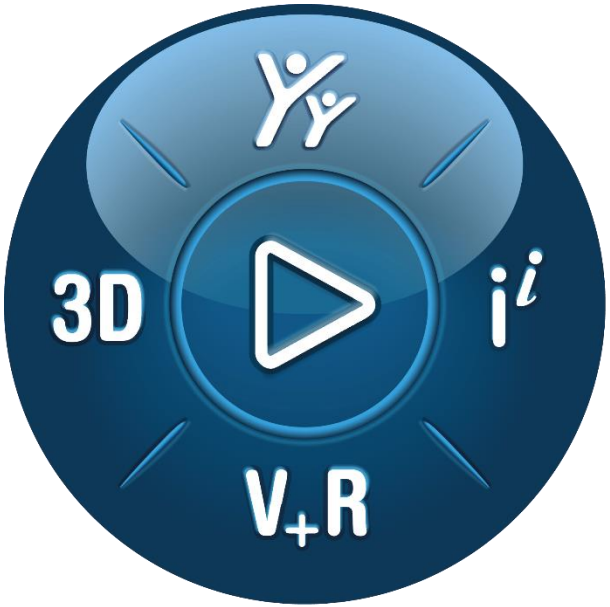


3DEXPERIENCE®

Model Based Systems Engineering

Matti Koskipää

DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

Agenda

Why Systems Engineering

Systems Engineering V-model and layers

Systems Engineering Frameworks and Methods

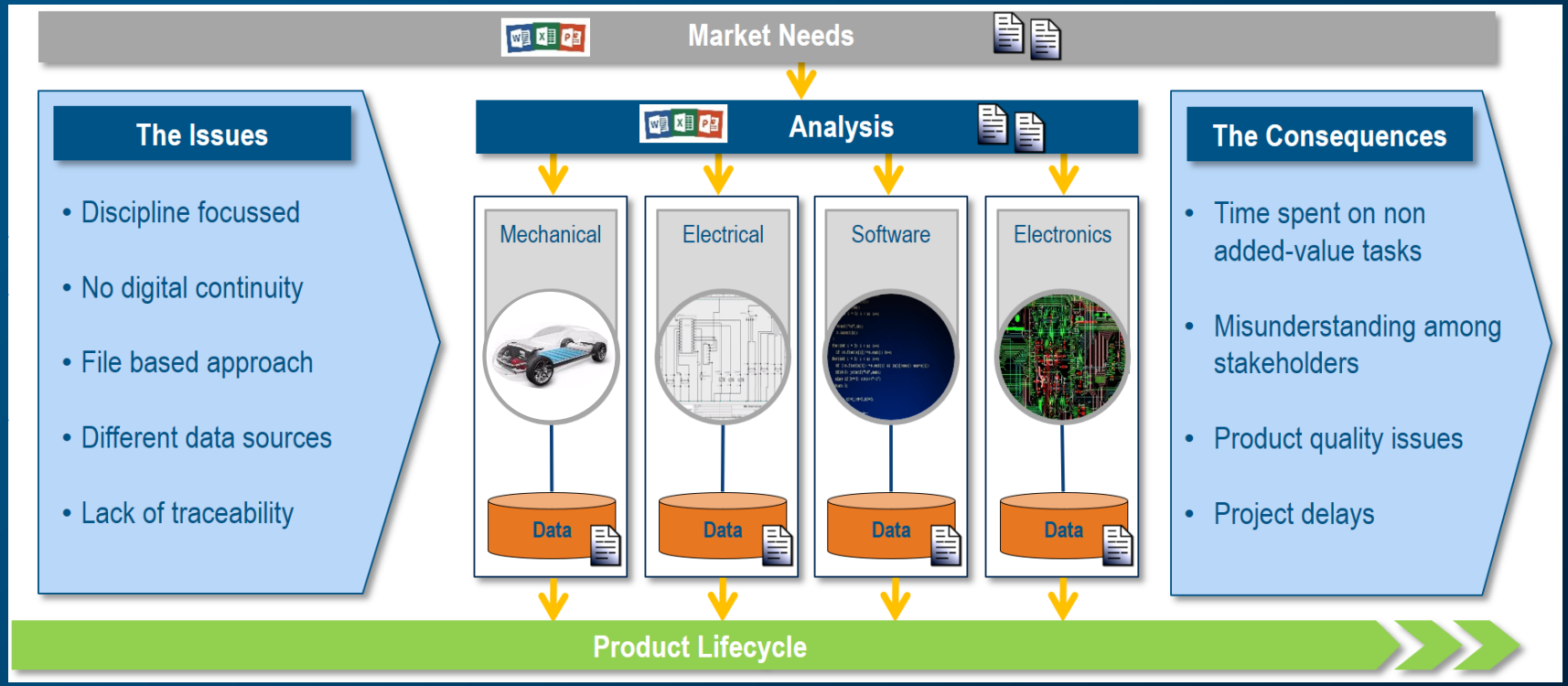
Implementing Systems Engineering

How you should use Systems Engineering

Agenda

- **Why Systems Engineering**
- Systems Engineering V-model and layers
- Systems Engineering Frameworks and Methods
- Implementing Systems Engineering
- How you should use Systems Engineering

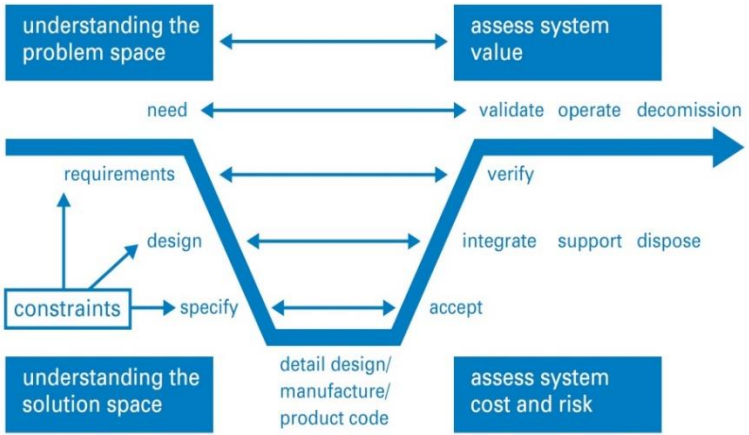
A Key Problem – Thinking in “Discipline Silos”



What is Systems Engineering?

Systems engineering is a holistic and systematic interdisciplinary approach and means to enable the realization of successful systems in large projects and connected worlds
Based on multi-industry best practices framework: ISO15288

- Understanding the problem before jumping into the solution (stakeholder needs, context, use cases, behavior)
- Strong focus on customer needs and required functionality for all product lifecycle phases
- Considering the complete problem incl. operations, performance, test, manufacturing, cost & schedule, training & support, maintenance, disposal
- Reducing complexity by decomposing the system of interests into subsystems with clearly defined functions, interactions, responsibilities,…



Source: INCOSE

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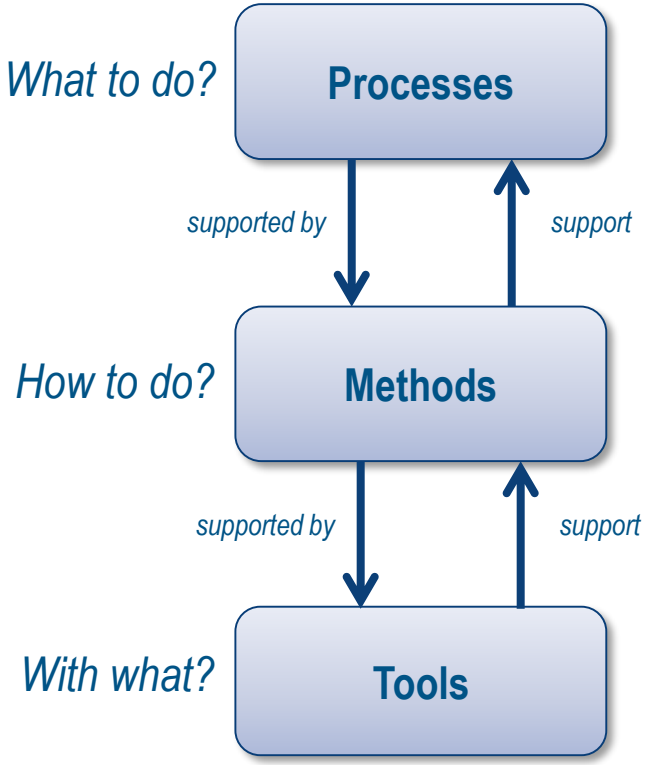
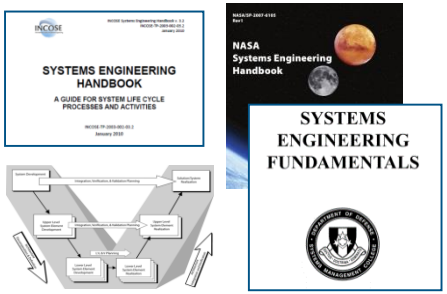
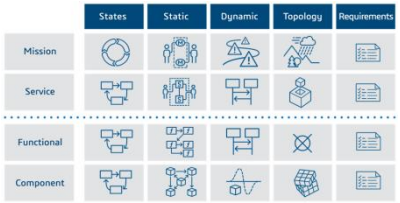
Systems Engineering Overview



Define activities to achieve a particular objective



Defines techniques to perform processes activities



Improve the efficiency of activities through methodology

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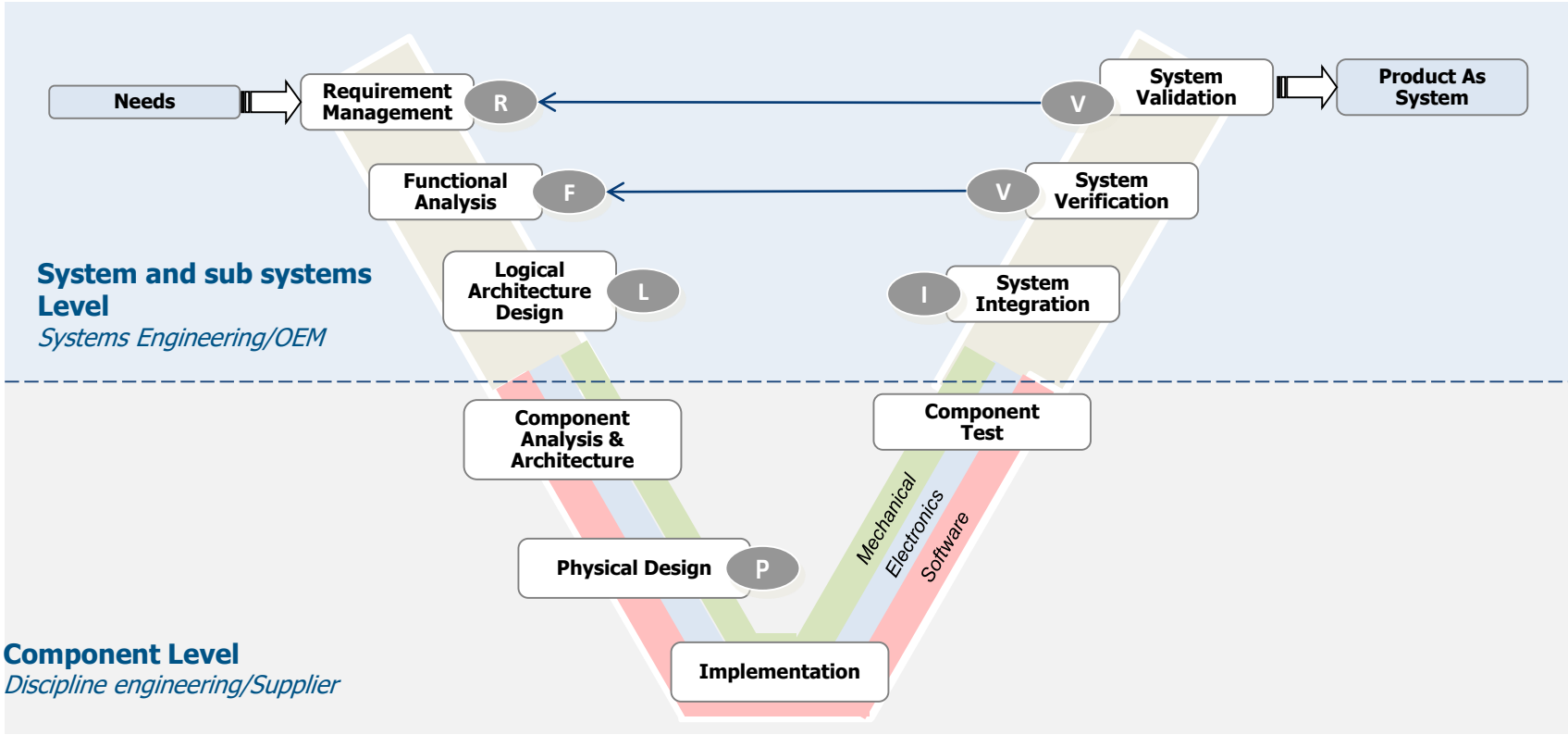
Systems Engineering V-model



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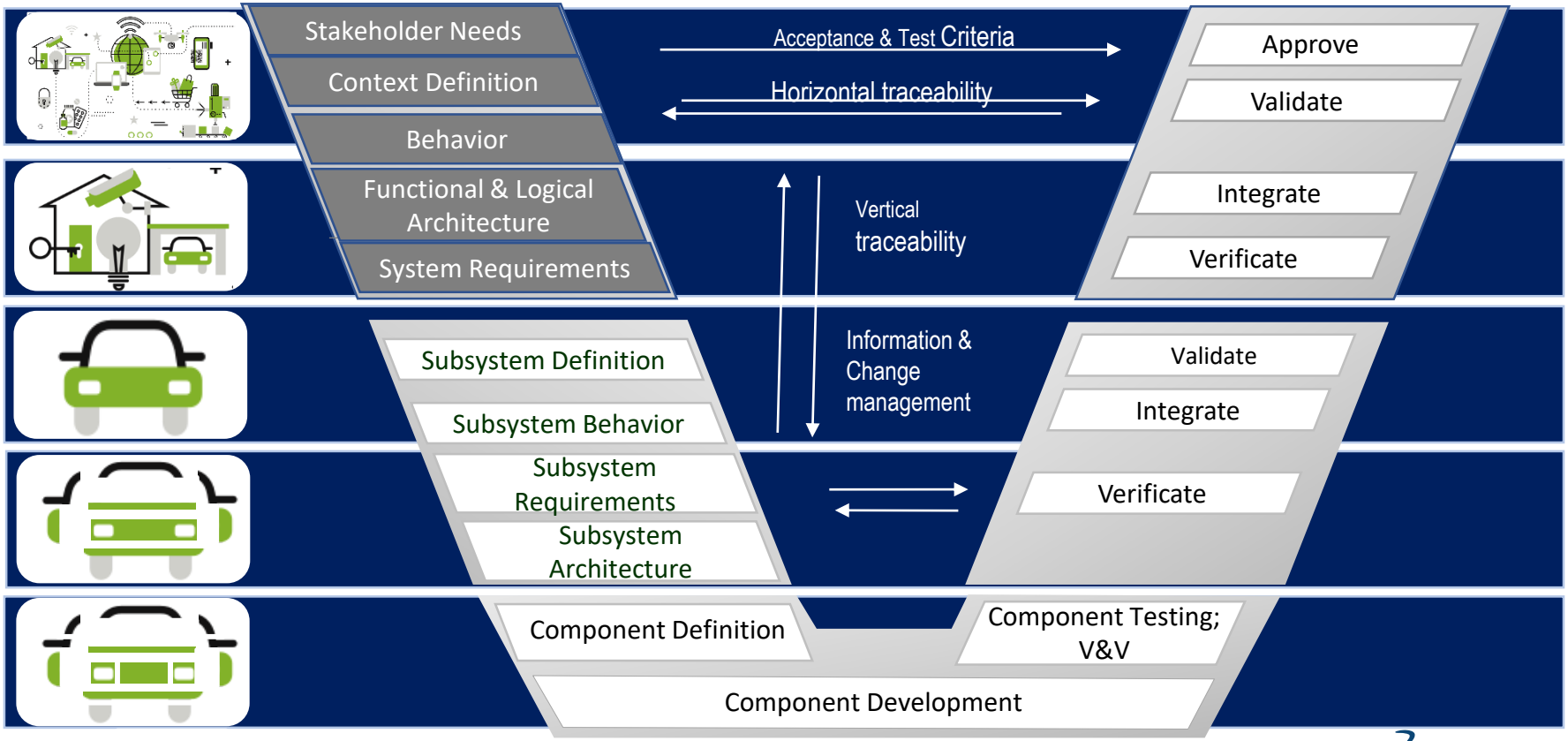
Systems Engineering V-model in more details



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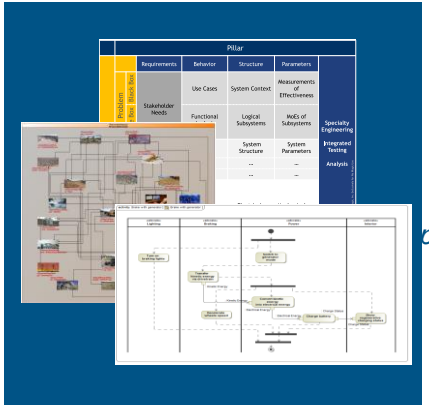
System model to federate disciplines and experiences

Requirements Model

traceability rationale

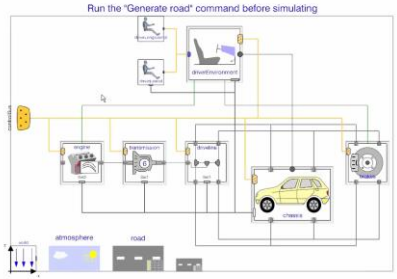
viewpoint



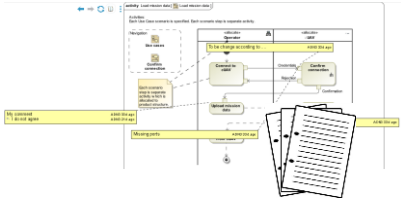
System Model

analysis needs

performance estimates

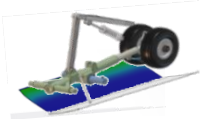


Analysis Models

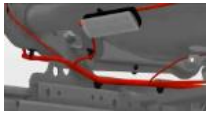


Collaboration

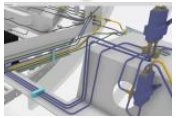
system framework for design



Mechanical Models



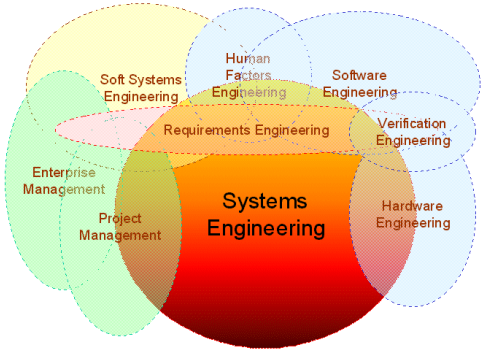
Electrical Models



Fluid Models

Electronic Models

Software Models



DASSAULT SYSTEMES

Agenda

Why Systems Engineering

Systems Engineering V-model and layers

Systems Engineering Frameworks and Methods

Implementing Systems Engineering

How you should use Systems Engineering

Cyber Systems framework

System of Systems

System

Component

End-to-End Traceability

Multi-systems contractual architecture and services

Contracting Authority

System Architecture & Functions

OEM

conceptual

implemented

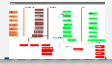
Cross-disciplines Solution Architecture & Functions

Geometrical Architecture

Electrical Electronics System Architecture

Hardware architecture

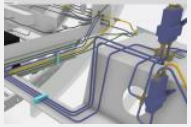
Software architecture



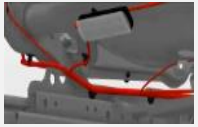
OEM

Mechanical components

Fluid components



Electrical components



Electronic components

Hardware

Software

Upstream studies

Downstream design

Supplier

DASSAULT SYSTEMES

CYBER PHYSICAL SYSTEM = System of Interest = SoI

System of Systems

Cyber Physical System

Sub Systems

End-to-End Traceability

Mission modeling, simulation and optimization

Operational View

Multi-systems contractual architecture and services models

Functional modeling simulation and optimization

Functional View

System Architecture & Functions models

Solution modeling simulation and optimization

Constructional View

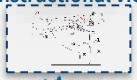
Solution Architecture models and 3D outfitting model

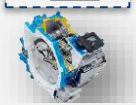
Mechanical

Operational View

Functional View

Constructional View





Fluid

Operational View

Functional View

Constructional View

Electrical

Operational View

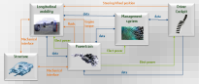
Functional View

Constructional View

Electronics/Embedded Software

Operational View

Functional View



Constructional View

Hardware architecture

Software architecture

Hardware

Software

Implementation diagrams and 3D physical models

Implementation View | Implementation View | Implementation View | Implementation View

Upstream studies

Downstream design

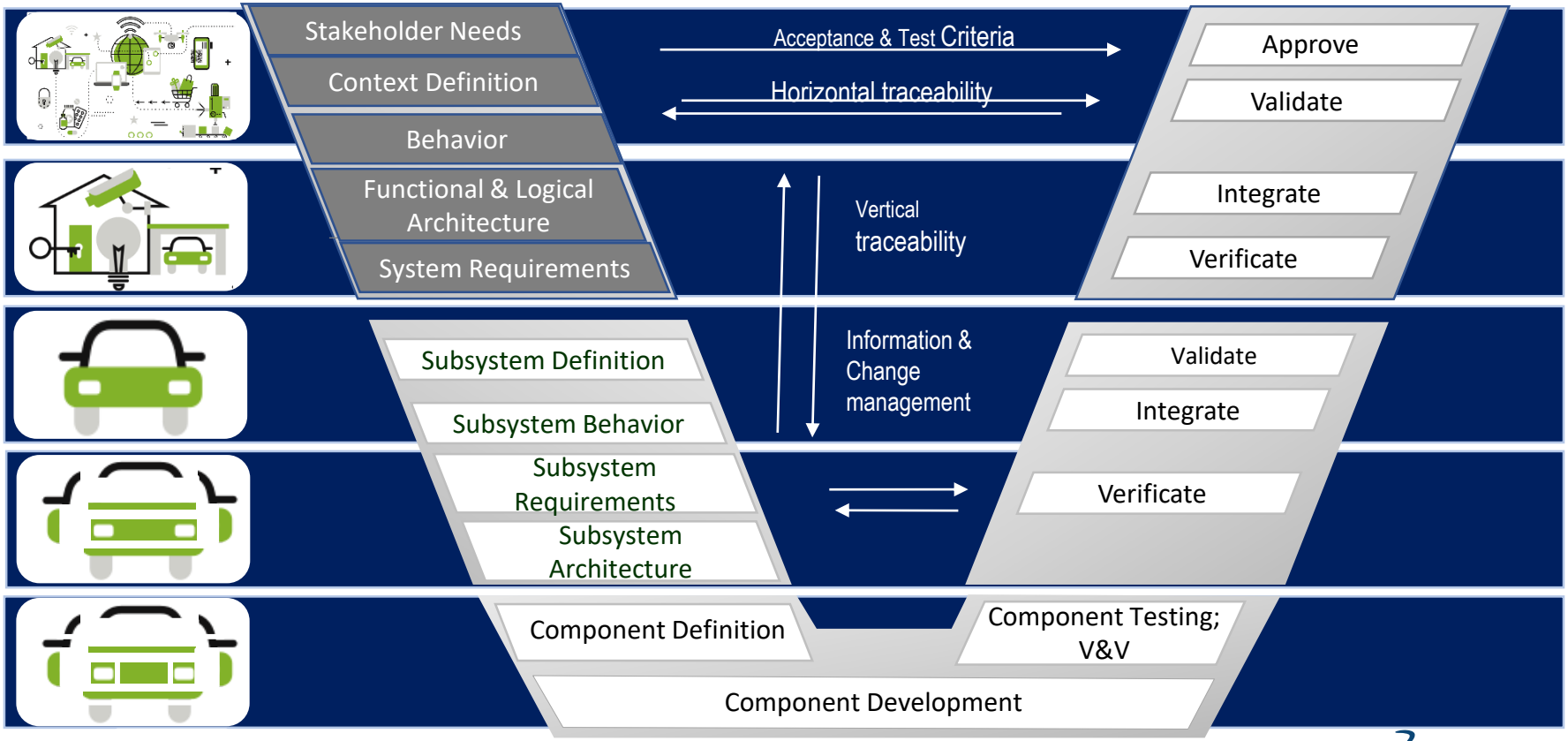
Contracting Authority

OEM

OEM

Supplier

Systems Engineering V-model in more details



DASSAULT SYSTEMES

Domains		Pillars				
		Requirements	Behavior	Structure	Parameters	Safety
Problem	Black Box	Stakeholder Needs	Use Cases	Context	Measurements of Effectiveness	PRA
	White Box		Functional Analysis	Logical Subsystems/ Geographic zones	MoEs of Subsystems	FMEA FTA
Solution		System Requirements	System Behavior	System Structure/ Space reservation	System Parameters	FMEA FTA
		Sub-system…	…	…	…	…
		Component…	Component Behavior	Product Structure/ Space reservation	Component Parameters	FMEA FTA
Implementation		Physical Requirements	Digital Mock up Mechanical, Electrical, Fluid, Electronics, Software…			FMEA FTA

System of Systems Engineering

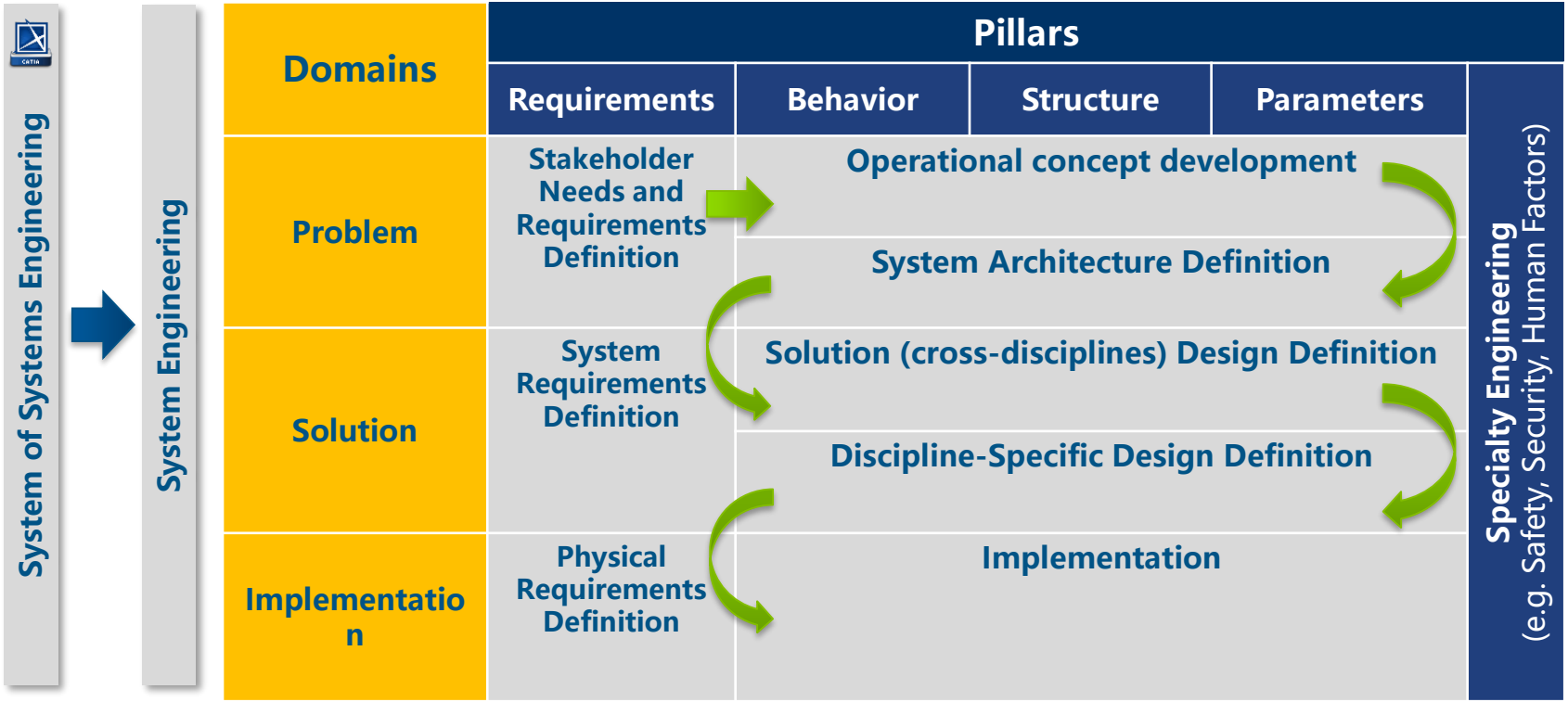
System Engineering

Domains	Pillars				
	Requirements	Behavior	Structure	Parameters	Specialty Engineering (e.g. Safety, Security, Human Factors)
Problem	Stakeholder Needs and Requirements Definition	What the system has to accomplish for the stakeholders?			
Solution	System Requirements Definition	How the system will work to fulfill the system specifications?			
Implementation	Physical Requirements Definition	How the system is built? Component specification			

DASSAULT SYSTEMES

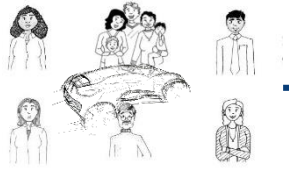
Cyber MagicGrid

Authoring flow summary



DASSAULT SYSTEMES

Typical high level process



Problem domain

Solution domain

Stakeholder Needs and Requirements Definition

Black Box System Definition: System Services

White box system definition: Technical Functions & sub-systems

System Requirements Definition

Solution Design Definition (incl. carry over)

Physical Requirements Definition

Implementation

System development

DASSAULT SYSTEMES

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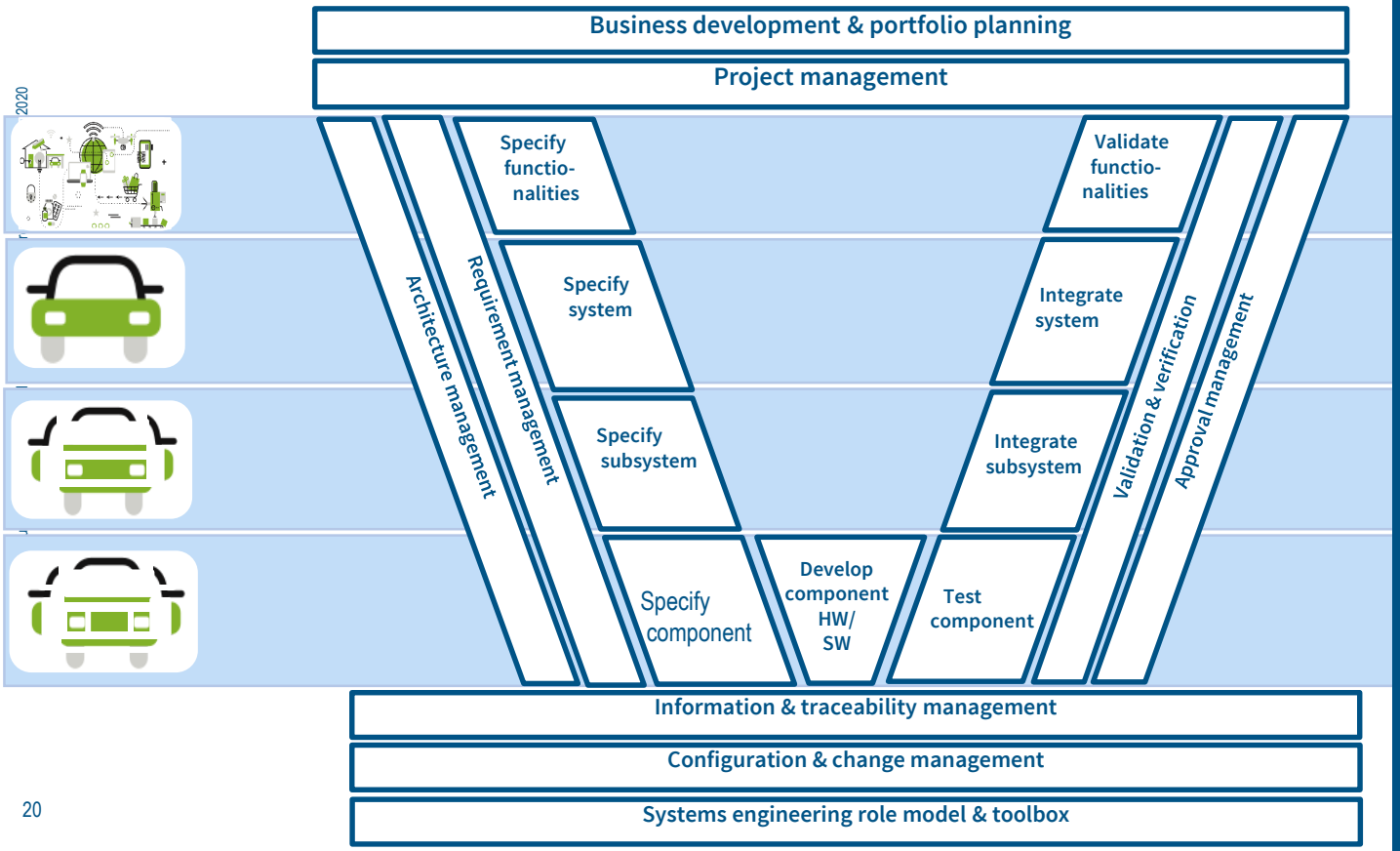
How to get started on the MBSE?



Gain points:

-50% prototypes

-20% time to market

-10% development cost

Innovation capability

significant reduction of project risks

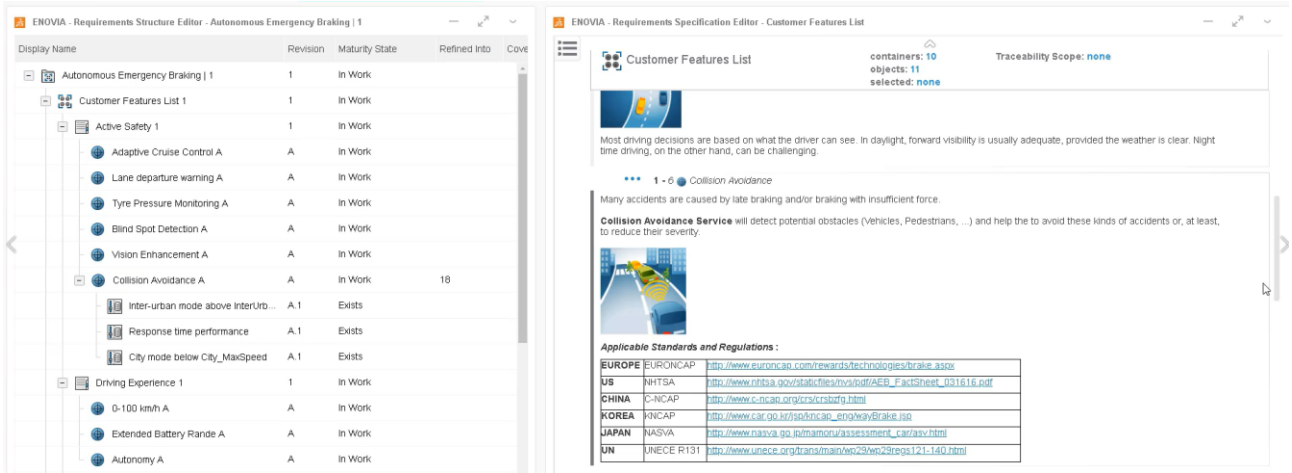
Compliance against regulations/standards

Pre-requisite for complex safety related functions (e.g. autononomous driving)

Enable handling of rising complexity

Requirements

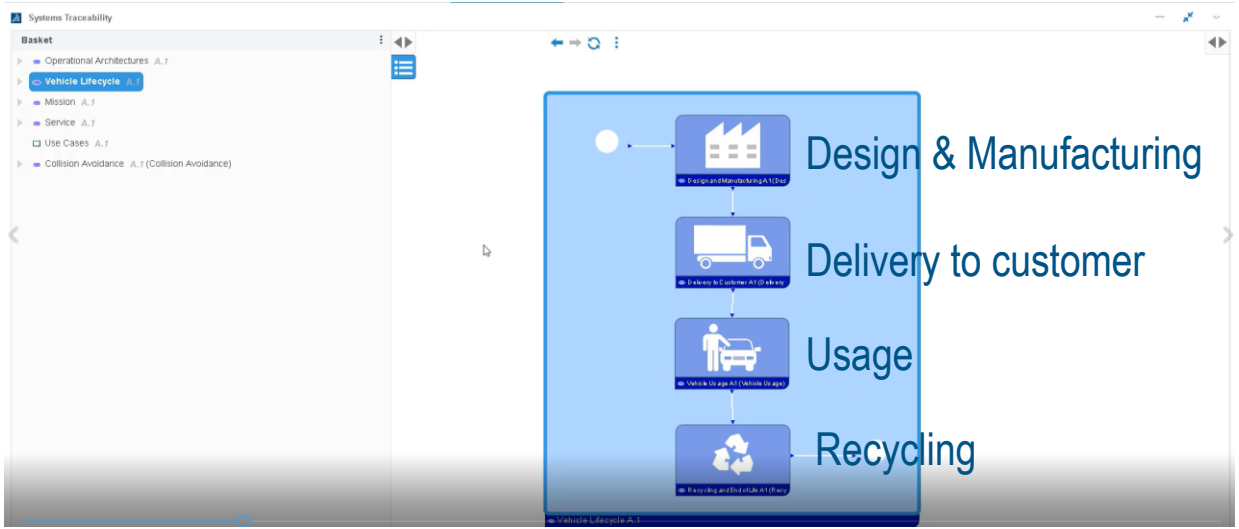
- **Unambiguous**.
  - Stated in such a way so that it can be interpreted in only one way.
  - Stated simply and is easy to understand.
- **Consistent**.
  - Is free of conflicts with other requirements.
- **Complete**.
  - Needs no further amplification : it is measurable and sufficiently describes the capability and characteristics to meet the stakeholder's need.
- **Singular**.
  - Includes only one requirement with no use of conjunctions.
- **Feasible**.
  - Is technically achievable, does not require major technology advances, and fits within system constraints (e.g., cost, schedule, technical, legal, regulatory) with acceptable risk.



Functional – Operational Architecture

Functional – Lifecycle

- Lifecycle is much more than the usage
- It is critically important to consider all steps of the life of the product/system



Is this missing something?

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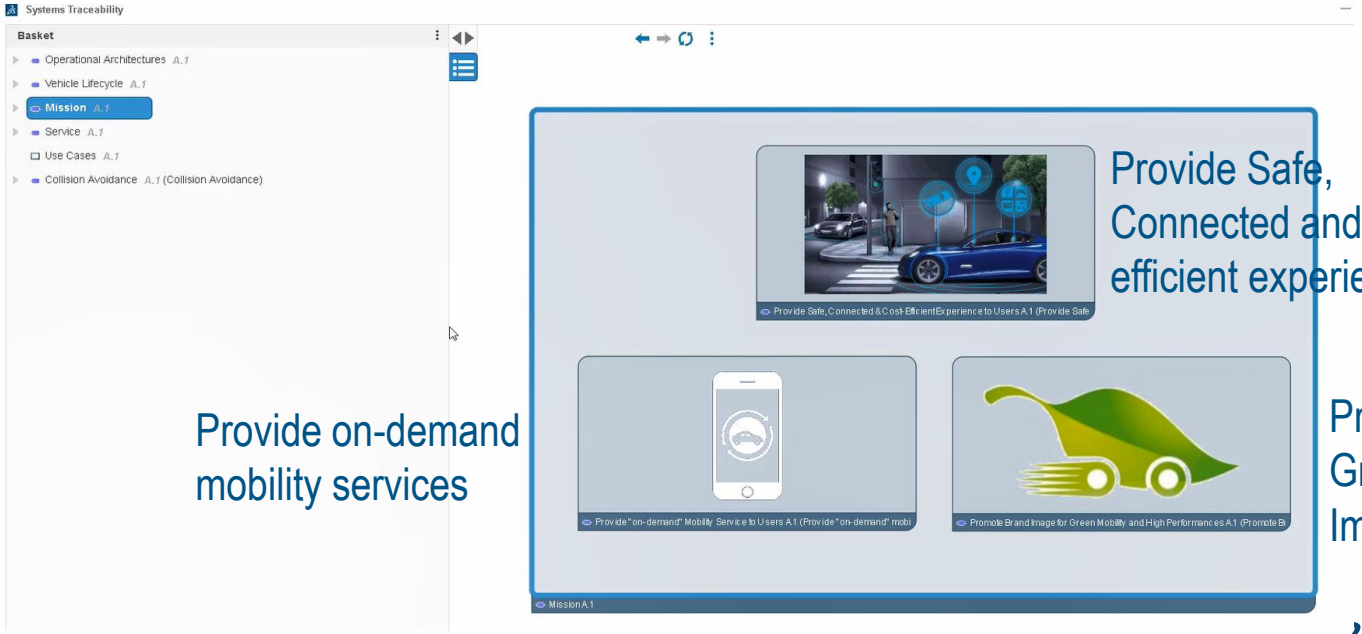
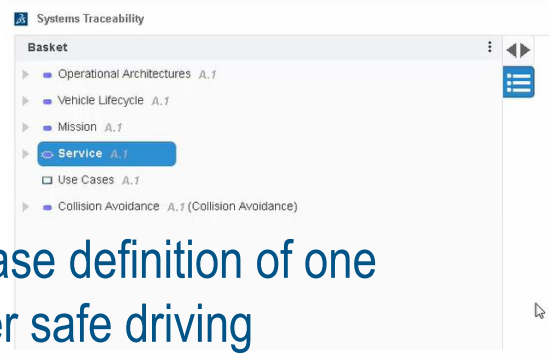
Functional - Mission

- With in Mission definition System of Systems and environmental factors will be taken into account

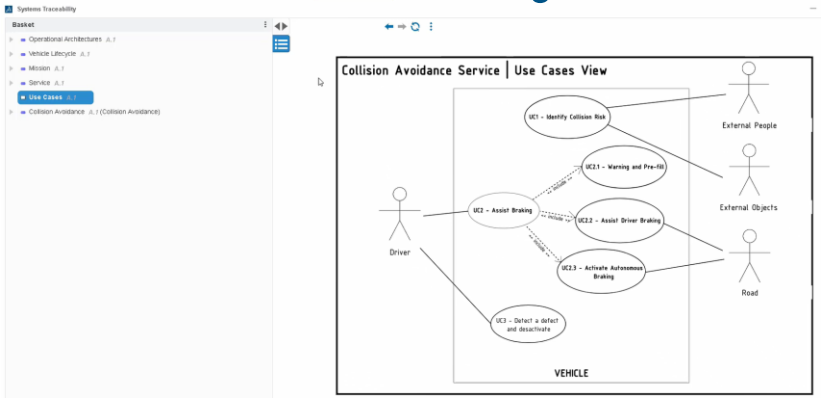


Functional - Services

Service definitions of the vehicle

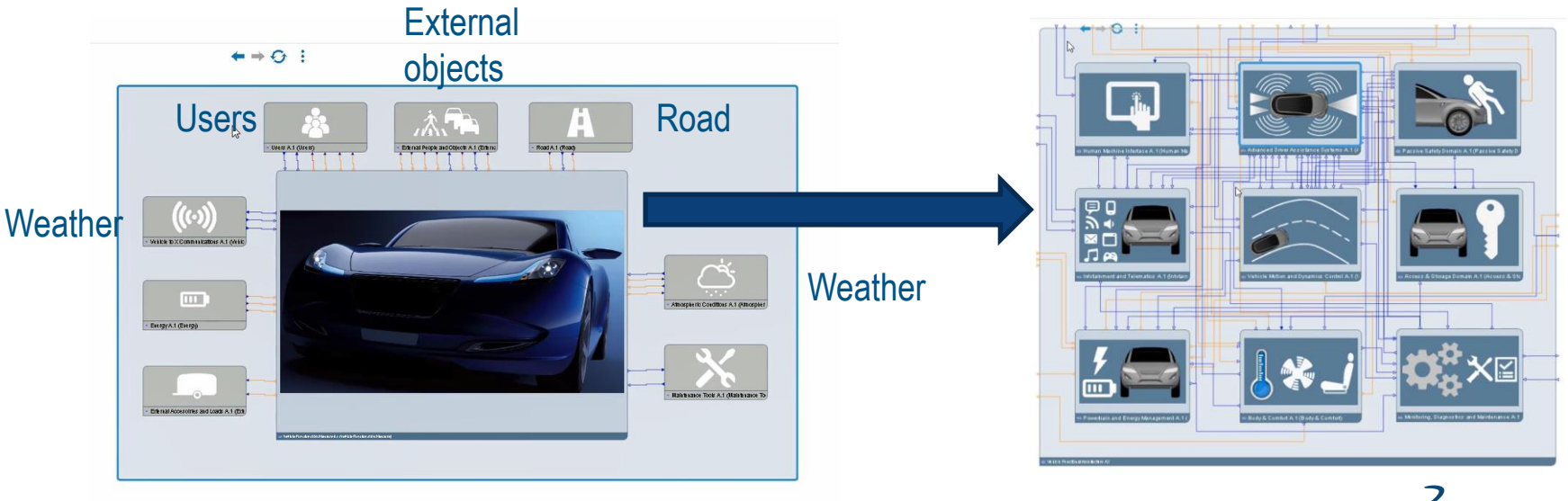


And a use case definition of one service under safe driving



Functional – Vehicle functional architecture

With Vehicle's functional architecture all the external actors and effecting environmental actors can be linked to the actual product and see the effect on the product itself.

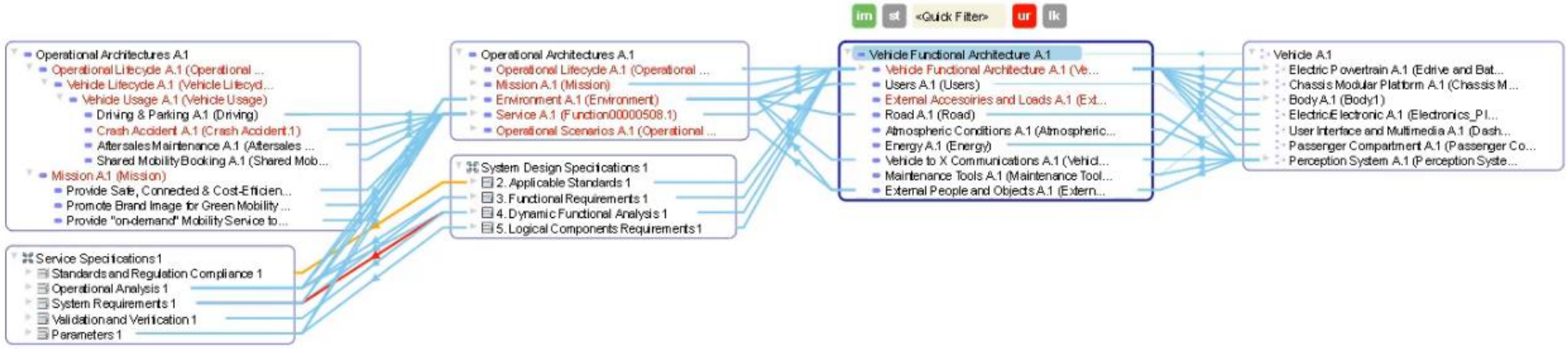


Logical architecture

Once the functions of the system had been defined, then in logical architecture we can define how the functions can be delivered to users

Traceability

Key is to manage this whole chain of objects, so that e.g. system architect can see what is the impact of a change in any of the objects.



DASSAULT SYSTEMES

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How could you implement System Engineering

- Look at the work as your requirement specification and split it into requirements.
- You could even further engineer the requirements to understand unclear areas
- Think of the lifecycle of the system of interest and the environment

Requirements

1. Create the report in pdf format. Handwritten solutions will not be accepted. Remember to attach the requested images to your report. Show all your mathematical solutions stage by stage in the report.
2. In the project reports, follow the same section titles 1...3 given in the assignment paper. (1. Background study (3 p), 2. Numeric Modelling (6 p), 3. Components (6 p))

→

1. Deliver report in PDF format
    1. Needed images shall be included into the report
    2. All mathematical solutions shall be shown in the report
        1. Mathematical solutions need to be shown stage by stage
2. In the report follow the sections define in the **MEC-E5001 Mechatronic Machine Design Project work**
    1. Report shall have sections 1-3