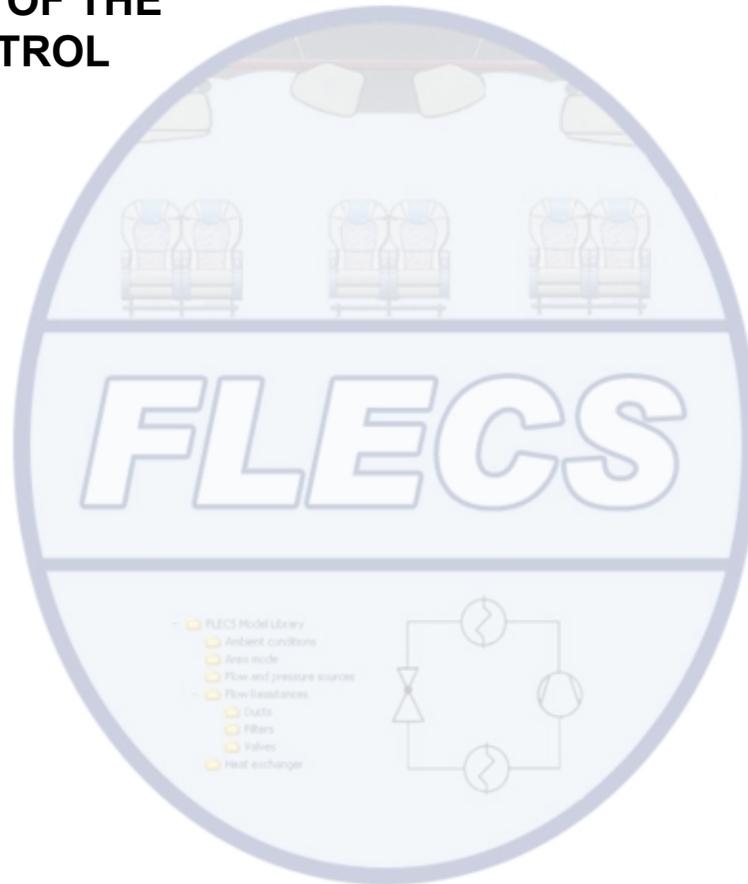


FLECS

FUNCTIONAL LIBRARY OF THE ENVIRONMENTAL CONTROL SYSTEM

A SIMULATION TOOL FOR THE SUPPORT OF INDUSTRIAL PROCESSES



Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences



Christian Müller

Hamburg University of Applied Sciences

FLECS Projekt

Partner:



Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences



Sponsor:

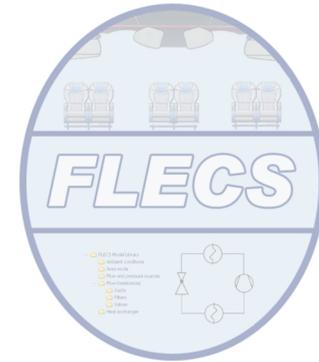
**Bremer Investitions- Gesellschaft
mbH**



**Behörde für Wirtschaft und Arbeit
Hamburg**



Freie und Hansestadt Hamburg
Behörde für Wirtschaft und Arbeit



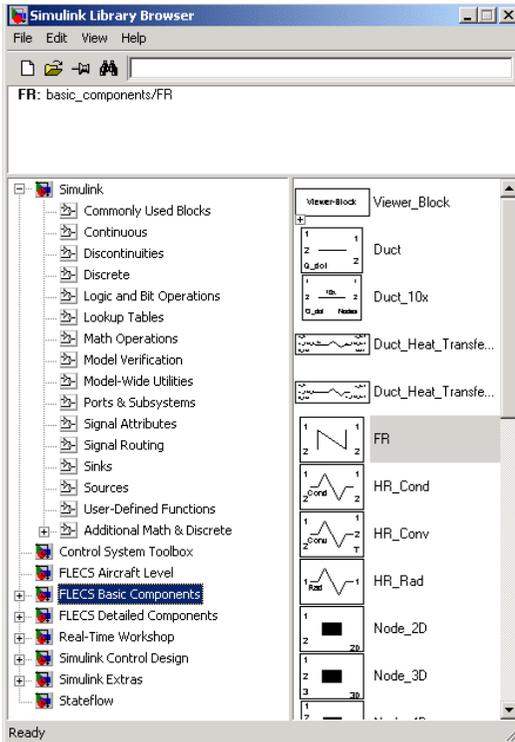
FLECS Database: Functional Simulation of the Environmental Control System and the Cabin



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MATLAB/Simulink

- C-Code Generation
- Real-Time Capability
- Hardware in the Loop Testing

Modular Approach

- Different System Architectures
- Different Detail Level

Graphical User Interface

- Parameter Input Masks
- Main GUI
 - Cockpit GUI, Display GUI
 - Interactive Mode, Batch Mode

- Dynamics of the Complex Systems
- Interactions between the Components

Functional Library

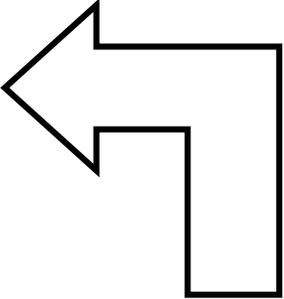
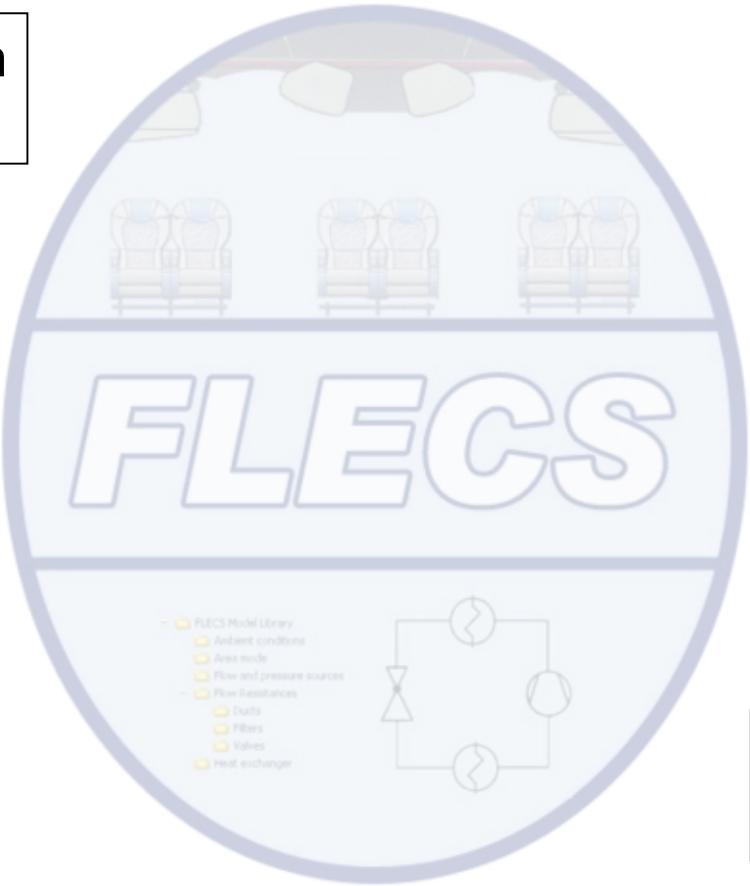
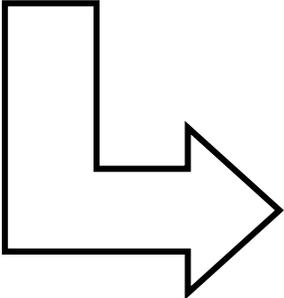


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Generic Simulation Models

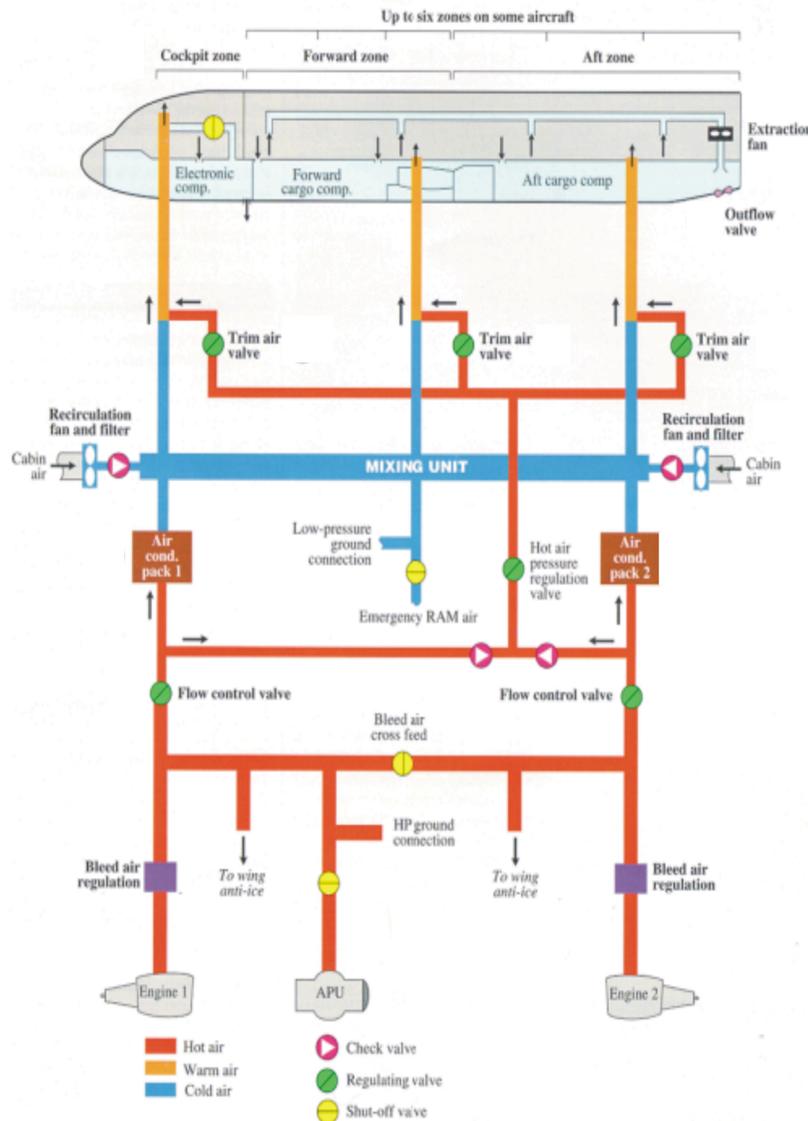


MATLAB/Simulink Software Platform

Enviromental Control System (ECS)



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Component

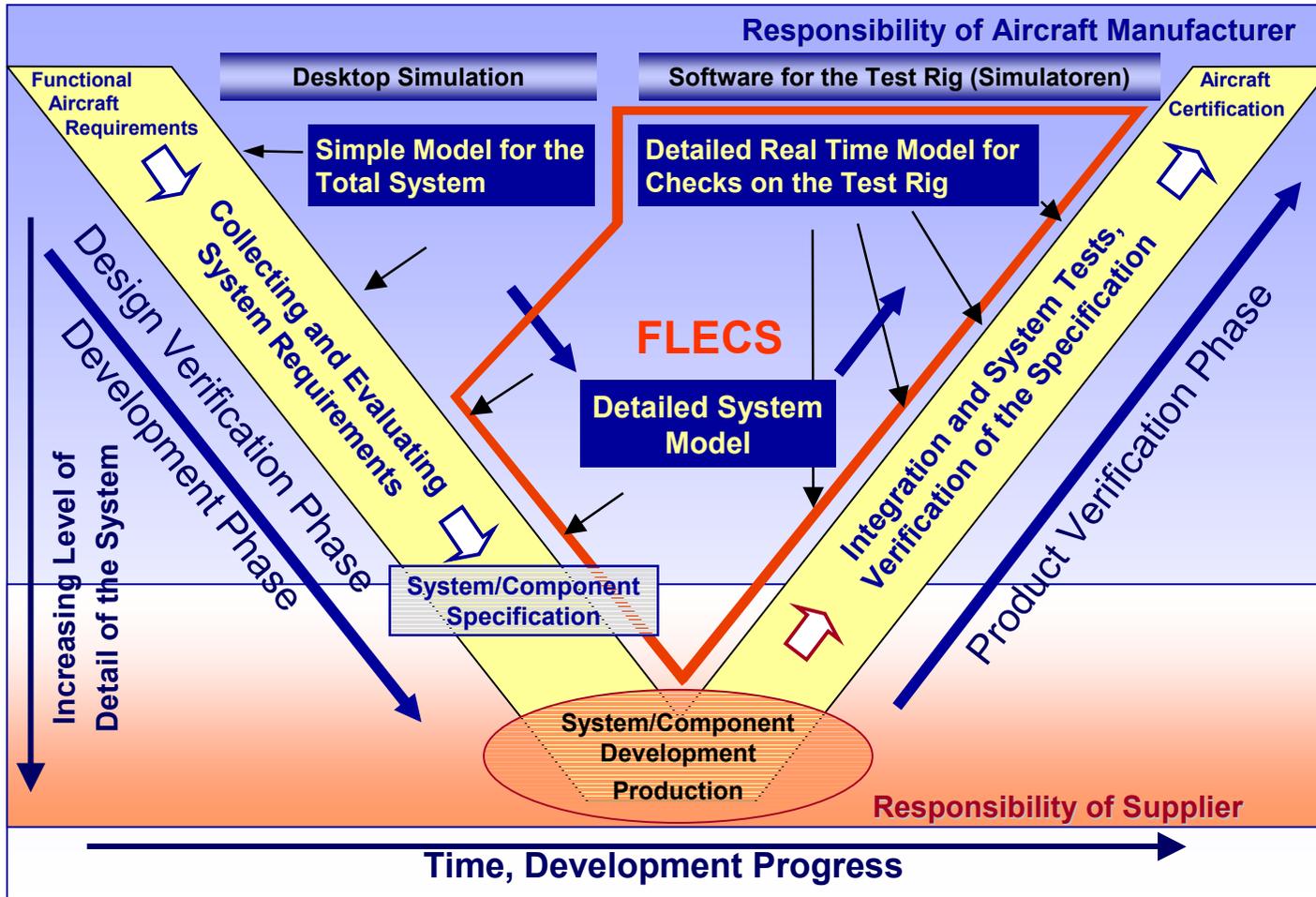
Classes:

- Ambient Conditions
- Aircraft Boundaries
- Flow Resistances
- Flow and Pressure Sources
- Volumes
- Area models
- Mixing Unit
- Heat Exchangers
- Air Cycle Machine and Air Compressor
- Ram Flow
- Vapor Cycle Systems
- Sensors
- Controls

Implementation of FLECS in the Industrial Process of Environmental Control System Development



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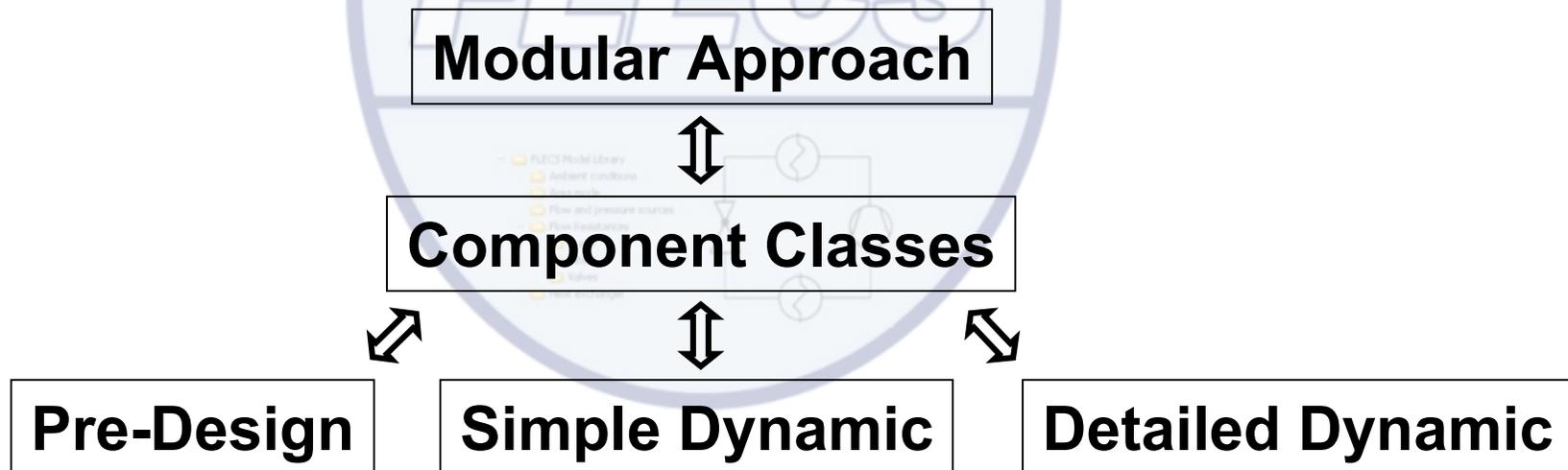
Implementation of FLECS in the Industrial Process of Environmental Control System Development



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- Support all Phases in the Design and Development Processes
- Investigation of a large Number of System Architectures
⇒ Optimum Architecture



Implementation of FLECS in the Industrial Process of Environmental Control System Development

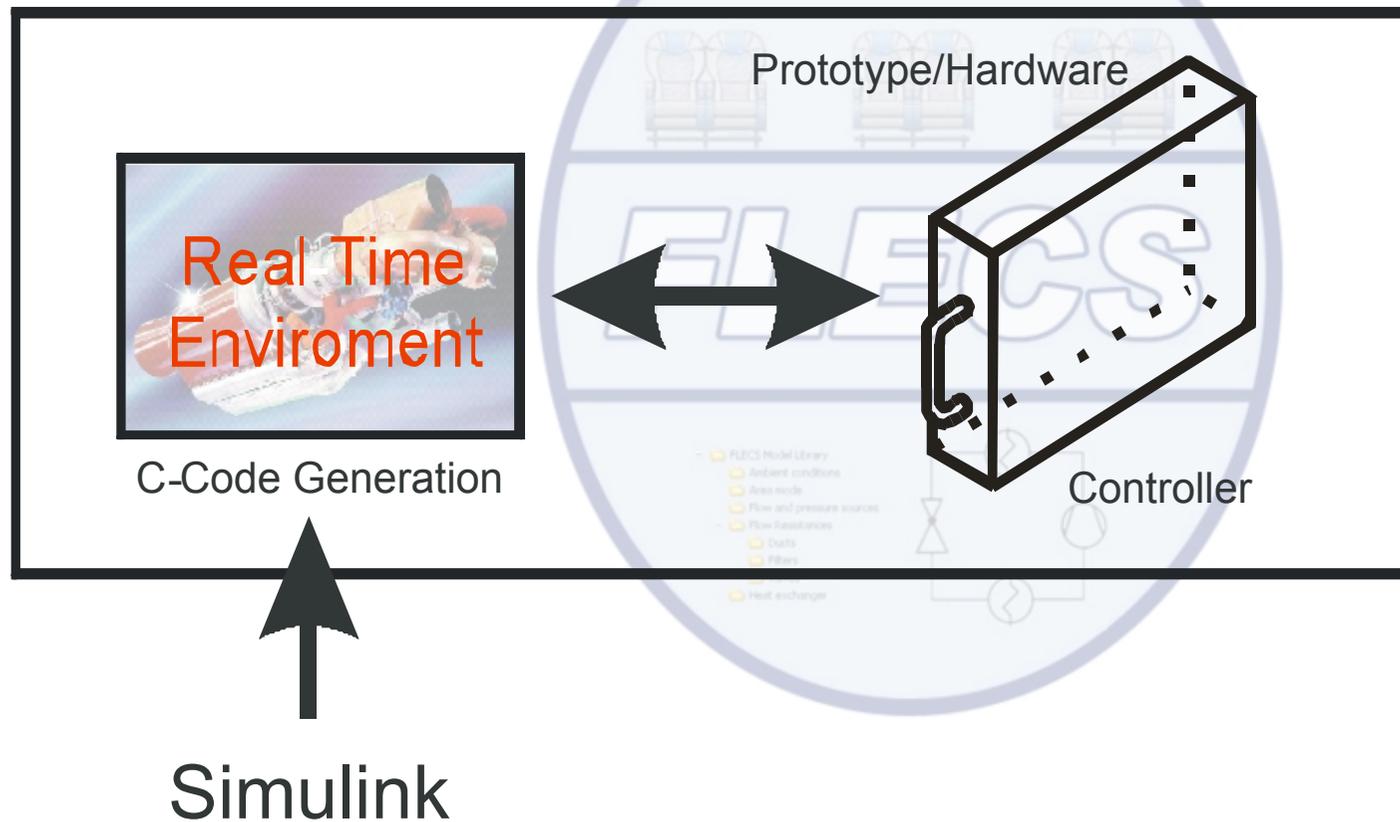


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Hardware in the Loop



Implementation of FLECS in the Industrial Process of Environmental Control System Development



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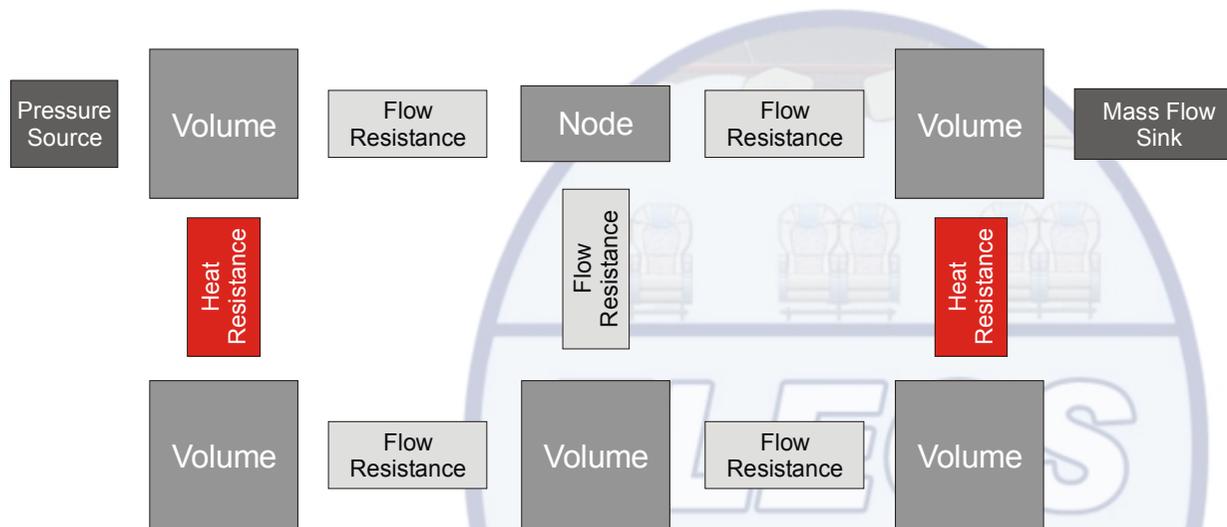
- Interactive Mode ⇔ Design Verification
- Batch Mode ⇔ Regression Testing
- Simulation Performance
 - Different Integration Step Size
 - Stability for Fix Step and Variable Step Solver
 - Appropriate Solver and Time Steps

⇒ **Software in the Loop Testing**

Modeling Approach and Implementation in MATLAB/Simulink : Network Topology



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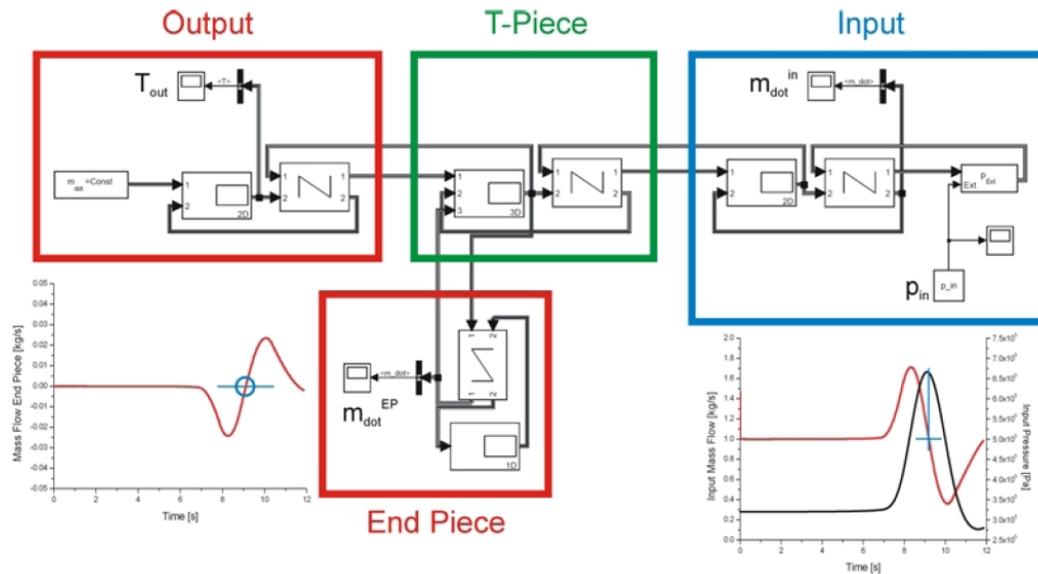
- Different System Sizes
- Different Time Evolutions
- Different Types of State Equations
- Crosslinked Setup of Heat Transfer and Air Flow
- Low and High Dynamic Simulation



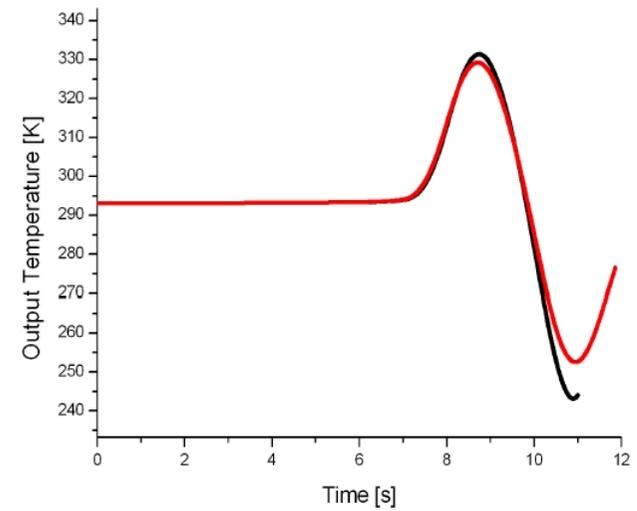
Highly Dynamic Simulation



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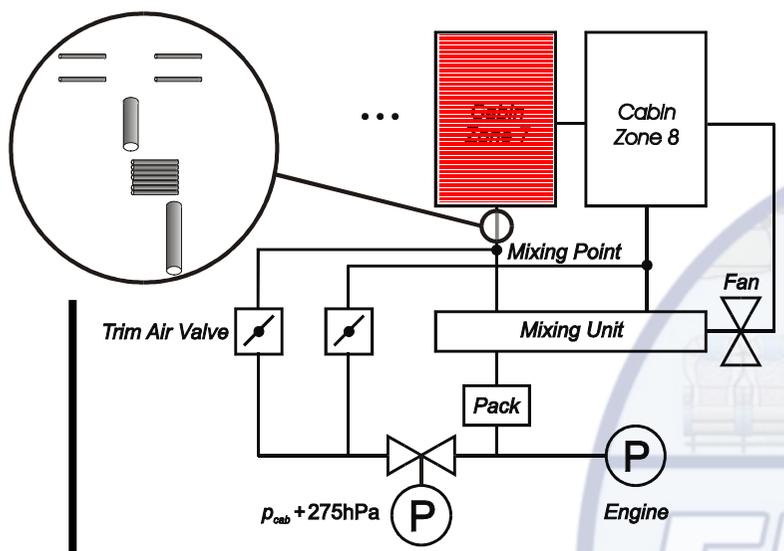


Stability





Validation



Validation

Measurement

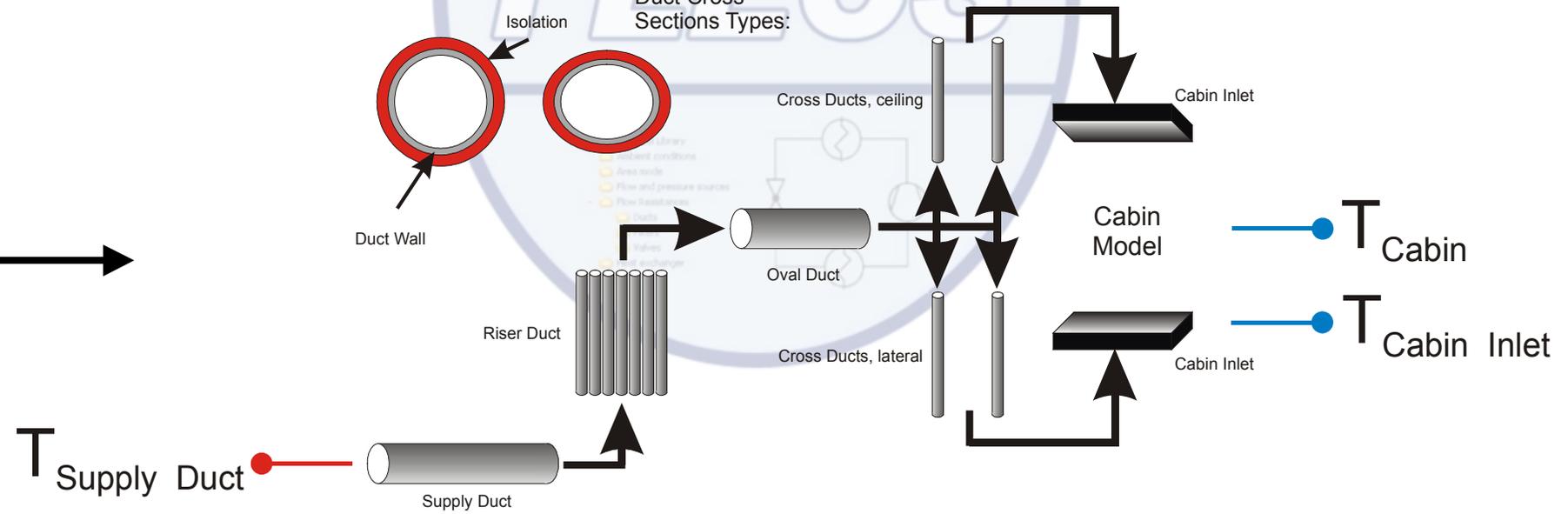
↔ Simulation

→ Algorithm

→ Discretization

Stability, Real-Time

Duct Cross Sections Types:



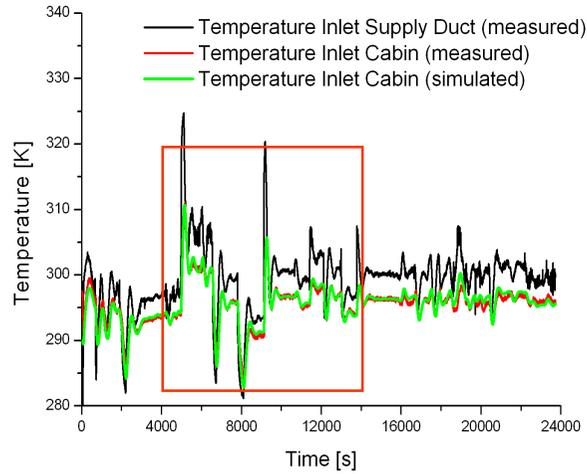
Results of the Validation



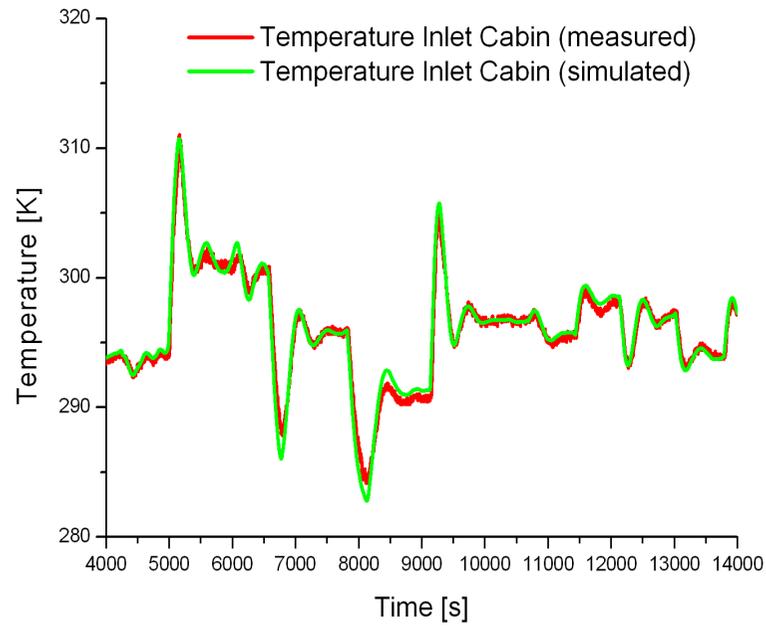
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Good Agreement

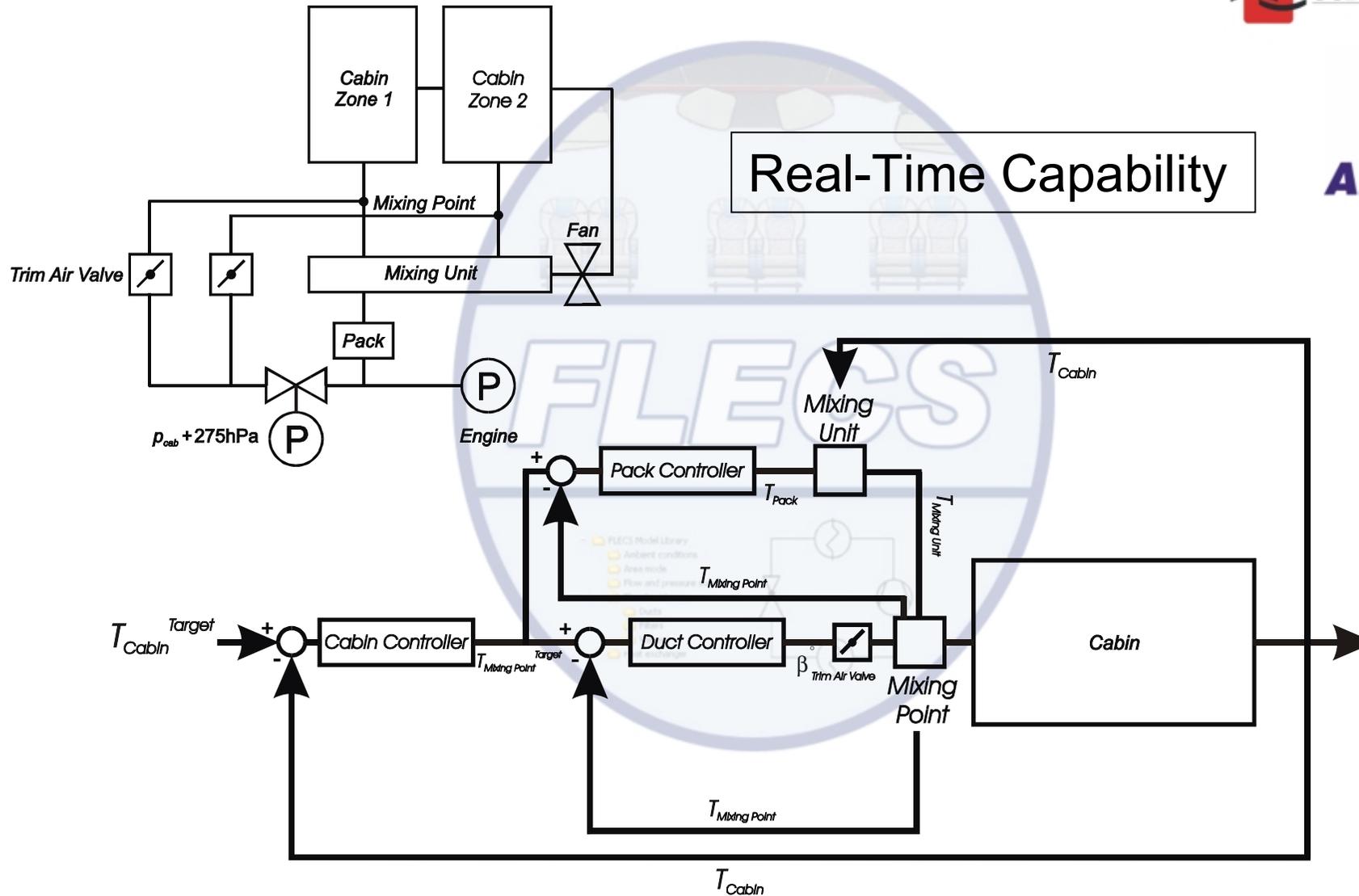


Control Aspects



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Real-Time Capability



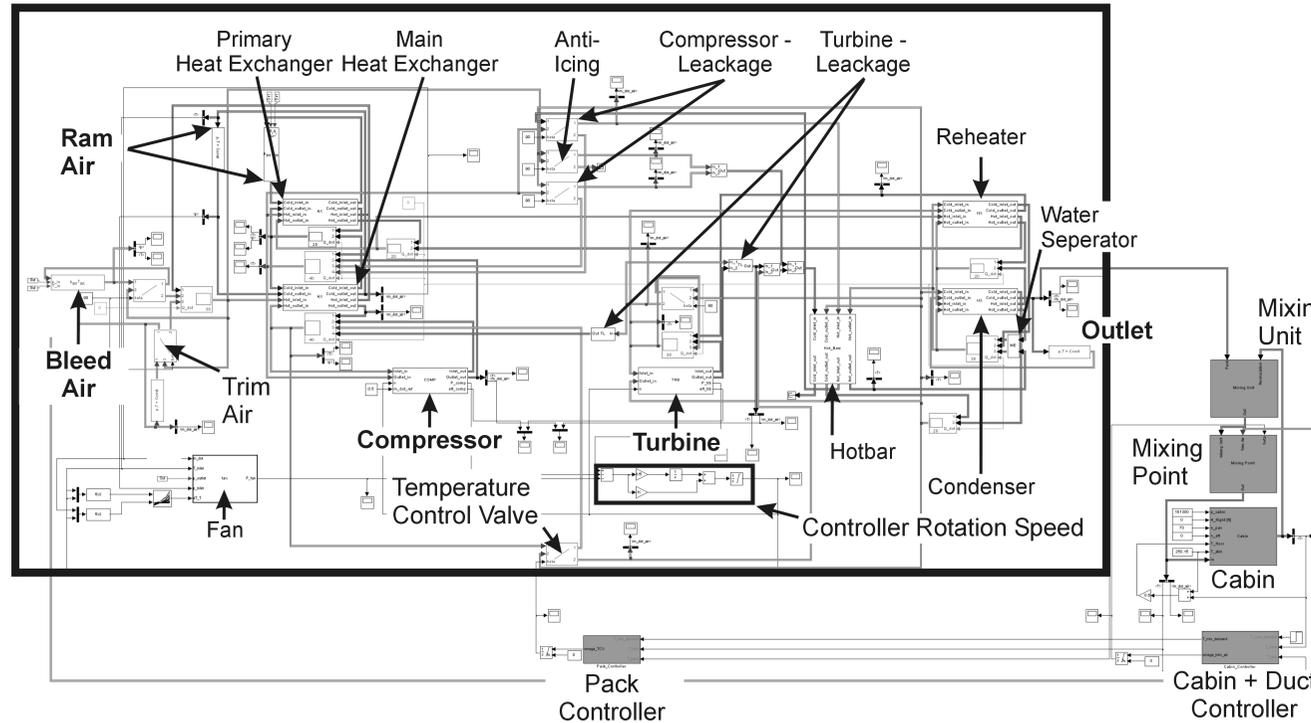
Dynamic Simulation of Complex Systems : Aircraft Pack



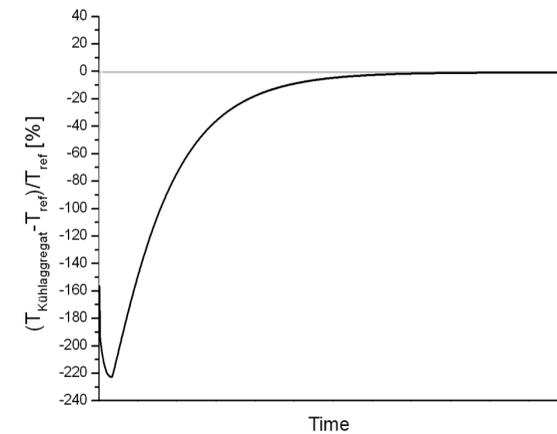
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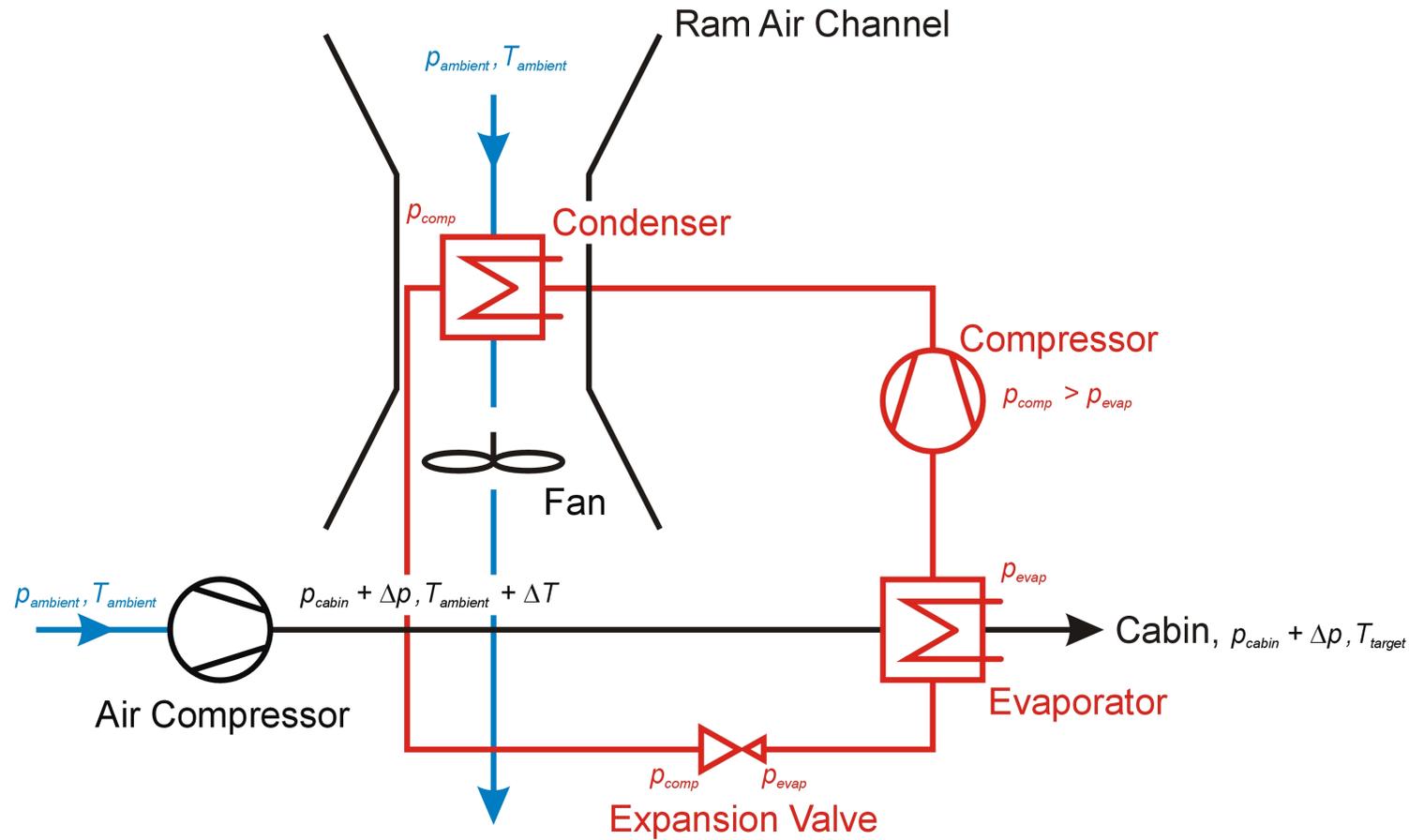
Real-Time Capability



Vapor Cycle System



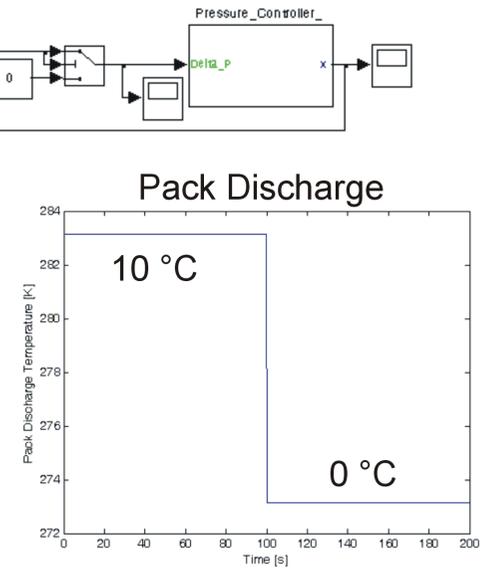
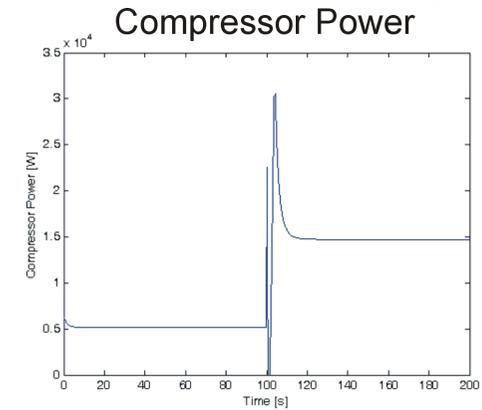
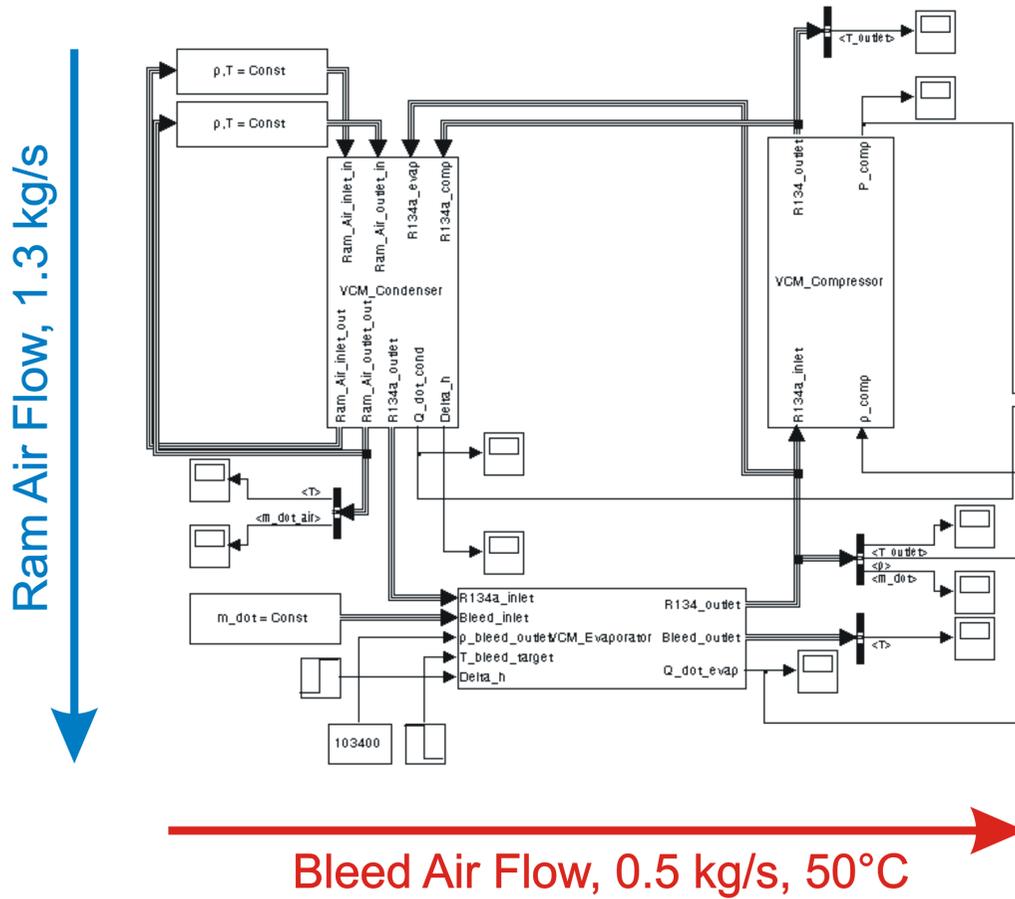
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Vapor Cycle System



ISA Standard Day



Summary



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- **FLECS :**
 - Database for the Enviromental Control System
 - Dynamic Simulation
 - Different System Architectures
 - Different Detail Level
 - Real-Time Capability
 - C-Code Generation
 - Hardware in the Loop Testing
 - Software in the Loop Testing
- **The FLECS Components are validated**
- **Stable Simulation of a High Dynamical Test Cases**
- **Design of Complex Control Systems**
- **Dynamic Simulation of Complex Systems : Aircraft Pack**
- **Future Concepts: Vapor Cycle System**