GEÁTAM05 - Numerical modeling of fluid flows

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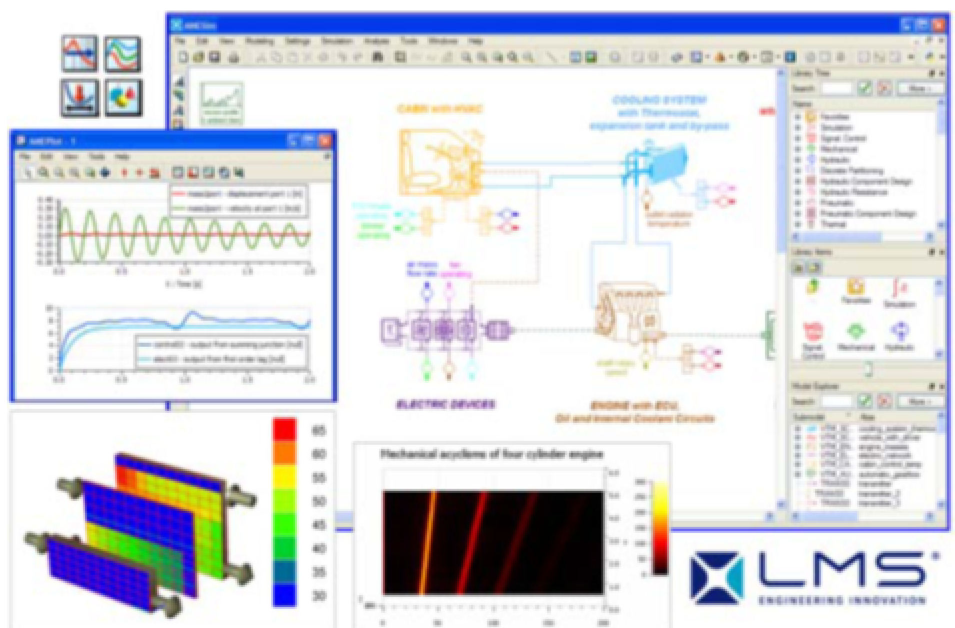
(after the 2-3 week)

Imagine.Lab AMESim

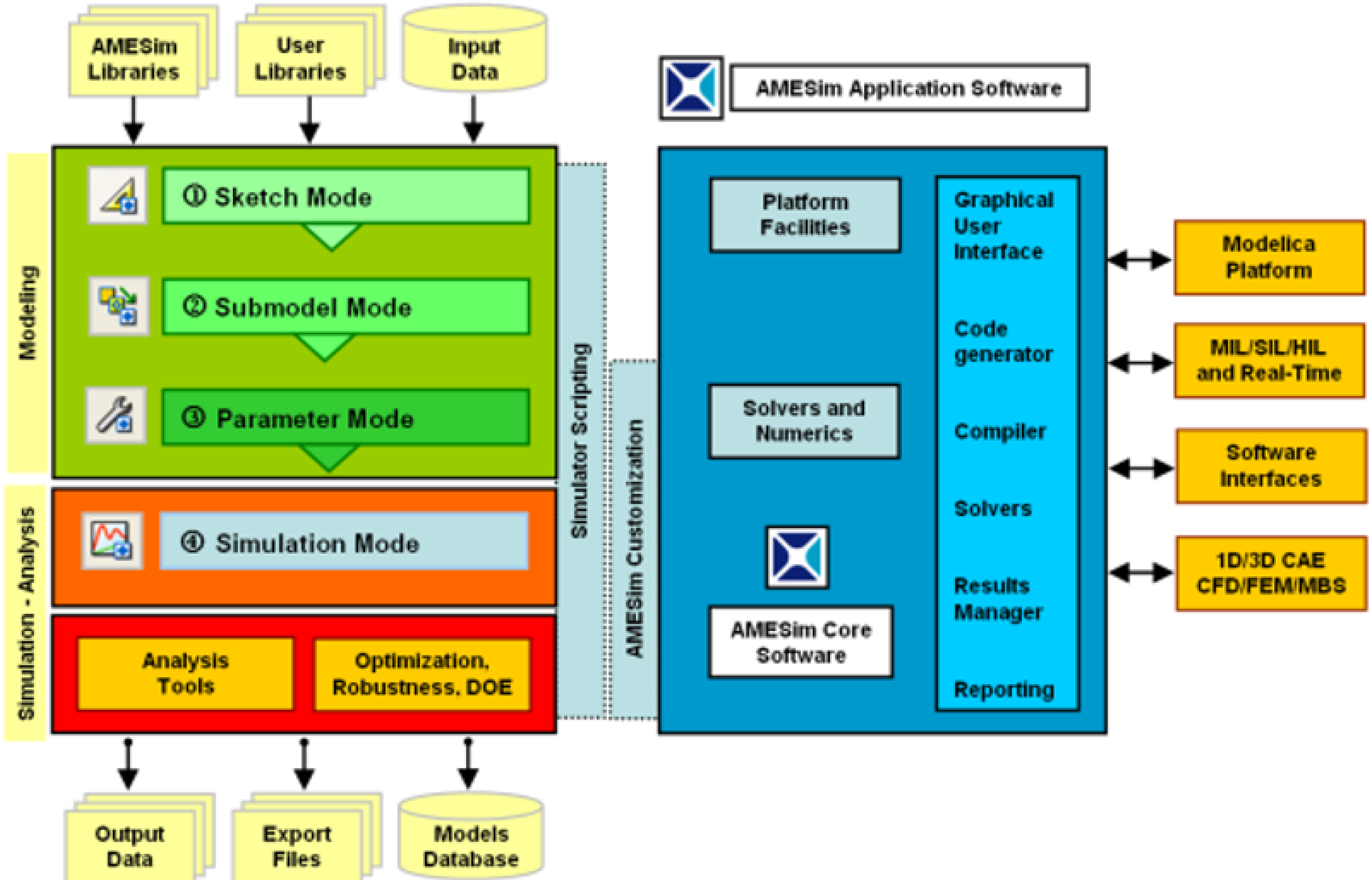
AMESim = Advanced Modeling Environment for performing Simulations of engineering systems.

- Simulation of physical multi-domain systems
- Broad range of application and physical domains
- Steady-state and transient analysis
- Time-domain and frequency-domain analysis
- Test systems with MIL/SIL/HIL (Model/Software/Hardware-in-the-loop) and Real-Time
- Linear and non-linear systems
- Input/output analysis
- Parameter sensibility analyses
- Vibration and order analysis
- Integration with CAE software tools



Imagine.Lab AMESim

Architecture (simplified view)



Imagine.Lab AMESim

AMESim is a **1D lumped parameter time domain** simulation platform.

1D means that the physical properties of the system (e.g. pressure, temperature) propagate along one dimension only (e.g. like the current in an electrical wire).

Lumped parameters are a simplification in a mathematical model of a physical system where variables that are spatially distributed fields are represented as single scalars instead.

Time domain is a term used to describe the analysis of mathematical functions, or physical signals, with respect to time. In the time domain, the signal or function's value is known for all real numbers, for the case of continuous time, or at various separate instants in the case of discrete time.

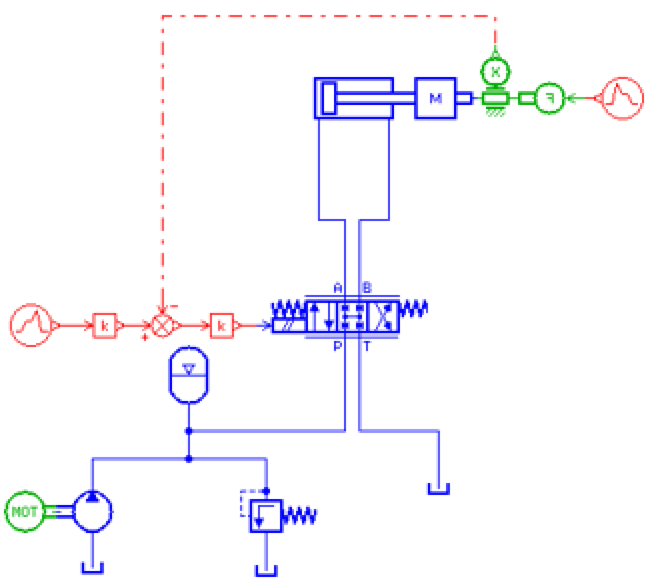
Imagine.Lab AMESim

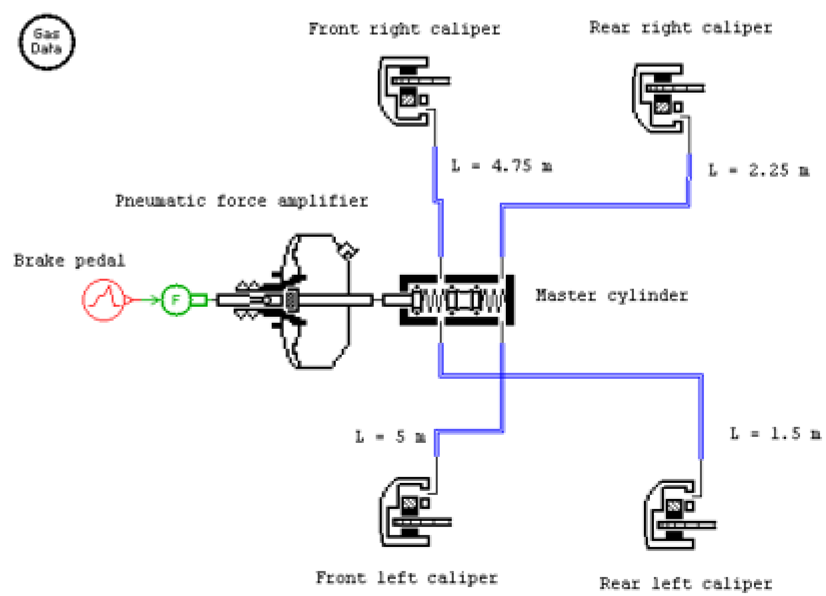
AMESim uses symbols to represent individual components within the system which are either:

• based on the **standard symbols** used in the engineering field such as ISO symbols for hydraulic components or block diagram symbols for control systems

or when no such standard symbols exist:

• symbols which give an **easily recognizable pictorial representation** of the system.





System simulation

A **system** is an organized, purposeful structure regarded as a ’whole’ consisting of interrelated and interdependent elements (components, entities, factors, members, parts etc.). These elements continually influence one another to maintain their activity and the existence of the system, in order to achieve the common purpose, the ’goal’ of the systems.

All systems:
- have **inputs**, **outputs**, and **feedback** mechanisms,
- maintain an internal quasi-steady-state despite a changing environment
- have **boundaries** that are usually defined by the system observer.

Every system is
- a part of a larger system
- is composed of sub-systems
- shares common properties with other systems that help in transferring understanding and solutions from one system to another.

Model of the system: the set of equations defining the behavior of the engineering system and its implementation as computer code.

Submodel: the equations and corresponding code for each component within the system.

System simulation within AMESim

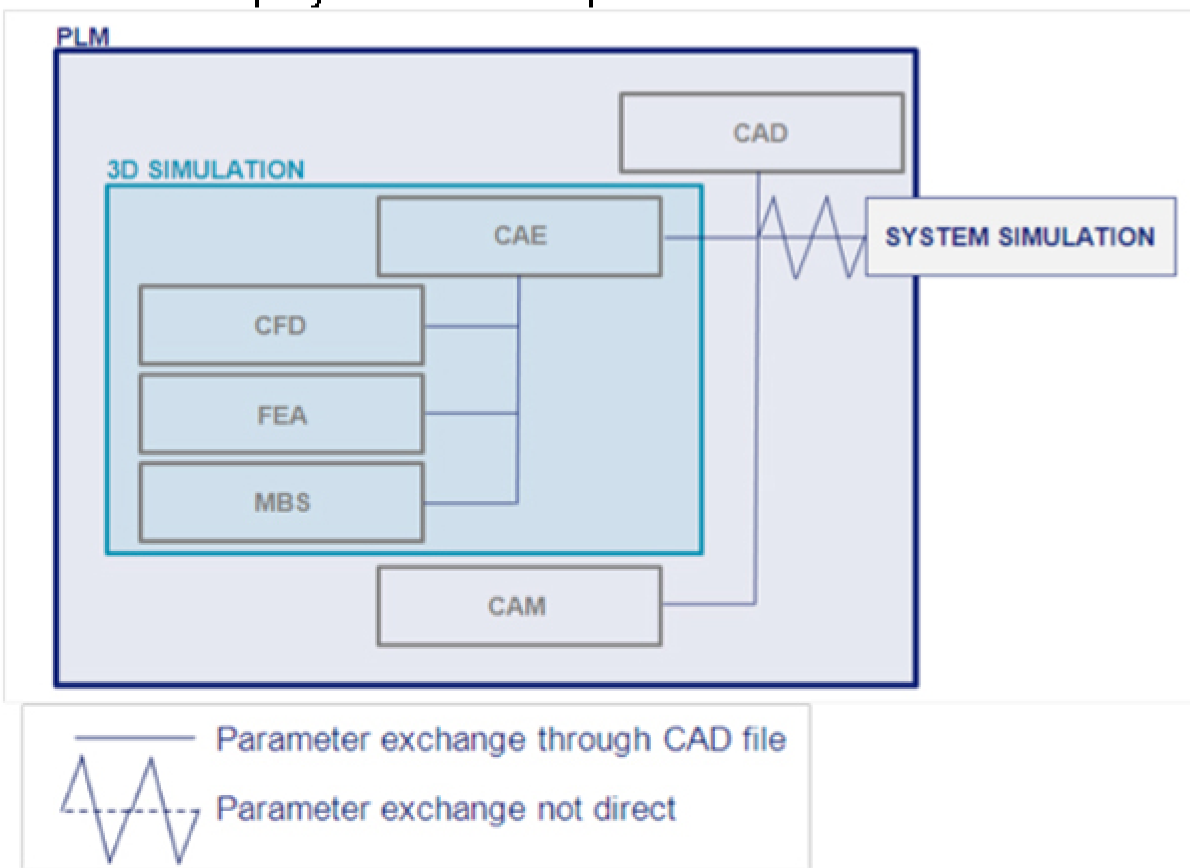
Simulation of multi-physics models, for transient analysis purposes, based on power exchanges.

- Can be started at pre-design and specification stages, with a reduced number of parameters.
- System simulation is (usually) based on time-dependent equations.
- System simulation is linked to the control of the power flow within a system, usually in close relations with automation, control, and electronics.
- This integration with controls and electronics is the mechatronics, which studies the behavior of intelligent systems.
- System simulation (usually) does not use full 3D based geometry.
- Requires a reduced number of parameters as input to describe the system to be analyzed and modeled.

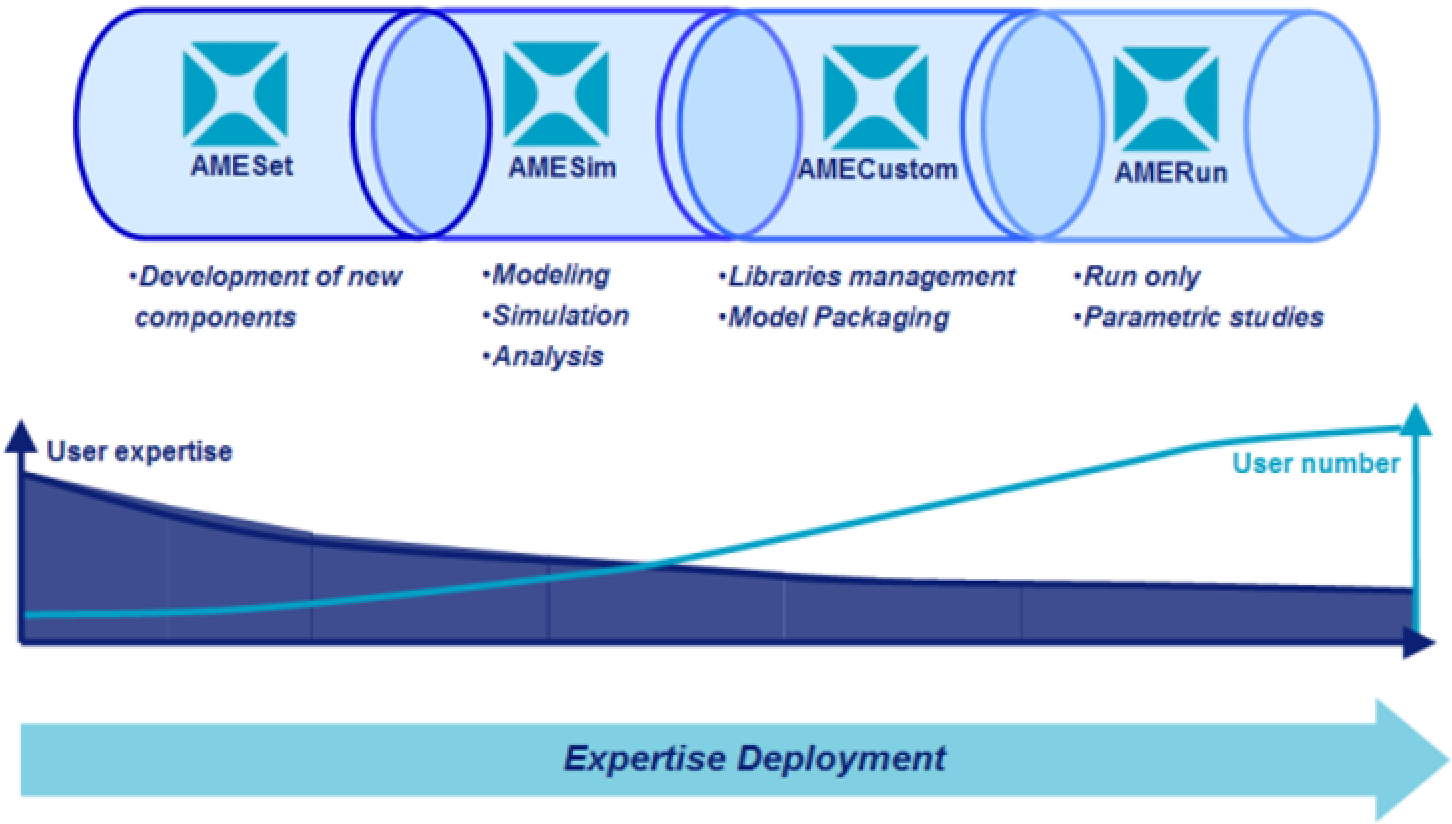
Positioning of system simulation

Most of the software tools used in the industry are based on exchanges of CAD files. CAD, CAE, CFD, FEM and Multi-body softwares are all linked to the exchange of 3D parameters. System simulation is usually not fully integrated into this process, most of the parameters are given by tables and results of experiments.

System simulation is a way of simulating complex systems with multiple sub-elements and different physics to be represented at the same time.



AMESim suite

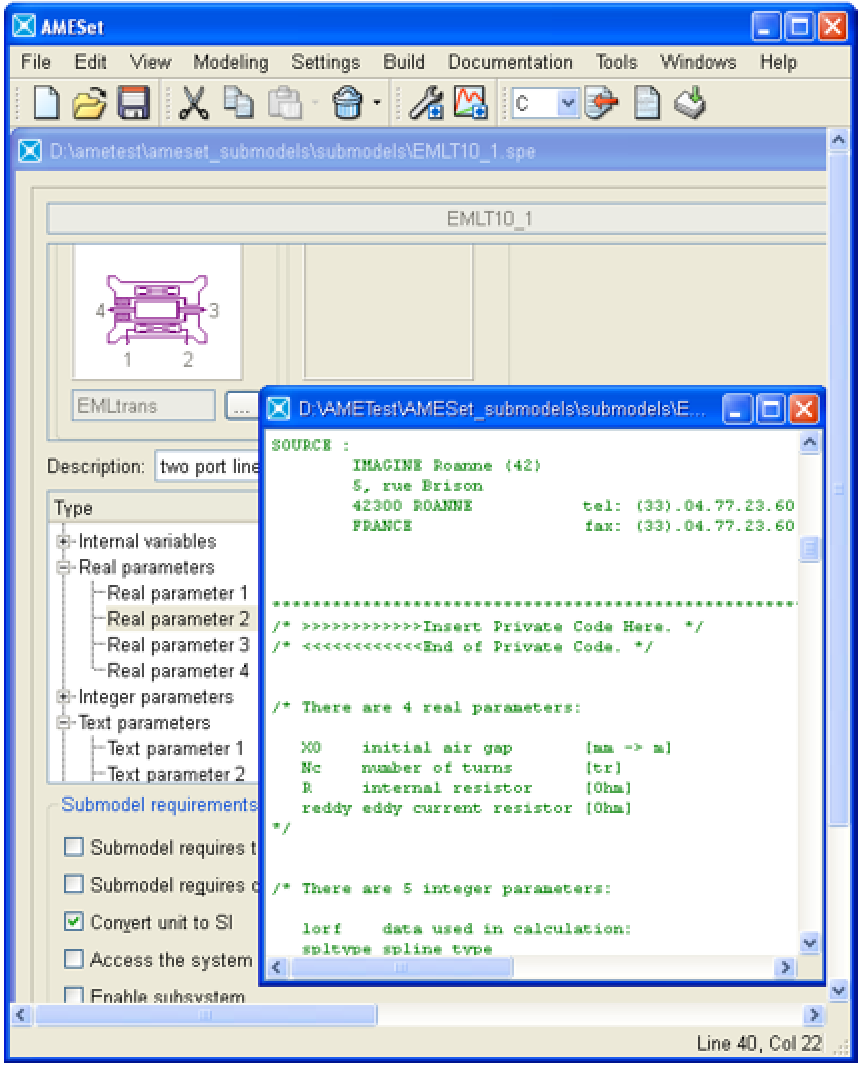


AMESim suite - AMESet

Advanced AMESim users can use AMESet to create new icons and submodels.

With AMESet, you can:

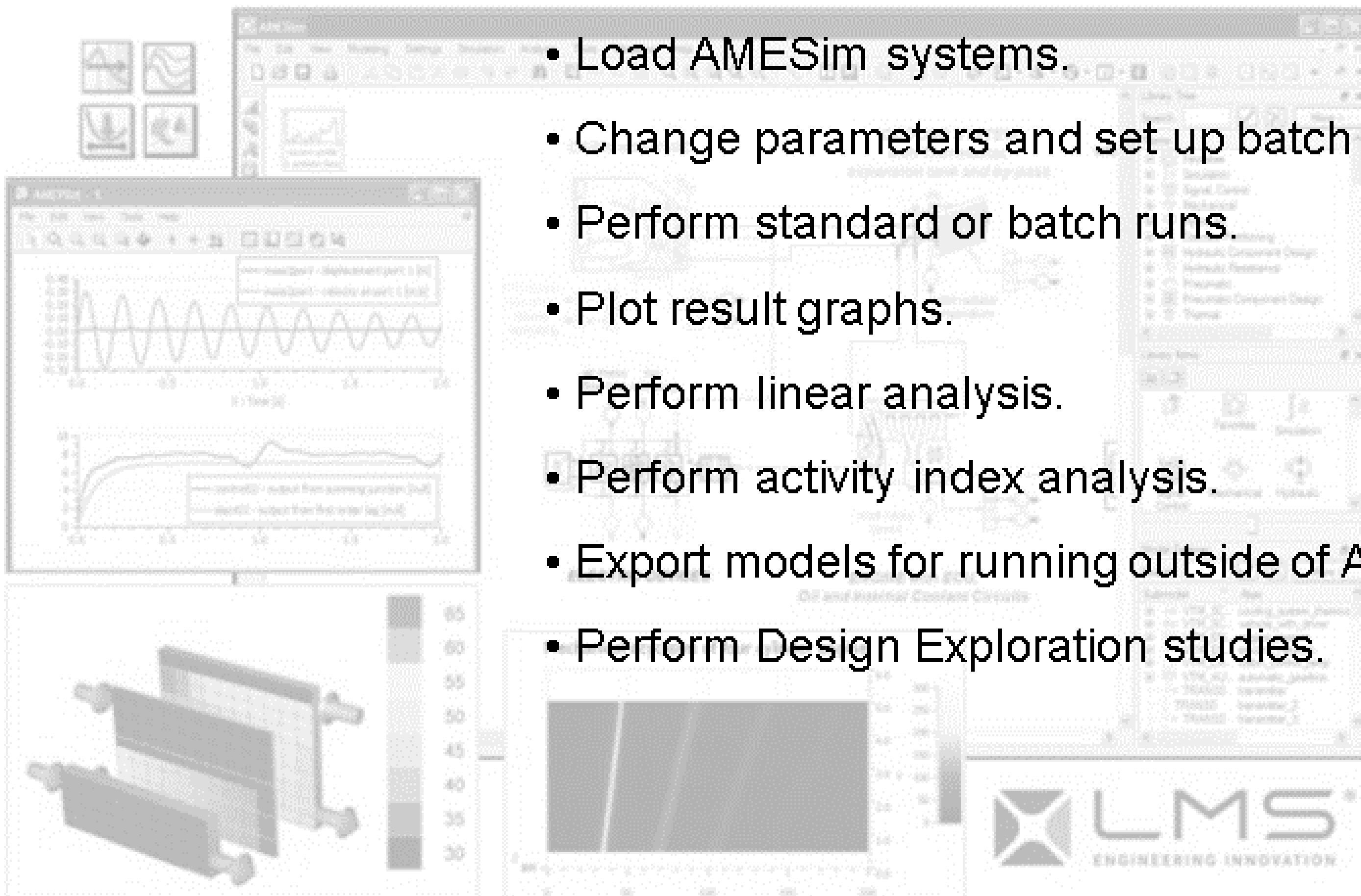
- Integrate new icons and submodels.
- Customize component categories and submodels.
- Create your own component (or line) submodels to extend the capability of AMESim into your own applications.



AMESim suite - AMESim

AMESim is the main product of the AMESim software suite. With AMESim, you can:

- Create new systems.
- Modify the Sketch of an existing system.
- Change the submodel behind a component.
- Load AMESim systems.
- Change parameters and set up batch runs.
- Perform standard or batch runs.
- Plot result graphs.
- Perform linear analysis.
- Perform activity index analysis.
- Export models for running outside of AMESim.
- Perform Design Exploration studies.

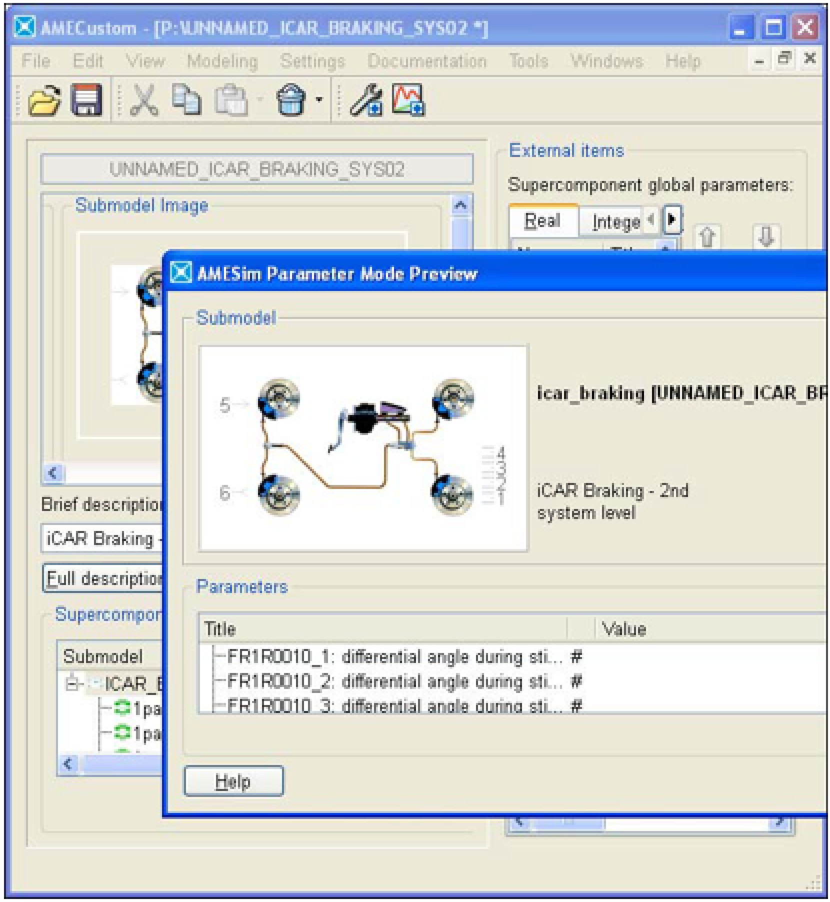


AMESim suite - AMECustom

With AMECustom, you can customize submodels and supercomponents.

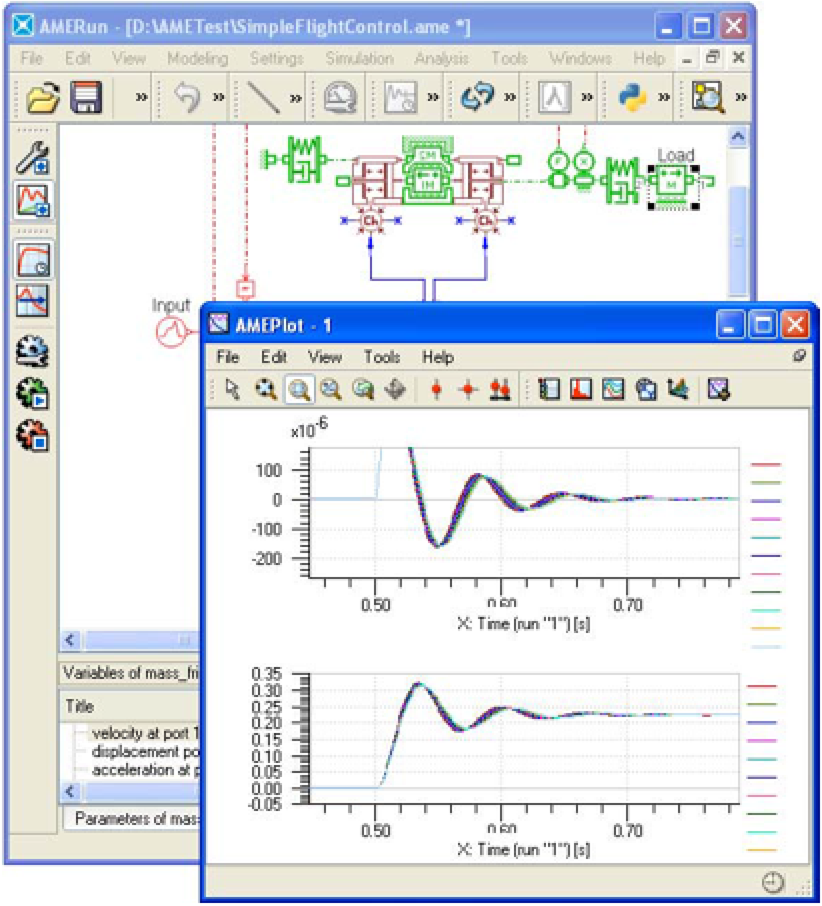
A customized object is based on a generic object over which a mask is placed. Only the parameters that are to be tested are kept visible.

It is possible to encode the components of a complex system before distributing it.



AMESim suite - AMERun

AMERun is AMESim without Sketch and Submodel modes. AMERun users can open systems in order to perform studies.



With AMERun, you **can**:

- Load AMESim systems.
- Change parameters and set up batch runs.
- Perform standard or batch runs.
- Plot result graphs.
- Perform linear analysis.

You **cannot**:

- Create new systems.
- Modify the Sketch of an existing system.
- Change the submodel behind a component.

AMERun can be used by:

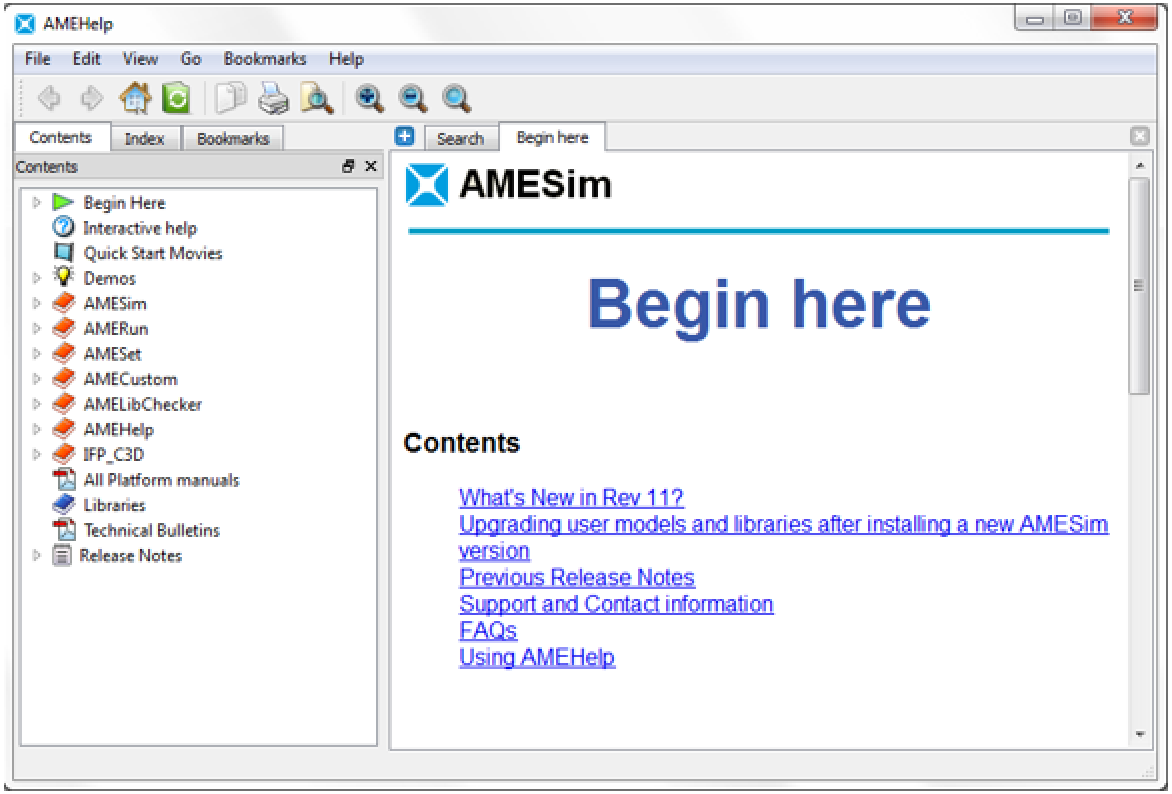
- Technicians doing many parameter studies using a system built in by an experienced engineer;
- Clients who receive pre-built systems from you;
- Sales staff who use pre-built systems to demonstrate system behavior to customers.

AMESim documentation

The documentation set is made up of:

- HTML and PDF manuals for each component of AMESim.
- PDF manuals for each library.
- HTML specification sheets for all submodels.

To access the online documentation: Select **Help/Online**, or use the **F1 key**.



The four AMESim working modes

Creating a simulation in AMESim:

- A sketch is built by adding symbols or icons to a drawing area (Sketch mode).
- Mathematical descriptions of components are associated with the icons (Submodel mode).
- The features and parameters of the components are set (Parameter mode).
- A simulation run is initiated, then the results are analyzed (Simulation mode).

In Sketch mode, you can:

- build a new system,
- modify or complete an existing system,
- remove a component submodel

In Submodel mode, you can:

- Select a submodel for each component
- Use the Premier submodel button so that the simplest submodel is automatically assigned to each component or line

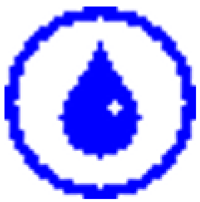
In Parameter mode, you can:

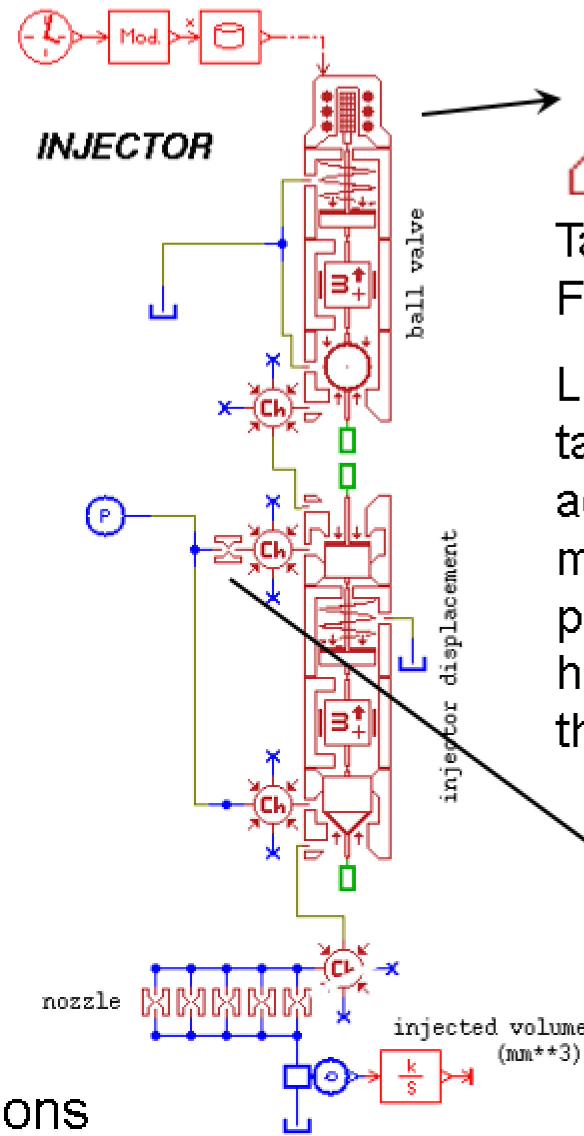
- Examine and change submodel parameters,
- Copy submodel parameters,
- Set global parameters,
- Select an area of the sketch and show common parameters in this area,
- Specify a batch run.

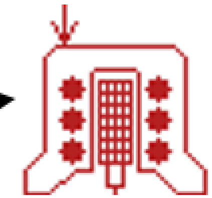
In Simulation mode, you can:

- Initiate simulation runs
- Create plots of results
- Store and load the configuration of your plots
- Initiate linearizations of the current system
- Perform various analyses on the linearized systems
- Perform Activity Index analysis

AMESim concepts: Diversity of complexity







Tabulated model with F(x,I) and L(x,I)

Lumped parameter model taking into account the actuator geometry, the material magnetic properties (without or with hysteresis, eddy current), the leakages…

Constant Bulk modulus β and density ρ

β and ρ function of pressure (aeration and cavitation)

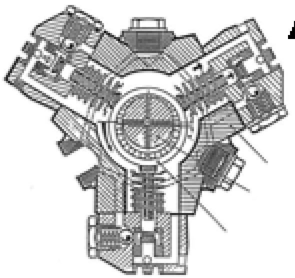
β and ρ function of pressure and temperature (thermal effects)

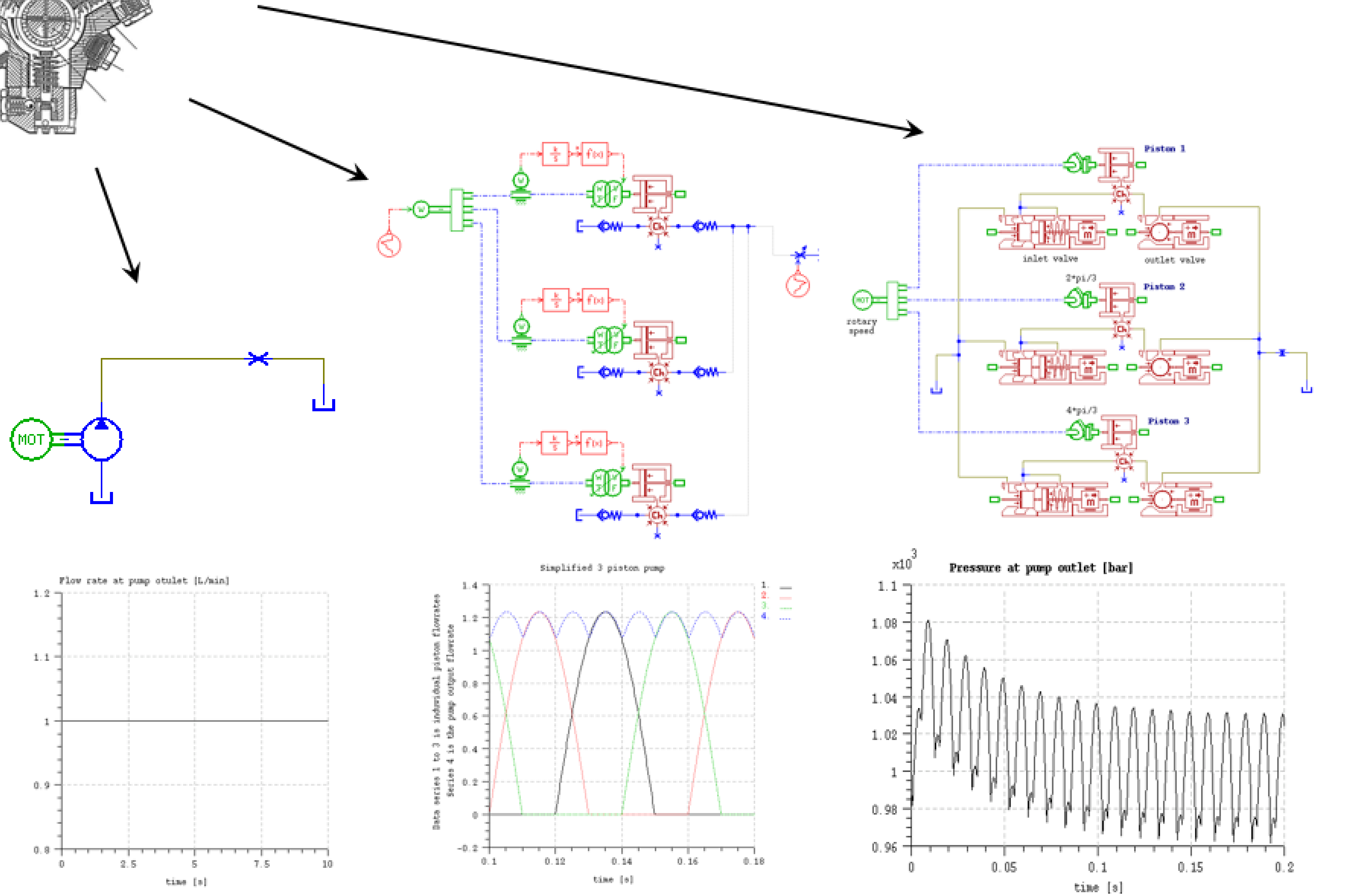
Laminar and turbulent flow

Cavitation number

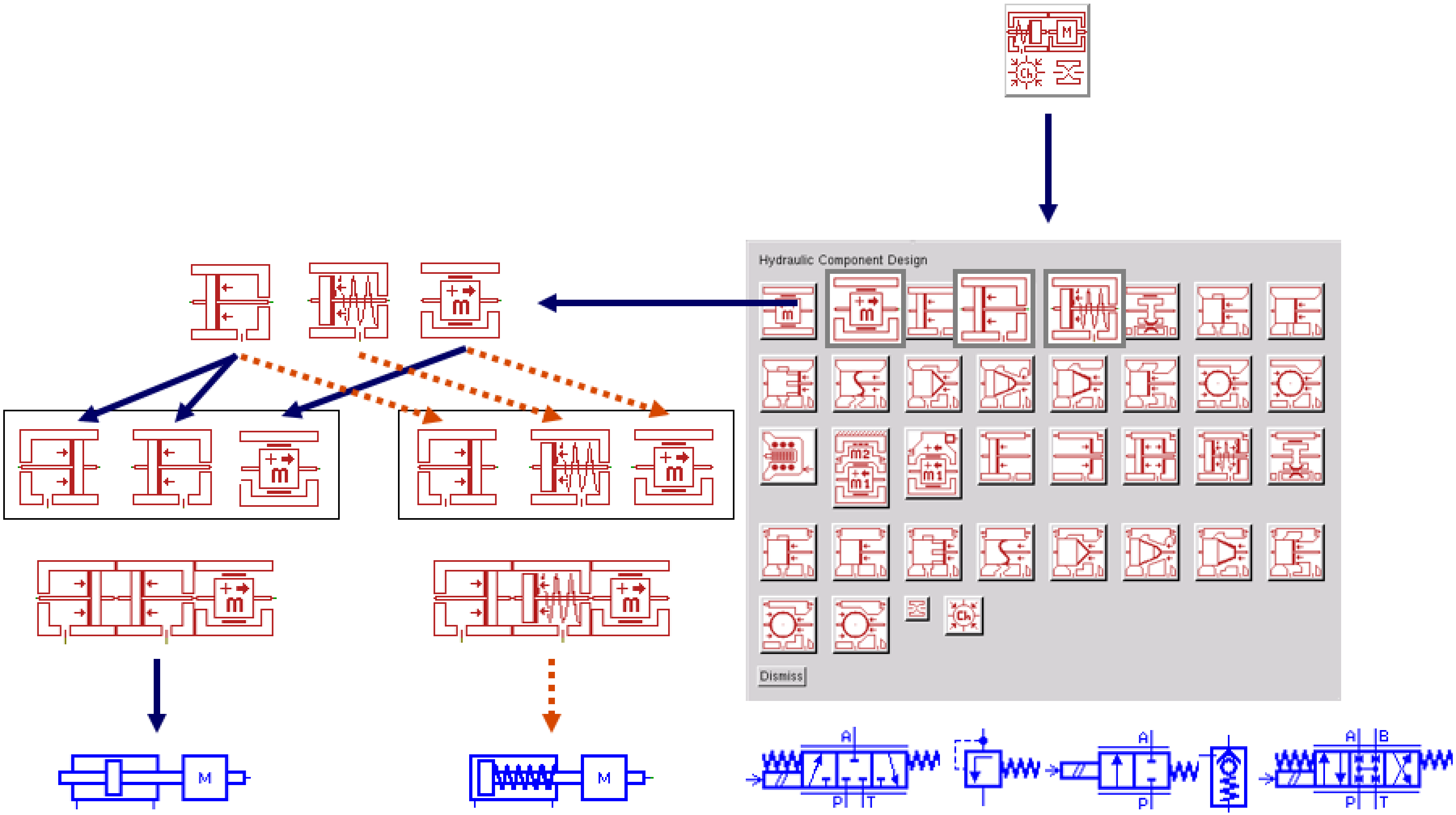
Different level of assumptions

AMESim concepts: Diversity of complexity





AMESim concepts: Basic elements

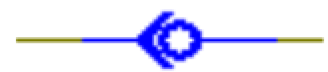


AMESim concepts: Modeling levels

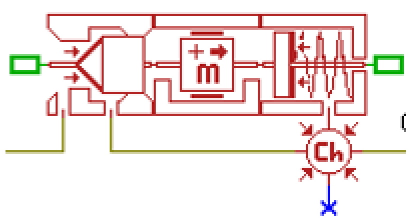
4 levels of modeling:

```
/*Calculation Function Executable Statements*/
   /* Jack area */
   area = c[0];
   *q1 = (*v3) * area / q0top_(p1);
   *f3 = (*f2) + (*p1) * area;
   *length = x0 - *x3;
   *vol1 = *length * area;
```

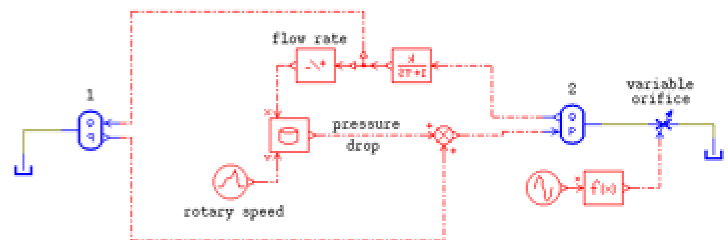
Equation level (AMESet)



Component level



Elementary technical functions



1 and 2 : conversion between hydraulic variables and signal variables

Block Diagram

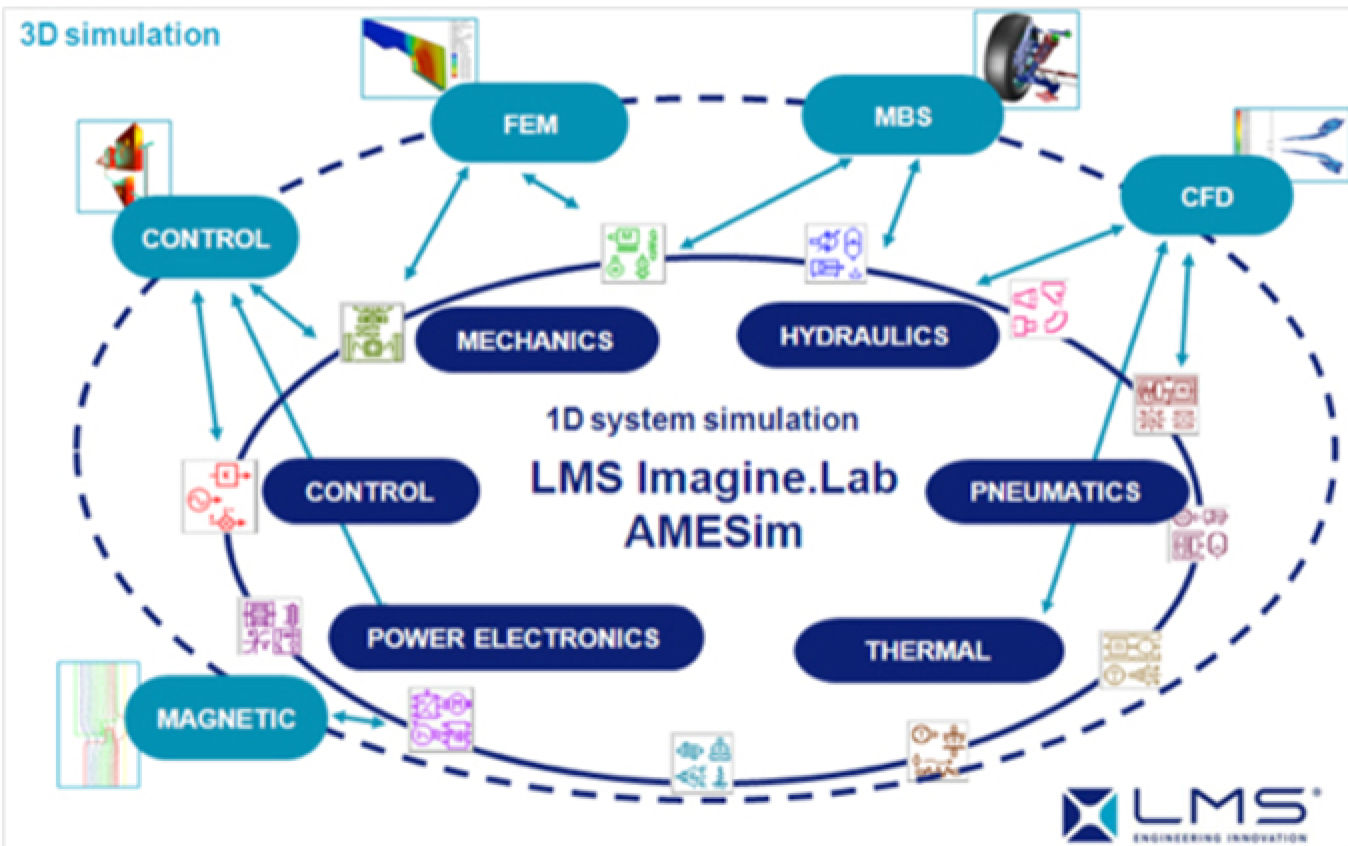
AMESim concepts: Solver

- Automatic and dynamic selection of the integration algorithm (LSODA, DASSL, DASKR)
- Fixed and non-fixed step
- Rigorous discontinuity handling
- Discrete partitioning
- Parallel processing
- Access to source code
- Co-simulation

AMESim concepts: Communication with other software

Interfaces: a direct communication path between softwares to enable them to work together so that the best features of each can be obtained.

Export facility: to pilot AMESim simulation executables from outside AMESim by defining inputs and outputs of the model and postprocessing operations.



AMESim concepts: Communication with other software

Interfaces:

- CFD software co-simulation with e.g. Fluent, CFX, StarCD, Eole
- FEM import of reduced modal basis with pre-defined frontier nodes
- MBS software co-simulation and import/export interfaces with e.g. LMS Virtual.Lab Motion, MSC.Adams

Modelica platform

- Modelica Import Assistant, Editor, Assembly, Compiler

MIL/SIL/HIL and Real-Time

- Plant/Control modeling: Simulink interface, LabVIEW interface
- Export to various Real-Time targets, e.g. xPC TARGET, dSPACE, Opal-RT, LabVIEW, Etas

AMESim concepts: Communication with other software

MIL: Model-In-the-Loop

Virtual models for the control (e.g. Simulink) and the system (e.g. AMESim) can be used and co-simulated for function specification or investigation on concepts.

SIL: Software-In-the-Loop

The generated C code for the control can be used in a virtual real-time environment. The software is connected to the system model and the operating environment of the controller is simulated.

HIL: Hardware-In-the-Loop

The control code is fully installed into the controller hardware, and can only interact with the system model through the proper IO of the controller. The system model is running on a real-time computer with IO simulations to fool the controller into believing that it is installed on the real system.

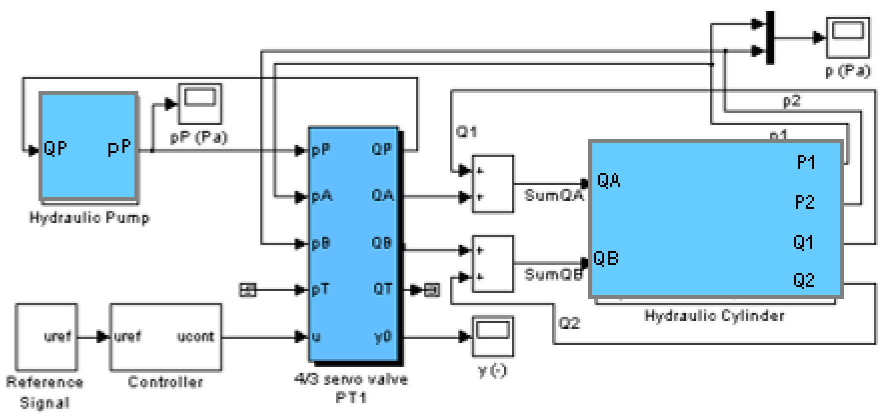
AMESim concepts: Multiport approach

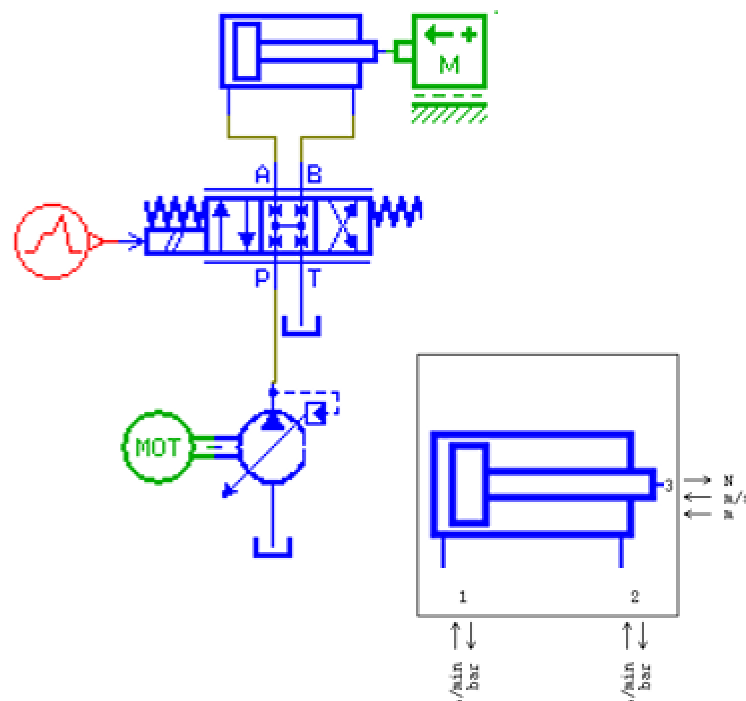
Signal approach:

- purely mathematical
- for automation experts

Multiport approach:

- components are interconnected by rules based on the exchange of power through the connections
- for engineers





AMESim concepts: Ports

Ports: The points at which icons are connected together.

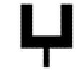
If a component icon has no ports then it cannot be connected to any other component (it can communicate though).

A port can only be connected to another port of precisely the same type. (Exception: signal ports can be attached to any other port.)

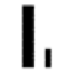
AMESim concepts: Ports

Port types:

- **Linear ports**: shafts with 1D linear motion (e.g. rod of an actuator).
  Associated quantities: force and velocity.

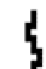


- **Rotary ports**: rotating shafts (e.g. pump and motor shafts).
  Associated quantities: torque and rotary velocity.

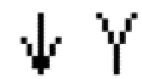


- **Flow ports**: hydraulic, pneumatic or thermal fluids representing flow inlets or outlets (e.g. hydraulic pump).
  Associated quantities: gauge pressure and volumetric flow rate (hydraulic), absolute pressure and mass flow rate (pneumatic) or absolute temperature and thermal power (thermal flow).

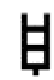
- **Electrical ports**: transmit electrical power.
  Associated quantities: voltage and current.



- **Signal ports**: transmit a quantity, the signal, to the next component. A signal is received at a signal input port and transmitted at a signal output port.
  Associated quantities: n/a



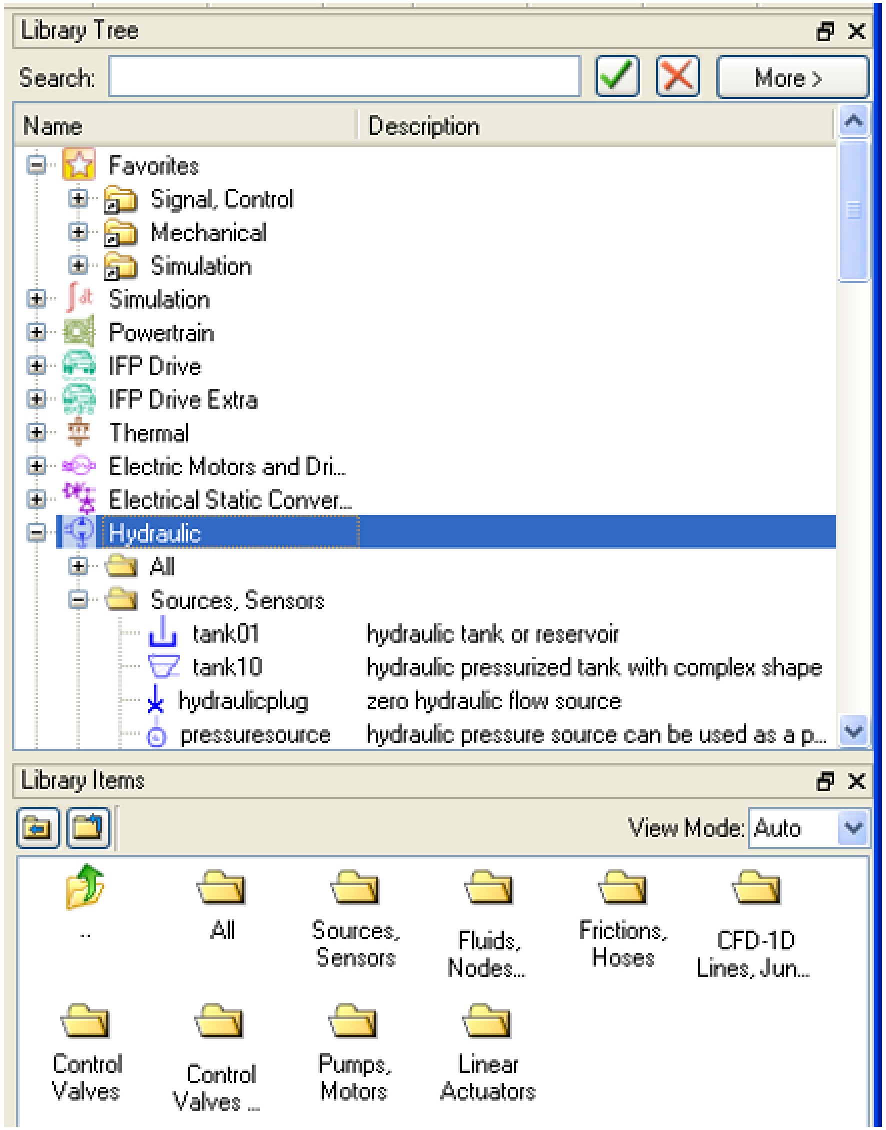
- **Thermal ports**: heat flow between solids or between a solid and a fluid.
  Associated quantities: temperature and thermal power.



AMESim concepts: Libraries

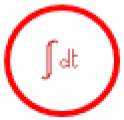
Library tree

- Each library groups its components into sub-folders
- Ability to dock the window elsewhere
- Search function
- Navigation buttons
- Docking libraries
- Favorites
- Create other folders

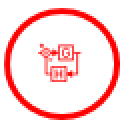


AMESim concepts: Libraries

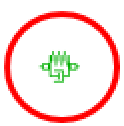
Standard



Simulation: contains components for analyzing statistics of runs, setting simulation parameters, print intervals, interactive components and for 3D models.



Signal, Control: contains all the components necessary to control, measure and observe your system. The *Signal, Control* category may be used to create block-diagram models of systems.



Mechanical: complements other **AMESim** libraries. The *Mechanical* category is often used in isolation to simulate complete mechanical systems. Linear and rotary motion elements are included.

AMESim concepts: Libraries

Additional

Air Conditioning: used to model steady state and dynamic behavior of air conditioning systems.

Automotive Electrics: used to model automotive electrical components.

Cam and Followers: used to model cams and followers.

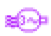
CFD1D: used to simulate gas flows in pipes and networks.

Cooling System: allows you to combine models for the cooling system, lubrication system, and exhaust system to study the complete thermal behavior of an engine.

Discrete Partitioning: used to divide big hydraulic systems into smaller sub-systems. This makes it possible to run a simulation as a form of co-simulation, improving simulation times.

AMESim concepts: Libraries

Additional

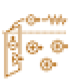


Electric Motors and Drive: used to model electric parts of the car which replace mechanical and hydraulic actuation.

Electrical Basics: contains the elements that cover basic needs for electrical components.

Electrical Static Conversion: contains the elements that cover power electronics components for electrical motors.

Electro-Mechanical: contains elements such as air gaps, metal elements, magnets and coils to construct a magnetic circuit such as a solenoid. Contains dynamic effects such as hysteresis and electric properties.



Electrochemistry components: offers a set of component submodels ready for use with existing **AMESim** components. It can be used in most engineering applications where flows of electrons and ionic species take place due to electrochemical reactions.

AMESim concepts: Libraries

Additional

- **Engine Signal Generator**: contains the elements that cover the generation of control signals for engines
- **Filling**: specialized for determination of the time taken to fill the lubrication circuits of an engine with oil during startup.
- **Fuel cell components**: dedicated to users developing fuel cell systems, for designing and optimizing the integration of fuel stacks inside systems.
- **Gas Mixture**: contains a large set of pneumatic components which can be combined to model various systems using gas mixtures with up to 20 species.
- **Generic Cosimulation**: contains submodels designed to provide co-simulation features - these submodels are designed to communicate between two solvers.
- **Heat Exchangers Assembly Tool**: used to study heat exchanger interactions within a confined environment, such as under the hood for automotive applications.

AMESim concepts: Libraries

Additional

Hydraulic: contains many general hydraulic components suitable for simulating ideal dynamic behavior based on component performance parameters.

Hydraulic Component Design: contains the basic building blocks of any hydro-mechanical system. The interpretation of the model layout is very easy and intuitive.

Hydraulic Resistance: creates large hydraulic networks, evaluate the pressure drops through the elements and modify the design of the system.

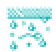
IFP Drive: used to compute fuel consumption, raw emissions and performance for conventional and hybrid vehicles.

IFP Engine: is dedicated to the modeling of performance, consumption and emissions for engines.

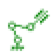
IFP Exhaust: used to model exhaust systems, and study fuel consumption and emissions of vehicles.

AMESim concepts: Libraries

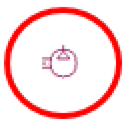
Additional



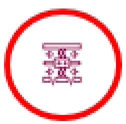
Moist Air: contains a set of thermal-pneumatic and thermal-hydraulic components for modeling systems dealing with moist air.



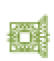
Planar Mechanical: used to model dynamics of bodies in two dimensions.



Pneumatic: contains component level models to model large networks, and basic elements to design complex pneumatic components.



Pneumatic Component Design: contains the basic building blocks of any pneumatic-mechanical system. The interpretation of the model layout is very easy and intuitive.



Powertrain: used to model systems such as driveline or complete manual, automatic or specialized gearboxes, including vibration and loss effects.

AMESim concepts: Libraries

Additional

Thermal: used to model traditional heat transfer modes between solid materials and to study the thermal evolution in these solids when submitted to different kinds of heat sources.

Thermal Hydraulic: used to model thermal phenomena in liquids and to study the thermal evolution in these liquids when submitted to different kinds of heat sources and power sources.

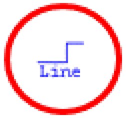
Thermal Hydraulic Component Design: used to study the pressure levels, the flow rates distribution, the temperatures and the flow rates evolution in the system.

Two-Phase Flow: used for modelling thermo-hydraulic systems where there is a change of phase (liquid-vapor).

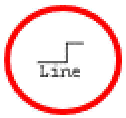
Vehicle Dynamics: is dedicated to ECU design, testing, robustness and fault diagnostics, ride and handling, behavior related to steering systems, behavior related to braking, and pre-sizing of vehicles.

AMESim concepts: Libraries

Not visible



Hydraulic lines: used to model hydraulic pipes and hoses with wave effects (lumped, distributed, Godunov, and Lax-Wendroff)



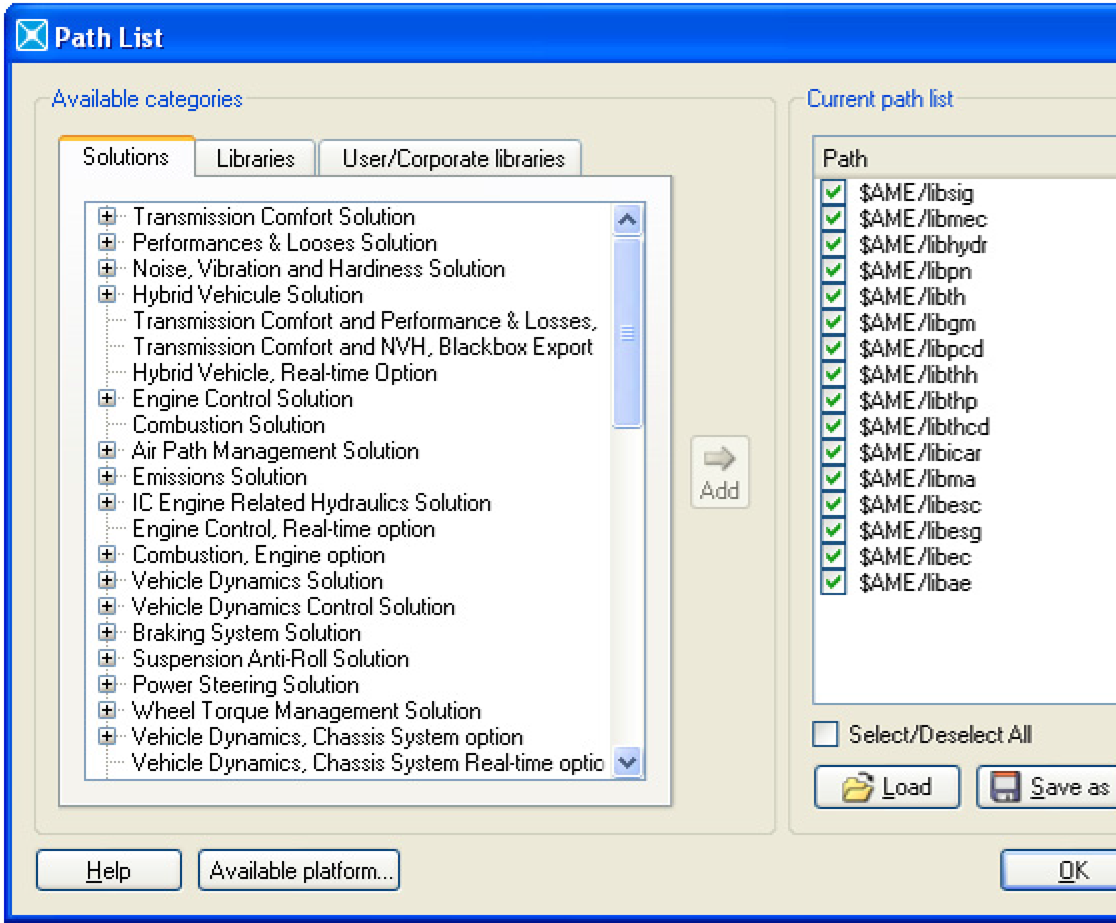
Pneumatic lines: used to model pneumatic pipes and hoses with wave effects (lumped, distributed).

AMESim concepts: Categories

The Category path list defines the Categories that will be available for modeling your system.

The Category path list controls:

- The component categories that are displayed in Sketch mode in AMESim,
- The accessible submodels,
- The way the executable files generated by AMESim are created,
- The priority for Premier submodel facility.



AMESim Best Practices

Run parameters

You can improve simulation runs by adjusting tolerance, maximum time steps, and solver types.

- Tolerance: The smaller you set the tolerance, the more accurate your results will be. Normally, tolerance should be in the range 1.0e-10 to 1.0e-3. Consider reducing the tolerance when the run does not converge.
- Maximum time step: The default value is 1.0e30, which is correct for most runs. However, occasionally AMESim takes too large steps, producing strange results. In such circumstances, you should reduce this value.
- Solver type: Using Cautious ensures that the maximum time step is limited to the value of the print interval.