SysML for embedded automotive systems

SysCARS methodology

Group Electronics Expertise and Development Services

Jean-Denis PIQUES

jean-denis.piques@valeo.com

February 2014

Valeo Key Figures 2012

Sales

11.8 Bn €

Record order intake:

15.8 Bn €

72,600
Employees

29
Countries

61
Research & Development Centers

12
Platforms of distribution

125
Production Sites

Valeo worldwide ranking
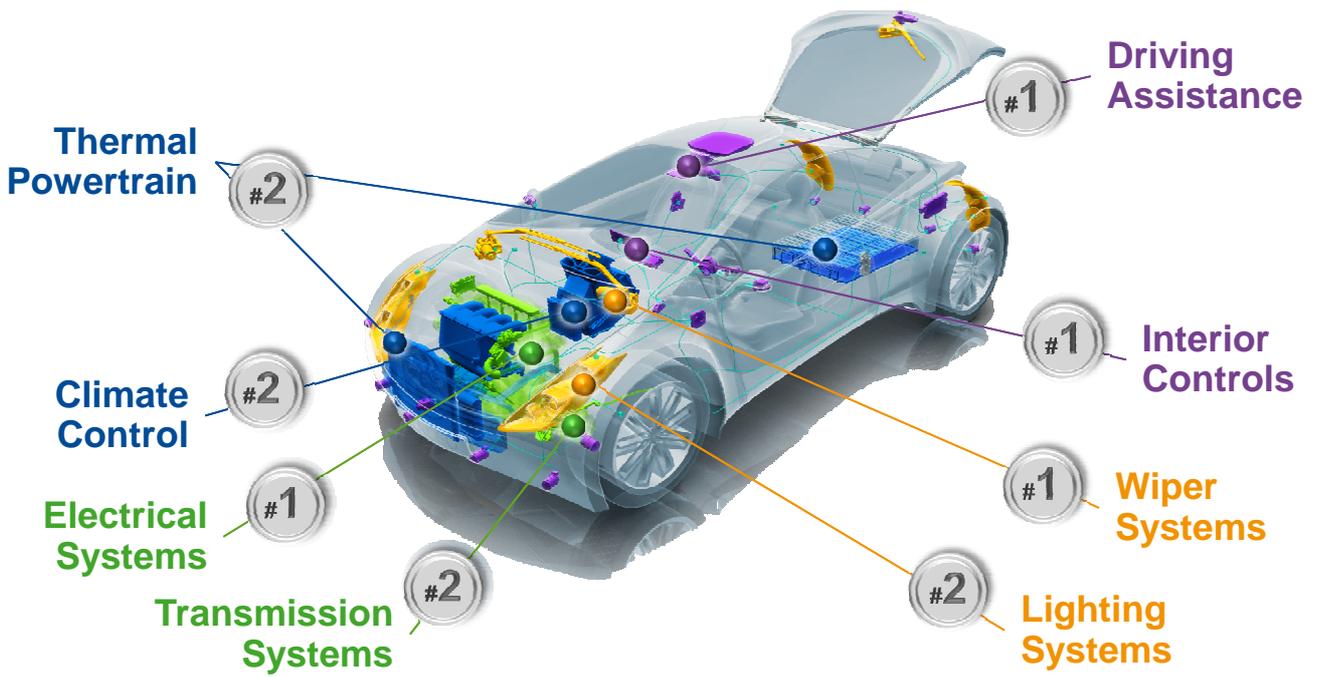
Driving Assistance **#1**

Thermal Powertrain **#2**

Climate Control **#2**

Electrical Systems **#1**

Transmission Systems **#2**

Interior Controls **#1**

Wiper Systems **#1**

Lighting Systems **#2**

end 2012

Model-Based System Engineering at Valeo

Deployment

Pilot Projects

SysML Profiling

Tool Selection

Training

Roles & Organization

System Process

2014

2012

2010

2008

2006
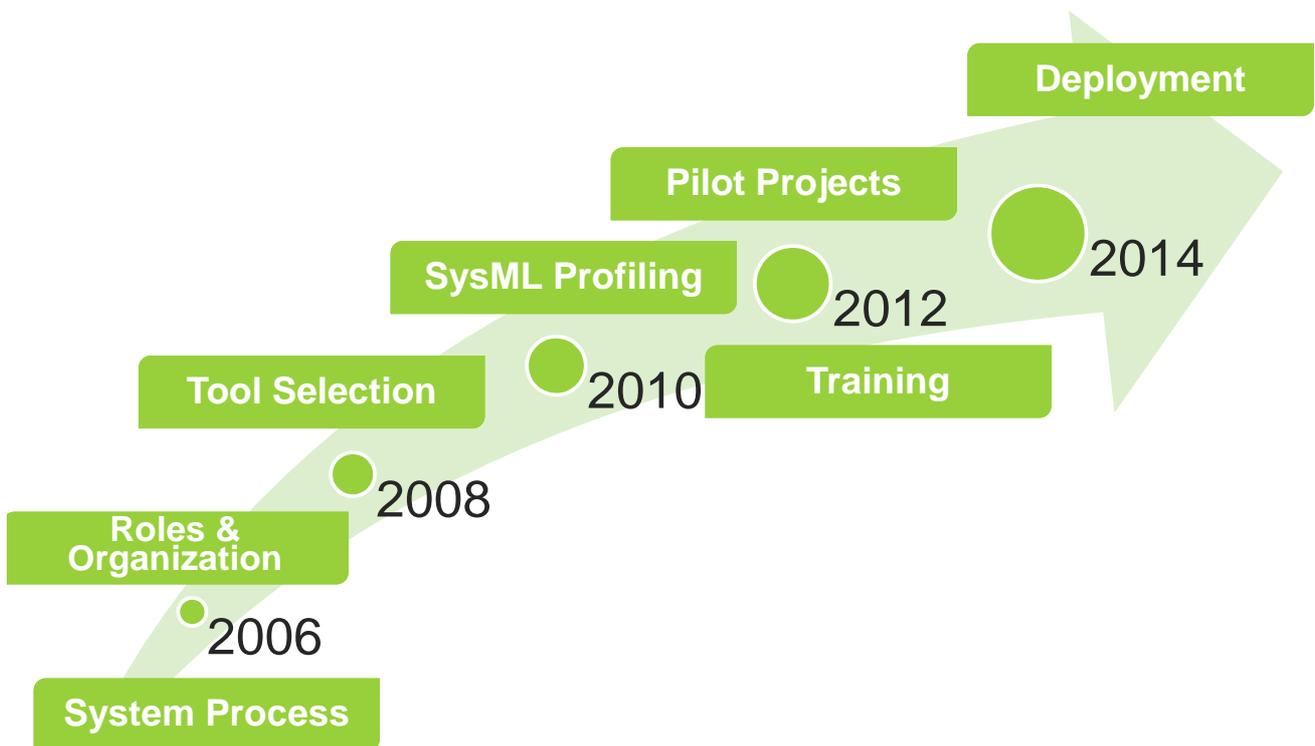
Examples of Pilot Projects with SysML-SysCARS

Gasoline Engine Fuel System

Electric Steering Column Lock (Safety concept)

Electrical Vehicle Inverter

Electric Power Steering
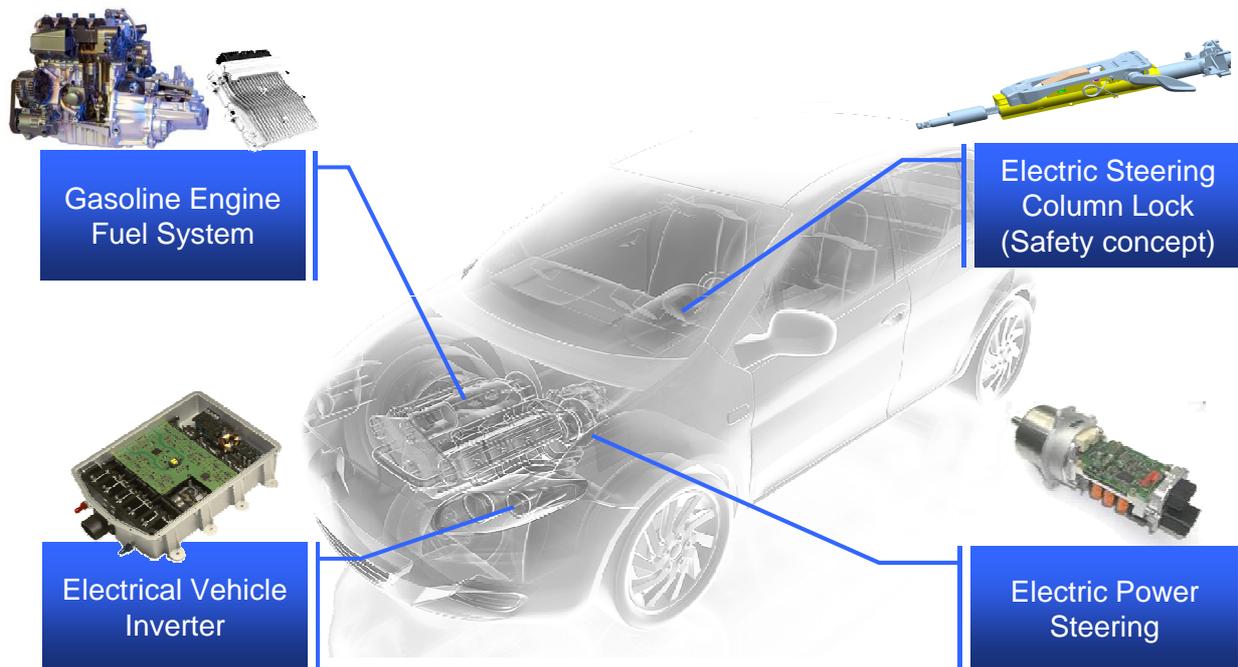
Motivations for Model-Based System Engineering
Area of Automotive Embedded Systems

Increasing complexity

- Mechatronics systems
- Business models
- Organizations involved
- Safety regulation (ISO 26262)

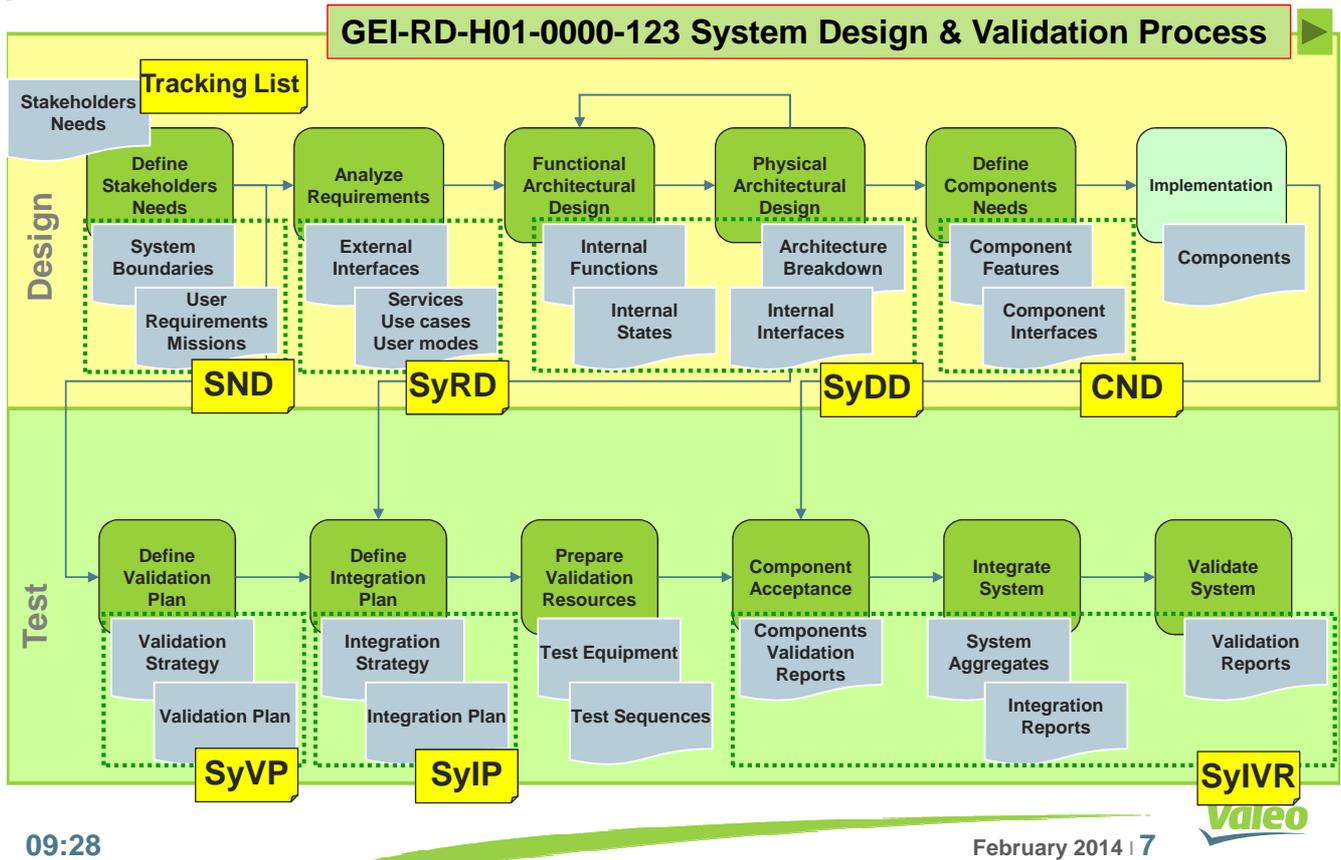### Model-Based System Engineering

- Higher level of formalization and traceability
- The model as a shared description to coordinate interdisciplinary works
- Capitalization of know-how and design justifications
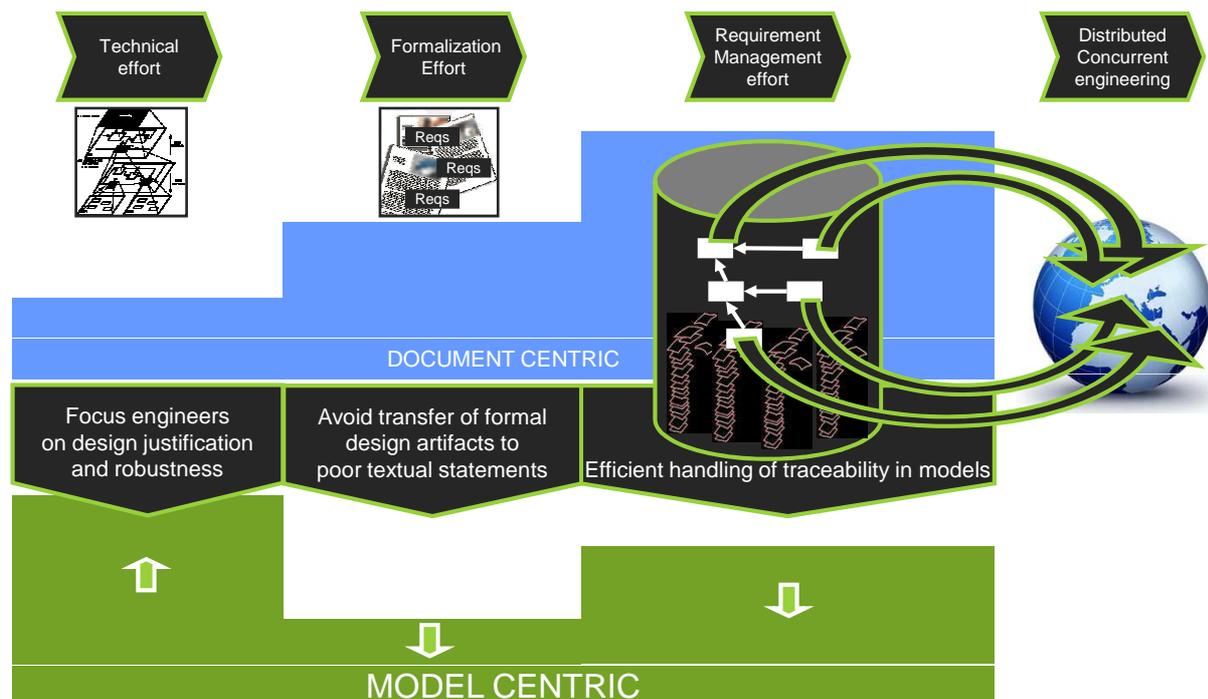- Improvement of efficiency thanks to "early validation" and reuse

Standard System Engineering Process (TFG12)

GEI-RD-H01-0000-123 System Design & Validation Process ▶

Tracking List

Design

Stakeholders Needs

Define Stakeholders Needs	Analyze Requirements	Functional Architectural Design	Physical Architectural Design	Define Components Needs	Implementation

- System Boundaries
- User Requirements Missions

SND

- External Interfaces
- Services Use cases User modes

SyRD

- Internal Functions
- Internal States

- Architecture Breakdown
- Internal Interfaces

SyDD

- Component Features
- Component Interfaces

CND

- Components

Test

Define Validation Plan	Define Integration Plan	Prepare Validation Resources	Component Acceptance	Integrate System	Validate System

- Validation Strategy
- Validation Plan

SyVP

- Integration Strategy
- Integration Plan

SyIP

- Test Equipment
- Test Sequences

- Components Validation Reports

- System Aggregates
- Integration Reports

- Validation Reports

SyIVR

Valeo

Towards a model-centric approach

Technical effort

Formalization Effort

Reqs
Reqs
Reqs

Requirement Management effort

Distributed Concurrent engineering

DOCUMENT CENTRIC

Focus engineers on design justification and robustness	Avoid transfer of formal design artifacts to poor textual statements	Efficient handling of traceability in models

⇧　　　⇩

⇩

MODEL CENTRIC

Improving efficiency by tansitioning from textual to model descriptions
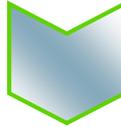
Valeo

System Modeling Tooling

To Support Valeo System Engineering Process (TFG12)

⚠️ Difficulty to keep different viewpoints consistent

- Requirements
- Use cases (test cases) and scenarios
- Operational modes and system states
- Functional/physical breakdown and architecture description
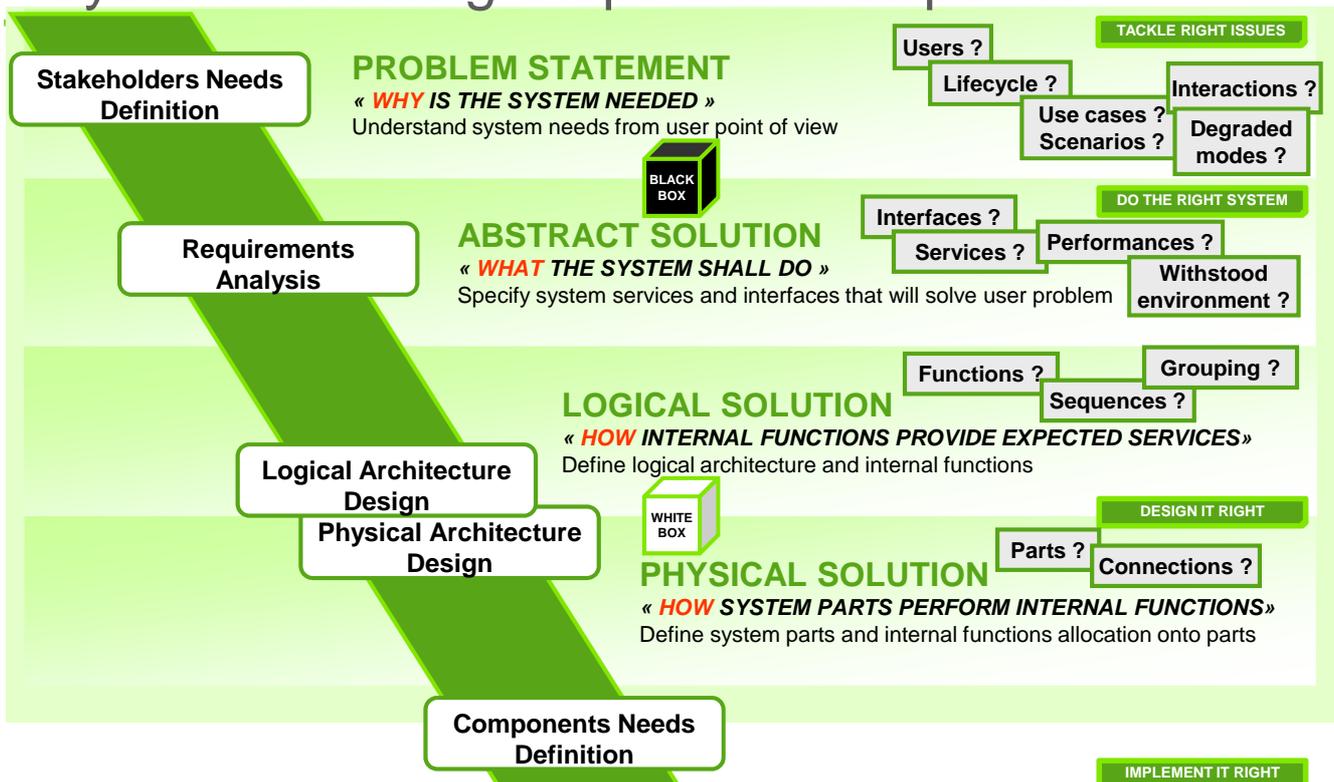
SysML as de Facto standard

- Standardized by OMG
- Independent from commercial tools
- XMI interchange format (to be improved)
- Increasing penetration in industrial sector

Valeo

System Modeling Steps and Viewpoints

Stakeholders Needs Definition

PROBLEM STATEMENT
« WHY IS THE SYSTEM NEEDED »
Understand system needs from user point of view

TACKLE RIGHT ISSUES
Users ?
Lifecycle ?
Interactions ?
Use cases ?
Scenarios ?
Degraded modes ?

BLACK BOX

Requirements Analysis

ABSTRACT SOLUTION
« WHAT THE SYSTEM SHALL DO »
Specify system services and interfaces that will solve user problem

DO THE RIGHT SYSTEM
Interfaces ?
Services ?
Performances ?
Withstood environment ?

Functions ?
Grouping ?
Sequences ?

LOGICAL SOLUTION
« HOW INTERNAL FUNCTIONS PROVIDE EXPECTED SERVICES»
Define logical architecture and internal functions

Logical Architecture Design

WHITE BOX

Physical Architecture Design

DESIGN IT RIGHT
Parts ?
Connections ?

PHYSICAL SOLUTION
« HOW SYSTEM PARTS PERFORM INTERNAL FUNCTIONS»
Define system parts and internal functions allocation onto parts

Components Needs Definition

IMPLEMENT IT RIGHT

SysML as the de facto standard to capture multiple SE viewpoints
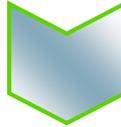
Valeo

Valeo SysCARS Methodology

(SysCARS: System Core Analyses for Robustness and Safety)

⚠️ **SysML alone not sufficient**

- Syntax but no semantics
- Many diagrams and artifacts sometimes redundant
- Provided without any methodology
- A pre-existing System Engineering process is required

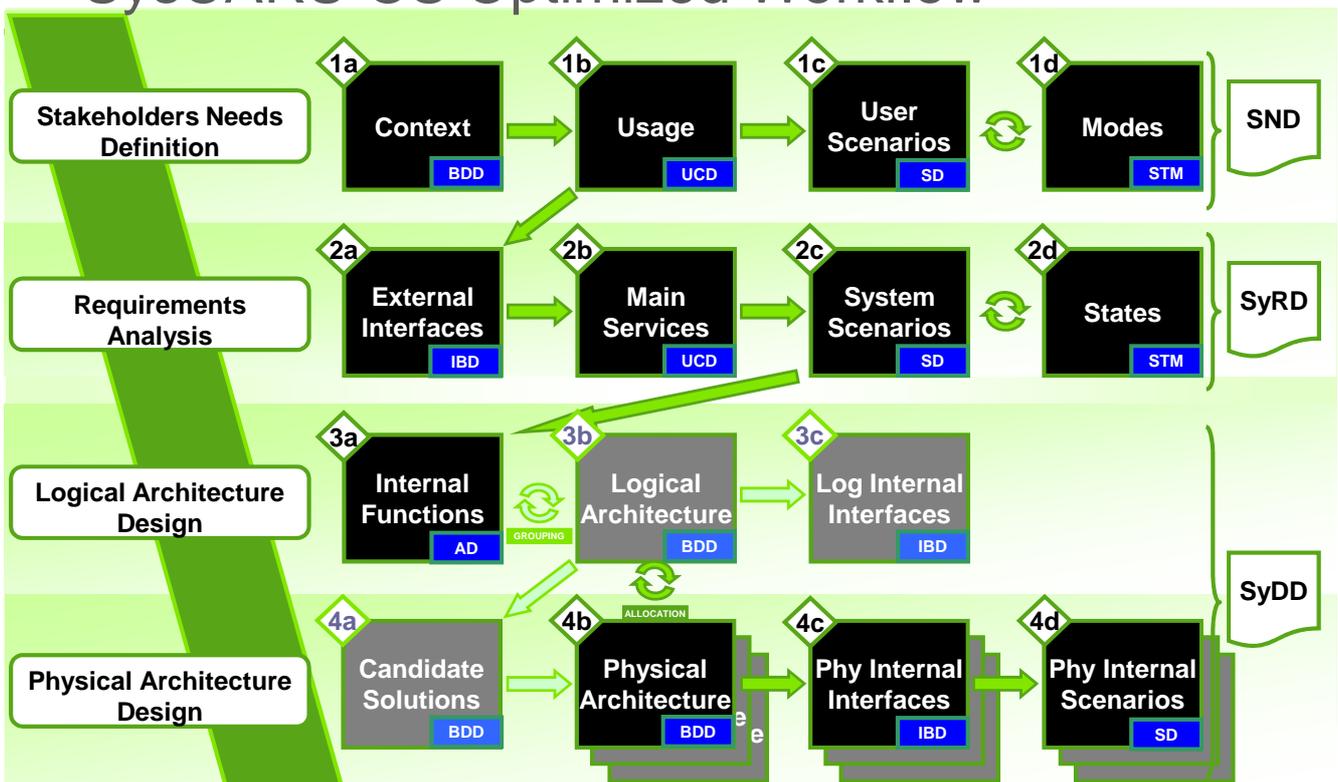**SysCARS as a precise guideline to use SysML**

- Sequence of modeling activities to be performed
- Subset of SysML diagrams and artefacts to be used
- Defined semantics ensuring model consistency
- Stereotypes and templates for automatic documentation generation

---

SysCARS-CS Optimized Workflow

Stakeholders Needs Definition	1a Context (BDD)	1b Usage (UCD)	1c User Scenarios (SD)	1d Modes (STM)	SND
Requirements Analysis	2a External Interfaces (IBD)	2b Main Services (UCD)	2c System Scenarios (SD)	2d States (STM)	SyRD
Logical Architecture Design	3a Internal Functions (AD)	3b Logical Architecture (BDD) GROUPING	3c Log Internal Interfaces (IBD)		SyDD
Physical Architecture Design	4a Candidate Solutions (BDD)	4b Physical Architecture (BDD) ALLOCATION	4c Phy Internal Interfaces (IBD)	4d Phy Internal Scenarios (SD)	

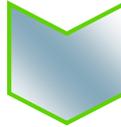**On carry over projects Logical Architecture design is bypassed**

Workflow-driven Approach

SysML Valeo Profile

⚠ Learning curve and standardisation

- Complexity of SysML tooling for non software specialists
- SysML / SysCARS slow learning curve
- Heterogeneity of results on different projects

Valeo Profile embedding SysCARS workflow

- Predifined package structure
- Guidance on the correct ordering of modeling activities
- Guidance on the relevant diagram to be used at each modeling step
- Stereotypes automatically put on artefacts, depending on modeling step

---

SysML Valeo Profile

VALEO Profile to help System Architects throughout the workflow

A new model is no more empty…

Pre-defined Package Structure

Embedded SysCARS Workflow
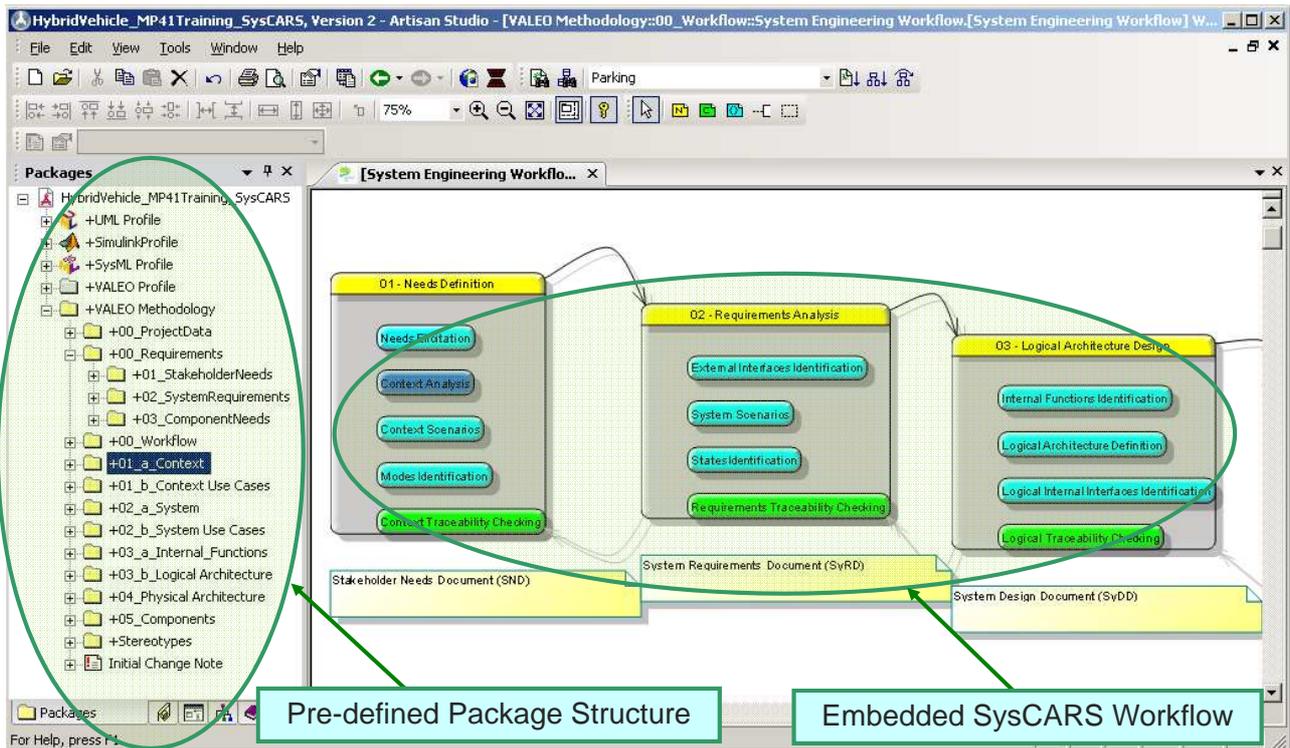
Workflow diagram monitors SE activities
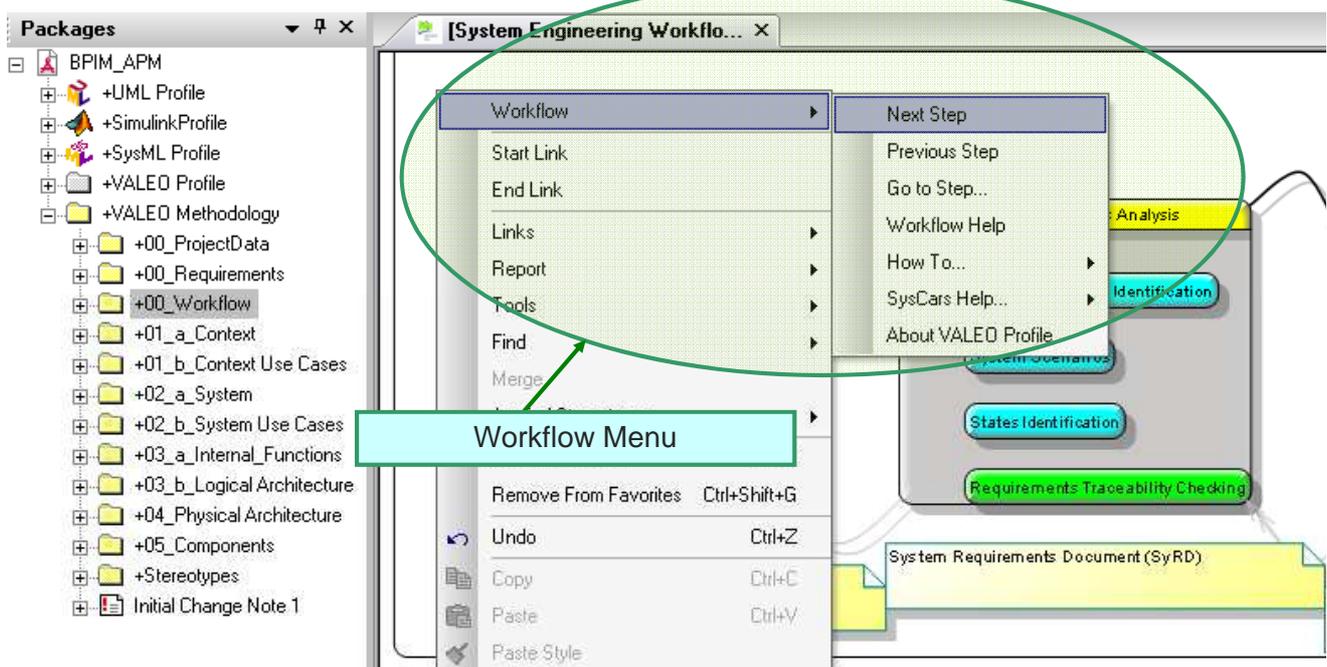
Workflow Menu

Available features depend on workflow state

Customized contextual Toolbar

Customized contextual Menu

Stereotypes are automatically set

Stereotype for Documentation

Requirements Attributes

Automatic Generation of Documentation

Independence Between Data and Documentation

Templates taking into account Valeo entities and customer specificities

---

Model Verification Policy

⚠️ **SysML simulation not (yet) adapted**

- ■ Limitations of SysML tools capabilities
- ■ Completeness of models not sufficient
- ■ Skills required antagonistic to (generalist) system engineers job profile

Static verification preferred to simulation

- ■ Traceability rules defined by SysCARS data model
- ■ Local traceability analysis with SysML tool
- ■ Global traceability analysis with traceability tool (Reqtify)
- ■ In the future, using a modeling rule checker

Local Traceability Verification

StakeholderNeeds Refine Traceability Matrix

Refined By

req Component Needs Satisfied By Physical Block [VEMU]

«requirement»
VEMU overall dimensions
id#
VEMU_C04
txt
Overall dimensions shall not exceed:
- Length = xx mm
- Heigth = xx mm
- Thickness = xx mm

«block»
«Physical Block»
VehicleEnergyManagementUnit-VEMU
operations
IF-018_ElaborateTorqueRequest ()
IF-019_MeasureVehicleVelocity ()
IF-020_EstimateBatterySOC ()
IF-021_MonitorTraction ()
IF-022_EstimateVehicleConditions (in ...
IF-023_ProportionPower ()
IF-024_WakeUpVEMU ()
flowPorts
inout vem_CanFrame : BusProtocol
inout vem_StationFrame : Communica ...
inout vem_DiagFrame : DiagnosisProt ...

«requirement»
VEMU communication harness
id#
VEMU_C02
txt
The Vehicle Energy Mangement Unit communication harness shall transmit the following signals:
<<Connector drawing attached>>

«requirement»
VEMU maximum weight
id#
VEMU_C03
txt
The weight of the Vehicle Energy Management Unit shall not exceed xxx g.

«requirement»
VEMU altitude conditions
id#
VEMU_C01
txt
The Vehicle Energy Manager Unit (VEMU) shall operate between -100 m and 3500 m altitude.

«satisfy»

StakeholderNeeds Requirement Table

Id#	Name	Txt	Refined By
U01	Acceleration in ZEV mode	In ZEV mode, time from 0 km/h to 100 km/h shall be less than 15 s	«Use Case» Accelerate (VALEO Methodology::01_b_Context Use Cases::Operational_UseCases)
U02	Altitude conditions	The vehicle shall operate between -100 m and 3500 m altitude.	«Use Case» Drive Vehicle (VALEO Methodology::01_b_Context Use Cases::Operational_UseCases)
U03	Battery refilling capability	It shall be possible to refill onboard electrical battery by connecting to external electrical power stations.	
U04	CO2 emissions in Hybrid mode	The vehicle CO2 (direct and indirect) impact will be limited to 80g/km in Hybrid mode. Nota: External electric power is supposed to be provided by nuclear plants.	«Use Case» Drive Vehicle (VALEO Methodology::01_b_Context Use Cases::Operational_UseCases)
U05	CO2 emissions in ZEV mode	The vehicle CO2 (direct and indirect) impact will be limited to 10g/km in ZEV mode (CO2 used for electric production). Nota: External electric power is supposed to be provided by nuclear plants.	«Use Case» Drive Vehicle (VALEO Methodology::01_b_Context Use Cases::Operational_UseCases)

Traceability checking now and modeling rule checker in the future

---

Global Traceability Verification

Stakeholders Needs Definition

Requirements Analysis

Logical Architecture Design

Physical Architecture Design

Coupling to Requirement Management Tools
Centralized vs Distributed Approach
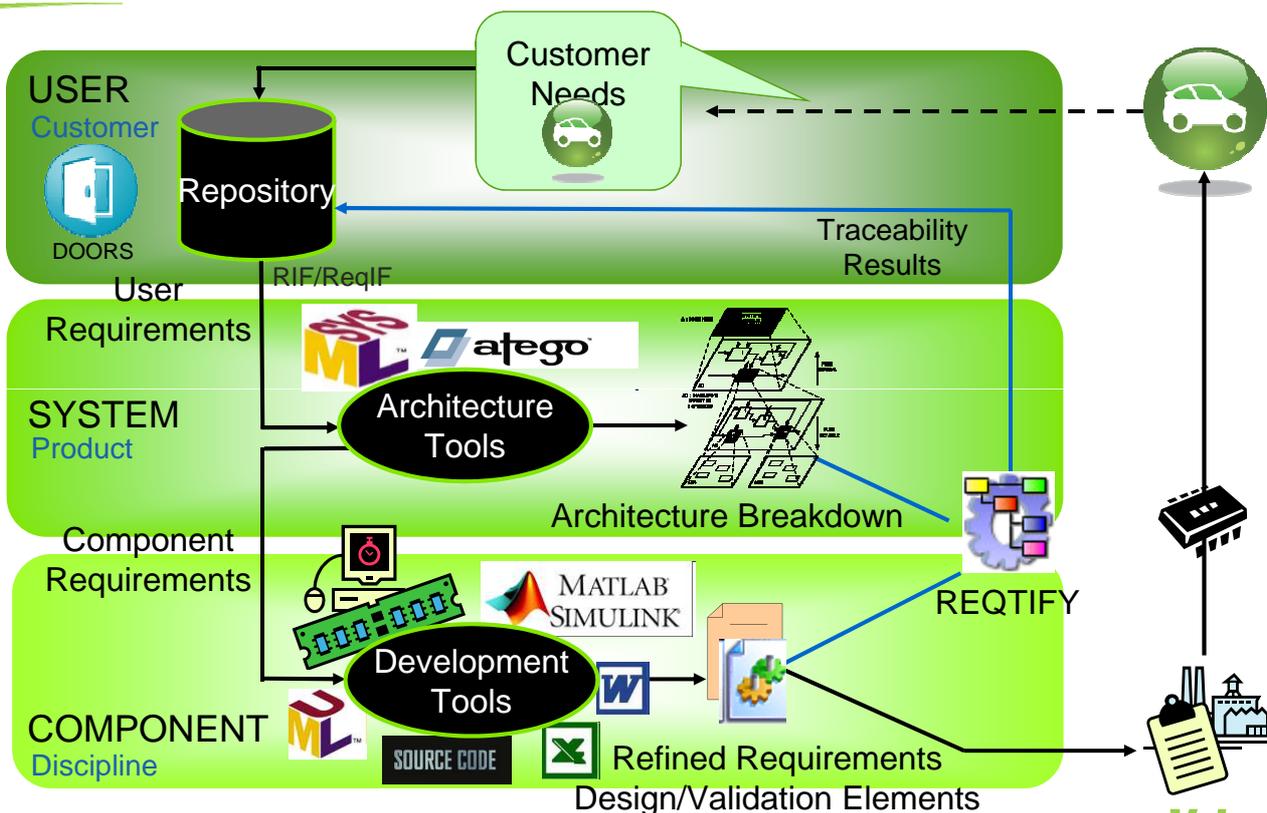
⚠ Centralized requirement management not optimized

- Redundancy between models and external repository contents
- Loss of time when re-writing requirements from models to ext. repository
- Loss of information when translating model items to natural language
- Loss of semi-formal verification possibilities
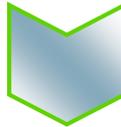
Distributed requirement storage

- People working with tools well adapted to their discipline
- User requirements synchronized with the external repository
- System and component requirements only formalized inside SysML
- Component specifications generated from the SysML model

Distributed Requirement Management

USER
Customer
DOORS

Customer
Needs

Repository

Traceability
Results

User
Requirements

RIF/ReqIF

SYSTEM
Product

atego

Architecture
Tools

Architecture Breakdown

REQTIFY

Component
Requirements

MATLAB
SIMULINK

Development
Tools

COMPONENT
Discipline

SOURCE CODE

Refined Requirements
Design/Validation Elements

SysCARS-CS Data Model

Implicit Traceability Links

Interfaces Requirements
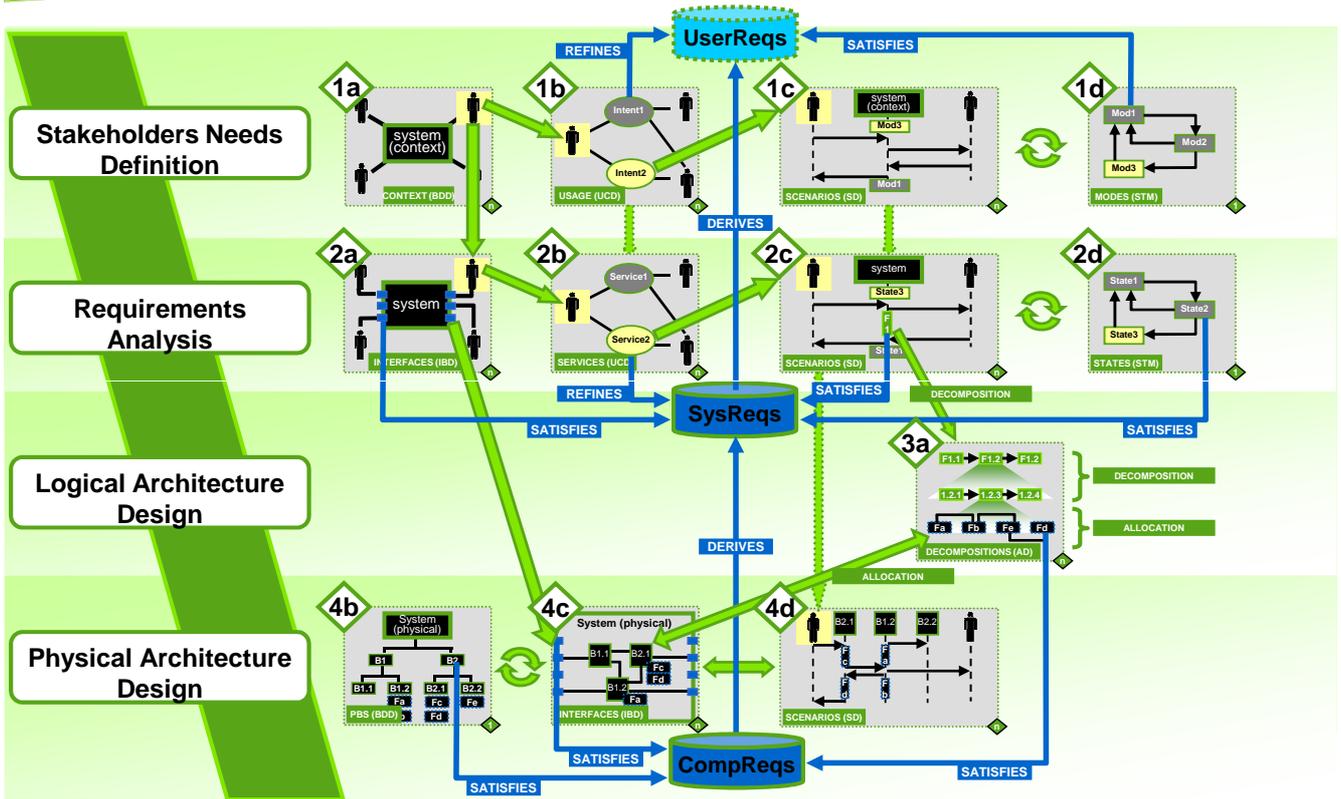
Functional Requirements
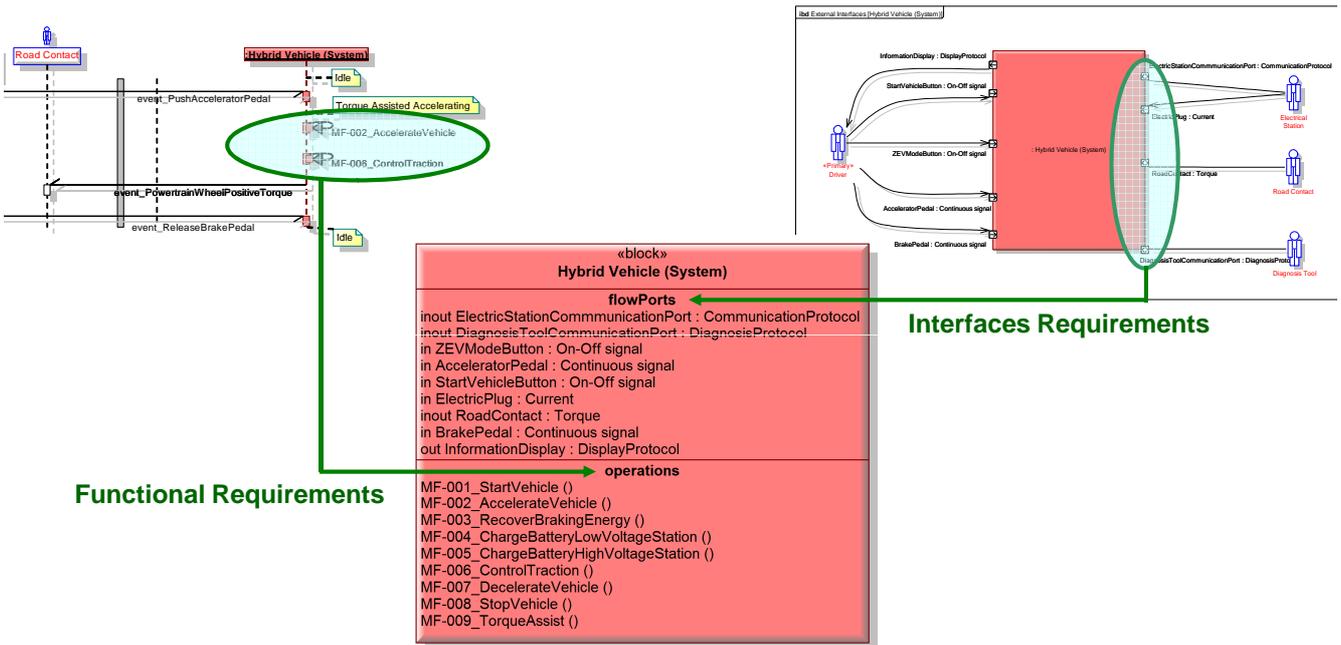
Blocks automatically populated, no textual requirement writing needed

Explicit Traceability Links

req Component Needs Satisfied By Physical Block [VEMU]

«requirement»
VEMU overall dimensions

id#
VEMU_C04

txt
Overall dimensions shall not exceed:
- Length = xx mm
- Heigth = xx mm
- Thickness = xx mm

«requirement»
VEMU maximum weight

id#
VEMU_C03

txt
The weight of the Vehicle Energy Management Unit shall not exceed xxx g.

«block»
«Physical Block»
VehicleEnergyManagementUnit-VEMU

operations
IF-018_ElaborateTorqueRequest ()
IF-019_MeasureVehicleVelocity ()
IF-020_EstimateBatterySOC ()
IF-021_MonitorTraction ()
IF-022_EstimateVehicleConditions (in ...
IF-023_ProportionPower ()
IF-024_WakeUpVEMU ()

flowPorts
inout vem_CanFrame : BusProtocol
inout vem_StationFrame : Communica ...
inout vem_DiagFrame : DiagnosisProt ...

«satisfy»

«requirement»
VEMU communication harness

id#
VEMU_C02

txt
The Vehicle Energy Mangement Unit communication harness shall transmit the following signals:
<<Connector drawing attached>>

«satisfy»

«requirement»
VEMU altitude conditions

id#
VEMU_C01

txt
The Vehicle Energy Manager Unit (VEMU) shall operate between -100 m and 3500 m altitude.

Explicit traceability links used for non functional requirements

Valeo

SysCARS Traceability at Architecture Level

SysML Model Artifacts

SysML Requirements

System (or System Element)
(Block)

Parameters
(Values)   V-x

Functions
(Operations)   F-y

Satisfy

Dynamic Behaviour
(State Machine)

Interfaces
(Ports)   <>

Non functional Requirements:

Global constraints

Mesurements of Performance (MoP)

Functional performance requirements

State/Transition performance requirements

Interface performance requirements

Valeo

Valeo

Conclusion

February 2014

Model-Based System Engineering at Valeo

Process ➡ **System Engineering Process (Valeo TFG12)**

Methods ➡ **SysCARS Methodology (CS for carry over, XS for innovation)**

Tools ➡ **SysML + Valeo Ergonomic Profile + Document Generator + Doc. Templates**

Organization ➡ **System Architect trained to SysCARS**

MBSE Topics of Interest

- Synchronizing with Satefy analyses (ISO 26262)

- Lean System Engineering life cycles and agility

- Product line management and reuse of COTS

- Link to multi-physics simulation for trade-off analyses

- Methods for verification of models

- Model-based testing for complex systems

Towards a functional digital mock-up for early validation

ERTS² 2014

Valeo

Thanks for your attention

Your questions are welcome