Participating Sites

- Distribution covering the largest part of Europe:
  - ASTRUID Stevenage
  - ASTRUID Portsmouth
  - ASTRUID Friedrichshafen
  - ASTRUID Bremen
  - ASTRUID Ottobrunn
  - ASTRUID 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 feedback 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 infrared emission
  - thermal conduction in structures
  - temperatures by means of other commercial packages (Esatan, Sinda/G)

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 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