

COMBINING SYSTEMS ENGINEERING WITH VIRTUALISATION TO ACCELERATE ENGINEERING



**Ulrich
SCHULMEISTER**

Vice President Technology
and Engineering
Robert Bosch GmbH



**Dr. Bassem
HASSAN**

Transportation & Mobility
Industry Director
EuroCentral
Dassault Systèmes



TRANSPORTATION & MOBILITY INDUSTRY DRIVERS



New Customer Experience



Transformation which was already happening ...

Dream, explore, validate then seamlessly produce bold new mobility options for demanding global consumers.

... is NOW accelerated with additional short term and transformation objectives

Reduce time to market and transform online customer journey experience to make it more attractive than competitors.

Electric, Connected and Autonomous Vehicles



Next-generation vehicle success requires advanced creative design, shared intelligence, systems engineering and multi-domain collaboration.

Co-Investments on hybridization & autonomous between several OEMs and increased importance of software.

Regulation, Quality & Costs Reduction



Accelerate profitable new opportunities, while ensuring quality, fulfilling global/local requirements, and minimizing expenses.

Ensure End-products quality, regulation compliance
Invest on short term pay back programs, reduce warranty cost.

Mass Production to Mass Customization



Improve visibility, efficiency, and control of manufacturing production and operations, within and across global/local plants.

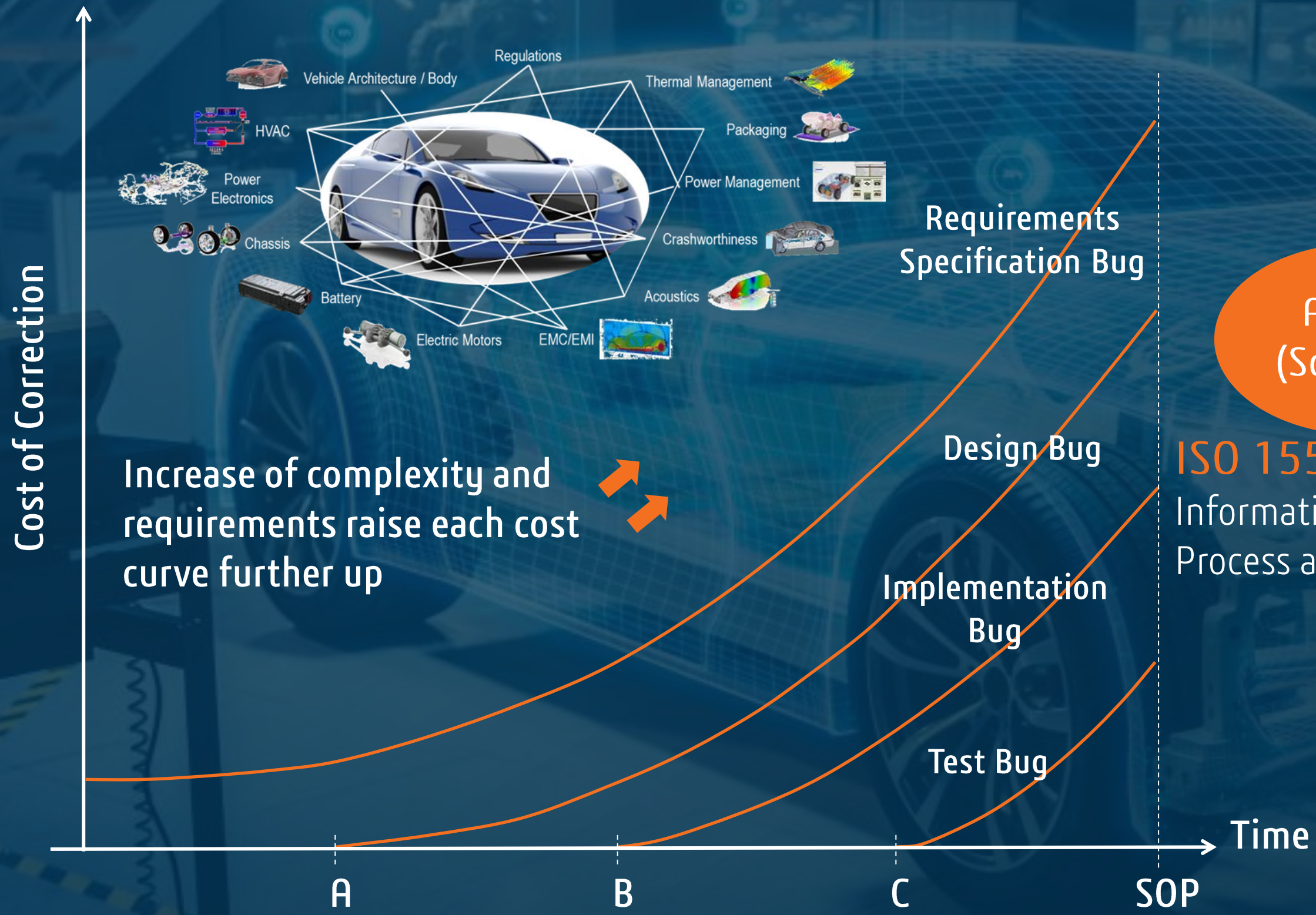
Improve supply Chain resilience and efficiency.
Increase components reuse.

Sustainable Mobility



New investments go to innovative and sustainable mobility companies and new type of vehicles (2/3 wheelers, last mile delivery ...)

CHALLENGE: MANAGE COMPLEXITY, ENSURE COMPLIANCE



Functional Safety

Cyber security



ASPICE (Software)

ISO/SAE 21434
Exploitation introduction leads to unintended behavior

ISO 15504
Information technology – Process assessment

Over the Air Software Update

Safety in Use (SOTIF)

ISO/PAS 21448
Algorithm decision leads to unsafe behavior

UNECE GVA SUM
Recommendation on software update

TOWARDS VIRTUAL TWIN EXPERIENCES



1981

1989

1999

2012

2020

2040

Part

Product

Process

System

Human

Universe

CAD

DMU

PLM

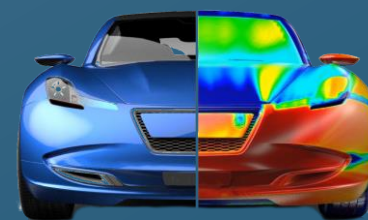
Platform

AI & Data Science

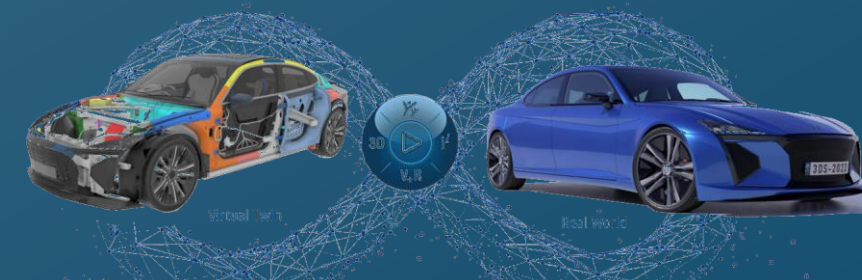
Multiscale Deep Science



Digital Twins



Virtual Twins



Virtual Twin Experiences



R2023X GA TRANSPORTATION & MOBILITY PORTFOLIO

EFFICIENT MULTI-ENERGY PLATFORM

- [CATIA] 01-POWERTRAIN SYSTEM ARCHITECTURE
- [CATIA] 02-POWERTRAIN ENGINEERING
- [SIMULIA] 03-POWERTRAIN STRENGTH, DURABILITY & VIBRATION
- [SIMULIA] 04-POWERTRAIN THERMAL MANAGEMENT
- [SIMULIA] 05-POWERTRAIN LUBRICATION
- [SIMULIA] 06-POWERTRAIN DYNAMICS
- [SIMULIA] 07-ELECTRIC DRIVE ENGINEERING
- [SIMULIA] 08-POWER ELECTRONICS ENGINEERING
- [SIMULIA] 09-BATTERY CELL ENGINEERING
- [SIMULIA] 10-BATTERY MODULE & PACK ENGINEERING
- [BIOVIA] 11-BATTERY MATERIALS DESIGN
- [SIMULIA] 12-FUEL CELL ENGINEERING
- [CATIA] 13-CHASSIS & SUSPENSION CONCEPT ENGINEERING
- [CATIA] 14-CHASSIS & SUSPENSION ENGINEERING
- [SIMULIA] 15- CHASSIS & SUSPENSION STRENGTH, DURABILITY & VIBRATION
- [CATIA] 16-VEHICLE ENERGY MANAGEMENT

SUSTAINABLE MULTI-FUNCTIONAL VEHICLE

- [CATIA] 01-BODY STRUCTURE CONCEPT ENGINEERING
- [CATIA] 02-BODY STRUCTURE ENGINEERING
- [SIMULIA] 03- BODY STRENGTH & DURABILITY
- [SIMULIA] 04-BODY STRUCTURE NOISE & VIBRATION
- [CATIA] 05- STAMPING DIE ENGINEERING
- [CATIA] 06-INTERIOR & EXTERIOR EQUIPMENT ENGINEERING
- [CATIA] 07-MOLD & TOOLING ENGINEERING
- [SIMULIA] 08-CABIN COMFORT
- [CATIA] 09-VEHICLE PACKAGING & COMPLIANCE
- [SIMULIA] 11-VEHICLE THERMAL MANAGEMENT
- [SIMULIA] 12-VEHICLE NOISE & VIBRATION
- [SIMULIA] 13-RAIL VEHICLE DYNAMICS
- [SIMULIA] 14-VEHICLE AERODYNAMICS

INNOVATIVE MODULES & TECHNOLOGIES

- [CATIA] 01-BODY STRUCTURE ENGINEERING
- [CATIA] 02-INTERIOR & EXTERIOR EQUIPMENT ENGINEERING
- [SIMULIA] 03- BRAKE SYSTEM ENGINEERING
- [CATIA] 04-CHASSIS AND SUSPENSION ENGINEERING
- [SIMULIA] 05- EXHAUST SYSTEM ENGINEERING
- [CATIA] 06-POWERTRAIN ENGINEERING
- [SIMULIA] 07-ELECTRIC DRIVE ENGINEERING
- [SIMULIA] 08-BATTERY CELL ENGINEERING
- [SIMULIA] 09-BATTERY MODULE & PACK ENGINEERING
- [BIOVIA] 11-BATTERY MATERIALS DESIGN
- [SIMULIA] 12-FUEL CELL ENGINEERING
- [CATIA] 13-STAMPING DIE ENGINEERING
- [CATIA] 14-MOLD & TOOL ENGINEERING
- [CATIA] 15-WIRE HARNESS ELECTRICAL ENGINEERING
- [SIMULIA] 16-POWER ELECTRONICS ENGINEERING
- [CATIA] 17-MECHANICAL ENGINEERING



ON-TARGET VEHICLE LAUNCH

- [DELMIA] 01-PART FABRICATION PROCESS ENGINEERING
- [DELMIA] 03-ADDITIVE MANUFACTURING
- [CATIA] 04-COMPOSITE ENGINEERING & MANUFACTURING PREPARATION
- [DELMIA] 05-PRODUCTION LINE DEFINITION & VALIDATION
- [DELMIA] 07-PAINTING LINE DEFINITION & VALIDATION
- [DELMIA] 08-BODY LINE DEFINITION & VALIDATION
- [DELMIA] 09-ASSEMBLY ROBOT PROGRAMMING & SIMULATION
- [DELMIA] 10-MOLD & DIE MACHINING
- [DELMIA] 11-NC PROGRAMMING & SIMULATION
- [DELMIA] 12- MANUFACTURING VIRTUAL COMMISSIONING
- [DELMIA] 13-ASSEMBLY PROCESS ENGINEERING & VIRTUAL BUILD
- [DELMIA] 14-FINAL ASSEMBLY PROCESS ENGINEERING & VIRTUAL BUILD



LEAN PRODUCTION RUN

- [DELMIA] 01-DEMAND PLANNING (S&OP)
- [DELMIA] 02-SUPPLY PLANNING (S&OP)
- [DELMIA] 03-MASTER PRODUCTION SCHEDULE
- [DELMIA] 04-MATERIAL SYNCHRONIZATION
- [DELMIA] 05-QUALITY EXECUTION
- [DELMIA] 07-PRODUCTION SCHEDULING
- [DELMIA] 08-PRODUCTION & MAINTENANCE EXECUTION
- [DELMIA] 10-ORDER PROMISING
- [DELMIA] 12-LEAN OPERATIONALMANAGEMENT
- [DELMIA] 13-MANUFACTURING CONTROL TOWER



SMART MOBILITY OPERATIONS

- [CATIA] 01-MOBILITY SYSTEMS ARCHITECTURE
- [CATIA] 02-MOBILITY SYSTEMS VIRTUAL TESTING
- [DELMIA] 03-RAIL CREW PLANNING
- [DELMIA] 04-RAIL CREW SCHEDULING
- [DELMIA] 05-RAIL CREW OPERATIONS



VIRTUAL GARAGE

- [NETVIBES] 01-MARKETING INTELLIGENCE
- [3DEXCITE] 03-COMMERCIAL TWIN CREATION
- [3DEXCITE] 05-MASS CONTENT CREATION
- [3DEXCITE] 06-PRODUCT SHOWCASE
- [3DEXCITE] 07-INSTANT PRODUCT COMMUNICATION



GLOBAL MODULAR ARCHITECTURE

- [ENOVIA] 01-STRATEGIC PORTFOLIO & PRODUCT PLANNING
- [ENOVIA] 02-COLLABORATIVE PLANNING EXECUTION & ANALYTICS
- [CATIA] 04-WEIGHT & BALANCE
- [ENOVIA] 05-SUSTAINABILITY DRIVEN ENGINEERING
- [CATIA] 06-REQUIREMENTS ENGINEERING, VERIFICATION & VALIDATION
- [ENOVIA] 08-VEHICLE ARCHITECTURE SYNTHESIS
- [NETVIBES] 09-SUPPLIER MANAGEMENT & SOURCING
- [ENOVIA] 10-CONTINUOUS PRODUCT DEVELOPMENT
- [ENOVIA] 11-COLLABORATIVE ENGINEERING DEFINITION
- [DELMIA] 12-COLLABORATIVE ENGINEERING TO MANUFACTURING
- [NETVIBES] 13-STANDARD COMPONENT MANAGEMENT
- [ENOVIA] 15-COLLABORATIVE DOCUMENT MANAGEMENT
- [ENOVIA] 16-3D DIGITAL MOCKUP VALIDATION
- [ENOVIA] 17-ENTERPRISE CHANGE & RELEASE PROCESS
- [ENOVIA] 18-EXTENDED ENTERPRISE
- [CATIA] 19-KNOW-HOW CAPITALIZATION AND AUTOMATION
- [CATIA] 20-DESIGN FAILURE AVOIDANCE
- [ENOVIA] 22-MATERIAL COMPLIANCE
- [ENOVIA] 23-CERTIFICATION & APPROVAL
- [NETVIBES] 24-DATA DRIVEN BUSINESS PERFORMANCE
- [SIMULIA] 25-CONTINUOUS SIMULATION MANAGEMENT



AFTERSALES & CUSTOMER SERVICE

- [CATIA] 01-REQUIREMENTS ENGINEERING, VERIFICATION & VALIDATION
- [DELMIA] 02-DESIGN FOR SERVICE
- [DELMIA] 03-SERVICE PROCESS ENGINEERING
- [DELMIA] 04-SERVICE TOOLING
- [NETVIBES] 06-DATA DRIVEN BUSINESS PERFORMANCE



ELECTRO MOBILITY ACCELERATOR

- [CATIA] 01-VEHICLE PACKAGING & COMPLIANCE
- [CATIA] 02-BODY STRUCTURE CONCEPT ENGINEERING
- [CATIA] 03-CHASSIS AND SUSPENSION CONCEPT ENGINEERING
- [CATIA] 04-CREATIVE DESIGN & STYLING
- [CATIA] 05-CLASS-A SURFACES
- [CATIA] 06-DESIGN EXPERIENCE & VALIDATION
- [CATIA] 07-WIRE HARNESS ELECTRICAL ENGINEERING
- [CATIA] 08-VEHICLE SYSTEMS ARCHITECTURE
- [CATIA] 09-POWERTRAIN SYSTEM ARCHITECTURE
- [CATIA] 10-BODY STRUCTURE ENGINEERING
- [CATIA] 11-CHASSIS AND SUSPENSION ENGINEERING
- [CATIA] 12-INTERIOR & EXTERIOR EQUIPMENT ENGINEERING
- [ENOVIA] 13-CONTINUOUS PRODUCT DEVELOPMENT
- [ENOVIA] 14-3D DIGITAL MOCKUP VALIDATION
- [ENOVIA] 15- COLLABORATIVE ENGINEERING DEFINITION
- [DELMIA] 16-LEAN AND AGILE DEVELOPMENT
- [NETVIBES] 17-SUPPLIER MANAGEMENT & SOURCING
- [ENOVIA] 19-COLLABORATIVE DOCUMENT MANAGEMENT
- [ENOVIA] 20-EXTENDED ENTERPRISE



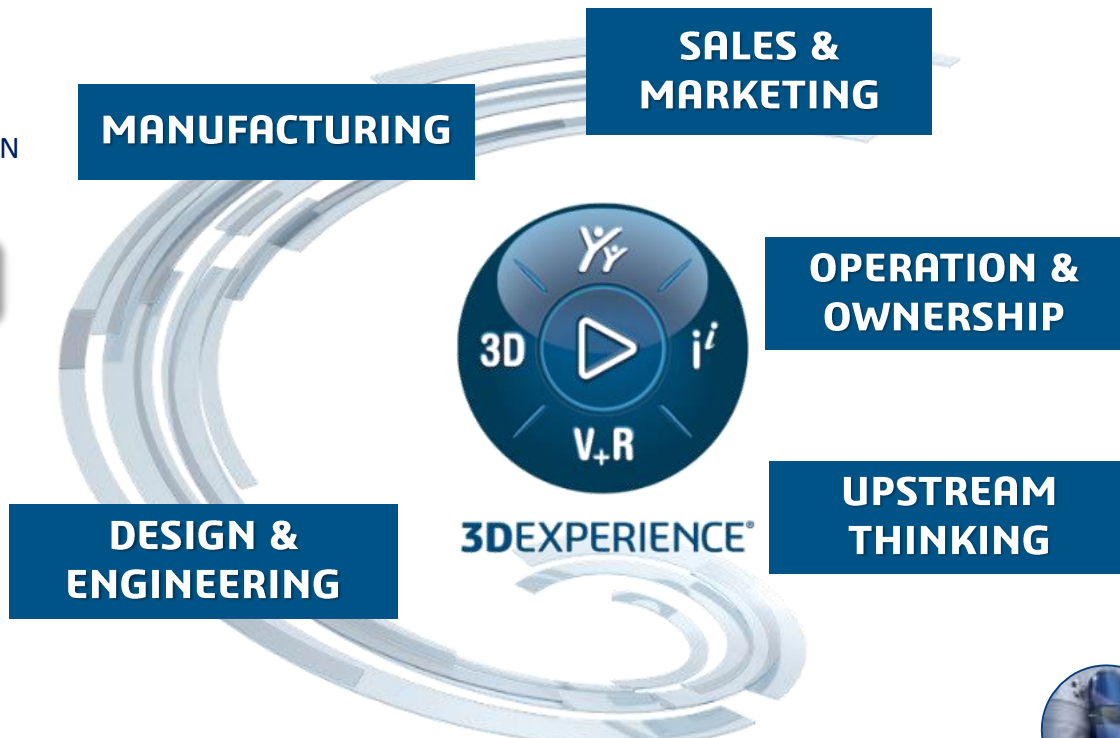
DRIVE EMOTION

- [NETVIBES] 01-BRIEFING, IDEATION & MARKET WATCH
- [CATIA] 02-CREATIVE DESIGN & STYLING
- [CATIA] 03-CLASS-A SURFACES
- [SIMULIA] 04-VEHICLE AERODYNAMICS
- [SIMULIA] 05-CABIN COMFORT
- [CATIA] 06-PERCEIVED QUALITY
- [CATIA] 07-DESIGN EXPERIENCE & VALIDATION



BID TO WIN

- [ENOVIA] 01-STRATEGIC PORTFOLIO & PRODUCT PLANNING
- [ENOVIA] 02-COLLABORATIVE PLANNING EXECUTION & ANALYTICS
- [NETVIBES] 03-SUPPLIER MANAGEMENT & SOURCING
- [ENOVIA] 05-COLLABORATIVE DOCUMENT MANAGEMENT
- [ENOVIA] 06-CONTINUOUS PRODUCT DEVELOPMENT
- [CATIA] 07-MECHANICAL ENGINEERING
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- [ENOVIA] 12-ENTERPRISE CHANGE & RELEASE PROCESS
- [ENOVIA] 13-EXTENDED ENTERPRISE



SMART, SAFE & CONNECTED

- [CATIA] 01-MOBILITY SYSTEMS ARCHITECTURE
- [CATIA] 02-VEHICLE SYSTEMS ARCHITECTURE
- [CATIA] 03-REQUIREMENTS ENGINEERING, VERIFICATION & VALIDATION
- [SIMULIA] 04-PERFORMANCE DRIVEN ARCHITECTURE
- [CATIA] 05-ELECTRICAL, ELECTRONICS AND SOFTWARE ARCHITECTURE
- [CATIA] 06-VEHICLE FUNCTIONAL SAFETY
- [ENOVIA] 07-INTEGRATED SOFTWARE ENGINEERING
- [CATIA] 08-EMBEDDED SOFTWARE ENGINEERING
- [ENOVIA] 09-ELECTRONICS DESIGN INTEGRATION
- [CATIA] 11-WIRE HARNESS ELECTRICAL ENGINEERING
- [CATIA] 12-FLUID SYSTEMS ENGINEERING
- [SIMULIA] 13-VEHICLE ANTENNA & SENSOR DESIGN & PLACEMENT
- [SIMULIA] 14-ELECTRONICS SYSTEM PERFORMANCE MANAGEMENT
- [CATIA] 16-CONTINUOUS EMBEDDED SYSTEMS TESTING & VALIDATION
- [CATIA] 17-ADAS/AD-TESTING & SIMULATION
- [CATIA] 18-SYSTEMS ANALYSIS



WHY WE ARE THE RIGHT PARTNER FOR AUTOMOTIVE OEMS DASSAULT SYSTEMES IS THE LEADING PARTNER FOR AUTOMOTIVE

72%

of all light weight vehicles delivered in 2021 were designed & engineered in CATIA



99%

of the Top 400 WW Automotive Suppliers use CATIA to develop Systems, Sub-Systems or Components

10/10*

of the Top New EV makers relies on CATIA & 3DEXPERIENCE for their virtual development

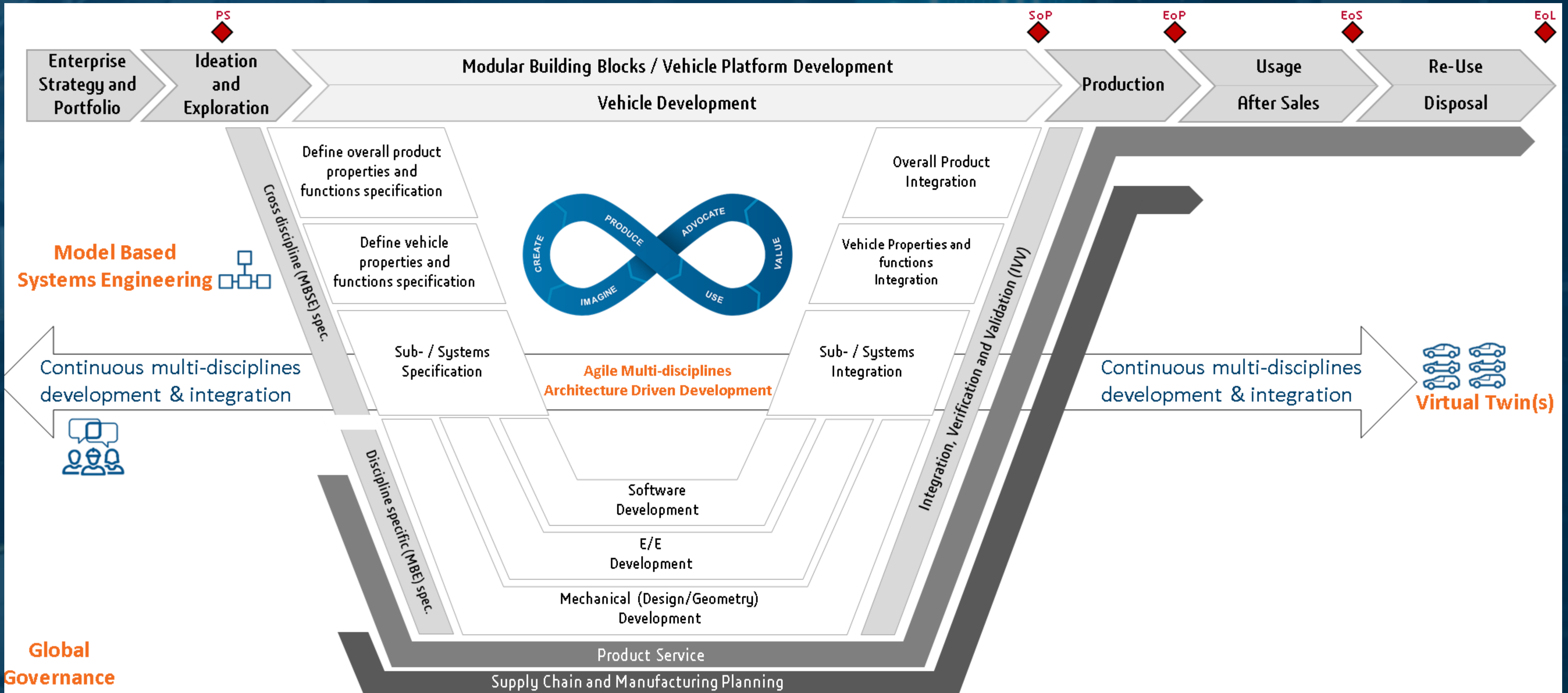


*November 2022, <https://www.energystartups.org/top/electric-cars/>

WHY WE ARE THE RIGHT PARTNER FOR AUTOMOTIVE OEMS DASSAULT SYSTEMÈMES IS THE LEADING PARTNER FOR AUTOMOTIVE

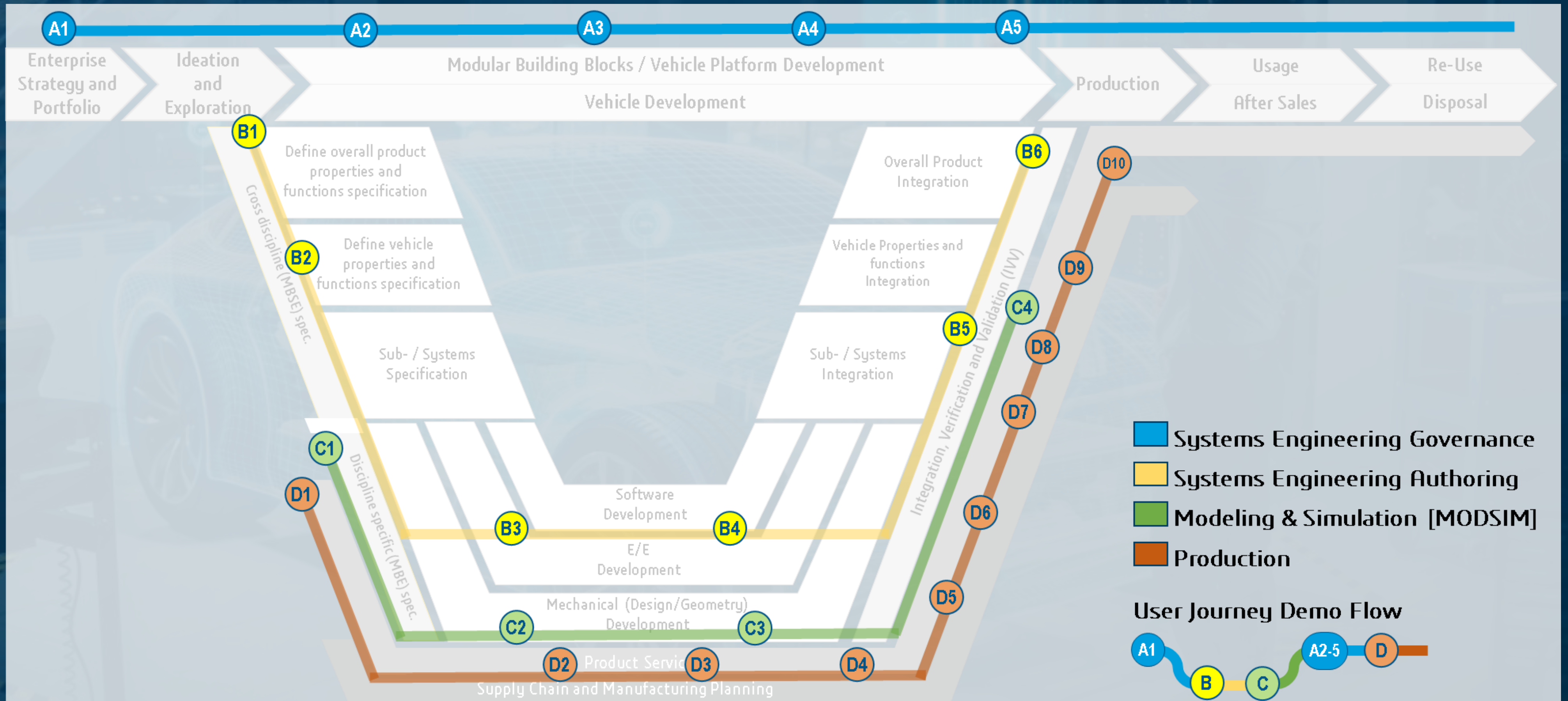


THE AUTOMOTIVE VEE MODEL AS A REFERENCE



Global Governance

AUTOMOTIVE USER JOURNEY



3DEXPERIENCE | Enterprise Governance Platform

Portfolio

Hybrid Projects

Agile Collaboration

Multi-Level Configurations

Maturity

Releases

Quality

Traceability

Sustainability

Change





**Ulrich
SCHULMEISTER**

Vice President Technology
and Engineering

Robert Bosch GmbH

COMBINING SYSTEMS ENGINEERING WITH
VIRTUALISATION TO ACCELERATE
ENGINEERING



Combining Systems Engineering with Virtualization to Accelerate Software Engineering

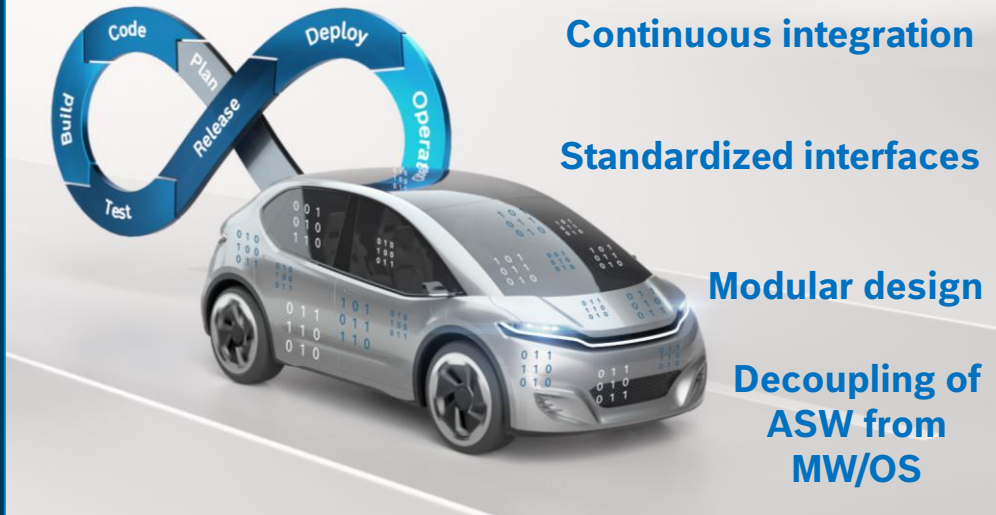
Ulrich Schulmeister
VP Technology and Engineering
Robert Bosch GmbH, Germany

October 16th, 2024



Software-defined Vehicle

SDV | Vehicle that can **evolve throughout its life cycle**:
It changes its key features **by changing its software**.



Technical solution – an SDV is enabled by...

- ASW/MW decoupling
 - E/E architecture
 - OS + MW
 - Virtualization technologies
 - Standard runtime environment
 - Portability to different vehicles or hardware platforms
- Connectivity
 - (Connected) Vehicle
 - (Cloud-based) DevOps Environment

How to develop, integrate and test the missing Feature in an efficient way?

Introduction

Imagine a feature of transferring control to a remote driver momentarily

What are the prerequisites to be fulfilled

- Required conditions are met to transfer control momentarily
 - Vehicle cannot operate or navigate on its own
 - Vehicle is in drivable condition
 - Change of driver is permissible from the surroundings point of view
 - Safety requirements are fulfilled
- Driver is authorized and authenticated to drive the vehicle. Authentication is automated and secure



This feature has to be implemented and validated for functionality, timing latency, safety, security & usability

What is a Feature ?

- *For the System Engineer in us ...*
A feature is “an abstract functional characteristic of a system of interest that end-users and other stakeholders can understand.”
[ISO/IEC 26550:2015]
- *For the Businessman in us ...*
A Feature is a **stakeholder perceivable behavior** of a system which has **positive impact on his purchasing decision**.
- A feature describes a system’s behavior, **not a (technical) system solution!**



Source: Volkswagen


“When I approach my car with a box in my hands, I want to be able to open the trunk without having to put the box down.”

Features have positive impact on stakeholders’ purchasing decisions
and are as a matter of principle independent from their technical realization in the Mobility System

Combining Systems Engineering with Virtualization to Accelerate Software Engineering

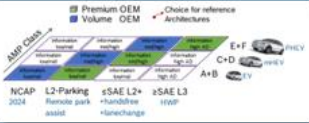
Gaining Speed in Systems Engineering

Business

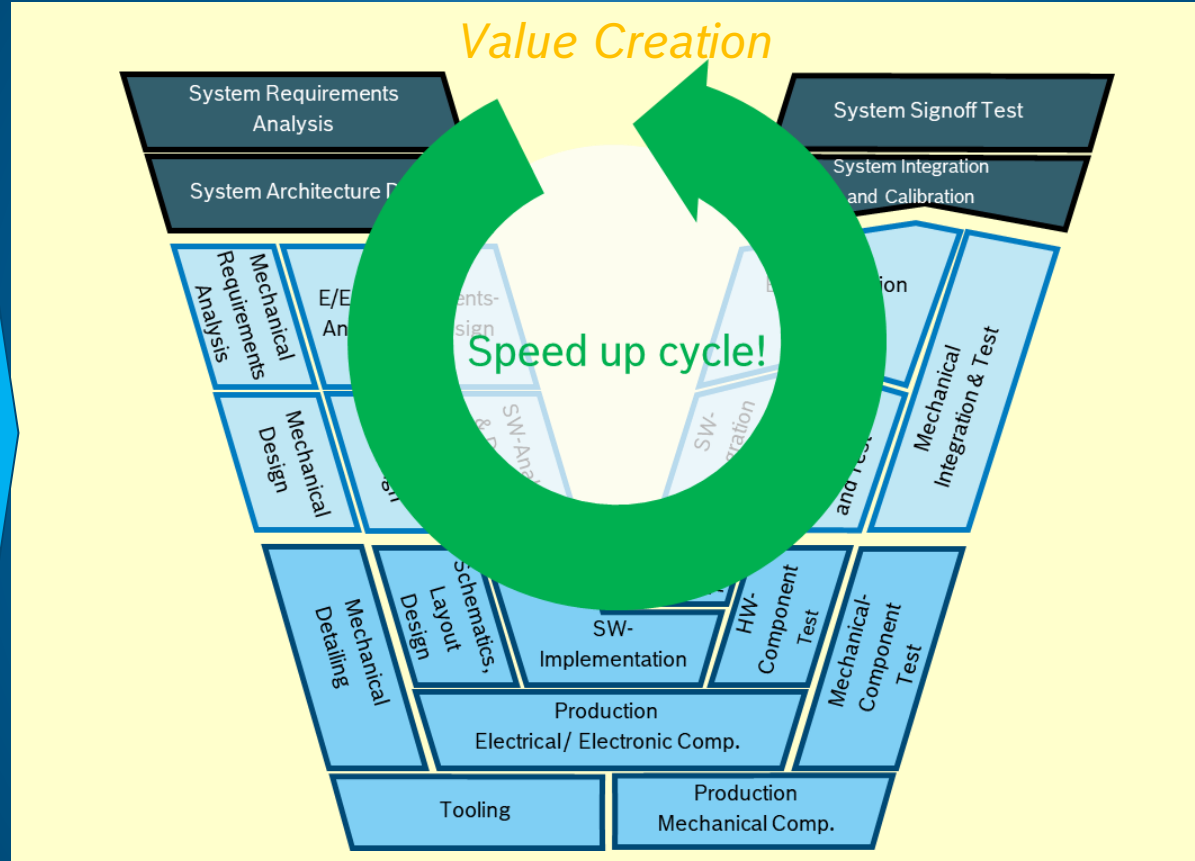


Features

Constraints



Vehicle Segments




Value Capturing

↻ Speed up by consequently applying model-based principles, automatization & virtualization

Combining Systems Engineering with Virtualization to Accelerate Software Engineering

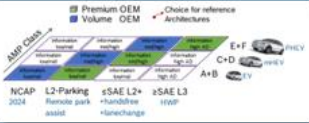
Gaining Speed in Systems Engineering

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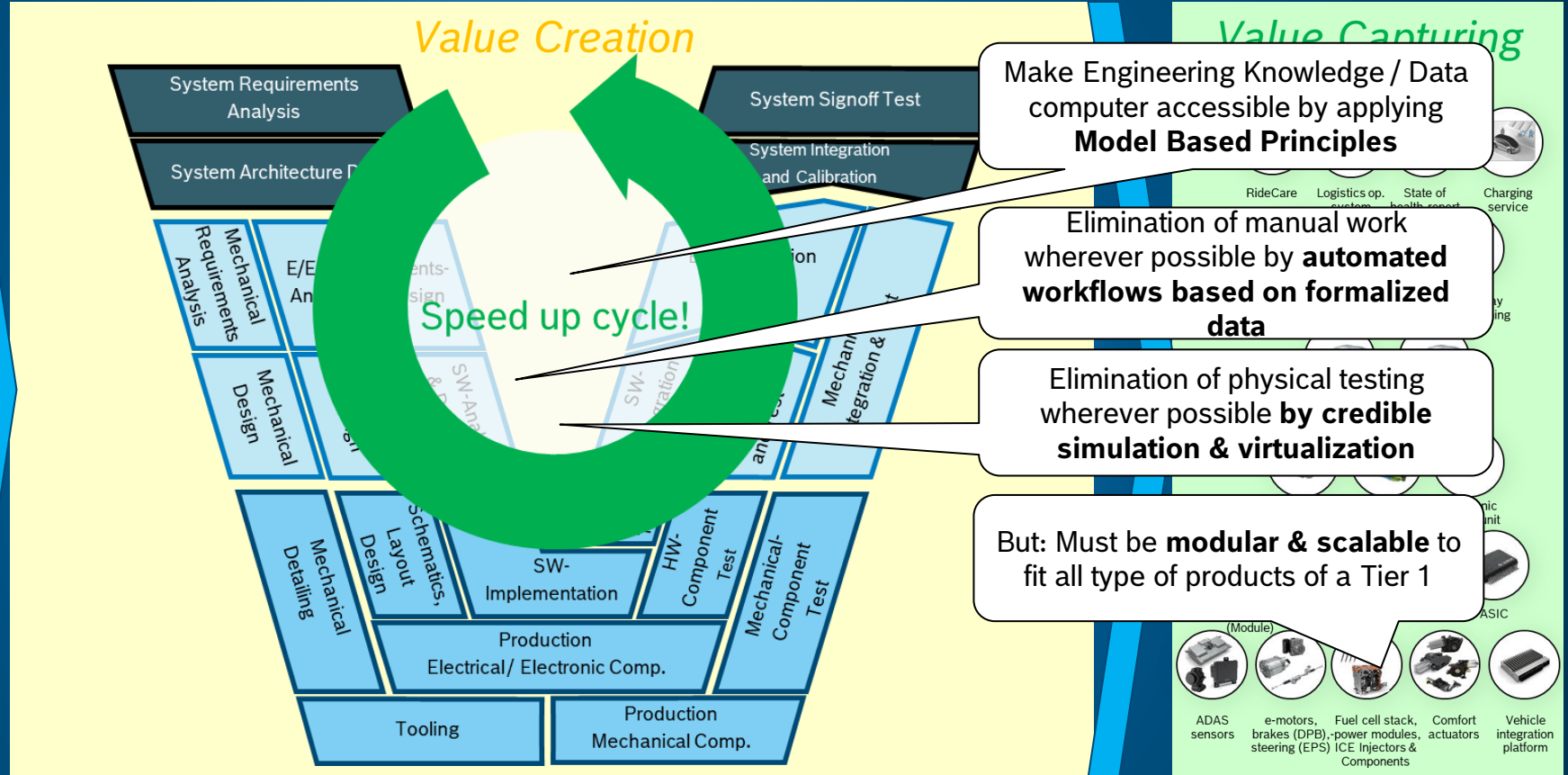


Features

Constraints



Vehicle Segments



Speed up by consequently applying model-based principles, automatization & virtualization

Combining Systems Engineering with Virtualization to Accelerate Software Engineering Design for Safety



<http://www.nexthamburg.de/userpost/klothoiden-und-schleppkurvenberechnung-beim-radwegebau/>



<https://www.telegraph.co.uk/news/newstoppers/howaboutthat/7547129/Council-condemned-over-Britains-shortest-cycle-lane.html>

Safety cannot be implemented afterwards!

Example: Derivation of Safety Goals / Safety Requirements from HARA

Safety Goal

“No transition of driving task to driver during driving”



- Vehicle in safe state
 - L4 system brings to the vehicle into safe position
 - L4 systems allows safe change of driver from passenger seat to driver seat → switch on warning lights
- Driver must be suitable and ready for take over of driving task
 - authentication via driving license
 - pressed brake pedal to enable start of driving

Residual risk that something happens anyway; 100% safety not possible!

The role of simulation in product engineering

Numerical Simulation

... will be a **game changer** in product engineering if used for **virtual release**

... is a **powerful approach** to



speed up development



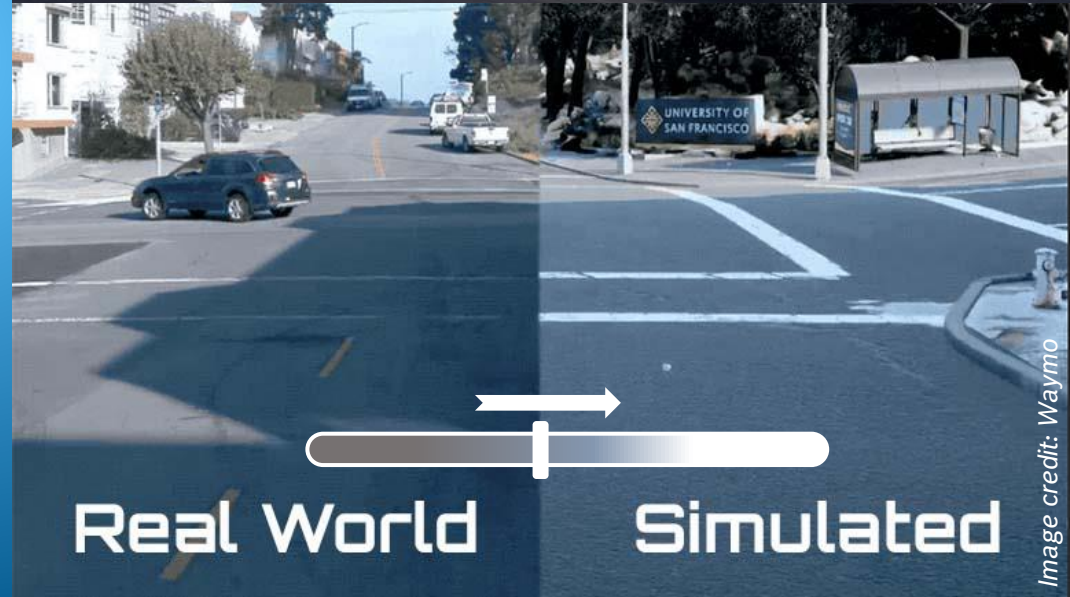
save costs



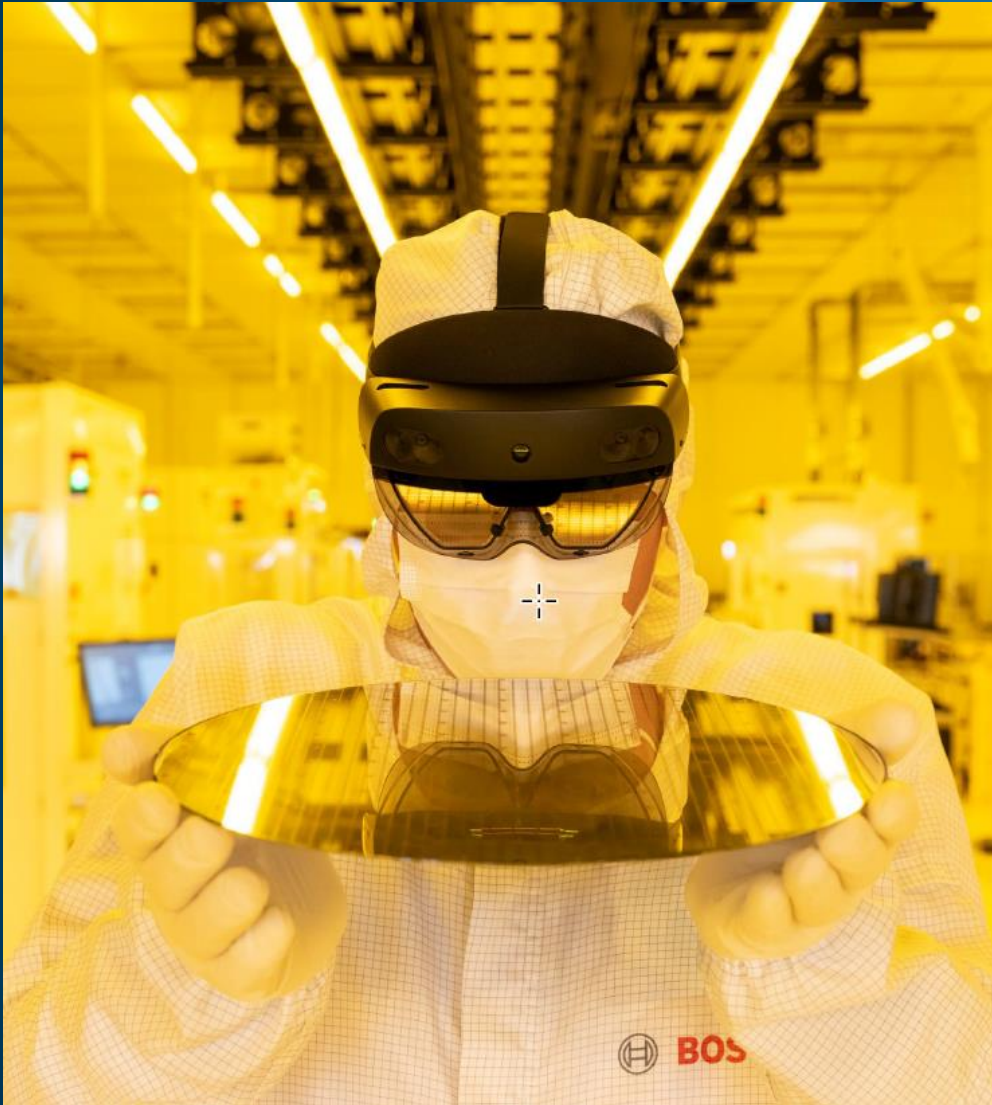
explore new business areas, where real testing is rather impossible (e.g. autonomous driving)

Trust

... in M&S results will be the **key enabler**



Combining Systems Engineering with Virtualization to Accelerate Software Engineering



**THANK
YOU!!!**

THANK YOU FOR YOUR INTEREST!

