EcosimPro

Modelling and Simulation Software

ECLSS LIBRARY

The ECLSS library provides a set of components for designing and analysing the most typical equipment and processes of Environmental Control and Life Support Systems in manned spacecrafts.

EcosimPro

EcosimPro is a powerful **modelling** and **simulation** tool with a simple interface that makes the design of **multidisciplinary** dynamic systems easy and intuitive using graphic diagrams.

For users with specific needs, EcosimPro provides an object-oriented non-causal approach towards creating reusable component libraries and is based on very powerful symbolic and numerical methods capable of processing **complex systems** represented by differential-algebraic equations (DAE) or ordinary-differential equations (ODE) and discrete events. However, low-level problems such as programming calls with numerical solvers, equation handling, etc, are solved automatically or using simple wizards.

Features

ECLSS is an EcosimPro professional library which provides a set of components to simulate the most typical process units, equipment and processes of the Environmental Control and Life Support Systems (ECLSS), such as cabins, crews, heat exchangers, pipes, pumps, reactors, electrolysers, etc.

EcosimPro is the standard tool of the **European Space Agency (ESA)**, used to support ECLSS analyses.

ECLSS modelling involves multi-disciplinary simulation, since ECLS operations consider a very wide range of different phenomena such as fluid flow, chemical reactions, electrochemical reactions, heat transfer and biological processes.This library is mainly adapted to the thermo-hydraulic analysis of air cabin loops of conventional ECLSS, but special case fluid flow problems like venting lines or pressure regulators can also be analysed.

The ECLSS library enables you to simulate heat transfer, chemical reactions and mass/energy balances, and to analyse system pressure drops based on user-specified operating conditions.

Models built with the library components assume that mass flow and heat flow is 1-dimensional. The intensive variables like pressure, temperature or compositions, are assumed average values in the control volumes or nodes considered (lumped modelling). The majority of components are able to evaluate reverse flow. Moreover, one or more types of fluids can be considered in the system, depending on the fluid loops in the ECLSS.

The library includes thermodynamic functions to calculate the properties of the following two types of working fluids:

- Perfect gas mixtures with or without water, where water can condense in solid or liquid phase and whose pressure must be in the region of atmospheric pressure or lower
- Real fluids like pure gases, water and pure liquid refrigerants

The intuitive EcosimPro graphical tool offers user friendly drag-and drop methodology and input data editors that help to build the flow sheet for the ECLSS model and specify the input data and parameters.

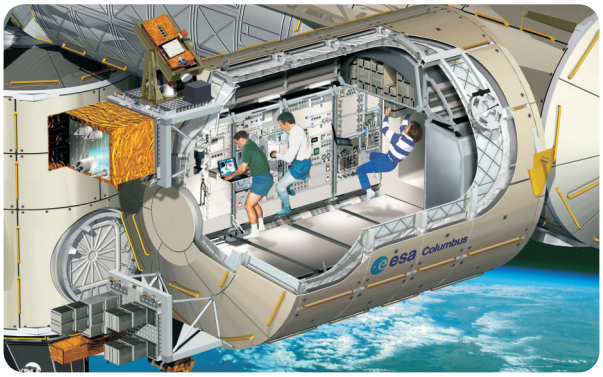
EcosimPro enables the user to easily develop new components or modify existing components in order to provide the ECLSS components with the required level of fidelity. This can be done graphically through a simple, user friendly interface, or through **EcosimPro's object-oriented** language which makes it possible to re-use existing codes.

The library has been designed so that the **process control system** can be included using the standard CONTROL library and so that the system's **thermal control system** (TCS) can be included using the standard THERMAL library. These two libraries are provided with EcosimPro.

The ECLSS library enables you to carry out **trade studies** and **preliminary designs** of ECLS systems, and to determine the component, subsystem and **system off-design performance**. Furthermore, it enables you to perform long duration transient analyses with reasonable CPU time consumption.

The components

The library includes ECLSS components to build the system simulation model; for example:



- **Cabin:** It represents a standard air volume or cabin. It takes into account the phenomena of deposition of the condensed liquid water and ice and the evaporation of the water film on the cabin wall. The cabin model is usually connected to submodels representing parts of the Air Management subsystem or to other cabins using hatches, and it can be connected to the thermal control system submodel and to the crew componentt
- **Crew:** It represents crew members, and some of the phenomena that have been taken into account in the formulation of this component type are: metabolic activity, breathing, evaporative and sensible heat losses from skin, skin blood flow, predictions of thermal comfort and thermal sensation...
- **Fittings:** There are some friction components to take into account pressure losses in the system such as: Expanders, Reducers, Grids, Wyes, Tees, Orifices, MitreBend, etc
- **Pipes:** There are several models of pipes with different levels of complexity to take into account thermal delay, bends, or molecular flow in venting lines
- **Valves:** The library includes several valve models to represent check valves, pressure regulator valves, liquid and gas valves...
- **Boundary conditions:** The library contains a set of components to specify the system boundary conditions; eg, temperature, composition of the working fluid, pressure, mass flow...
- **Sensors:** The library includes a set of sensors which can be used to implement ECLSS control loops
- **Other components:** The library also contains models of equipment normally found in ECLS systems, such as **pumps, fans, tanks, filters,** and models of more specific ECLS equipment, such as **chemical reactors, fuel cell stack, electrolyser, membrane, LiOH cartridges...**

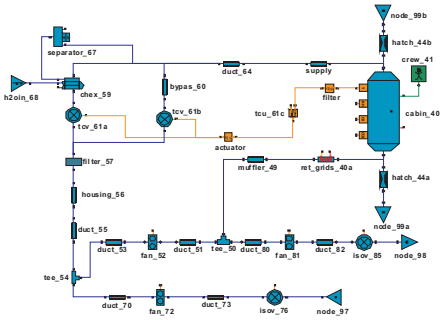
Example

The APM is one of the major elements of the Columbus Orbital Facility (COF) programme, which represents the European contribution to the International Space Station (ISS). The APM is designed for multidisciplinary payload missions which include the microgravity, life science, earth observation, space science and technology disciplines.

The APM Environmental Control and Life Support Subsystem provides a pressurised environment during module transportation to orbit and for on-orbit operation when docked to the Space Station with related crew operations. The APM cabin loop is part of the ECLSS, and it provides the following main functions:

1. Collection of heat loads from crew and radiative and convective heat loads from surrounding surfaces. Transfer of loads to the Thermal Control Subsystem (TCS) via the cabin air loop condensing heat exchanger (CHX)
2. Collection of humidity produced by the crew and potential water leakage to the cabin from the CHX
3. Ventilation of the habitable area with revitalisation being achieved via intermodule ventilation (IMV)

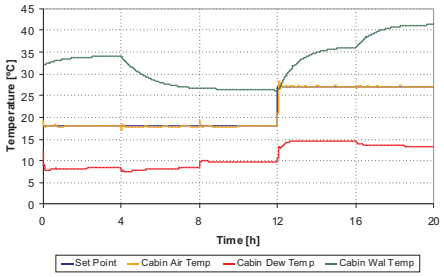
The APM cabin loop was modelled using EcosimPro's professional ECLSS library, and the final model is shown in the figure. The APM loop provides Temperature and Humidity Control.



The following were the objectives of the model simulations:

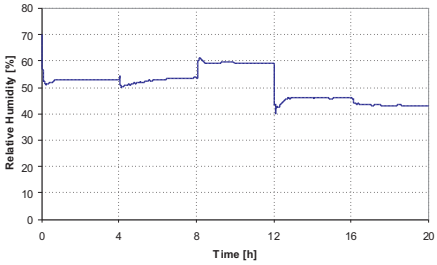
1. Tune the CHX bypass controller to minimise the number of control valve displacements while maintaining adequate control of the temperature and humidity
2. Determine the steady state performance of the system under different conditions
3. Determine the transitions between the different APM operating modes to check that the ECLSS is able to maintain the required environment in the APM cabin

All the above objectives were achieved with the model. The model correlated well with the hydraulic and temperature control tests performed on the APM cabin loop. Some results for the transitions between the different operating modes are reported below. The system is able to keep the temperature close to the setpoint during all phases within the acceptable tolerance, irrespective of the setpoint selected (18 or 27°C).



Plot 1

The relative humidity in the cabin is always within the required range from 25% to 70%.



Plot 2