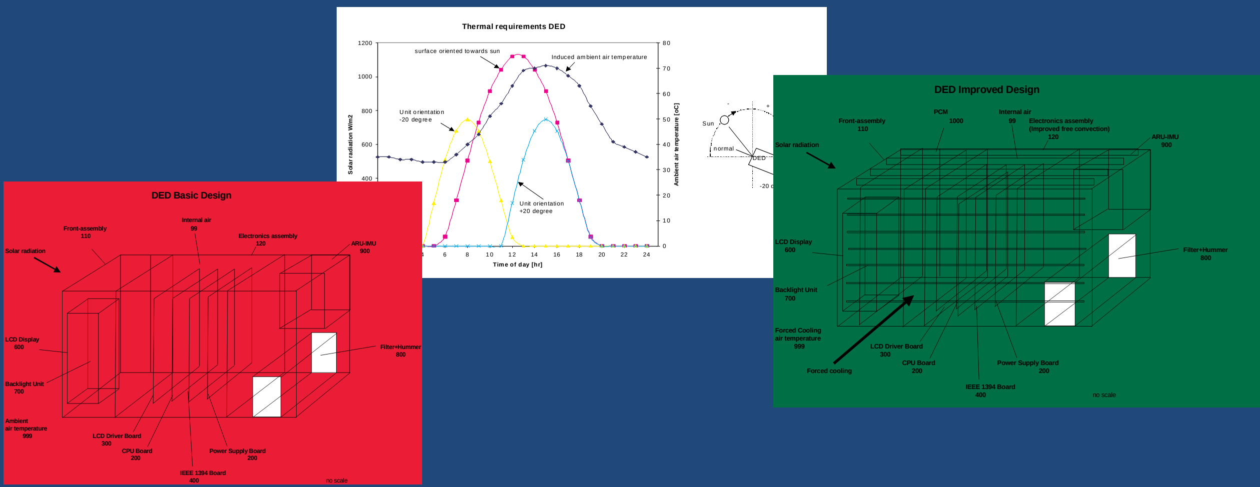
Integrated thermal design and the thermal numerical toolbox



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Introduction

Integrated thermal design in small thermal designs

- **More and more thermal design is started in early phases of design (concurrent design) to:**
  - Minimise mass of thermal control subsystem
  - Avoid re-design at the end of a project
  - Maximise integration of structural and thermal design
  - Reduce development time and costs

Introduction

Thermal S/W packages are useful tools in early trade-offs to:

- **Perform transient analysis**
- **Determine impact of orbital changes**
- **Compare design options**
- **Perform sensitivity analyses**

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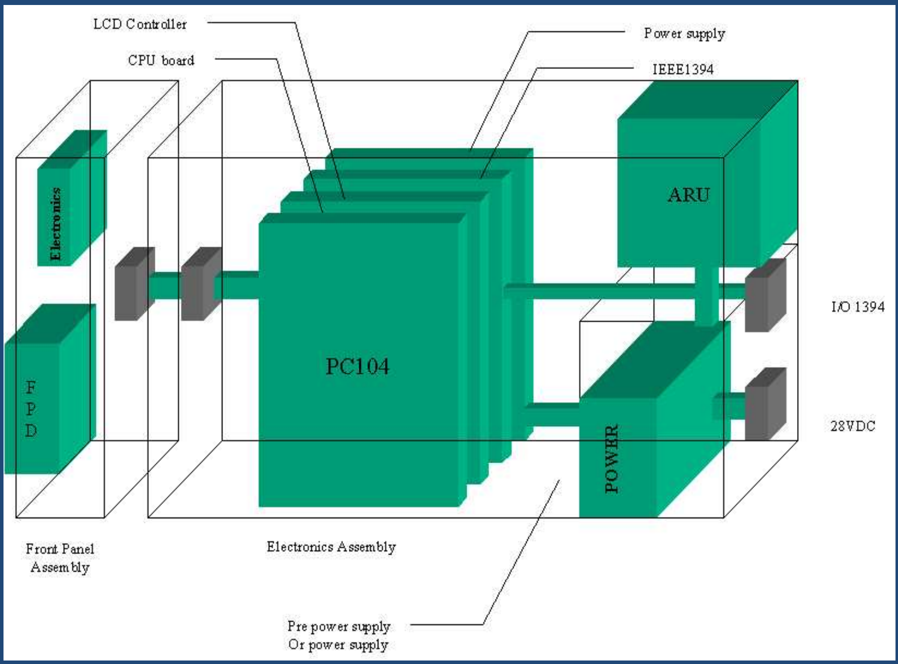
Thermal design of a cockpit control panel in desert conditions



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Thermal design of a cockpit control panel in hot conditions

- **Problem to solve:**
  - A basic thermal design for a cockpit panel display does not meet the temperature requirement of 85 °C during:
    - non-operational conditions in hot conditions
    - start-up in hot conditions

- **Conditions**
  - Solar radiation 1120 W/m^2 at maximum.
  - Ambient air 71 °C.
  - An adiabatic interface with instrument panel is required.
  - Cooling air 35 °C

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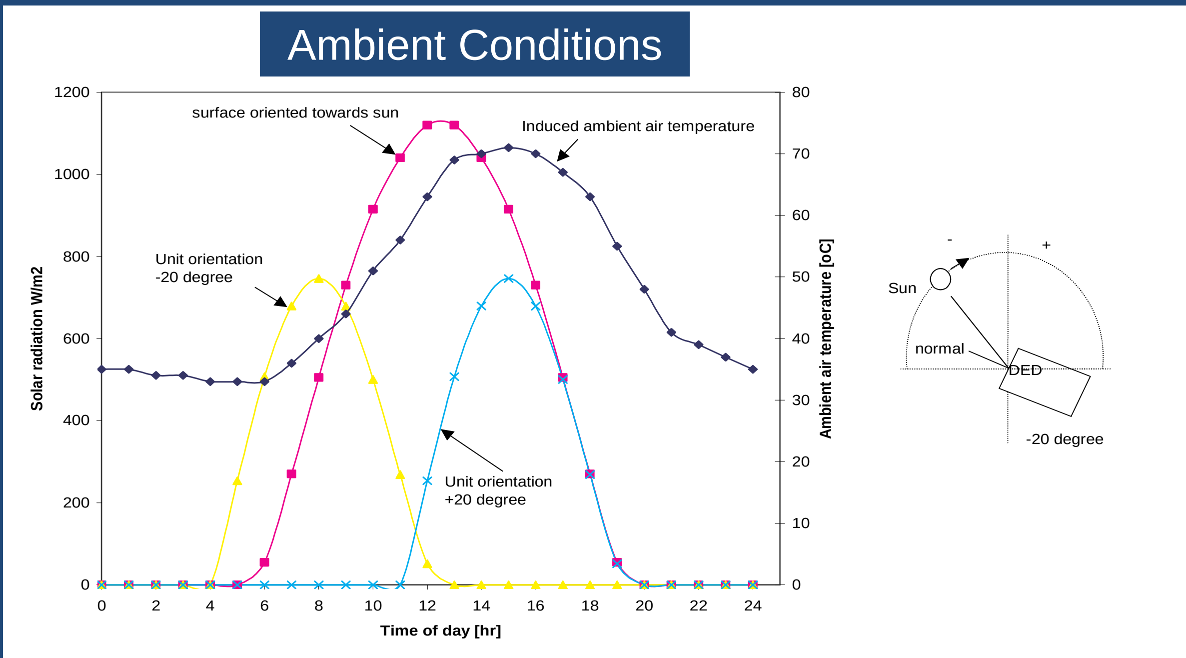
Thermal design of a cockpit control panel in hot conditions



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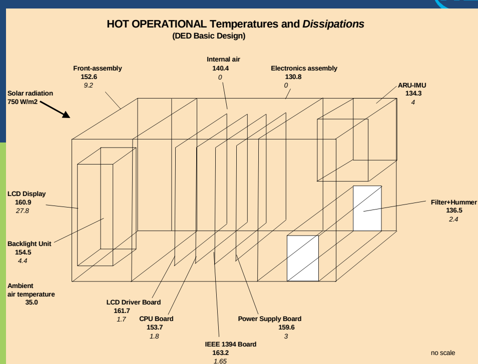
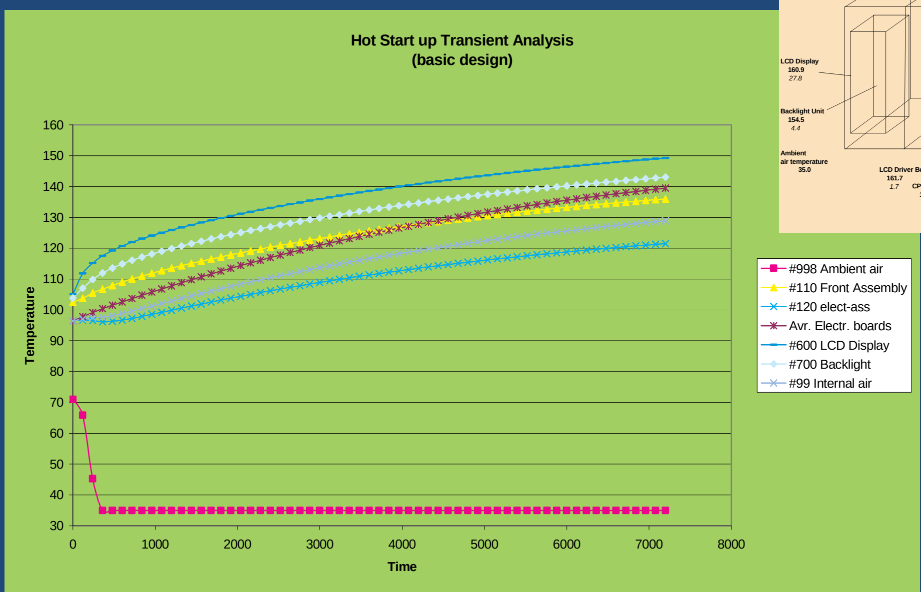
Thermal design of a cockpit control panel in hot conditions

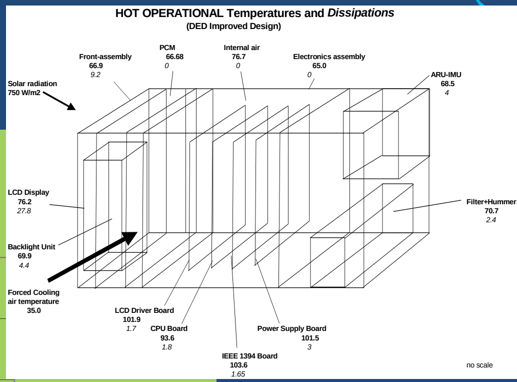


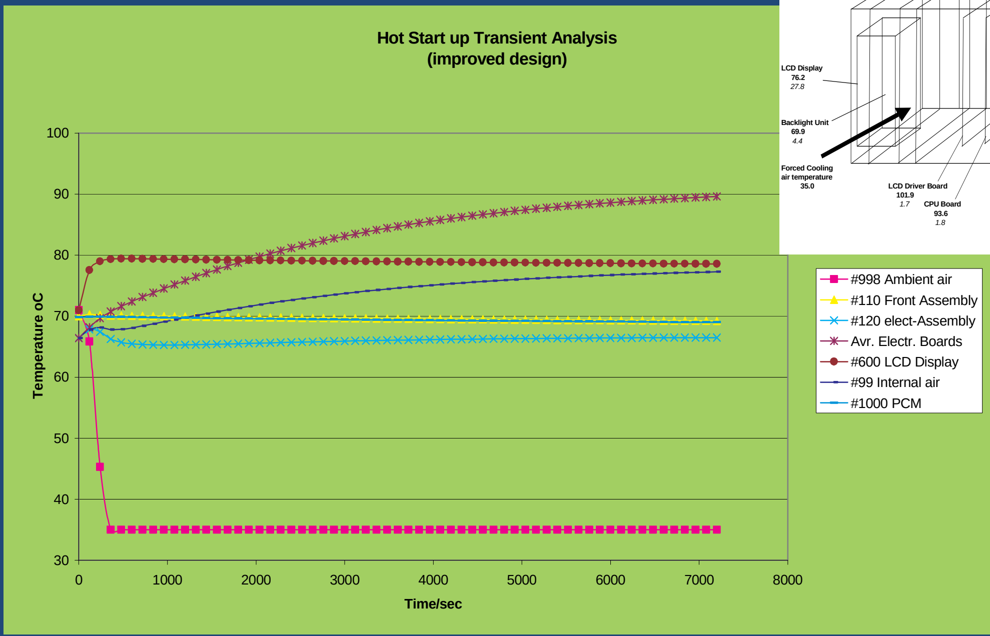


Basic Design

- Free convection
- No thermal H/W

Thermal design of a cockpit control panel in hot conditions





Improved Design

- Forced convection
- PCM

Thermal design of a cockpit control panel in hot conditions

- **Transient thermal modelling was needed and convinced the customer to change design.**
- **PCM is easy implemented in ESATAN, however:**
  - It is not (yet) a standard feature.
  - Error messages are unclear.
  - ESATAN provides no support for structured set-up of in-house ESATAN-code.

Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **A high-insulating experiment container was required to keep a biological bacterial growth experiment below 10 °C for 4.5 days without active cooling.**

- **Conditions**
  - Ambient temperature 22 °C.
  - Limited volume.
  - Limited power budget (no active cooling).
  - Overall thermal conductivity less than 0.1 mW/m*K is required.

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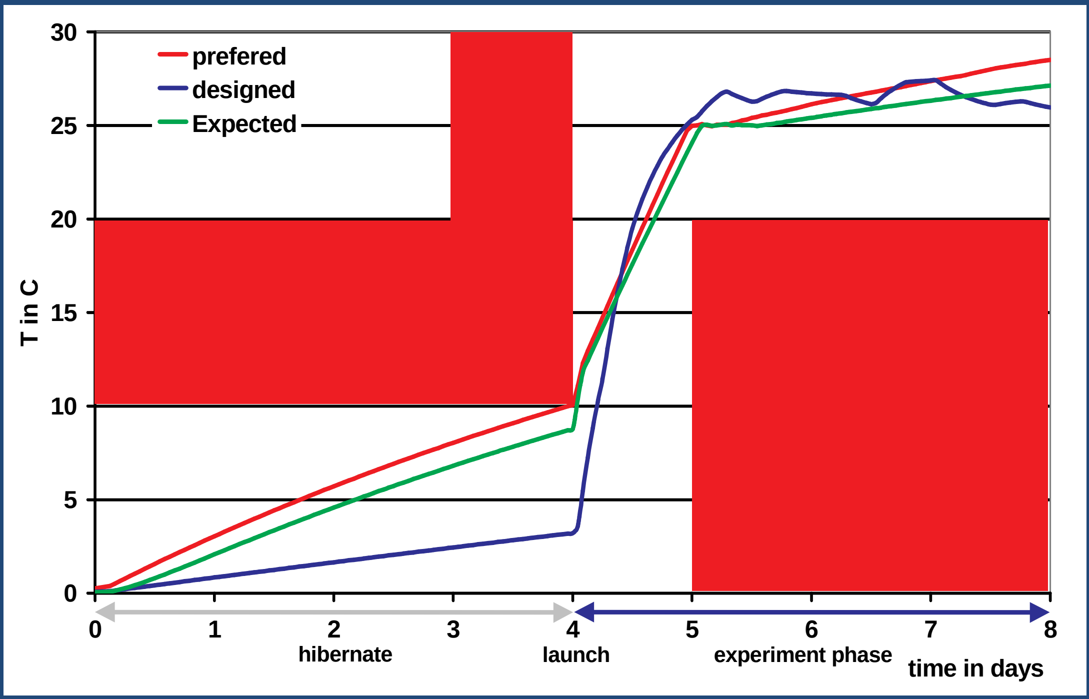
Thermal design of the pre-launch isolation of the BIOFILTER experiment



Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **Design**
  - A high insulating container is manufactured with high vacuum and MLI.
  - PCM is added as heat capacity and latent heat.
  - A heater is implemented to heat the experiment
- **Results**
  - Design ready in 6 months after start thermal design.
  - Overall conductivity is 0.4 mW/mK (0.2 W/m*K required)
  - 150 g PCM (5.9 °C) is enough to satisfy the temp. requirements.
  - Heater power is sufficient to heat the experiment to 25 °C.

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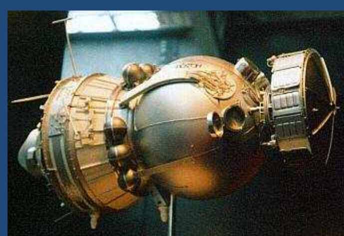
Thermal design of the pre-launch isolation of the BIOFILTER experiment

- **Transient thermal modelling was used to calculate design performance and to support design trades.**
- **MLI performance is strongly dependent on vacuum**
  - Test were needed to confirm feasibility.
- **The modelling was performed by a new ESATAN user**
  - ESATAN showed to be easy to learn but error messages were unclear.
  - Effort was unfortunately for nothing.



Requirements to the thermal numerical toolbox for integrated design

- **Easy user interface with short learning curve.**
- **Large toolbox with material properties.**
- **Easy interfaces with ESARAD/RADCAD/STK etc.**
- **Toolbox with (with a small number of nodes) thermal design options such as:**
  - Phase change materials
  - Honeycomb material
  - MLI (in vacuum)
  - Heat pipes (LHP, CPL)
- **Possibility of easy implementation of new design options.**

Conclusion & recommendations

- **The ESA thermal numerical toolbox is a useful tool in integrated (thermal) design, to support design trade-offs for:**
  - **transient thermal modelling**
  - **impact of orbital changes**
- **Most capabilities are present in current ESATAN however**:
  - **The user interface can be more structured.**
  - **The error messaging is often unclear.**
  - **The program invites the user to program him/herself. Also here a structure could provide faster modelling.**

Conclusion & recommendations

- **Statement:**
  The added value of small thermal models in the early phase of a project is orders larger than the added value of large thermal models in later stages of a project.

- **Therefore:**
  R&D of thermal S/W tools should be focussed on development of tools and data exchange to support thermal trade-offs.

- **Open source S/W is certainly a possibility to increase the improve the functionality and efficiency of the current S/W-tools.**