid system

- **Typical outputs of the software :**
  - Overall performances of the propulsion system (impulse, consumed mass)
  - Temperature of the fluid in the lines

CAP : Example of application Hydrazine temperature in the lines

- **The hydrazine temperature in the Ariane 5 Vehicle Equipment Bay (VEB) shall remain in a specified range**

- **Modelling of hydrazine temperature involved :**
  - A thermal model of the temperature in the tubing :
    - Conducto/convective flux in the fluid
    - Conducto/convective flux between the fluid and the line wall
    - Radiative flux between the line wall and the environment
    - Conductive flux between the the wall and the structure

- **The overall thermal network of the VEB environment and the coupling with the lines come from an ESATAN model of the VEB**

Computation of hydrazine temperature

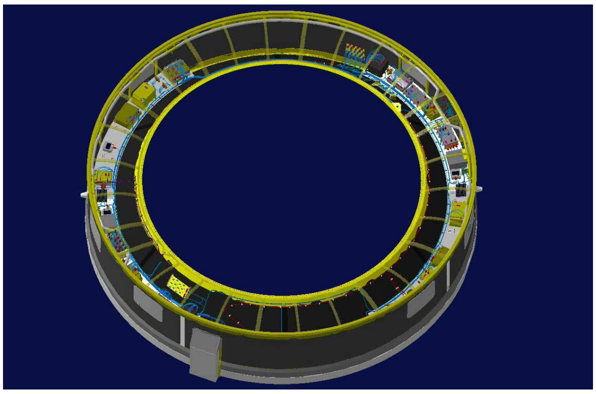
VEB ESATAN model

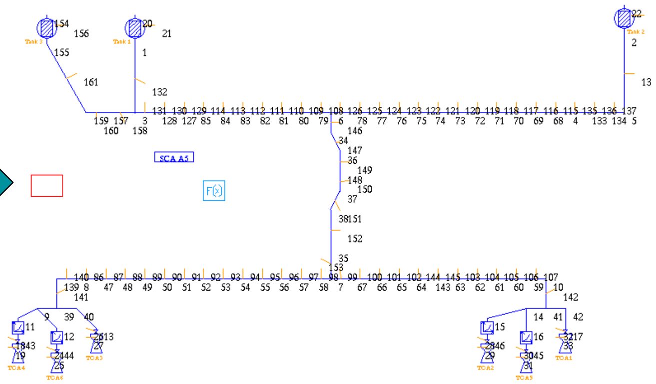
CAP model of VEB hydrazine tubing

+

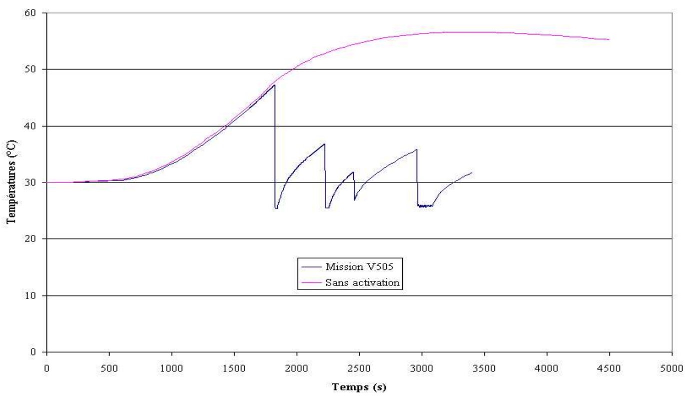
CAP model of VEB thermal network

Hydrazine temperatures

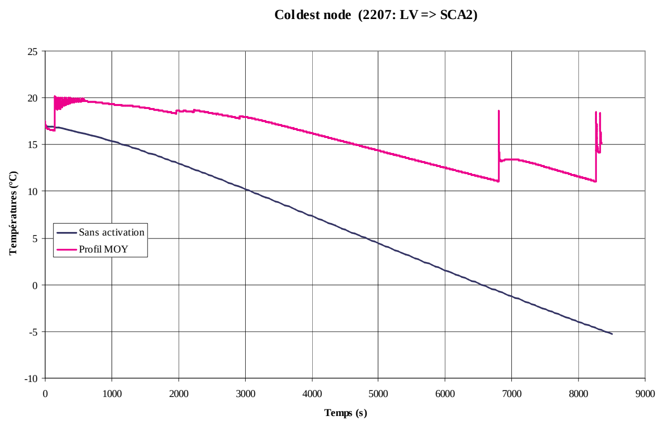




CAP : Examples of results



Hot case



Cold case