Using EcosimPro for Thermal and Thermo-Hydraulic Analysis in ESA

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Plan of the presentation

1. What is EcosimPro?
2. Why and when using it for thermal / thermo-hydraulic analyses?
3. Main features of the tool
4. Examples of application
5. Next steps
What is EcosimPro?

• EcosimPro is a general software package for modelling and simulating dynamic systems. It can be used and customised for any problem domain which can be represented by Differential-Algebraic Equations (DAE) and Discrete Events.

• It is particularly well-suited for the analysis of lumped-parameter models.

• The software consists of a front-end simulation layer (language and user interface) on top of C++ and provides Object-Oriented Modelling capabilities.
What is EcosimPro?

- Initially developed in 1990 to address the growing requirements for ECLSS analyses and to establish a standard analysis tool in this domain.
- Since then it has been continuously upgraded and supported by the Agency.
- Re-targeted for the PC-Windows platform in 1999 and to make use of state-of-the-art technologies.
What is EcosimPro?

- Recent application for ECLSS: Columbus for the ISS

COLUMBUS Orbital Facility (COF)
Why and when using it for thermal and thermo-hydraulic analyses?

• Typical usage: For small and medium-size analyses (typically less than 500/1000 nodes)

• When compared with traditional thermal analysis tools EcosimPro provides the following advantages:
  – Object Oriented Modelling capabilities
  – Symbolic handling of equations e.g. $T' = q / C$, $x'' = m * g$
  – Non causality e.g. $T' = q / C \iff C = q / T' \iff q = T' \cdot C$
  – Integrated environment (schematic editor / post-pro)
  – Ideal for multi-disciplinary problems e.g. Controller modelling
  – Easy connectivity with COM e.g. with Excel
Main features

- Object-Oriented Modelling is particularly adapted when using the lumped parameter method and a bottom-up approach. **Interfaces** between **components** (models) are clearly defined together with **public** and **private** data, equations and events belonging to a component.

- By supporting non causality, EcosimPro helps in re-using components and libraries of components because the **experiments** (analysis cases) are defined externally to the component.
Main features

Build **component** for thermal unit & define the **interface**, what is **public** and what is private

Define several unit test cases by specifying the interface e.g. boundary nodes using an **experiment**

All test passed?
Main features

Integrate the **component** in a system without any modification

This is a new component ...

... with its own interface, public and private data/equations
Main features

Take a **component C1** built, compiled and tested

From this component **inherit** a component **C2** with extra data/functionality (Examples: A diffusive node can be derived from a more general class nodes)

This allows the user to easily derive new components and to avoid redundancy of information. Any changes to C1 are propagated to C2 when C1 is recompiled (dependency tree)
Main features (example of inheritance)

```plaintext
--- Diffusive node with a max and min temperature

COMPONENT DNodeWithMinMax IS_A DNode

DATA
  DECLS
  REAL tmin "Minimum temperature (deg. C)"
  REAL tmax "Maximum temperature (deg. C)"

INIT
  tmin = 1.E+05 -- very large positive value
  tmax = -1.E+05 -- very large negative value

DISCRETE
  tmin = min(tmin, T)
  tmax = max(tmax, T)

END COMPONENT
```
Main features (example of inheritance)

--- Diffusive node, check compliance with specifications

COMPONENT DNode_With_Specs IS_A DNodeWithMinMax

DATA

REAL tmin_specified = 0.  "Minimum specified temperature (deg. C)"
REAL tmax_specified = 0.  "Maximum specified temperature (deg. C)"

DECLS

BOOLEAN UpperLimit_Exceeded "(Boolean)"
BOOLEAN LowerLimit_Exceeded "(Boolean)"
REAL Difference_tmax_reached_tmax_specified
REAL Difference_tmin_reached_tmin_specified

INIT

-- Initial conditions
UpperLimit_Exceeded = FALSE
LowerLimit_Exceeded = FALSE

...
Main features (example of inheritance)

...  
DISCRETE
  -- Verification of inputs
  ASSERT ( tmax_specified >= tmin_specified ) WARNING "Tss < Tsi"
  -- Checking if limits are reached
  WHEN ( tmax >= tmax_specified ) THEN
    UpperLimit_Exceeded = TRUE
  END WHEN
  WHEN ( tmin <= tmin_specified ) THEN
    LowerLimit_Exceeded = TRUE
  END WHEN
CONTINUOUS
  Difference_tmax_reached_tmax_specified = tmax - tmax_specified
  Difference_tmin_reached_tmin_specified = tmin - tmin_specified
END COMPONENT
Main features (example of inheritance)
Main features (EcosimPro GUI)
Main features (Schematic editor)
Examples of application: Thermal

The Platinum Data Collection Unit Equipment is part of the Temperature Data Acquisition System in the LSS (ESTEC)

Requirements

- **Verify** a Steady State HOT worst case during a review
- **Do it in “real time”**!
- Analyse and provide results to internal customer (testing)
Examples of application: Thermal

Detailed or Reduced PCB model(s) can be used
Examples of application: Thermo-Hydraulic

- 4 separate Cold Volumes
- 4 thermoelectric Cooling Units
- Integration into Boeing 4 post rack
- VIP Insulation
- GFC shell structure

RFR description
(Fig: Astrium-GmbH)
Examples of application: Thermo-Hydraulic

Topology of the RFR component HalfRackRight

Complete RFR model:
• 2362 independent variables
• 2354 equations (179 DAE and 2175 Algebraic explicit equations)
• 8 boundary conditions.
Examples of application: Thermo-Hydraulic

Door Opening scenario

Cargo Temperature in Lower CV

-17 -16.5 -16 -15.5 -15 -14.5 -14 -13.5 -13 -12

0 2 4 6 8 10 12

TIME (days)

TEMPERATURE (C)

- Cargo Temp. in Bottom Drawer
- Cargo Temp. in Middle Drawers
- Cargo Temp. In Top Drawer

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Examples of application: Thermo-Hydraulic

Door Opening scenario

![Graph showing Powers - Door Openings - RF Mode](graph.png)
Next Steps

• Consolidate existing libraries and develop new specific libraries e.g. two-phase / capillary

• Improve interfaces with other ESA tools: ESARAD, ESATAN and ThermXL

• Independent industrial assessment will be conducted by Astrium-GmbH and presented at the ICES 2002
Some users in the Aerospace Business

- ESA-ESTEC, The Netherlands
- NASA Marshall Space Flight Center, USA
- ASTRIUM, Germany
- ALENIA, Italy
- CASA, Spain
- SNECMA, France (Gas Turbines)
- Rolls Royce, UK

More information? [http://www.ecosimpro.com](http://www.ecosimpro.com) or email to Olivier.Pin@esa.int or Pedro.Cobas@ecosimpro.com