

Predictive Engineering Analytics WIEPF16

**André Oliveira, Engineering
Services Manager**

A **prediction** (Latin *præ-*, "before," and *dicere*, "to say"), or **forecast**, is a statement about an **uncertain event**.

Engineering

is the application of mathematics, empirical evidence and scientific, economic, social, and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, processes and organizations.

Analytics

is the discovery, interpretation, and communication of meaningful patterns in data. Especially valuable in areas rich with recorded information, analytics relies on the simultaneous application of statistics, computer programming and operations research to quantify performance.

What is Predictive Engineering Analytics?

The hability to accurately predict product performance across a range of engineering disciplines, mechanical and controls, and all the stages of product development.

Concept – Release - Usage

Create a Digital Twin of the product to verify and validate product performance throughout the product lifecycle.

Analytics, Optimization, Short Development Cycle

... And coupling to that powerful data analytics tool do data analytics across all engineering disciplines including usage data to enable design space exploration and optimize the product performance and in shortest development cycle.

The world is evolving



The world is evolving...

Addressing these challenges requires a new approach



Companies must evolve their product engineering practices to meet these new challenges or risk becoming obsolete

How to create a bridge from this lack of knowledge and innovative techniques?

How to speed up application, capaciting and in-house independent use?

One constant: addressing these engineering challenges...
...without compromising time-to-market, quality and cost

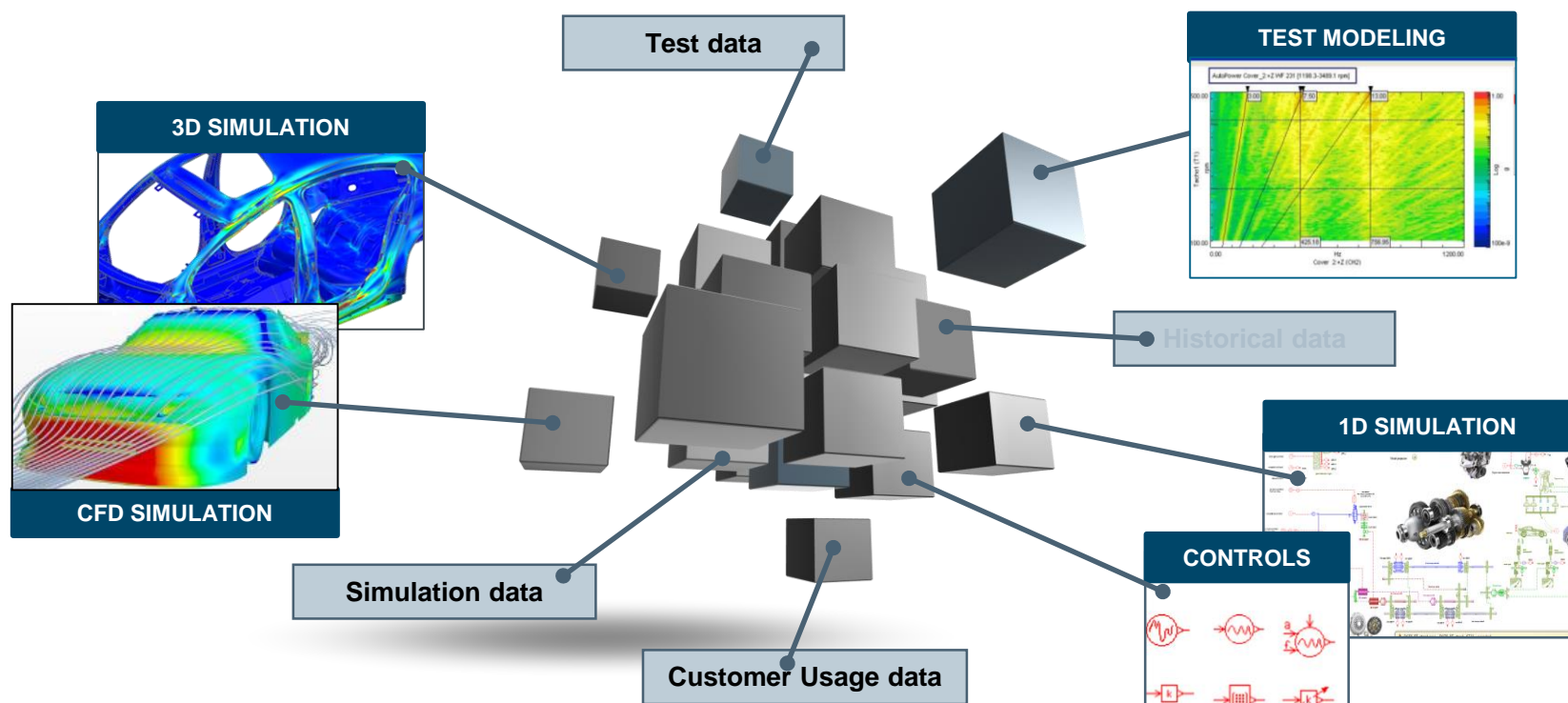
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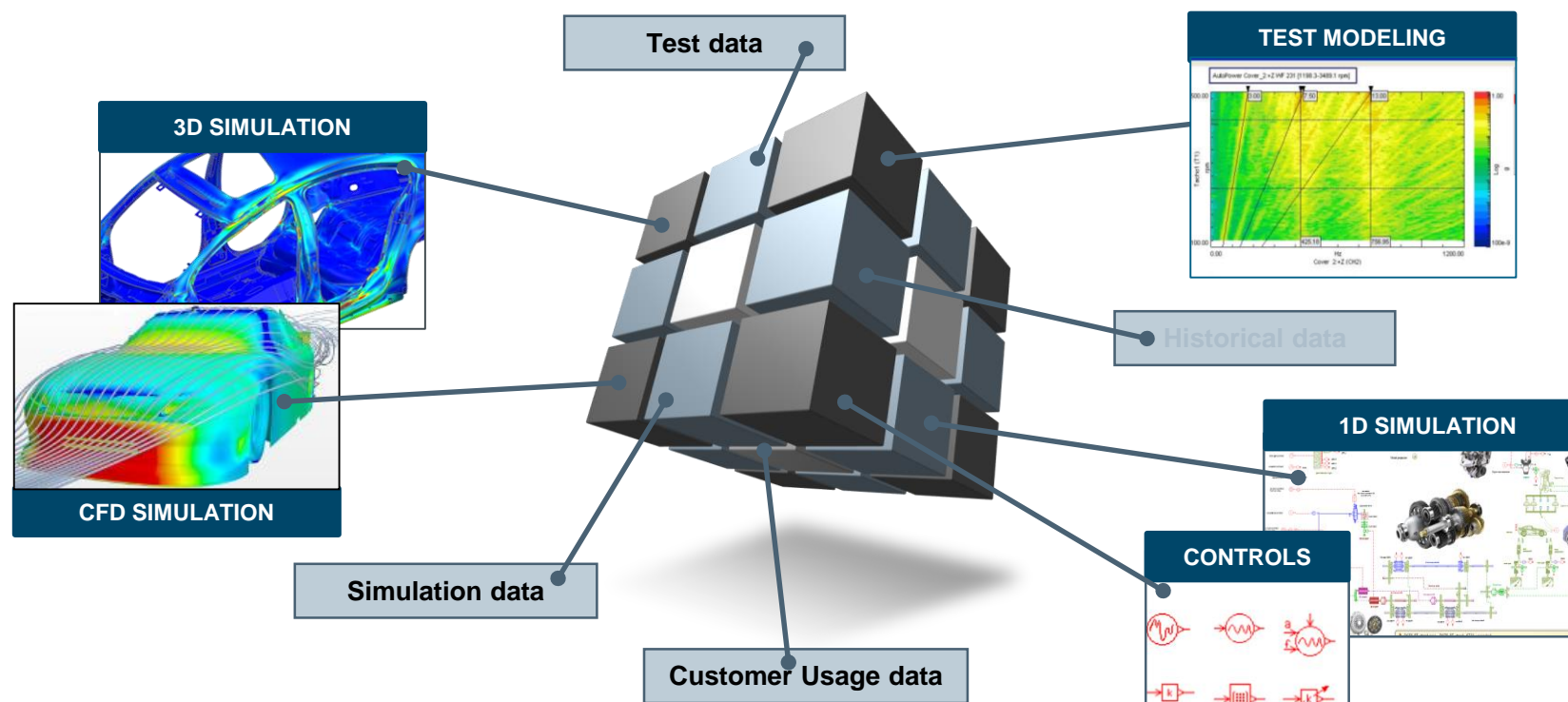
From disconnected models and data ...



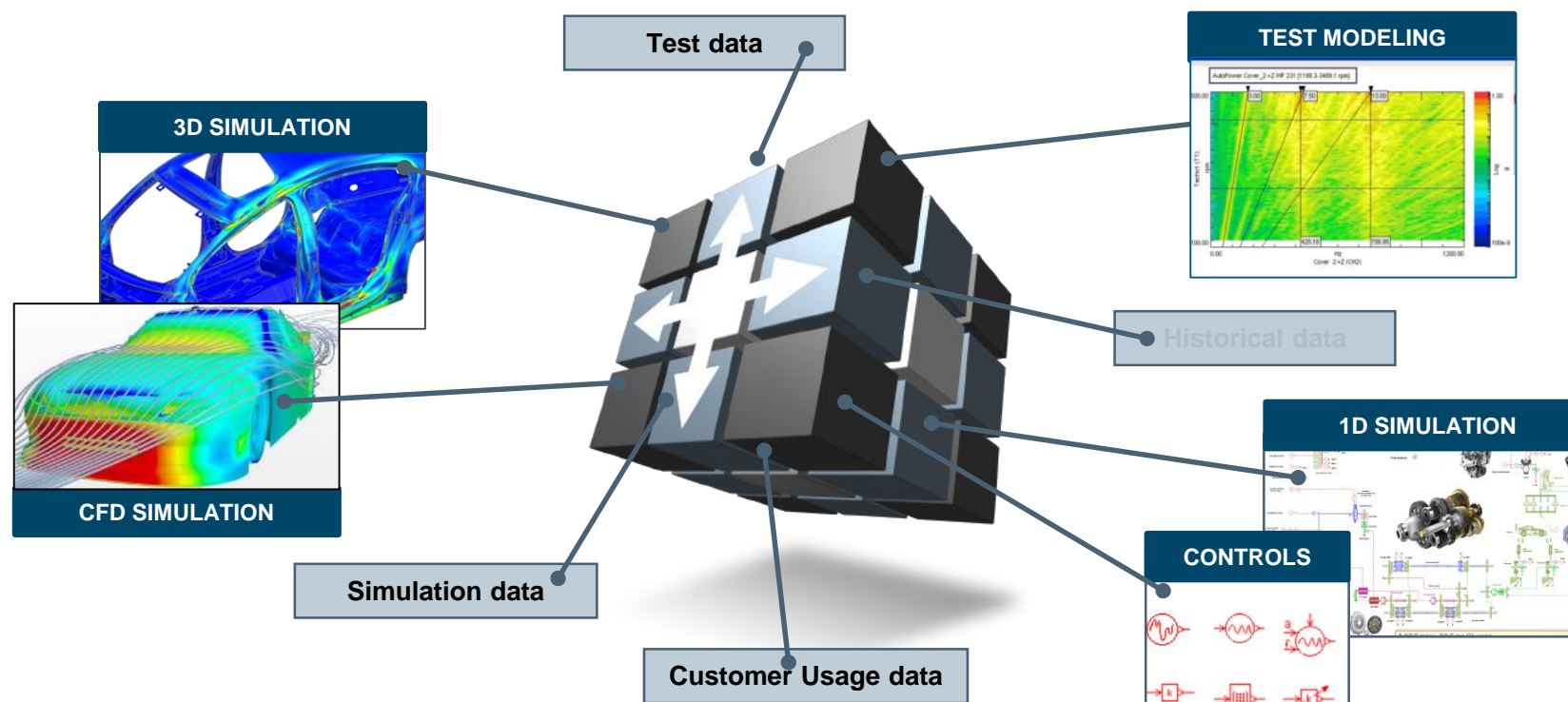
From disconnected models and data ...



...to a performance Digital Twin



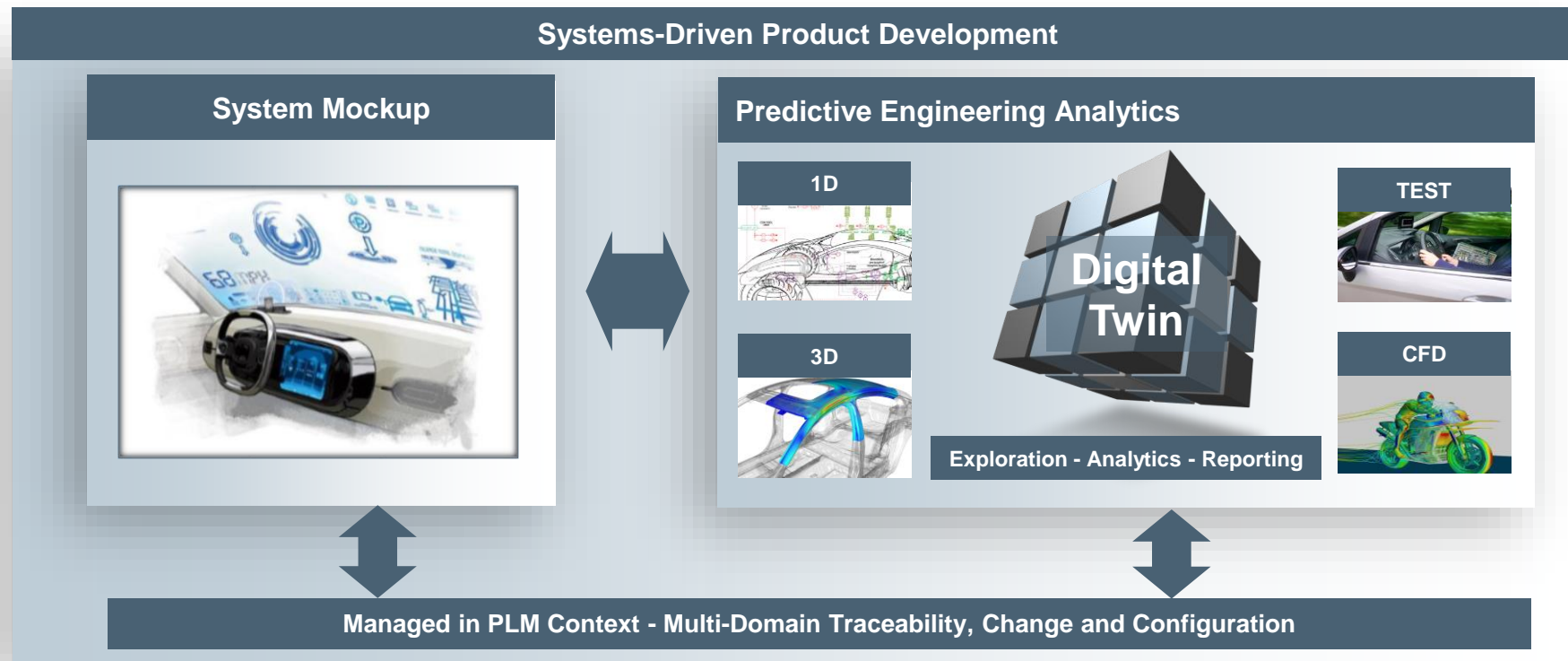
... enabling Predictive Engineering Analytics



Predictive Engineering Analytics

Role in Systems-Driven Product Development

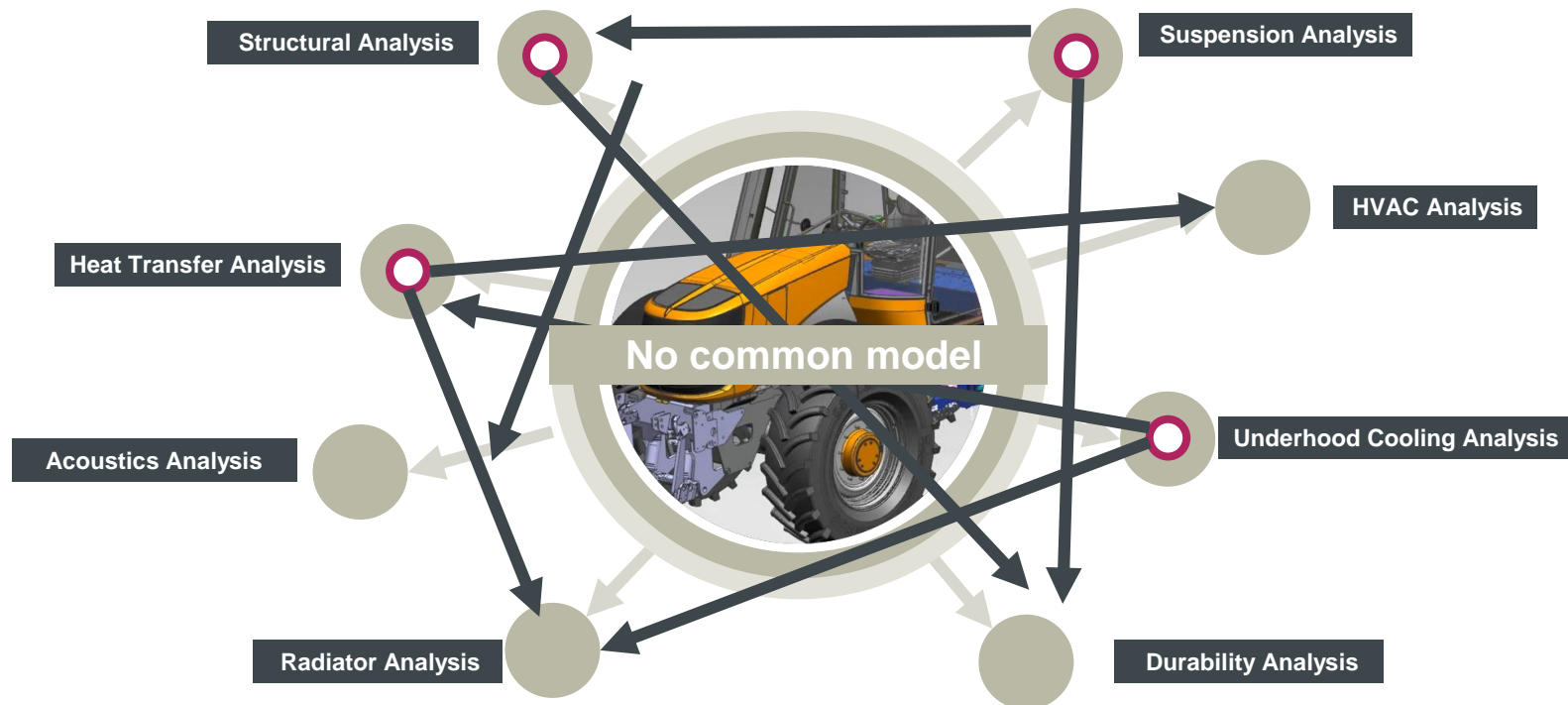
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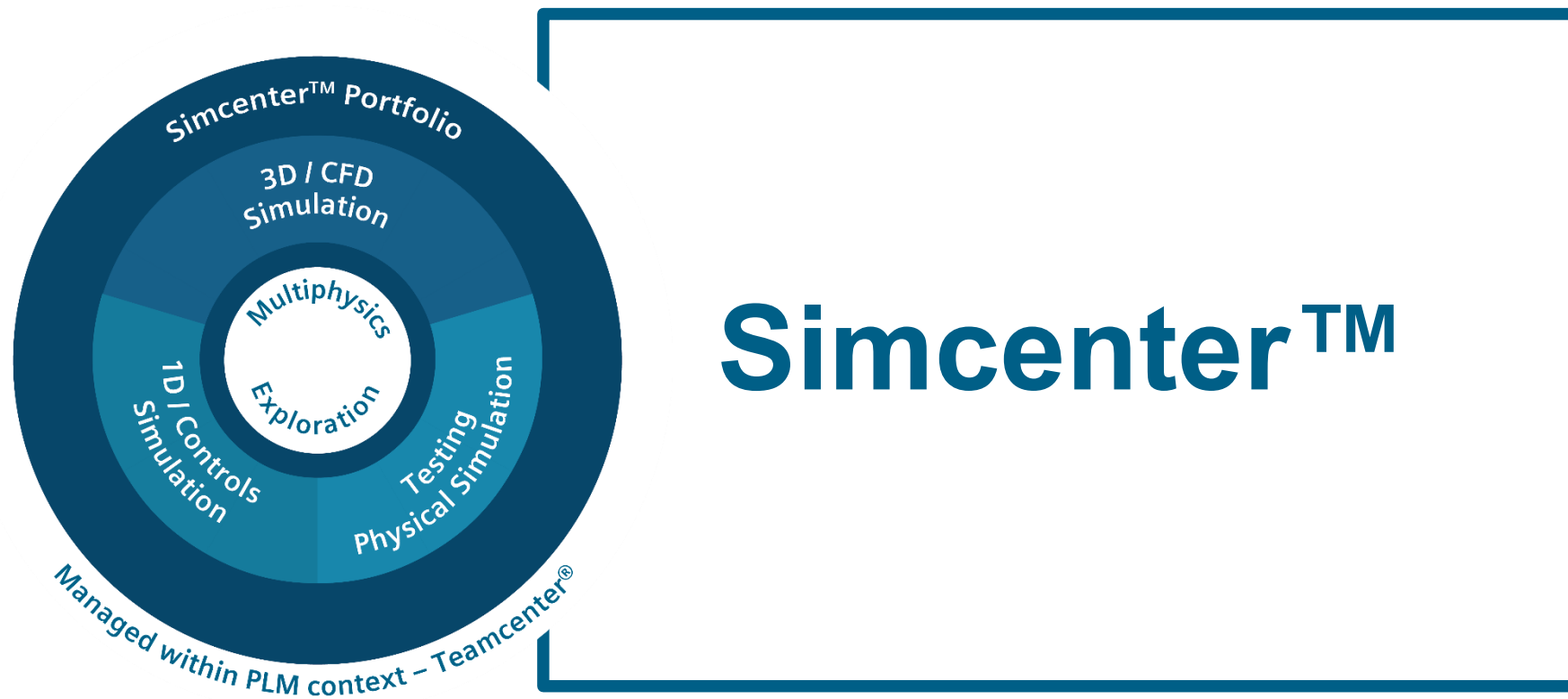
3D simulation today

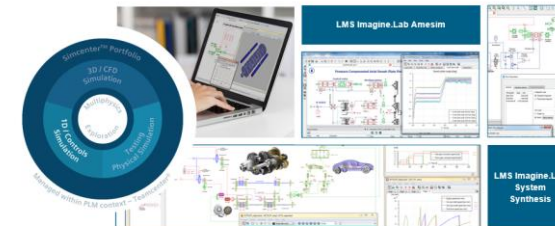
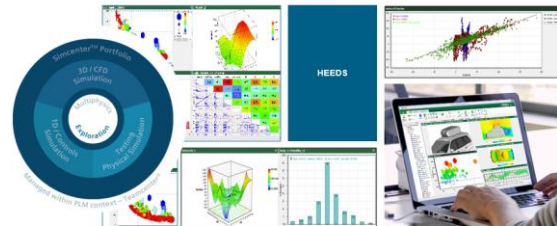
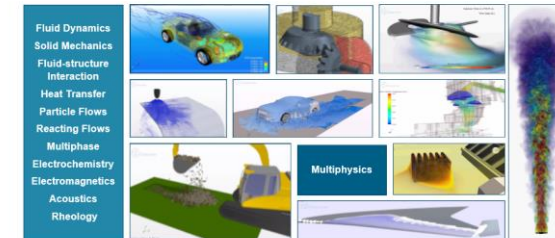
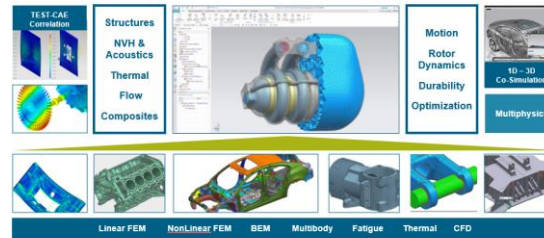
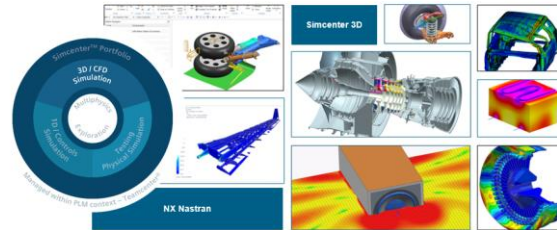
Disconnected, ad-hoc

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Introducing Simcenter™ Portfolio for Predictive Engineering Analytics





Engineering services – LMS & CD-adapco

Experience and global talent for valued customer partnerships

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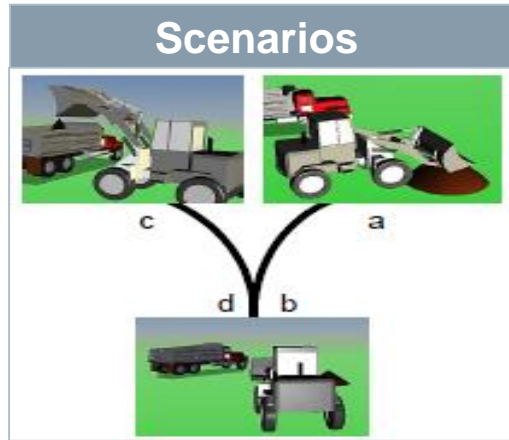
LMS Imagine.Lab Amesim Hydraulic components and systems modeling

FPNI 2016 - Brazil

LMS Imagine.Lab Amesim 1D simulation platform

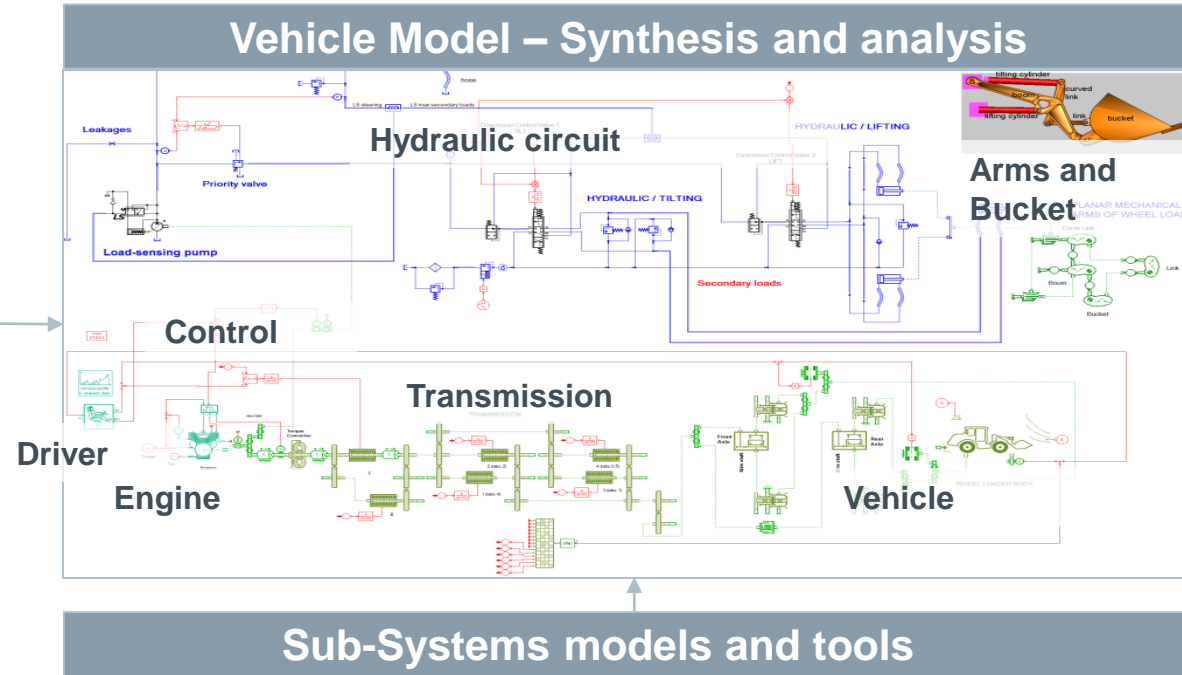
...from vehicle synthesis to sub-systems optimization...

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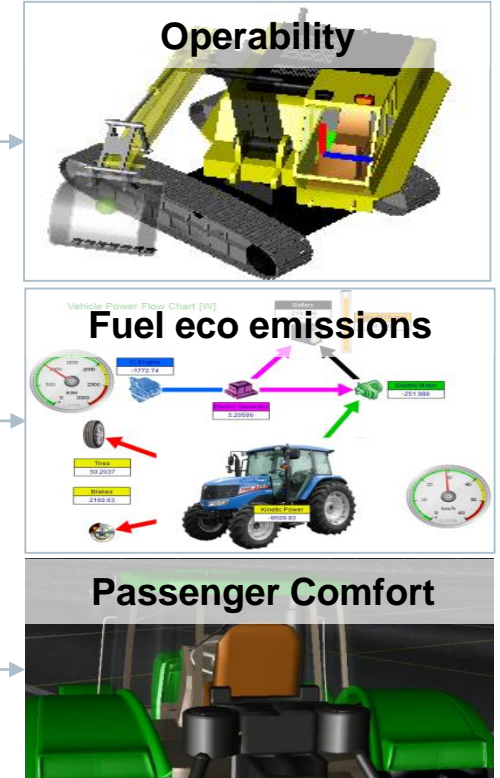


Multiple working scenario's

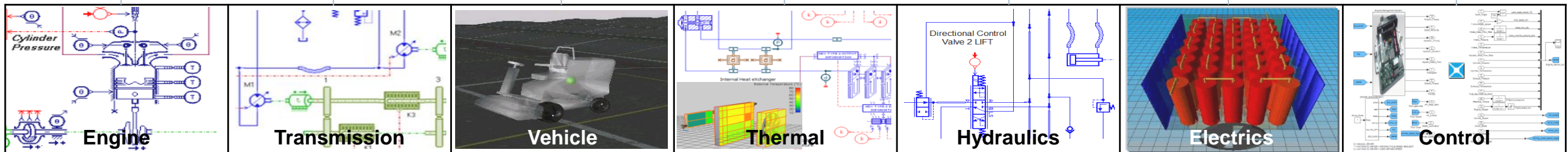
DLG Power-Mix, Y-cycle, JCMAS H020:2007 ...



Sub-Systems models and tools



Performance attributes

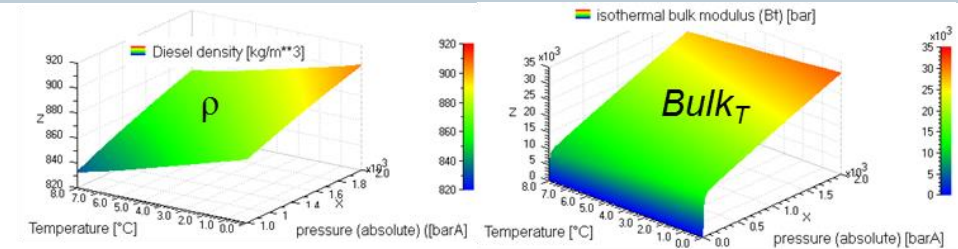


Solution portfolio

Advanced hydraulic fluid properties

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- **Compressible liquids with strict handling of fluid properties** as a function of p & T : thermodynamic variables always respect mass and energy conservation principles
- **Aeration and dissolution** of air within the liquid
- **Cavitation** (vapor generation)
- Comprehensive **database** of common liquids **within LMS Amesim** (oils, fuels, coolants...)
- Possibility to **generate customized fluids** (Media Properties Assistant for thermal-hydraulics)



Three aeration options available (R14)

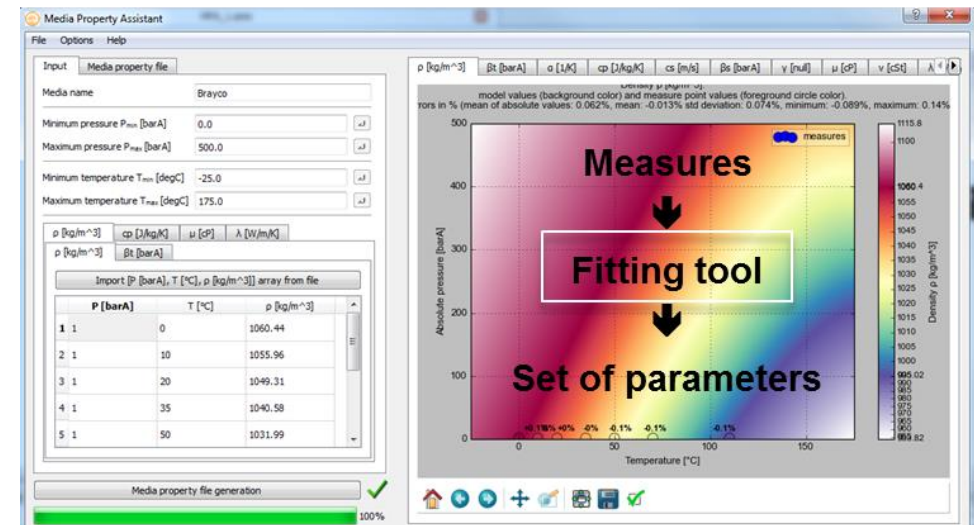
Enumeration in TFFD3 and TFFD4 fluids

aeration/dissolution **constant gas content**

constant gas content
gas transport
gas transport and dynamics

- Constant total gas content
- Transport of gas content only
- Transport of gas content, with aeration and dissolution dynamics

NEW

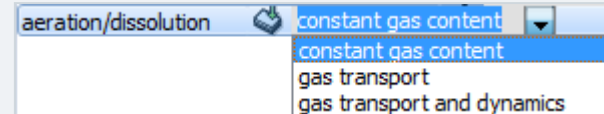


Different complexity levels for aeration models

Three aeration options



► Enumeration in the fluid submodel



- Constant gas content
- Gas transport (variable gas contents, without dynamics)
- Gas transport, with aeration and dissolution dynamics

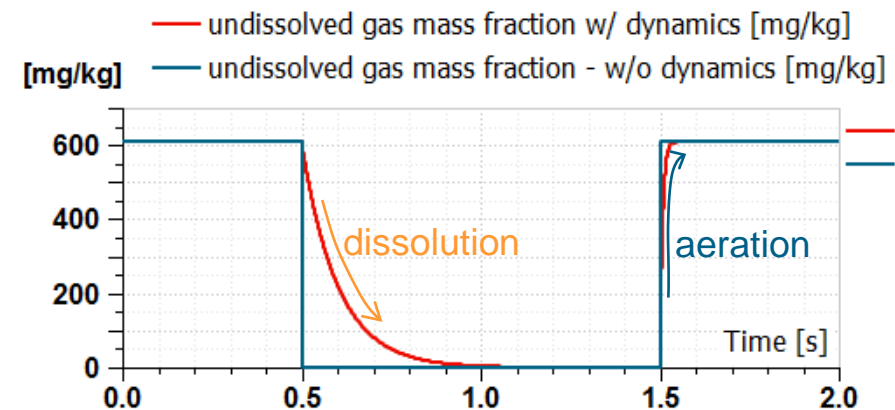
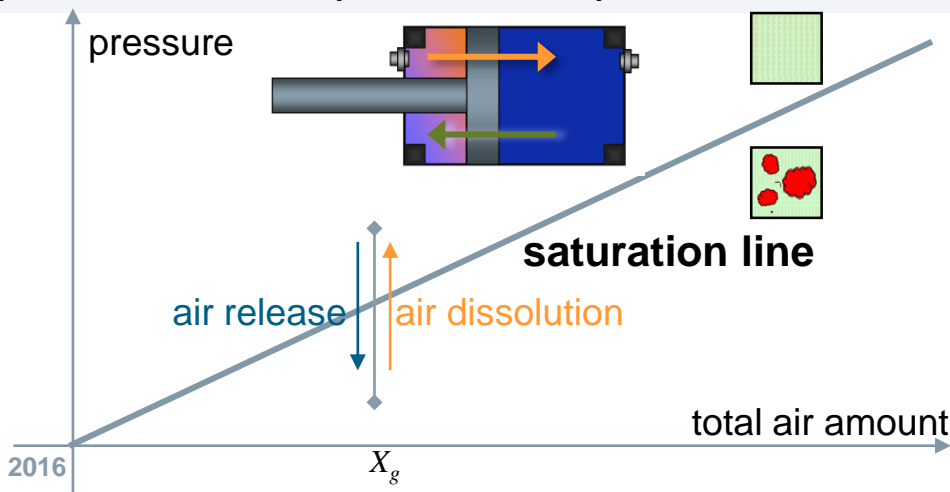
Dynamics for dissolution and aeration



aeration/dissolution	gas transport and dynamics
aeration time constant	0.001 s
dissolution time constant	0.1 s

- First order dynamics, characterized by time constants, for both air release and dissolution

Compression/decompression step to a closed volume, crossing the saturation pressure:



Introduction to pumps

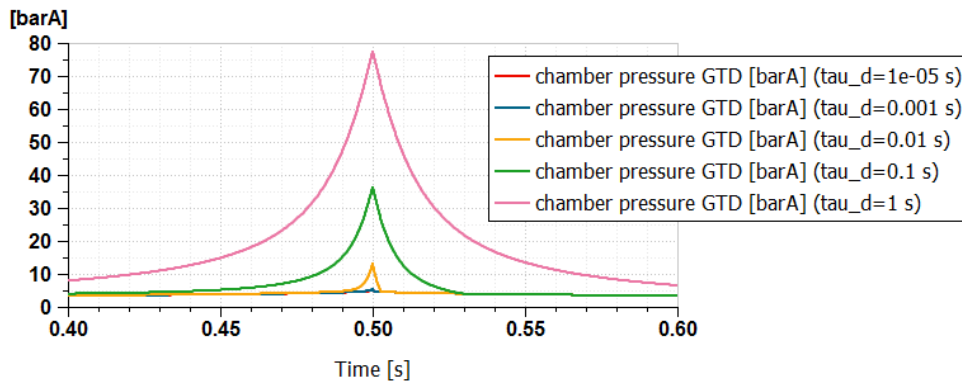
Effects of aeration and dissolution dynamics on fast compressions

Time constants for air release/dissolution allows to consider

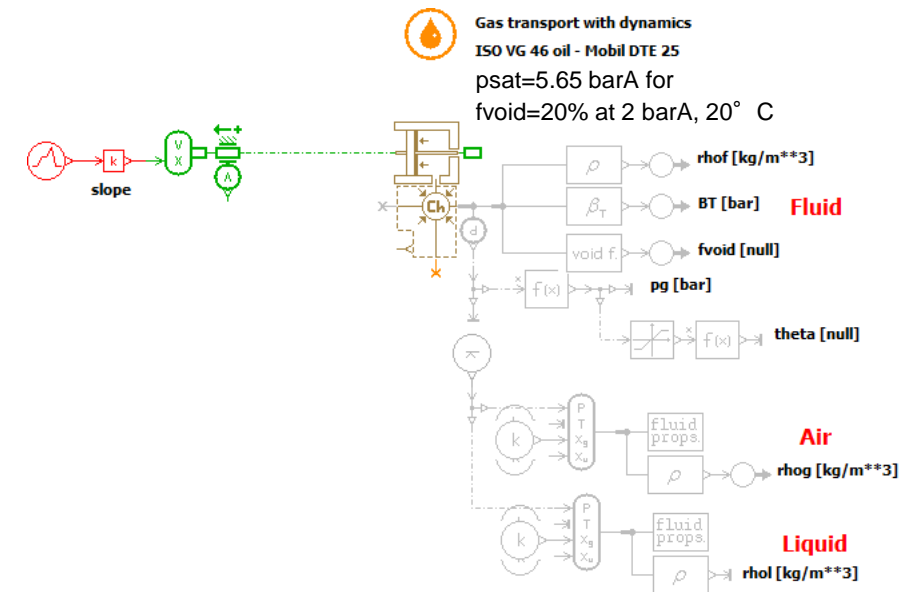
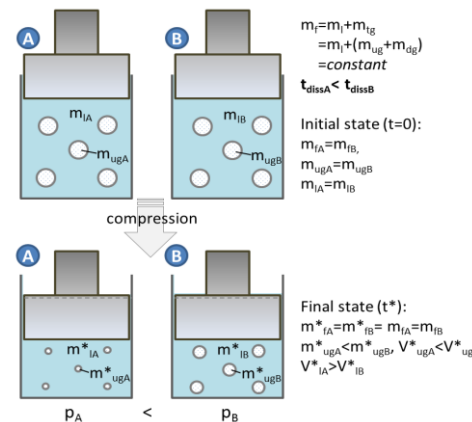
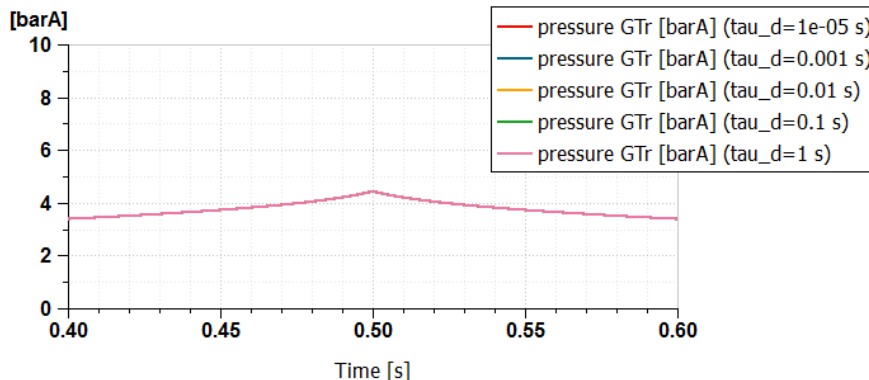
- Complex processes of bubbles formation, growth and collapse with a simplified first order response

aeration/dissolution	gas transport and dynamics	aeropt
aeration time constant	constant gas content	aeratau
dissolution time constant	gas transport	disstau
	gas transport and dynamics	

Gas transport option with different dissolution dynamics



Gas transport option (without dynamics)

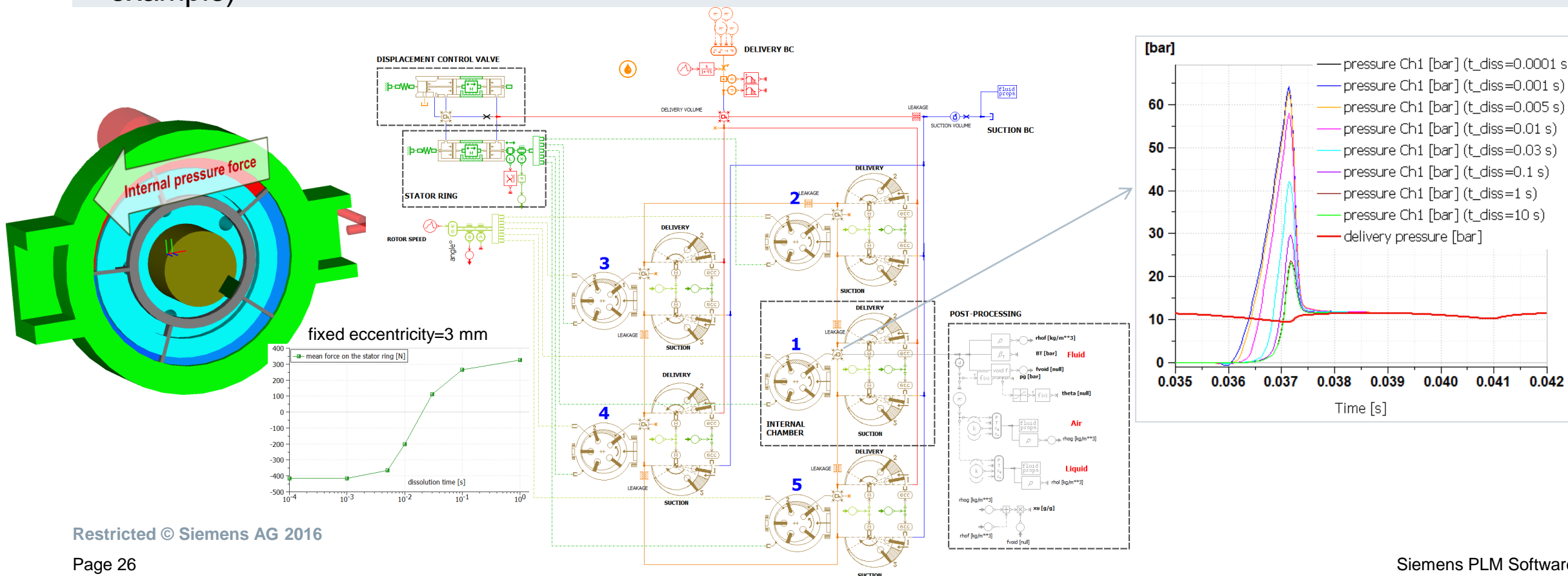


Pressure levels depend on dissolution dynamics for “fast” compression/expansion cycles

Effects of gas dynamics on hydrostatic pumps

dissolution dynamics may have significant effects on ...

- internal pressure peaks and NVH characteristics
- regulated displacement coming from the force balance on the control device (stator ring, for example)

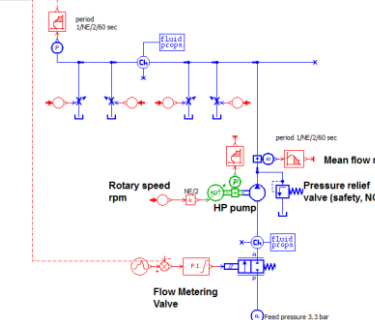
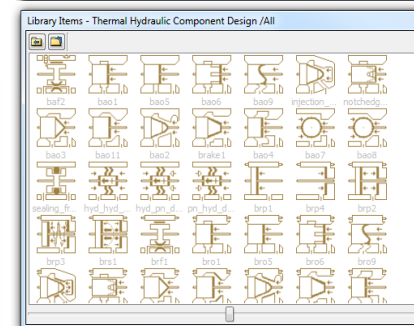
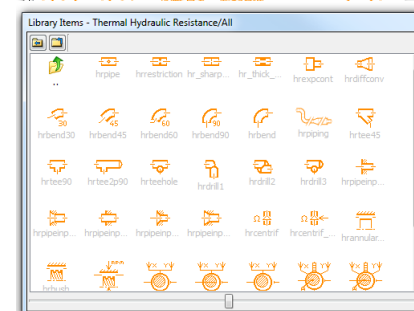
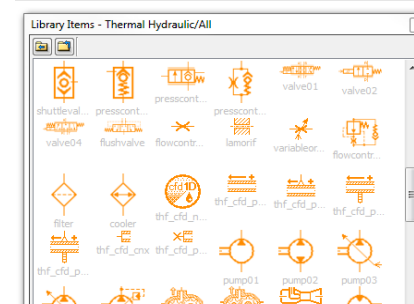
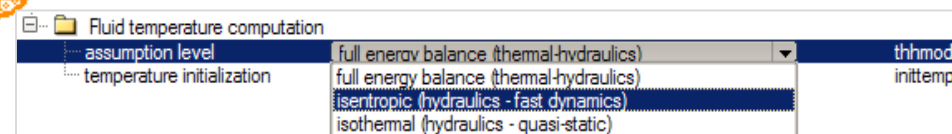


Solution portfolio

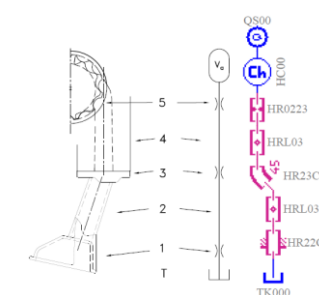
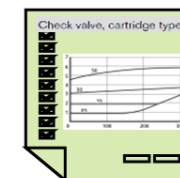
Hydraulic, hydraulic resistance and hydraulic component design libraries

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- **Different simulations possible in just 1 click** with thermal-hydraulic libraries:
Isothermal (constant temperature), adiabatic (temperature increase due to compression only) or full energy conservation (heat exchanges)
- **Functional hydraulic library** for overall/prevaling behaviors
- **Hydraulic resistance library** for local pressure losses in high flow - low pressure systems
- **Hydraulic component design library** for full dynamics

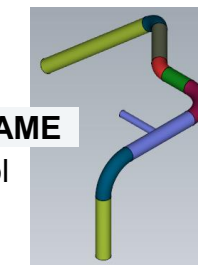


Functional Datasheet

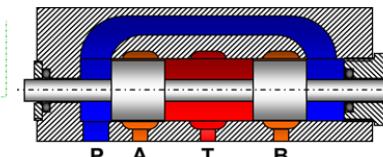
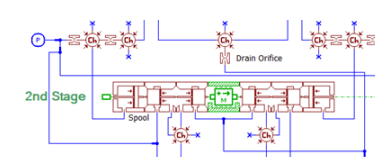


CAD Drawing

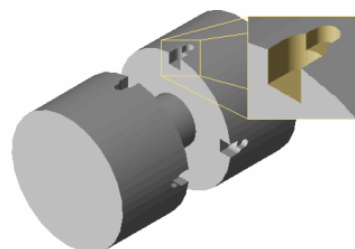
CAD2AME
tool



CAD Drawing



Siemens PLM Software

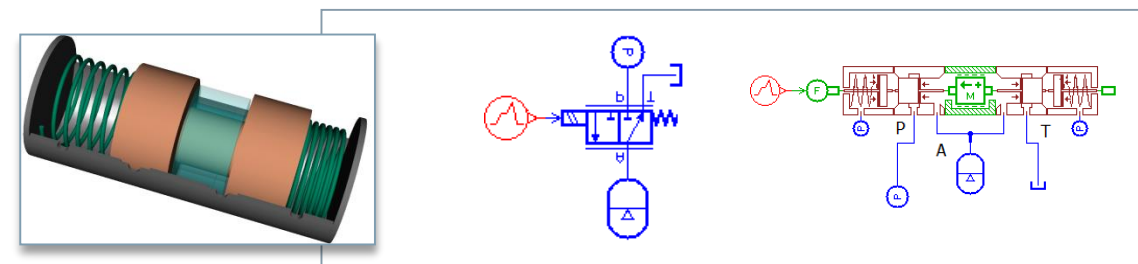
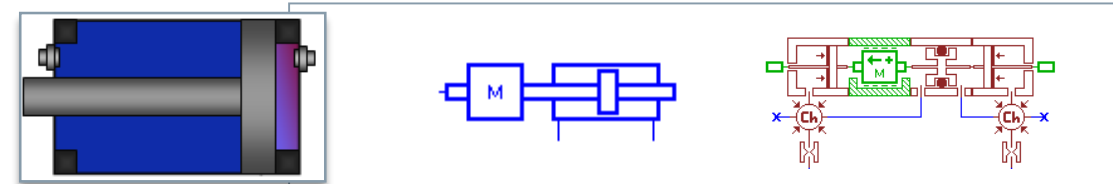
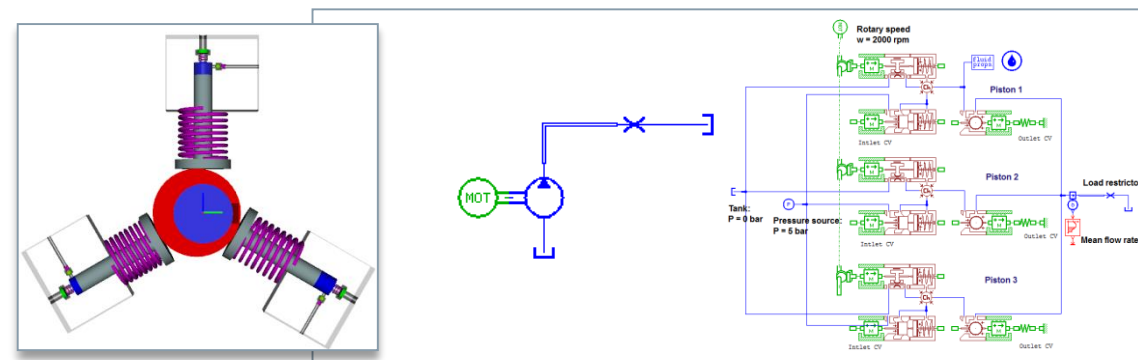


Solution portfolio

Scalable modeling approach

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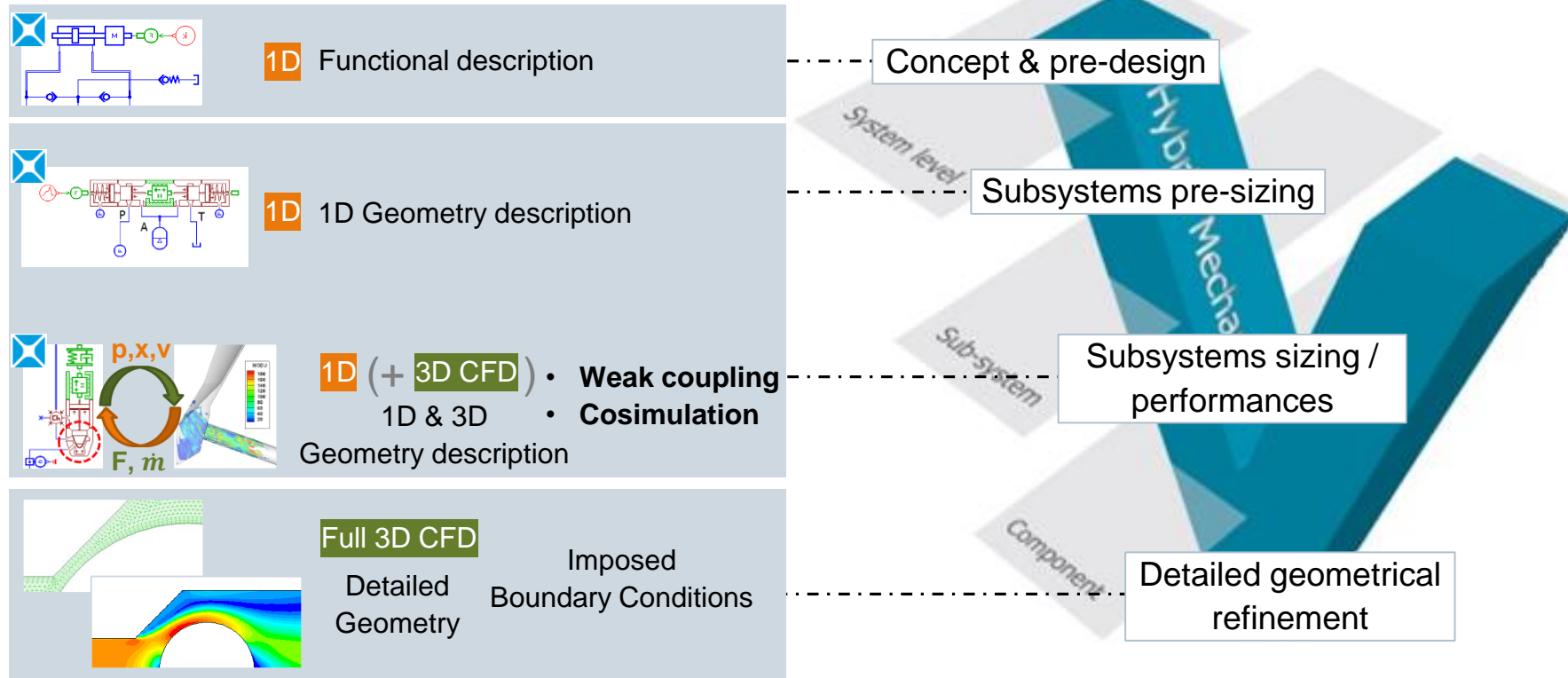
- **Different complexity levels** depending on simulation targets:
 - Overall trends or detailed high-fidelity behaviors
 - Available input data (functional datasheet or CAD drawings)
 - Dynamics to be represented: quasi static, slow or fast transients
- **Tabulated, functional and detailed geometrical models** for system, sub-system and component level simulation



Solution portfolio

Link with with 3D (fluid) simulation tools

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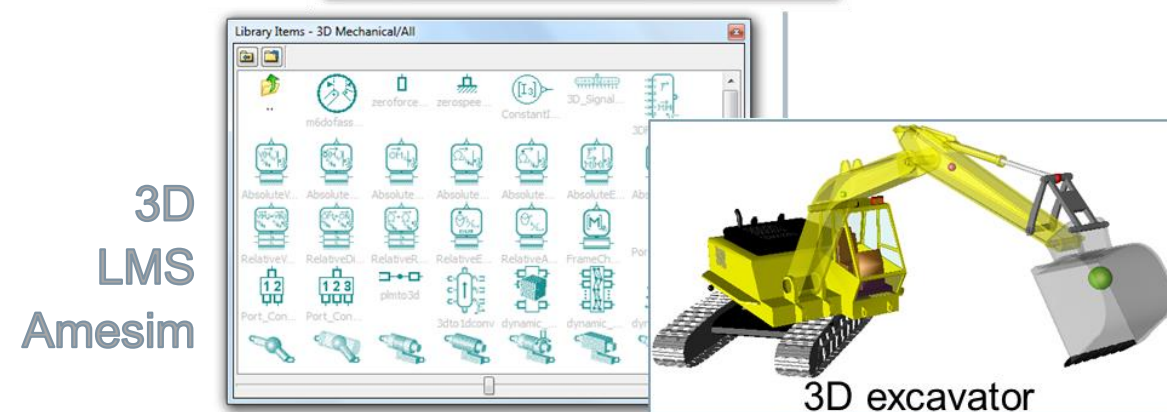
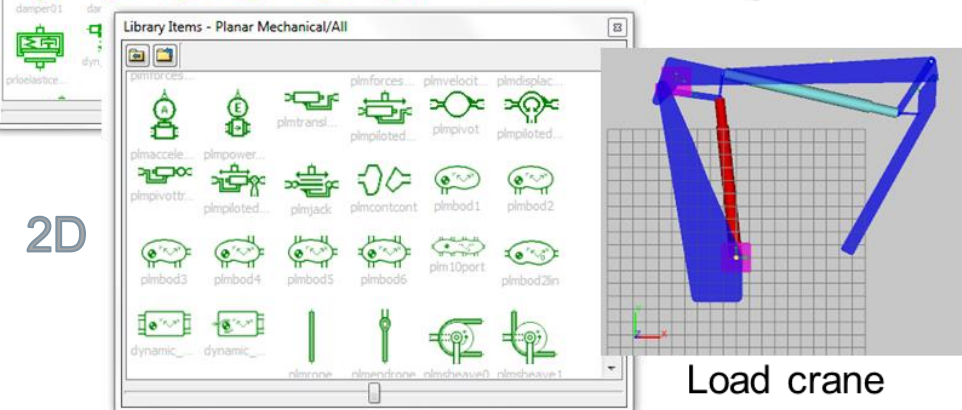
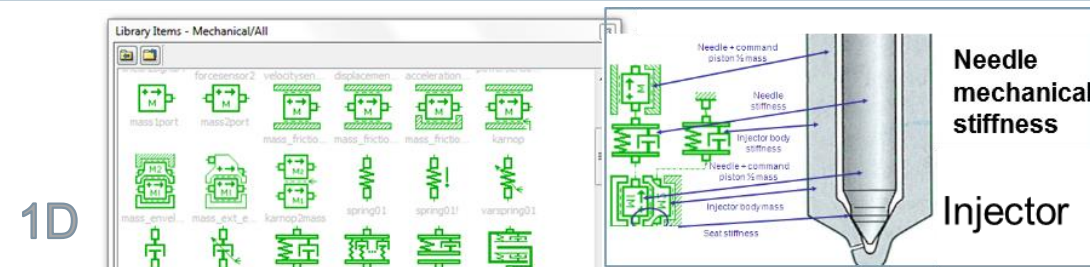
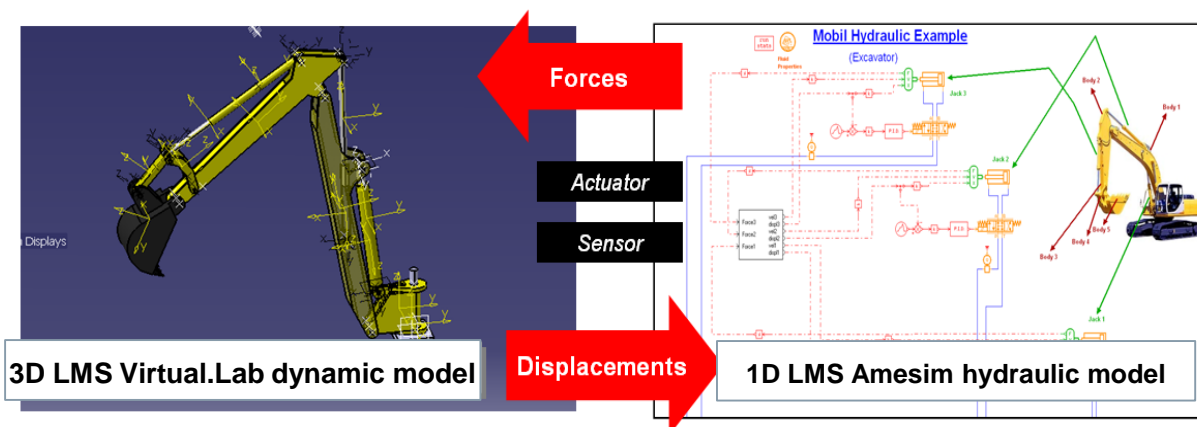
- 1D added value: fast transient analysis, multi-domain system simulation also if no CAD available
- 3D added value: very local detailed analysis

Solution portfolio

Link with mechanics

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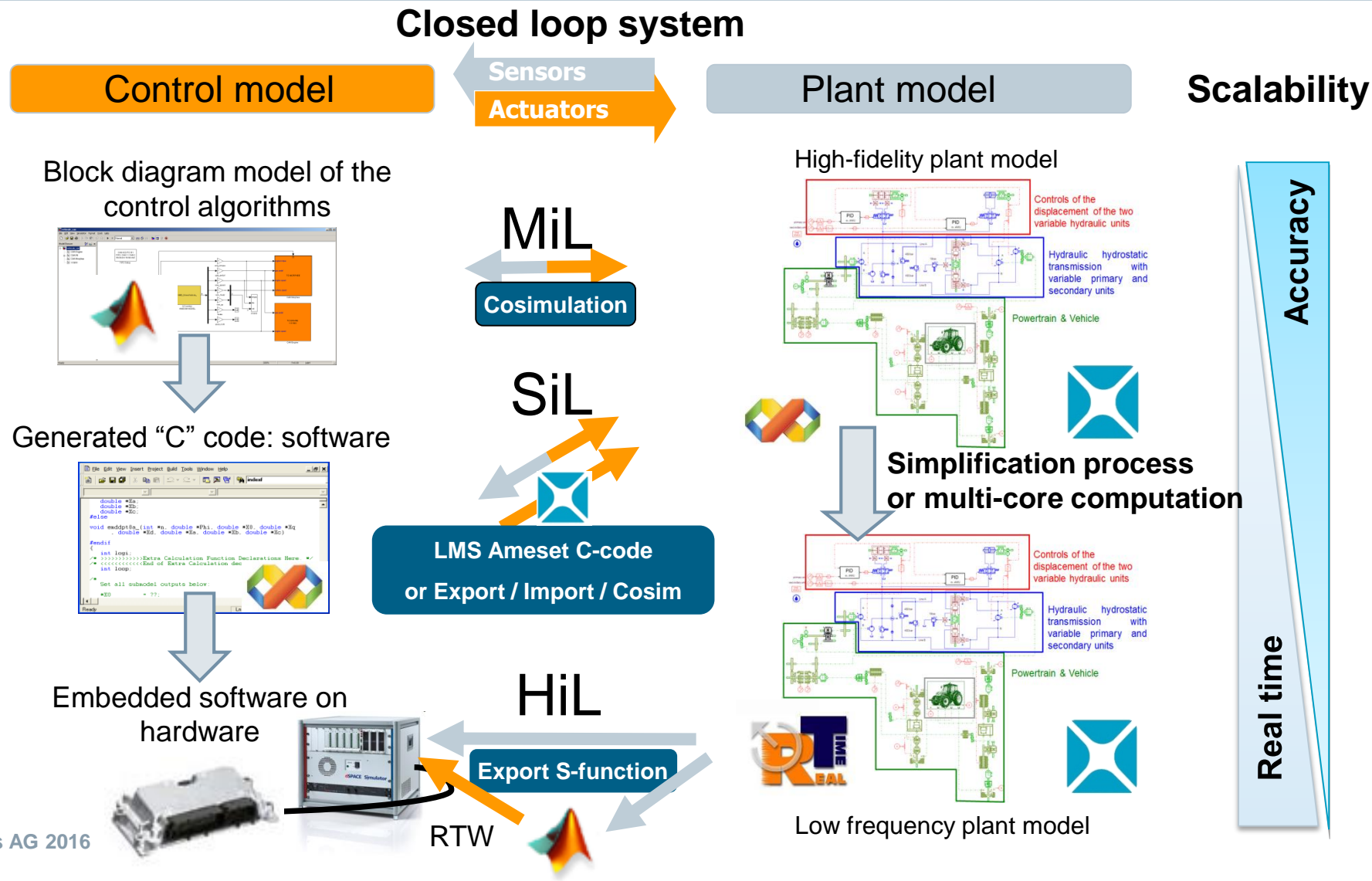
- **1D linear or rotary mechanics**
- **2D and 3D mechanical representation** with automatic assembly and animation tools
- **Elementary physics** (inertias, stiffness and damping) and **applicative elements** (gears, ropes & pulleys, cams...)
- **Interfaces 3D tools:** LMS Virtual.Lab Motion, ADAMS...

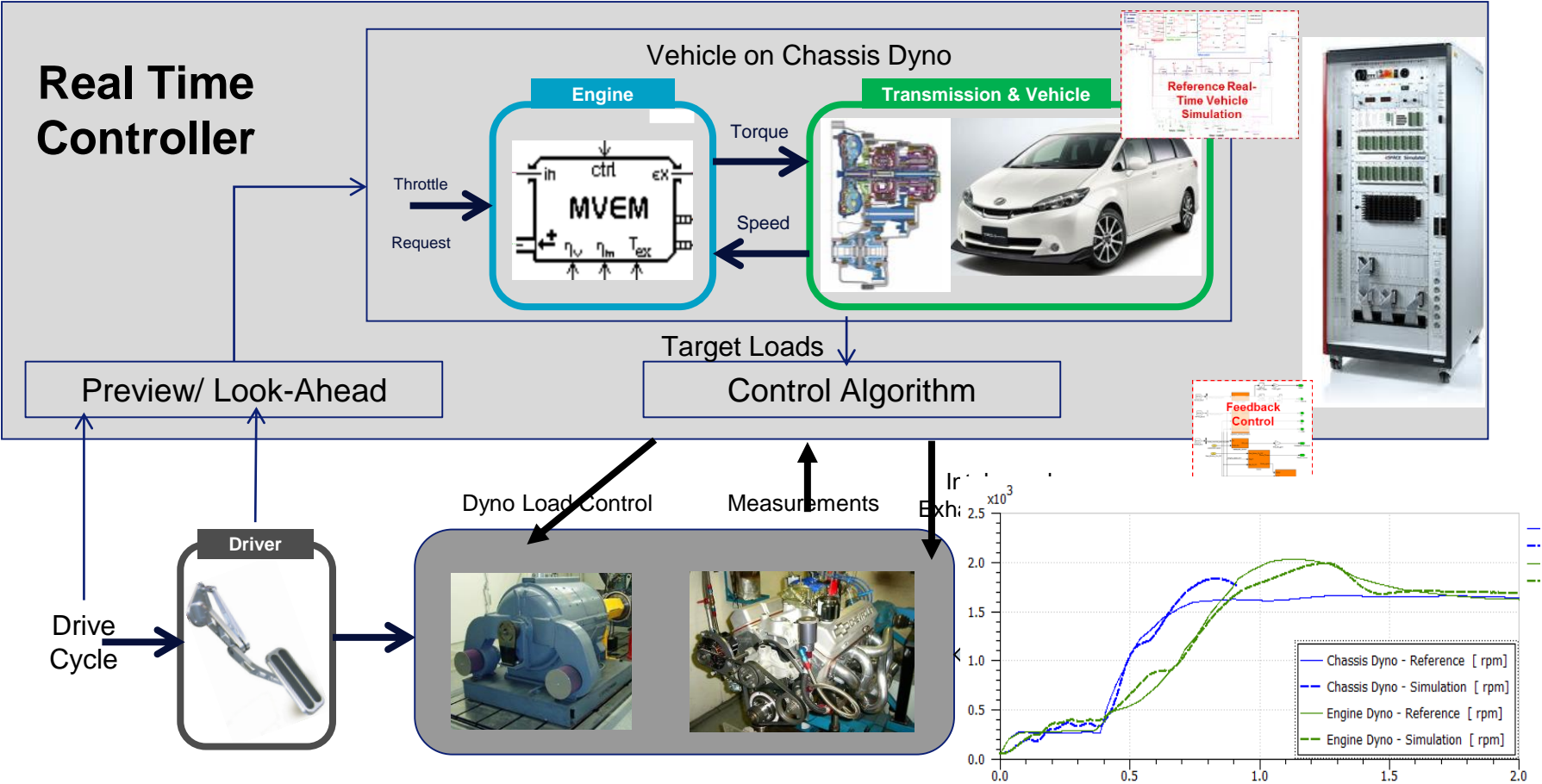


Solution portfolio

Link with Simulink controls

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Solution portfolio

Linear analysis tools for component design

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Linear analysis , what for?

PROBLEM

- Reduce **amplitude of oscillations** in excited systems = **component/system design**
- Check the **system stability** in the frequency range = **control & design**

What can you expect for linear analysis?

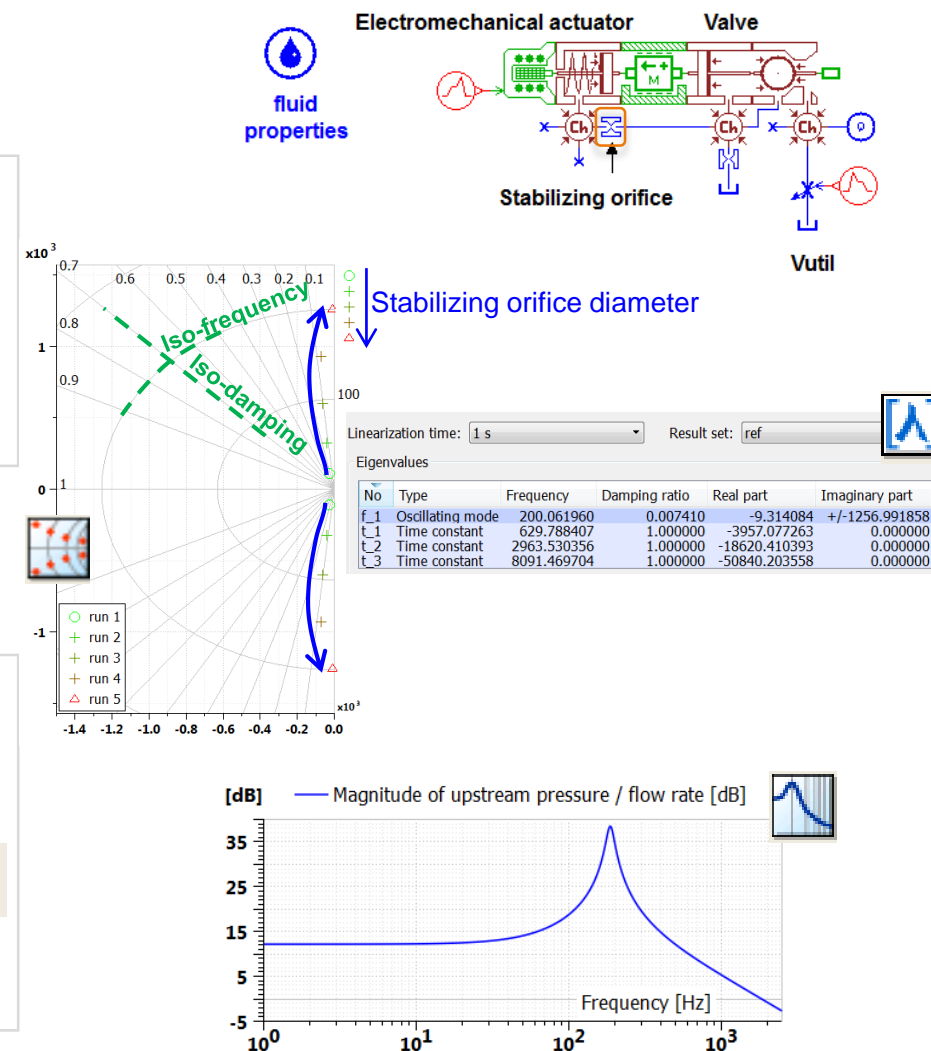
SOLUTION

Eigen values = natural frequencies + damping ratios 

Modal shapes = distribution natural modes over observers 

Frequency response = output/input frequency response: $Y(s)/U(s)$ 

Root Locus = sensitivity analysis in frequency-domain 



Kawasaki Precision Machinery (KPM): LMS Imagine.Lab Amesim application cases on hydraulic pump

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Challenges

- **Low-noise** design
- **Torsional vibration analysis**

Solution

- LMS Imagine.Lab Mobile Hydraulics Actuation Systems solution

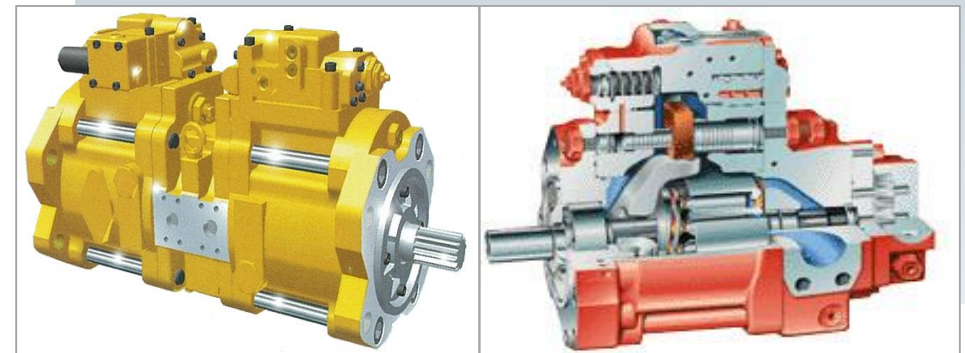
Benefits

- **Optimize the valve plate timing and notch shape** for reducing noise and pulsations
- Verify the **torsional resonant frequency of the pump-engine-flywheel system** with simple modeling
- View results in an intuitive and comprehensive way
- Shorten development time of the hydraulic pumps

“Simulation is very useful in an early stage study. We can choose experiment condition and achieve shorter developing time with less man-hours.”

LMS Imagine.Lab Amesim helps us understand intuitively and its models are easy to be shared.”

M. Ohmi
Kawasaki Precision Machinery
2005 Japan LMS Amesim User Conference



Liebherr: LMS Imagine.Lab Amesim to streamline hydraulic component development

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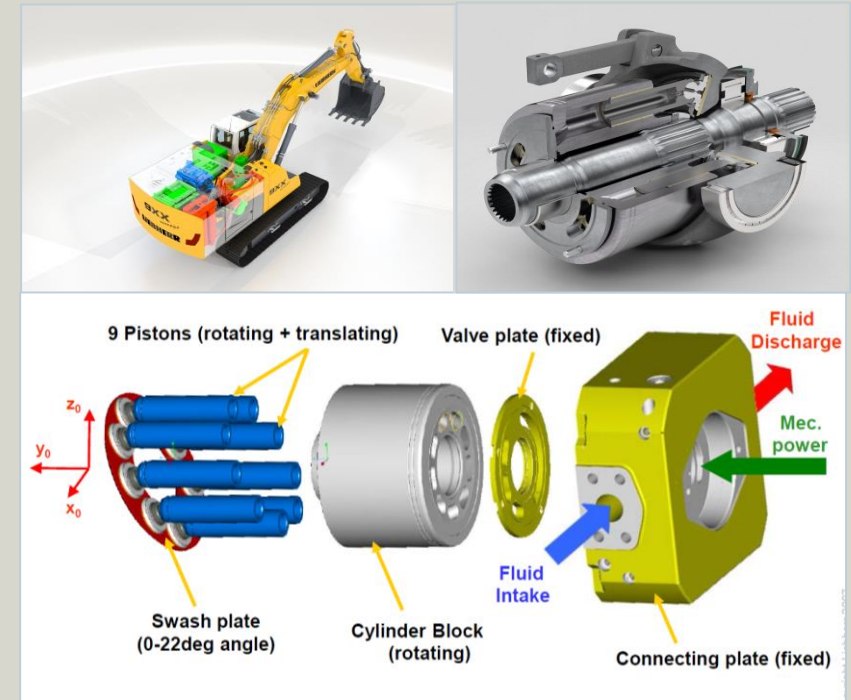
Challenges

- Optimize **axial piston unit** design
- Increase **off-highway vehicle** performance
- Improve **design process efficiency**

Benefits

- Gain better understanding of **axial piston pump physical behavior**
- Optimize **swash plate dynamic behavior** to meet the requirements of modern high-speed applications:
 - Decreased response time
 - Increased bandwidth frequency of the pump displacement servomechanism

As LMS Amesim features a robust solver and a broad set of industry-oriented component libraries for hydraulic applications, it enables Liebherr to build ever more detailed and accurate models.



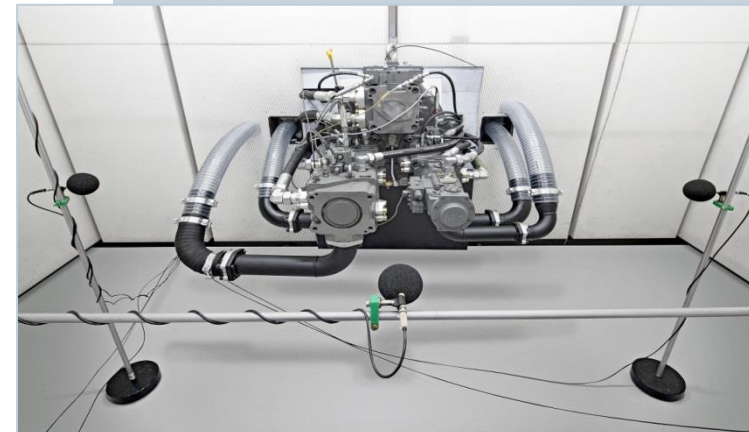
Liebherr: LMS Imagine.Lab Amesim to streamline hydraulic component development

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Benefits (*continued*)

- Reduce **fluid- and structure-borne noise emissions** to maximize the driver comfort
- Assess different design options under the variety of working conditions:
 - Pump speed
 - Differential pressure
 - Adjusted displacement volume
 - Oil viscosity, etc.
- Significantly **reduced number of prototypes**
- Enhanced **collaboration** among company sites
- Strengthened internal **expertise** from component design to system integration

LMS Amesim helped Liebherr to obtain some parameters that would have been very difficult or even impossible, to obtain through tests. Using the new simulation methods has completely changed the development process for hydraulic products at Liebherr Machines Bulle SA as the engineers don't have to rely exclusively on measurements any more. This significantly decreases the number of prototypes, especially for the valve plate design.



Fluid System: LMS Imagine.Lab Amesim to solve instability issues in hydraulic components

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Challenges

- Solve **dynamic stability issues** on the test bench
- Seamlessly conduct studies on **the flow regulation**
- Point directly in the right direction and shorten **time-to-market** substantially

Solution

- LMS Imagine.Lab Thermofluids Systems solution

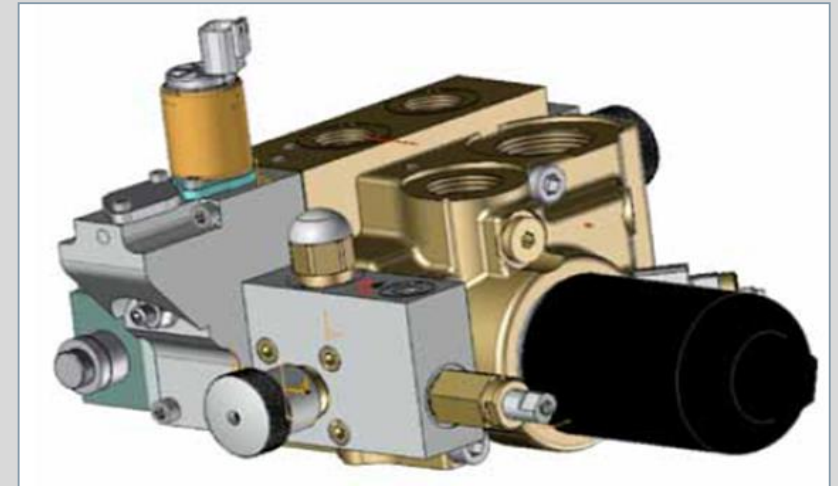
Benefits

- Determine the right **trade-off balance** between stability and performance parameters **for its pressure relief valves**
- Assess **product performance** according to various customer environment scenarios
- Integrate into the **entire simulation process** and handle **input from other software** like SolidWorks Flow Simulation CFD software

"Our investment in LMS Amesim has tangibly saved us time, money and needless efforts by highlighting potential issues before prototype creation.

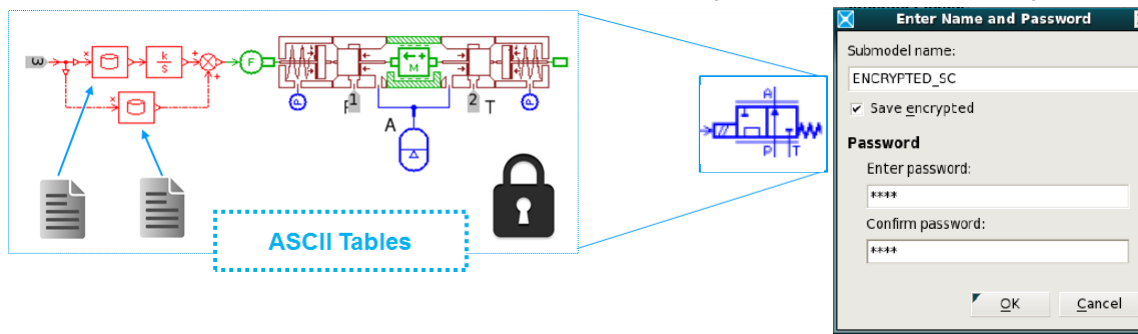
We now spend half the time on prototype adjustment. And we have certainly saved on product touch-ups and late-stage modifications."

Xavier TARDY
CEO, FLUIDESIGN



Conclusions

- LMS Amesim as **the preferred 1D simulation platform** for **hydraulic components** and **systems analysis**:
 - Design and optimize innovative hydraulic systems and components
 - Deep insights into physical systems
 - Subsystems integration to evaluate global performances
 - Controls development through physical plants models as MiL, SiL and HiL
- Easy **collaboration** between **different departments** and between **suppliers-OEMs**
 - Standalone simulators in Simulink
 - IP protection with the LMS Amesim encryption capability



- **Engineering experience capitalized in LMS Amesim solutions (+25 years)**



Thank You