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Amesim液压系统在军工行业高级应用

邓博文 西门子工业软件 系统仿真高级顾问

Agenda:

系统仿真概述
军工行业的应用概述
军工行业-液压应用
液压高级应用
总结

Simcenter system simulation solutions
Solution landscape

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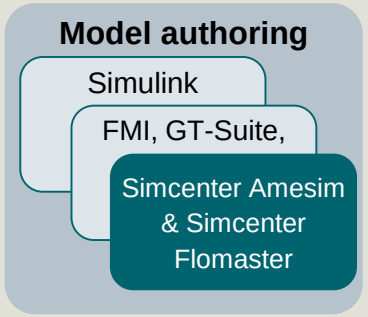
Persona's

System simulation model authors

- System simulation **model authoring**
- **General purpose mechatronic system simulation and thermo-fluid** platforms

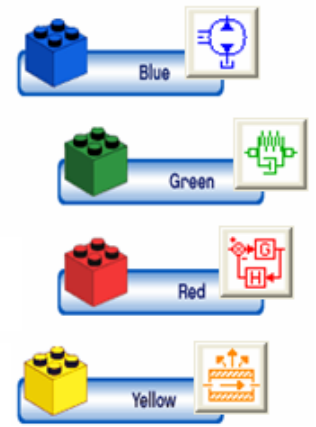
Taxonomy

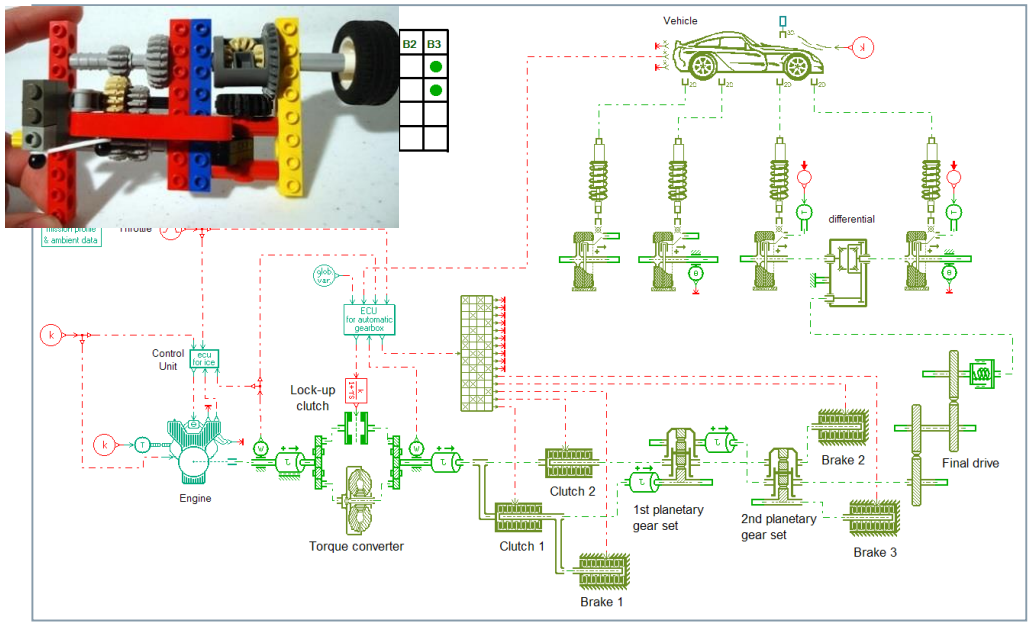
Simcenter System Simulation



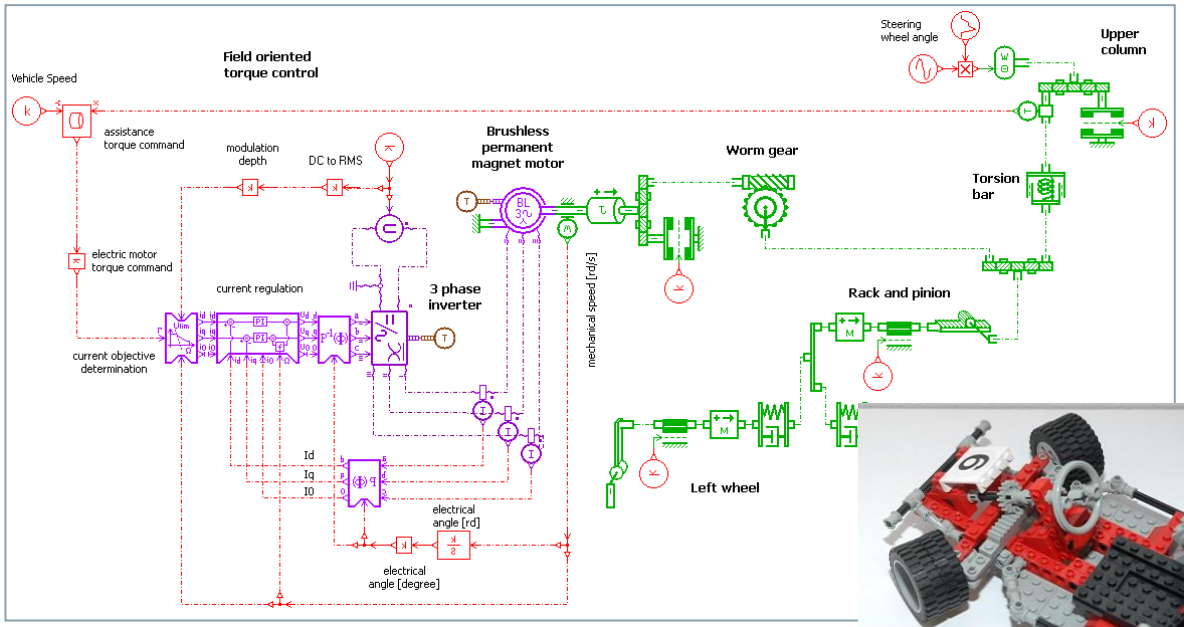
Modeling?

- Amesim as a **multi-domain tool** with compatible libraries:
  - 机械: common mechanical models
  - 传动: advanced mechanical systems acting in powertrain
  - 电子电气: electrical basic components
  - 电机: elements of rotary motors
  - 液压: elements for hydraulic circuits
  - 汽车、航空: elements to build emission and fuel economy models





变速器



电控单元

“Model” for Systems Performance Engineering

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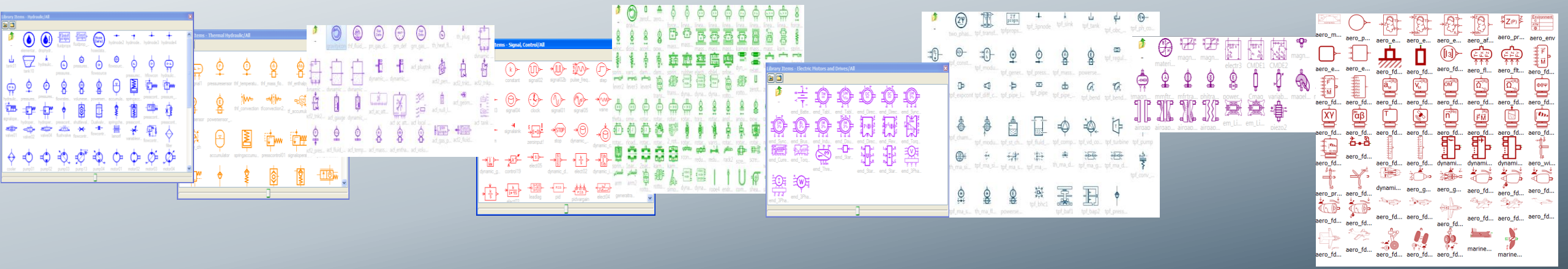
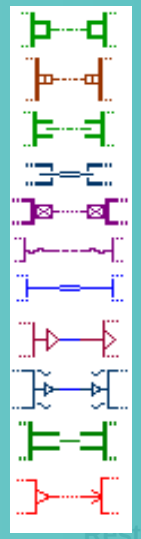
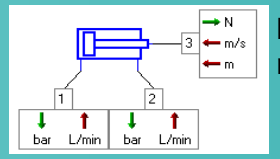
50+ 专业库，5000+物理模型， 机电液热控专



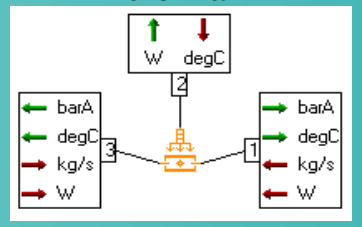




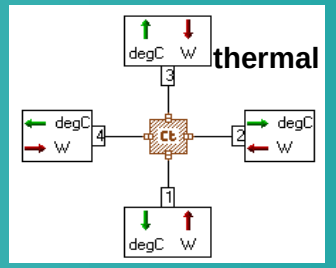
linear
mechanical

hydraulic

thermal

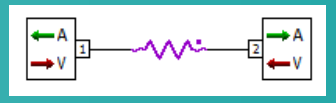


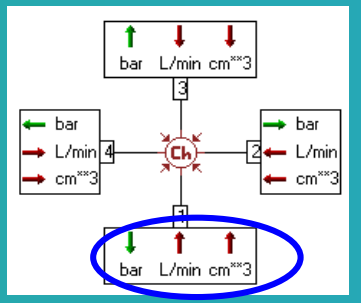
thermal
hydraulic

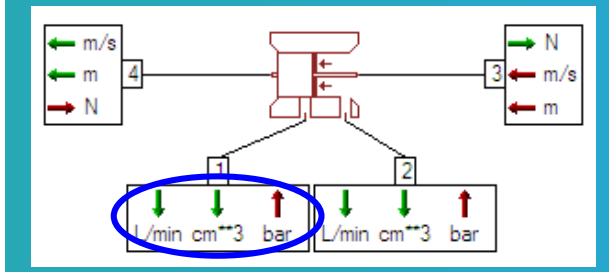


thermal

electrical







位置伺服控制系统

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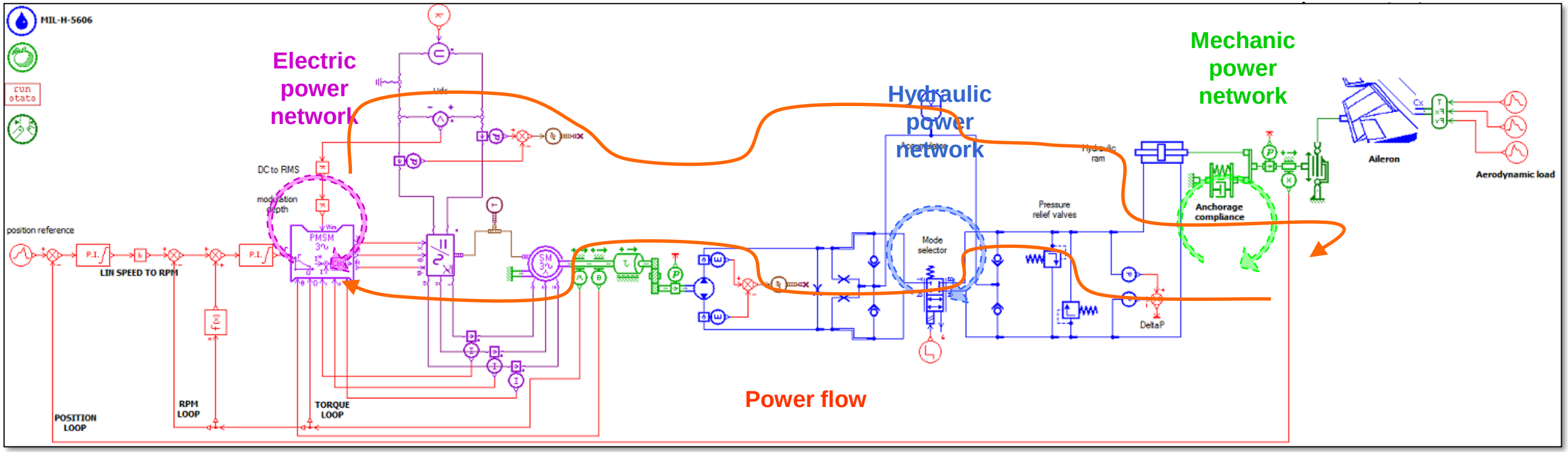

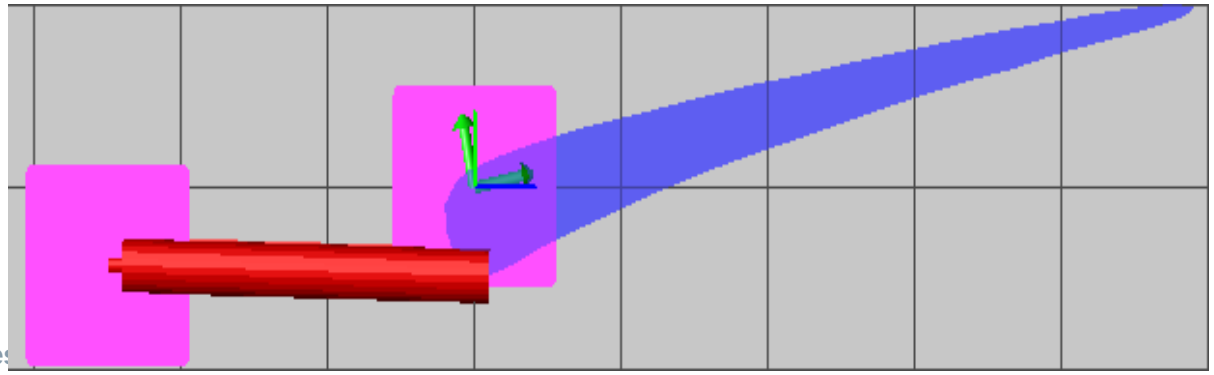

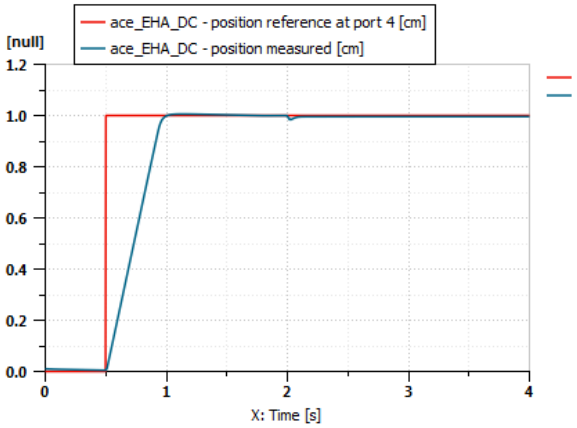

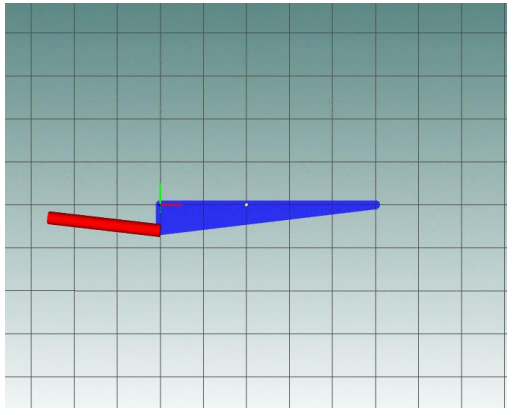

Simcenter system simulation solutions
Solution landscape

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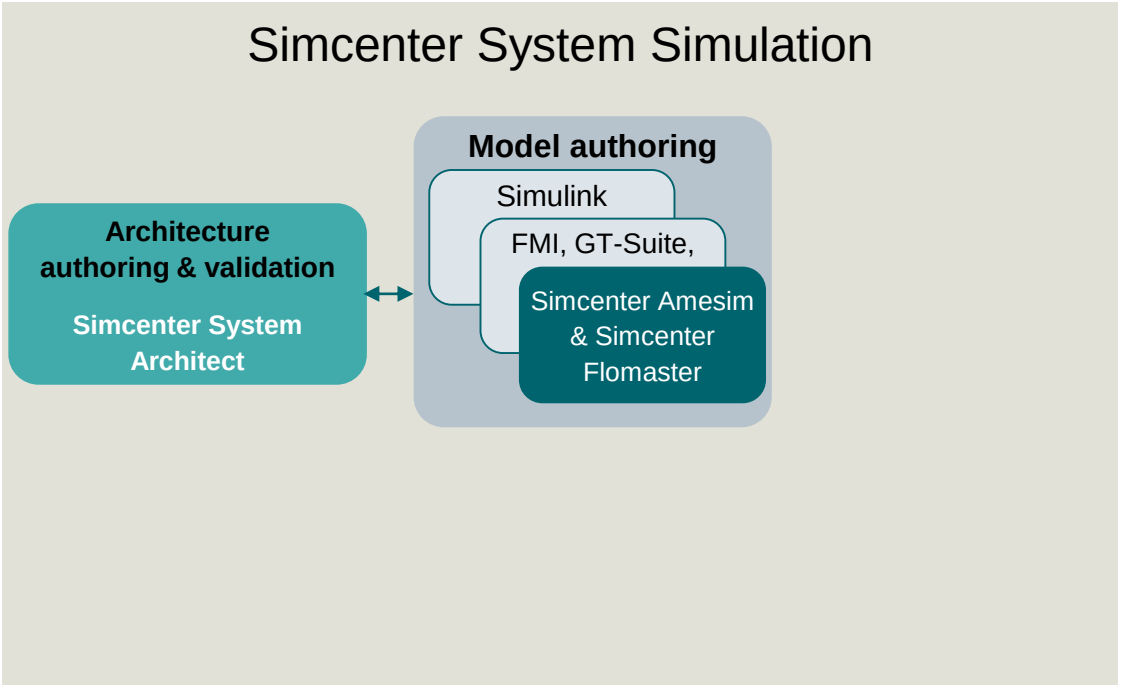
Persona's

System simulation model authors
- System simulation **model authoring**
- **General purpose mechatronic system simulation and thermo-fluid** platforms

System simulation architects
- System simulation **architecture authoring**
- **Architecture validation** by assembly, execution & post-processing of system simulation models from multiple authoring environments
- Typically **few architectures** created p. company

Taxonomy



Simcenter System Architect

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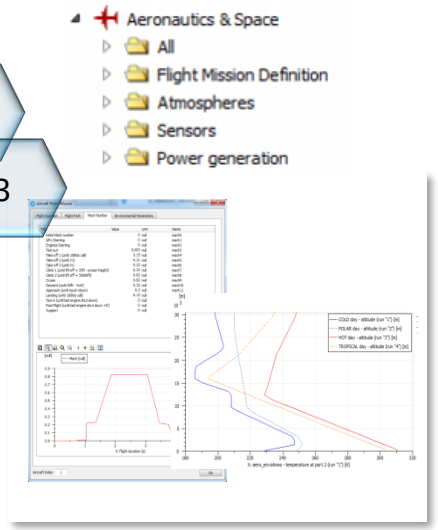
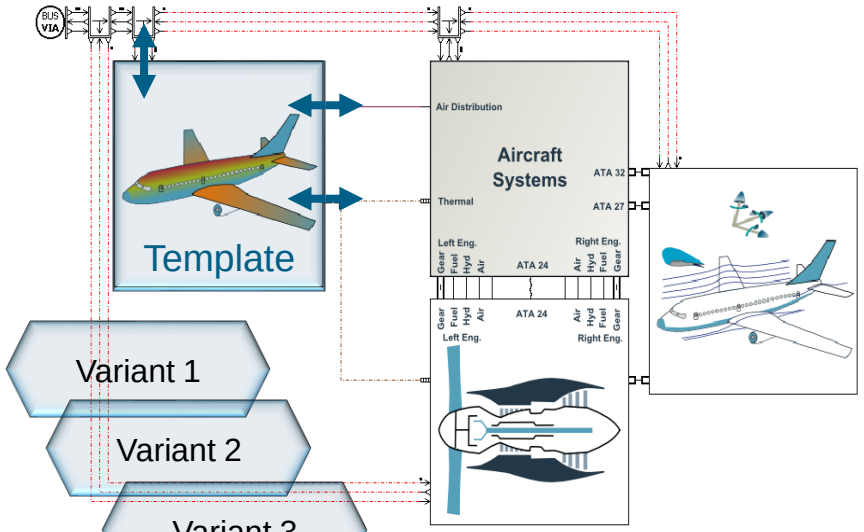
Scenarios

Scenario 1
Scenario 2
Scenario 3
…



Manage and execute multiple **scenario's.**

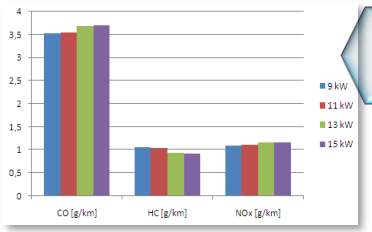
System model – Architect and analysis



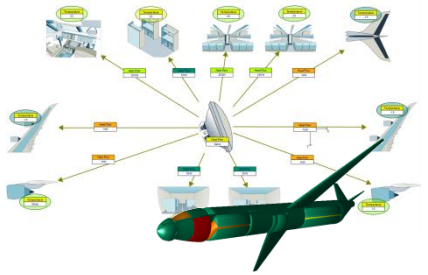
Variant 1
Variant 2
Variant 3
…

Ensure **integration** of behavioral models created in different tools by different departments.

Performance



Attribute 1
Attribute 2
Attribute 3
…



Manage and evaluate multiple **variants**.

Enable **multi-attribute balancing**.

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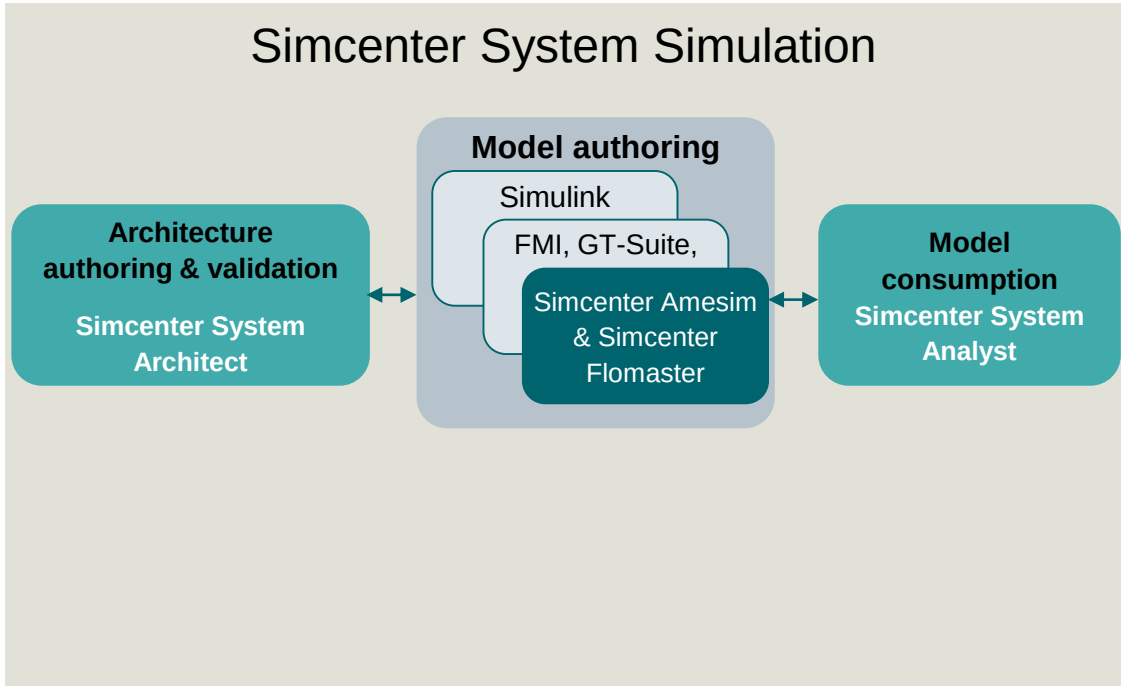
System simulation consumers
- **"Consumption"** of created architectures and models for high volume/variants/… verification & validation
- **Easy-to-use, high-productivity**, extended with dedicated to specific industry capabilities (f.i. terminology, post-processing, etc.)
- **Many (non-expert) users**

Taxonomy



Model complexity hidden to the Analyst

no CAE skills、 directly assembling and configuring simulation models

evaluate hundreds of system variations and select appropriate parameters and components

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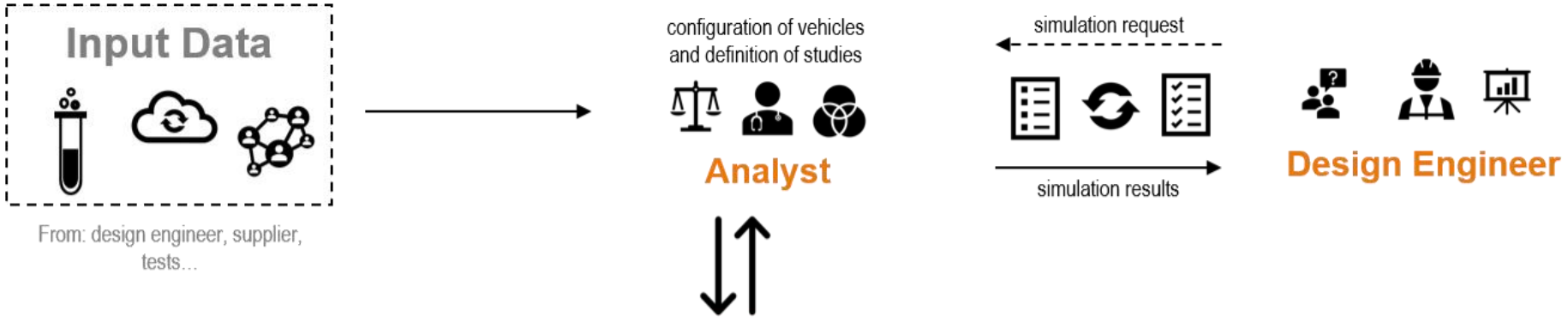

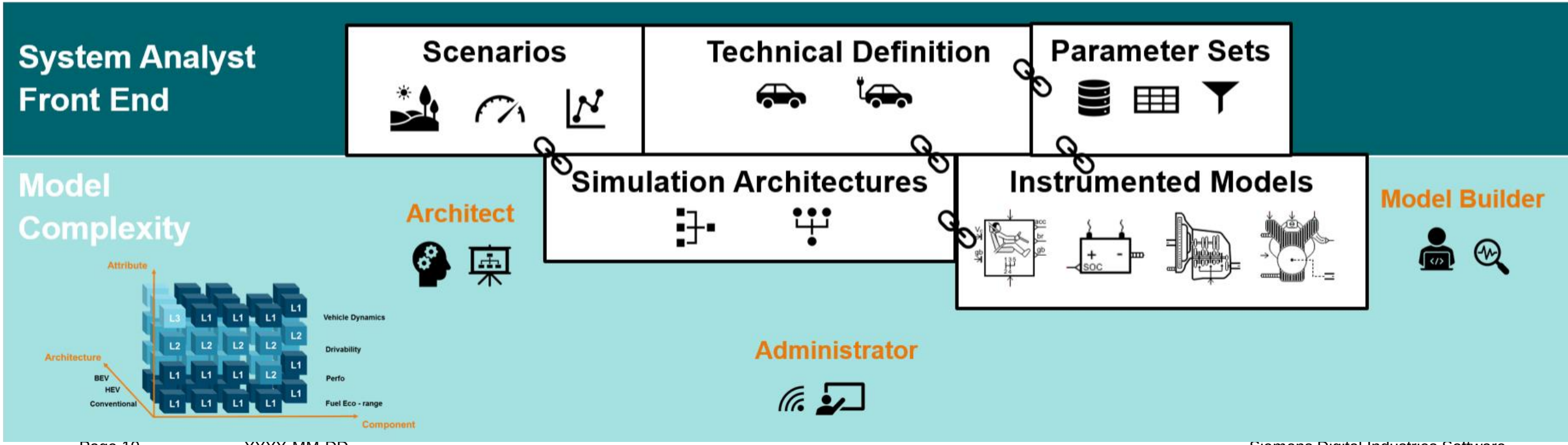

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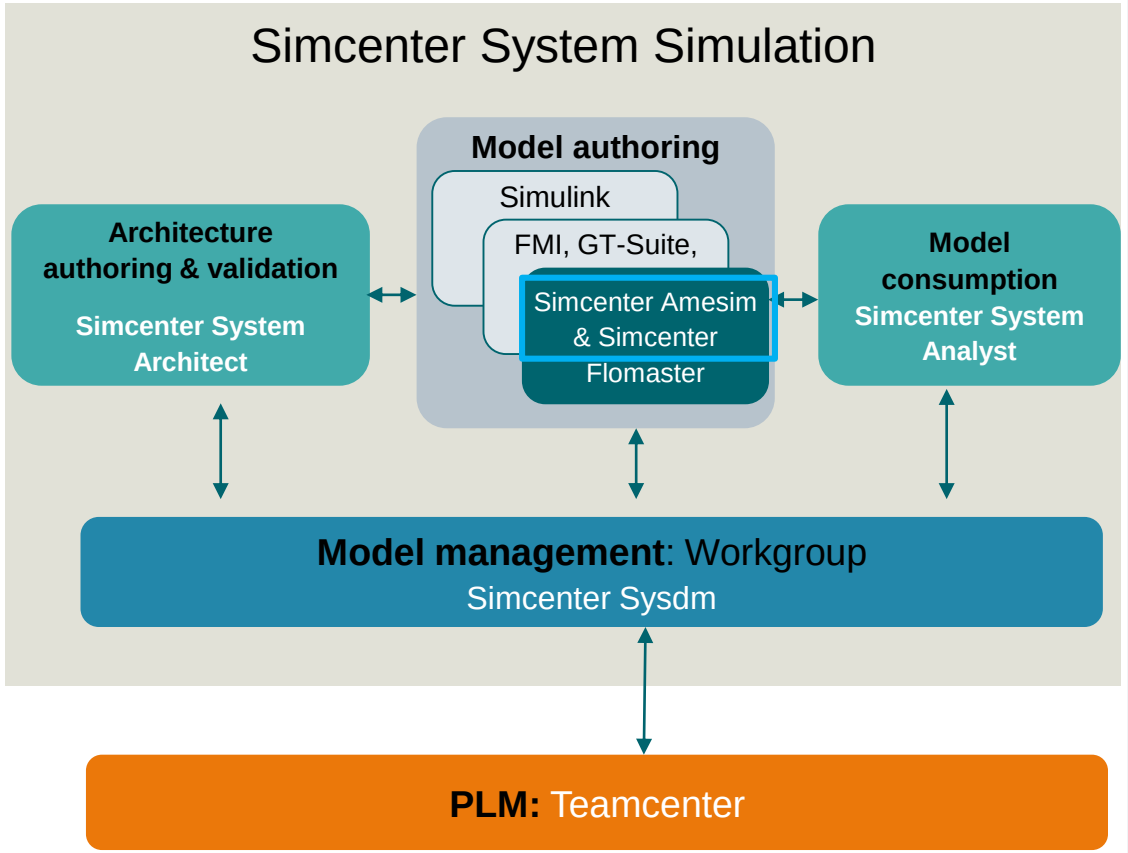
System simulation model management supporting all above persona's
- **Workgroup model management with a connection to PLM**

Taxonomy



Agenda:

系统仿真概述
军工行业的应用概述
军工行业-液压应用
液压高级应用
总结

航空行业

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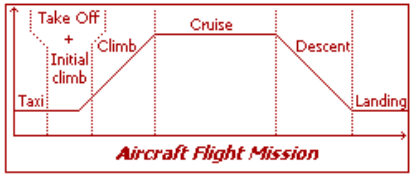
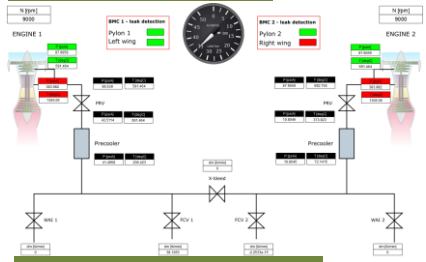
- 统一的仿真体系管理思路，实现子系统/系统/整机级的耦合仿真。
- 通过各种飞行工况、控件及仪表的定义，开展虚拟试验，减少实物试验。
- 虚拟集成飞机包含机械、电气、液压、气动、热和控制等，实现多学科和多物理的融合。

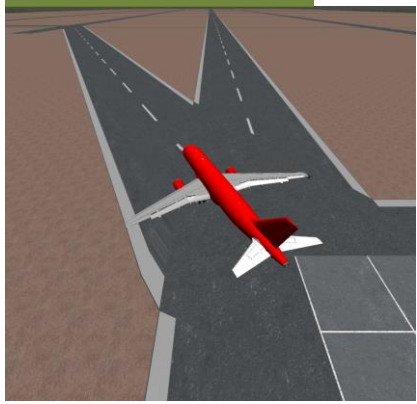
飞行工况



控件及仪表



3D显示等处理



航空行业

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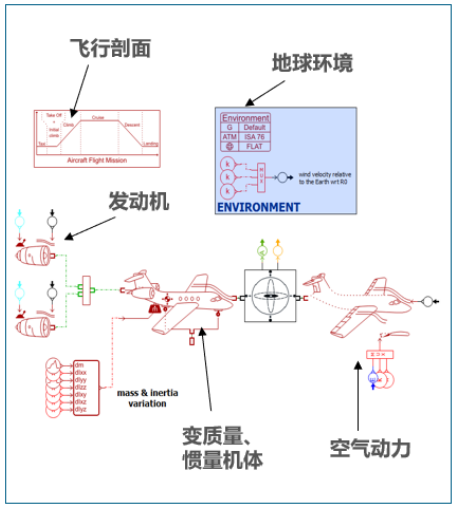
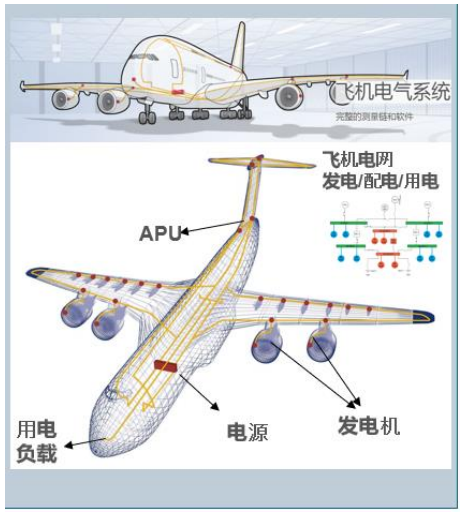
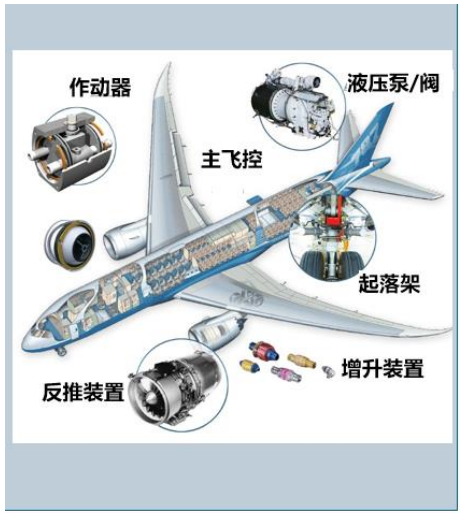
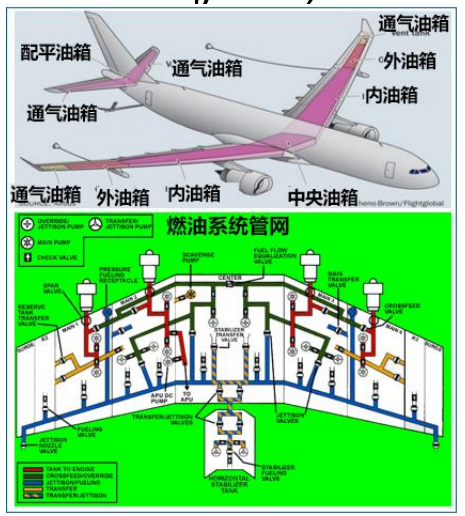
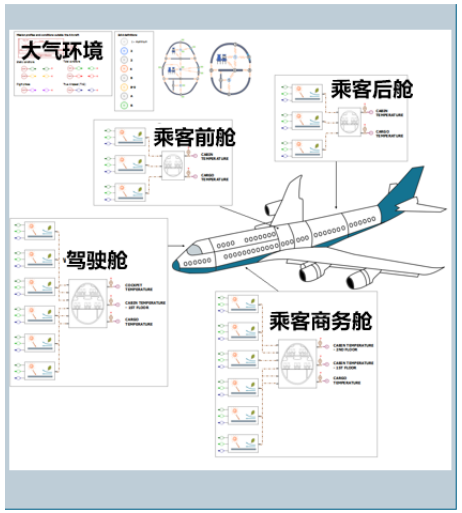
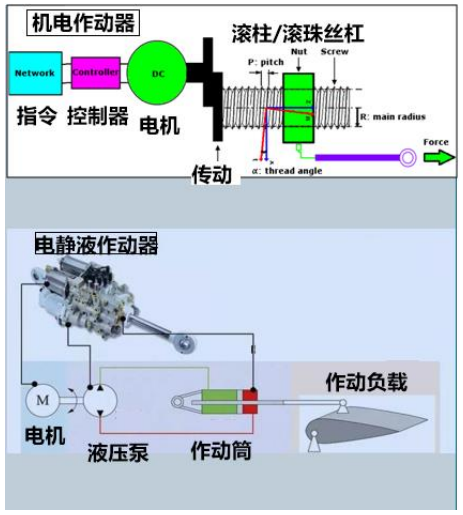


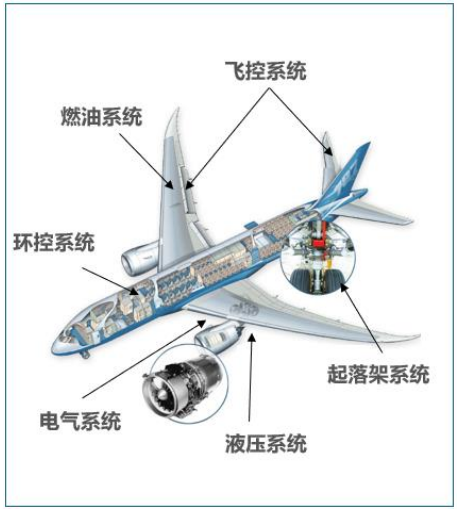




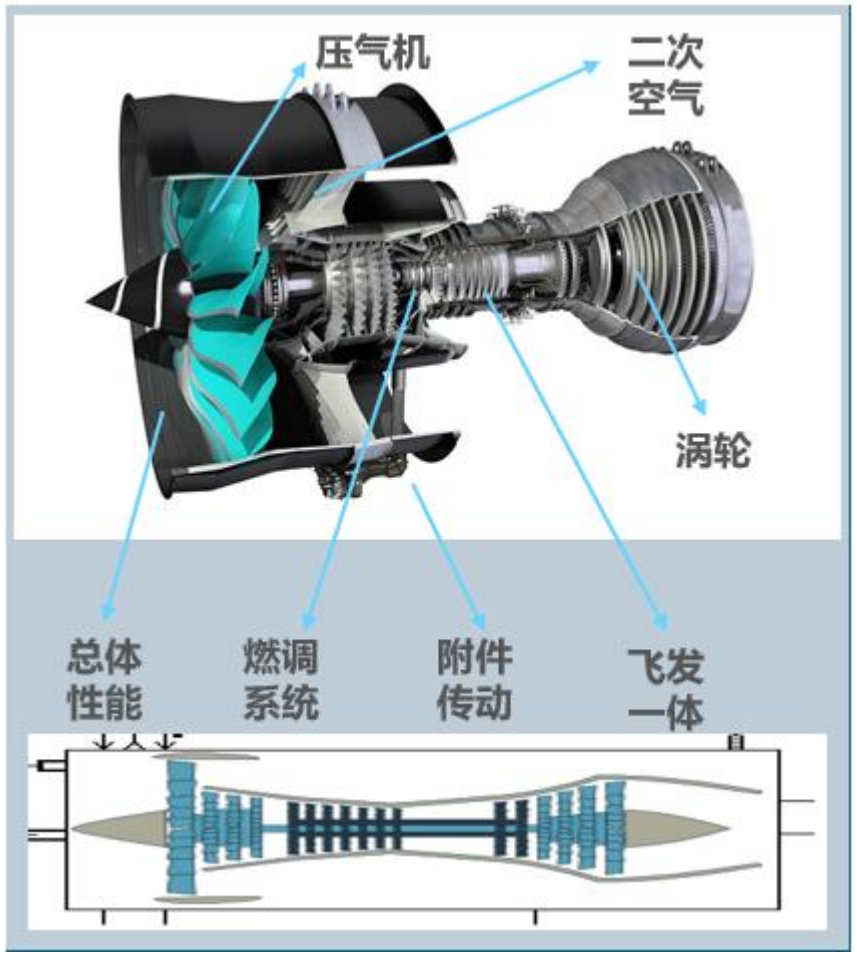


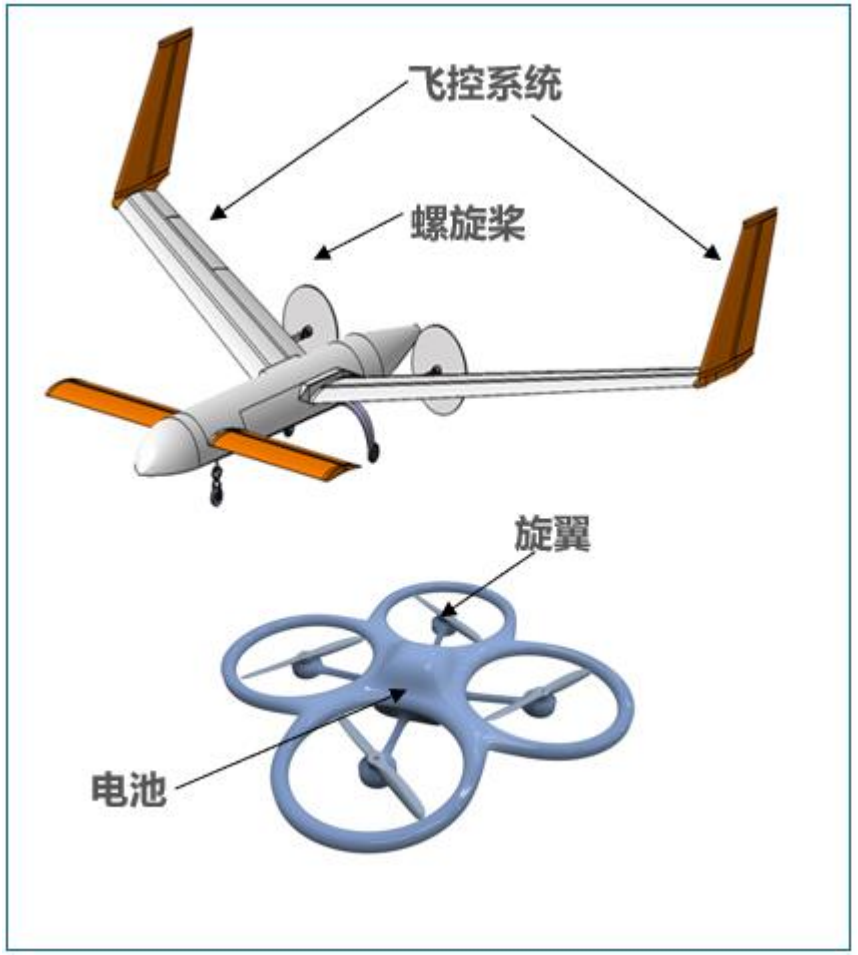






航空行业





航天兵器行业

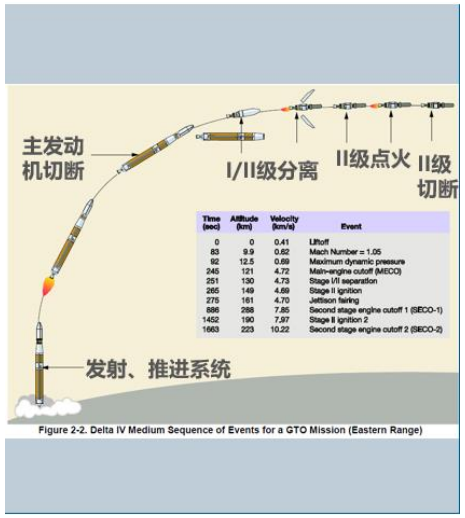
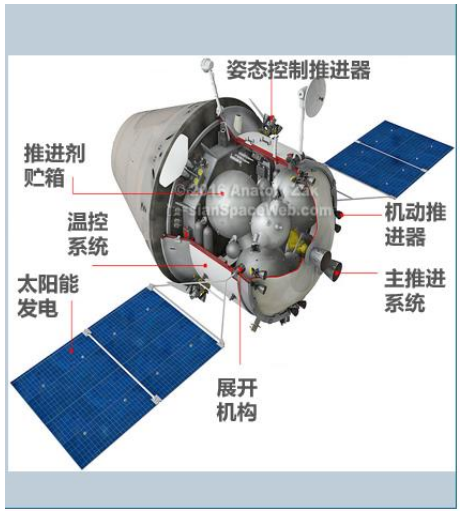
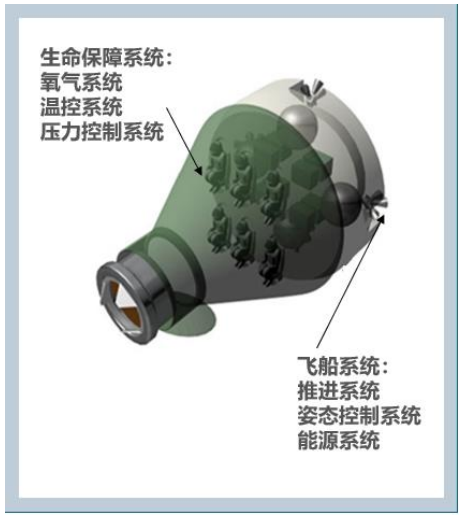
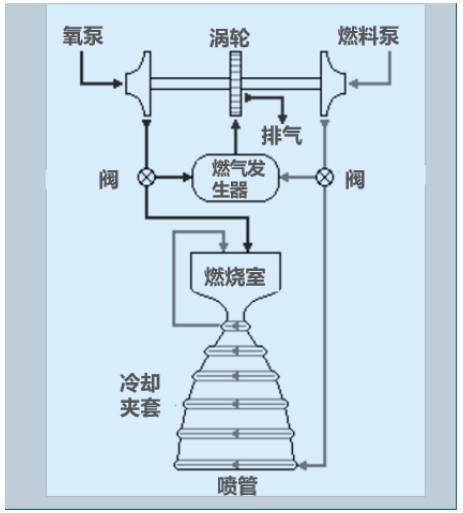


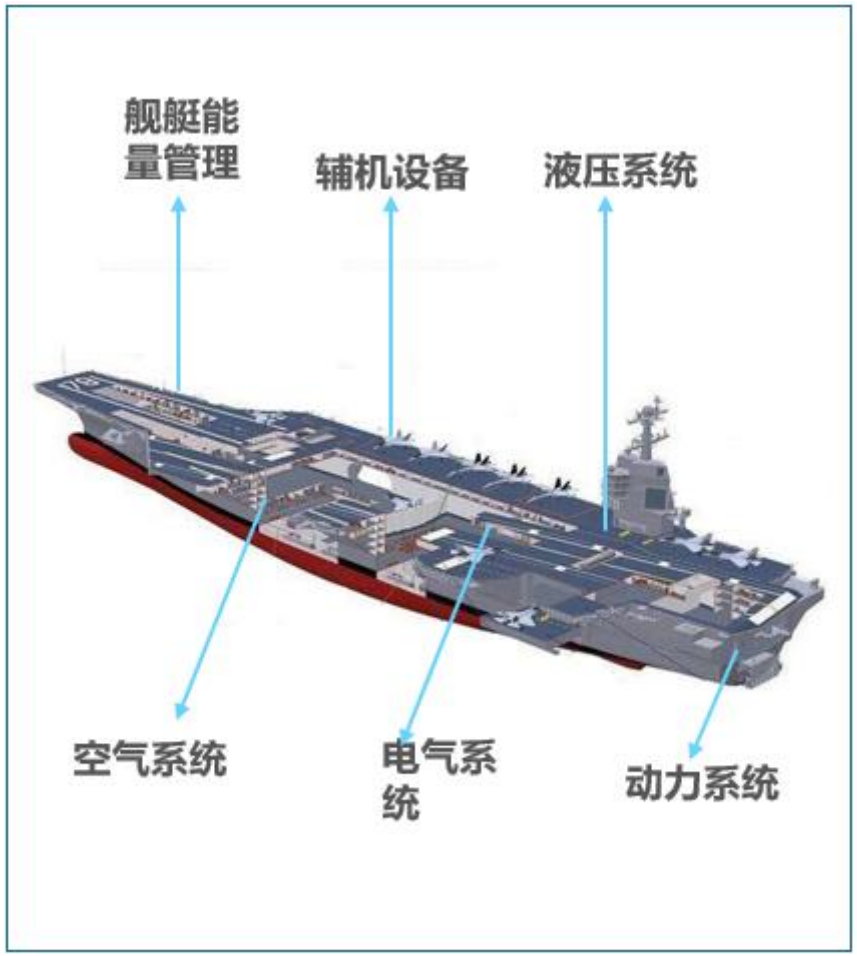
Figure 2-2. Delta IV Medium Sequence of Events for a GTO Mission (Eastern Range)

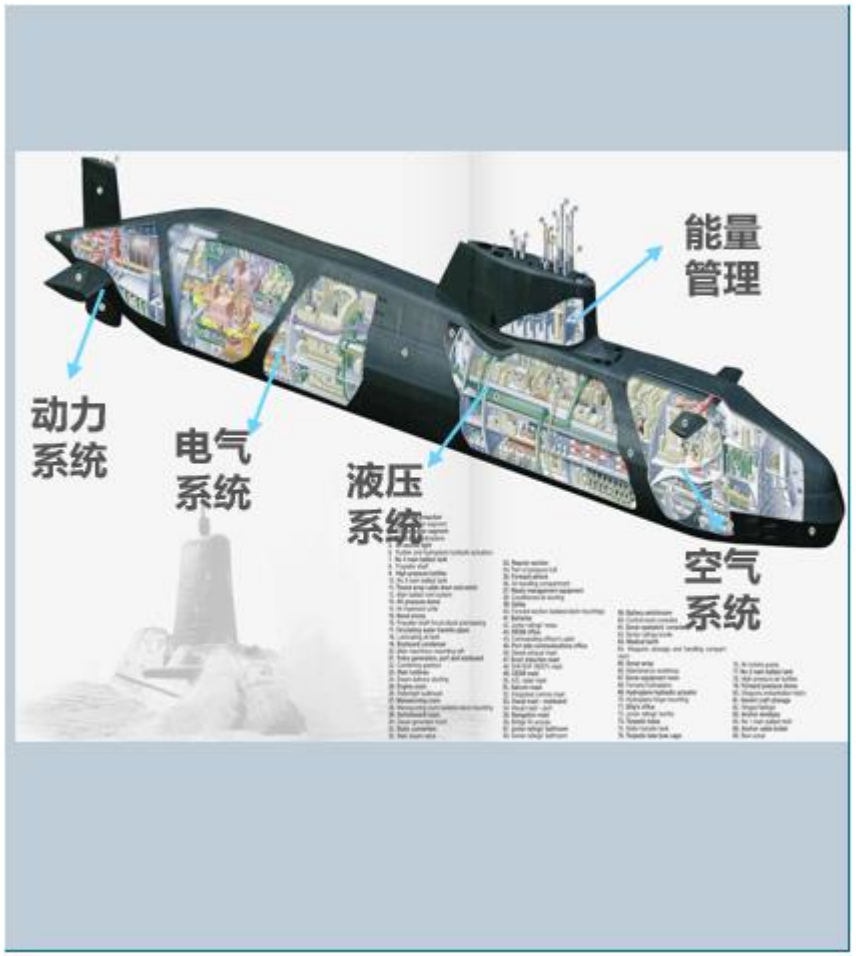






船舶行业





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总结

1.Predictive modeling of aircraft hydraulic & electrical systems for “What-if analysis”

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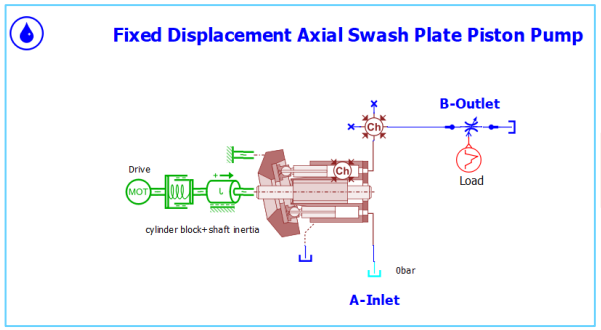
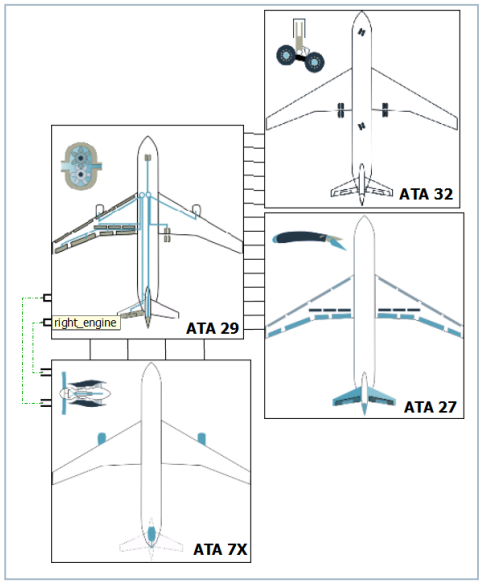
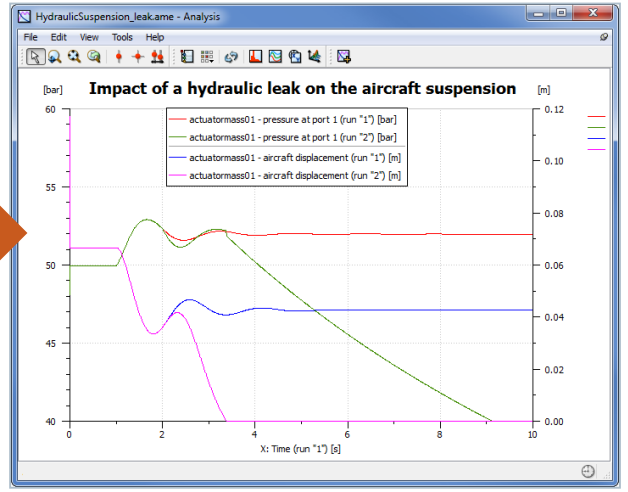
Hydraulic power system



Simcenter Amesim model

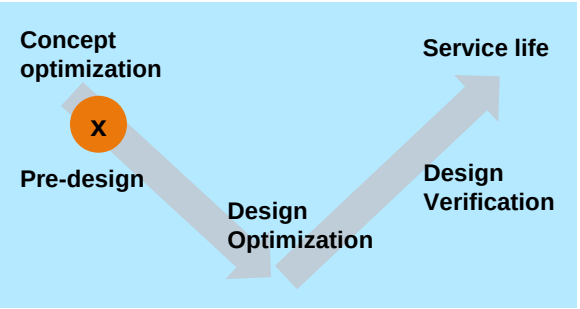


Virtual test bench



Value-adding outcome

- Ability to answer OEM request → credibility gain
- Tool for strategic design orientation → more efficient research process



perform a high level power analysis

assess the flow balance between the hydraulic power generators and consumers and the pressure available.

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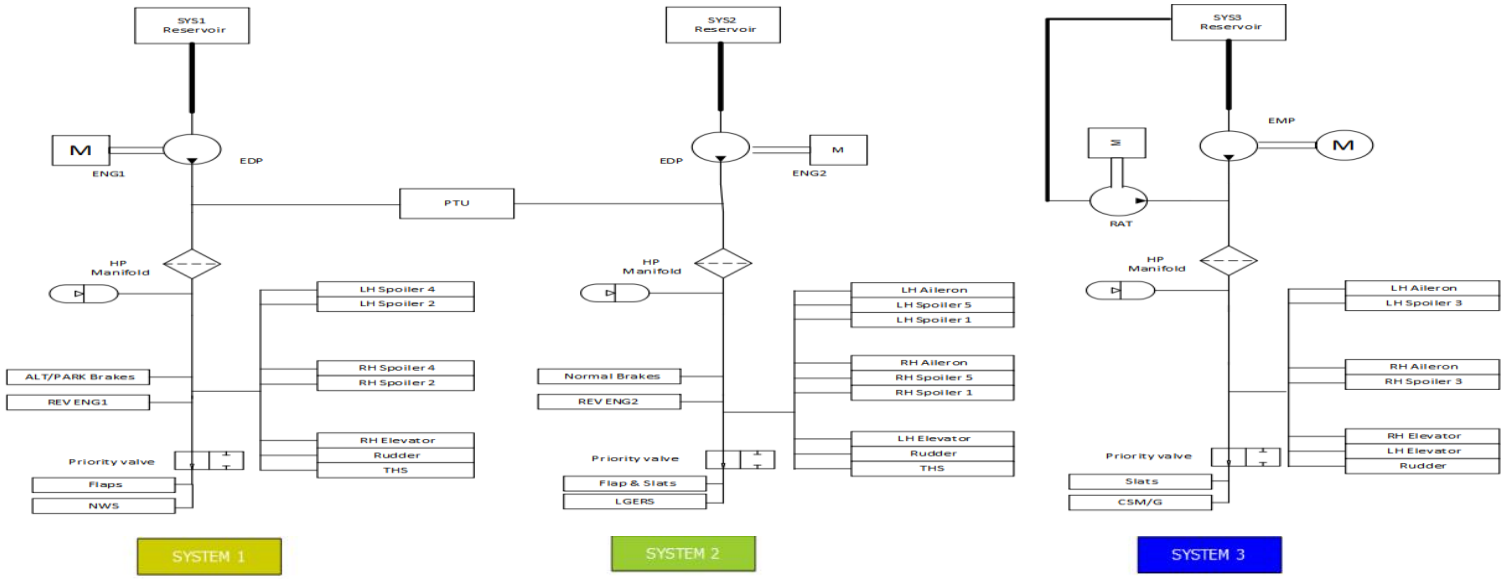

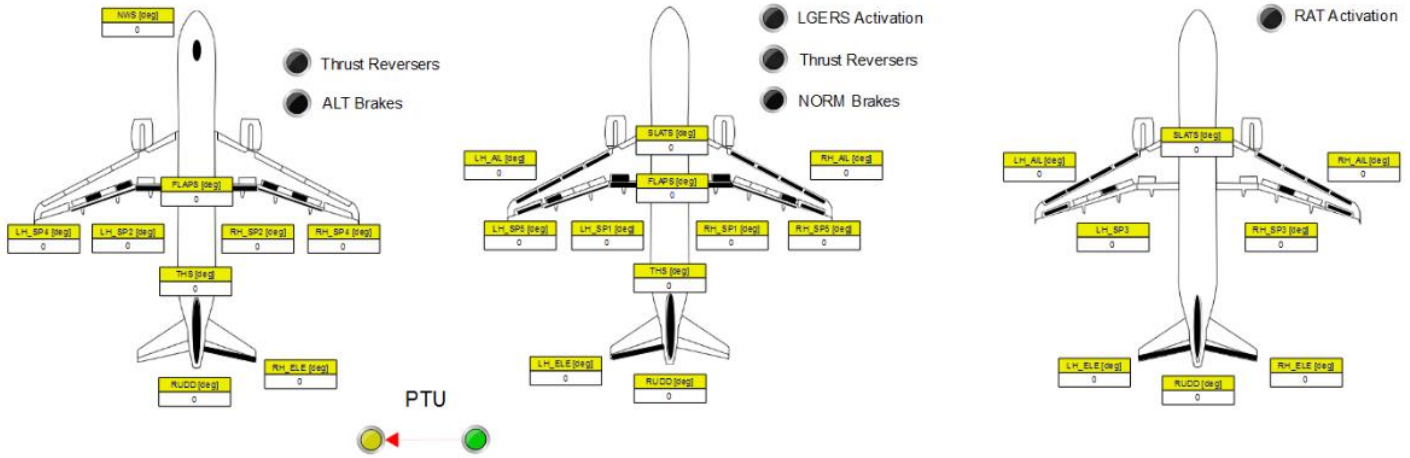

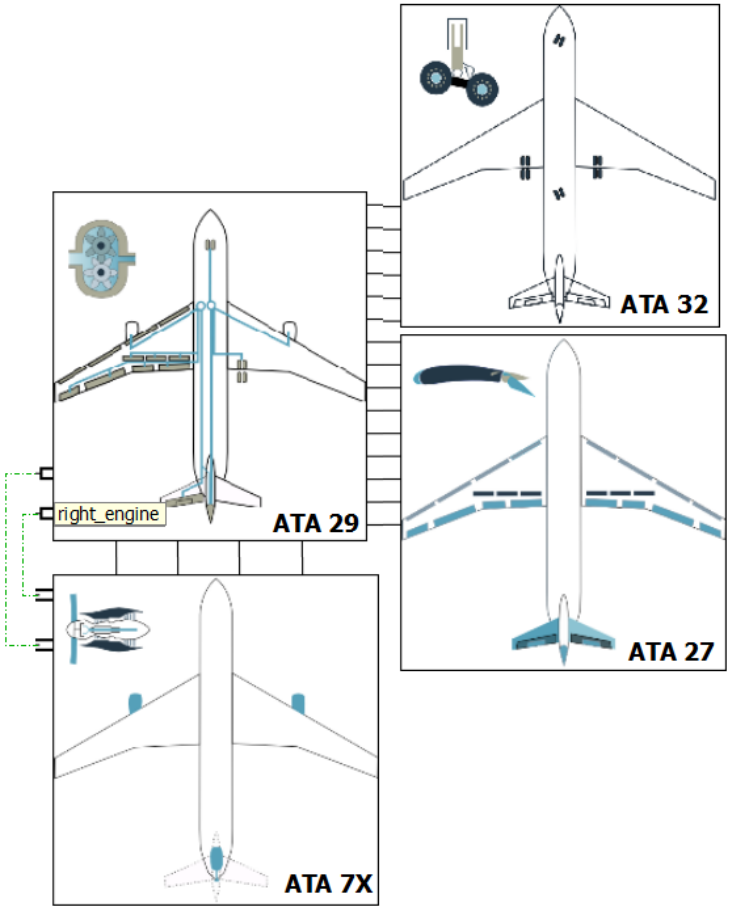

L. Wang – INSA Toulouse – France – [thesis]

Force fighting for active/active redundant actuation system

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2012

Présentée et soutenue par :
LIJIAN WANG
Le mardi 18 décembre 2012
Titre :
Force Equalization for Active/Active Redundant Actuation System Involving Servo-hydraulic and Electro-mechanical Technologies

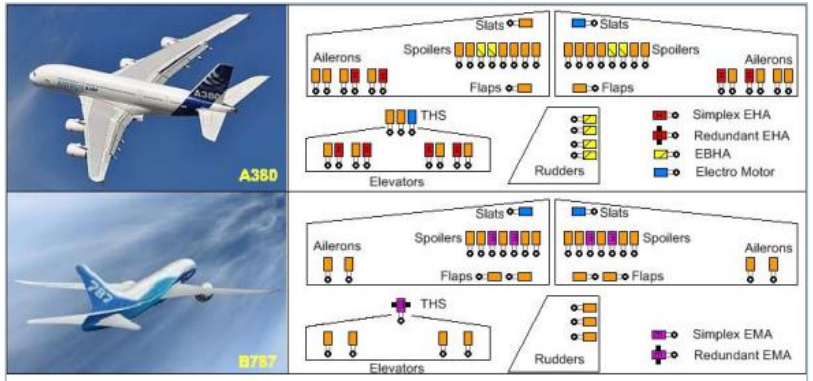

Fig 1-5 Development from early FBW system to recent applications

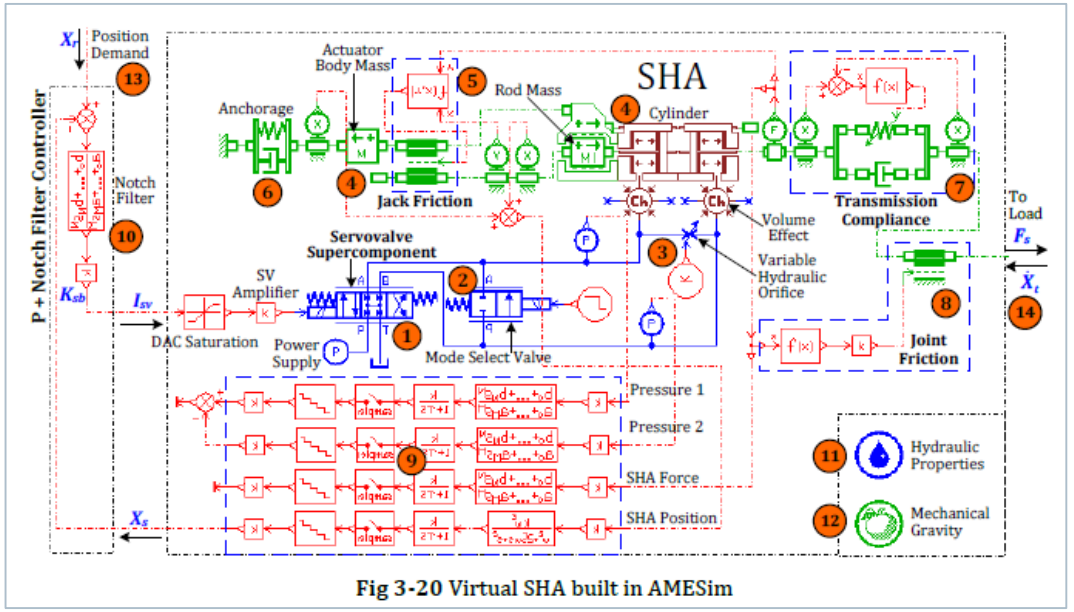

Fig 3-20 Virtual SHA built in AMESim

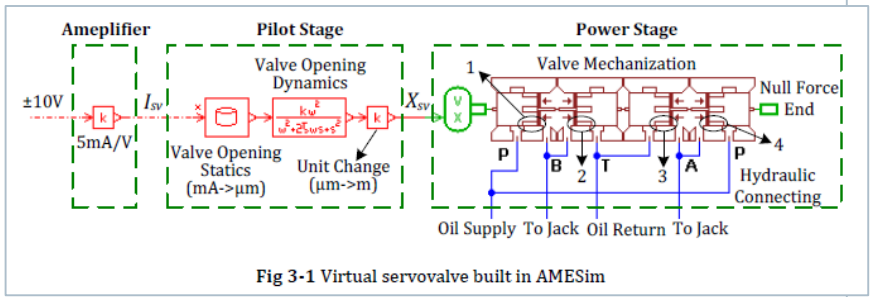

Fig 3-1 Virtual servovalve built in AMESim

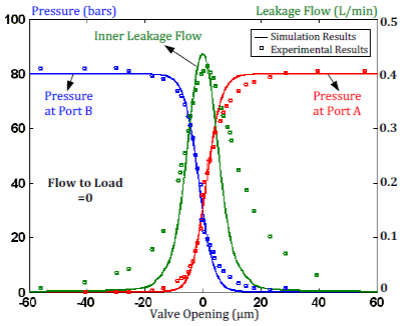

Fig 3-4 Comparison of simulation and experimental results on valve pressure gain

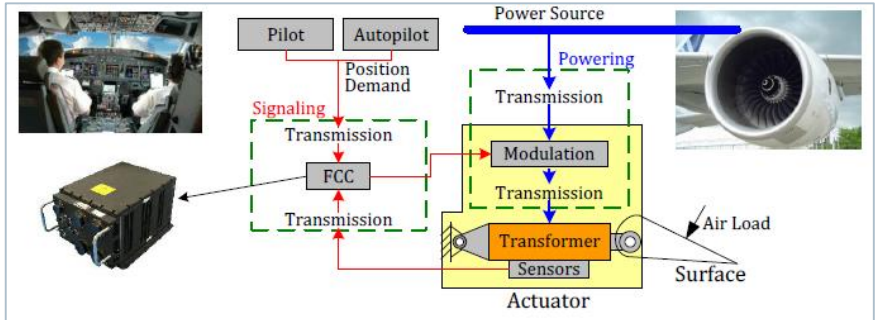

Fig 1-3 Configuration of flight control system

Helicopter cooling
2.Thermal and fluid design up to industry standards

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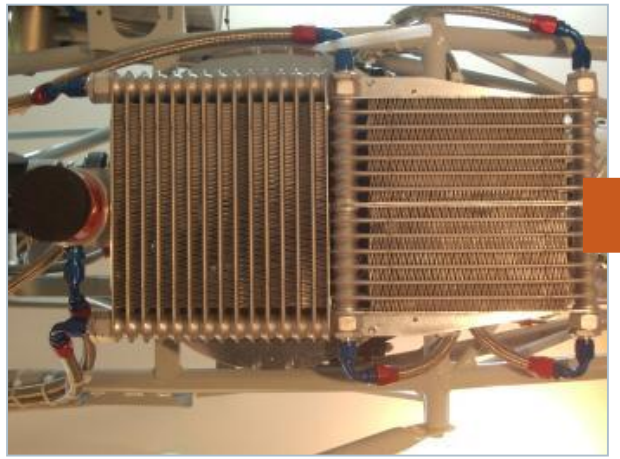
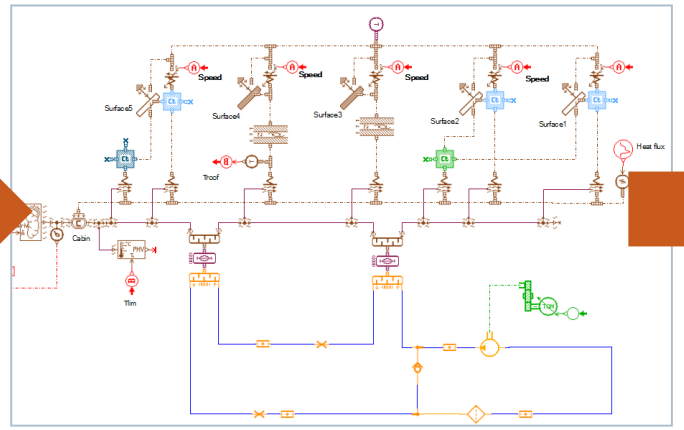
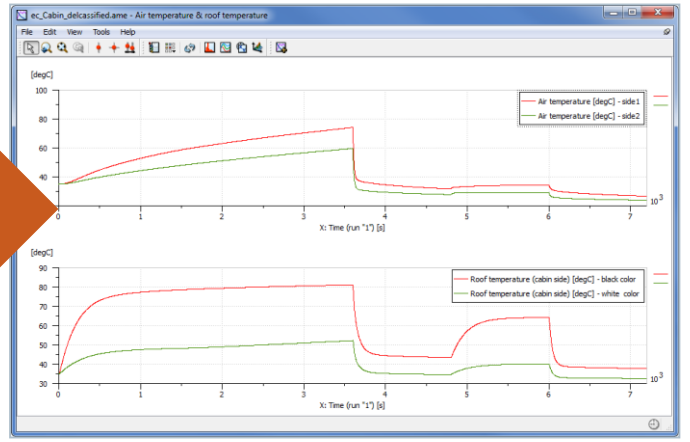
Cooling system



Simcenter Amesim model

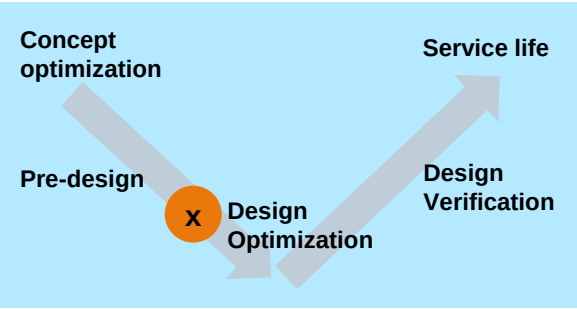


Analysis of gearbox and engine cooling



Value-adding outcome

- Controlled & validated process for cooling design:
  - → More robust cooling systems
  - → Better managed design cycle times



T. Rave and al. – Hamburg-Harburg TU – Germany – [paper]

Integrated thermal-dynamic analysis of airplane hydraulic systems

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2013

INTEGRIERTE THERMISCH-DYNAMISCHE ANALYSE VON FLUGZEUG-HYDRAULIKSYSTEMEN

T. Rave, C. Dunker, F. Thielecke
Technische Universität Hamburg-Harburg, Institut für Flugzeug-Systemtechnik
Neßpriel 5, 21129 Hamburg, Deutschland

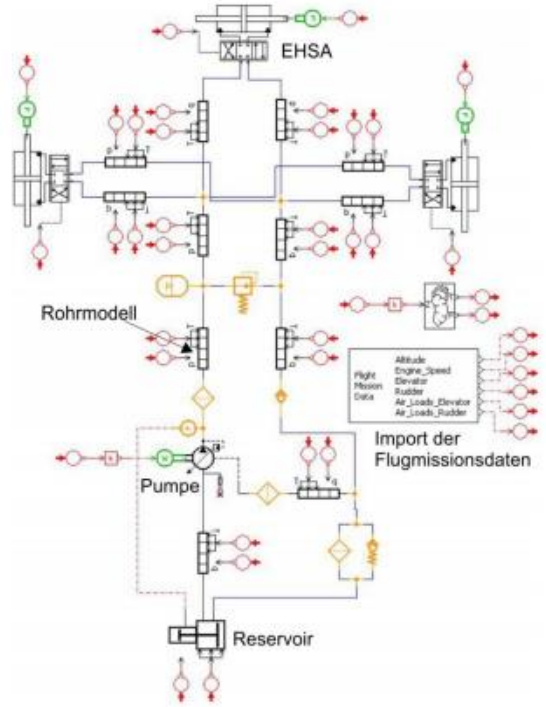

BILD 5. AMESIM System mit verschiedenen Komponenten der Modellbibliothek

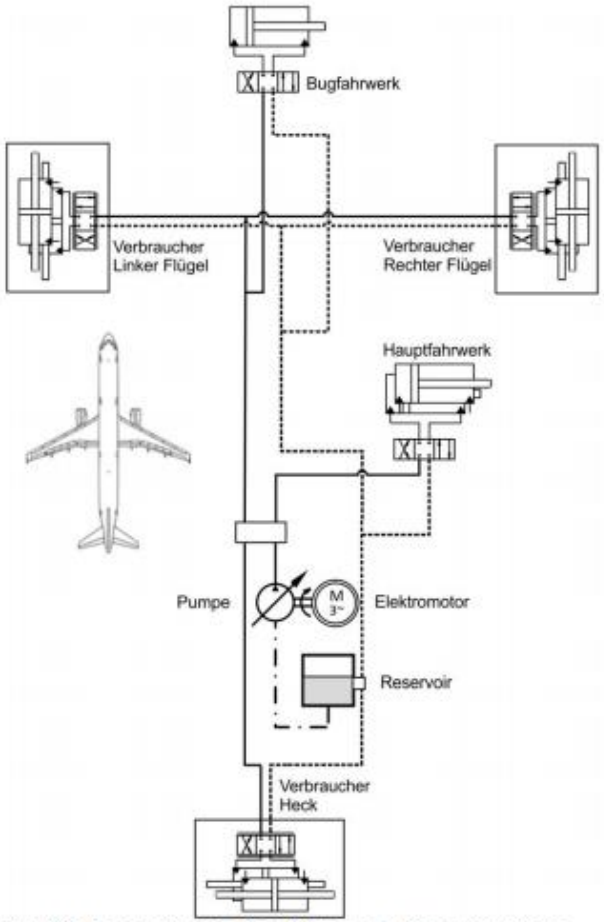

BILD 6. Schematische Darstellung des Beispielsystems

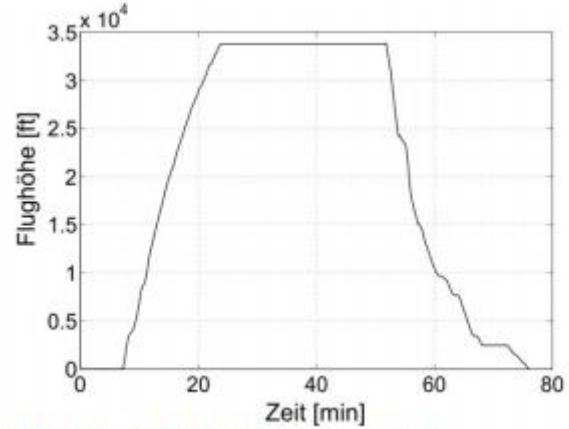

BILD 7. Vereinfachtes Flugmissionsprofil

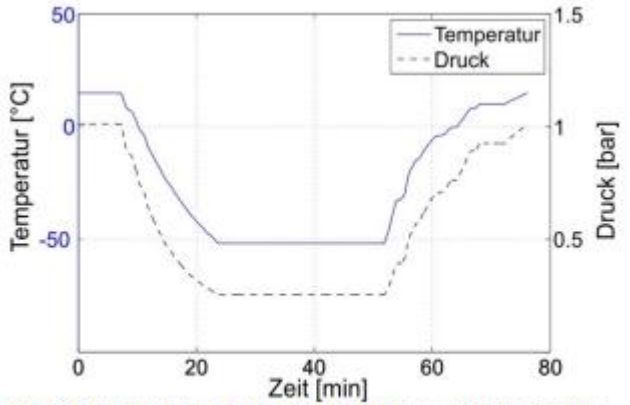

BILD 8. Verlauf des Umgebungsdruckes und der Temperatur

Surface transient actuation

3.Dynamic response characterization for the hydro-mechanical control

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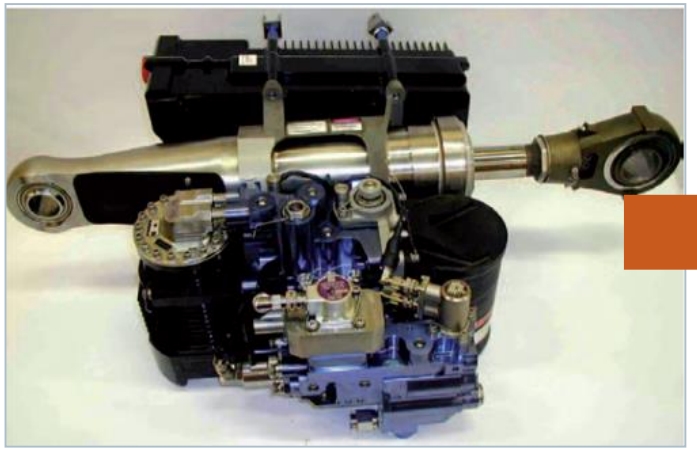
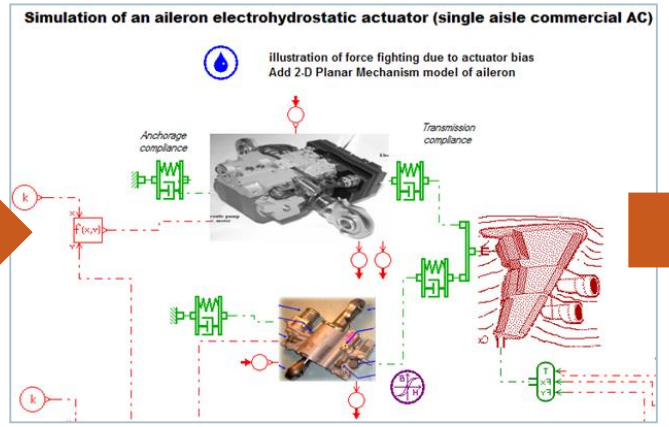
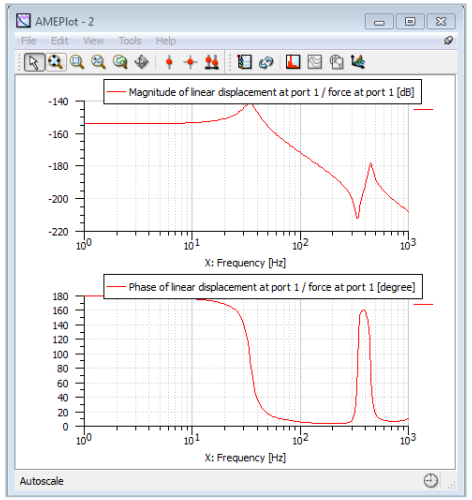
Hardware with undesired frequency modes



Simcenter Amesim model

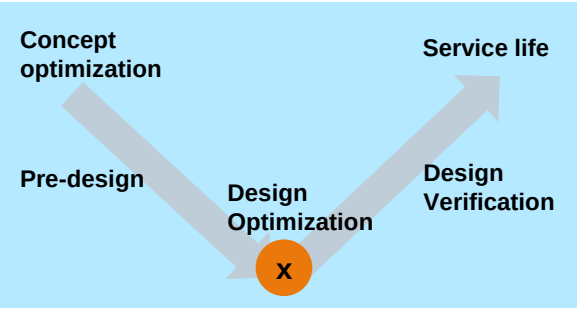


Frequency behavior analysis



Value-adding outcome

- Predictive modeling for surface transient behavior analysis
- Identification of the in-service undesired couplings → safer and more reliable (re)-design



T. Marger – ENSAM ParisTech – France – [thesis]

Valve design of hydro-mechanical servoactuator

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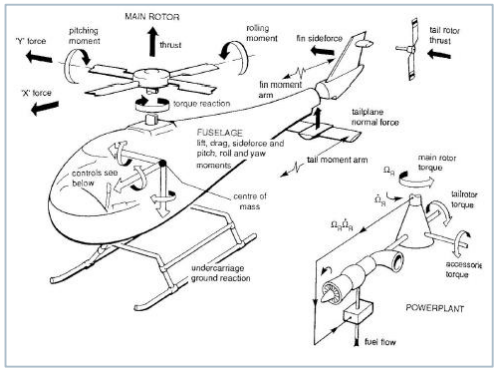
2010

Thibaut MARGER
le 13 décembre 2010

Valve design of hydro-mechanical servoactuator under cost and mixability criteria



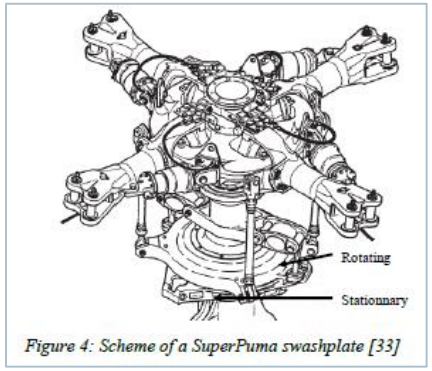


Figure 4: Scheme of a SuperPuma swashplate [33]

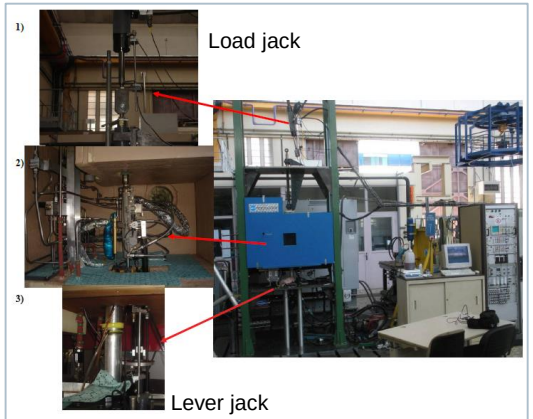


Figure 49: Servoactuator test bench; 1) Load jack; 2) Servoactuator to be tested; 3) Lever jack

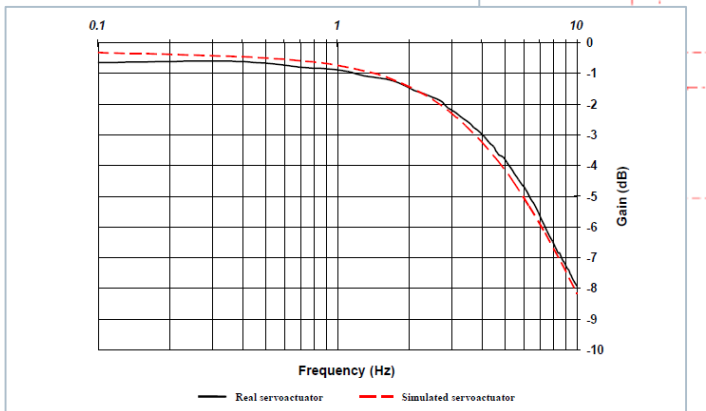


Figure 65: Magnitude of simulated servoactuator compared with the real tested servoactuator - Input magnitude: +/-1mm, restriction diameter Ø1.15mm.

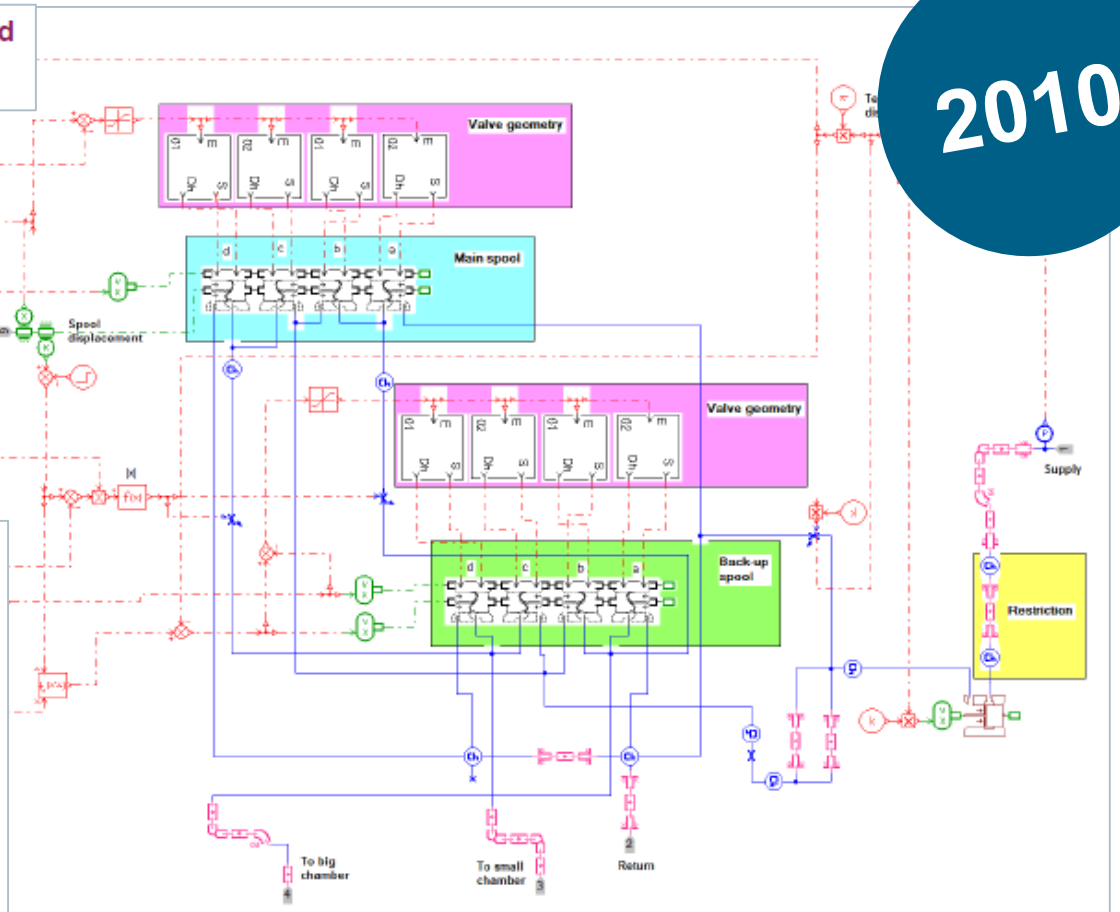


Figure 30: AMESim dynamic valve model

A. Heininen - Tampere University – Finland – [master thesis]

Aircraft main landing gear shock absorber

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2015

ARTTU HEININEN
MODELLING AND SIMULATION OF AN AIRCRAFT MAIN LANDING GEAR SHOCK ABSORBER
Master of Science Thesis

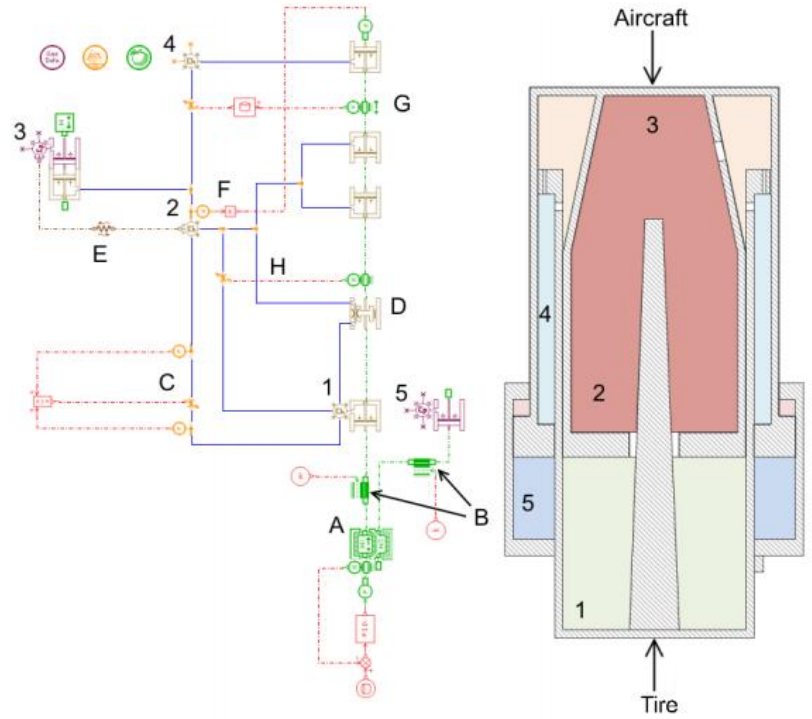

Figure 3.6. *The block diagram of the oleo-pneumatic shock absorber.*

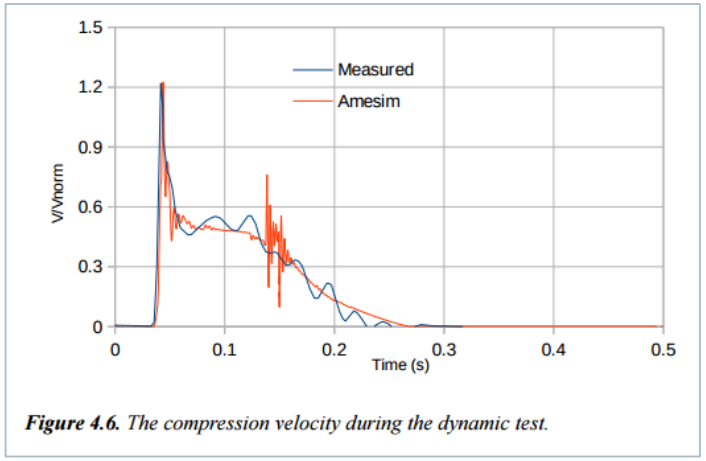

Figure 4.6. *The compression velocity during the dynamic test.*

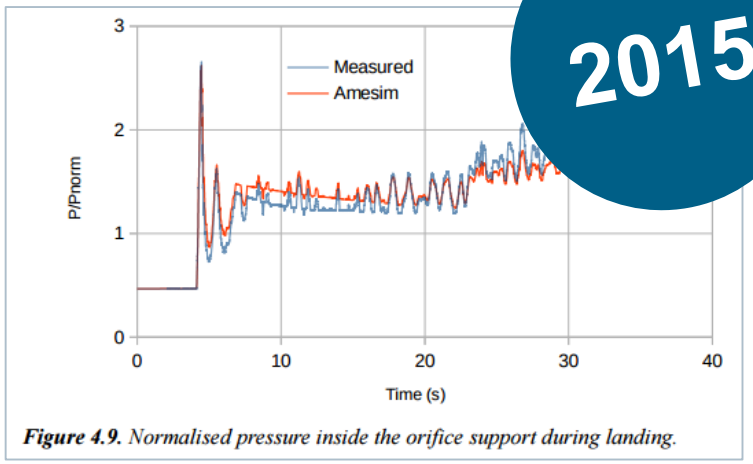

Figure 4.9. *Normalised pressure inside the orifice support during landing.*

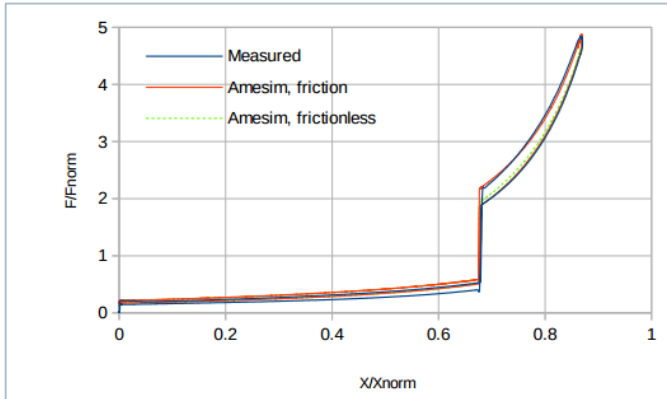

Figure 4.3. *A normalised force-displacement curve of a normally serviced shock absorber.*

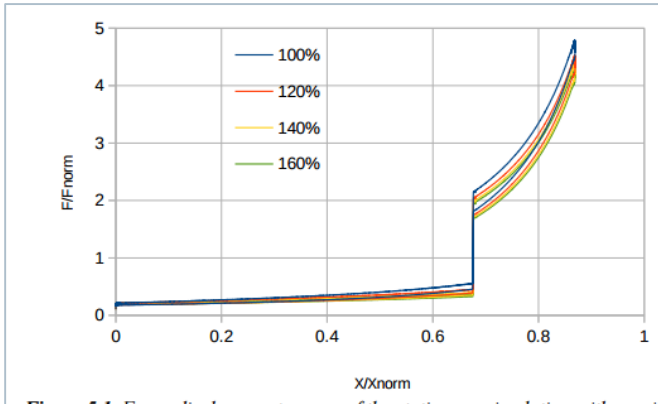

Figure 5.1. *Force-displacement curves of the static case simulation with varying nitrogen volume.*

Real-time brake testing

4.Real-time export of the high-fidelity model and accuracy verification

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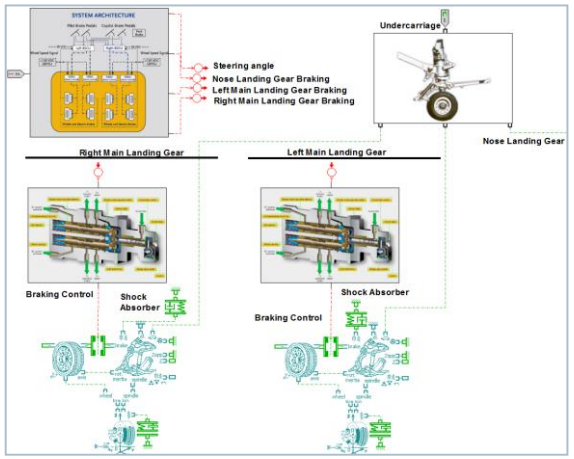
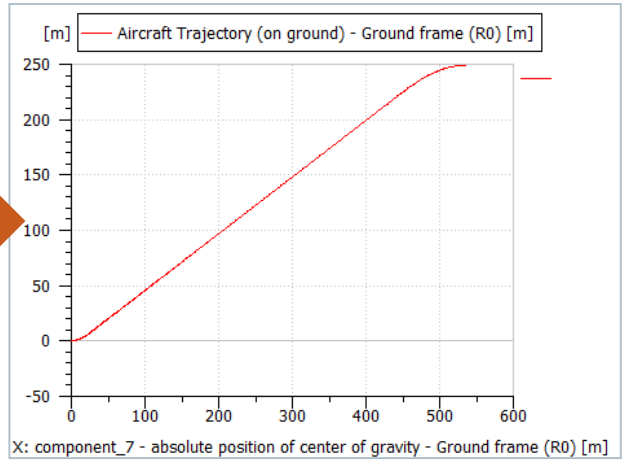
Braking testing

Simcenter Amesim model

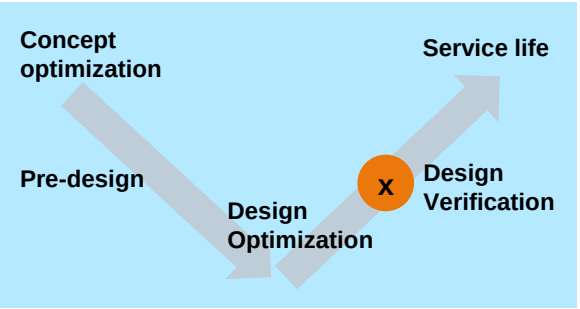


Subsystem validation



Value-adding outcome

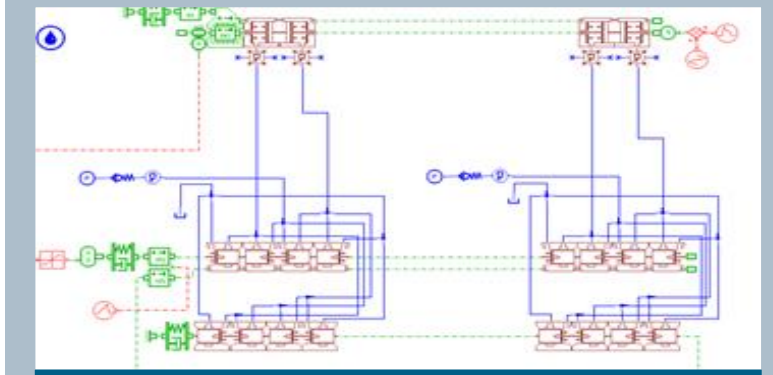
- Fewer tests, better initial performance → large cost savings
- Integrated team work → faster, more consistent design
- Tool & method support for future designs → shorter time to market



Airbus Helicopters
Reducing prototype costs by a factor of 4

- **Shortened hydraulic system optimization cycle by a factor of 3**
- **Decreased prototype costs by a factor of 4**
- **Avoided late delivery penalties**

From component and system engineering to real-time simulation



Dynamic analysis of hydraulic systems

Real-time models for full flight simulators

- Ensure accuracy of plant and real-time hydraulics models
- Enhance flight simulators' fidelity

"Being able to anticipate a problem is a significant source of cost and risk reduction."

Hydro-mechanical fuel regulator

5.Re-engineering of the entire hydro-mechanical system

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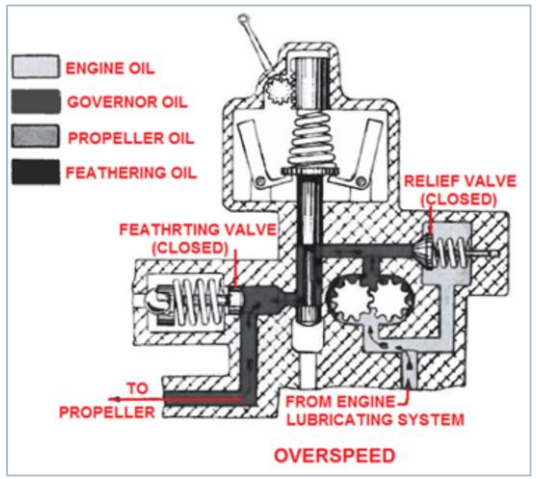
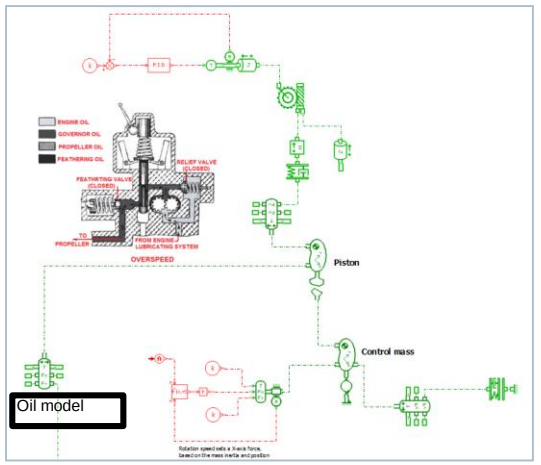
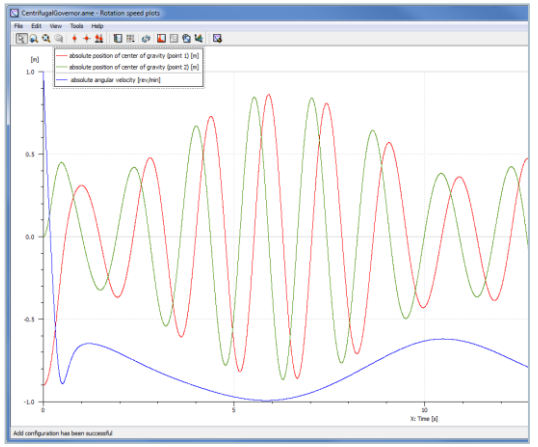
Fuel regulator



Simcenter Amesim model

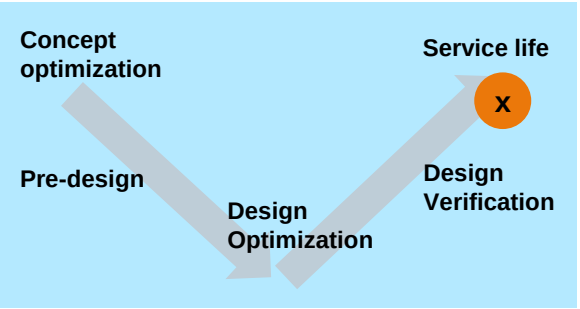


Reliable predictions



Value-adding outcome

- Model made available → answer to OEM requirements (safety & fuel consumption improvements)
- Ability to answer future in-service hardware support requests (modes and concessions, incident replay etc…) → credibility gain



Anomalous Pressure Fluctuations in Aircraft Hydraulic Systems

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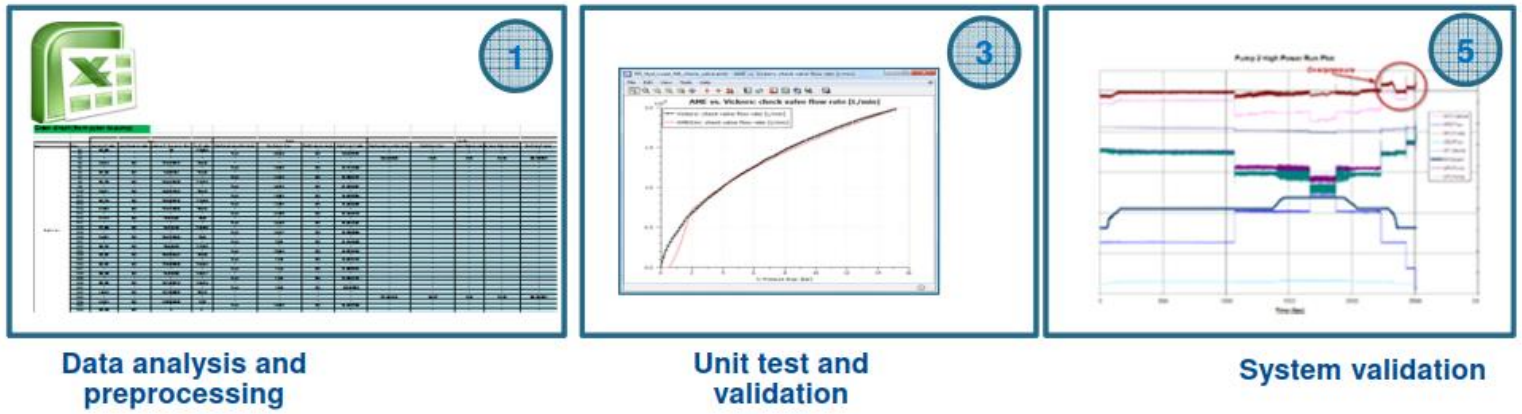

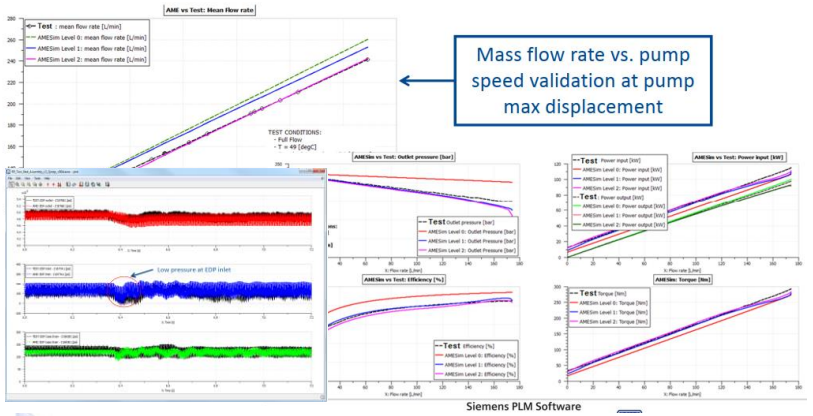

- Generating system pressure results from simulation of test cases under which EDP failure has occurred is more expedient
- Simulation is more cost effective than engine testing
- Hydraulic system pressures can be captured where it is impossible/difficult to make a physical measurement within the hydraulic system i.e. within EDP piston chambers and EDP inlet

Agenda:

系统仿真概述
军工行业的应用概述
军工行业-液压应用
液压高级应用
总结

Hydraulic Libraries in Simcenter Amesim

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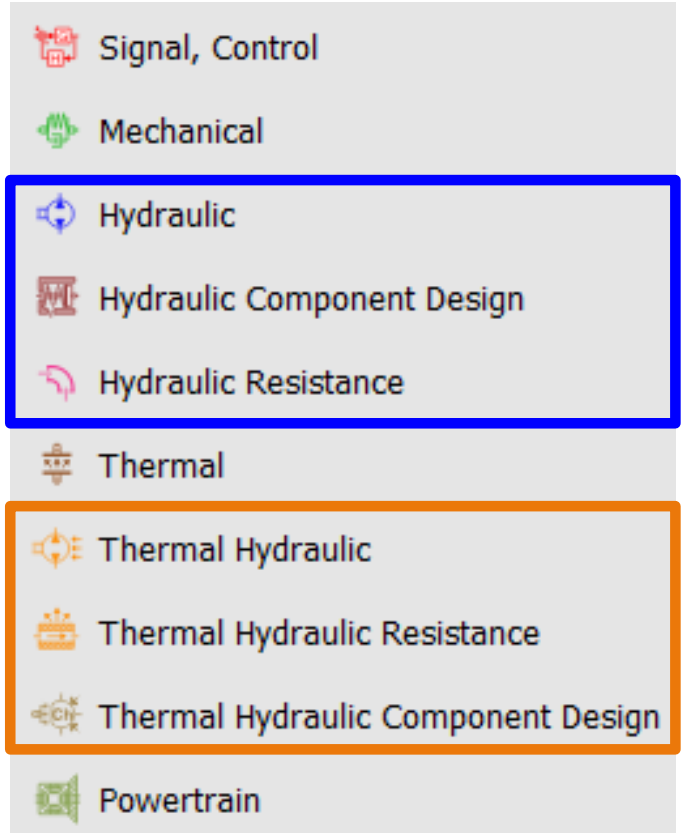
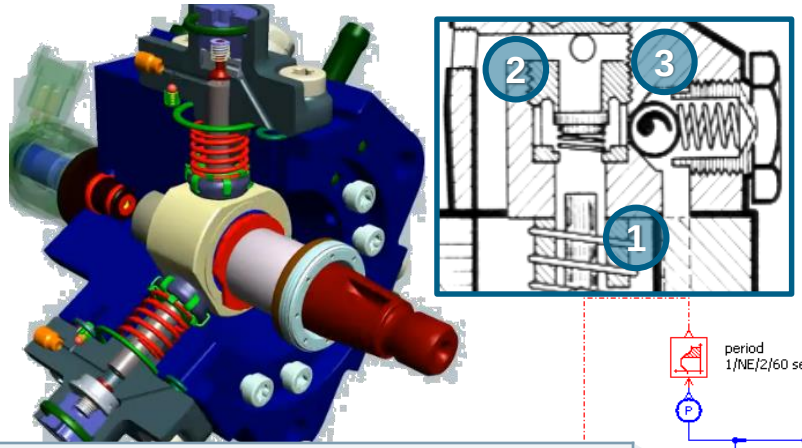
There are 6 Simcenter Amesim libraries to simulate hydraulic components and systems

- Hydraulic Library (**HYD**)
- Hydraulic Resistance Library (**HR**)
- Hydraulic Component Design library (**HCD**)
- Thermal Hydraulic Library (**THYD**)
- Thermal Hydraulic Resistance Library (**THR**)
- Thermal Hydraulic Component Design library (**THCD**)



Model Scalability
High-pressure pump example



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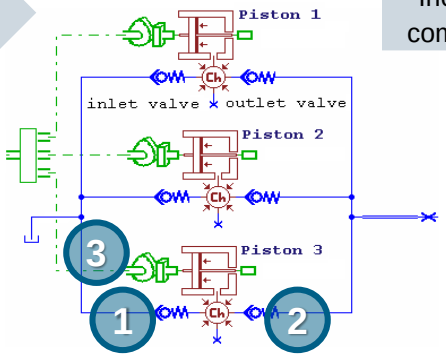
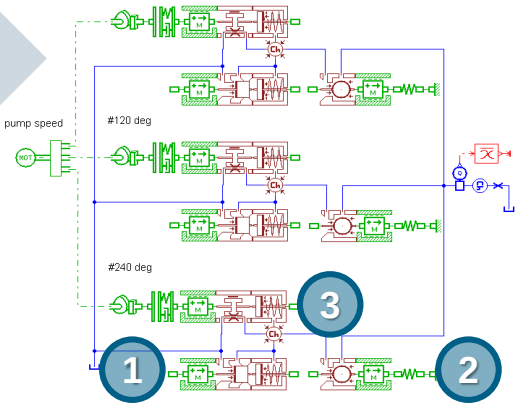
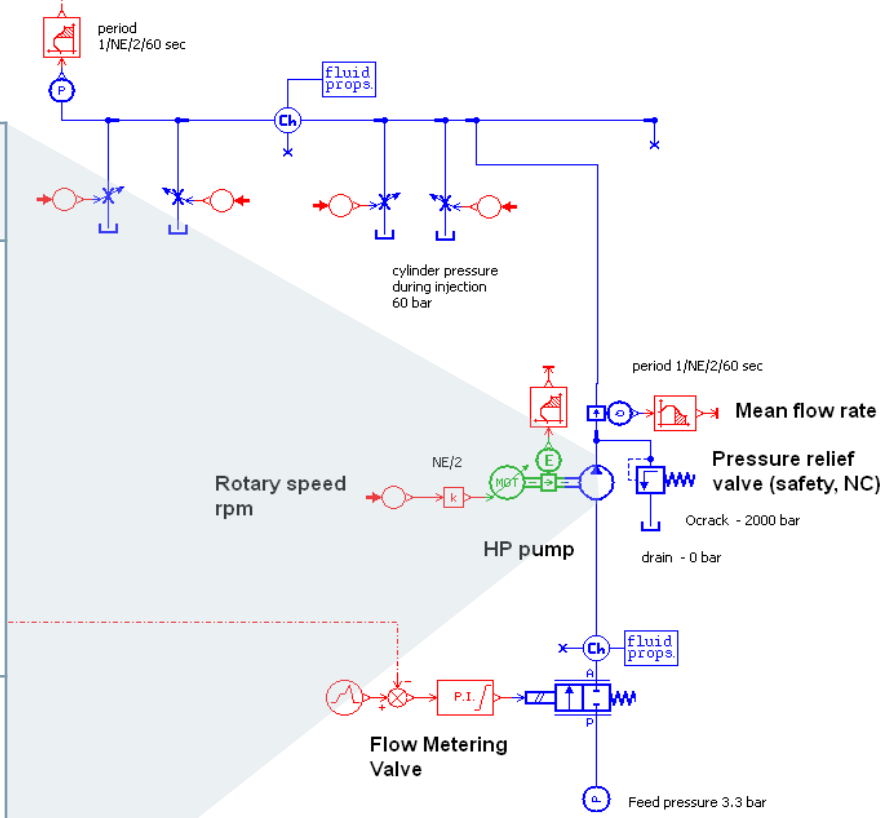
Functional model	Detailed **H**ydraulic **C**omponent **D**esign model 1	Detailed **H**ydraulic **C**omponent **D**esign model 2
Increase complexity →	Increase complexity →	
Mean flow / torque	Flow rate and torque ripples due to: • kinematics • fluid compressibility	Flow rate and torque ripples due to: • kinematics • fluid compressibility • check valves' dynamics • loss of contact cam-follower • leakages







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Fluid Properties

Simcenter Amesim

Fluid properties

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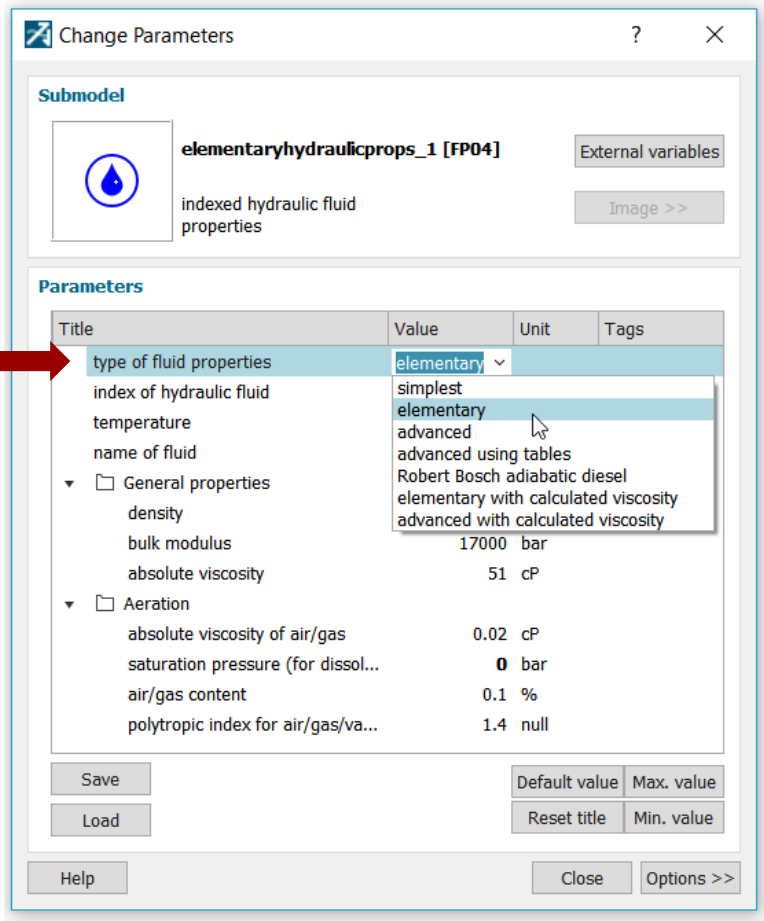
The 3 essential properties to handle dynamic effects in hydraulic networks are:

- **Density** Density is defined as mass divided by volume, inertial effect
- **Bulk modulus** Bulk modulus is a measure of the stiffness of the fluid
- **Viscosity** Viscosity is a measure of the resistance of a fluid which is being deformed by shear stress

The **air/gas content, saturation pressure** and **vapor pressures** are essential to handle aeration and cavitation phenomena.

The most relevant **thermal-related properties** are the thermal conductivity, specific heat and thermal expansion…which are evaluated and used in **thermal hydraulic libraries**.

Type of Fluid Properties



Simplest

Very simple model and assumptions. Rarely used.

Elementary

Identical to Advanced model but some parameters are not accessible (default value).

Advanced

"Generic" fluid model considering liquid but also air/gas and vapor bubbles (fluid aeration and cavitation).

Advanced using tables

This uses an ASCII file to define fluid properties as a function of **pressure** and **temperature**. Air/gas release and cavitation models are identical to the ones used in the Advanced model.

Robert Bosch adiabatic diesel

This model was developed in collaboration with Robert Bosch GmbH and was validated with measurements.

Fluid properties
Aeration and cavitation in Simcenter Amesim

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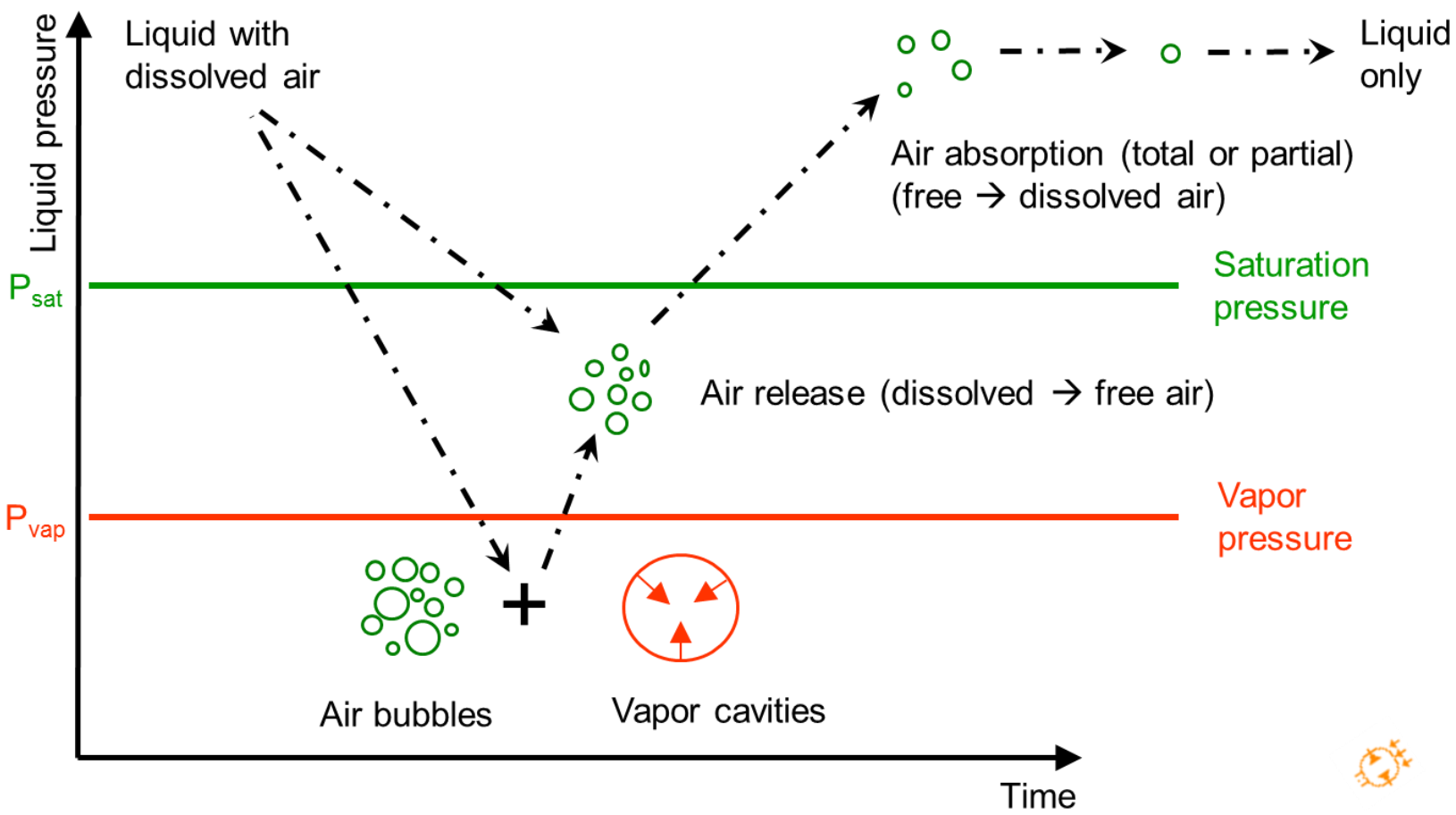
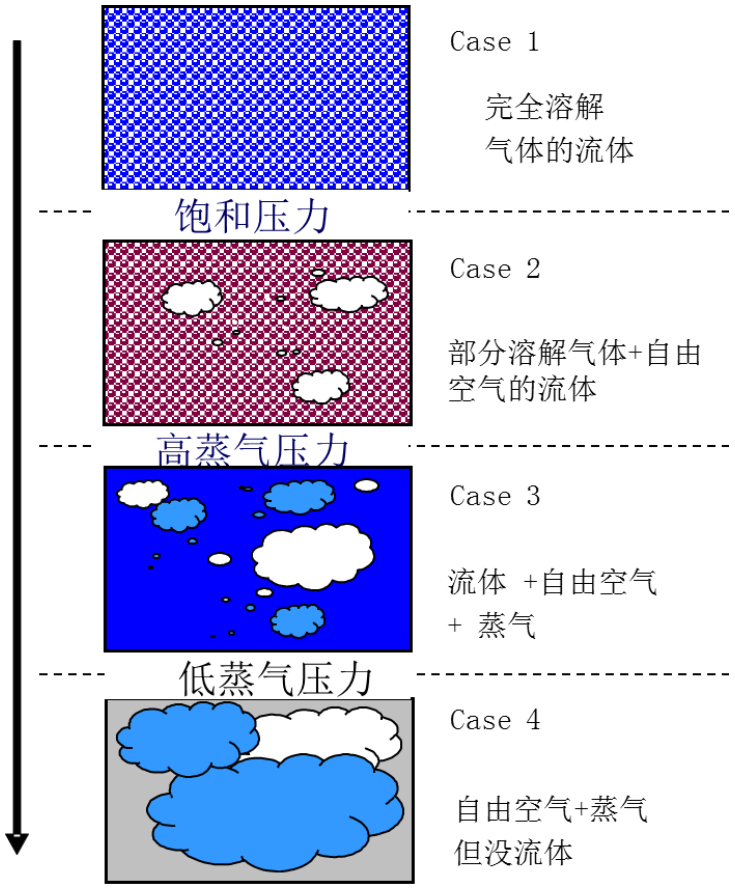
Comparison between cavitation and aeration





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Hydraulic Pumps

Simcenter Amesim supports the modeling of any type of pumps

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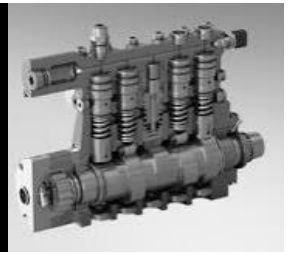
Vane pump

Gerotor and trochoidal pump

Variable displacement vane pump

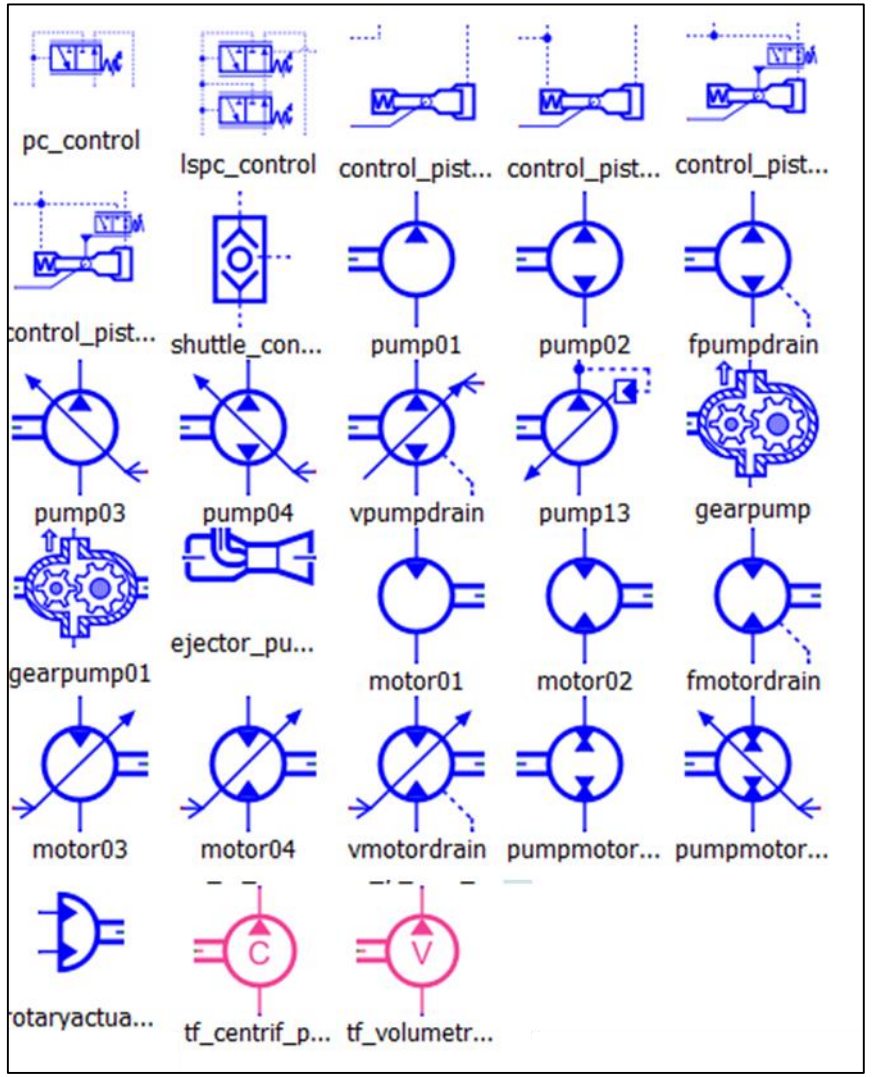
External gear pumps

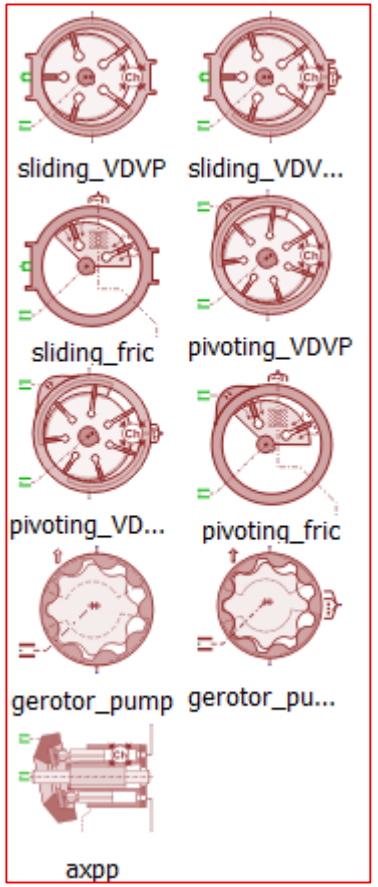
Radial and axial piston pump

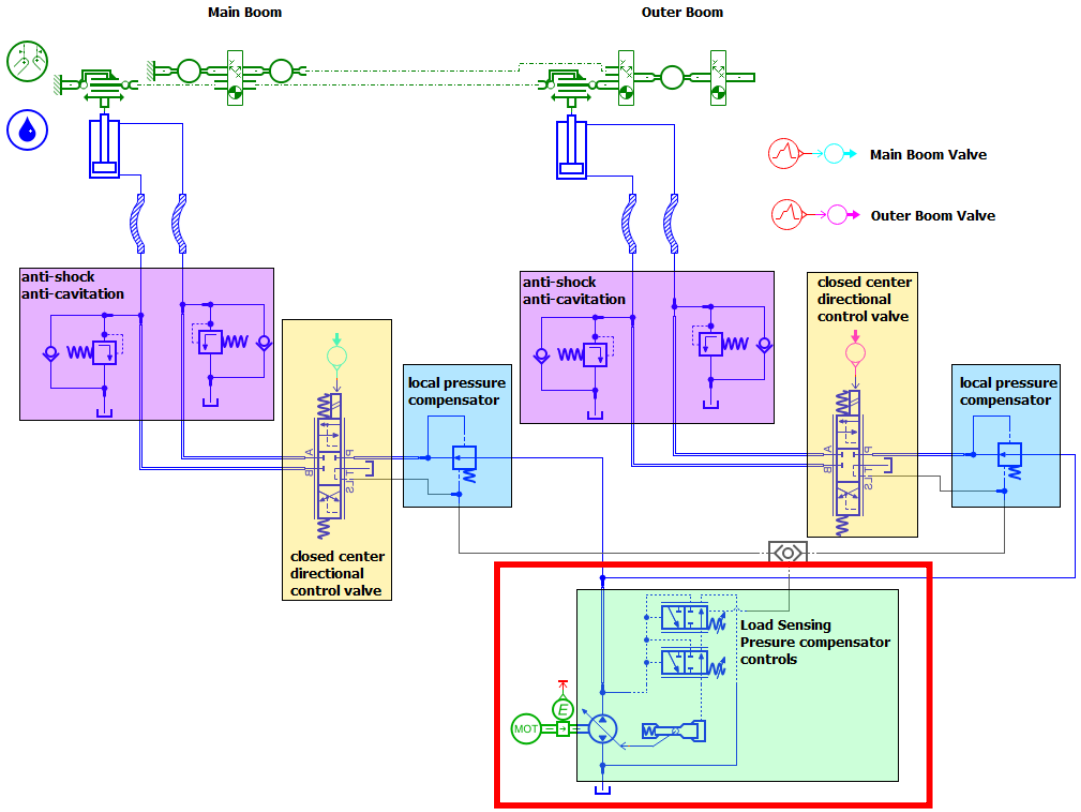


Piston pumps with load sensing control

System Level Analysis







Automatic pumps sketch generation with CAD Import

For gerotor pumps and vane pumps

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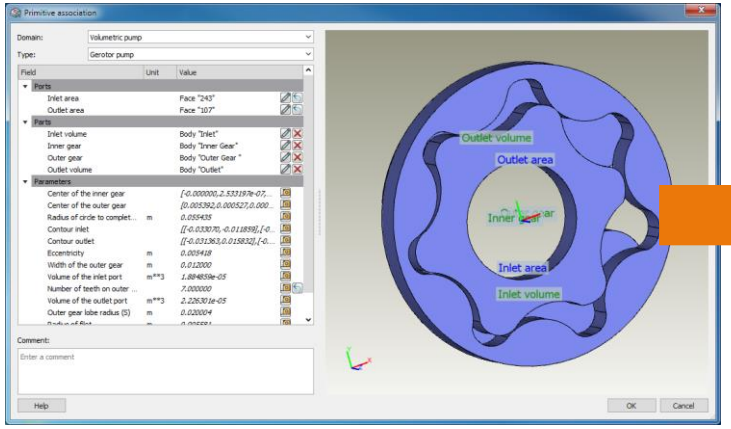
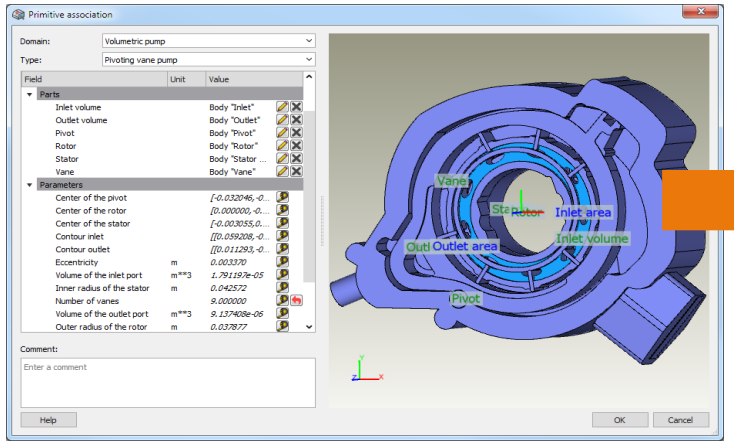
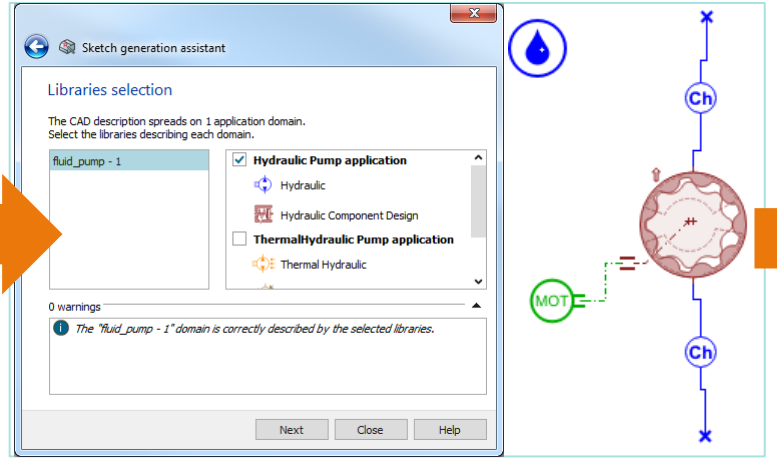
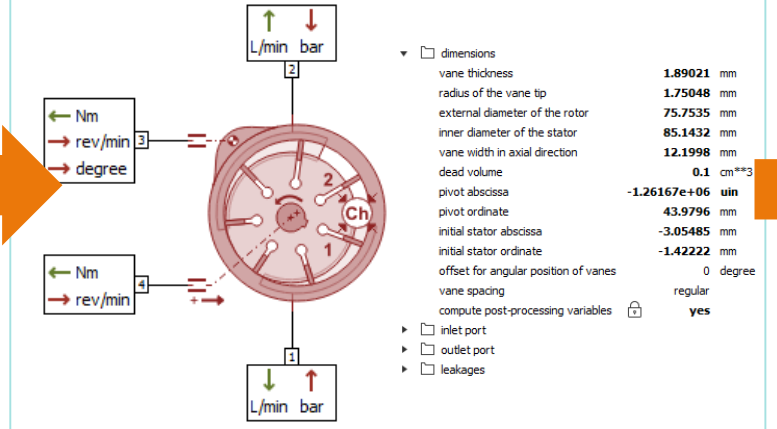
Pump CAD parameters retrieval



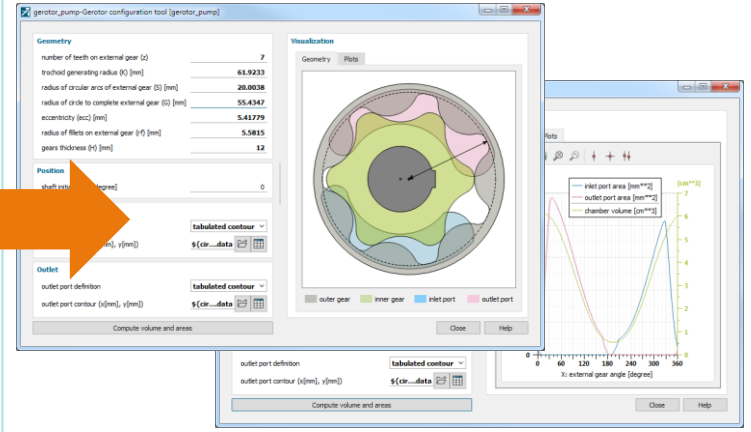


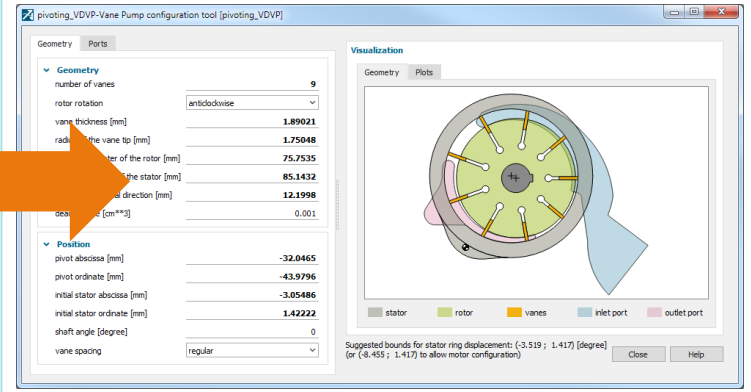
Automatic sketch generation





Dedicated app for pumps





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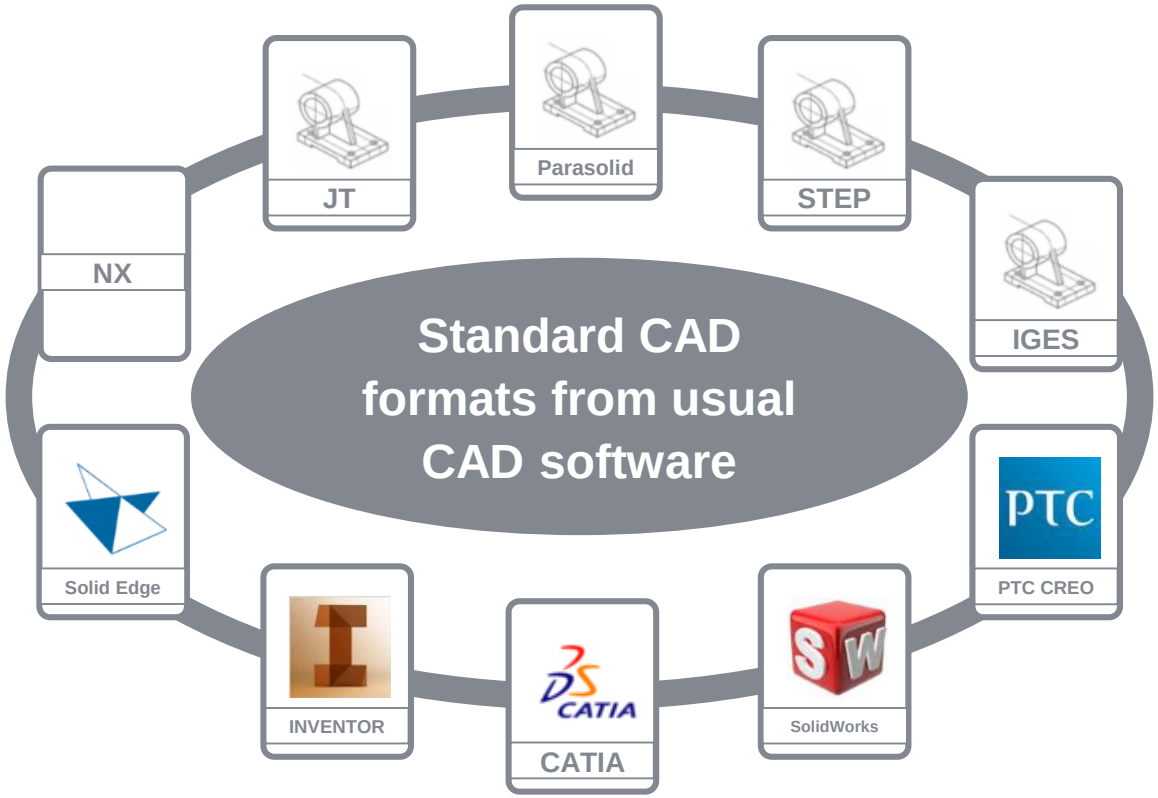
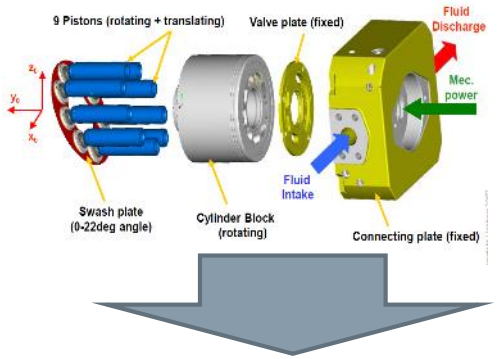
Hydraulic CAD Imported

CAD import

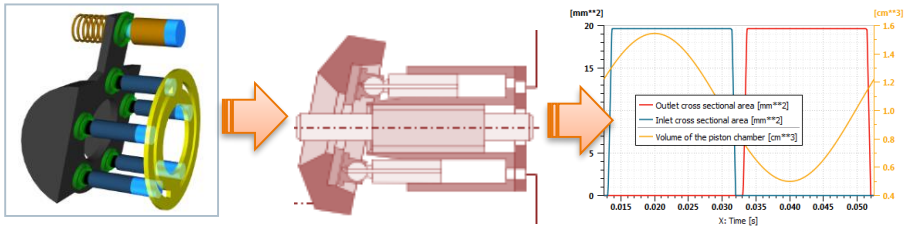
- Import your in-house CAD
- Use standard files to mix multiple sources

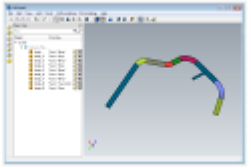


CAD2AME import to generate 1D sketch



CAD ➔ Automatic Sketch ➔ Quick Analysis Generation

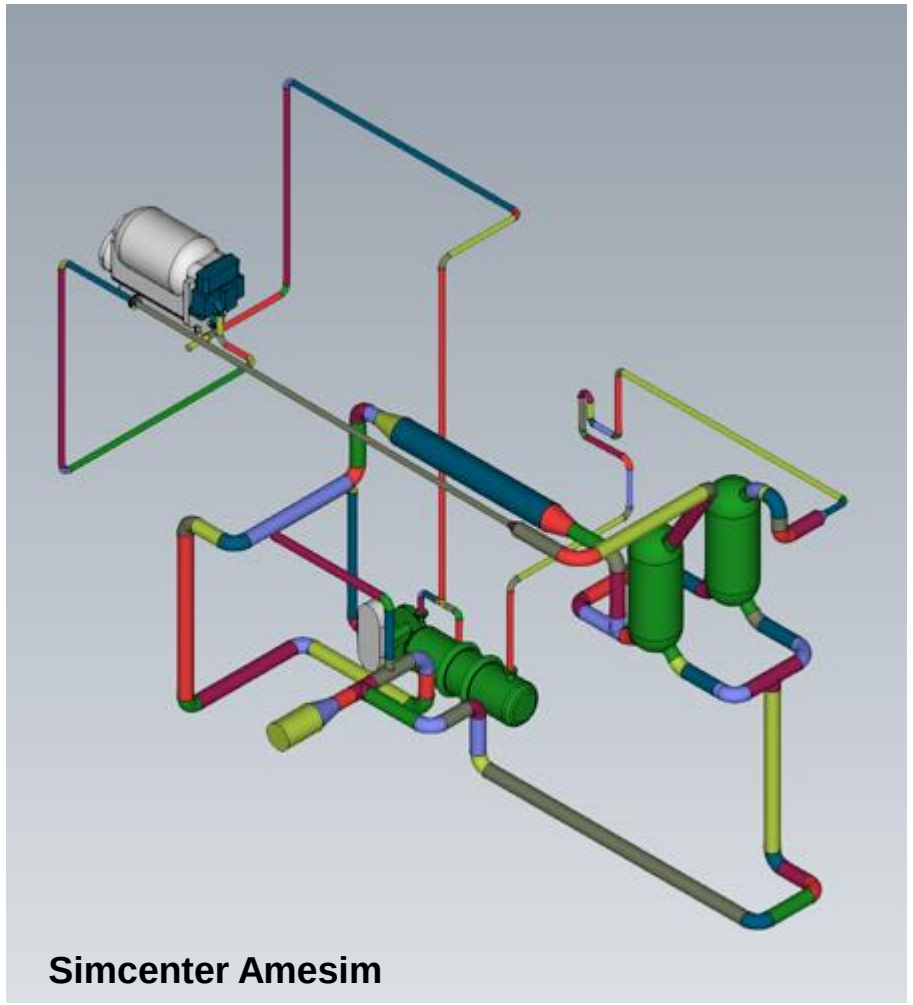




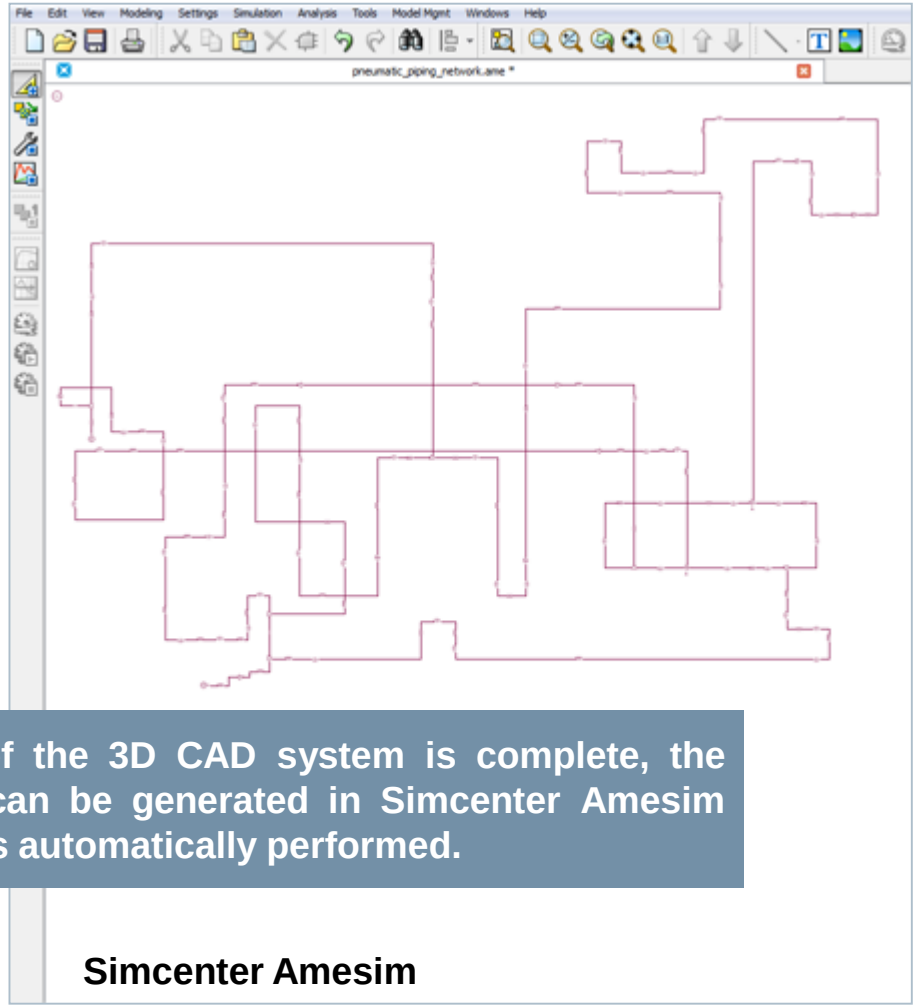
Amesim demo

Sketch generation
A simple CAD to get familiar to sketch generation.

Application: piping network of a power plant



Simcenter Amesim



Simcenter Amesim

Once the description of the 3D CAD system is complete, the corresponding sketch can be generated in Simcenter Amesim with parameters settings automatically performed.

Generation of a vane pump model using CAD data

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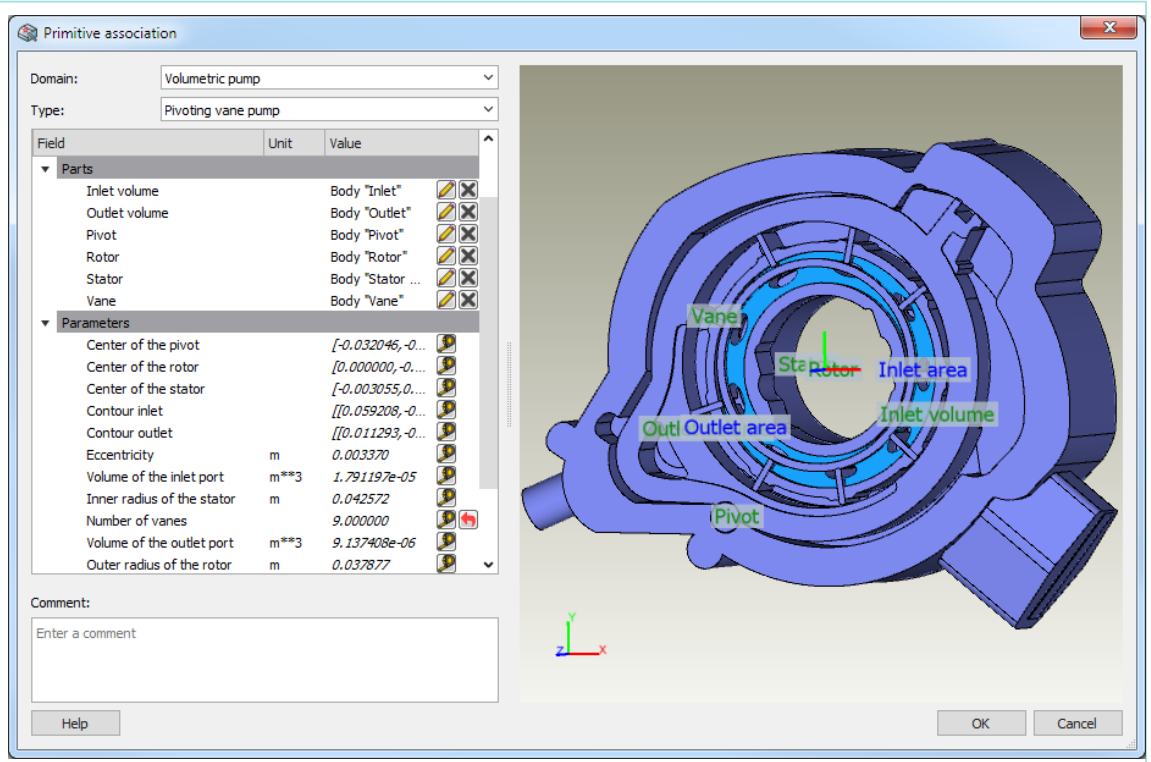
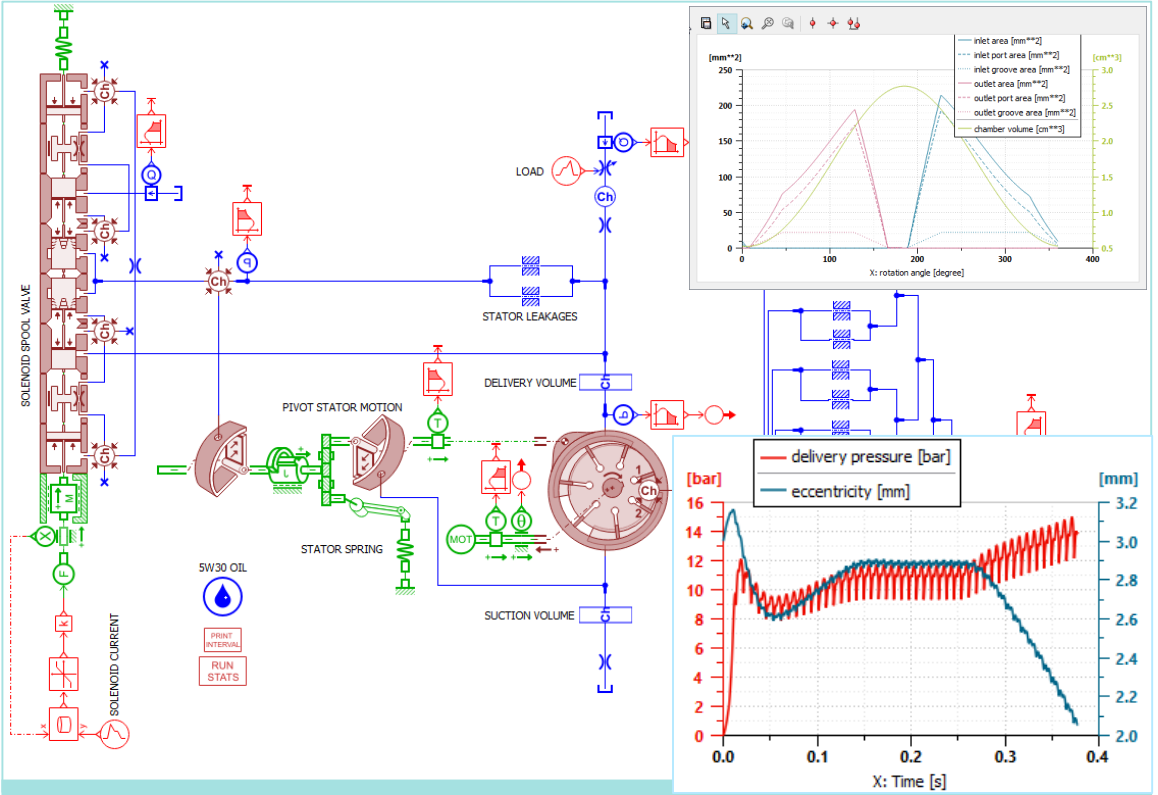


The automatic pump sketch generation allows to reduce considerably the time needed to create a detailed pump model in the early design phase.



Easily visualize the pump geometry and analyze the influence of the design parameters on the system behavior

Swash plate pump modeling workflow, from CAD to Simcenter Amesim model

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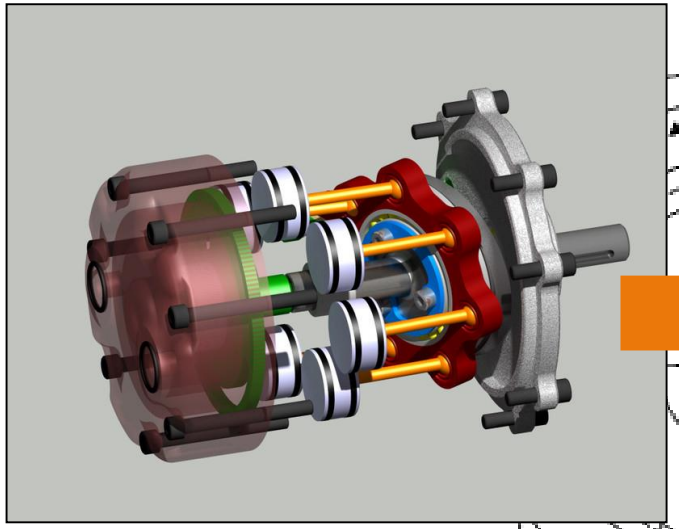
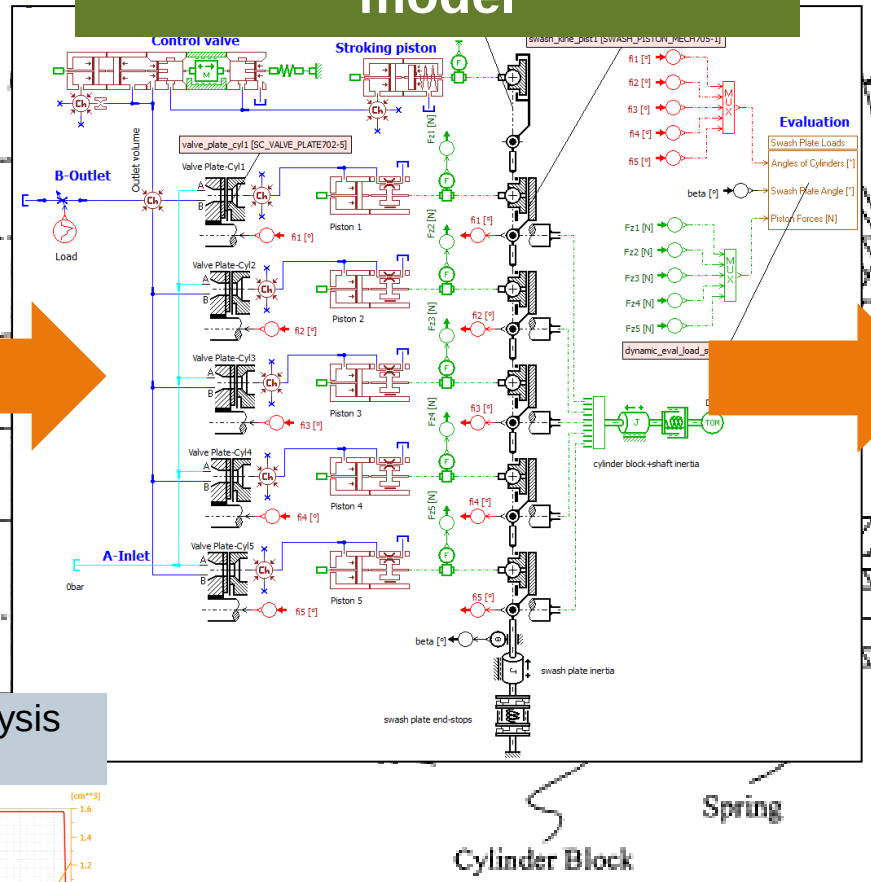
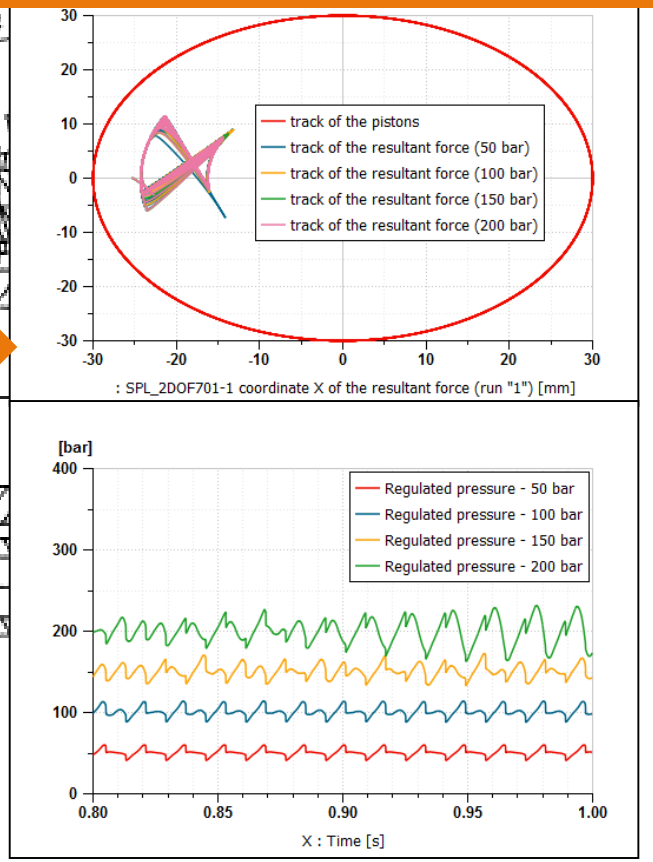
Pump CAD



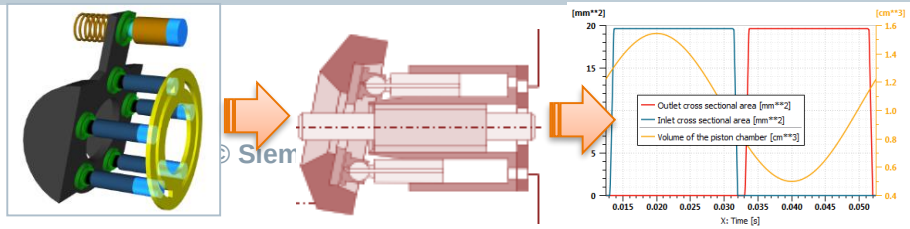
Simcenter Amesim pump model



Swash plate load and pressure peaks analysis



CAD ➔ Automatic Sketch ➔ Quick Analysis Generation



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Hydraulic Valve

Many technologies of hydraulic valves, depending on...

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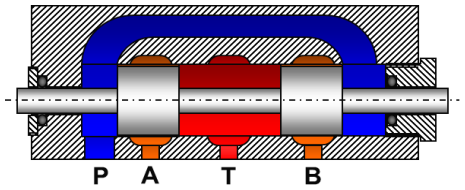
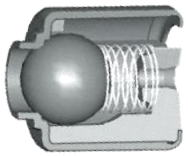
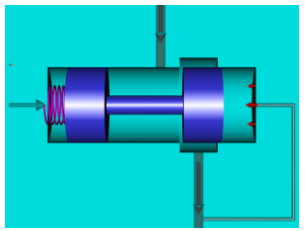
Regulated / controlled variable

- Directional control valves
- Pressure control valves
- Flow control valves

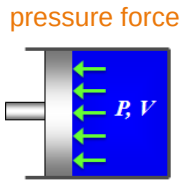


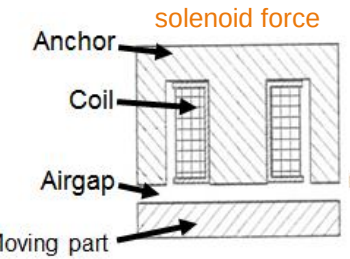


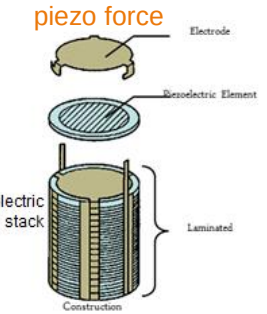


Type of valve operation

- Mechanic
- Hydraulic / pneumatic
- Electric:
  - Solenoid actuation: continuously variable force or PWM
  - Piezoelectric actuation (fast dynamics)

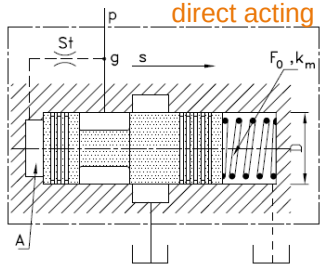


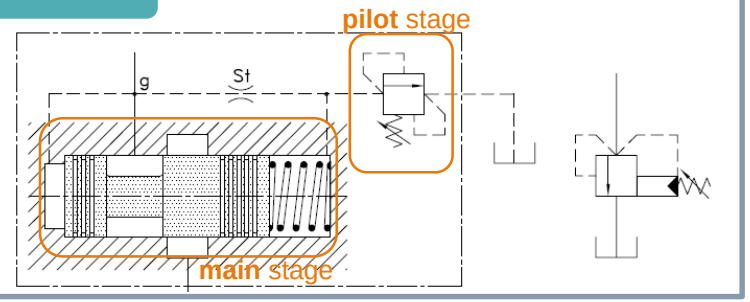




Number of stages

- One main stage: direct acting valves
- Pilot and main stages (high power):
  - Piloted valves





液压阀

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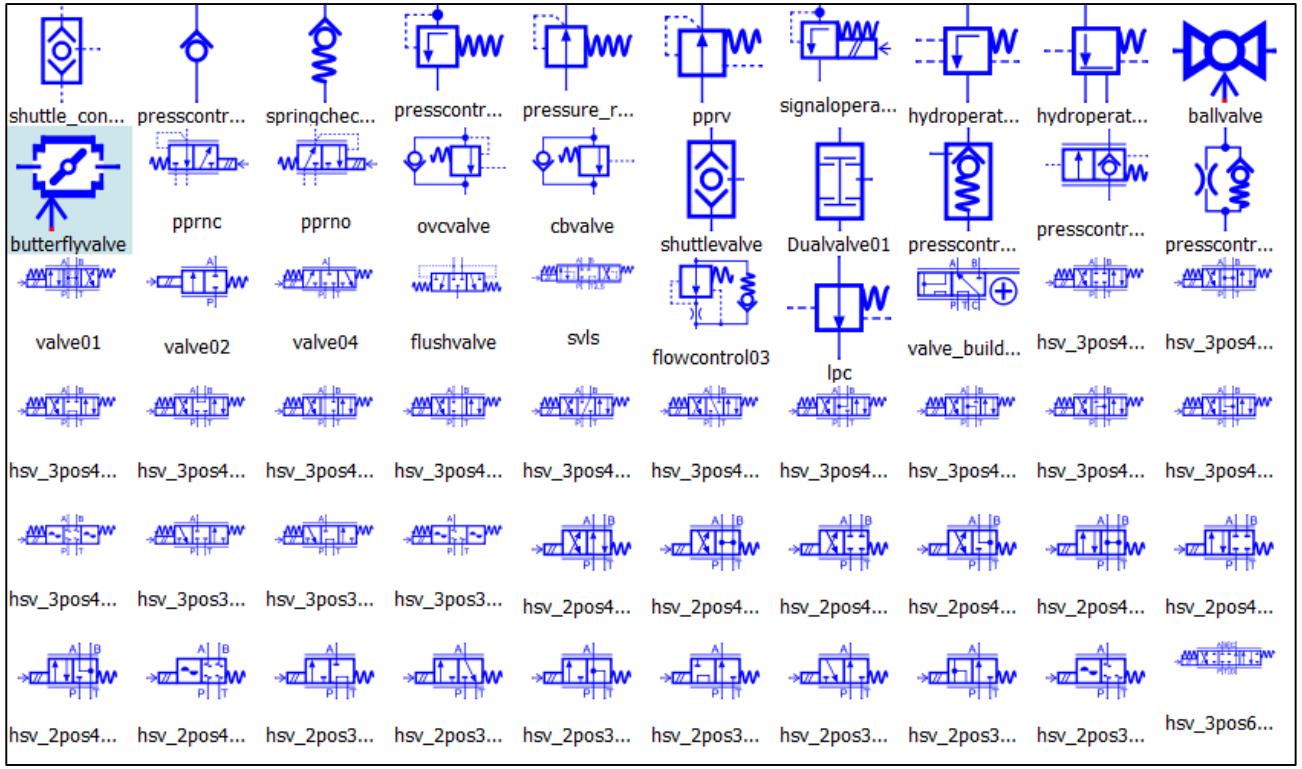

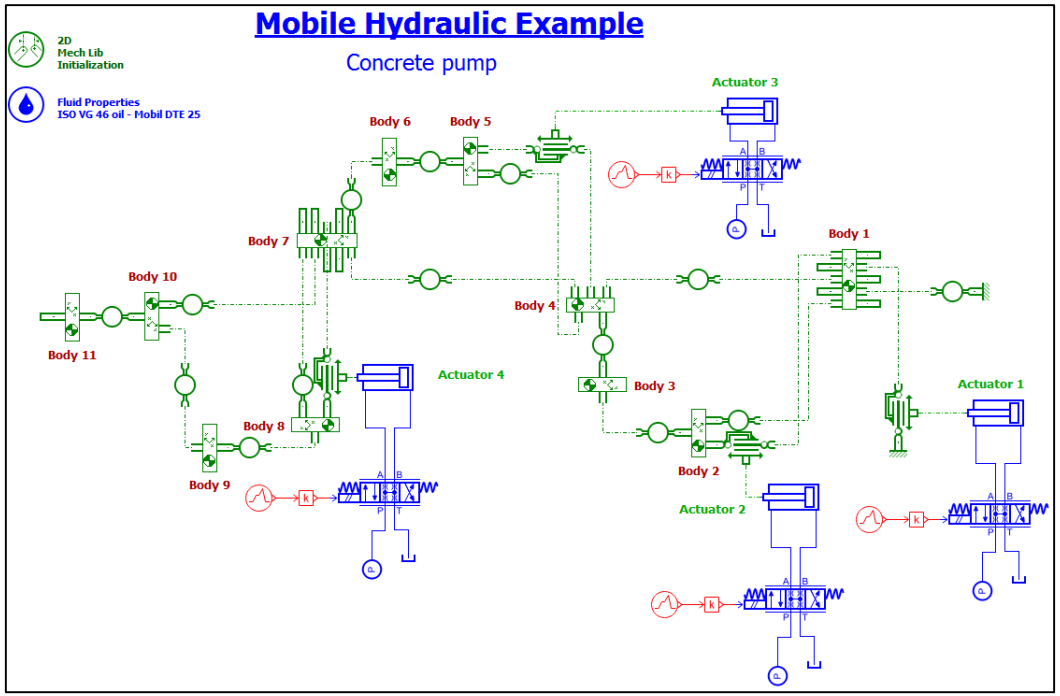

压力控制阀，流量控制阀，方向控制阀

Valve Builder

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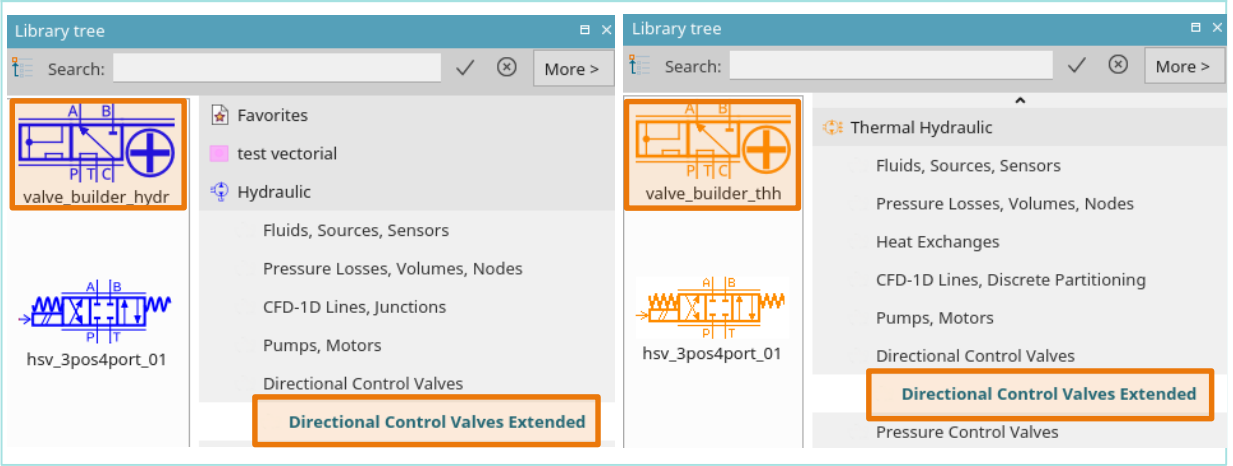
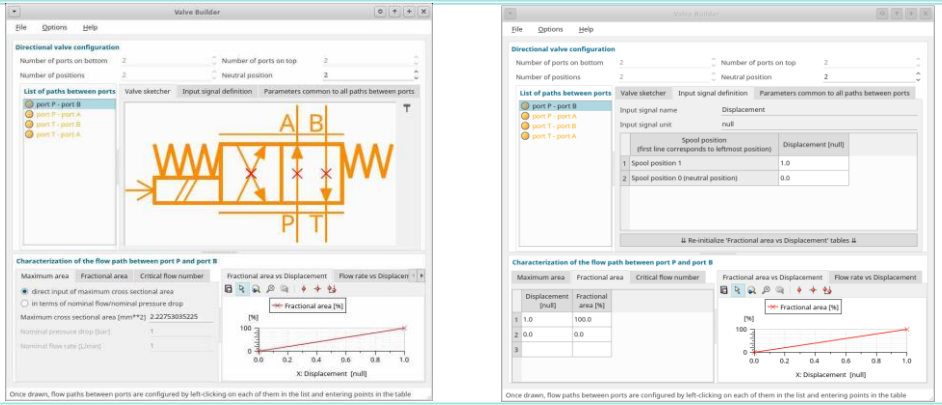
Hydraulic and Thermal-hydraulic libraries

- Create directional control valves by drawing flow paths in a dedicated sketcher.
- Specify pressure drops for each flow path.
- Automatically generate the desired parametrized model, with its appropriate icon drawing.

Available in the Hydraulic and Thermal-hydraulic libraries



Sketcher and configuration view



Valve Builder

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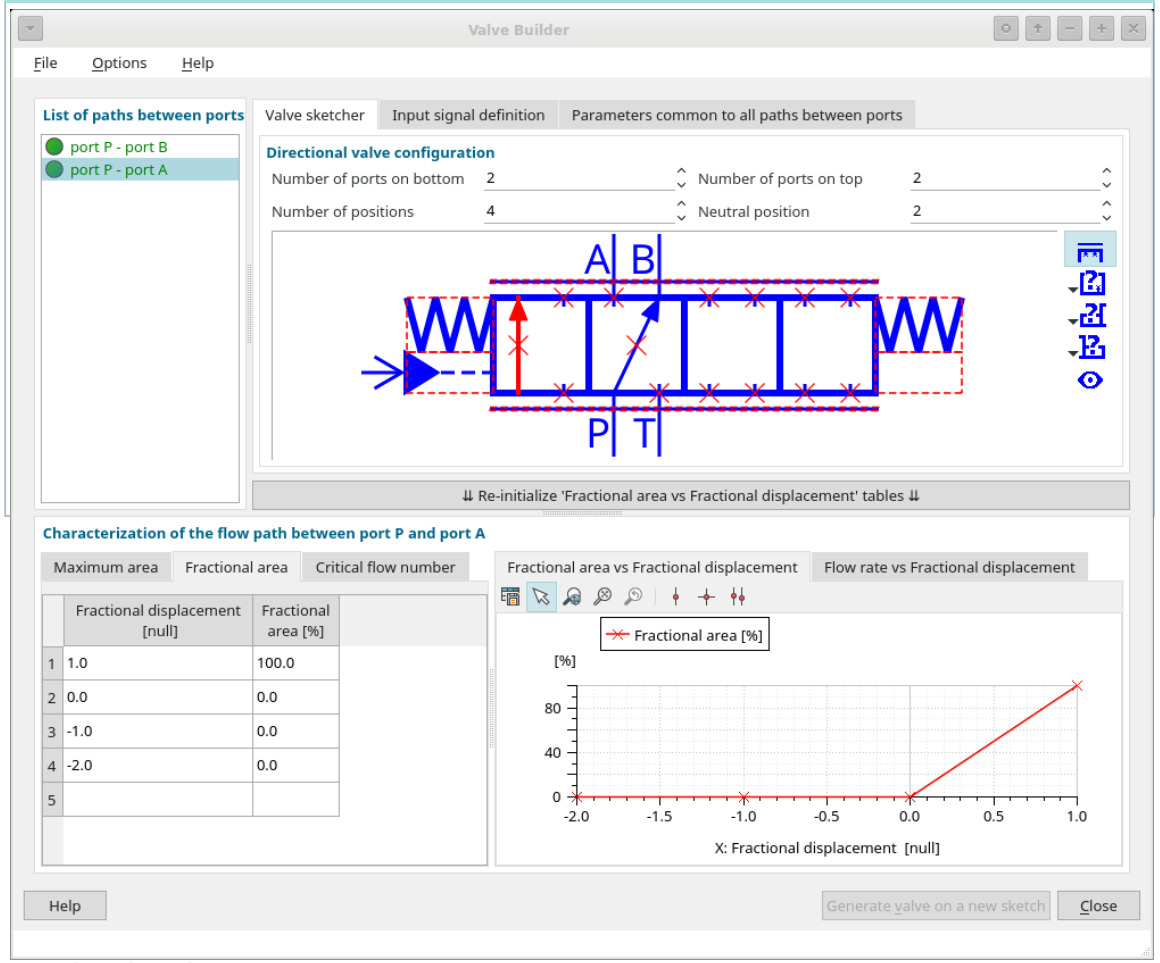
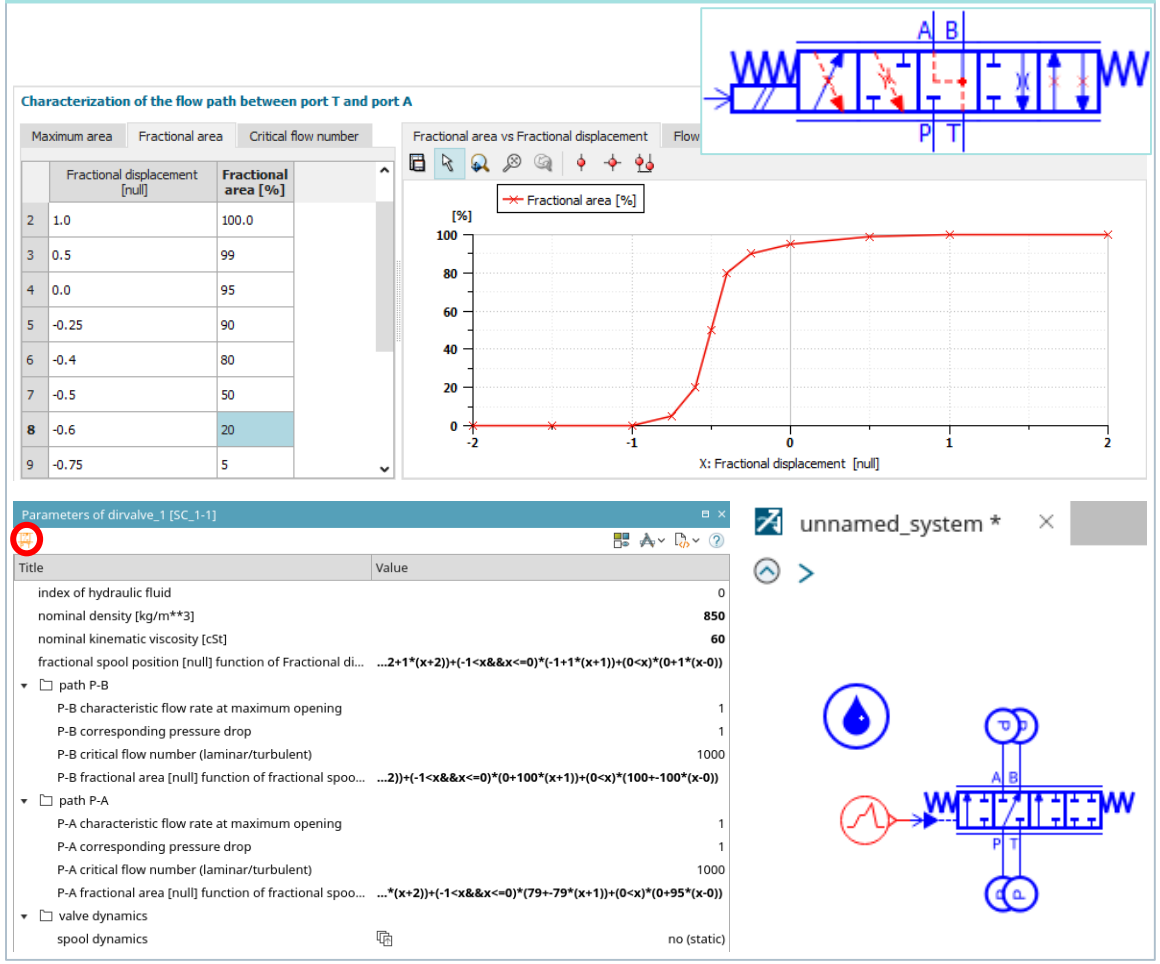
Sketcher to draw the valve configuration



Easily configure flow path



Check valve dynamics

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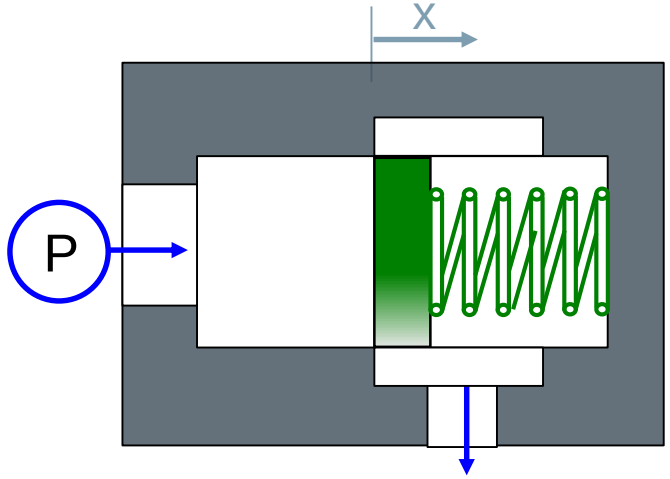
Target:

- Size the valve, based on few main parameters



Characteristics:

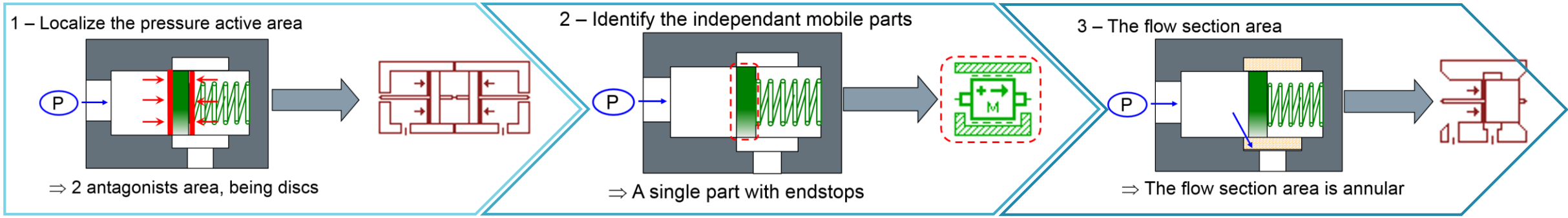
Cracking pressure = 10 [bar]

Flow = 100 [L/min] @ 30 [bar] fully open

+

Diameter of the valve = 8 [mm]

Mass of the valve = 10 [g]



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Hydraulic Pipes

液压管道

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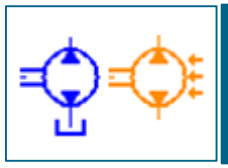
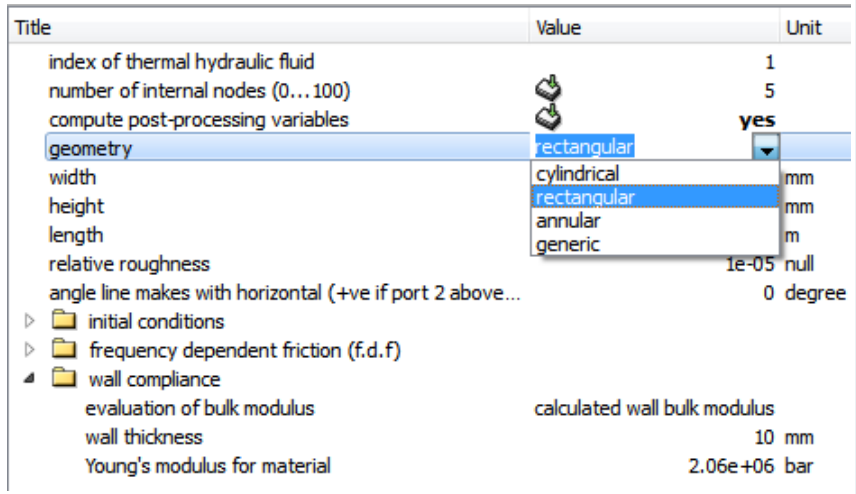


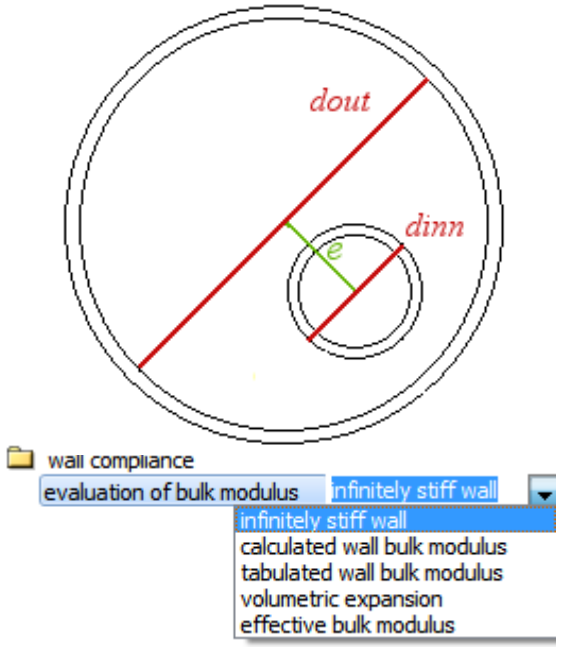
Hydraulic
Thermal hydraulic

- 管道几何形状
- 管道壁面弹性模量

New pipe geometries



Handling of wall compliance



Pipe Material	Absolute roughness Δ
drawn brass	1.5 µm
drawn copper	1.5 µm
commercial steel	45 µm
wrought iron	45 µm
asphalted cast iron	120 µm
galvanized iron	150 µm
cast iron	260 µm
wood stave	0.2 to 0.9 mm
concrete	0.3 to 3 mm
riveted steel	0.9 to 9 mm

管道模型选择工具

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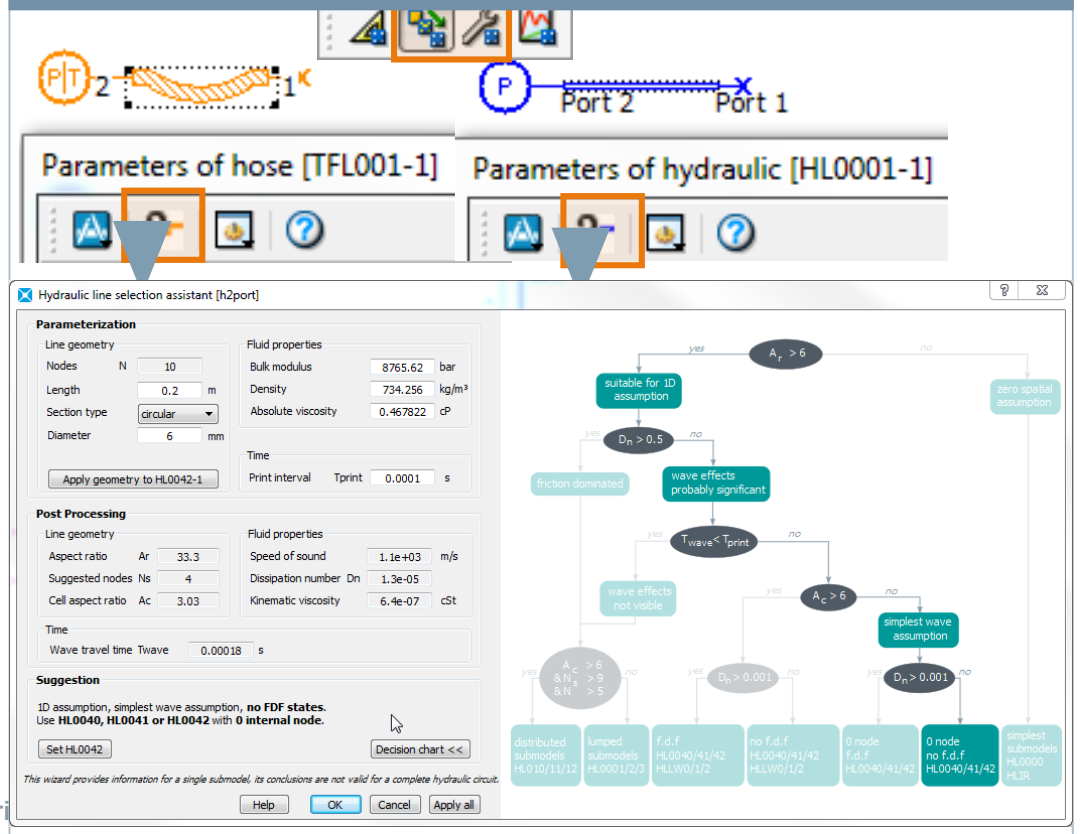
Hydraulic
Thermal hydraulic

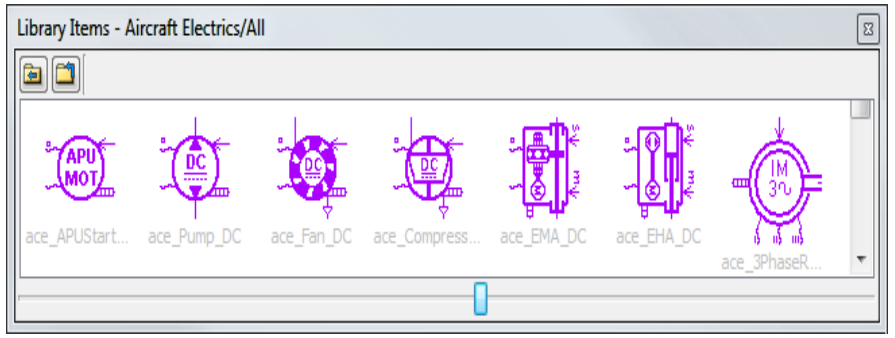
- 管道子模型选择工具

Tool available before simulation run



	Lumped (L) / Distributive (D)	Causality	Fluid Compressibility	Friction	Fluid inertia	Wave phenomena	frequency dependent friction	Wall compliance
Direct	-	-	-	-	-	-	-	-
HL000	L	C	✓					✓
HL02I	L	IR		✓	✓			
HL01 HL02 HL03	L	C-R R-C-R C-R-C	✓	✓				✓
HL04 HL05 HL06	L	C-IR IR-C-IR C-IR-C	✓	✓	✓	✓		✓
HL004 HL005 HL006	L	C-IR IR-C-IR C-IR-C	✓	✓	✓	✓	✓	✓
HL10 HL11 HL12	D	C-R-***-C-R R-C-***-C-R C-R-***-R-C	✓	✓				✓
HL020 HL021 HL022	D	C-IR-***-C-IR IR-C-***-C-IR C-IR-***-IR-C	✓	✓	✓	✓		✓
HLG20 HLG21 HLG22	D	C-IR-***-C-IR IR-C-***-C-IR C-IR-***-IR-C	✓	✓	✓	✓		
HL030 HL031 HL032	D	C-IR-***-C-IR IR-C-***-C-IR C-IR-***-IR-C	✓	✓	✓	✓	✓	✓

Electro-Hydrostatic Actuator parameter setting tool



- Provision of no-load, stall and continuous rated points
- Selection of parameters to be optimized
- DC motor, power converter, pump and jack parameters optimization
- Efficiency, speed and current curves visualization

Targets

1. Targets

power electronics efficiency	0.85
input DC voltage [V]	28
continuous force [N]	5000
current under cont. force [A]	Not mandatory
speed under cont. force [m/s]	Not mandatory
stall load [N]	12500
stall current [A]	30
no-load speed [m/s]	0.05

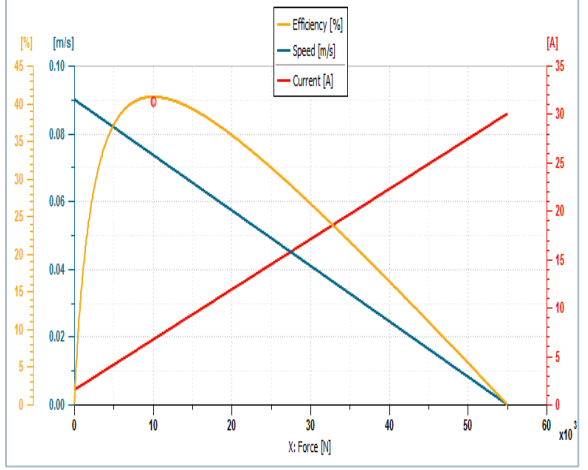
Parameters to be optimized

2. Parameters

torque constant [V*s/rad]	2.40612	☑
stator resistance [Ohm]	1.09803	☑
shaft Coulomb friction torque [Nm]	0.437126	☑
shaft viscous friction coef [Nm/(rev/min)]	0.0222636	☑
gear ratio [null]	1.01177	☑
gear efficiency [null]	0.999975	☑
pump displacement [cc/rev]	667.509	☑
pump hydromechanical efficiency	0.668073	☑
rod diameter [mm]	360	☐
piston diameter [mm]	400	☐
jack friction coef [N/(m/s)]	0.500006	☑

Run Opt

Efficiency/speed/current



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平台新功能

Model converter

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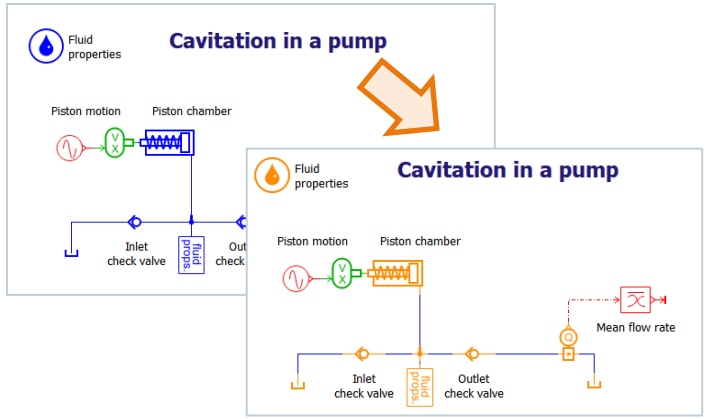
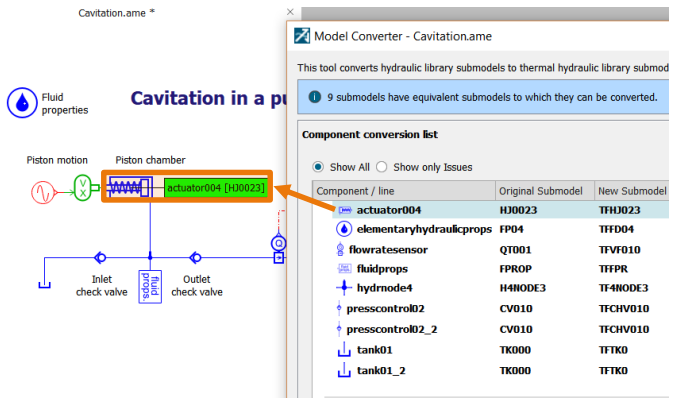
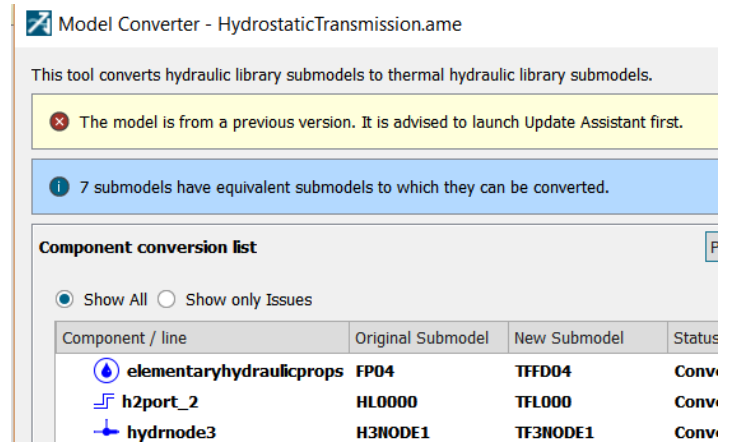
Conserve model structure and parameterization



Interact with the sketch



Model conversion notifications



FEATURES

- Same sketch presentation and parameterization
- Interaction between the tool and model sketch by clicking the component and getting labeled component in sketch
- Notification of conversion success, submodel which could not be converted and conversion details by component

BENEFITS

- Start new research efficiently by re-using existing models
- Conduct troubleshooting efficiently with the help of conversion status and dedicated information for each component
- Get information about the conversion scope with transparent messages

Support of Microsoft Visual C++ 2015–2019 compilers

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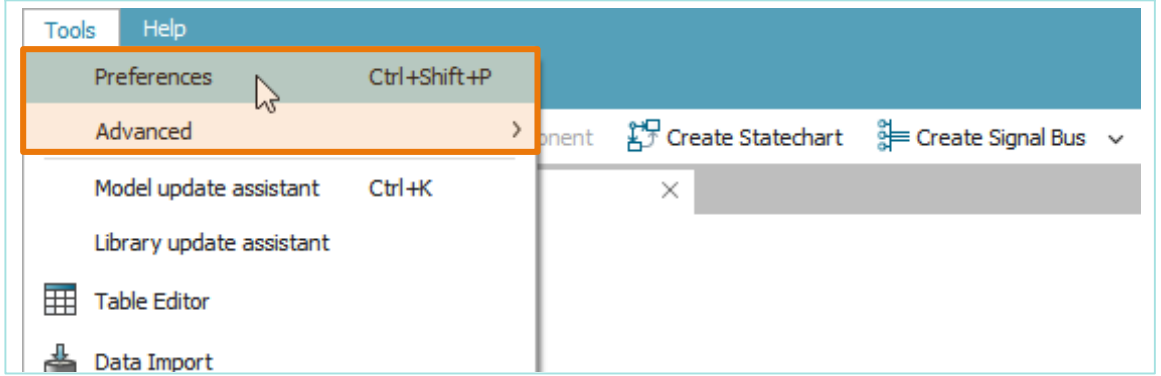
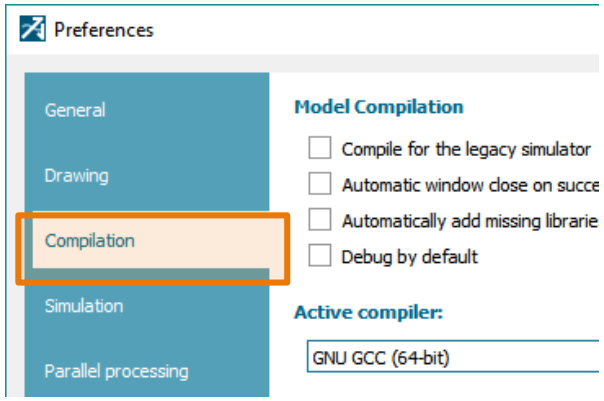
Platform Facilities

- Simcenter Amesim now complies with versions 2015 to 2019 of the Microsoft Visual C++ compiler under Windows, for the 64-bit compilation of (super)components or models

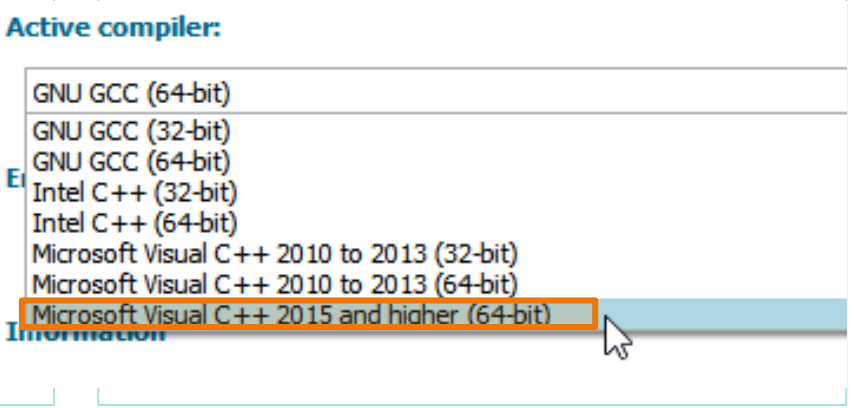
On a Windows PC with Microsoft Visual C++ compiler 2015, 2017 or 2019 installed, open the Simcenter Amesim preferences menu



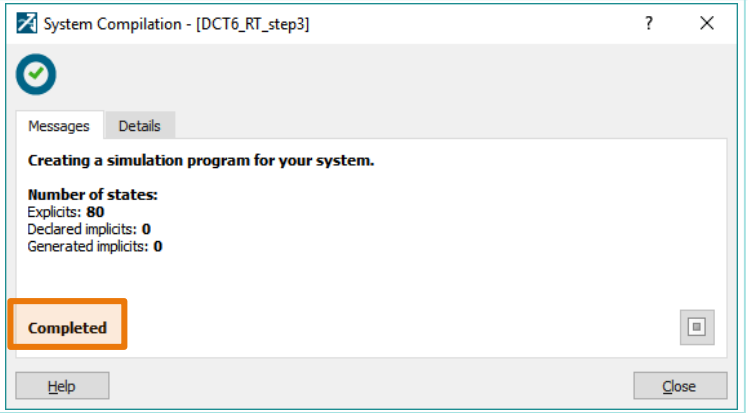
Look for the Compilation tab



Select "Microsoft Visual C++ 2015 and higher (64-bit)"



Compile your model



Performance analyzer: stability regions

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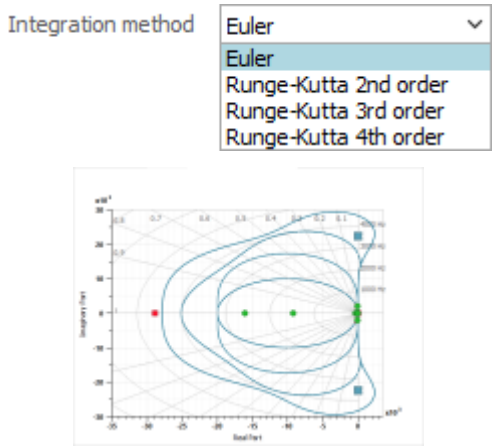
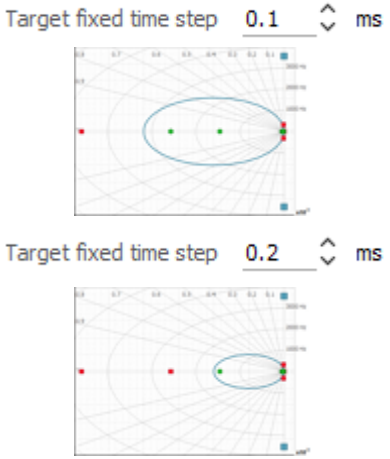
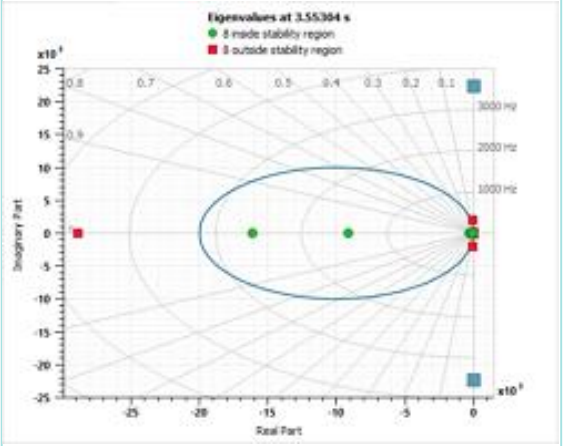
Integration method selection



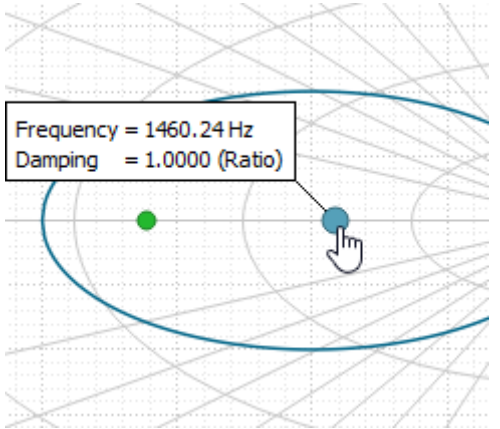
Fixed time step setting



Color and shape differentiators



Eigenvalues properties tag



FEATURES

- Selection among integration methods related to available fixed time step solvers within Simcenter Amesim
- Numerical stability region update according to fixed time step to be used
- Access from plot to additional information on eigenvalues

BENEFITS

- Ensure that your model can be exported to real-time target
- Identify straightforwardly the best suited numerical integration method for a given fixed time step
- Comprehend quickly which eigenvalues – and so model components – are the roots of diverging simulation

Performance analyzer: frequencies pane enhancements

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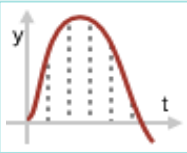
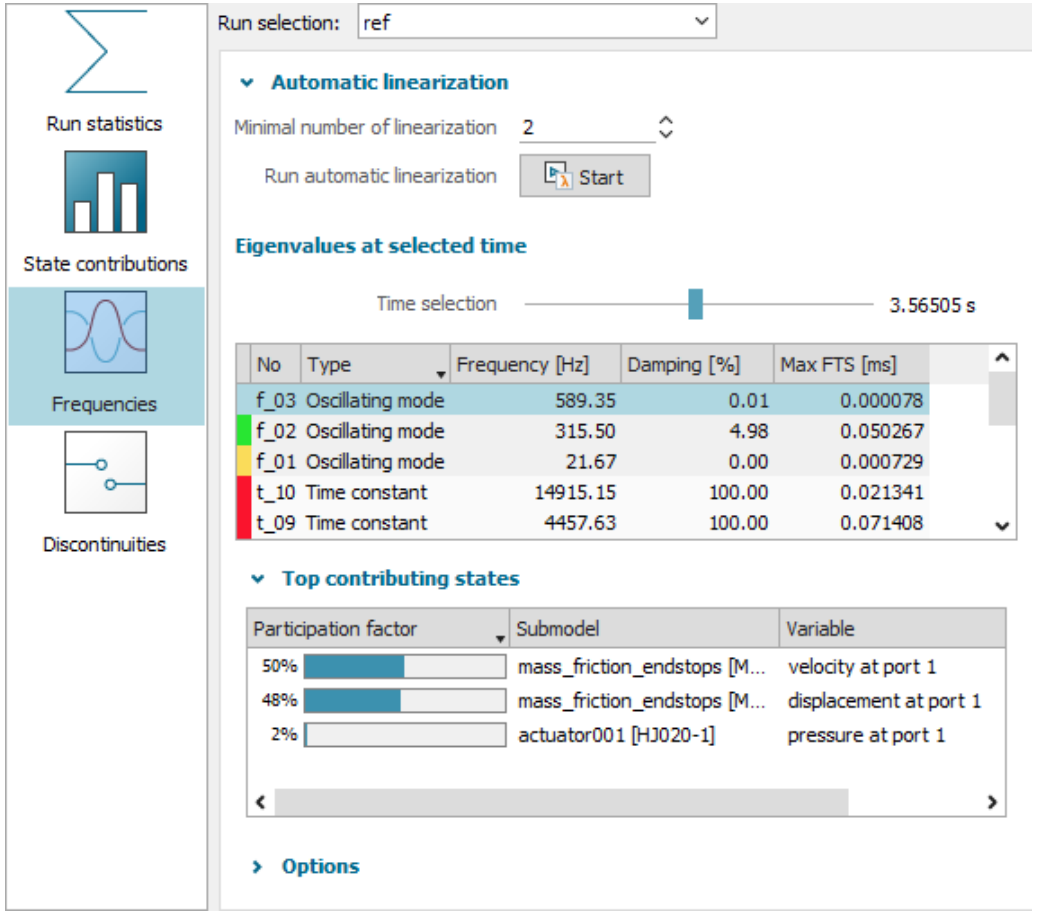


Solver and Numerics

- Identify undamped and unstable high natural frequencies of the system in order to reduce CPU time
- Detect which components are the most important contributors for each eigenvalues
- Get limiting fixed step integration to get stable model when exporting to real-time target

From Performance Analyzer



Performance analyzer: frequencies pane enhancements

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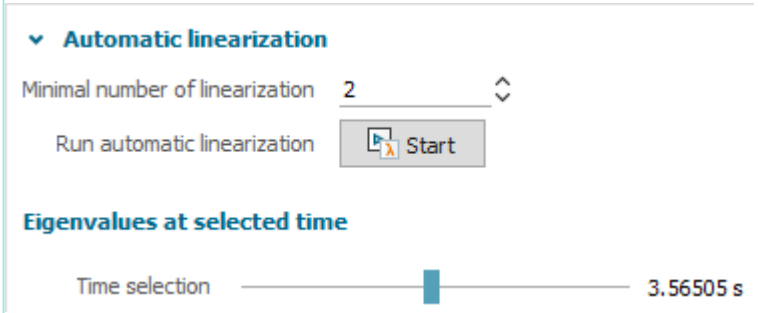
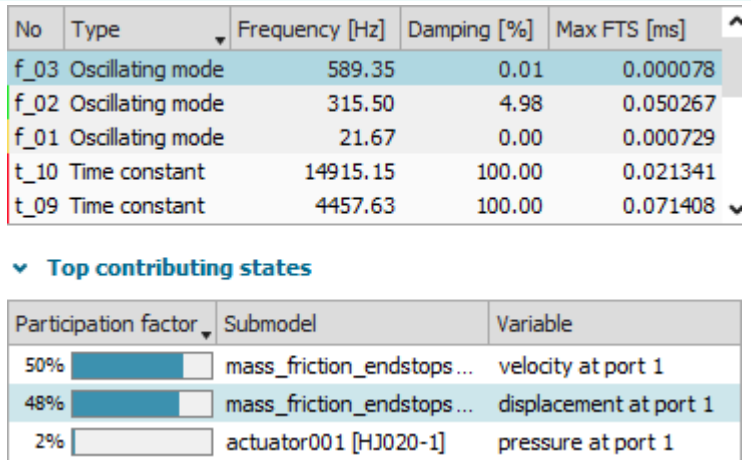
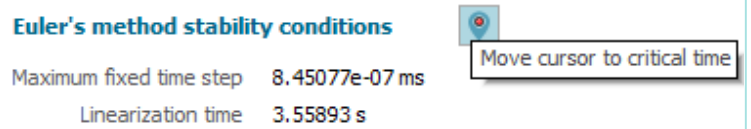
Automatic linearization and time selection



Eigenvalues and participation factors



Stability conditions for real-time export



FEATURES

- Automatic detection of stiff solving instant
- Eigenvalues and associated participation factors computation at detected time
- Euler's explicit method stability conditions for real-time model conversion

BENEFITS

- Catch up directly information about solving slow-down without any additional analysis
- Visualize easily which components of your system are the limiting ones for model speed-up
- Get numeric conditions for real-time export

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Agenda:

系统仿真概述
军工行业的应用概述
军工行业-液压应用
液压高级应用
总结

Simcenter Amesim history

30 years experience in mechatronic simulation

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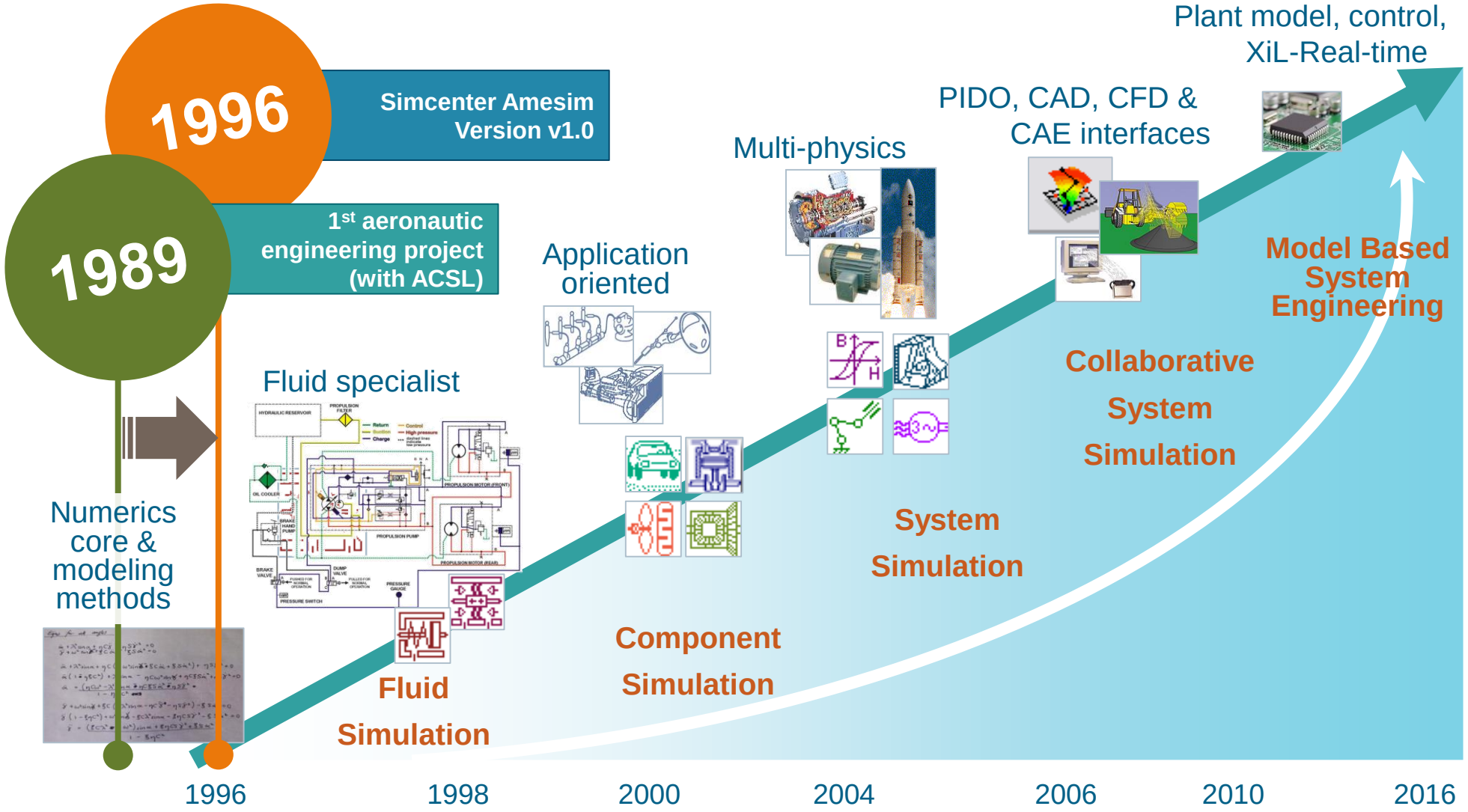

Opening and Coupling with CAE world

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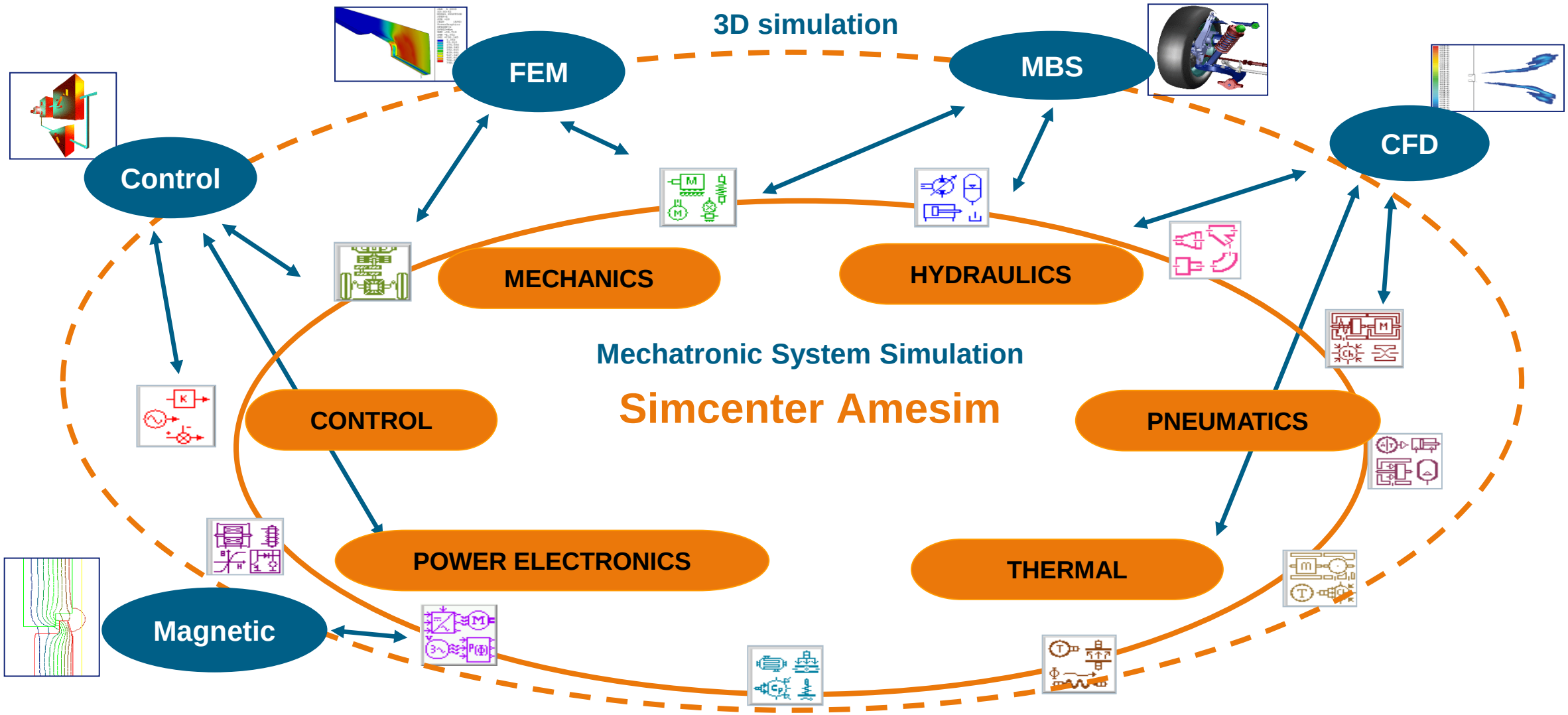

Thank you

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