

Appendix P

TCDT: An environment for preliminary thermal analysis and design

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Thermal Concept Design Tool

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Overview

- **Background**
- **TCDT System**
- **TCDT Databases**
- **Thermal Calculator**
 - Linear Conductors Definition
- **Thermal Simulation Manager**
 - Design Process with TCDT
- **Conclusions**

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Background (1/2)

FEASIBILITY AND PRELIMINARY PHASES

REQUIREMENTS FOR TCS DEVELOPMENT:

- Experience of Thermal Control System (TCS) development
- Attitude towards a cooperative effort within the system
- Deep knowledge of specific software tools

HIGH PRIORITIES:

- Investigation of design options
- Optimisation of time schedule
- Interaction with other disciplines
- Conceptual activities rather than simulation activities

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Background (2/2)

ESA AWARDED A CONTRACT TO **BLUE ENGINEERING** AND **ALCATEL ALENIA SPACE TORINO** WITH THE OBJECTIVE TO IMPROVE THIS SCENARIO WITH A NEW TOOL ABLE TO:

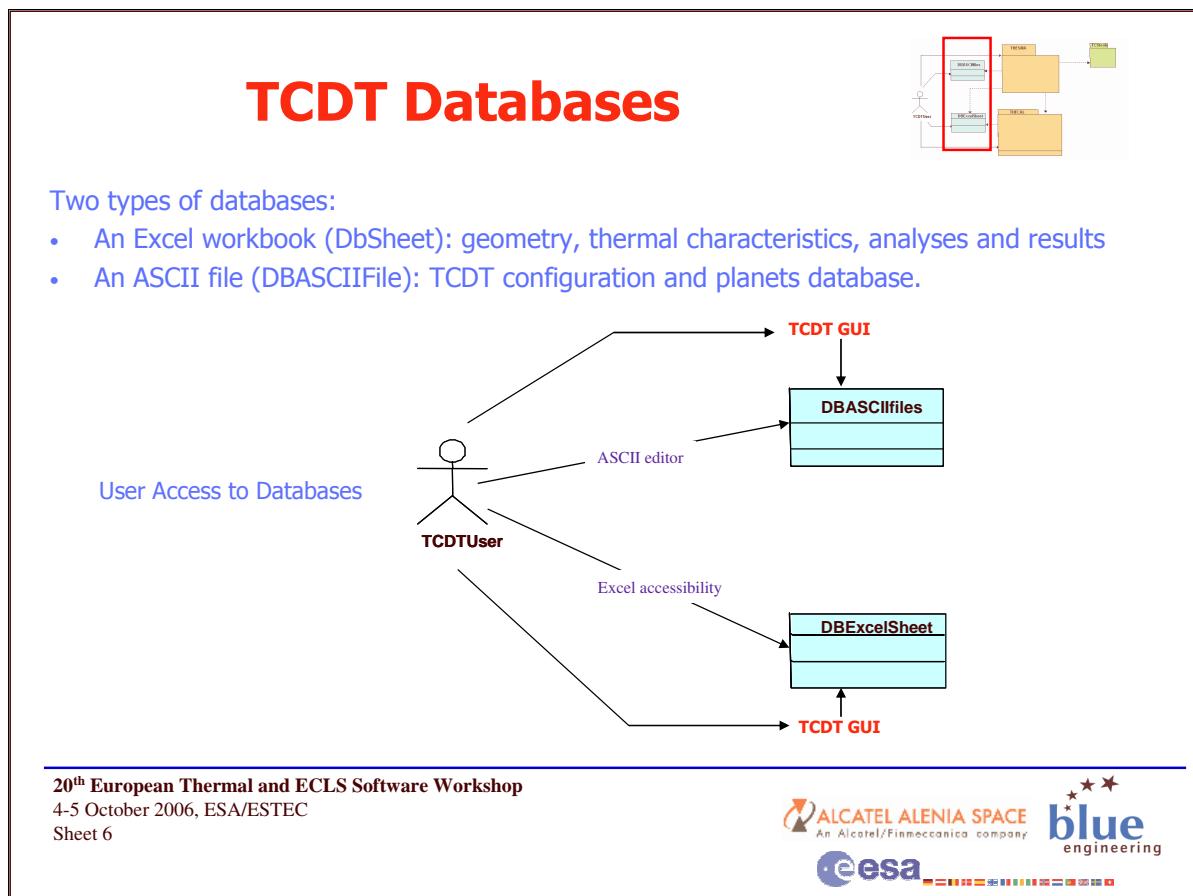
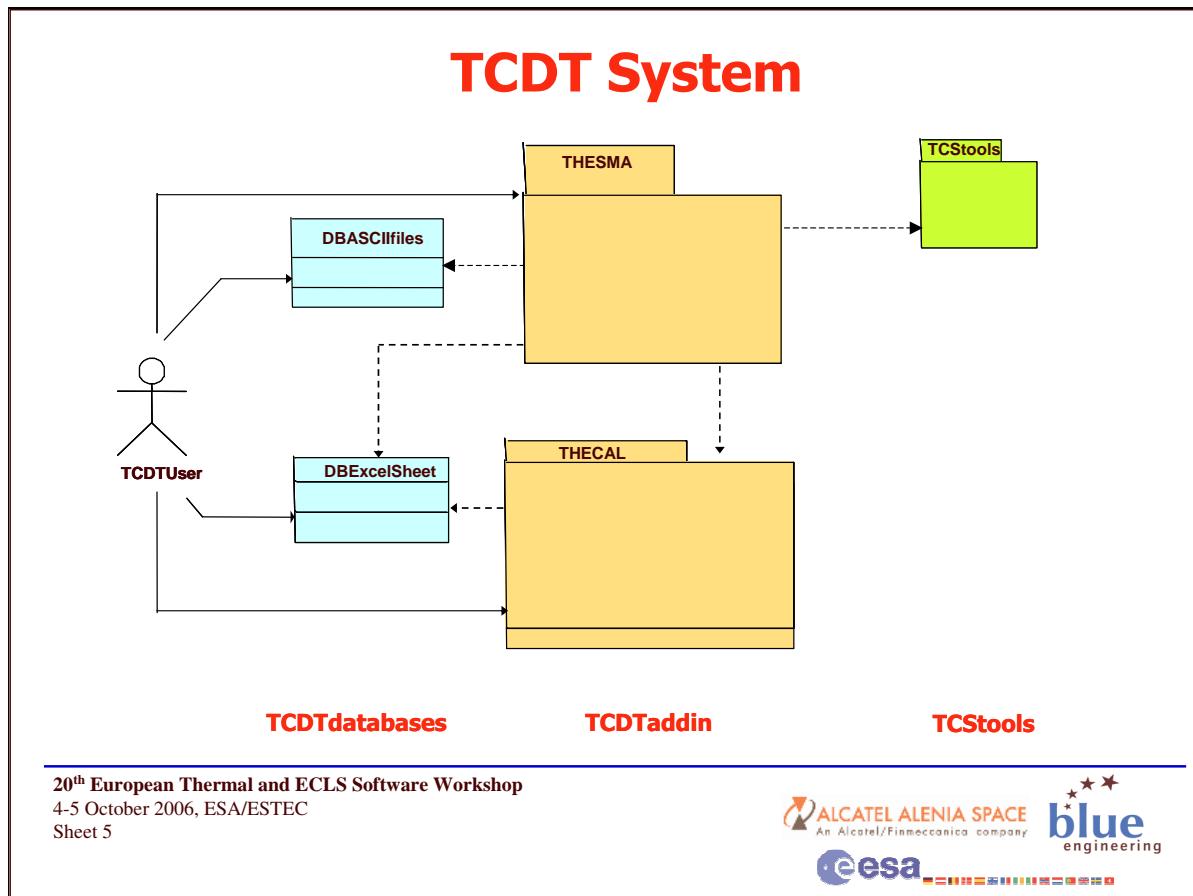
- Provide a flexible and easy environment to investigate a large number of different configurations and TCS options
- Increase the integration between the TCS discipline and other disciplines, in order to speed-up the S/C optimisation
- Support a change of method in the S/C and in particular TCS design, moving toward a design oriented approach
- Exploit the functionalities of ESATAN, ESARAD, ThermXL, ARTIFIS and TOPIC by allowing the user to use them at an higher level

Activity

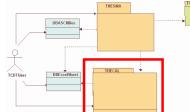
- started in April 2004
- TCDT ver. 1.1 delivered th 4th of September 2006

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Thermal Calculator



The Thermal Calculator (THECAL) allows to:

- Calculate Mass (M), Centre of Gravity, Moments of Inertia and thermal capacitances
- Calculate conductive couplings and contact conductance for simple geometrical configurations
- Calculate radiative conductors and external fluxes calculated for simple geometrical configurations
- Calculate sink temperatures, heat exchanged for nodes and group of nodes according to data in the DBsheet
- Select among possible Insulation and thermal interface



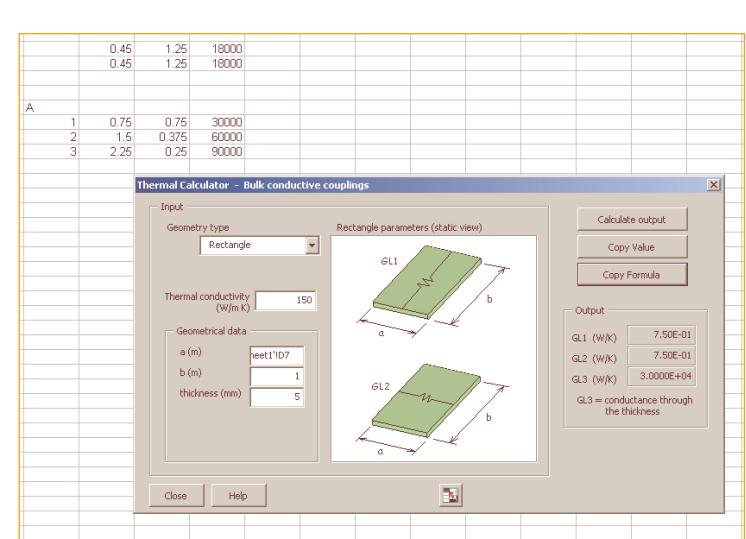
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Linear Conductors Definition

Bulk Conductive Couplings

- THECAL Form
- THECAL Function
- TCDT Help



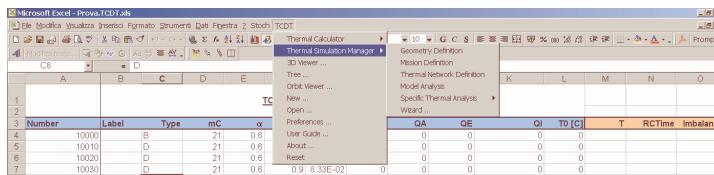
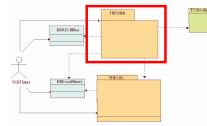
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Thermal Simulation Manager

The Thermal Simulation Manager (THESMA) allows to:

- Build geometrical and thermal mathematical models
- Create input files for the external tools
- Define missions, radiative and thermal analysis cases
- Run analysis cases with the external tools
- Retrieve the results of analysis cases previously performed
- Perform specific analysis and design tasks on pre-built geometrical/thermal typical configurations
- Perform parametric analyses (e.g. for extreme cases assessment)



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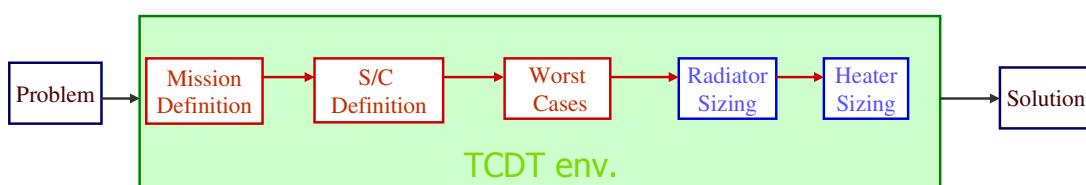
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Design Process with TCDT (1/7)

Preliminary design process with the THESMA

- Mission to Ceres for a S/C in a circular orbit
 - apoapsis/periapsis: 300 km
- Radiator and heater power sizing for an equipment mounted on +Z panel.
 - $15^{\circ}\text{C} < \text{Tequipment} < 30^{\circ}\text{C}$
 - $Q_{\text{Iequipment}}$
 - hot case = 200 watt
 - cold case = 100 watt
 - radiator decoupled from the rest of the S/C



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Design Process with TCDT (2/7)

Mission Definition

TCDT Mission:

Orbit Name	OrbitCeres
Sun/Planet Parameters :	
Planet radius (km)	475
Planet-Sun distance (10's km)	415.215
Planet temperature (K)	167
Albedo factor [-]	0.113
Surface emittance (mW/m²)	0.27
Solar declination (deg)	0
Sunradice (km)	696000
Sun temperature (K)	5770
Sun geo (mW)	274
Thermal Environment	
Solar constant (W/m²)	Calculated
Earth constant value (W/m²)	177
Orbital Parameters :	
Orbit Centre	PLANET CENTRED
Inclination (deg)	90
Argument of perigee (deg)	0
Altitude at perigee (km)	300
Altitude at apogee (km)	300
Ascending Node(deg)	45
TOPIC epoch	12:00:00 AM
Spacecraft Attitude	
Attitude definition type	Pointing Vectors
Pointing Vectors	[0.0 0.0 1.0] ZENITH
First Pointing Direction	[1.0 0.0 0.0] VELOCITY
Second Pointing Vector	[0.0 0.0 0.0] PLANET ORIENTED
Second Pointing Direction	
First General Direction	
Second General Direction	
LODS	
1st Euler's angle q (deg)	0
2nd Euler's angle q (deg)	0
3rd Euler's angle q (deg)	0
1st Euler's angle, rotation rate (deg/s)	0
2nd Euler's angle, rotation rate (deg/s)	0
3rd Euler's angle, rotation rate (deg/s)	0
Spin	No
Rot axis 1 component Rx w/ SCS	0
Rot axis 2 component Ry w/ SCS	0
Rot axis 3 component Rz w/ SCS	0
No. of spin positions	5
Camera Parameters	
No. of orbital positions	8
Include ellipse=entrypoint positions	Yes
Offset (deg)	0.5
Initial True Anomaly	0

Orbit Viewer

Orbit Form

Mission Worksheet

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An Alcatel/Finmeccanica company
blue
engineering
esa

Design Process with TCDT (3/7)

S/C Definition

Nodes

Node ID's	Model Tree	Loc X	Loc Y
5500	SA-Y	0	0
5510	5000 / 5500 "SA-	0	0
5520	5010 / 5510 "SA-	0	0
5530	5020 / 5520 "SA-	0	0
6500	6000 / 6500 "SA-	0	0
6510	5010 / 6510 "SA-	0	0
6520	5020 / 6520 "SA-	0	0
6530	5030 / 6530 "SA-	0	0
Body	1120 / #2120 "Bo	0	0
	1130 / #2130 "Bo	0	0
	1140 / #2140 "Bo	0	0
	1150 / #2150 "Bo	0	0
	1160 / #2160 "Bo	0	0
	1170 / #2170 "Bo	0	0
	1180 / #2180 "Bo	0	0
	1190 / #2190 "Bo	0	0
	1200 / #2200 "Bo	0	0
	1210 / #2210 "Bo	0	0
	1220 / #2220 "Bo	0	0
	1230 / #2230 "Bo	0	0
	1240 / #2240 "Bo	0	0
	1250 / #2250 "Bo	0	0
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	1270 / #2270 "Bo	0	0
	1280 / #2280 "Bo	0	0
	1290 / #2290 "Bo	0	0
	1300 / #2300 "Bo	0	0
	1310 / #2310 "Bo	0	0
	1320 / #2320 "Bo	0	0
	1330 / #2330 "Bo	0	0
	1340 / #2340 "Bo	0	0
	1350 / #2350 "Bo	0	0
	1360 / #2360 "Bo	0	0
	1370 / #2370 "Bo	0	0
	1380 / #2380 "Bo	0	0
	1390 / #2390 "Bo	0	0
	1400 / #2400 "Bo	0	0
	1410 / #2410 "Bo	0	0
	1420 / #2420 "Bo	0	0
	1430 / #2430 "Bo	0	0
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	2250 / #3250 "Bo	0	0
	2260 / #3260 "Bo	0	0
	2270 / #3270 "Bo	0	0
	2280 / #3280 "Bo	0	0
	2290 / #3290 "Bo	0	0

3D Viewer

Geometric Form

Radiator Form

Model Tree

GNodes Worksheet

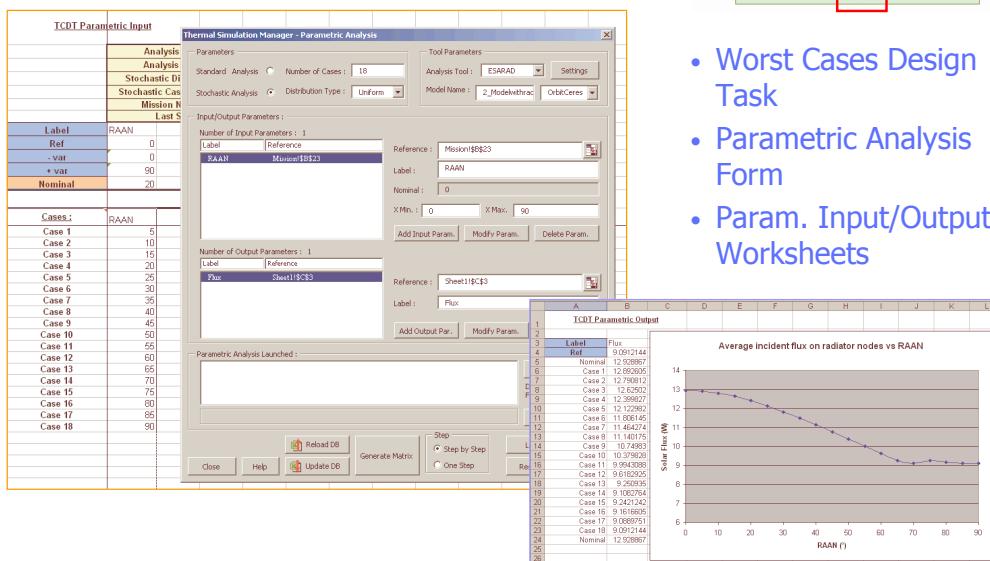
TNodes Worksheet

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Design Process with TCDT (4/7)

Worst Cases

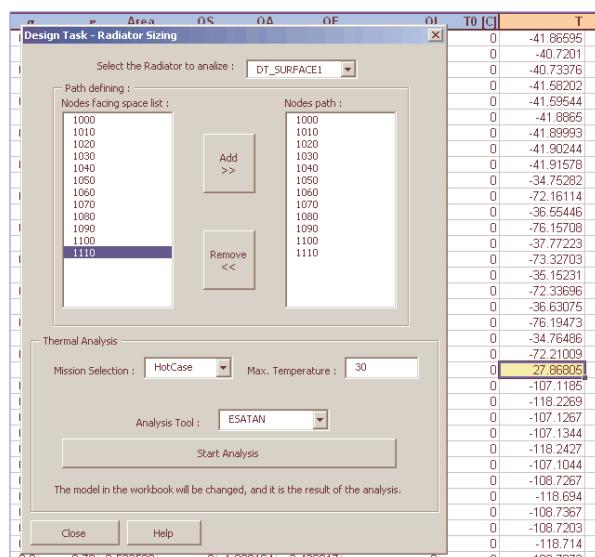


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Design Process with TCDT (5/7)

Radiator Sizing

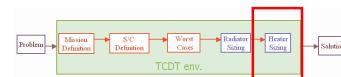
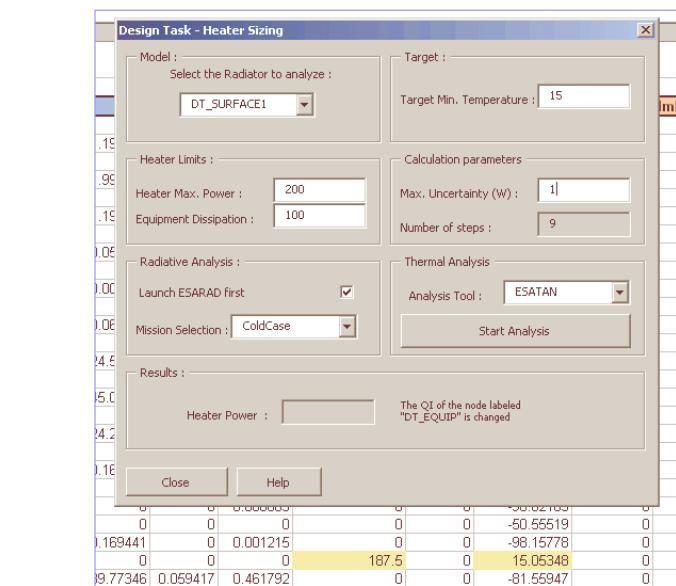


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Design Process with TCDT (6/7)

Heater Sizing



- Heater Sizing Design Task

- TNodes Worksheet

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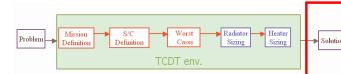
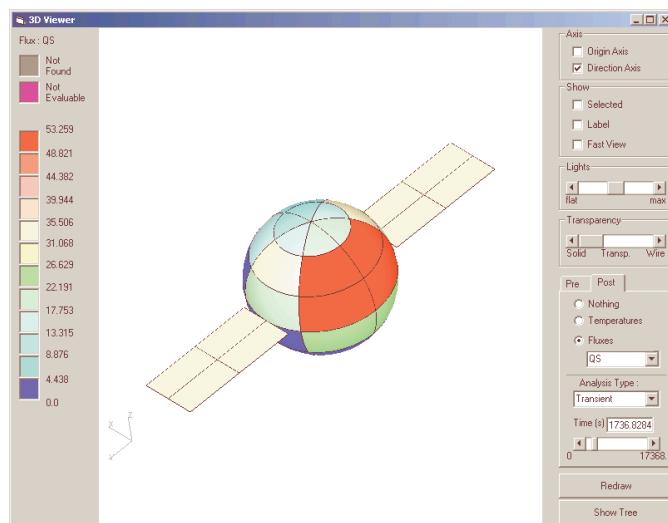
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Design Process with TCDT (7/7)

Results Processing



- 3D Viewer

- Model Tree

- GNodes Worksheet

- TNodes Worksheet

- Results Worksheet

- Arrays Worksheet

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Conclusions (1/3)

TCDT: easy and flexible environment for design investigation

Data collected in a single Excel workbook:

- Quick checks, updating and organisation
- Quick definition of tables and charts for presentations and documents
- Quick data organisation for rapid data exchange with other disciplines

Data used at the same time for model definition and elaborations:

- Reduction of risk of discrepancies between documentation and models
- Allowing a reliable speed up of thermal engineers activities

Possibility to manage different configurations:

- Quick design configuration evolution without any limit in the number of design options.

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Conclusions (2/3)

TCDT: a new approach to analysis/design for thermal engineer

TCDT high-level functionalities:

- Predefined design tasks
- Predefined thermal/geometrical primitives
- Full capability to manage single, parametric and iterative analyses
- Advanced GUI for model and analysis checks

TCDT low-level functionalities:

- Possibility to define user design tasks
- Possibility to define any thermal-geometrical model
- Possibility to add user functions

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Conclusions (3/3)

TCDT: lessons learnt and possible future development

lessons have been learnt for future activities:

- More code in VB environment (Compiled DLL) to improve performance
- VBA environment within Excel sometimes is not enough flexible and reliable

Useful and natural continuation for future activities:

- Development of ModelTree and 3DViewer
- Development of mission analysis versus a thermal/radiative analysis
- Further development of parametric analysis: stochastic analysis with different distributions, optimization procedures.
- Implementation of a material database.
- Further development of GL generator of THESMA.
- Implementation of other dedicated modules for results data processing.
- Implementation/integration of internal solvers.

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