



EcosimPro/ESPSS/LPRES

Overview

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Empresarios Agrupados

Empresarios Agrupados



- **Empresarios Agrupados (EA)** is an architect-engineering organization with broad international experience and diversified interests in areas such as power generation and power plants, energy innovative projects, aerospace, systems simulation, etc.
- EA's partner companies are Técnicas Reunidas, Iberdrola, Gas Natural Fenosa and GHESA
- EMPRESARIOS AGRUPADOS provides engineering and consulting services in more than 37 countries



EMPRESARIOS AGRUPADOS



EcosimPro General Description

EcosimPro General Description



- **EcosimPro** is a simulation tool developed by Empresarios Agrupados (EA) for modelling 0D-1D mathematical models based on Differential-Algebraic Equations and discrete events.
- It was originally an **ESA** project for modelling complex environmental control and life support systems for the International Space Station (Columbus and Hermes).
- EcosimPro is a user-friendly simulation tool for modelling simple and complex physical processes with an intuitive GUI and an non-causal object-oriented modelling language.



EcosimPro
Modelling and Simulation Software

PROOSIS 
Propulsion Object Oriented Simulation Software

PROOSIS General Description



- PROOSIS is currently the state-of-the-art tool for advanced gas turbine engine performance
- PROOSIS has all the capabilities of EcosimPro plus some additional capabilities required for simulating aeronautical gas turbines such as performance maps handling, multipoint design tools, design with constraints, etc.
- It also provides the TURBO toolkit with typical components for modelling any type of gas turbine



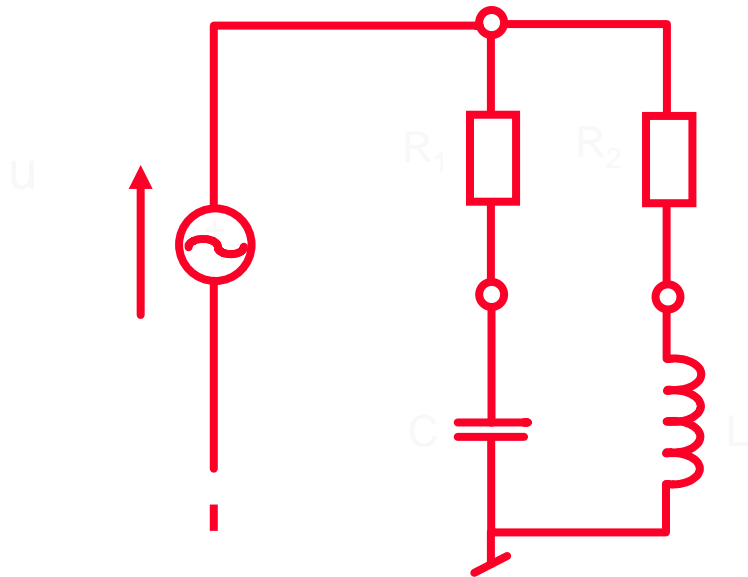
EcosimPro
Modelling and Simulation Software

PROOSIS 
Propulsion Object Oriented Simulation Software

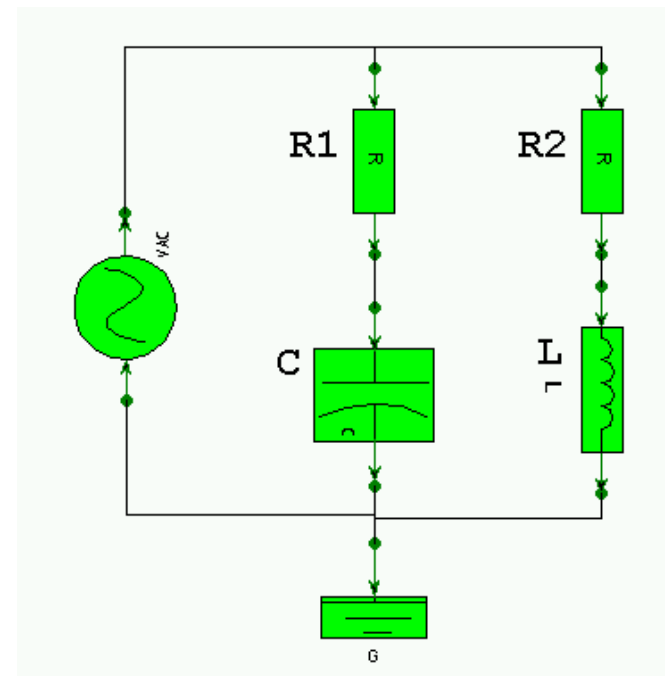
EcosimPro General Description



Object-Oriented



Electrical circuit

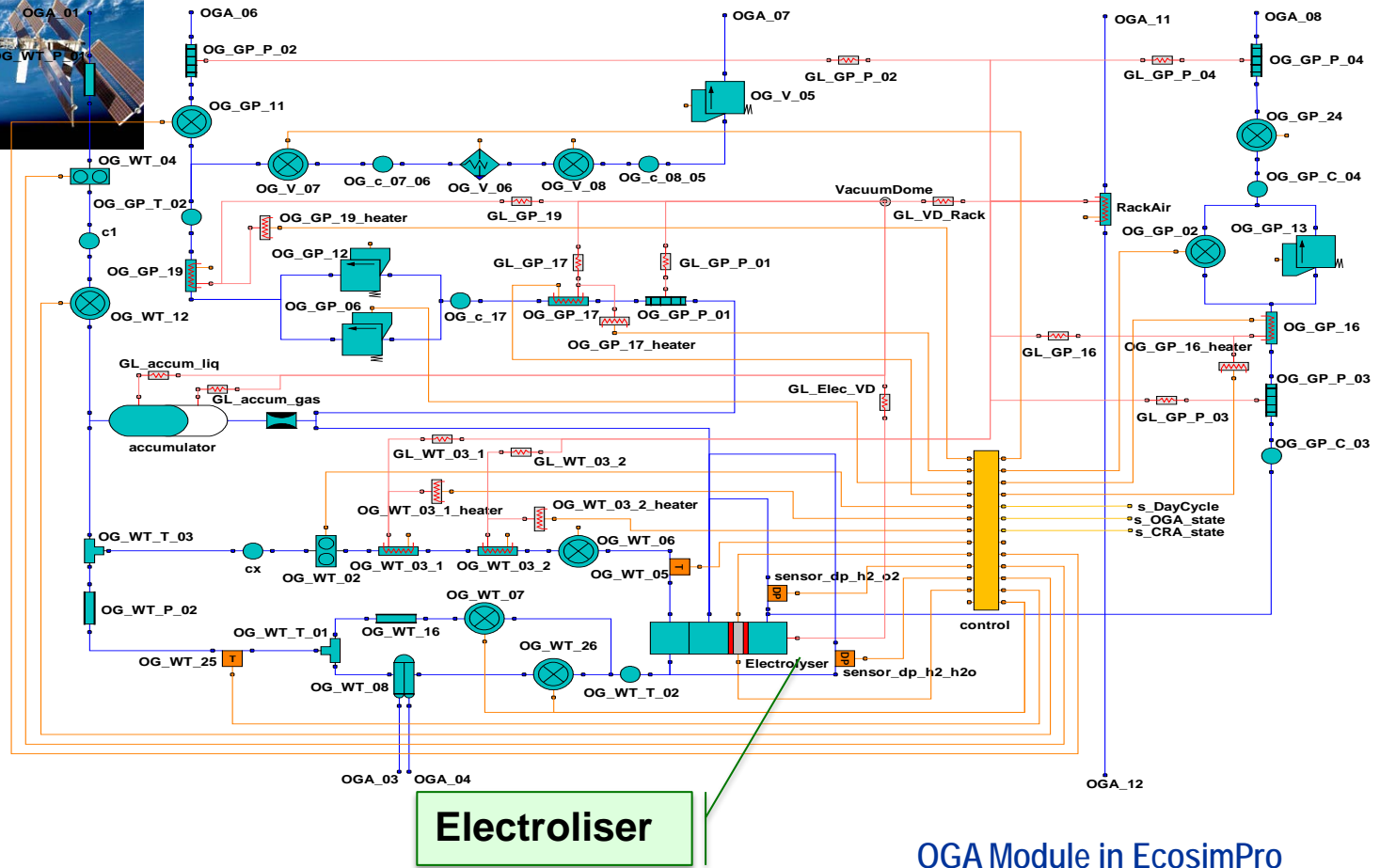


EcosimPro Model

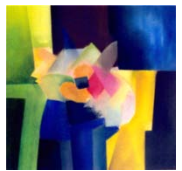
EcosimPro General Description



Air revitalization model for the ISS



EcosimPro General Description



Multi-domain Simulation Tool

EcosimPro
Modelling and Simulation Software

PROOSIS
Propulsion Object Oriented Simulation Software

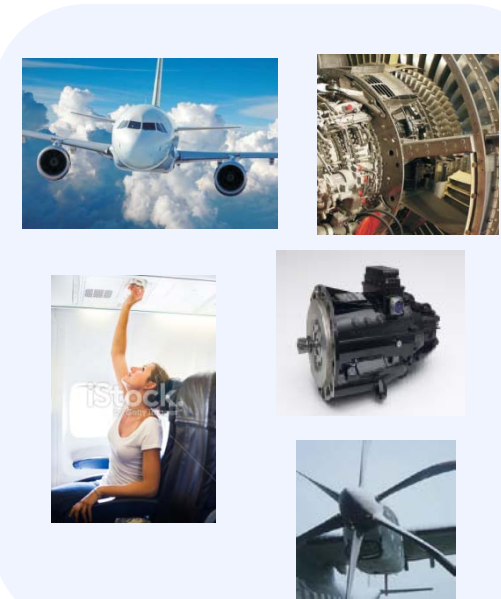
Space



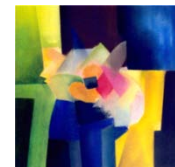
Energy & Process



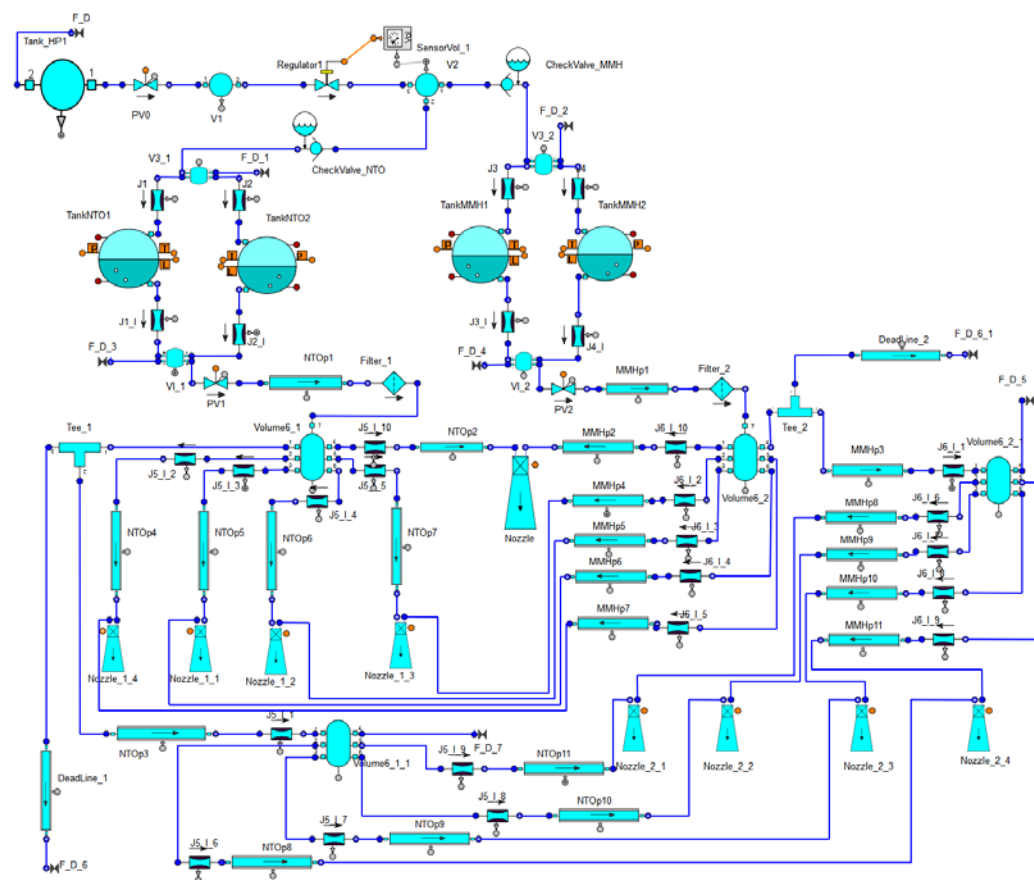
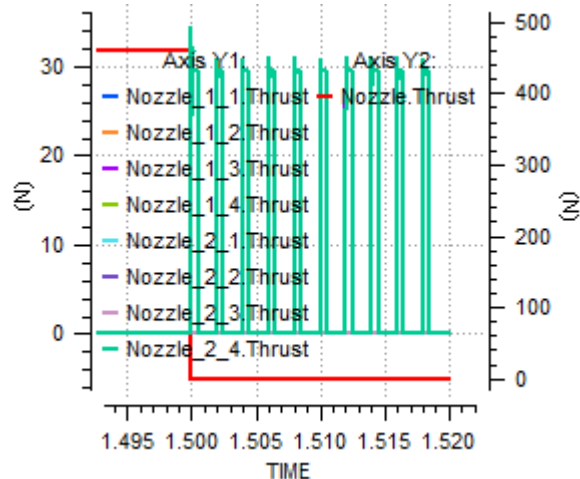
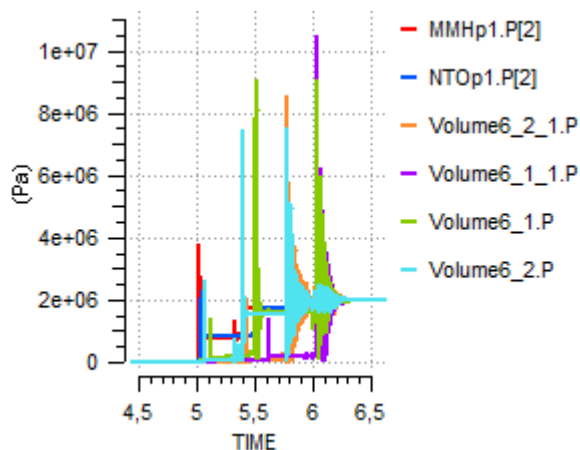
Aeronautics



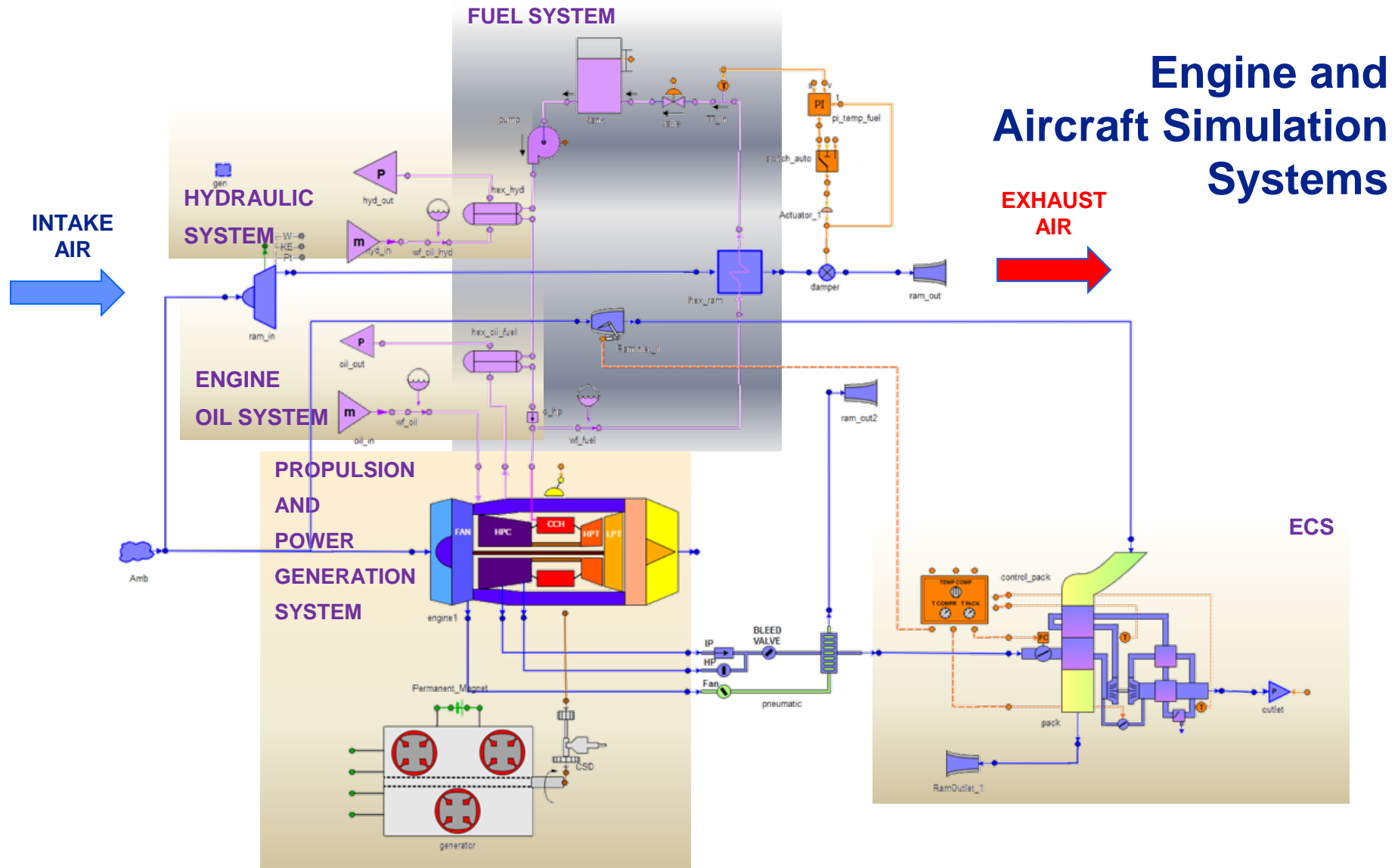
EcosimPro General Description



ESPSS libraries: Pulsing Thruster System



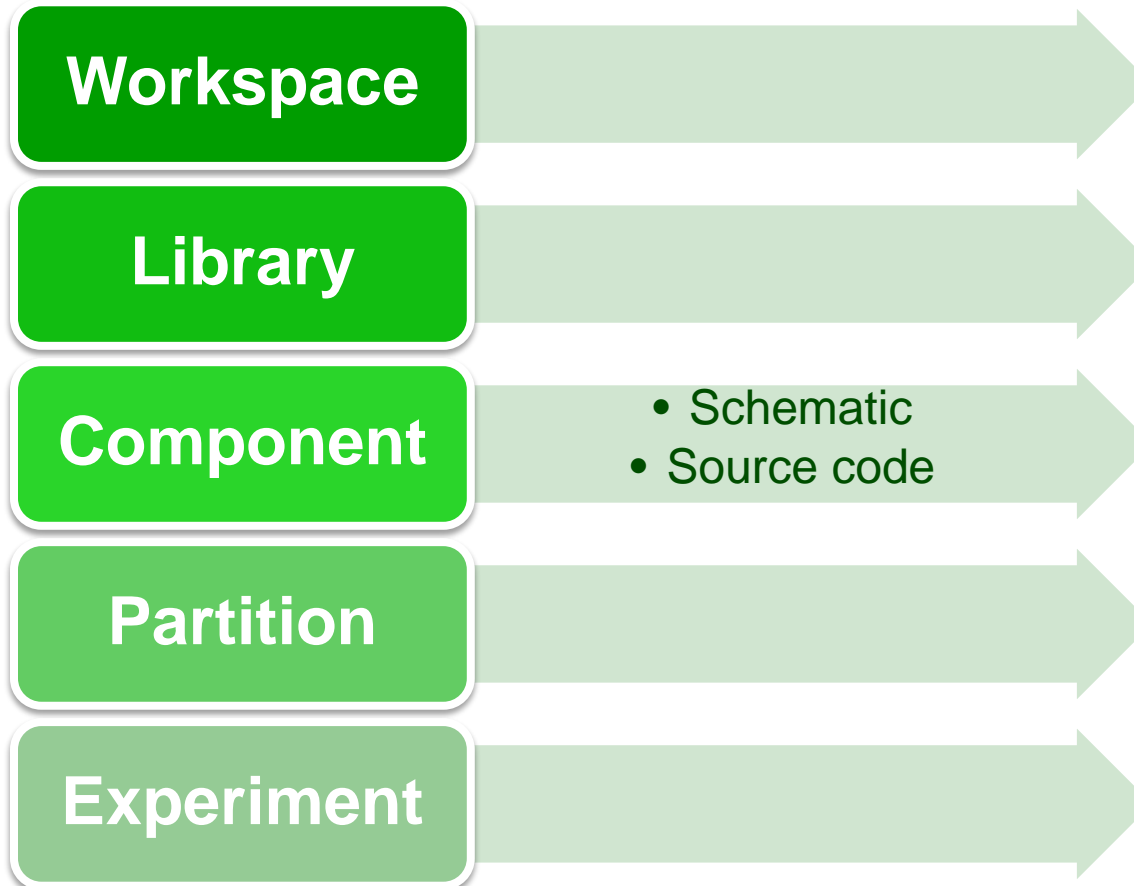
EcosimPro General Description



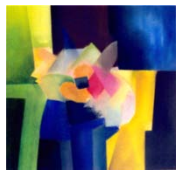


EcosimPro Main Concepts

EcosimPro Main Concepts



EcosimPro Main Concepts



General Toolbar

Schematic Toolbar

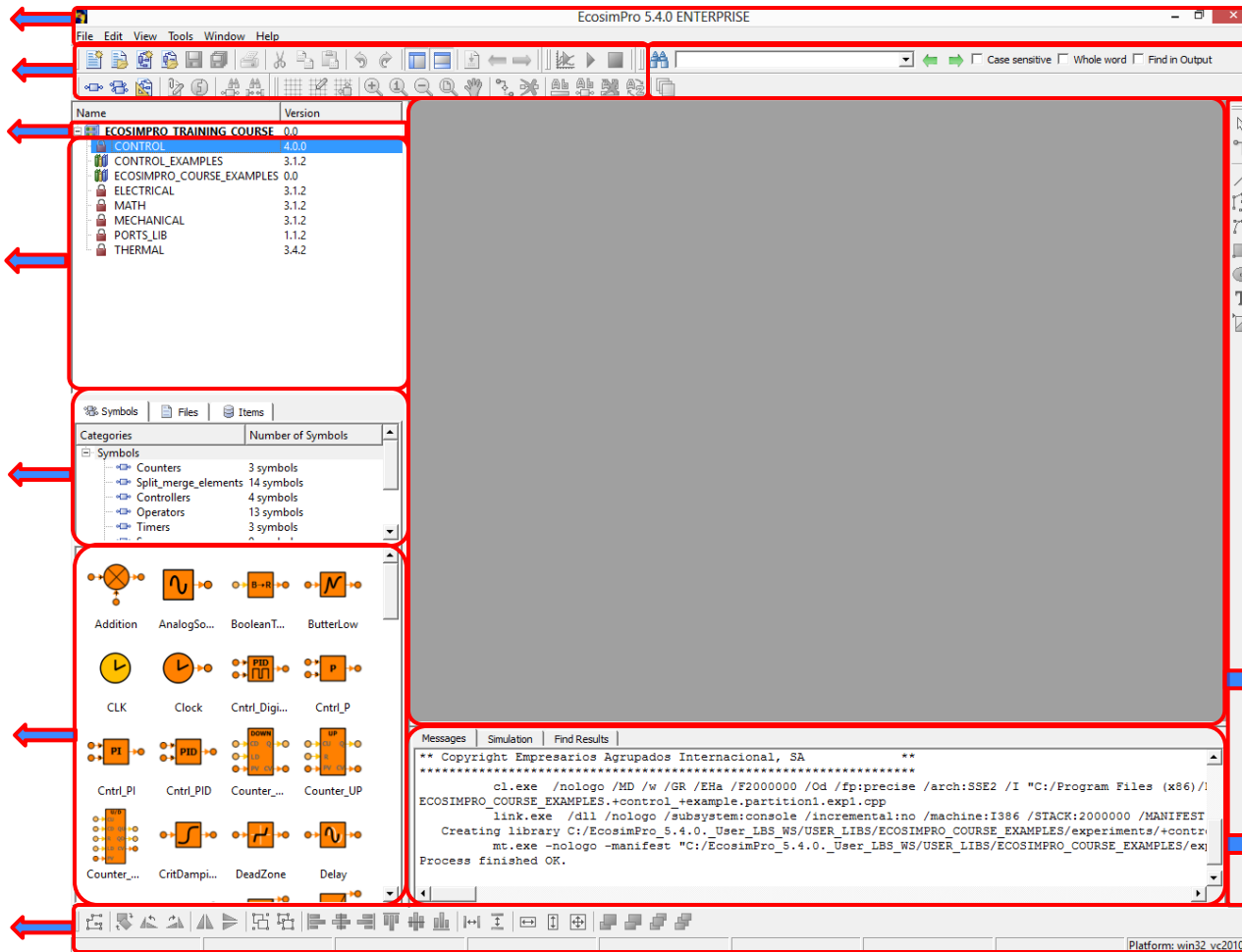
Work Space

Library Area

Library Subcategories

Library Palette

Graphical Handling Toolbar



Searching Area

Graphical Toolbar

Editing Area

Messages Area

EcosimPro Main Concepts



- **Components:**

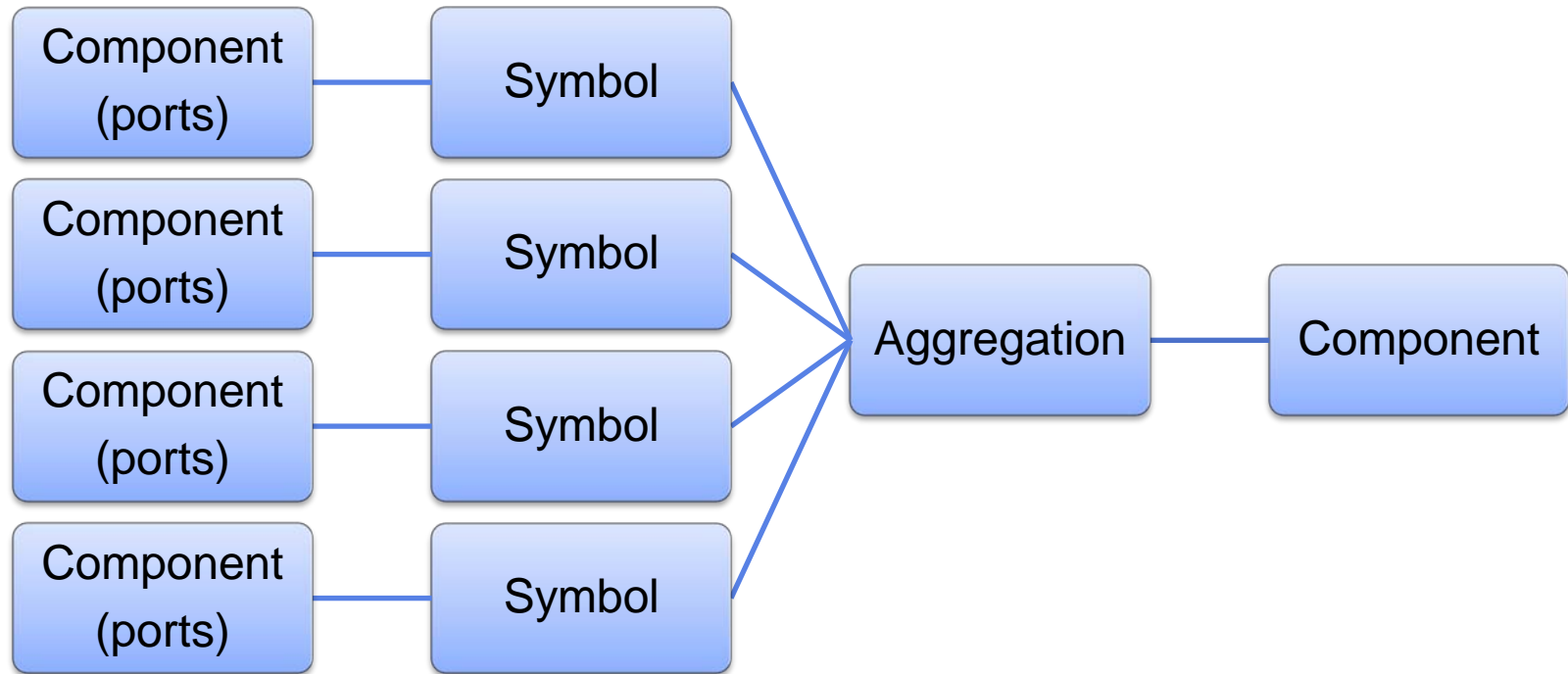
- Components are the basic elements in EcosimPro.
- Equations can be introduced not as assignments, but as physical expressions:

$$\begin{aligned} &F = m * a \\ &\text{or} \\ &F - m * a = 0 \\ &\text{or} \\ &a = F/m \end{aligned}$$

This allows reuse of components for multiple uses...
The equations are automatically transformed!

Explicit – Algebraic variables

EcosimPro Main Concepts

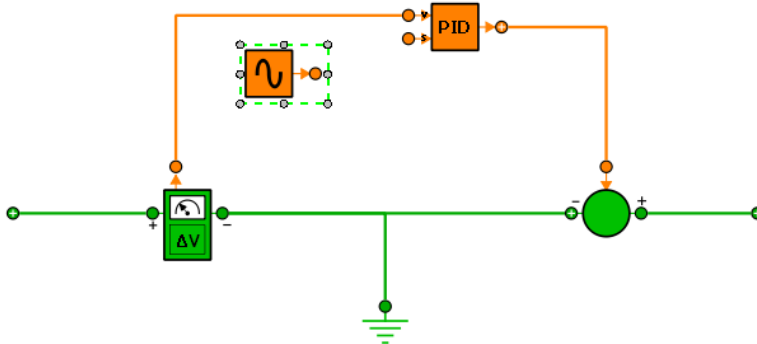


EcosimPro Main Concepts

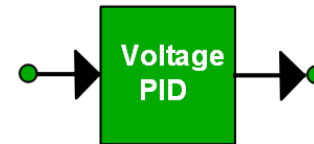


Aggregation

- Complex models may be developed by means of **aggregation**: The user can add additional components graphically by dragging and dropping their symbols to the schematic work area



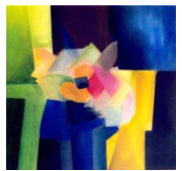
Compilation OK.
End compiling file



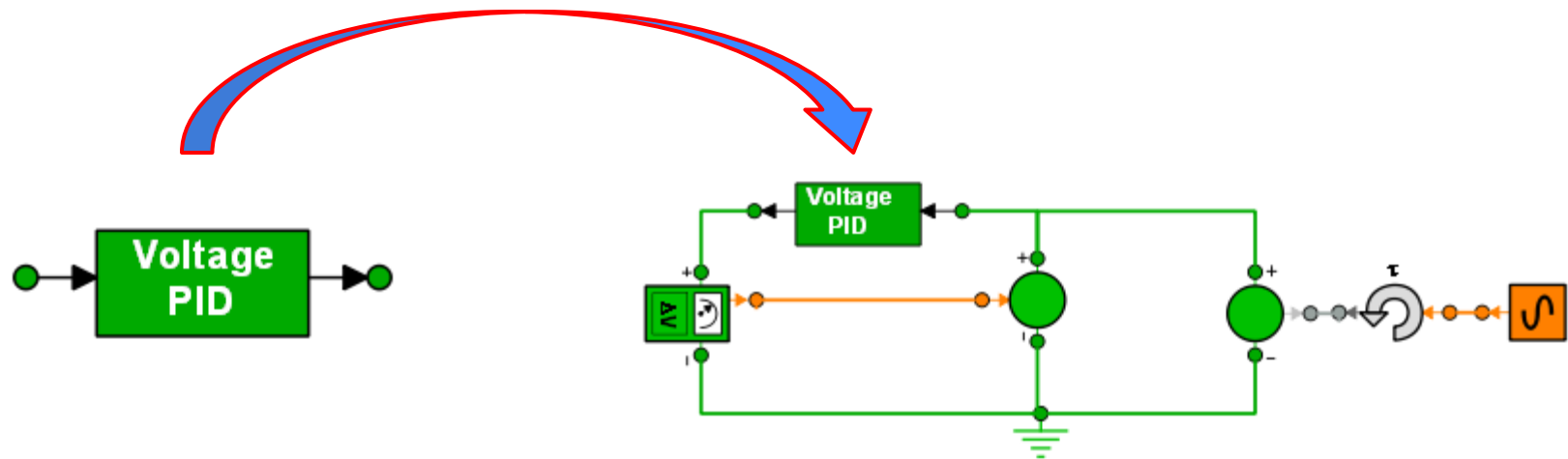
`C Voltage_PID_Controller`

- Ports must be added to the model in order to provide the necessary external connections and communications.

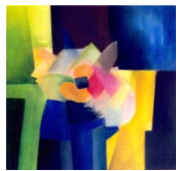
EcosimPro Main Concepts



- More complex graphical models may be developed afterwards reusing the previous developed components like a single one.

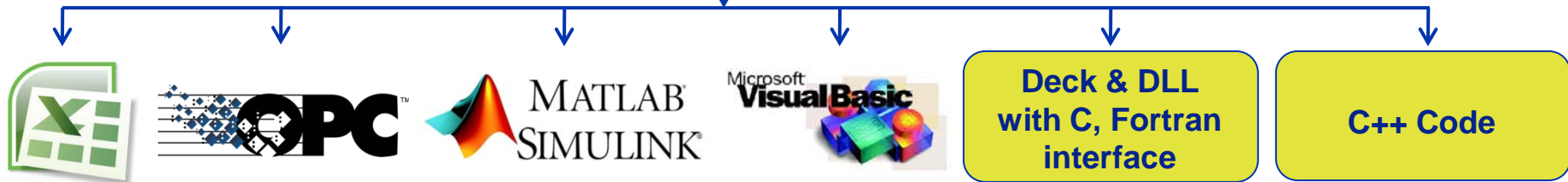


EcosimPro Main Concepts

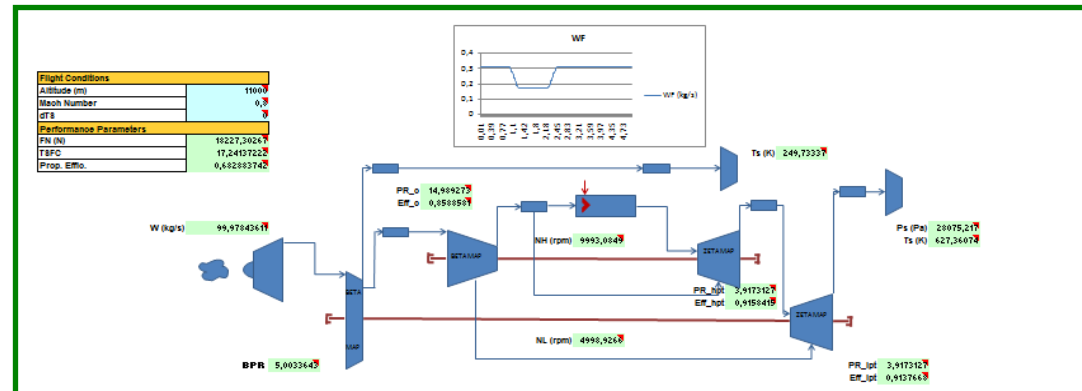


CONNECTIVITY

EcosimPro
Modelling and Simulation Software



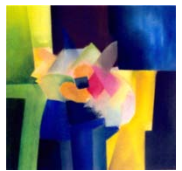
Excel Spreadsheet connected to an aircraft engine model





LPRES Toolkit Main Concepts

LPRES Main Concepts

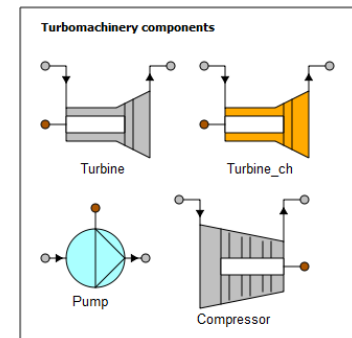
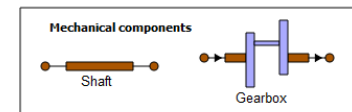
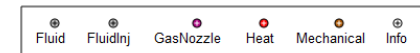
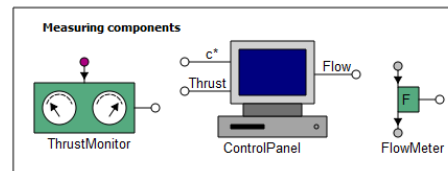
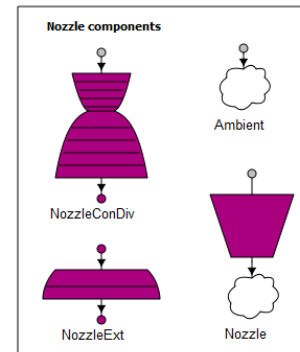
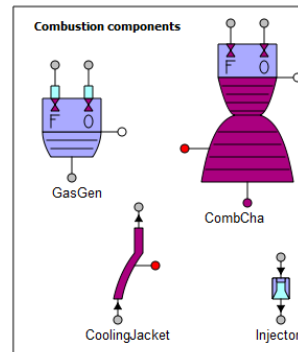
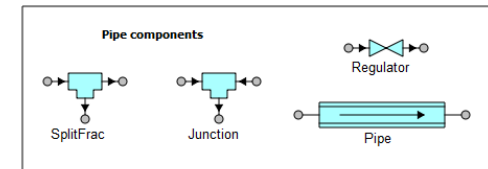
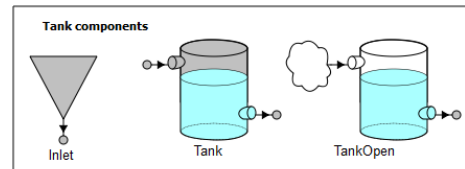


Today... LPRES: Liquid Propellant Rocket Engine Simulation

The learning curve of ESPSS is too long.

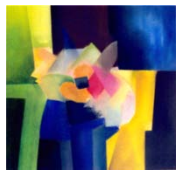
LPRES is a simplified calculation library.

- Steady calculations.
- Perfect gases and liquids.
- Phase change limited to some components.
- Analytical models.

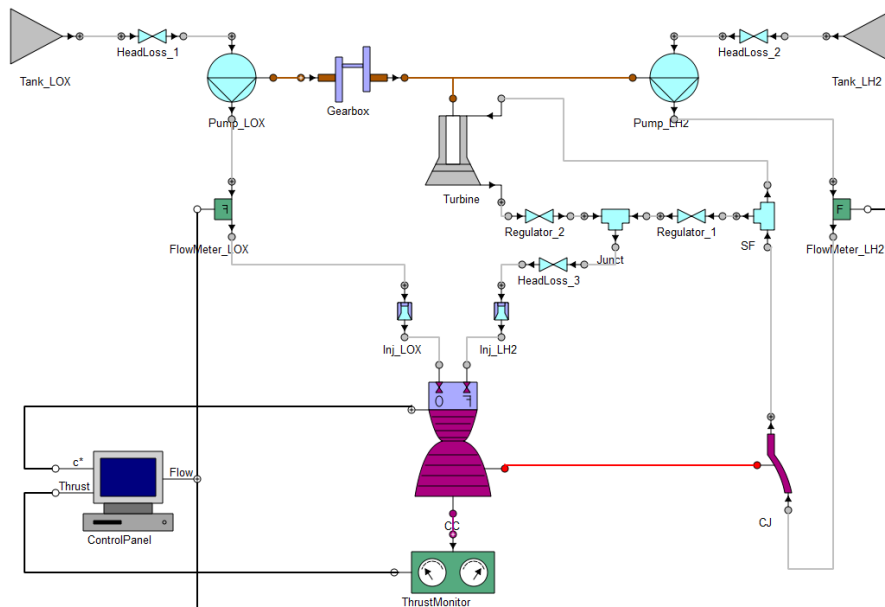


LPRES

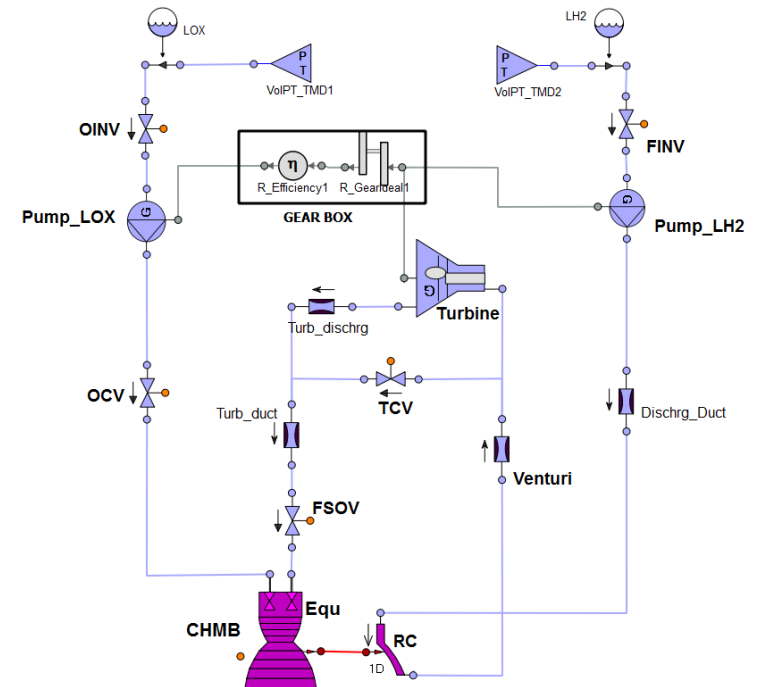
LPRES Main Concepts



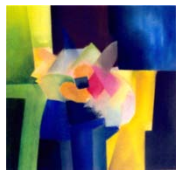
LPRES (educational)



ESPSS (professional)

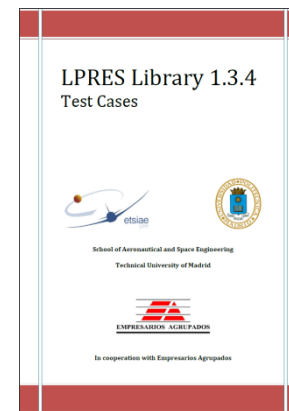
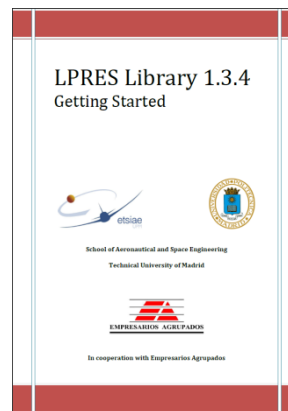
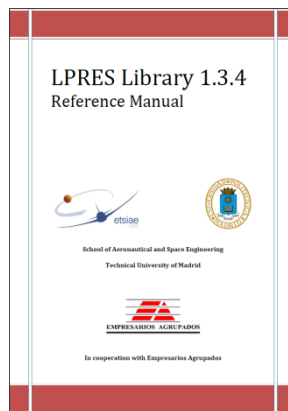


LPRES Main Concepts



LPRES available documentation

- LPRES Library Reference Manual
- LPRES Library Getting Started
- LPRES Library Test Cases





ESPSS Toolkit Main Concepts

ESPSS Main Concepts



Objectives

- **ESPSS** (European Space Propulsion System Simulation) is an ESA initiative to create a European simulation platform for spacecraft and launch vehicle propulsion systems.
- It consists of a set of libraries based on **EcosimPro** simulation environment, incorporating an open (reusable) object-oriented programming language, a powerful DAE solver and a friendly Graphic User Interface.
- ESPSS provides a state-of-the-art tool in propulsion systems analysis successfully validated with the help of experiments including priming cases, two-phase tank filling processes and the Ariane 5 ESC-A upper stage.

ESPSS Main Concepts



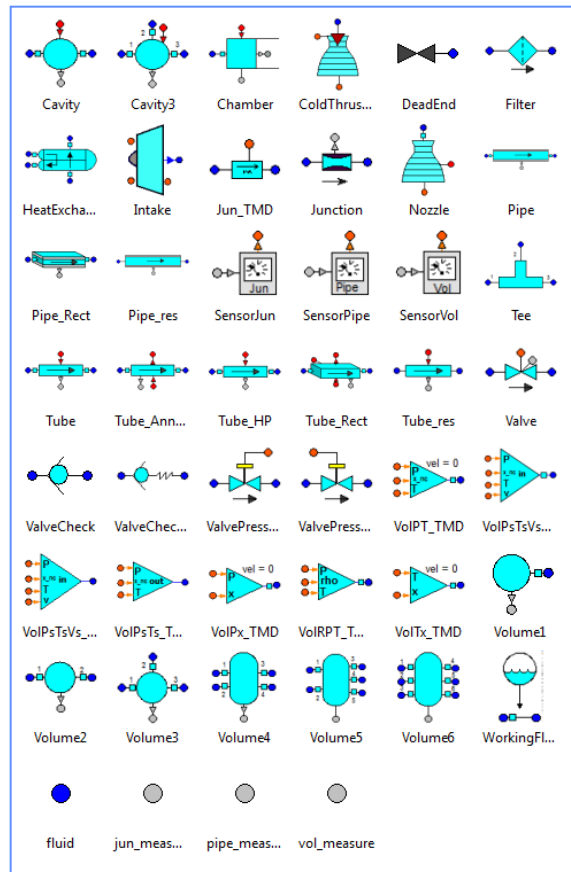
Applications

- Pressurization systems including priming processes, tank behaviour, mechanical or electronic pressure regulators, etc.
- Liquid, hybrid and solid rocket engines including one or more combustion chambers, turbo machinery and two phase cooling systems
- Air-breathing engines with subsonic and supersonic combustion
- Movement and attitude of satellites, orbital transfers and orbit control
- Electric propulsion systems

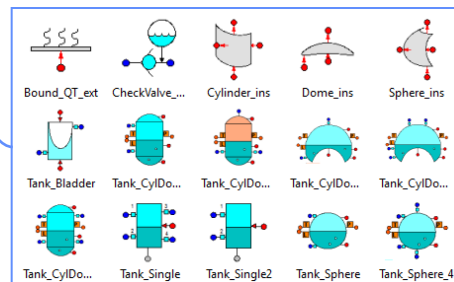
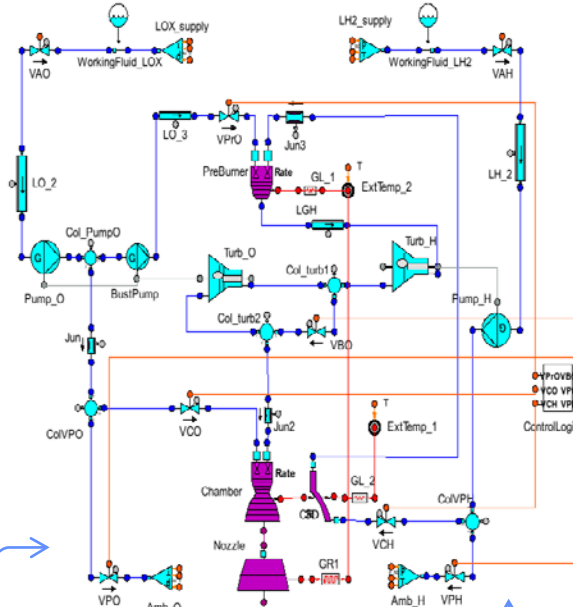
ESPSS Main Concepts



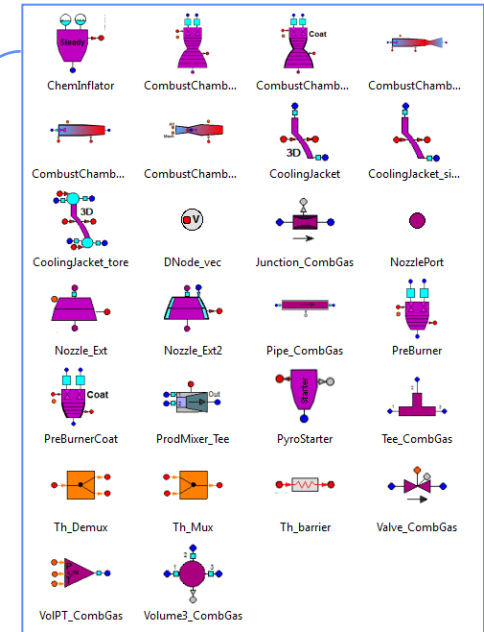
ESPSS libraries provide palettes of components which allow to build complex systems graphically:



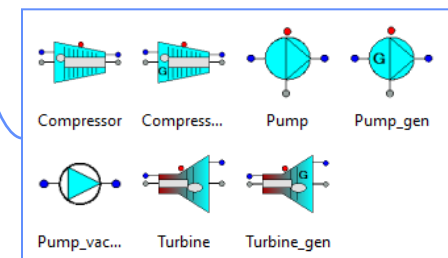
FLUID_FLOW_1D



TANKS

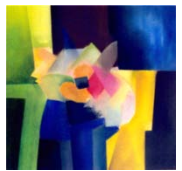


COMB_CHAMBERS

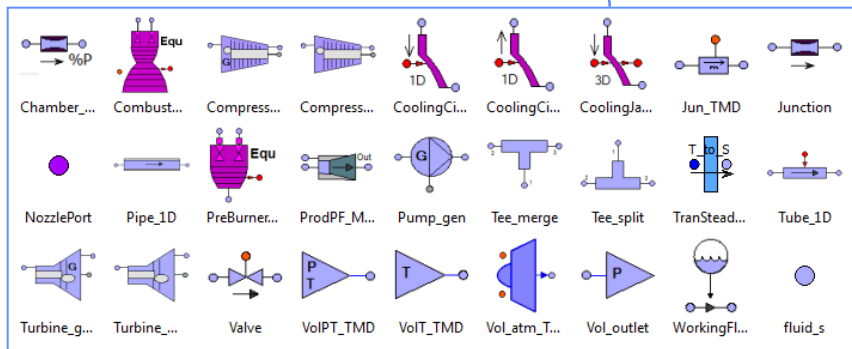
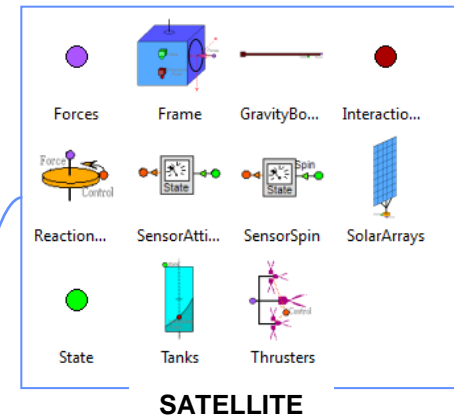
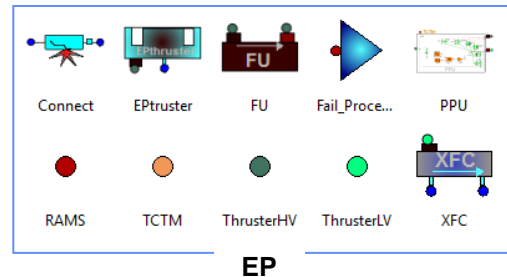
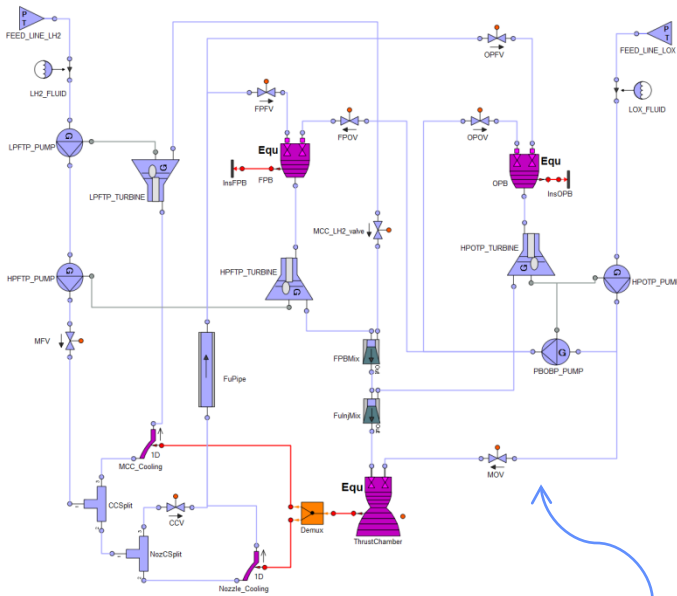


TURBOMACHINERY

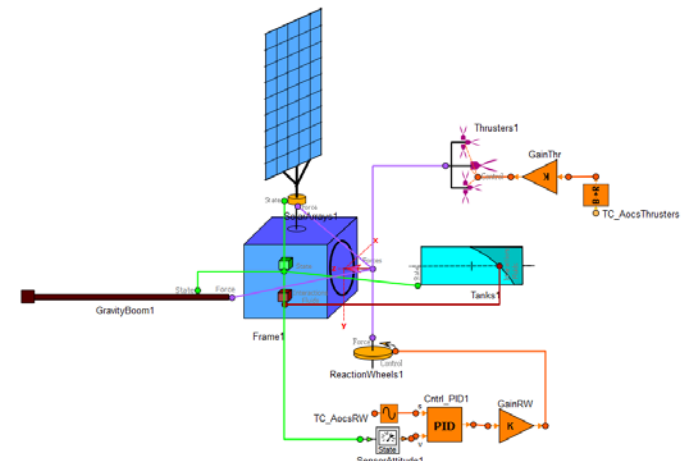
ESPSS Main Concepts



ESPSS libraries provide palettes of components which allow to build complex systems graphically:



STEADY





Libraries (I)

- FLUID_PROPERTIES

A set of functions that return the properties of the fluids used in the ESPSS models. It can handle most of the fluids used in rocket propulsion, supported in different categories: perfect gas, simplified liquid, Van der Waals fluids, real properties, mixtures of a main fluid and a non-condensable gas.

- FLUID_FLOW_1D

Pipes, volumes, valves & pressure regulators and other special components to simulate 1D two-fluid two-phase transient systems, including easy selection of the working fluid, calculation of pressure losses, reverse flow, inertia and gravity, heat transfer phenomena, etc.



Libraries (II)

- TANKS

Different tank types normally used in rocket engines and spacecrafts, with different levels of complexity (e.g. bladder tanks, 1D tanks, etc.)

- TURBO_MACHINERY

Pumps, compressors and turbines allowing to simulate generic or user-defined performance maps, start-up and shut-down transients, etc.

- COMB_CHAMBERS

Different components to simulate liquid, hybrid and solid rocket engines, including pressure drops, heat transfer phenomena, vaporization models, cooling jackets, etc.



Libraries (III)

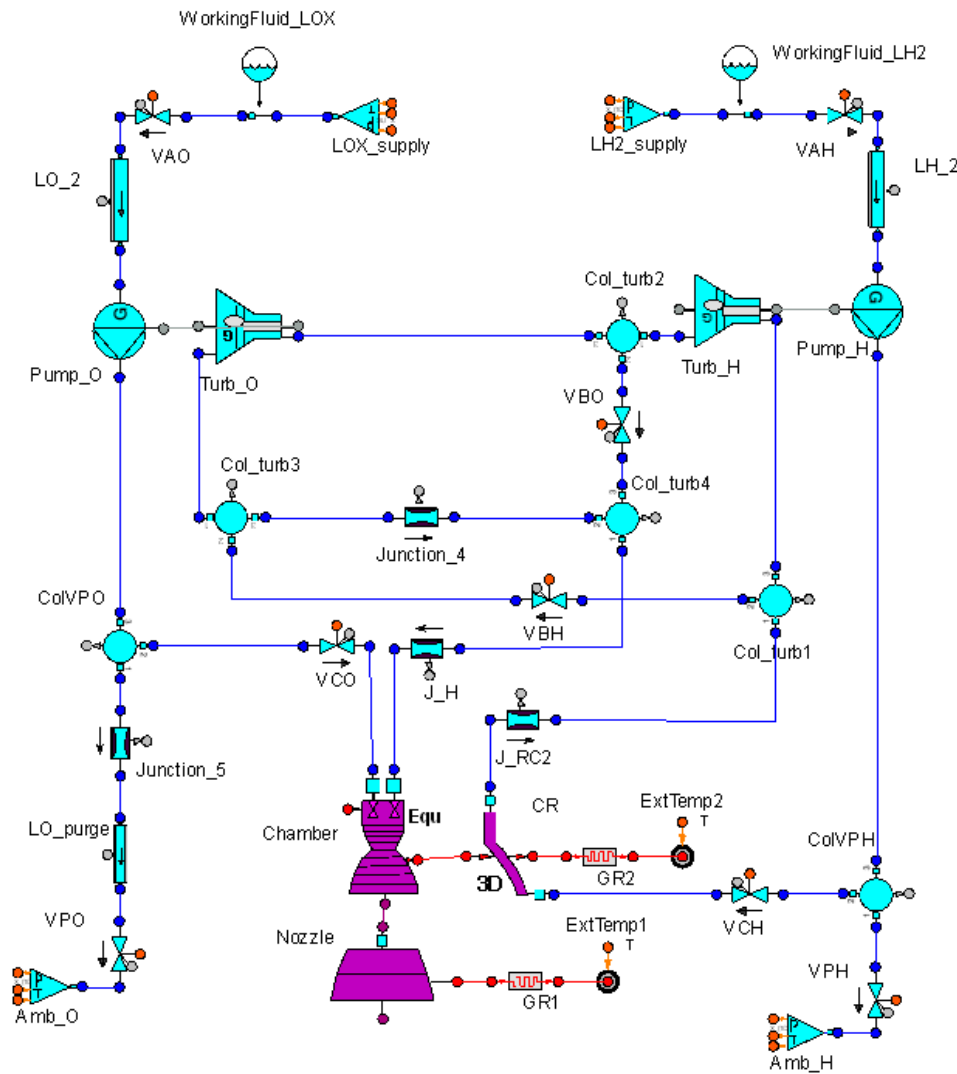
- **STEADY**

It contains a complete set of components to calculate stationary states of models under design and off-design conditions

- **EXAMPLES libraries**

Several libraries containing example models to show some of the capabilities and serving as template for the users

ESPSS Application Examples



The model is able to simulate the start-up and shut-down of the engine.

The main processes simulated during the startup are:

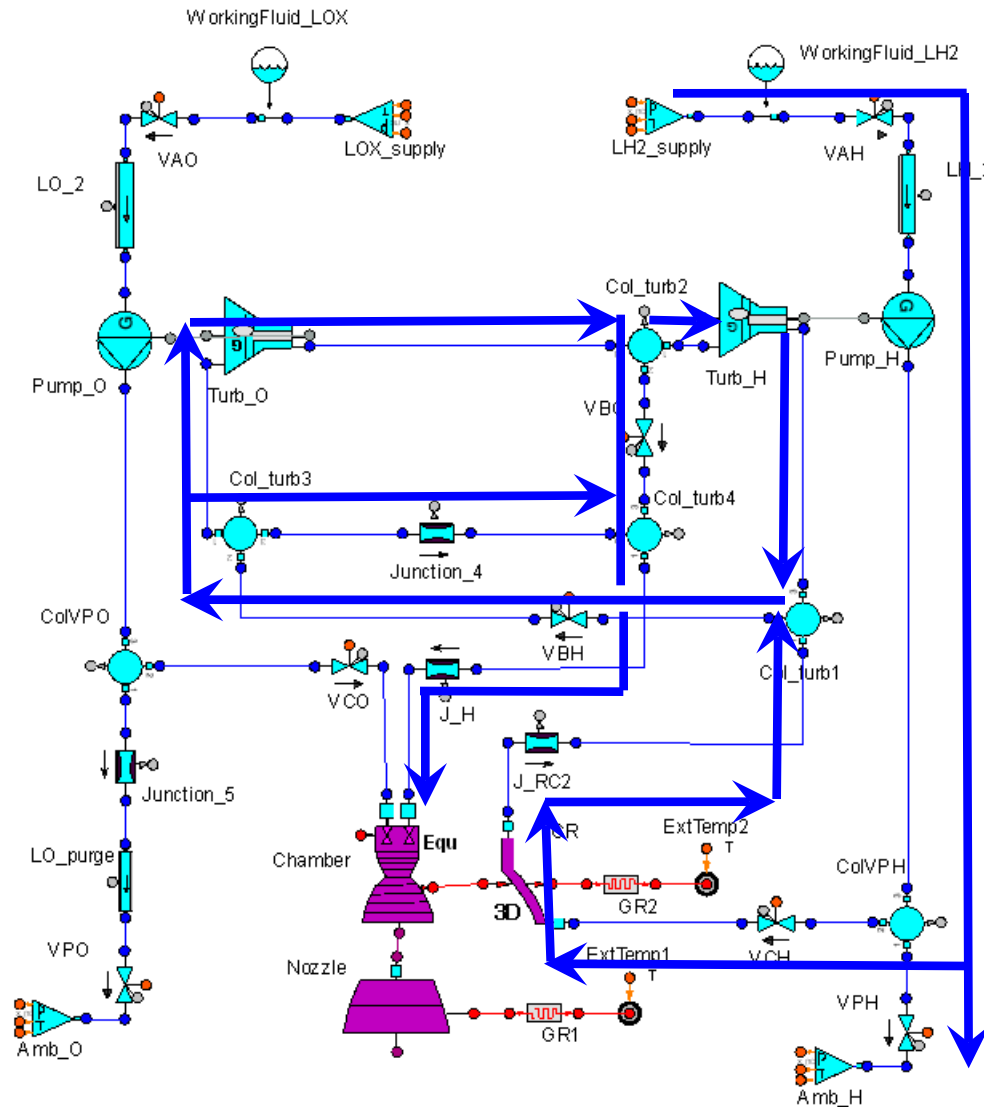
- Priming of the cavities
- Vapor pressurization inside the combustor before ignition
- Simplified model for the LOX vaporization inside the combustor
- Pressure/temperature rise in the chamber during ignition

At the end of the shut-down generalized two-phase flow can be observed in the feeding lines.

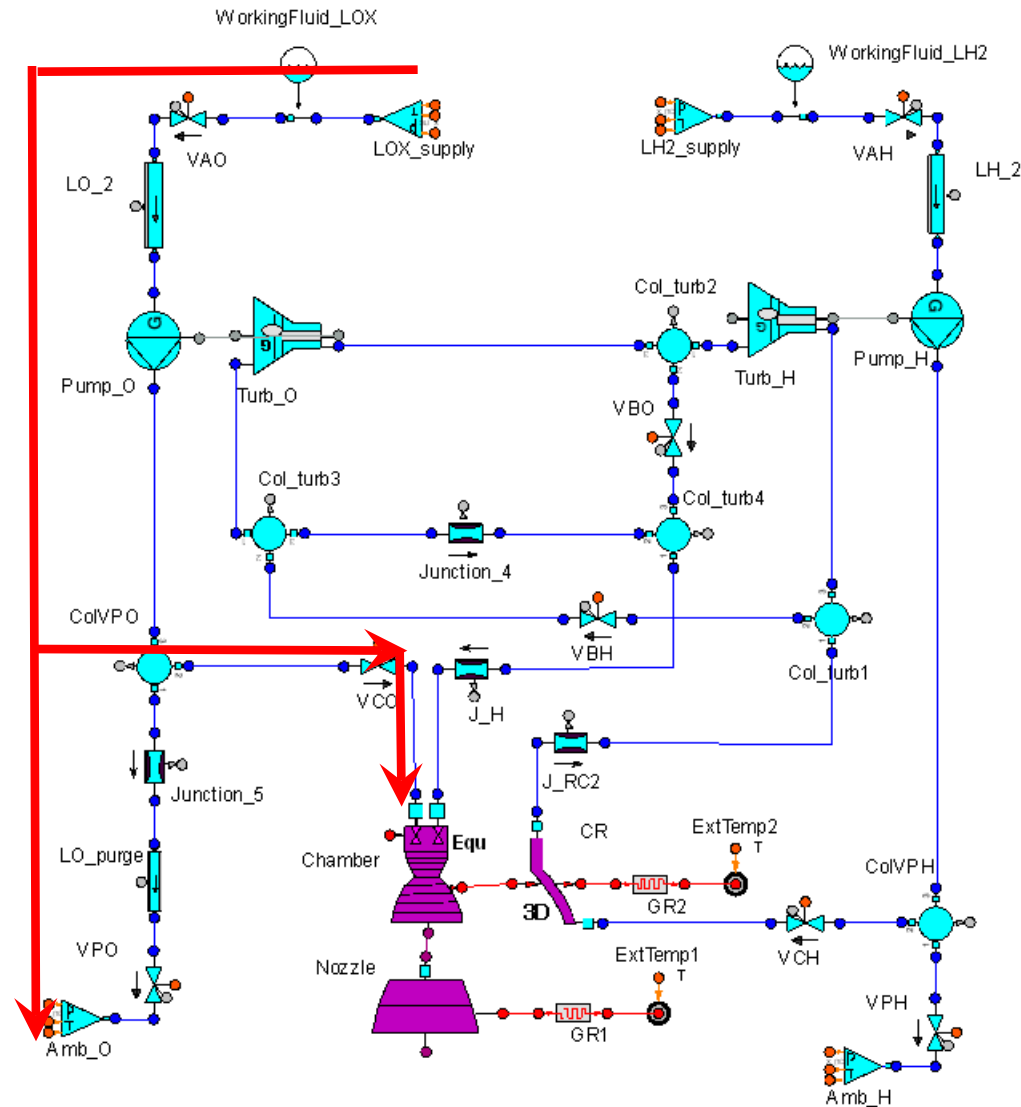


Reducer line

ESPSS Application Examples



ESPSS Application Examples



ESPSS Application Examples

