ESTEC
Thermal and Structures Division

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?

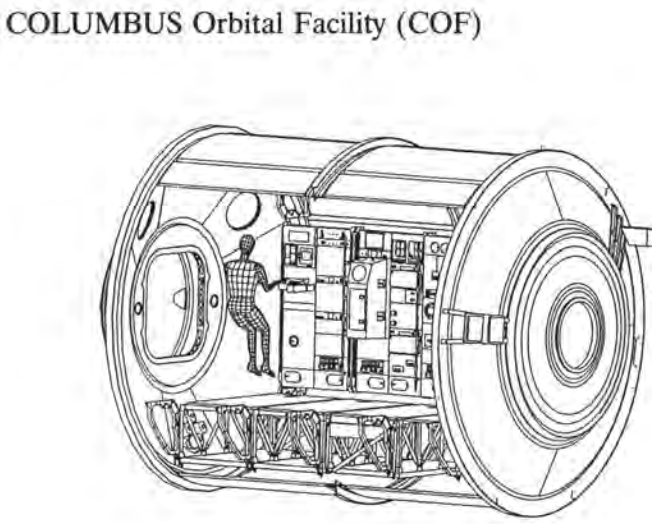
- EcosimPro is a general software package for modelling and simulating dynamic systems. It can be used and customised for any problem domain which can be represented by Differential-Algebraic Equations (DAE) and Discrete Events
- It is particularly well-suited for the analysis of lumped-parameter models
- The software consists of a front-end simulation layer (language and user interface) on top of C++ and provides Object-Oriented Modelling capabilities

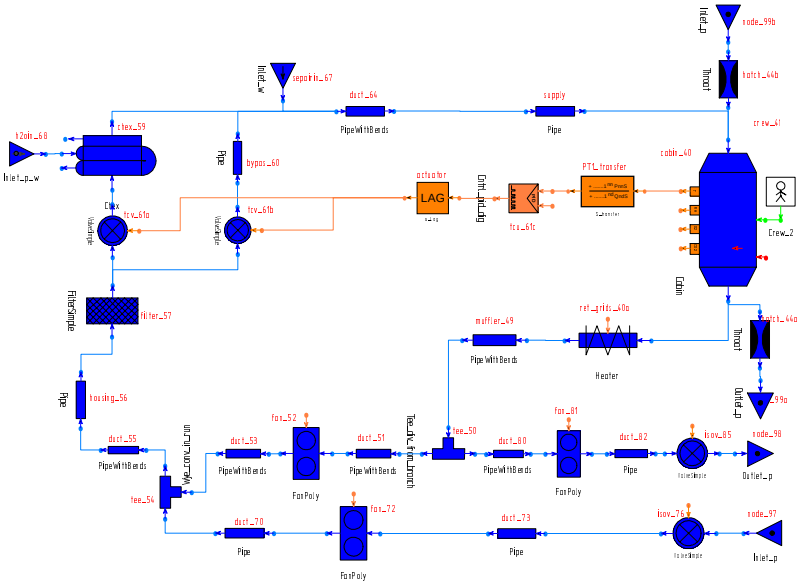
What is EcosimPro?

- 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





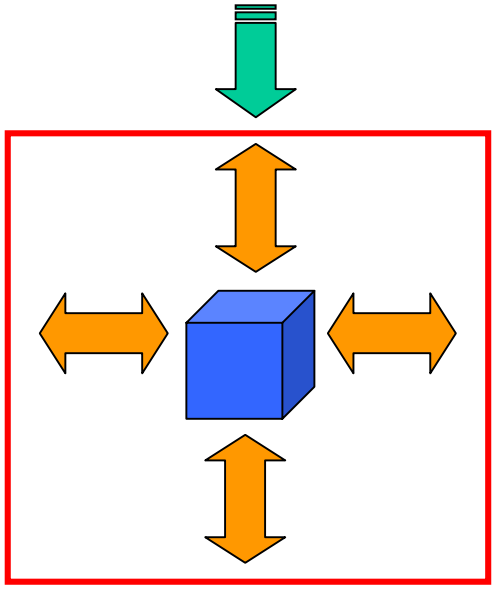
Why and when using it for thermal and thermo-hydraulic analyses?

- 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 <=> C = q / T' <=> q = T' 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

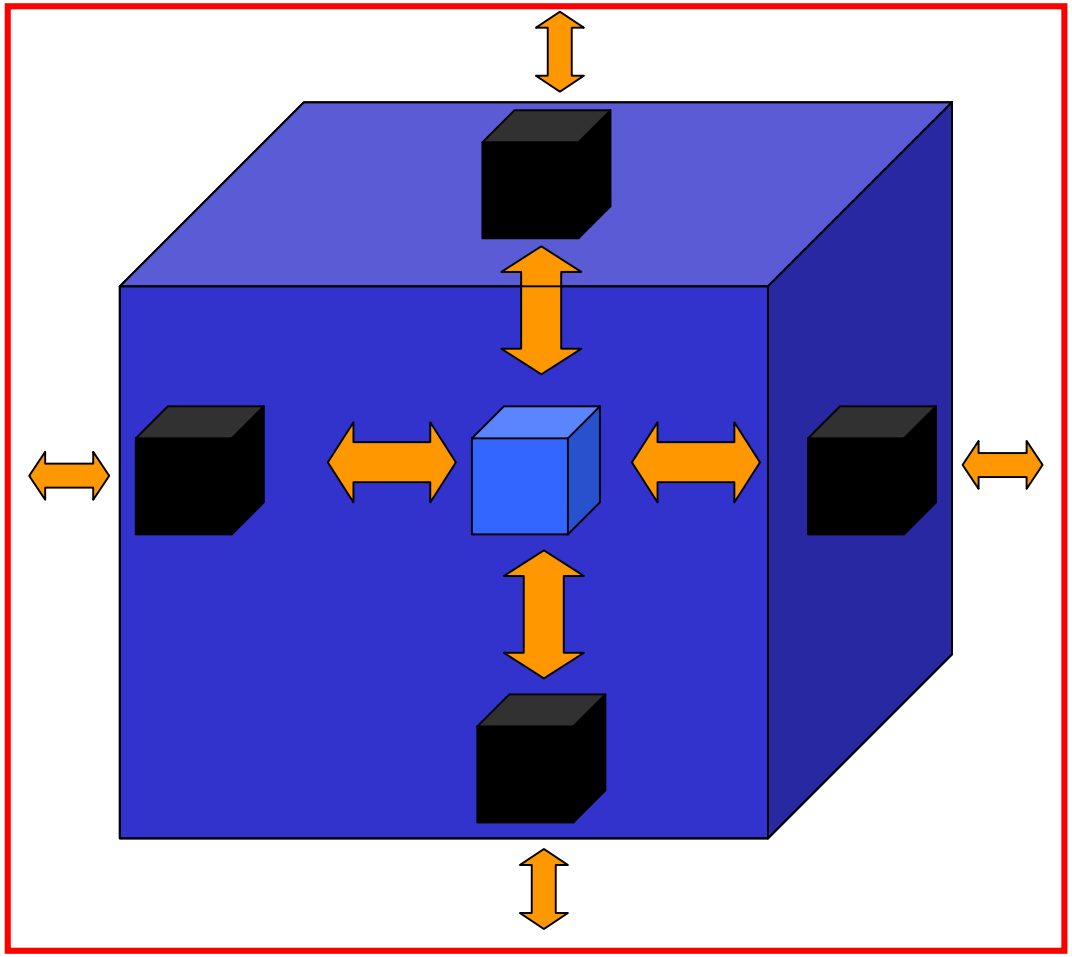


Build **component** for thermal unit & define the **interface**, what is **public** and what is private

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

All test passed?

Main features

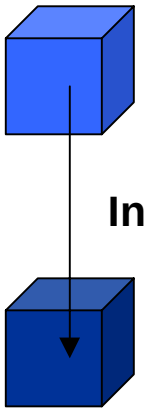


Integrate the **component** in a system without any modification

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)

```
--- 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
  CONTINUOUS
        tmin = min(tmin, T)
        tmax = max(tmax, T)
END COMPONENT
```

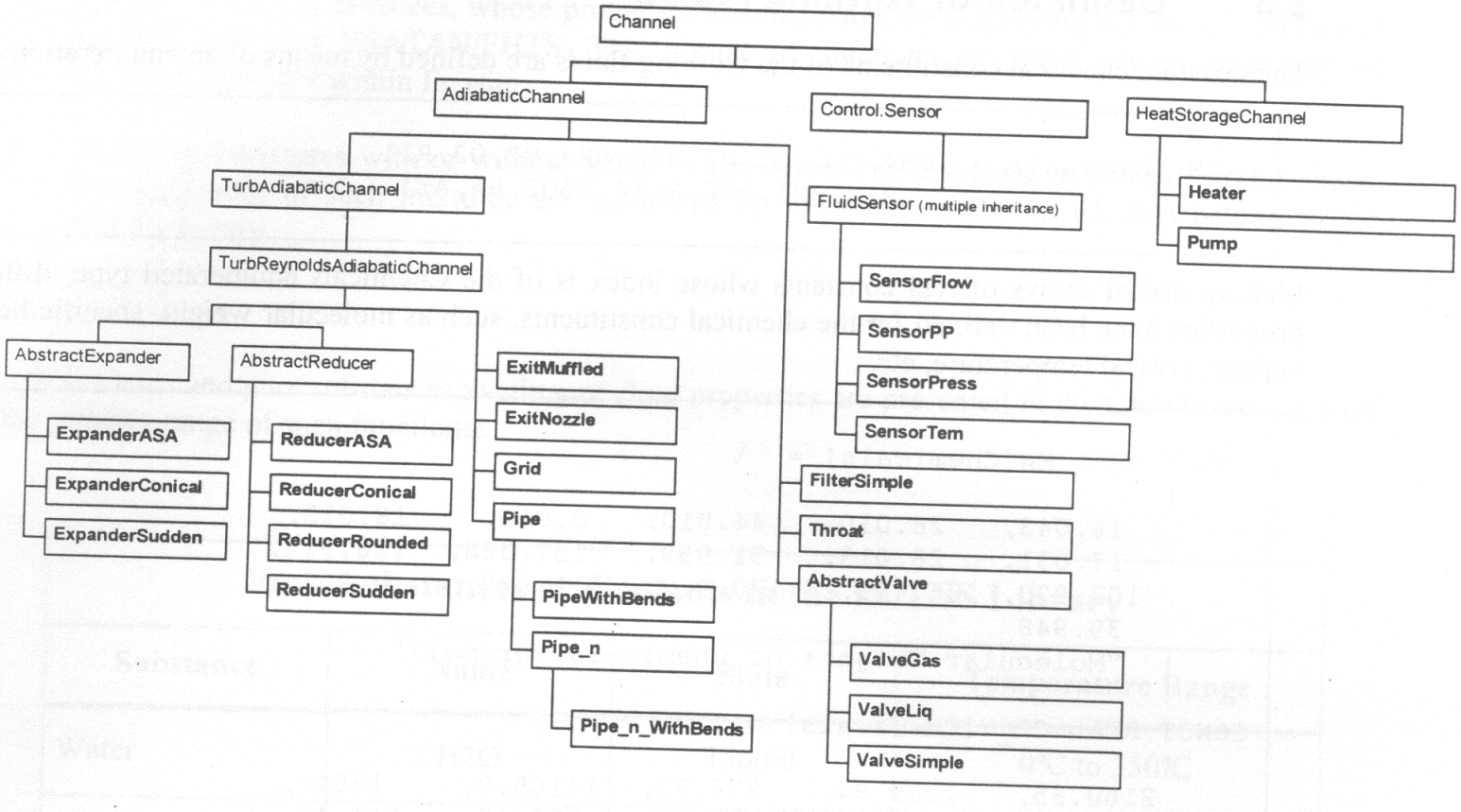
Main features (example of inheritance)

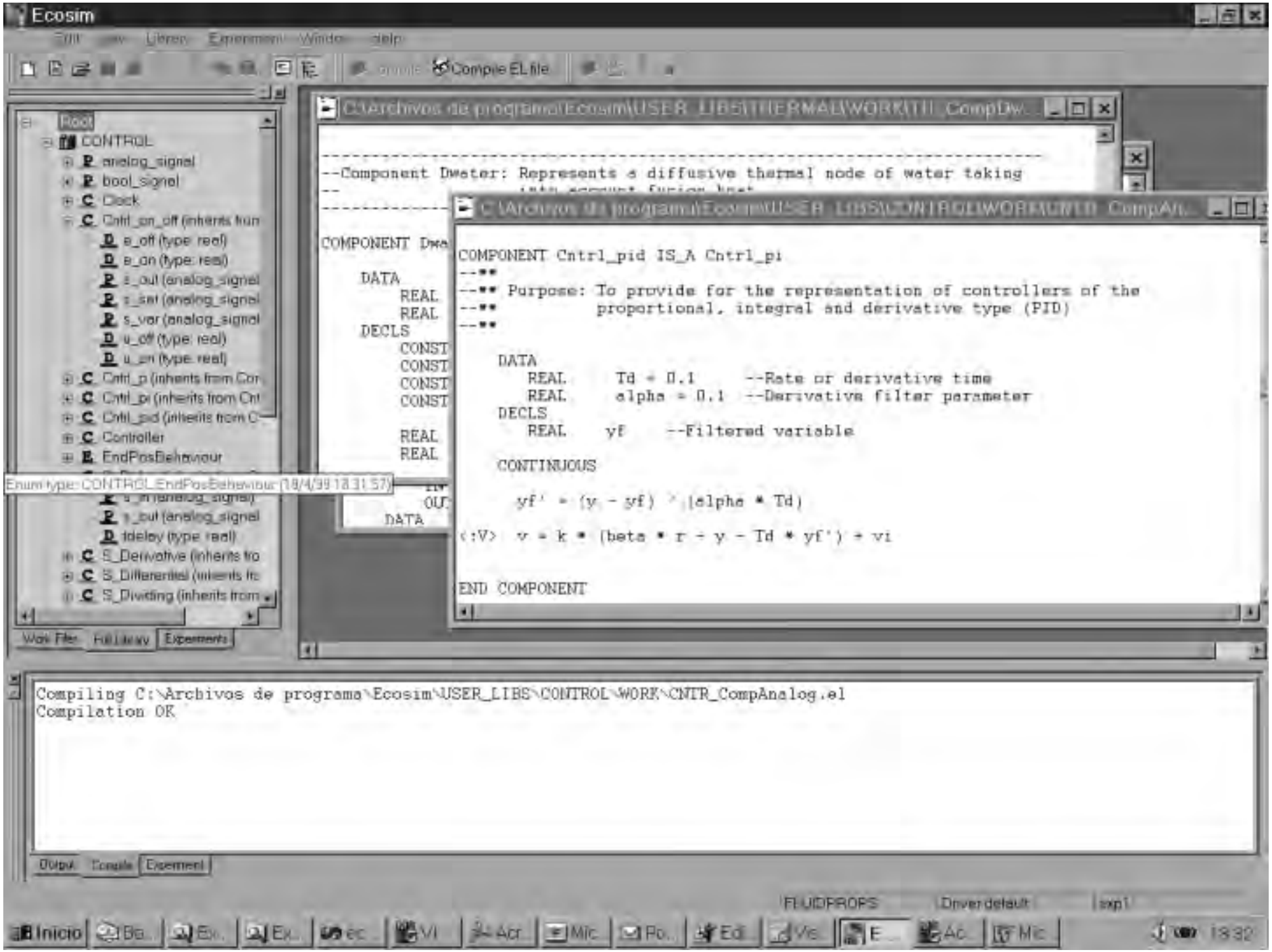
```
--- Diffusive node,  check compliance with specifications
-------------------------------------------------------------------------------------------
COMPONENT DNode_With_Specs IS_A DNodeWithMinMax
 DATA
          REAL tmin_specified = 0.        "Minimum specified temperature  (deg. C)"
          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)

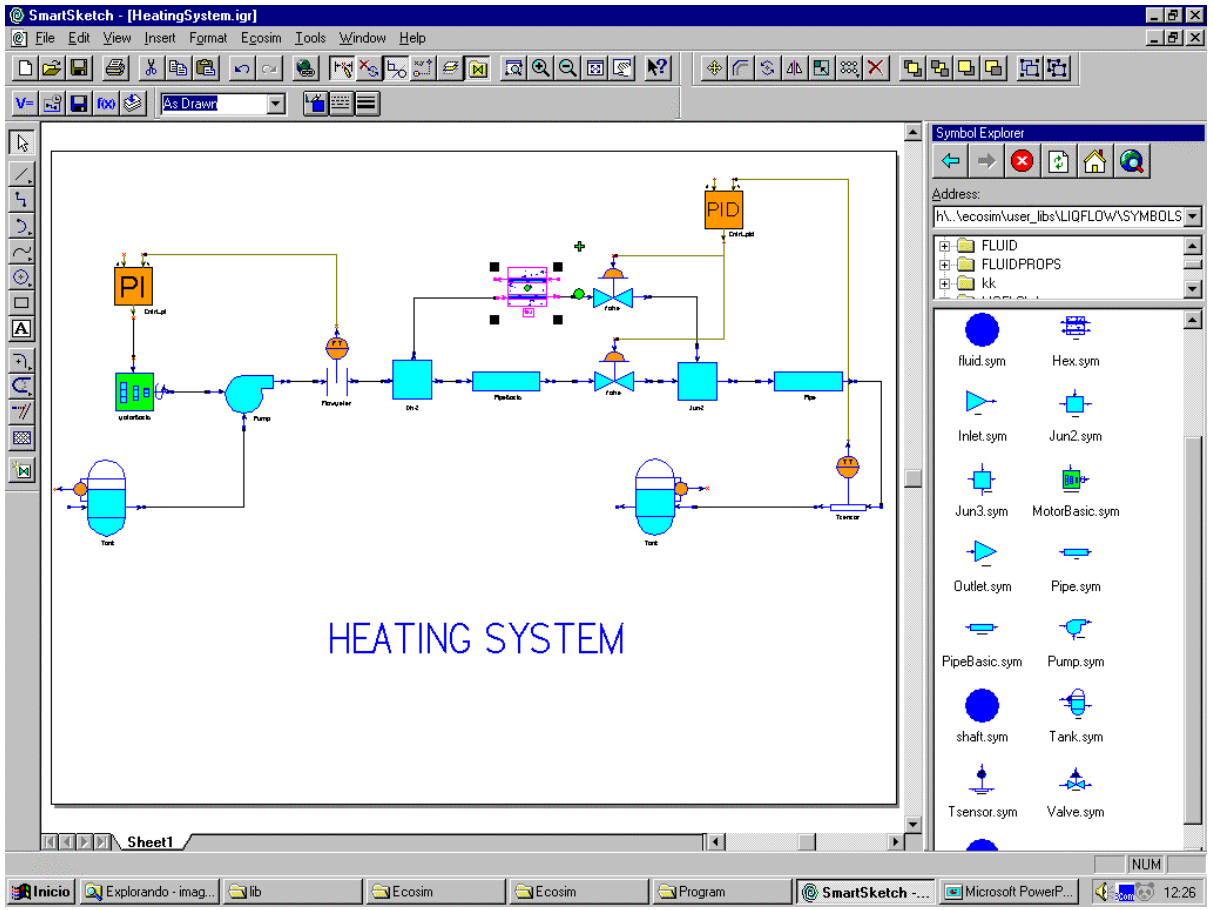
```
...
DISCRETE
        -- Verification of inputs
        ASSERT ( tmax_specified >= tmin_specified ) WARNING "Tss < Tsi"
        -- Checking if limits are reached
        WHEN ( tmax >= tmax_specified ) THEN
                UpperLimit_Exceeded = TRUE
        END WHEN
        WHEN ( tmin <= tmin_specified ) 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)



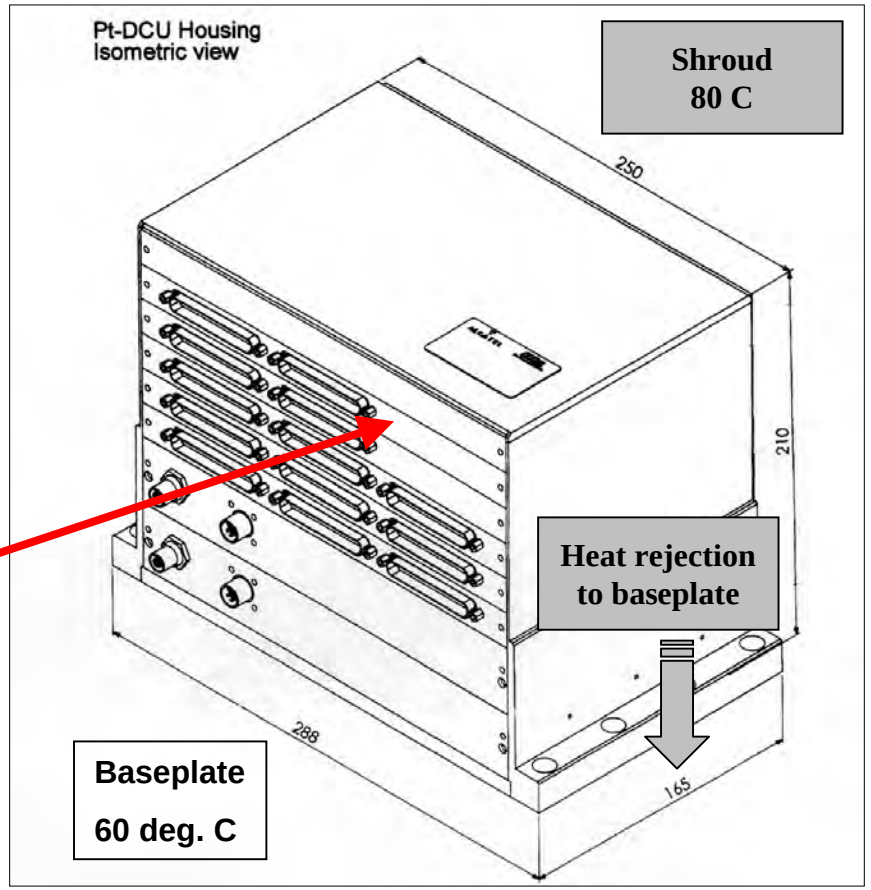

Ecosim
Compile EL file
Root
CONTROL
analog_signal
bool_signal
Clock
Cntrl_on_off (inherits from
e_off (type: real)
e_on (type: real)
s_out (analog_signal
s_set (analog_signal
s_var (analog_signal
u_off (type: real)
u_on (type: real)
Cntrl_p (inherits from Cor
Cntrl_pi (inherits from Cnt
Cntrl_pid (inherits from C
Controller
EndPosBehaviour
Enum type: CONTROL_EndPosBehaviour (18/4/99 18:31:57)
s_out (analog_signal
tdelay (type: real)
S_Derivative (inherits fro
S_Differential (inherits fr
S_Dividing (inherits from
Work Files
Hot Library
Experiments
C:\Archivos de programa\Ecosim\USER_LIBS\THERMAL\WORK\TH_CompDw
--Component Dwater: Represents a diffusive thermal node of water taking
COMPONENT Dwa
DATA
REAL
REAL
DECLS
CONST
CONST
CONST
CONST
REAL
REAL
OU
DATA
C:\Archivos de programa\Ecosim\USER_LIBS\CONTROL\WORK\CNTR_CompAn
COMPONENT Cntrl_pid IS_A Cntrl_pi
--**
--** Purpose: To provide for the representation of controllers of the
--** proportional, integral and derivative type (PID)
--**
DATA
REAL Td = 0.1 --Rate or derivative time
REAL alpha = 0.1 --Derivative filter parameter
DECLS
REAL yf --Filtered variable
CONTINUOUS
yf' = (y - yf) / (alpha * Td)
(:V) v = k * (beta * r - y - Td * yf') + vi
END COMPONENT
Compiling C:\Archivos de programa\Ecosim\USER_LIBS\CONTROL\WORK\CNTR_CompAnalog.el
Compilation OK
Output
Compile
Experiment
FLUIDPROPS
Driver default
exp1
Inicio
13:32

Main features (Schematic editor)



Examples of application: Thermal

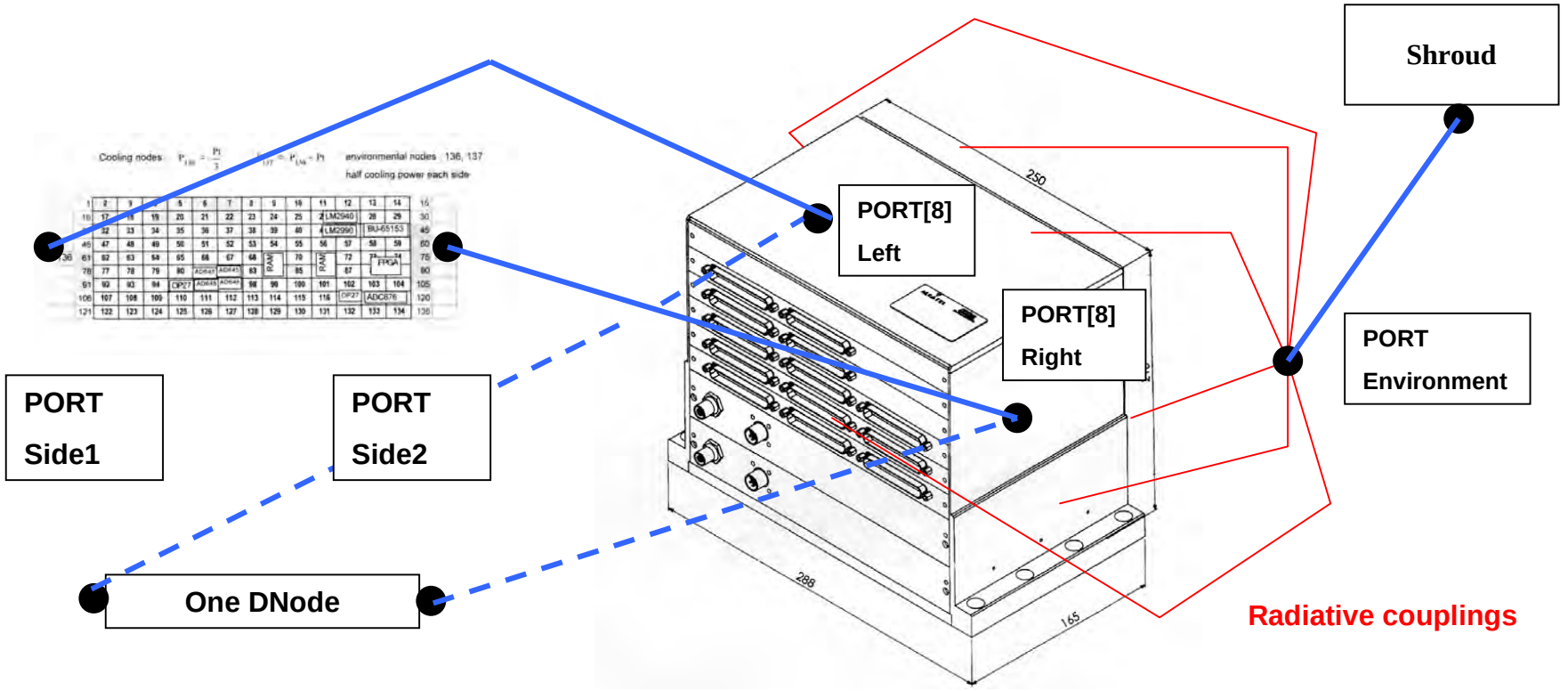
The Platinum Data Collection Unit Equipment is part of the Temperature Data Acquisition System in the LSS (ESTEC)



Requirements

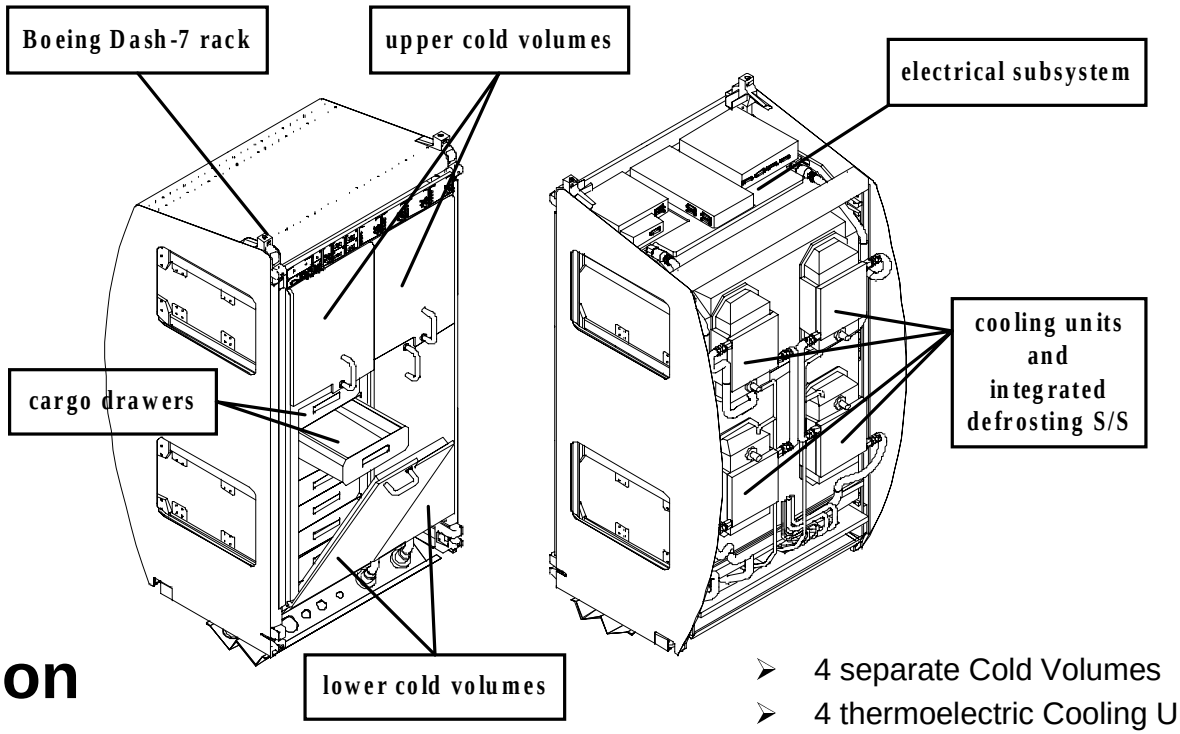
- **Verify** a Steady State HOT worst case during a review
- **Do it in "real time"!**
- Analyse and provide results to internal customer (testing)

Examples of application: Thermal



Detailed or Reduced PCB model(s) can be used

Examples of application: Thermo-Hydraulic



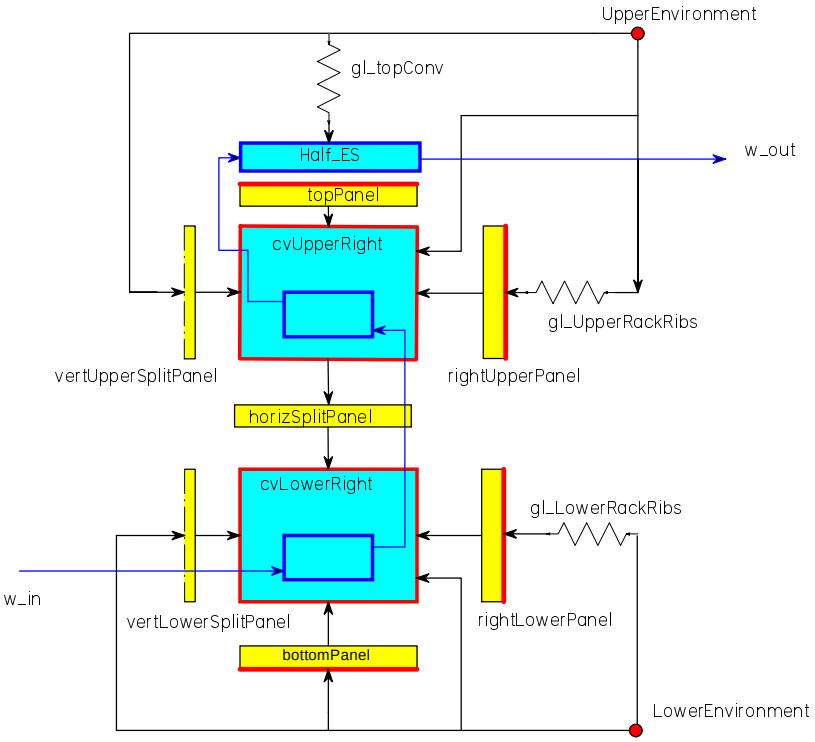
RFR description

(Fig: Astrium-GmbH)

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

Examples of application: Thermo-Hydraulic

Topology of the RFR component HalfRackRight

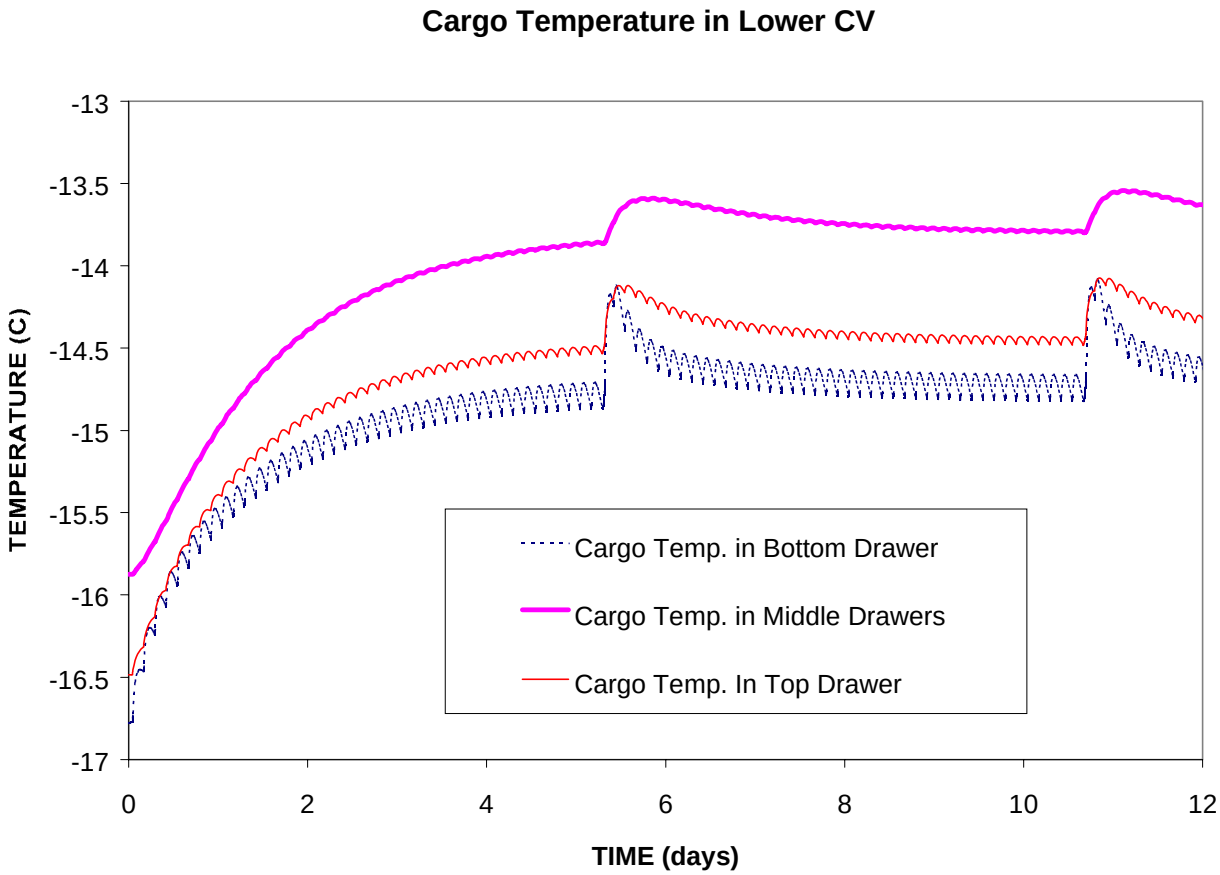


Complete RFR model:

- 2362 independent variables
- 2354 equations (179 DAE and 2175 Algebraic explicit equations)
- 8 boundary conditions.

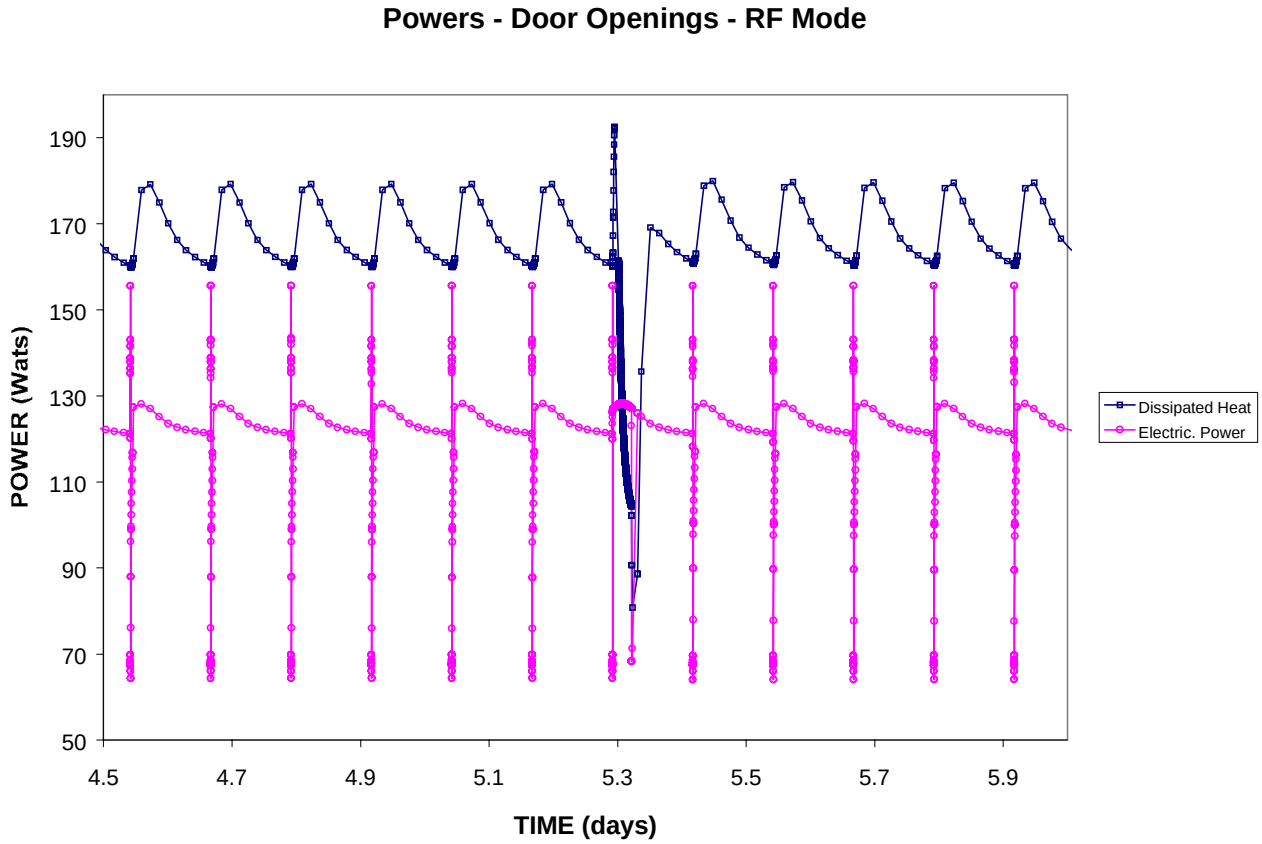
Examples of application: Thermo-Hydraulic

Door Opening scenario



Examples of application: Thermo-Hydraulic

Door Opening scenario



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** or email to Olivier.Pin@esa.int or Pedro.Cobas@ecosimpro.com