ENVIRONMENTAL CONTROL LIBRARY

Overview

Modelon

AGENDA

- ❑ About Environmental Control Library
- ❑ Key Benefits
- ❑ Key Capabilities
- ❑ Key Applications
- ❑ Library Contents
- ❑ Modelon Compatibility
- ❑ Latest Release: 2021.1

ABOUT ENVIRONMENTAL CONTROL LIBRARY

- A Modelica model library for aircraft environmental control systems analysis and design
- Designed to study energy consumption and thermal conditions that affect the level of comfort for passengers and crew
- Performance aspects driven by large variations in ambient conditions (humidity, temperature)
- ECL models account for important effects through first principles and fully support bidirectional flow.
- Developed internally at Modelon since a number of years together with a European airframe company
- ECL is a package hardened through industrial program deployment

KEY BENEFITS

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- Flexible composition of user-defined system architectures for efficient model management
- Real-time capable high performance models, enabling Hardware-In-the-Loop (HIL) applications
- Full support for bidirectional flow for analysis of all modes of operation on ground and in flight
- Efficient representation of moist air, enabling robust and fast simulation of large-scale systems
- Online visualization of simulation results for intuitive understanding of the system behaviour
- Configurable model fidelity for faster simulation and right complexity level
- Easy integration with other libraries

Modelon

KEY CAPABILITES

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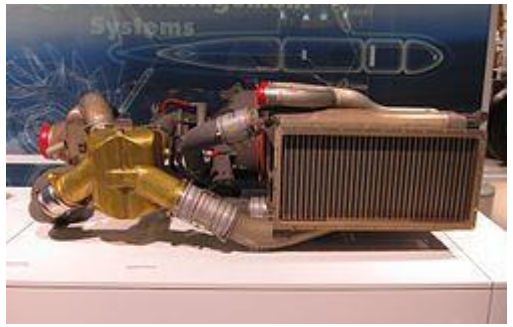
- Air cycle refrigeration systems that can be modeled
  - Two wheel bootstrap system
  - Three wheel bootstrap system
  - Reversed bootstrap system
  - Ram powered reverse bootstrap
- Vapor cycle refrigeration systems
- Liquid cooled systems



C919, air cycle machine
Source: Wikipedia

KEY APPLICATIONS

KEY APPLICATIONS

- Offline simulation of complete ECL-system through complete flight envelope and all operating conditions
  - Large systems
  - Includes controls, sequential and feedback

- Real time simulation of the same system models
  - Some simplifications, but the same overall model (real time capability achieved through model configuration selection)
  - To be included in the special flight simulator hardware

- Cabin and ram air modeling

EXAMPLE: RAM AIR COOLING SYSTEM

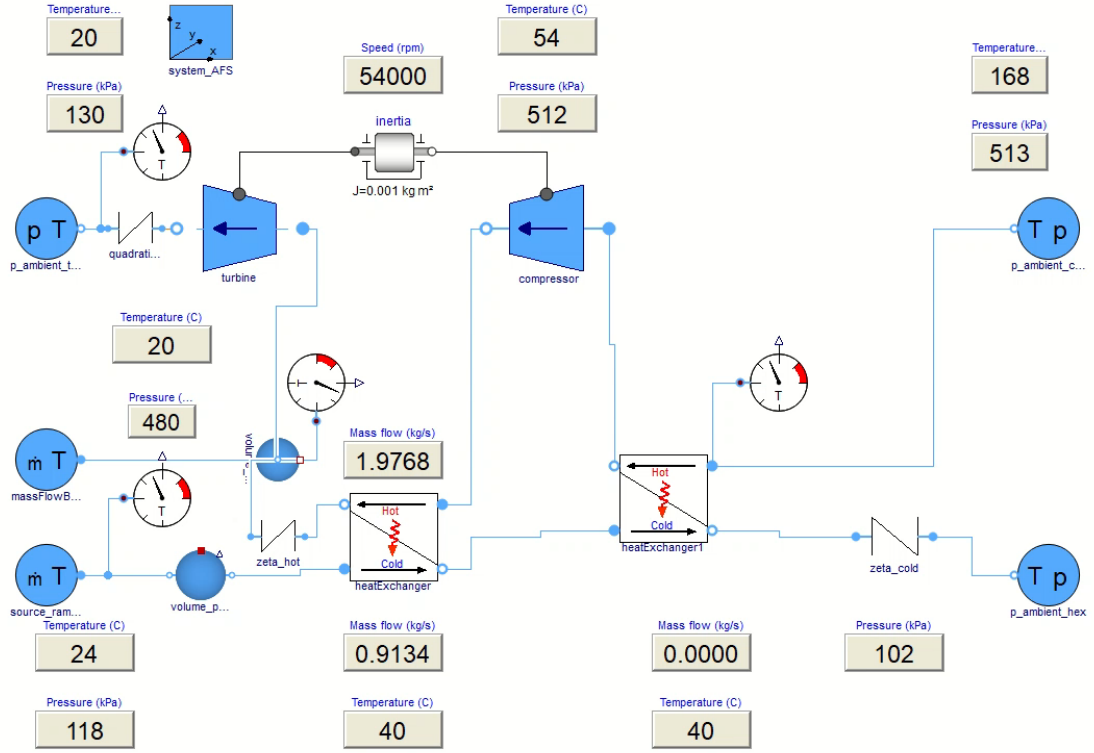
Quasi-steady-state components:

- System
- Turbines
- Compressors
- Heat exchangers
- Flow resistances
- Sinks/sources

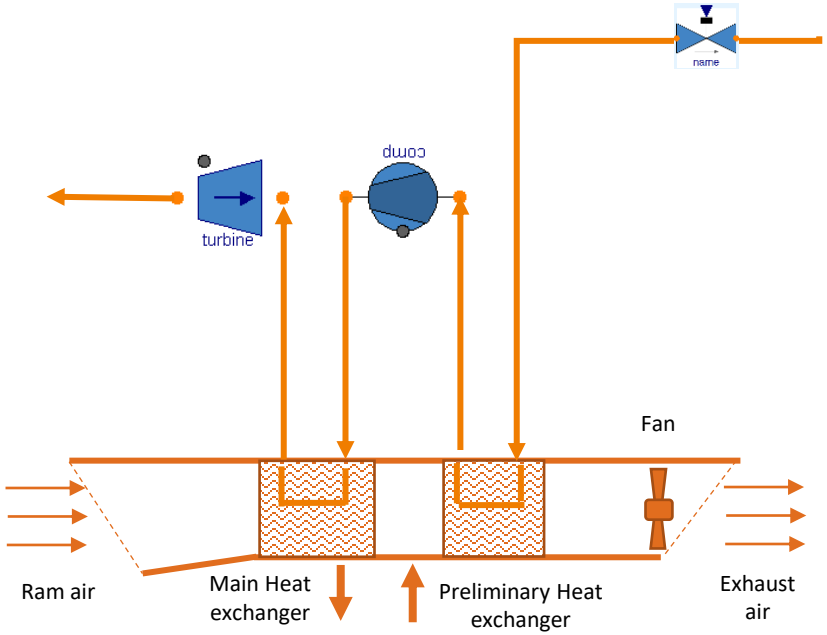
Mass and energy storage:

- Dynamic volumes (incl. E.g. moisture condensation)

Ram Air



A RAM AIR COOLING SYSTEM



- A system architecture like the above can be easily built using ECL

LIBRARY CONTENTS

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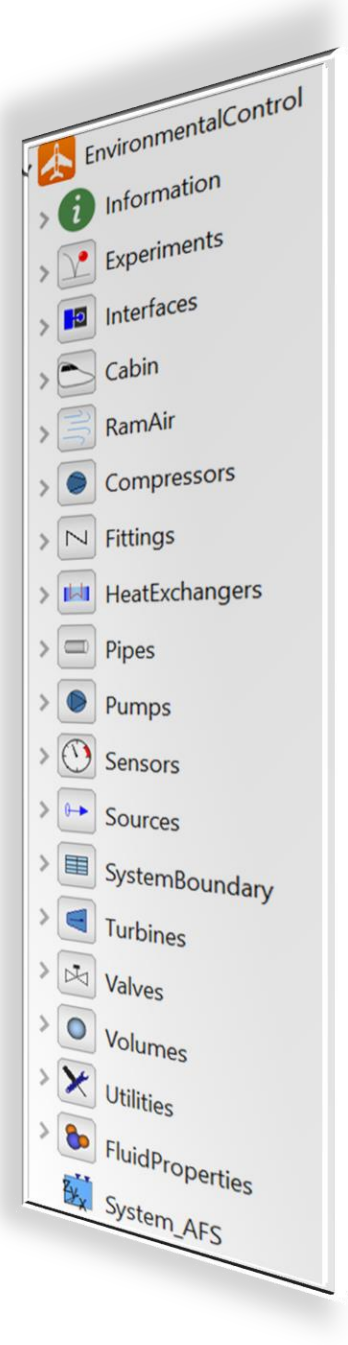
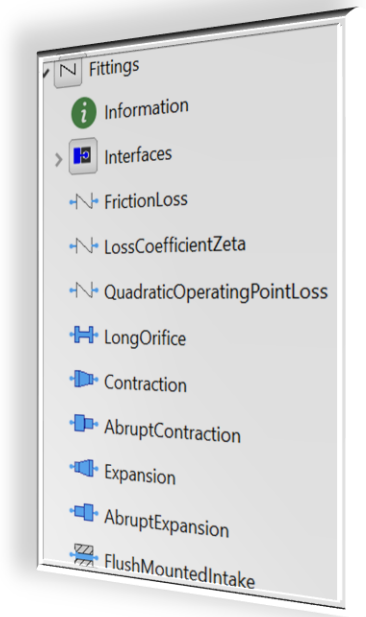
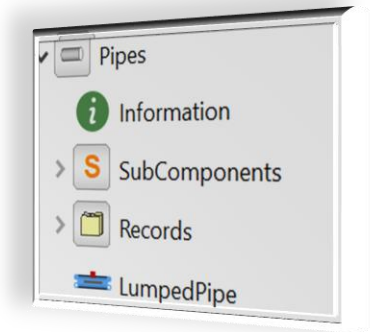
- An efficient and numerically robust framework suitable for large-scale complex systems.
- The library includes:
  - Heat exchangers
  - Compressors
  - Turbines
  - Pumps
  - Volumes
  - Valves
  - Cabin
  - Ram air
  - Pipes
  - Fittings

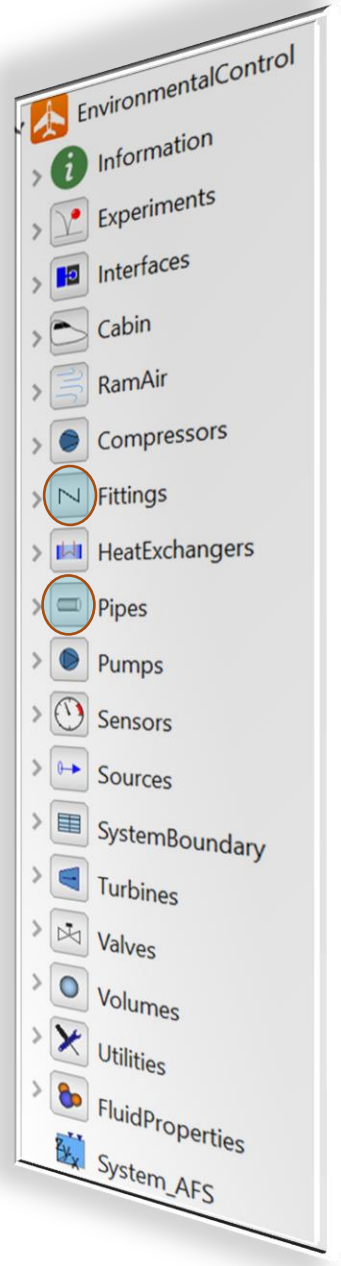


PIPES AND FITTINGS

- Pipe model that lets you choose between purely static mass and energy balances and one with (optional) dynamic volume included
- Heat transfer: external only exposes volume temperature to port, internal resistance defined by constant coefficient
- Fittings contain flow resistance models based on flow characteristic functions that can determine flow from either pressure drop or mass flow rate.

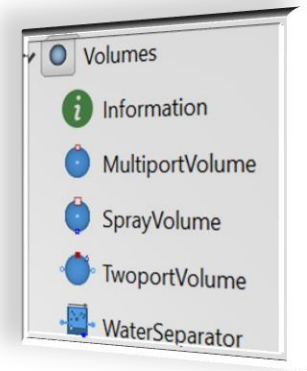


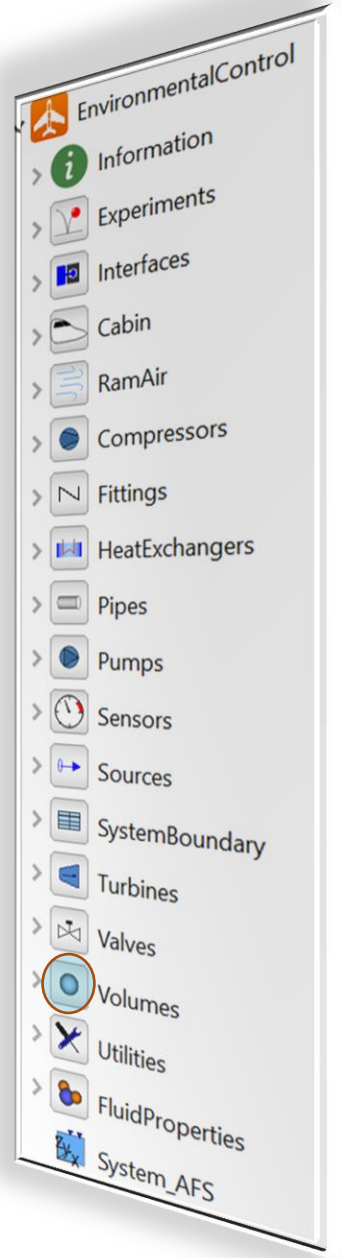




VOLUMES

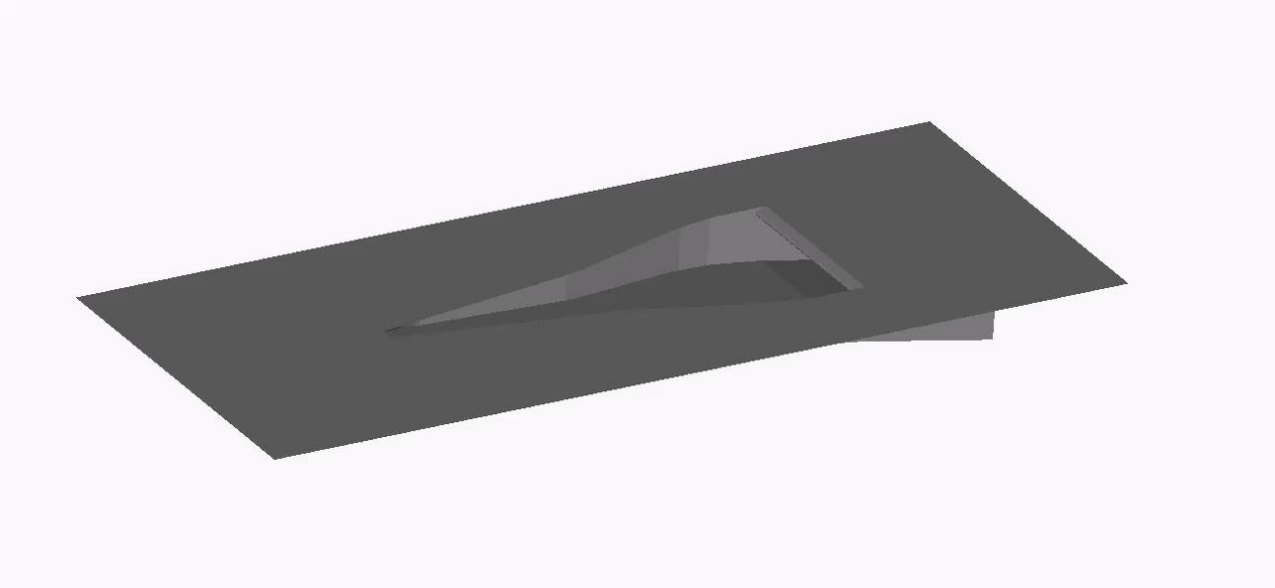
- Dynamic energy and mass balances
- Volume without hydraulic resistance
- Spray volume with additional water spray inlet
- Static water separator model

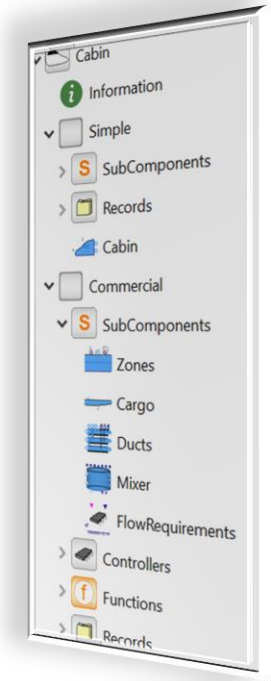


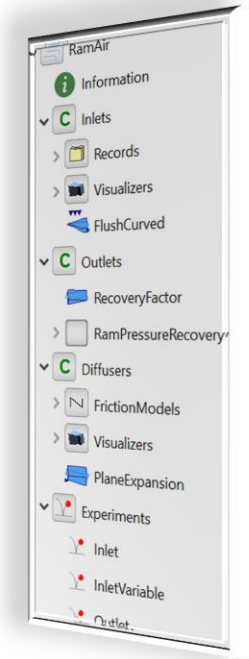


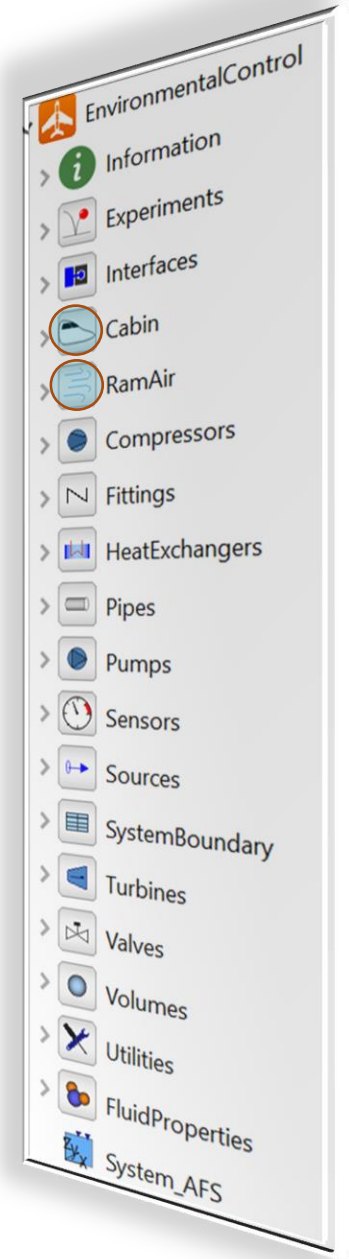
CABIN AND RAM AIR

- Models for aircraft cabins with lumped pressure and temperature.
- Models for ram air channel components.



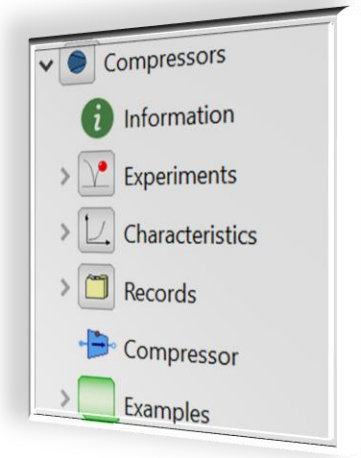


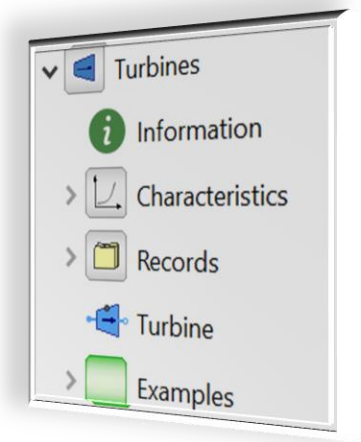


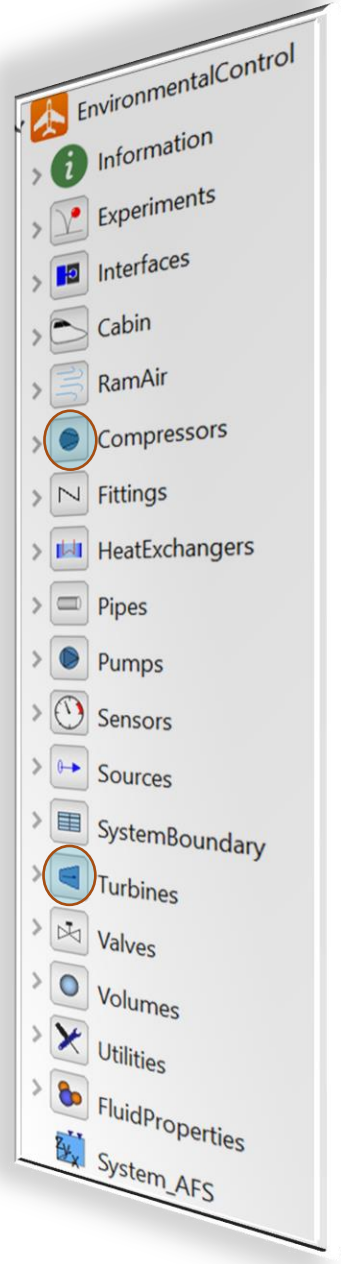


TURBINE AND COMPRESSOR

- Table based components
- Characteristic maps to be provided as tables
- Draft physical components based on Hans' ideas.

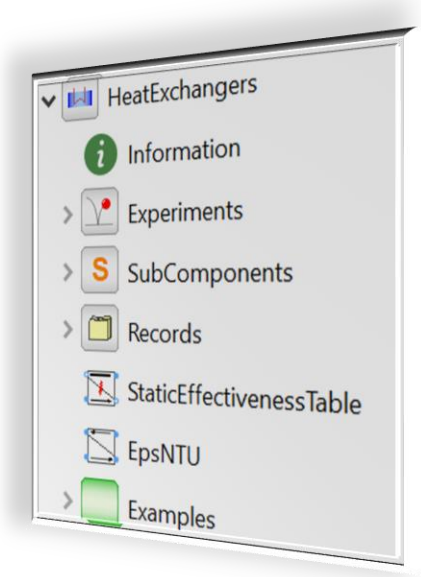


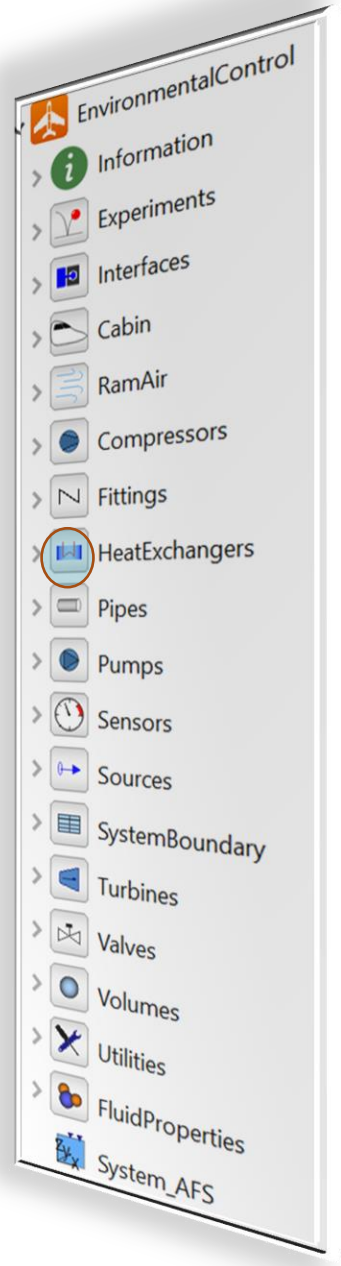




HEAT EXCHANGERS

- Table based component with water condensation
- Basic EpsNTU-version (dry conditions only)

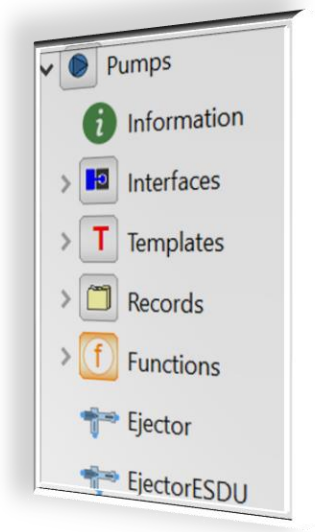


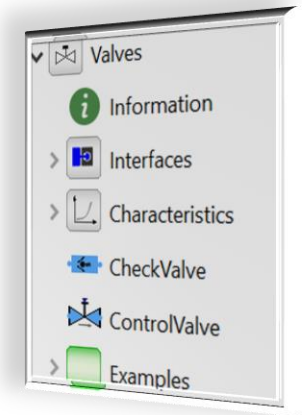


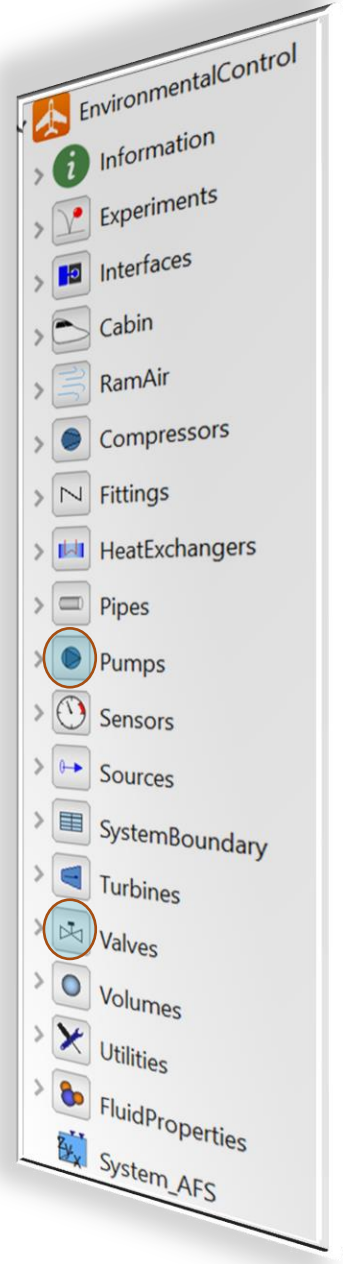
PUMPS AND VALVES

- Ejector with three ports
  - Motive flow inlet port
  - Suction port
  - Discharge port
- Ejector ESDU

- Check valve
- Control valve (Kv-value parameterization)



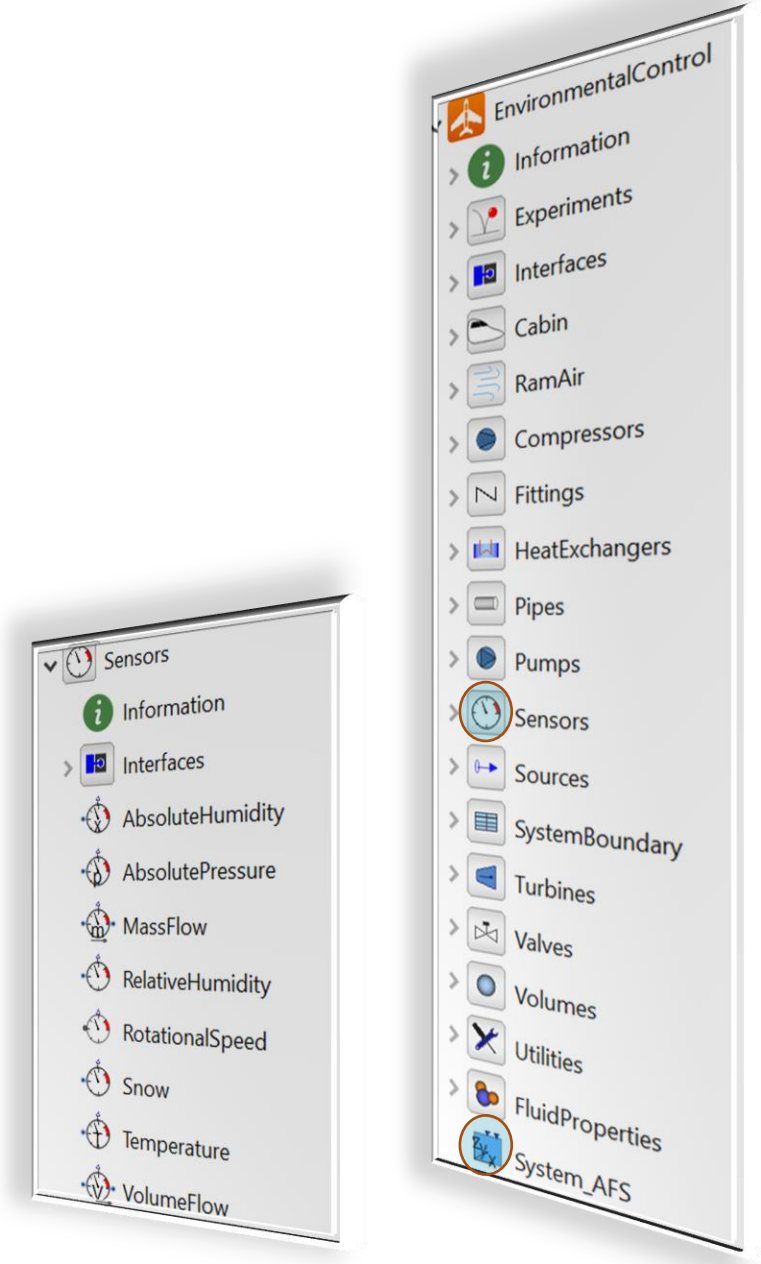




SENSORS AND FLUIDS

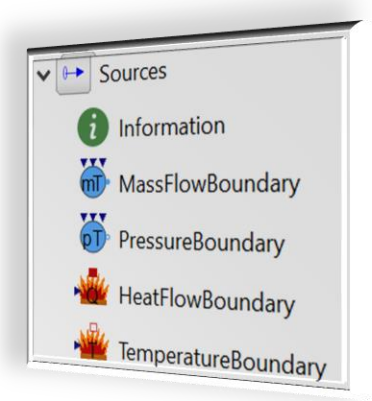
- Single port sensors: p, T
- Two port flow sensors: m_flow, V_flow

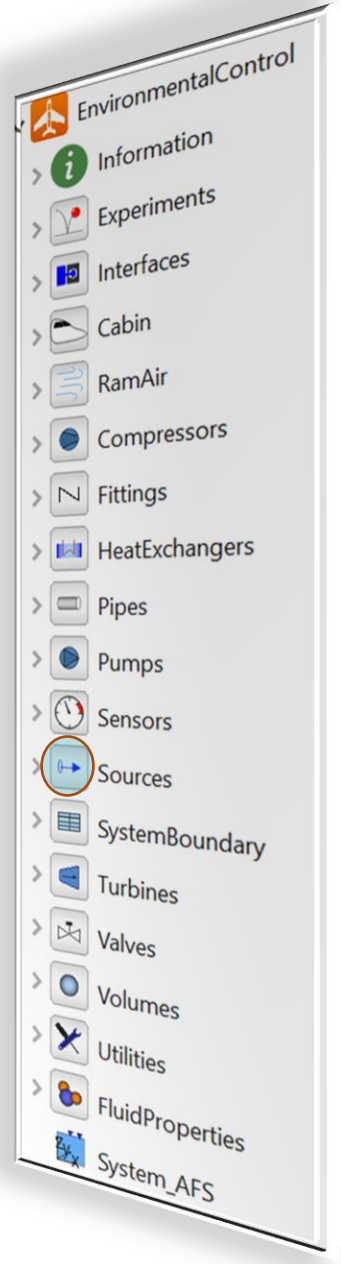
- System settings and boundary conditions
  - System settings (altitude, Mach number, etc.)



BOUNDARY CONDITIONS

- Pressure source/sink,
- Mass flow source/sink
- Options: set parameters, signal inputs, use atmosphere information from system component

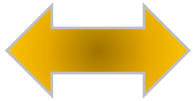




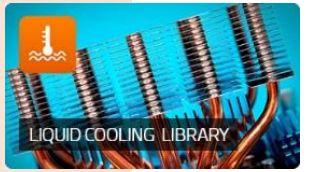
MODELON COMPATIBILITY

RECOMMENDED MODELON LIBRARY COMPATIBILITY

- Air cycle refrigeration systems
  - Turbofan system
  - Bootstrap system
  - Reversed bootstrap system
  - Ram powered reverse bootstrap
- Vapor cycle refrigeration systems
- Liquid cooled systems



- Environmental Control Library
  - moist air
  - turbines
  - fans
  - compressors
  - ejector
- Fuel System Library
  - acceleration forces
  - positioning in 3D space
  - air/fuel mixed and unmixed
- Vapor Cycle Library
- Liquid Cooling Library
- Heat Exchanger Library



LATEST RELEASE

RELEASE: 2021.2

New Features

- The pressureRecovery parameter is now a replaceable model in RecoveryFactor. This allows the possibility to redeclare a custom model to compute the pressure recovery factor

Enhancements

- Removed not in use parameters from system_AFS component
- Some icon rendering issues have been fixed