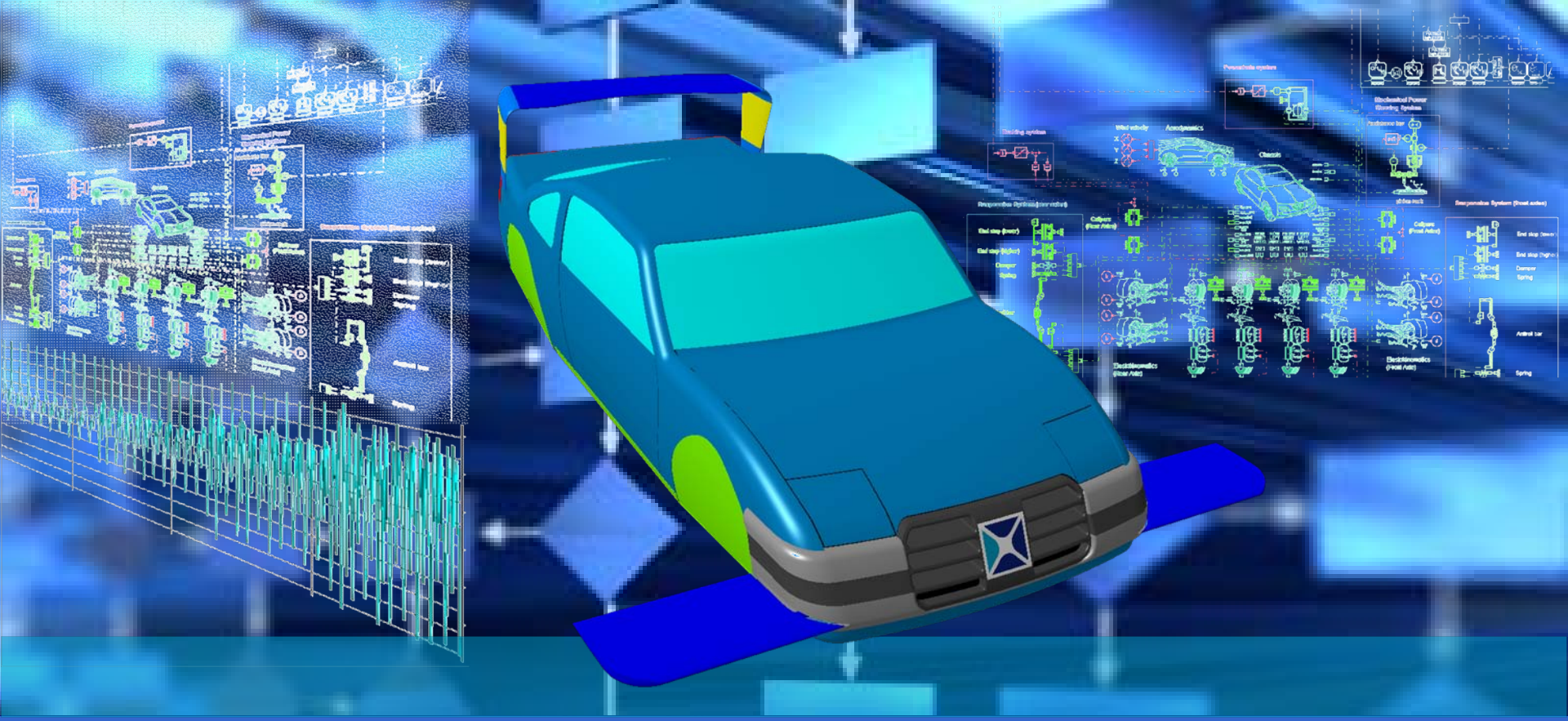


Engineeing the 2020 PLASVEE Vehicle

...a vision of the potential for system simulation in the year 2020...

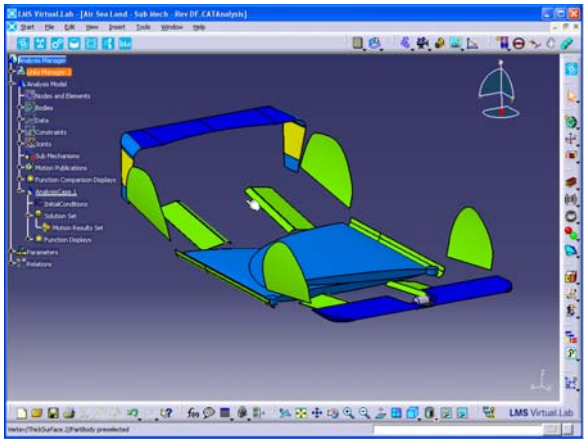
Keith Moss, Chris Paulson, Nicolas Orand, Koen De Langhe
Jan Leuridan

LMS International
October 30th, 2008

NA Regional Summit 2008 NAFEMS
2020 Vision of Engineering Analysis and Simulation
October 29 - 31, 2008 | Hampton, Virginia

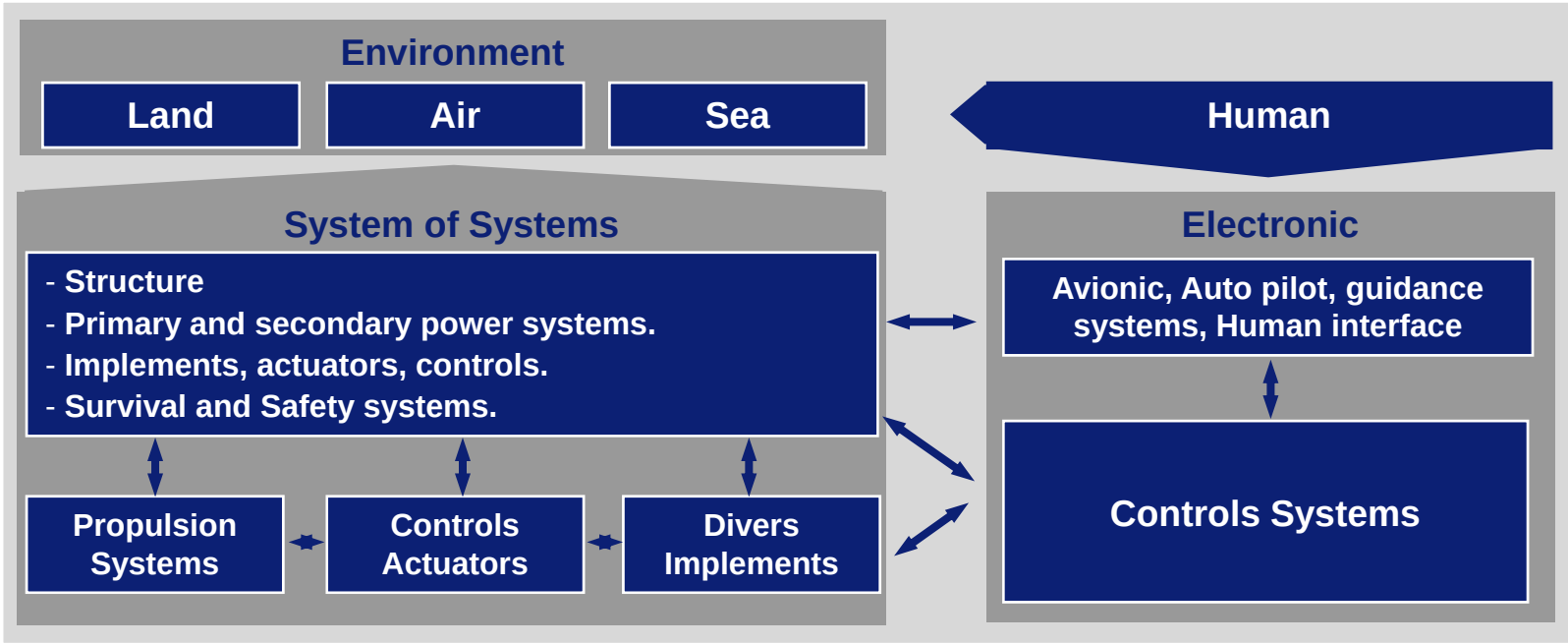
LMS® ENGINEERING INNOVATION

PLASVEE – A radical new product concept
Challenges of the PLASVEE development



The simulation process needs to cover:

- Preliminary concept analysis, early trade-offs and system validation
  PLASVEE is untried product architecture
- Realistic system level simulation of detailed design,
  multi-domain and multi-level simulation
  PLASVEE is sophisticated product concept,
  performance assessment requires system level simulation
- "Mechatronics" simulation
  PLASVEE performance will rely heavily on use of electronics and controls



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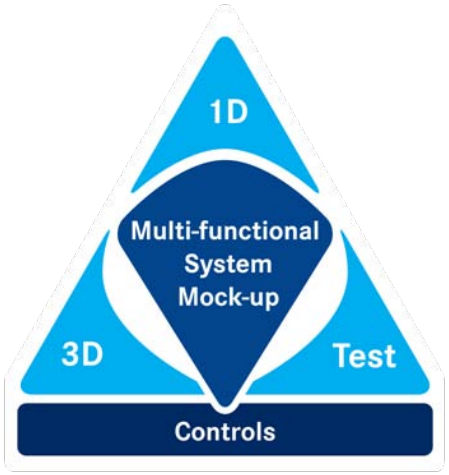
Simulation environment for engineering PLASVEE



Simulation based on:

- Multiple simulation applications for functional domains: 1D, 3D and Test
  Heterogeneous simulation environment
- Environment to build simulation mock-ups for realistic system analysis, combining 1D, 3D and Test, and control models:
  Multi-functional and multi-level (Scalable)
  function of design stage and purpose of simulation
  Based on: co-simulation, open standards (e.g. MODELICA)
- Control system development using "plant" models that are "associative" to physics system models
  Realistic "plant" models, for off-line and real-time
- Data management supports Simulation Life Cycle management and Simulation IP Capitalization (multiple domains, disciplines)

To enable:

- Early system analysis and trade-off's
- Realistic system level simulation
- Frontloading subsystem testing and validation – avoiding late stage integration issues
- Integrated mechatronic simulation and optimization

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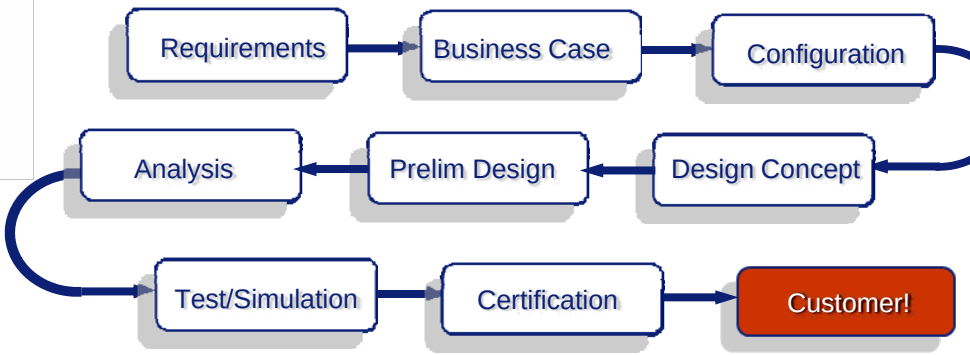
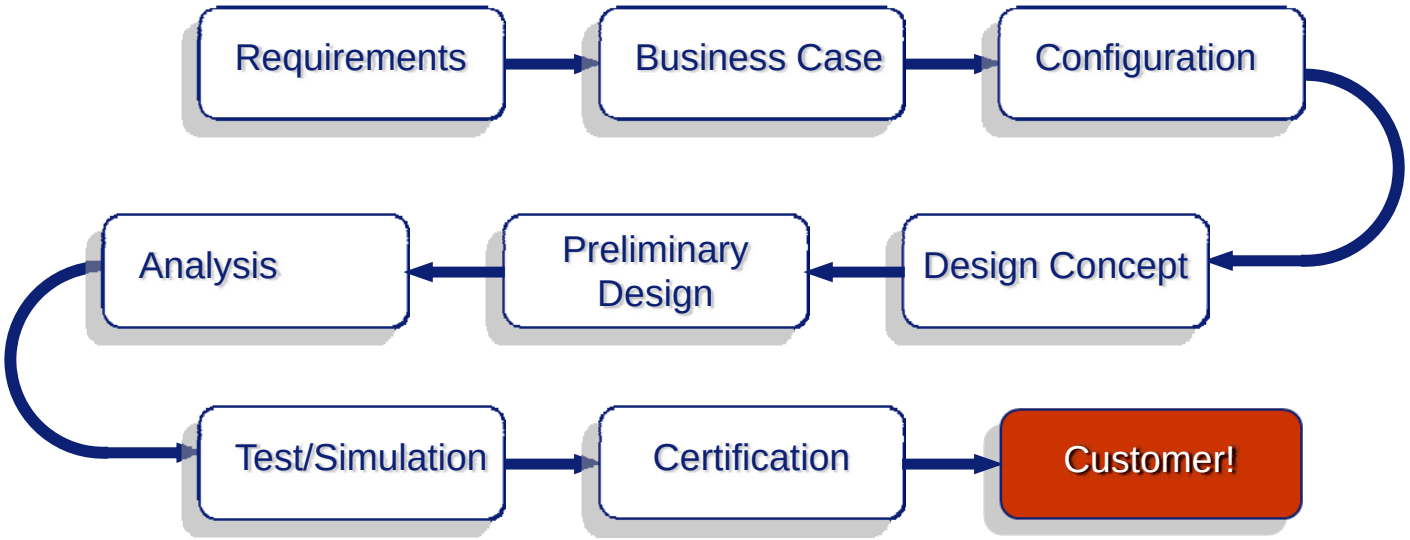
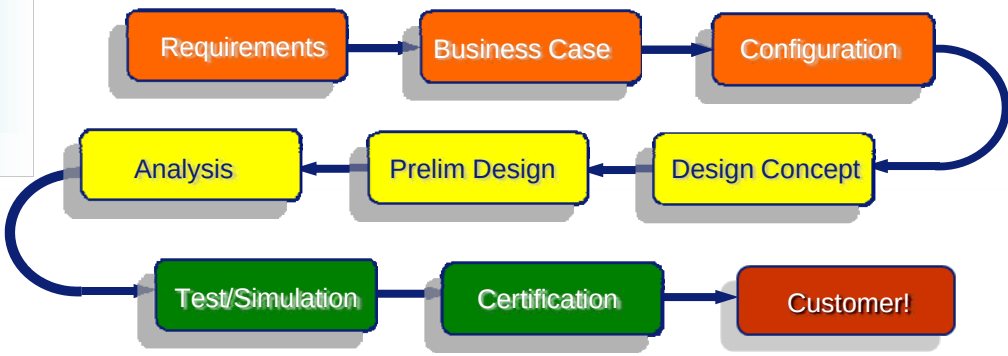
The Role of Digital Simulat
Developing a PLASVEE© f

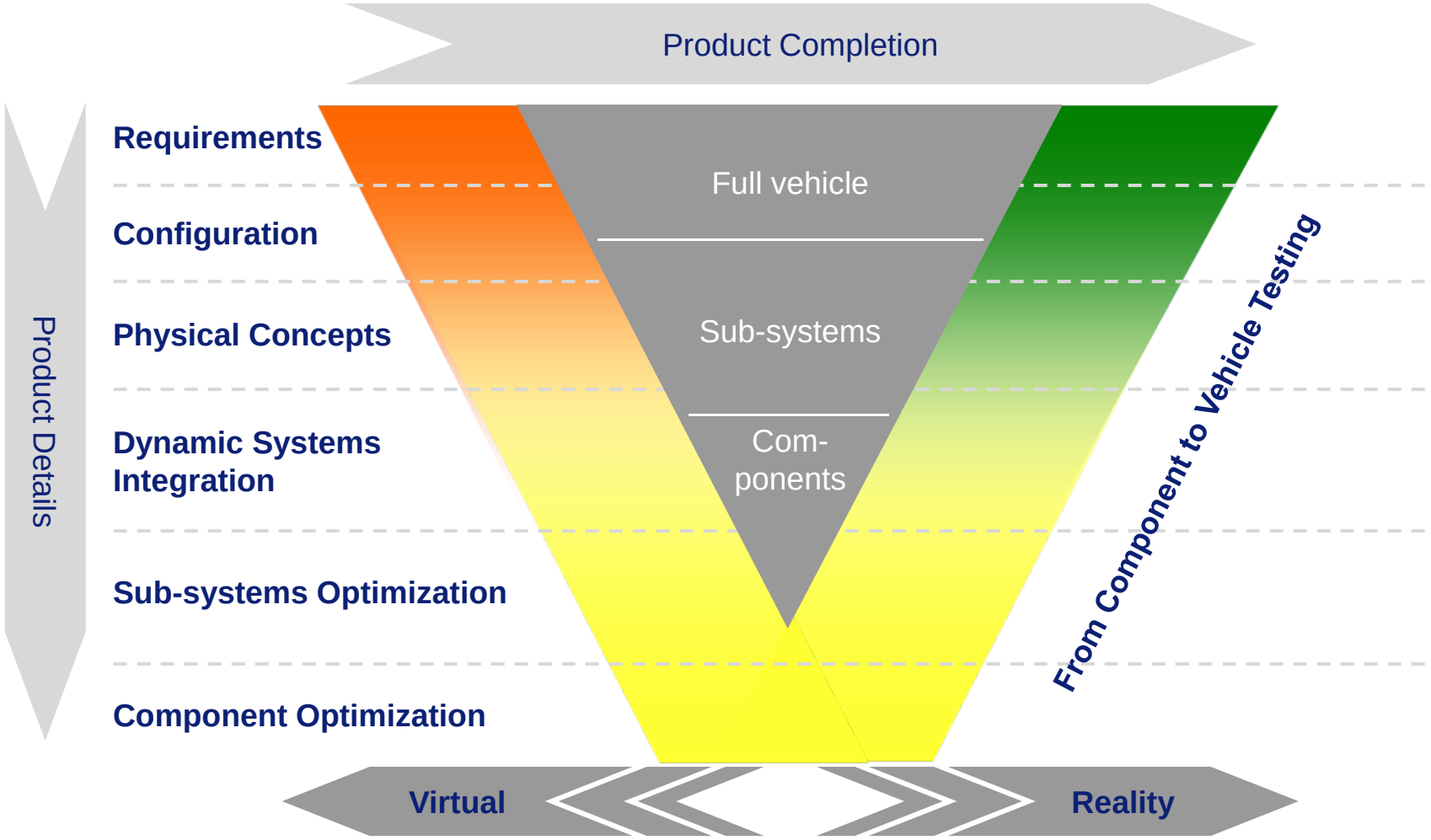




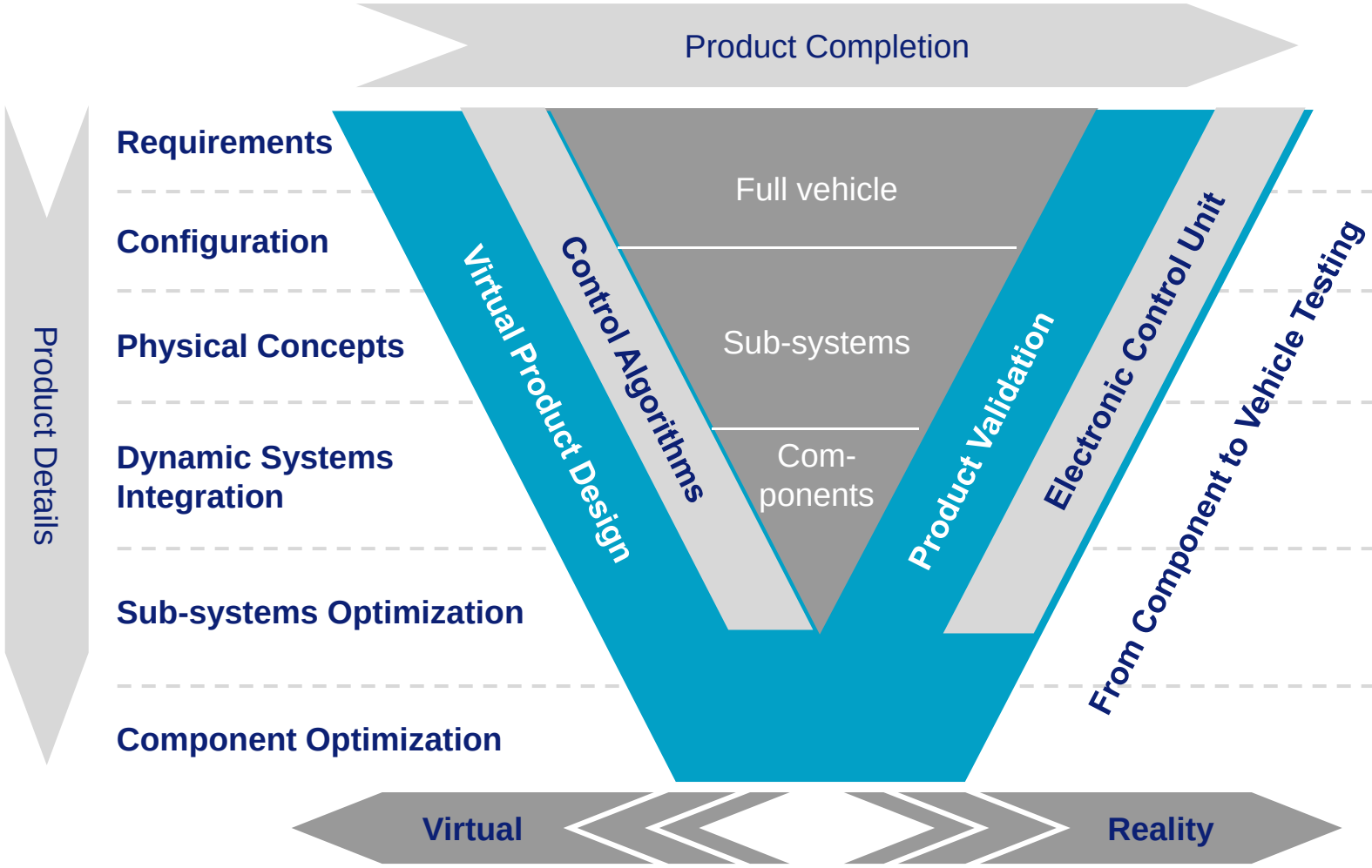
LMS ENGINEERING INNOVATION

The Role of Digital Simulation in Developing a PLASVEE© for 2020



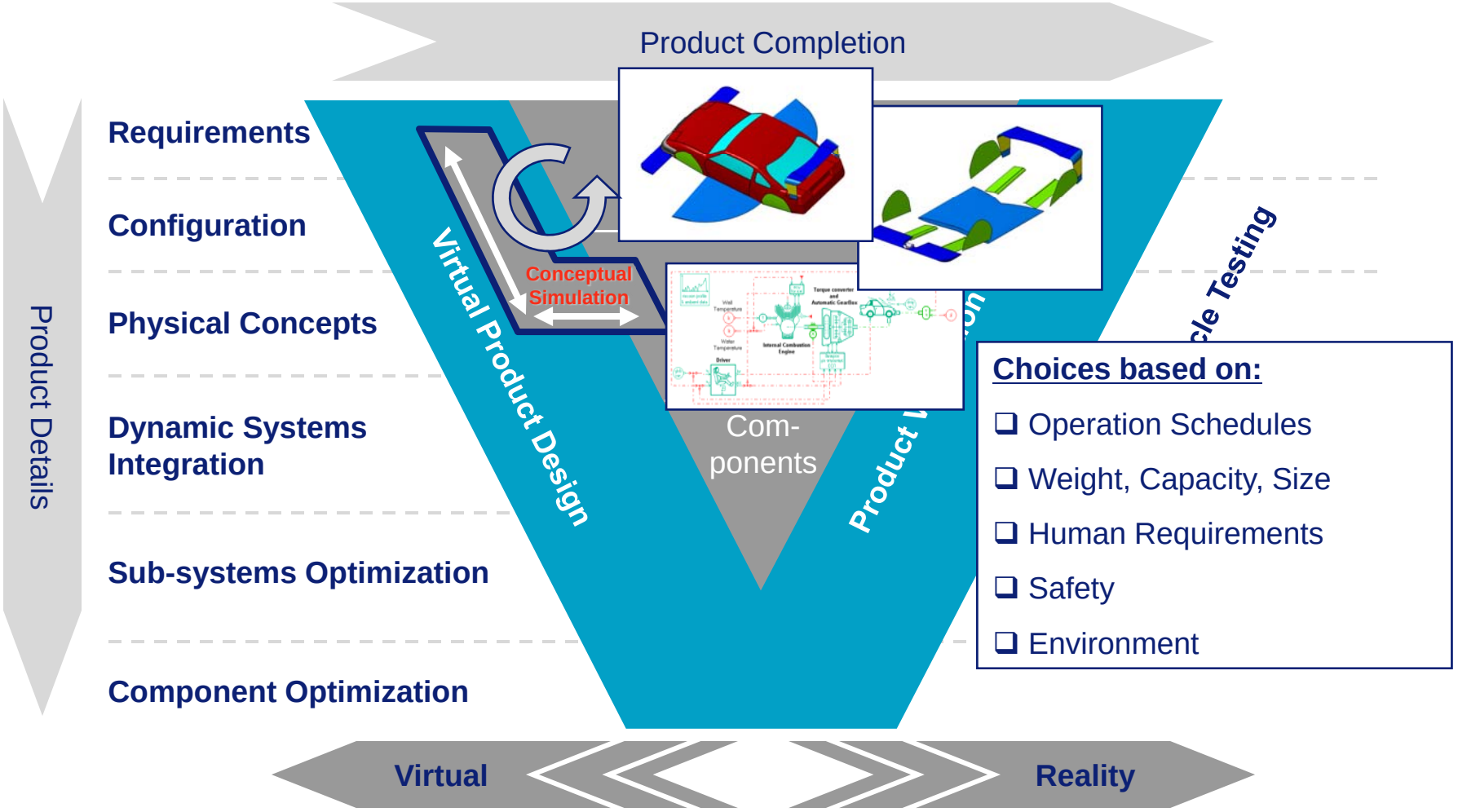


The Role of Digital Simulation in Developing a PLASVEE© for 2020



Preliminary Design – Prequalification of Technologies

At the very early stage of the selection of the technologies and initial configuration the controls are unnecessary. Conceptual simulation plays a key role in selecting technologies at different levels.



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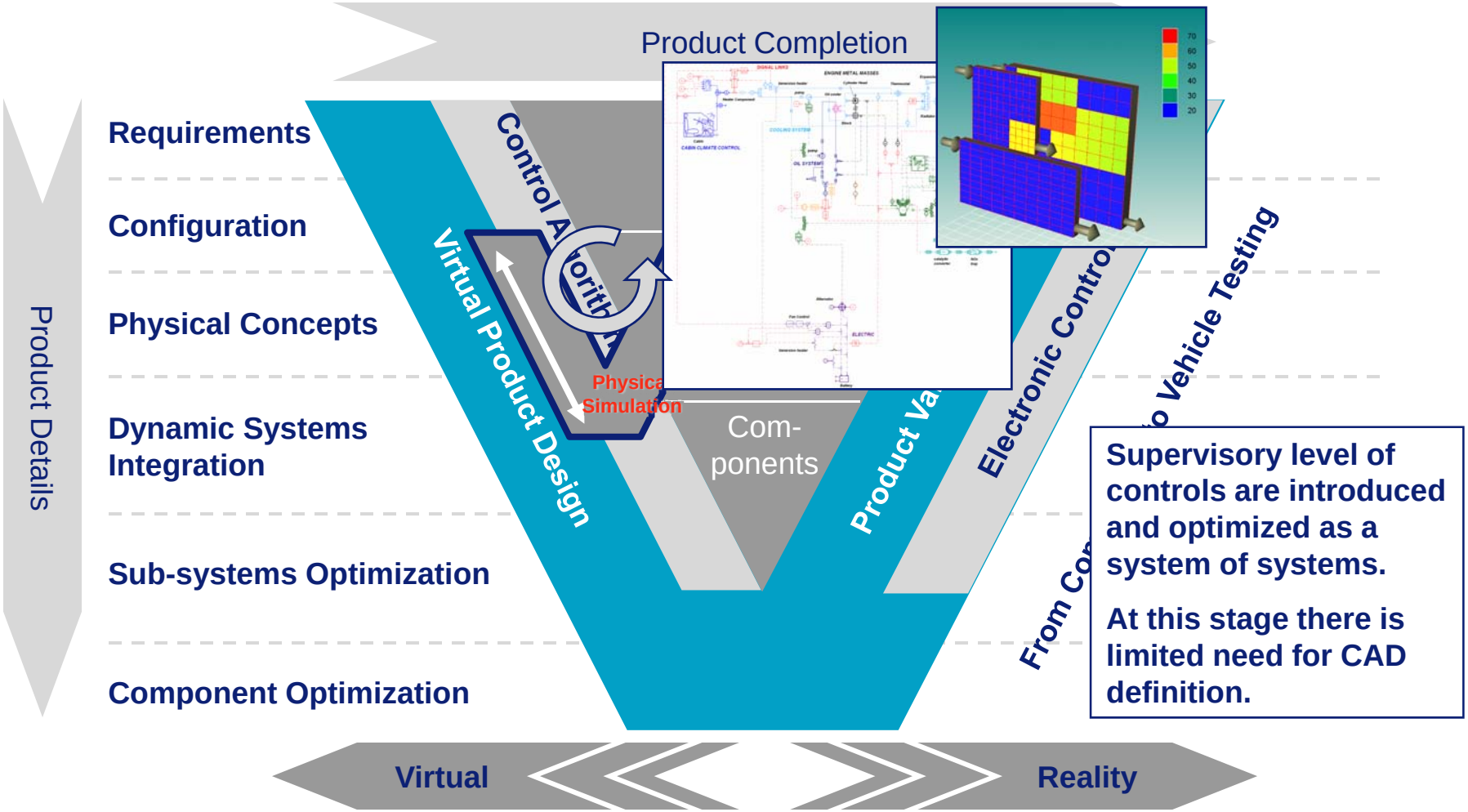
Validation of Technologies and Optimization of Architecture through Full Vehicle Energy Management

The initial architecture and technologies are optimized through the analysis of full vehicle energy management. Basic controls are required to account for schedule and supervision of sub-systems.



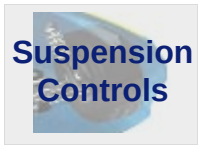
LMS ENGINEERING INNOVATION

Mastering compromise of conflicting requirements
Example: PLASVEE driveability and fuel economy

Example: “Driveability” optimization in context of fuel economy

1D Simulation

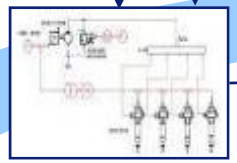
- Combustion process and parameters
- Coupling to ECU
- Control models for gearbox, torque converter, active suspension

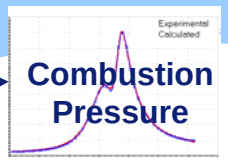


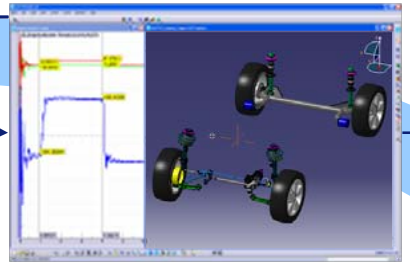
3D Simulation

- Detailed MBD model: powertrain, driveline, chassis and suspension
- Integrated controls for gearbox, active suspension…

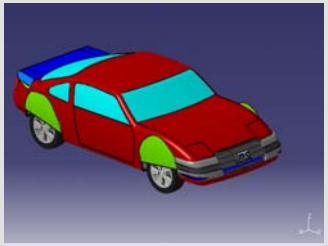
ECU







Driver Input - Throttle



Driveability:

Tip-in –Tip-out, WOT

Gear shift…

ECU Controller
Combustion parameters
Suspension controller
Gearbox controller

Combined Optimization Driveability

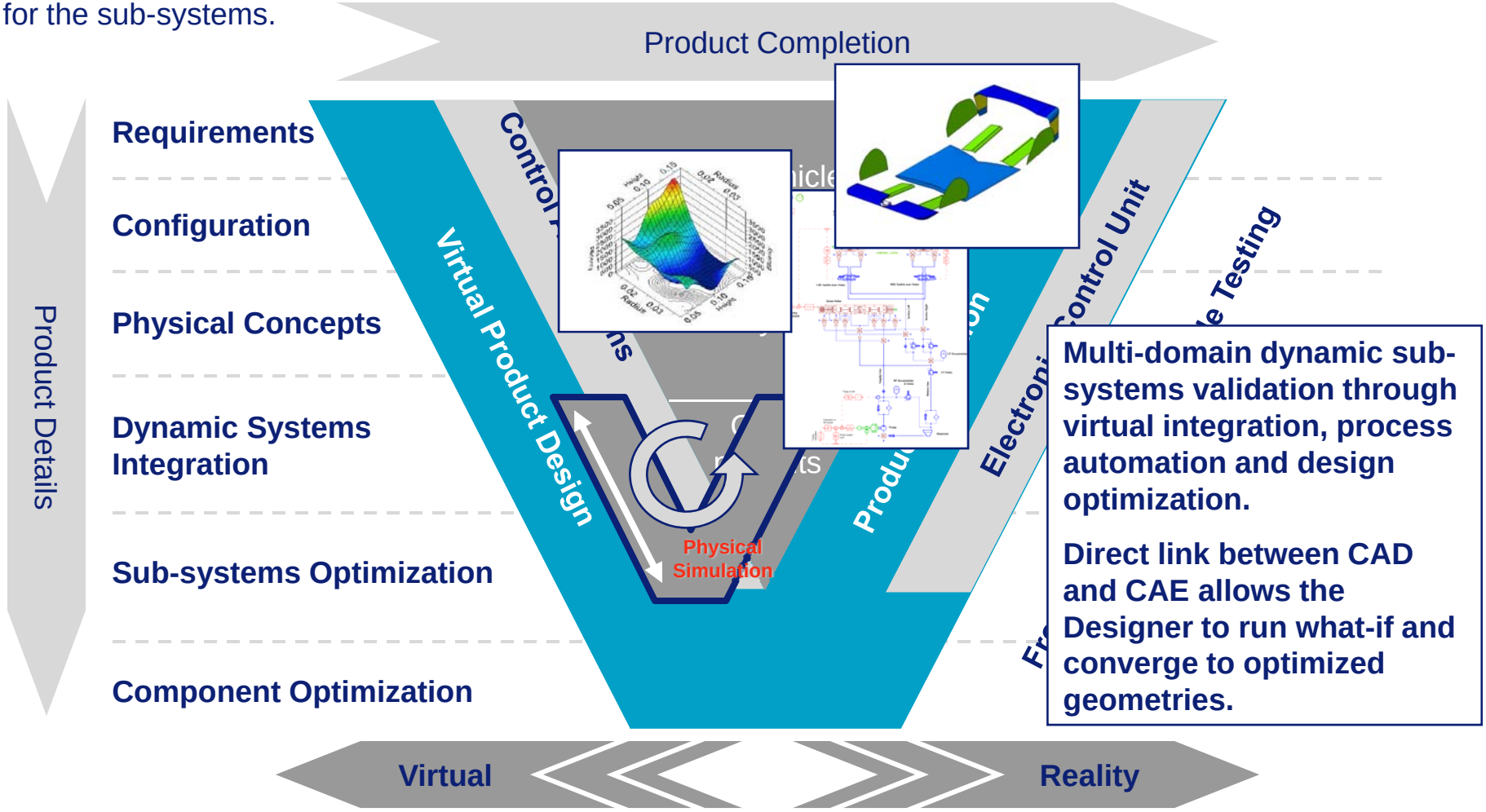
Combustion - Controls – Vehicle

Engine Mount layout
Driveline stiffness
Suspension layout

LMS ENGINEERING INNOVATION

Virtual Sub-systems Integration

The technologies and basic architecture of the system being selected, the virtual integration of the sub-systems is required for dynamic couplings and refining the concepts. Detailed controls are designed for the sub-systems.



Multi-domain dynamic sub-systems validation through virtual integration, process automation and design optimization.

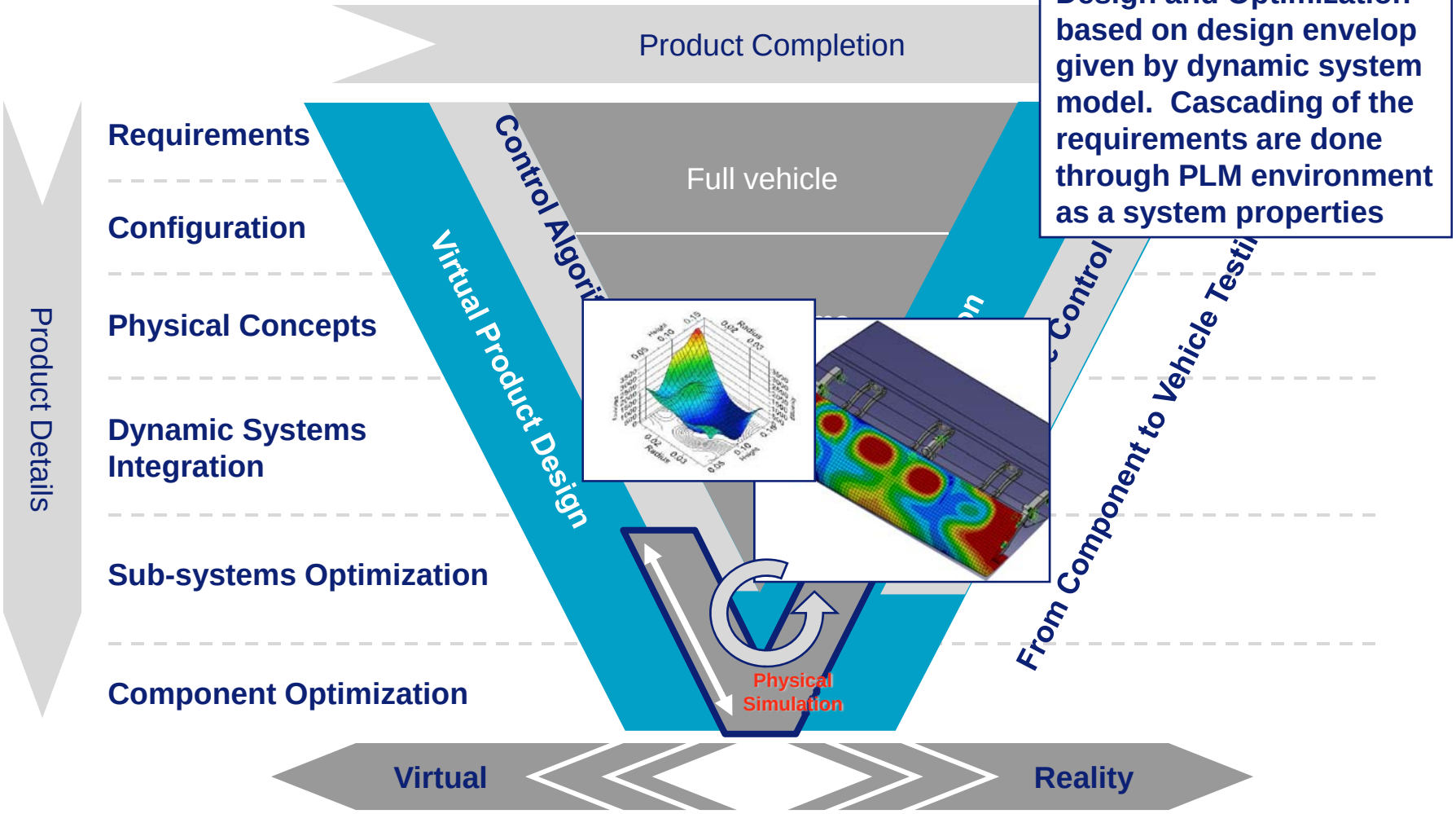
Direct link between CAD and CAE allows the Designer to run what-if and converge to optimized geometries.

LMS ENGINEERING INNOVATION

Detailed design

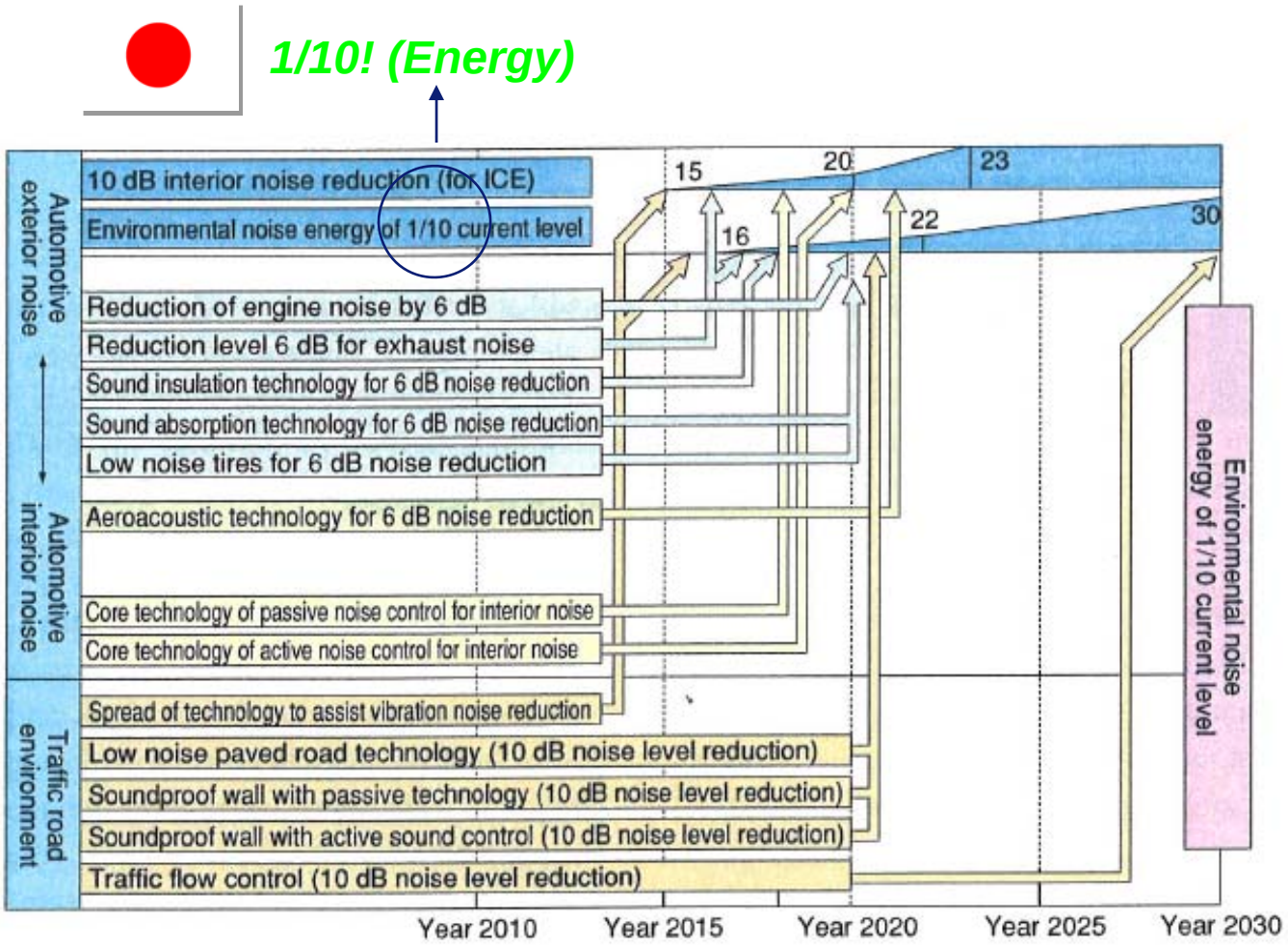
Focus is now brought to the component design and optimization.

Detailed Component Design and Optimization based on design envelop given by dynamic system model. Cascading of the requirements are done through PLM environment as a system properties



LMS ENGINEERING INNOVATION

Sustainable Mobility
More strict environmental noise regulations



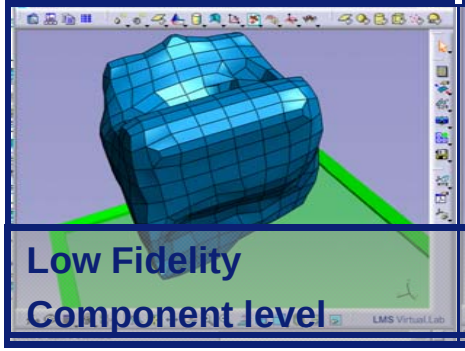
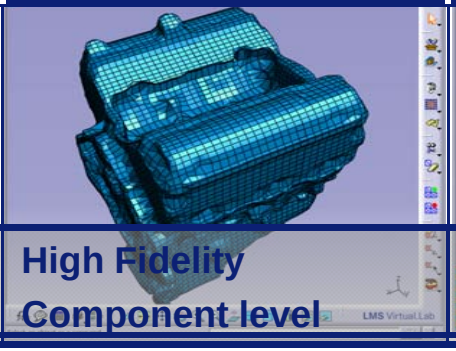
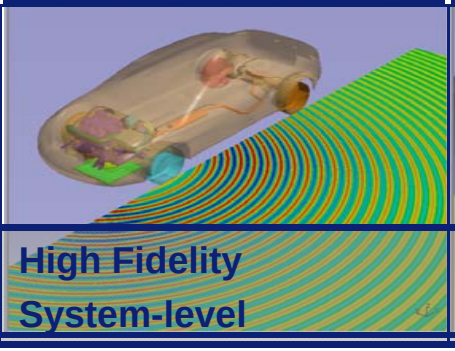
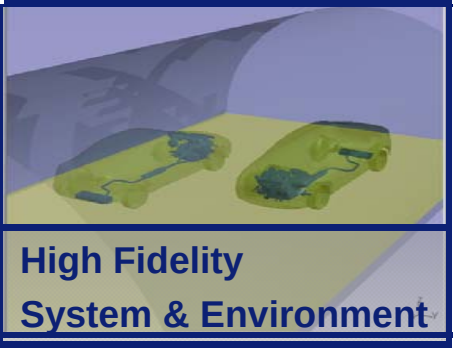
Source: The Automobile in the Year 2030, JSAE, December 2007

-10 dBA
By 2020

Source:
"Strategic Research Agenda"
ERTRAC, 2004
(European Road Transport Research Advisory Council)

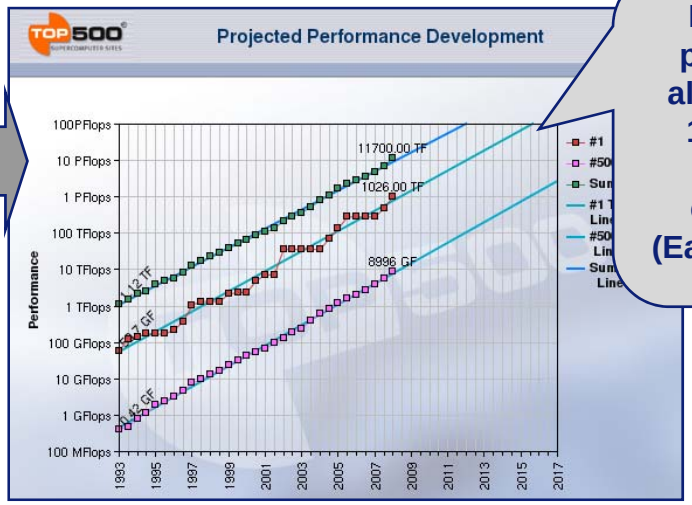
LMS ENGINEERING INNOVATION

Full scale acoustic analysis - system & environment
Enabling PLASVEE to meet environmental noise regulation

90	2000	2010	2020
			
Low Fidelity Component level	High Fidelity Component level	High Fidelity System-level	High Fidelity System & Environment

2020 Acoustic Simulation

New simulation algorithms based of **Multi-pole Expansion (FMBEM) optimized for massive parallel computing** allow to increase acoustic model complexity up to 100's of Million BEM elements by 2020.

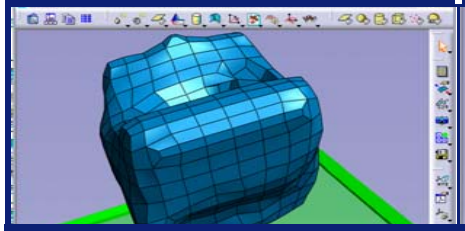
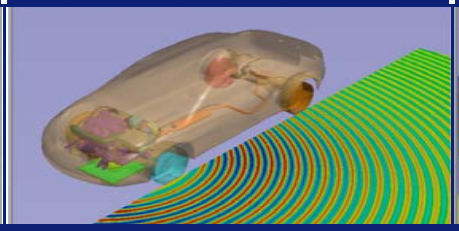


New algorithms are optimized for Massive Parallel Computing.

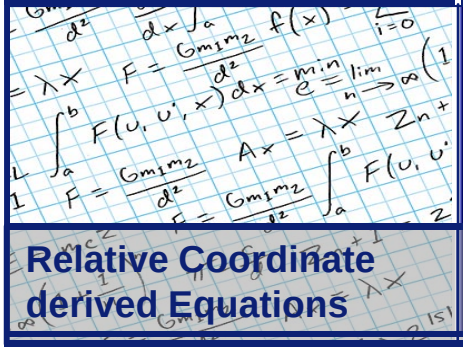
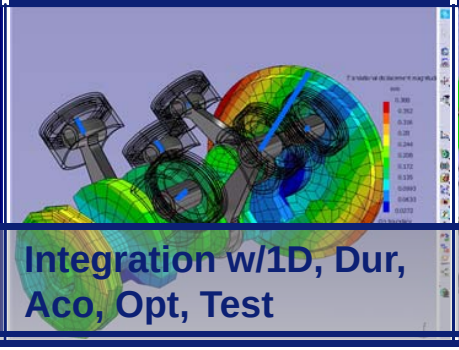
By 2020: massive parallel computing allows to go beyond 100 PETAFLOPS . Note: Fastest computer in 2003 (Earth Simulator) is 10 000 times slower

LMS ENGINEERING INNOVATION

Full scale dynamic analysis - system & environment
Enabling PLASVEE for functional performance

90	2000	2010	2020
			
Low Fidelity Component level	High Fidelity Component level	High Fidelity System-level	High Fidelity System & Environment

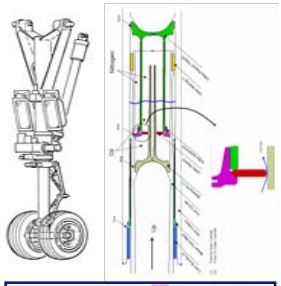
2020 Dynamic Simulation

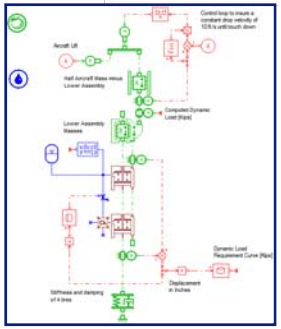
<80	90	2010	2020
			
Relative Coordinate derived Equations	General Coord. MBS Assembly, Rigid + FEA	Integration w/1D, Dur, Aco, Opt, Test	RT + CoSim Hi Fi Cluster-Driven RBDO

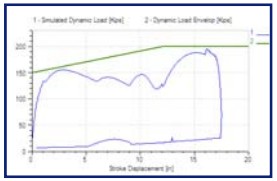
LMS ENGINEERING INNOVATION

Scalable 1D/3D CAE
To support different design stages

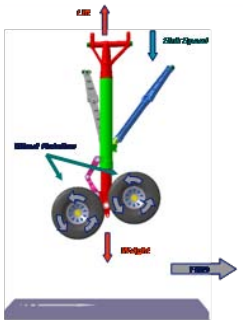
Example: Landing gear analysis

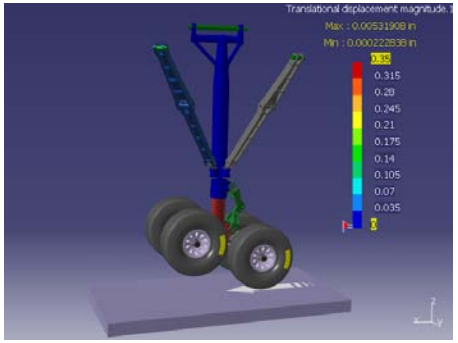


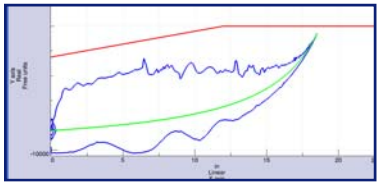




Increasing Model Details



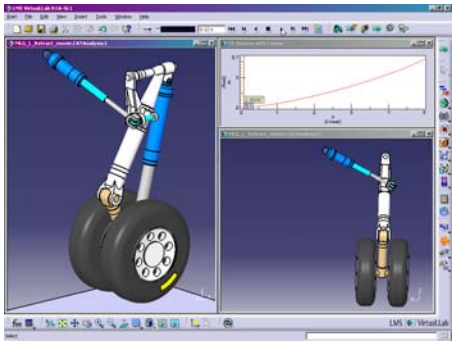




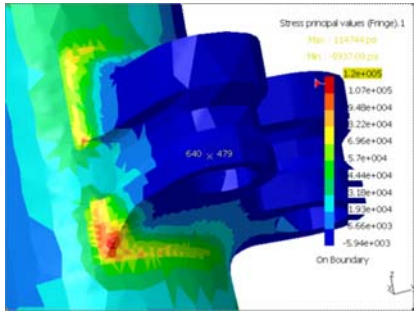
Increasing Model Details

Increasing Model Details

A/C Ground Loads & Handling



Landing Failure Mode Analysis



Landing Gear Structural Analysis

1D Simulation

Oleo-Pneumatic Damper

Double Chamber
Orifice Sizing & Optim. Tire

3D Simulation

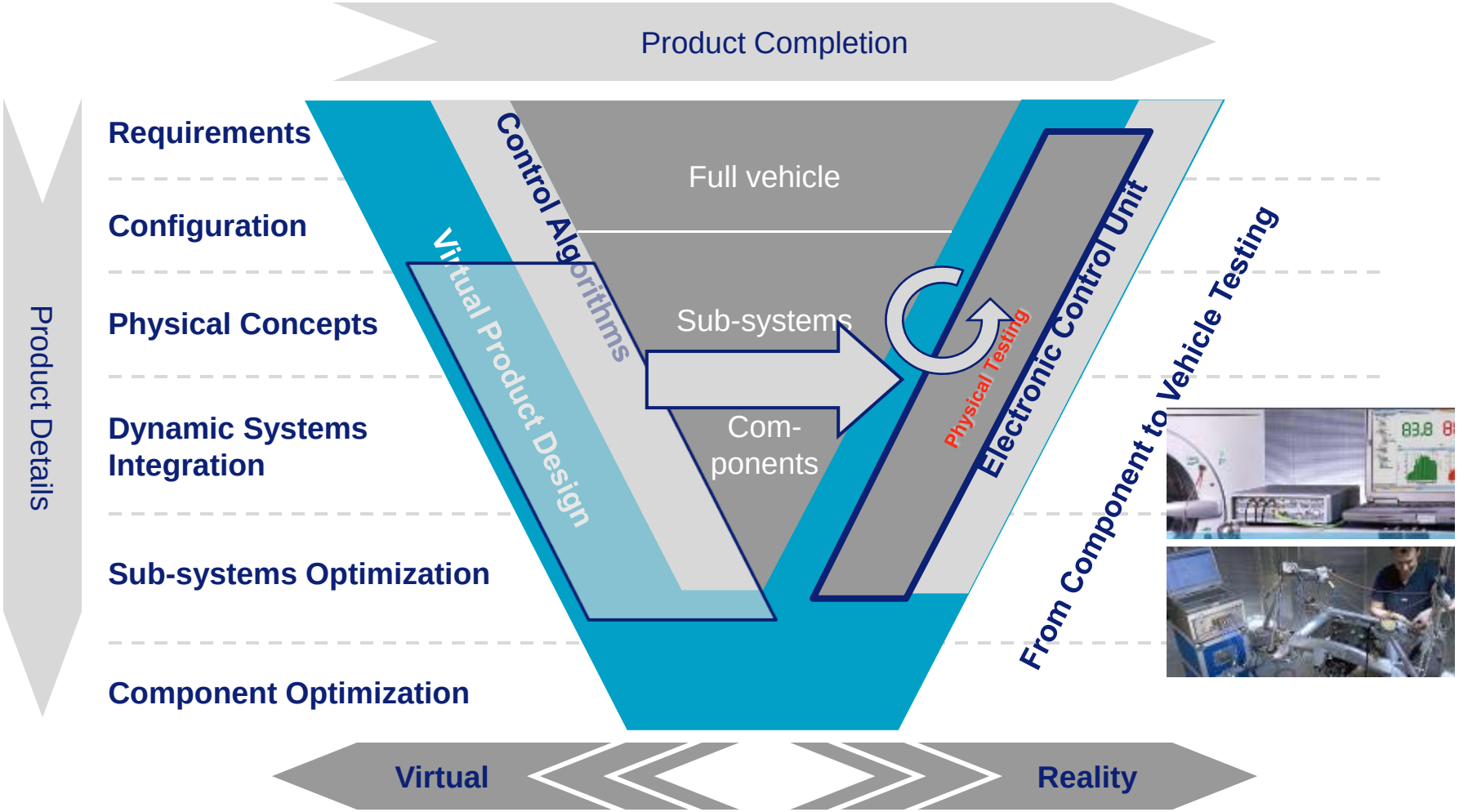
Detailed Landing Gear

Detailed Geometry – incl. flexibility
Detailed Non-linear Behaviour
Tire models

LMS ENGINEERING INNOVATION

Components to vehicle integration and testing

The validation of the components, sub-systems and vehicle is done through testing, numerical models are used to substitute missing parts or embedded controls.



LMS ENGINEERING INNOVATION

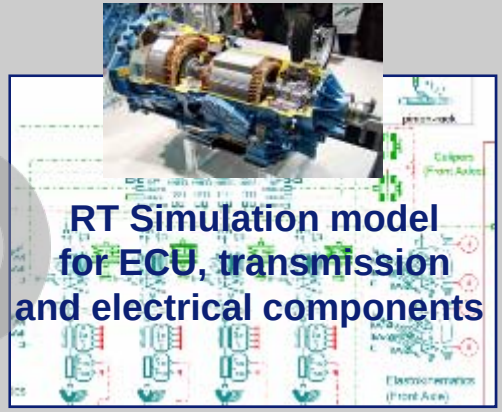
Frontloading validation and physical testing Enabled by the multi-functional system mock up

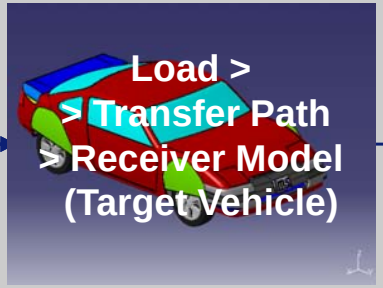
- Simulate on the test cell the “working” of target build-in environment
- Process and analyze test cell data in context of target build-in environment

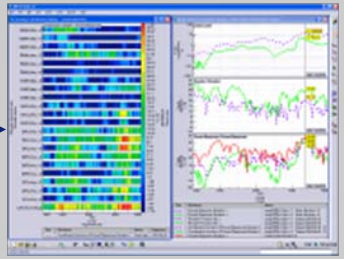
Example: testing and calibration of ICE to be used in hybrid powertrain

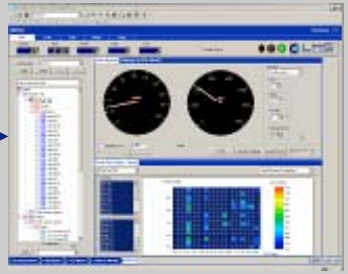
Pressure – Accel.

HiL





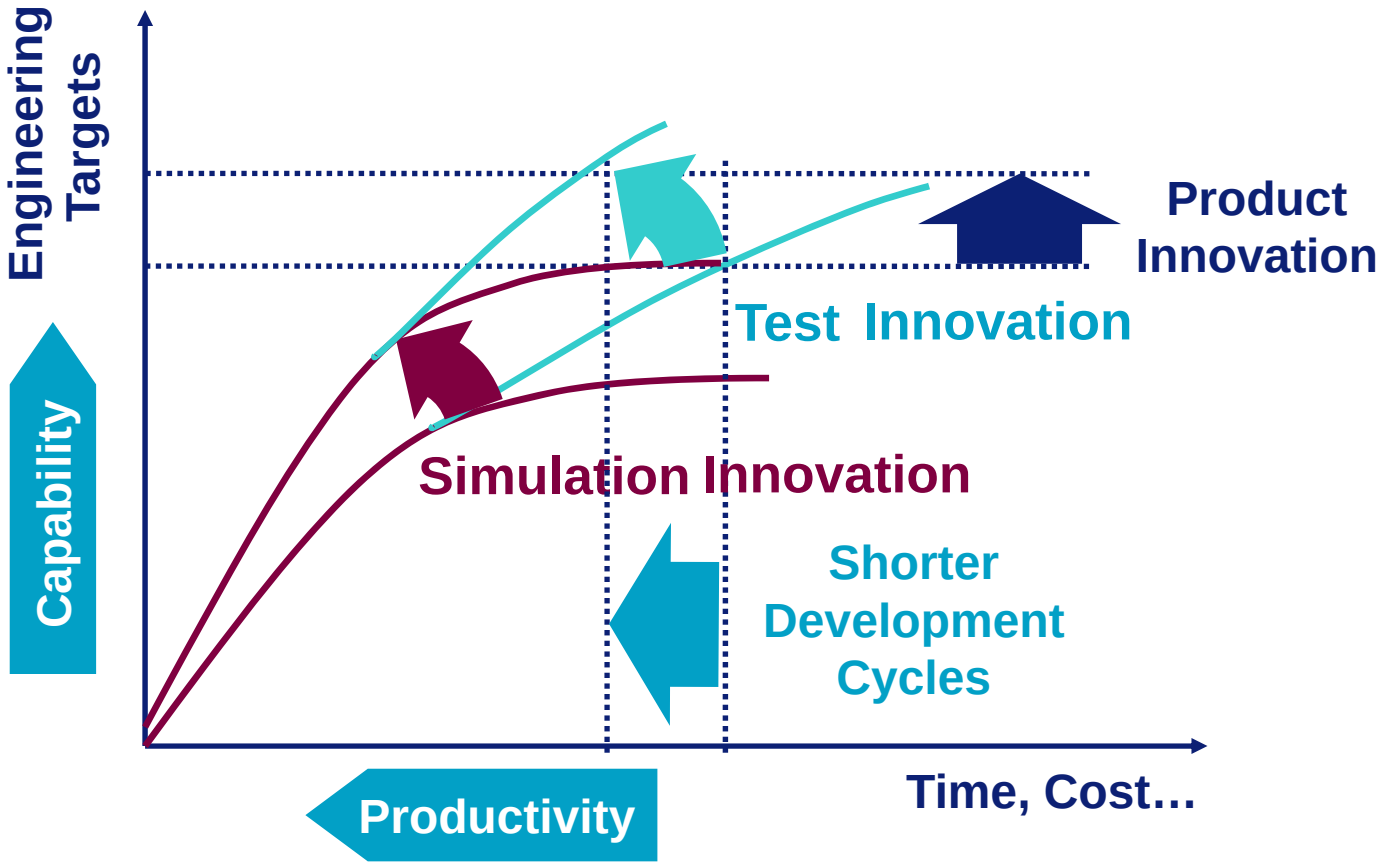




Pressure – Accel.

Simulation is key to enable frontloading of testing and validation

Test and simulation
In combination to succeed with design challenges



LMS ENGINEERING INNOVATION

PLASVEE – Using model based controls

From multiple individual controllers (2005)…

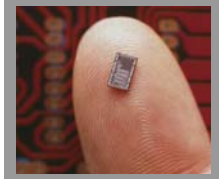
Best-in-Class Engine ECU

Computing power limited to Controls

Complex wiring harness

Increasing Design Details

…to full Model based control (2020)



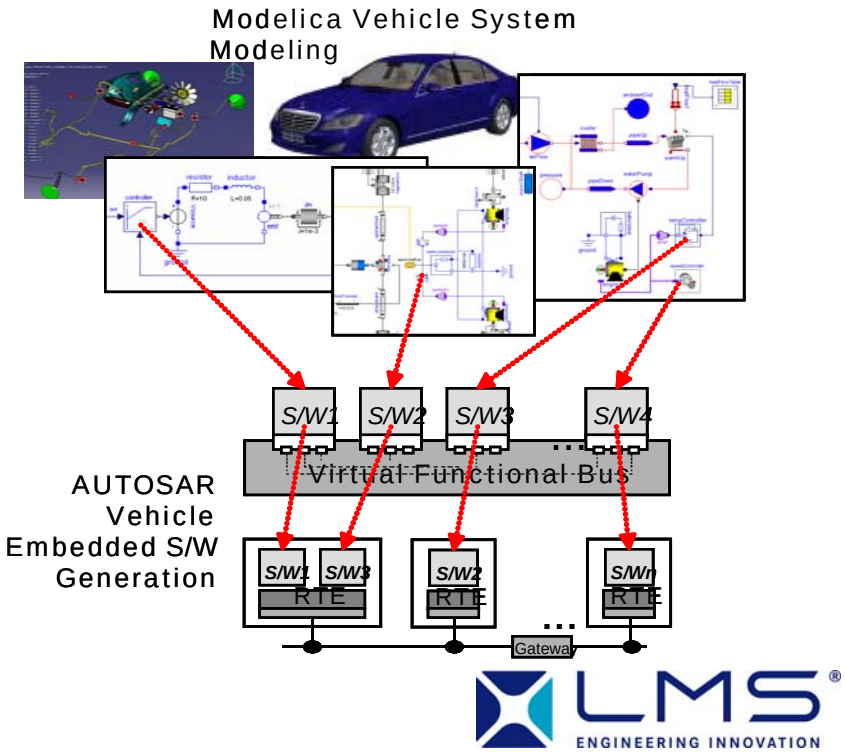
Today's Embedded Multi-Core Technology

Embedded Control Algorithm & and Full Vehicle Plant Model

Wi-Fi Communication Technology with Sensors and Actuators

Embedded Control Algorithm and Full Vehicle Plant Model

1. Full **system mock-up** is designed as one system of systems. This full system is embedded.
2. Full system mock-up is run at FRT (**Faster than Real Time**) in predictive mode utilizing history trace and auto-recalibration techniques.
3. The Control Algorithms are used in **adaptive mode** to optimize the use the control of multi-power units in the best out of hundreds operating configurations, thanks to **object oriented** semantic.



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Thank you

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