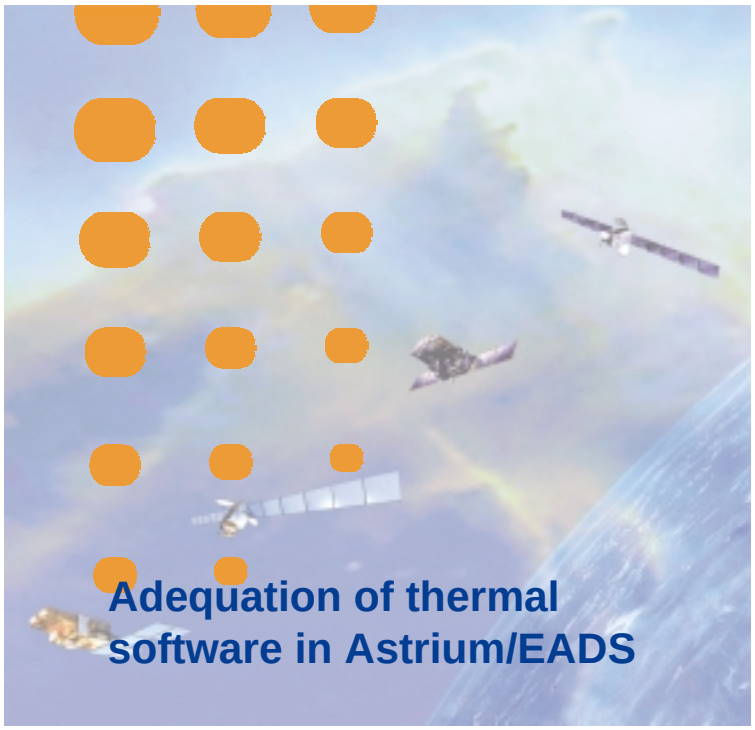


Participating Sites

- **Distribution covering the largest part of Europe :**
  - ASTRIUM Stevenage
  - ASTRIUM Portsmouth
  - ASTRIUM Friedrichshafen
  - ASTRIUM Bremen
  - ASTRIUM Ottobrunn
  - ASTRIUM Toulouse
  - EADS-LV Les Mureaux
  - EADS-CASA Espacio Madrid

Thermal studies in Astrium/EADS

- **All types of space-related activities**
  - Launchers and space infrastructure : Ariane 5, ATV, AR4 and Soyuz
  - Scientific : XMM, Cryosat, Rosetta, Mars Express, Beagle 2, Lobster, First-Planck
  - Observation : Metop, Envisat, Spot5, Helios2, Rocsat
  - Telecommunication : HotBird, NileSat, Astra 2B, Intelsat X, Inmarsat 4
  - Instruments : ASAR, TerraSAR, HIRDLS, MHS
- **Analyses in all spacecraft development steps**
  - Preliminary design,
  - Thermal system and equipment designs and analyses,
  - Tests : venting, vacuum chamber
  - In-flight data analysis (thermal control aging, model correlation)

Thermal software

A large experience of thermal engineering tools

- **Thermal geometrical modelling and thermal radiation**
  - Principal tool : THERMICA
  - ESARAD : Used on ESA projects. Principal tool at Astrium Stevenage
  - IDEAS/TMG
  - internal software : RMC, RAYSPA, RAYSOL (EADS-LV)
- **Thermal conduction**
  - THERMICA
  - IDEAS/TMG
  - ESATAN
  - Internal software : MONA, SISTHER (EADS-LV)

Thermal software

- **Thermal network analyzer**
  - ESATAN, standalone or integrated in THERMICA
  - TMG
- **Thermal framework :**
  - THERMICA
  - IDEAS
  - Internal software : SISTHER (EADS-LV)
- **Thermo-elastic analysis :**
  - IDEAS
  - NASTRAN
- **AeroThermal :**
  - Internal software : AEROTHER
- **Venting**
  - FLUENT

Major issues/problems

User feed-back permits to identify the development priorities

- **Model generation**
  - Requirement for CAD-like tools and interfaces with CAD tools
  - Combination of sub-models
- **Thermal model exchange**
  - Constraints imposed by : customer requirement, tools used in-house, sub-contractors limited capabilities

    Example : ASAR
    - instrument level analysis with TMG
    - Reduced model in ESATAN for the prime contractor and ESA
    - Main sub-contractors using :TMG, SINDA, ESATAN and THERMICA
    - Sub-contractors also have sub-contractors using different tools
  - Implies : model duplication, keep skills on several software
  - Need for standardization : STEP/TAS, STEP/NRF, HDF …

Major issues/problems

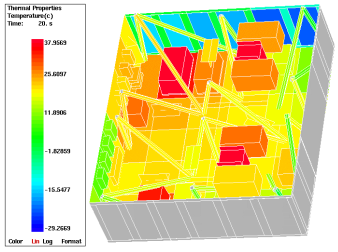
- **Esatan solution routines**
  - Problems in transient with mixed small and high capacitances (CPS Mars Express) or mixed small and high radiative couplings (ROCSAT)
- **Postprocessing**
  - Considered as insufficient by users
  - Example of solution : IDEAS or PATRAN used to do fancy pictures
- **Thermo-elastic analyses**
  - Temperature transfer is cumbersome
  - IDEAS regarded as a good package combining everything
- **Model Reduction**
- **FE thermal analysis tool required for specific analyses**

Major issues/problems

- **METOP**
  - Problems using ESARAD (Oracle)
  - ESATAN problems with large model
  - Post-processing with Unix tools
- **Mars Express**
  - Fluxes around Mars with temperature cartography of the Planet
- **Marfeq (Madras instrument on Proteus platform)**
  - Fast rotating cylinder, periodically showing space to internal elements

Thermica current status

- **Thermica is an integrated thermal chain used for the design of the spacecraft thermal control :**
  - in feasibility studies
  - for technological choices (e.g. : passive or active controls)
  - during correlation with test predictions
- **Thermica computes :**
  - thermal radiation exchanges with space and between surfaces
  - external fluxes : Sun, Earth Albedo, Earth infra-red emission
  - thermal conduction in structures
  - temperatures by means of other commercial packages (Esatan, Sinda/G)



Thermica temperature display on SPOT5 payload

THERMICA current status

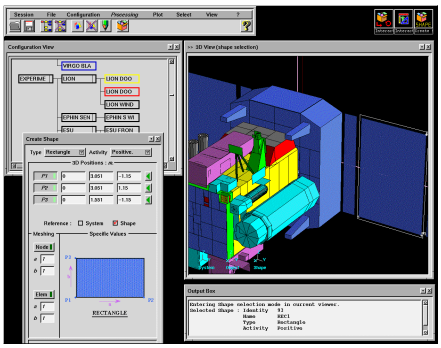
- **THERMICA takes advantage of common developments with other applications requiring 3D models :**
  - Mass, balancing and inertia computation
  - Environment : Environment models, Radiation Dose analysis, Debris and Meteoroids, Oxygen Atom
  - In orbit perturbations : air drag, solar pressure, gravity gradient, magnetic moment
  - Plume impingement (chemical propulsion),
  - Electrical propulsion impingement,
  - Power analysis
  - Antenna patterns : GTD and Method of moments

THERMICA current status

- **Framework common to all the applications :**
  - development optimisation
  - easier for users to move from an application to the other

- **model building capabilities :**
  - interactive model builder (V4)
  - interface with CAD tools (IGES, UNV, STEP/TAS, VRML)

- **display capabilities :**
  - interactive 3D display for pre and post-processing (incl. isocontours)
  - 2D plots



THERMICA current status

- **THERMICA mission definition module developed in synergy with :**
  - Mission analysis tools (MAGiC)
  - Mission Planning and AOCS validation tools (Simis2)

Thermica used in the world

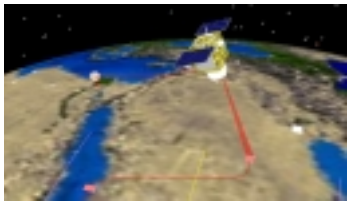
- **Europe : roughly 35 companies**
- **USA : Boeing (heavily used), Hughes, Kodak**
- **Rest of the world : Japan, Israël, Australia**

- **Boeing's comments :**
  - Easy to learn, no formal training required
  - Easy to use geometry building tools
  - Very responsive to proposal activities
  - 14 major satellite programs supported in 18 months (Teledesic, Ellipso, @Contact, Discoverer II, Refly, GPS II F, Mars Sample Return, GE*,…)
  - Productivity increase compared to TMG, Nevada or TSS

Thermica next version (V4)

- **Interactive model builder**
  - New shapes (revolution shapes, prisms, polygonal shapes with holes)
  - Sub-models

- **New mission definition module**
  - Kepler +J2 orbit generator
  - Extended to interplanetary missions
  - Orbital change from thruster impulse
  - More flexibility for pointing sequences chaining
  - Enhanced graphical display

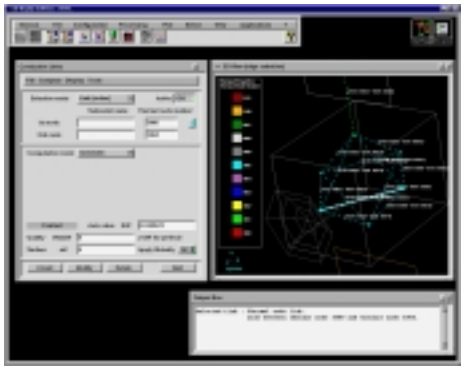


Thermica next version (V4)

- **Thermal radiation**
  - Planetary albedo and Infra-red models
  - Fast spin on a portion of the model

Thermica

- **Thermal conduction (V4)**
  - interactive module for conduction definition
  - automatic calculation from the spacecraft 3D model (already available)
  - fixed or parametric values can also be input



Thermica future developments

- **Thermal model generation**
  - Improved interface to CAD tools (CATIA)
- **Thermal radiation**
  - Improved accuracy control
  - Improved ray-tracing
- **Thermal conduction**
  - Improved calculation for node merging
  - Temperature dependent and non-isotropic material
- **Network analyser**
  - Add flexibility in the input deck generation
- **Post-processing**
  - Graphical displays in the flux budget analysis
- **Model reduction**
  - On-going studies

Conclusion

- **Need for unifying development efforts in Europe**
  - Increasing competition (US software)
- **No need to impose software in Europe**
  - Bad experience on METOP
  - Companies often forced to maintain several software
  - STEP/TAS is a good solution
- **Need to improve ESATAN solution routines**
  - SINDA/G : 4 to 5 times faster
- **Polytan development not a priority**
  - Existing frameworks : Thermica, TMG, Thermal desktop…
- **Prepare thermal tool integration in CAD/CAE packages**
- **Studies on thermo-elastics**
- **Provide validated post-processing tools to the thermal engineers**