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Bridging the Gap between System and Component Design for Vehicle Electrification using Model Based Systems Engineering (MBSE)

Date : 17-18 May 2022

Agenda

- Introduction
- Challenges in Electric Vehicle development
- Bridging the gaps through MBSE
- How MBSE helped
- TCS Enablers for MBSE

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Introduction

Speaker Introduction

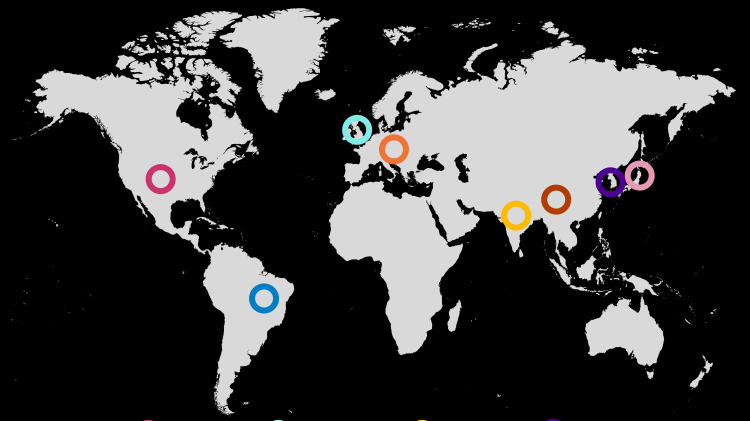
Yutika Patwardhan
Tata Consultancy Services
IoT & Digital Engineering
Head of Centre of Excellence for FuSa, MBSE, Auto Electronics

- 20 +Years in Automotive Embedded Systems- (EV, ADAS, Body Electronics)
- INCOSE CAB representative for TCS
- SME-Functional safety, Functional Safety L2 Certified by TUV SUD
- Technical manager for BMS software, Project lead for modeling and simulation(E/E features)
- Tools Expertise – MBSE tool chains, SysML tools, Safety Analysis tool chain, Requirement Management, ALM tool chains

Neha Surjekar
Tata Consultancy Services
IoT & Digital Engineering
MBSE - Solution Lead, Auto Electronics Centre of Excellence

- 12 + Years experience in Automotive Embedded Systems
- Experience in MBSE (UML, SysML), ADAS, Body domain
- Member INCOSE, INCOSE India Chapter
- Tools Expertise - MBSE tool chains, SysML tools, Requirement Management, ALM tool chains
- Key member in deploying MBSE practices across various accounts
- Certified Scrum Master

TCS Automotive Experience Summary



11,000+ Engineers

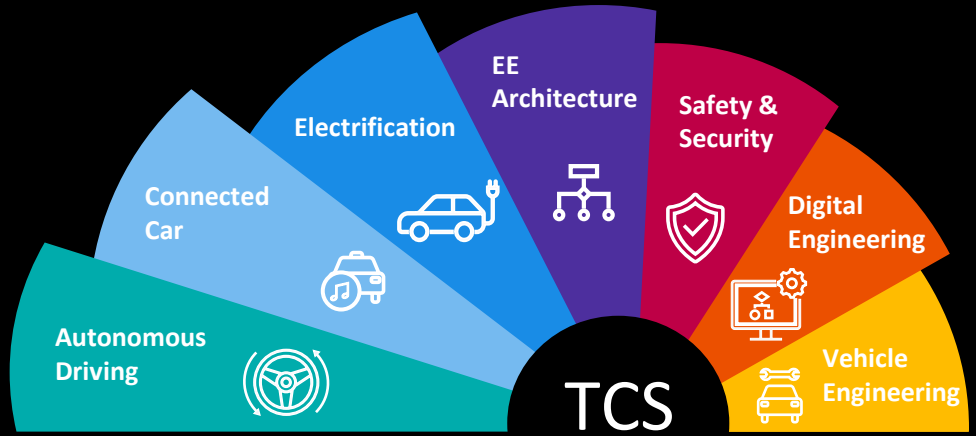
Working in **15+** Countries

Spread across **50+** Customers

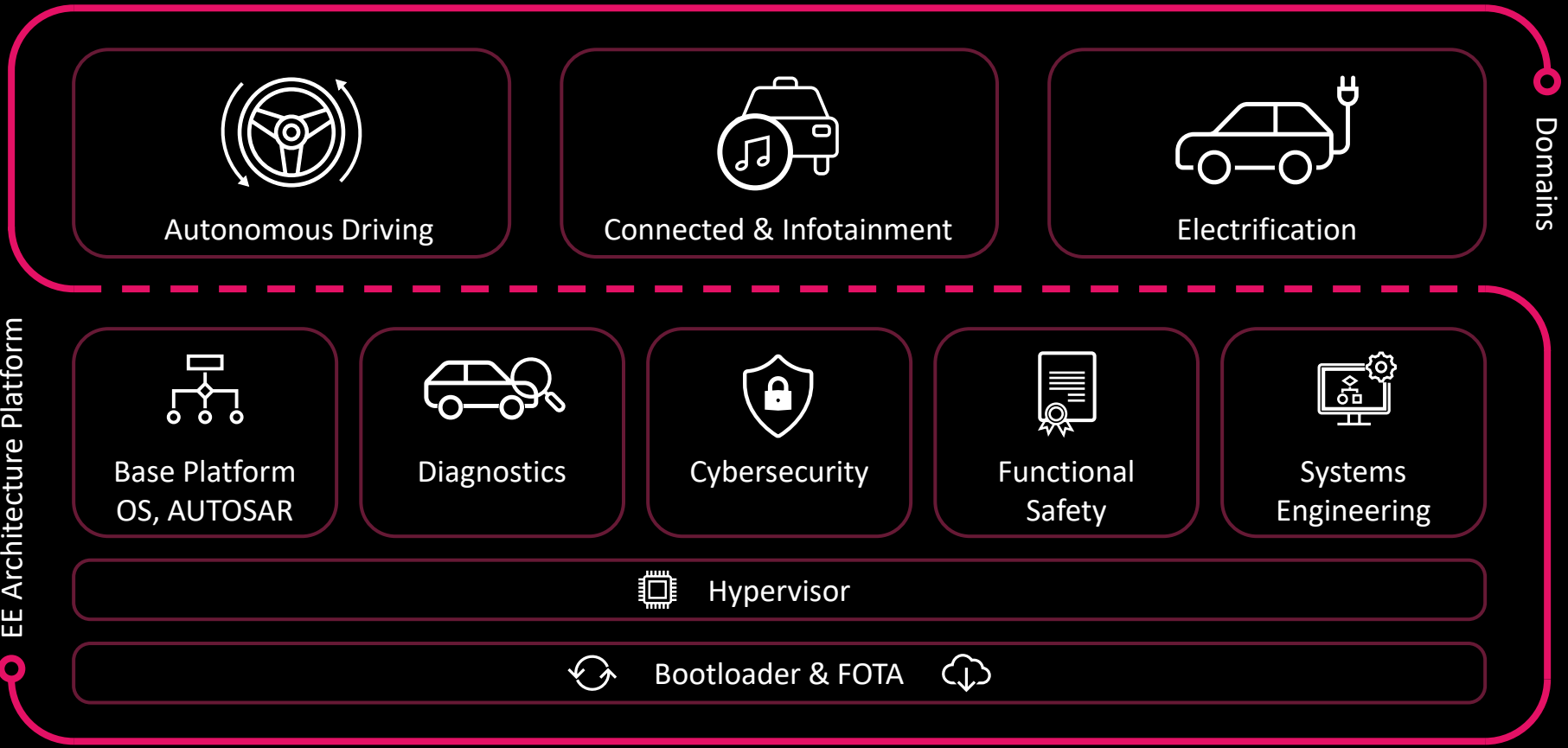
7000+
Electrical & Electronics Engineers

4000+
Vehicle & Powertrain Engineers

TCS recognized as a
Leader in ACES Automotive Engineering Services
by Everest Group



TCS Automotive Electrical & Electronics Portfolio



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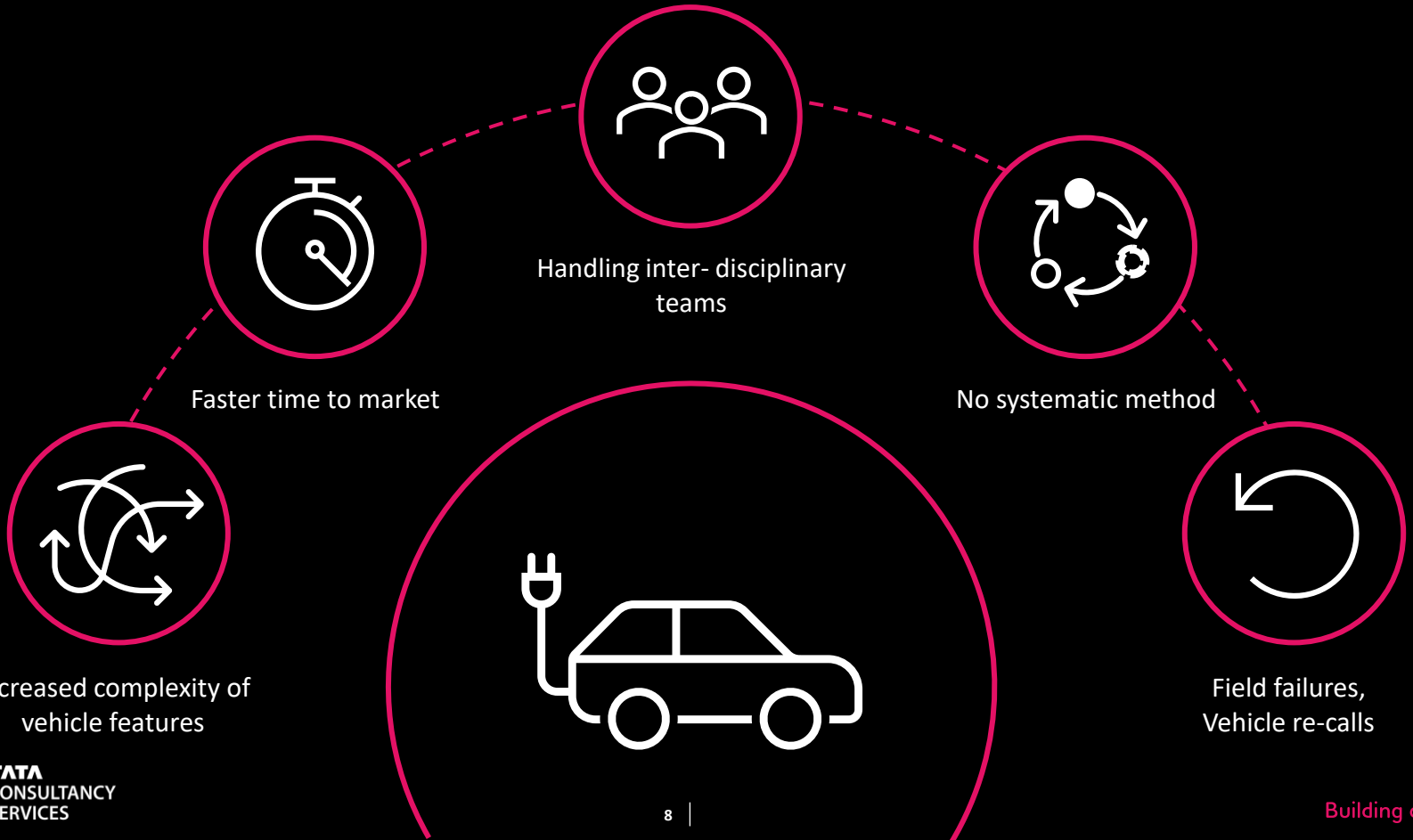
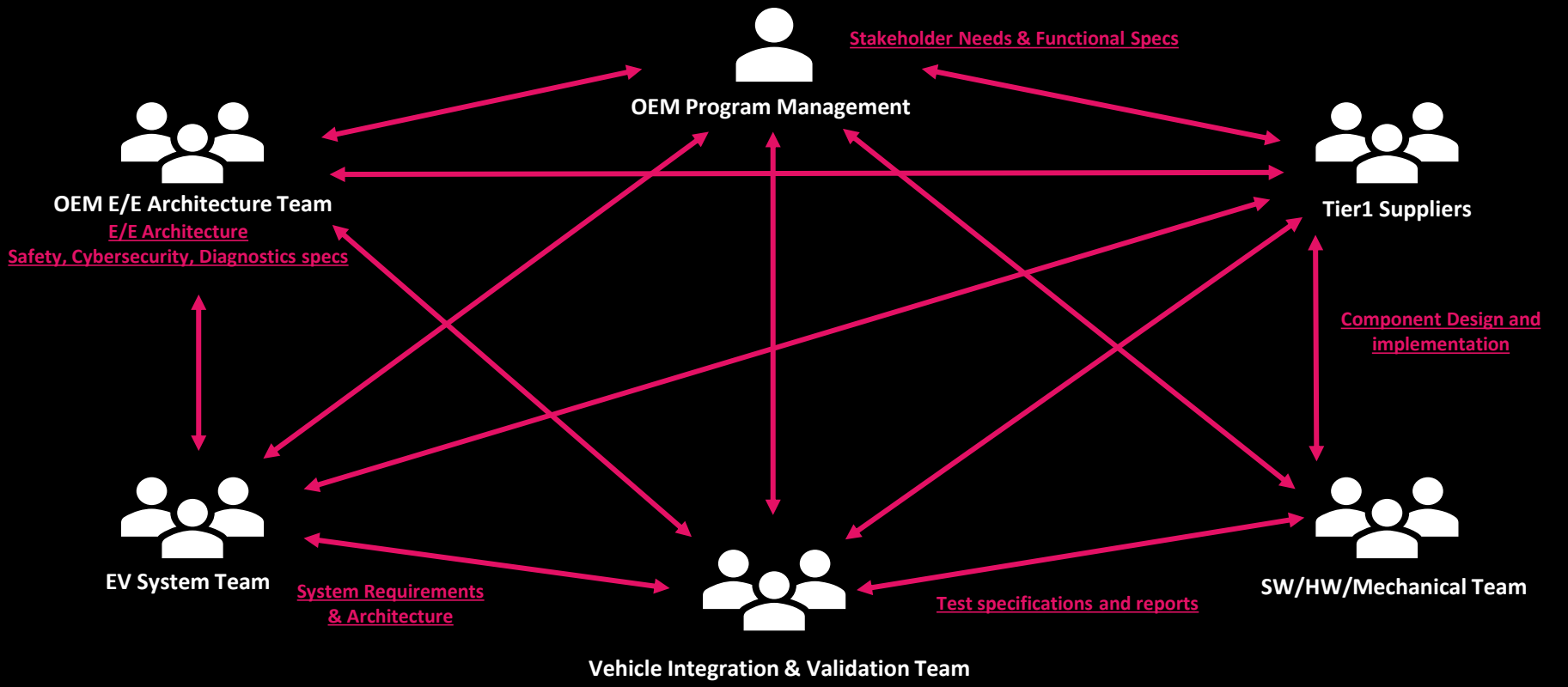
Challenges in Electric Vehicle Development

Automotive Trend - Vehicle Electrification – Challenges



Traditional Vehicle Electrification Development



Complex system design and development need complicated cross-functional interaction

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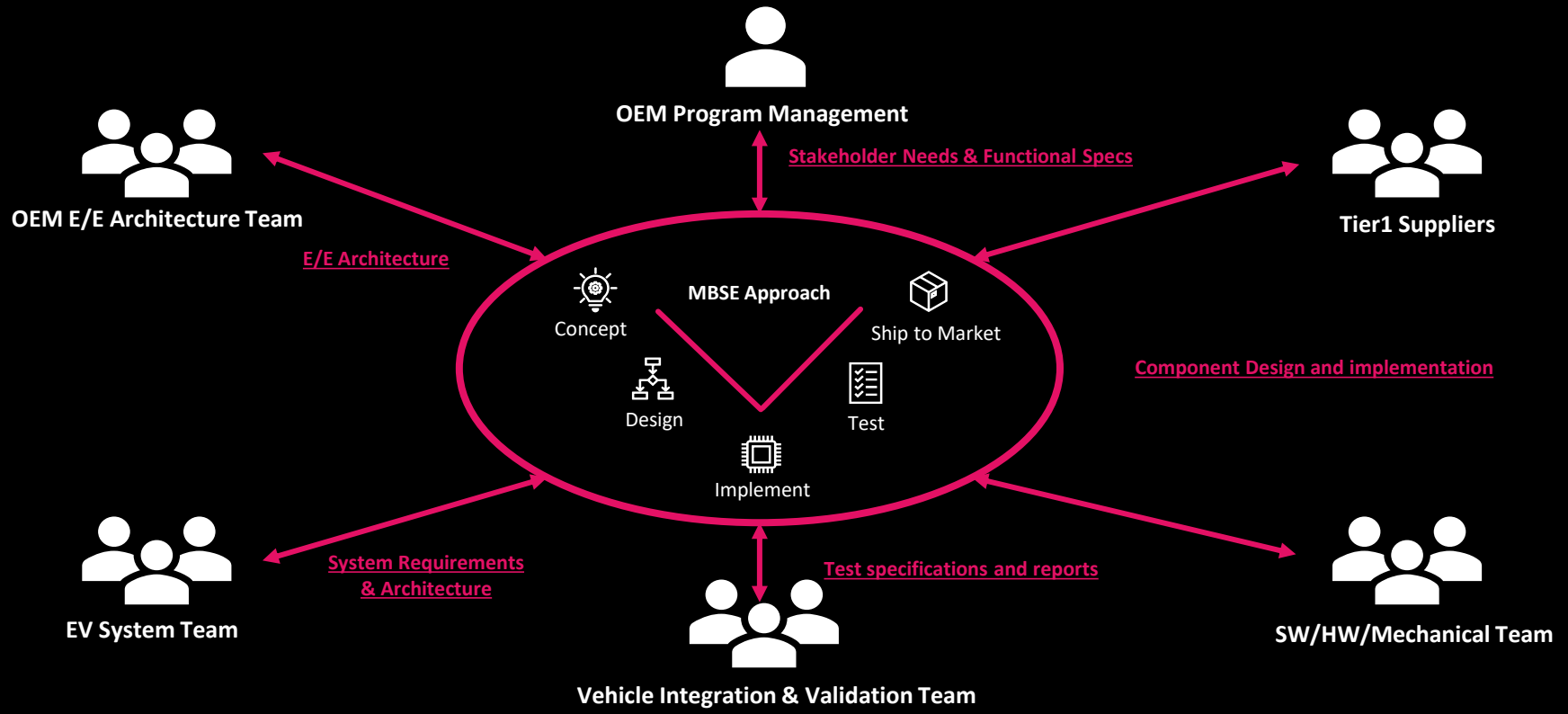
Bridging the Gaps through MBSE

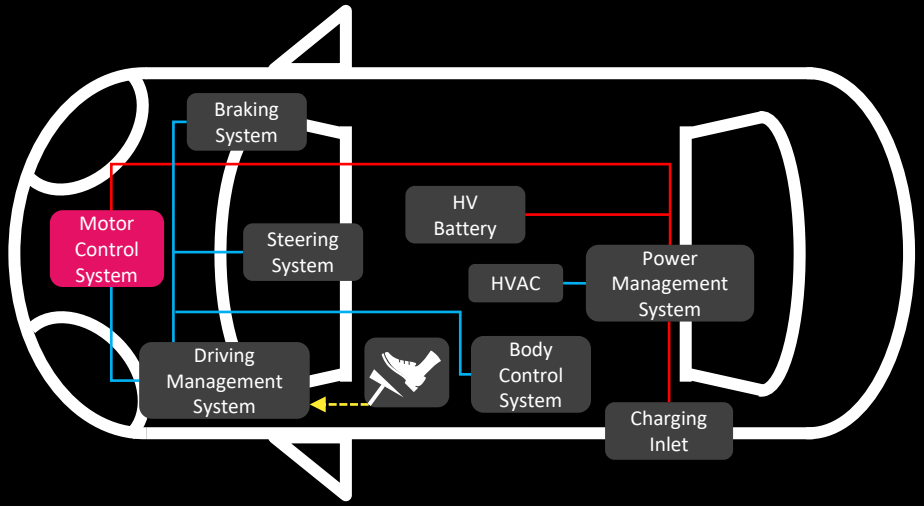
Adaption of MBSE for Vehicle Electrification Development



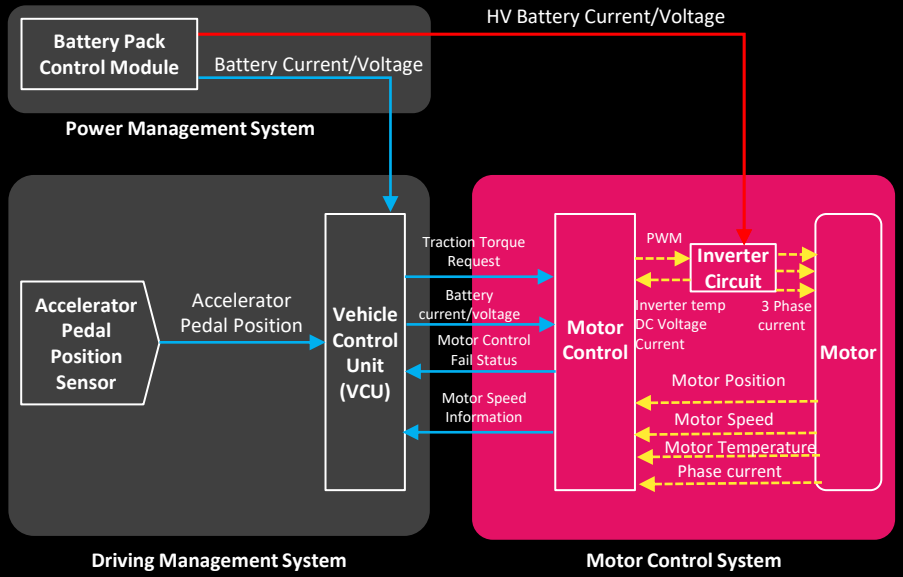
System Engineering aims to ensure, the pieces work together to achieve the objective of the whole

Motor Control System Development using MBSE

Vehicle Context



System Context *



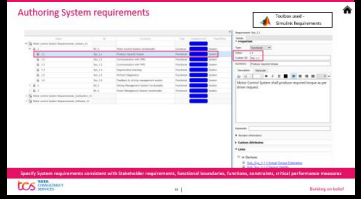
Data Communication
High Voltage Line
Hardwired Connection

* *High level Representation of Motor torque control, not an exhaustive architecture*

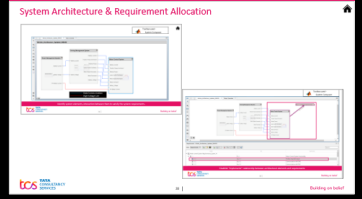
MBSE applied to Motor Control System Development

System

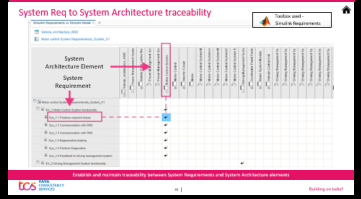
Authoring System Requirements



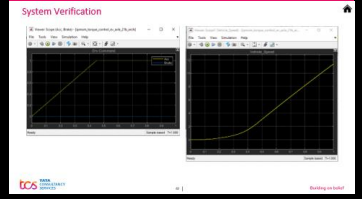
System Architecture & Req Allocation



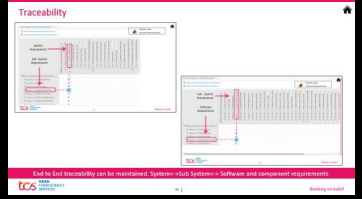
Sys Req to Architecture Traceability



System Verification

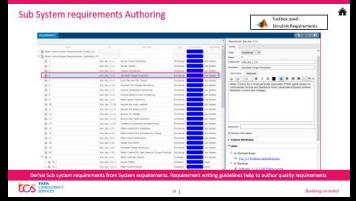


End – End Traceability

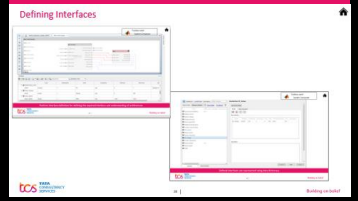


Sub-system

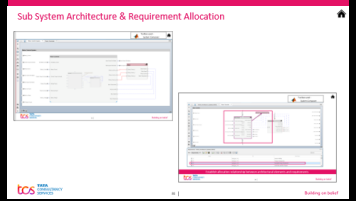
Authoring Sub Sys Requirements



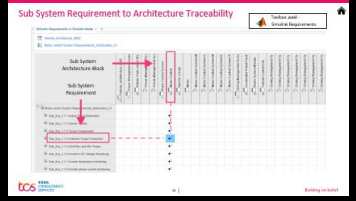
Defining Interfaces



Sub Sys Architecture & Req Allocation

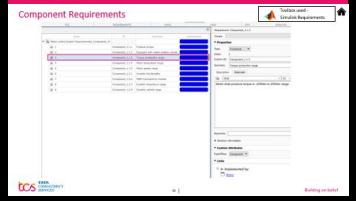


Sub Sys Req to Arch traceability

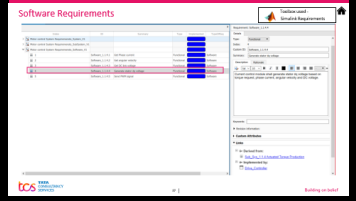


Component

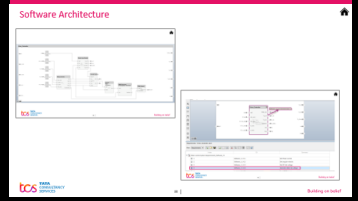
Component Requirements



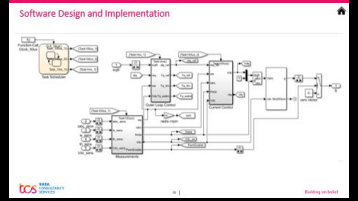
Authoring Software Requirements



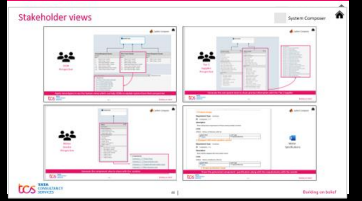
SW Architecture & Req Allocation



Software Design & Implementation



Stakeholder Views



How MBSE helped

Benefits

Seamless traceability:

EV Propulsion system requirements

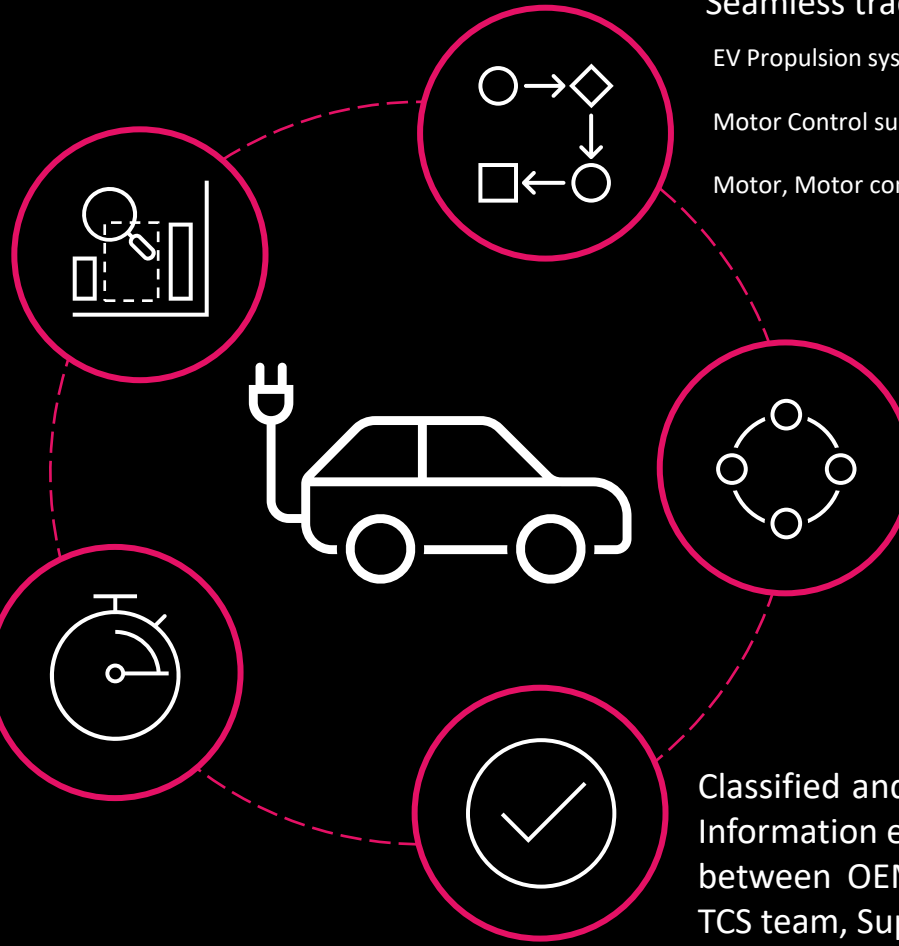
↕

Motor Control sub- system requirements

↕

Motor, Motor control ECU detailed requirements, design

Gaps between System and Component design Identified before implementation



Stakeholder views for OEM System team, TCS team, Suppliers

Reduction in time taken for adapting MBSE

Classified and Precise Information exchange between OEM Team, TCS team, Suppliers

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TCS in MBSE

TCS in MBSE

8+ Customer Engagements

INCOSE Working Group Contributor

10+ years of SysML Cross-industry Experience

- System Requirement Decomposition & Maturation
- System Architecture & Design
- Simulation of System Functional behavior
- Integration of System Engineering & Functional Safety
- Expertise in Multiple Tools & Tool Chain Integration

ADAS | Body - Chassis | Infotainment | Powertrain | Electrification

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Thank you

Contact : IoT.De@tcs.com

Authoring System requirements

Toolbox used -
Simulink Requirements

Index	ID	Summary	Type	Implemented	TypeOfReq
Motor control System Requirements_System_V1					
1	EV_1	Motor Control System functionality	Container		System
1.1	Sys_1.1	Produce required torque	Functional		System
1.2	Sys_1.2	Communication with DMS	Functional		System
1.3	Sys_1.3	Communication with PMS	Functional		System
1.4	Sys_1.4	Regenerative bracking	Functional		System
1.5	Sys_1.5	Perform Diagnostics	Functional		System
1.6	Sys_1.6	Feedback to driving management system	Functional		System
2	EV_2	Driving Management System functionality	Functional		System
3	EV_3	Power Management System functionality	Functional		System
Motor control System Requirements_SubSystem_V1					
Motor control System Requirements_Software_V1					

Requirement: Sys_1.1

Details

Properties

Type: Functional

Index: 1.1

Custom ID: Sys_1.1

Summary: Produce required torque

Description | Rationale

Motor Control System shall produce required torque as per driver request.

Keywords:

Revision information:

Custom Attributes

Links

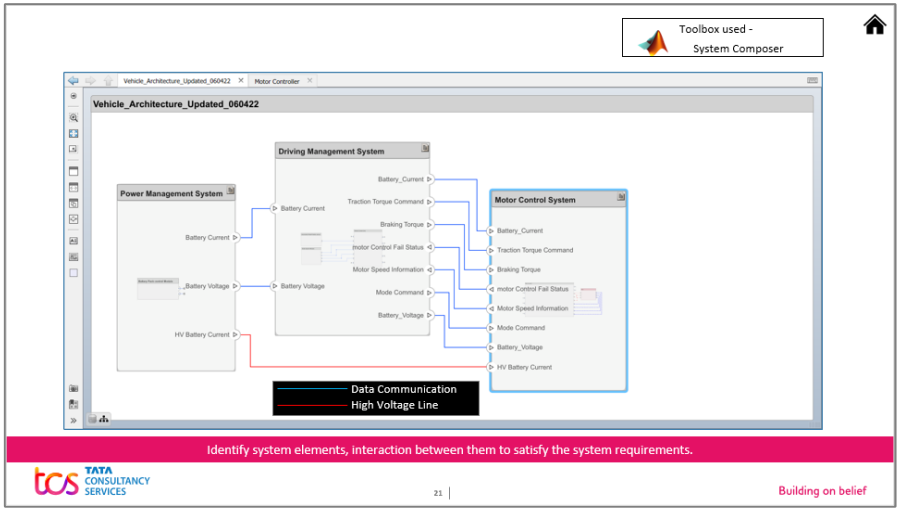
⇒ Derives:

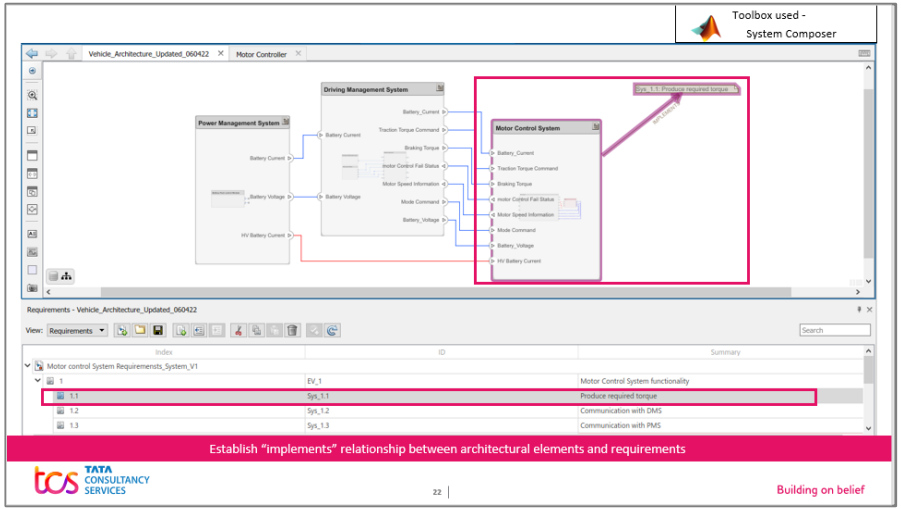
Sub_Sys_1.1.1 Actual Torque Estimation

Sub_Sys_1.1.2 Sensor Validity

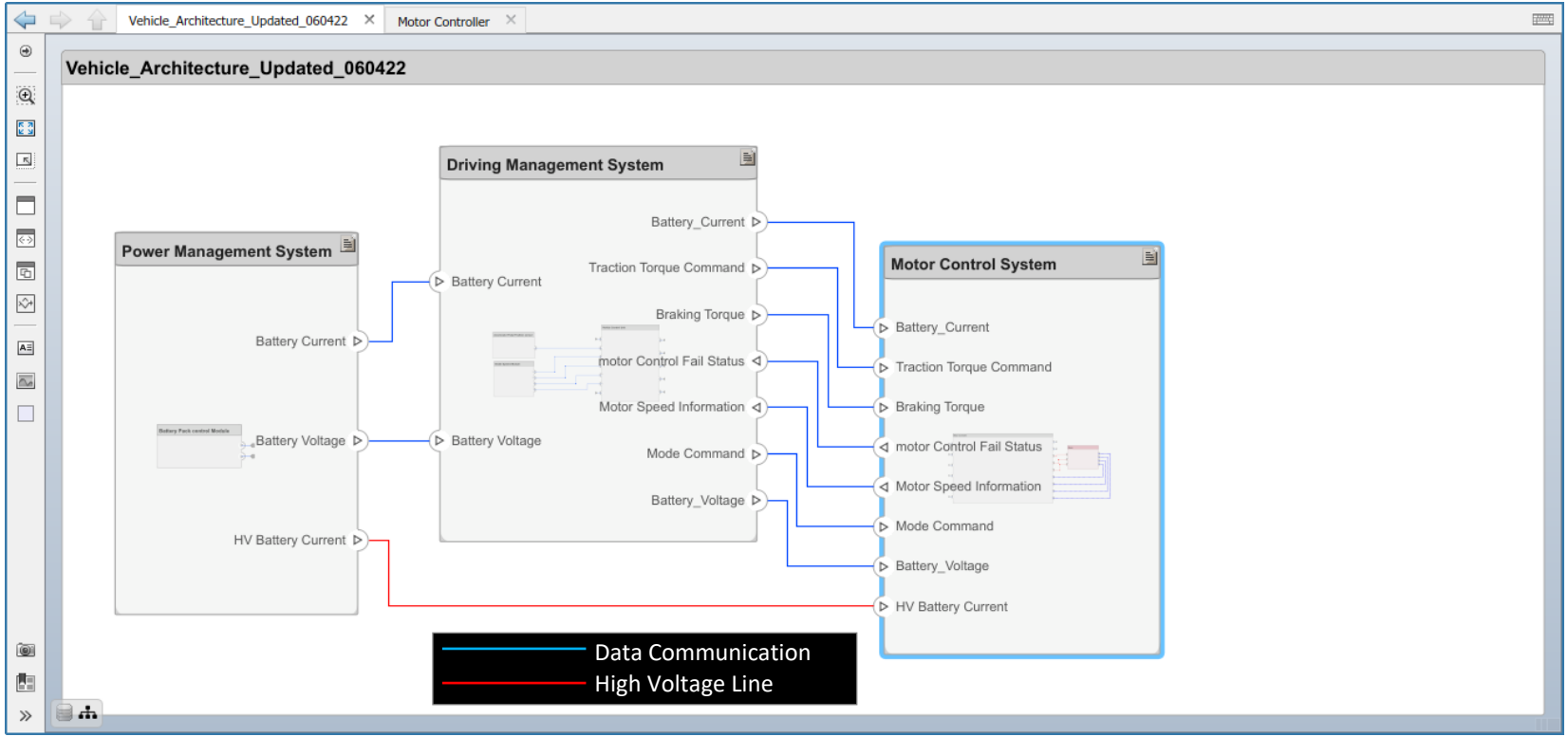
Specify System requirements consistent with Stakeholder requirements, functional boundaries, functions, constraints, critical performance measures

System Architecture & Requirement Allocation



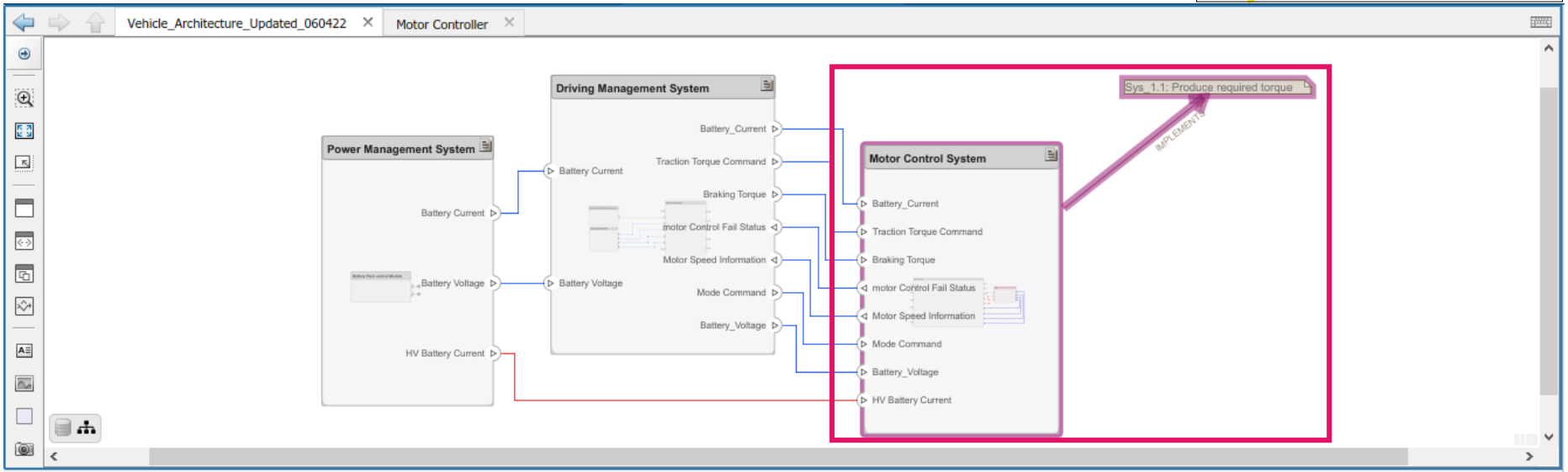


Toolbox used -
System Composer



Identify system elements, interaction between them to satisfy the system requirements.

Toolbox used -
System Composer



Requirements - Vehicle_Architecture_Updated_060422

View: Requirements

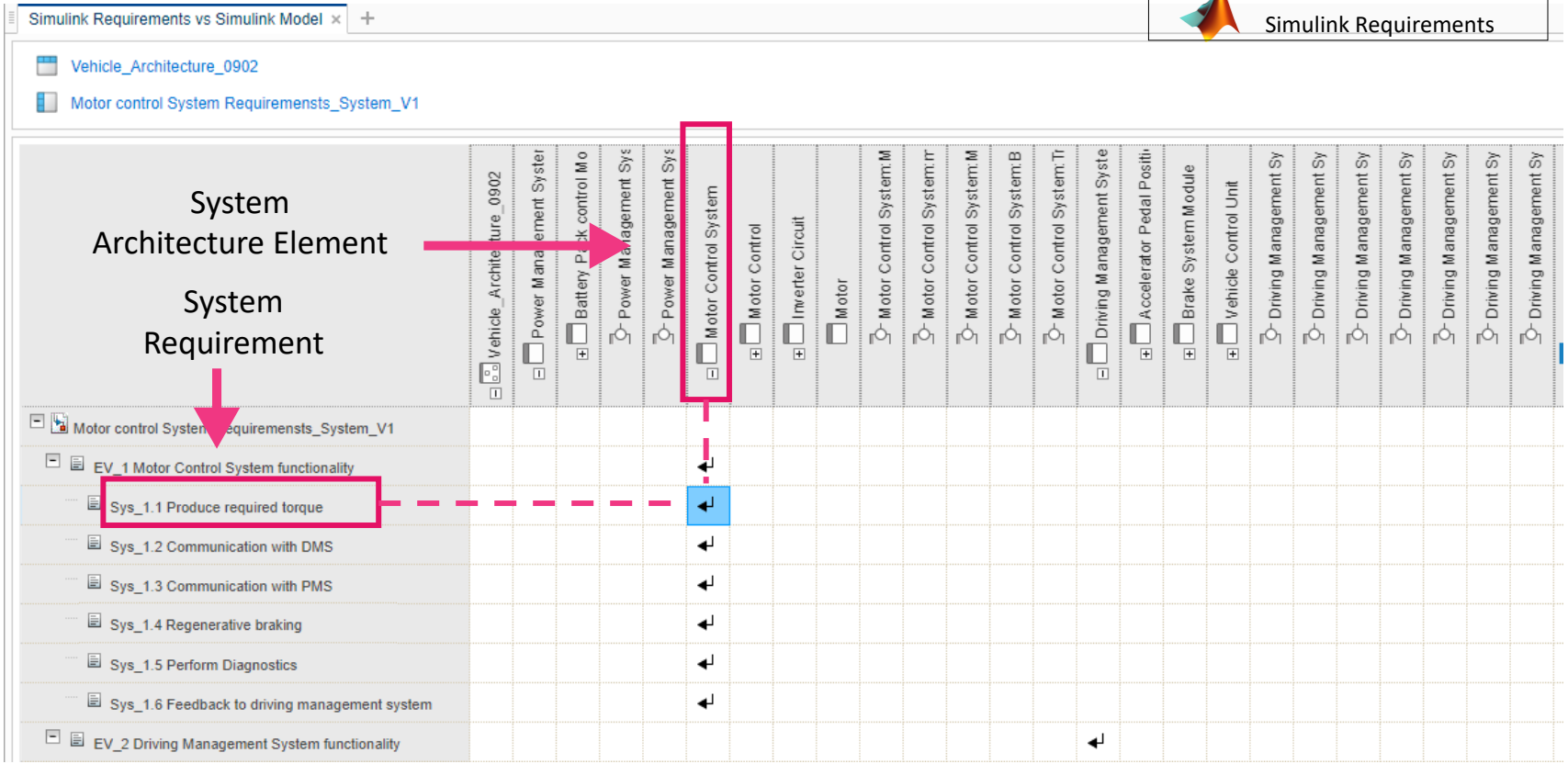
Search

Index	ID	Summary
Motor control System Requirements_System_V1		
1	EV_1	Motor Control System functionality
1.1	Sys_1.1	Produce required torque
1.2	Sys_1.2	Communication with DMS
1.3	Sys_1.3	Communication with PMS

Establish “implements” relationship between architectural elements and requirements

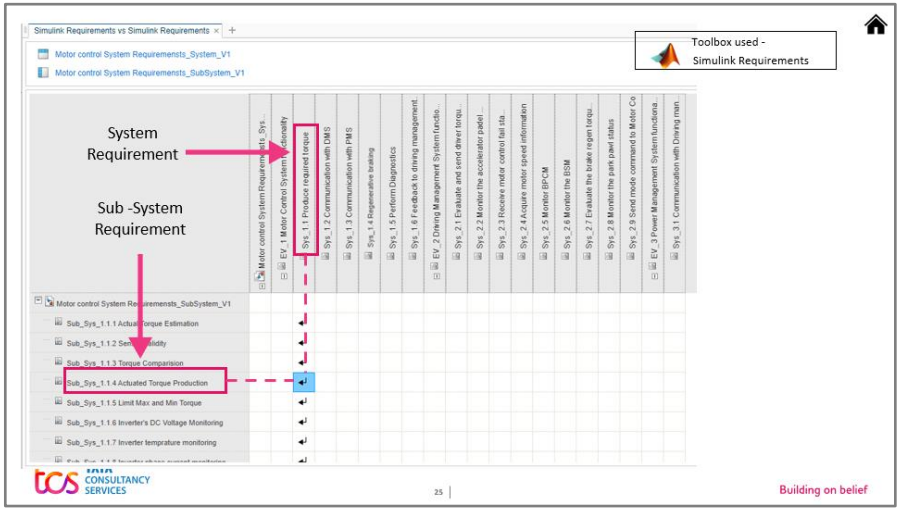
System Req to System Architecture traceability

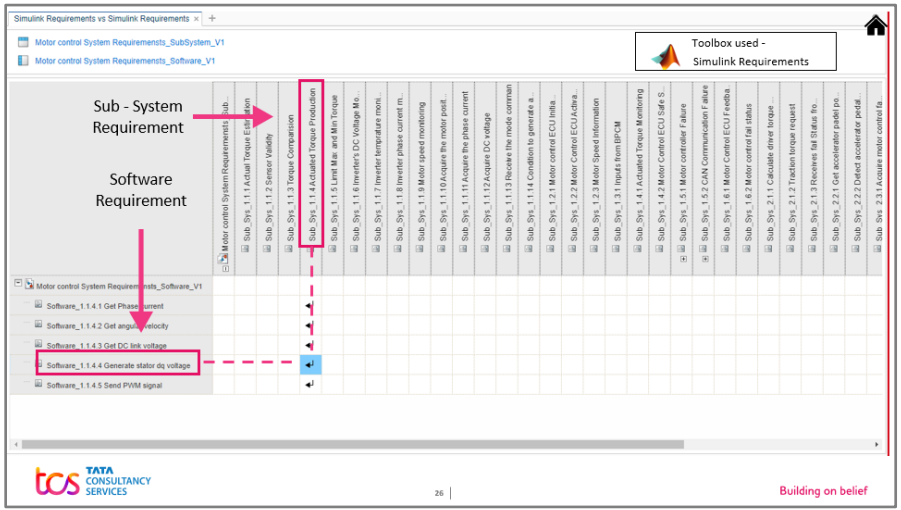
Toolbox used -
Simulink Requirements



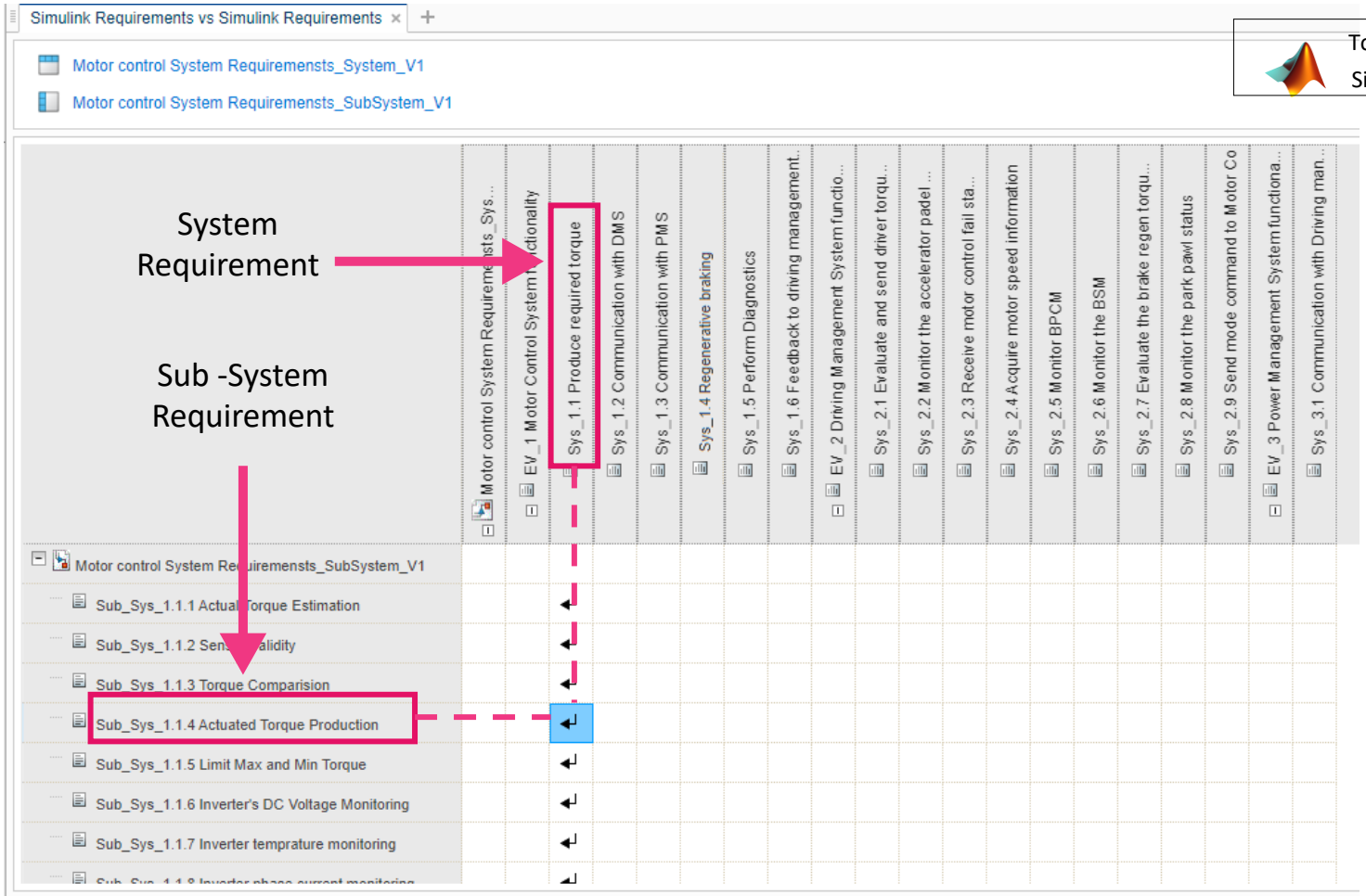
Establish and maintain traceability between System Requirements and System Architecture elements

Traceability





End to End traceability can be maintained. System<->Sub System<-> Software and component requirements



Toolbox used -
Simulink Requirements

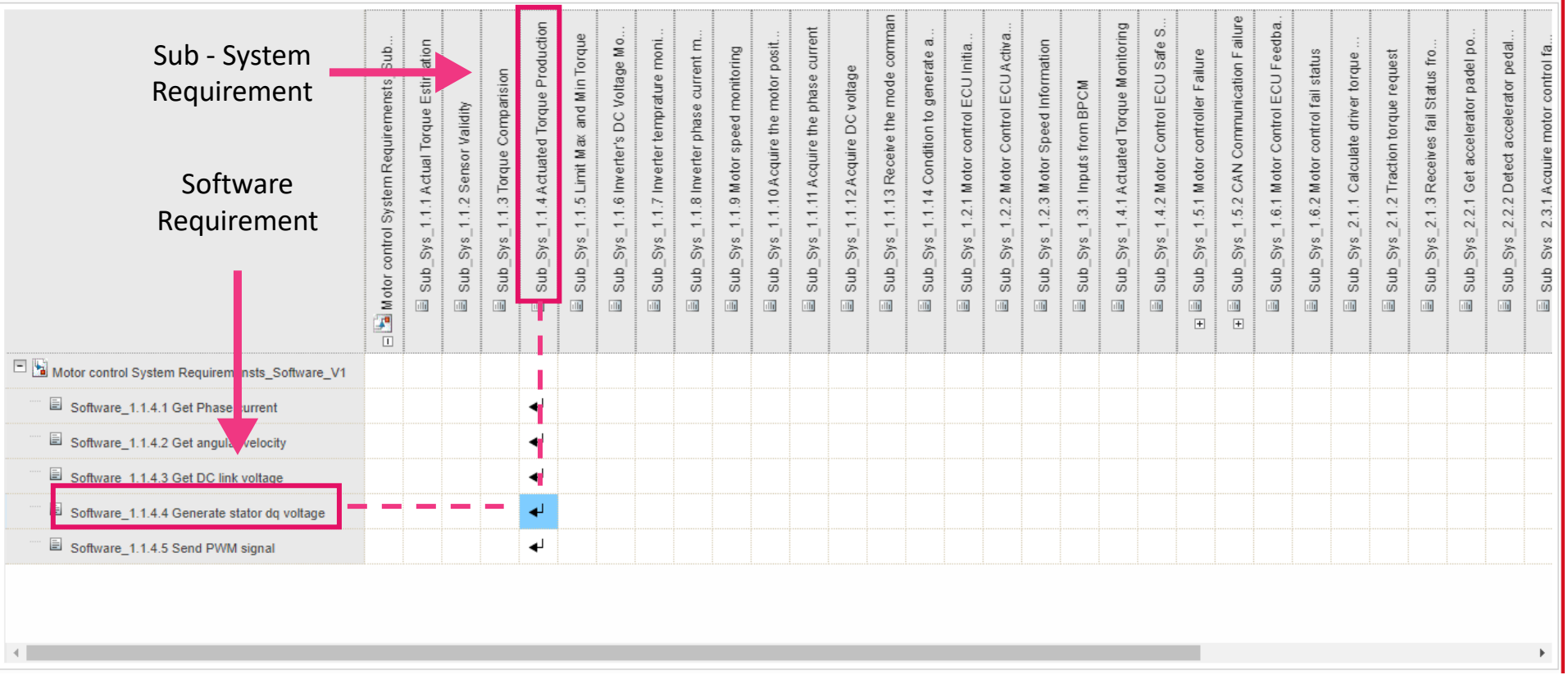
Motor control System Requiremensts_SubSystem_V1

Motor control System Requiremensts_Software_V1

Toolbox used -
Simulink Requirements

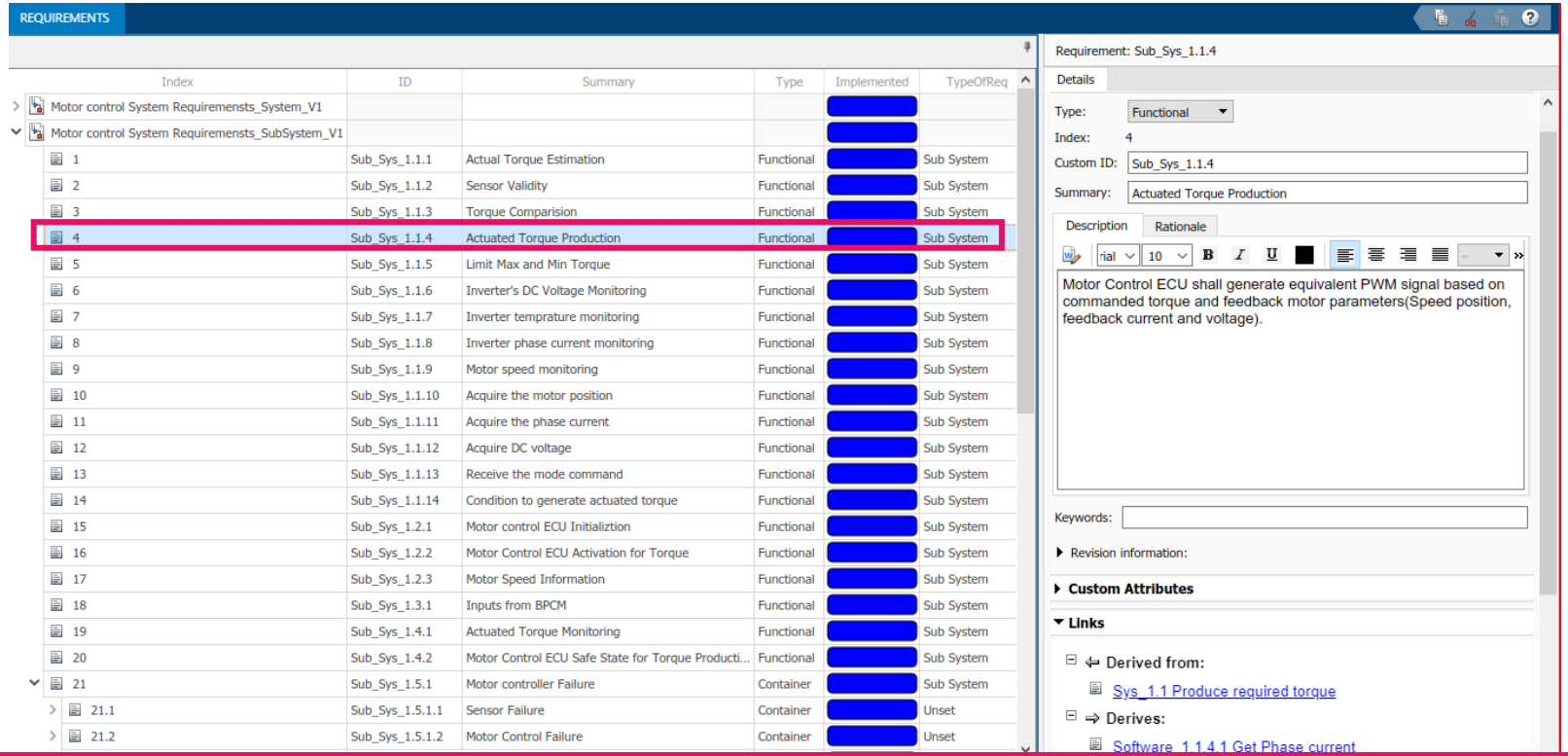
Sub - System Requirement

Software Requirement



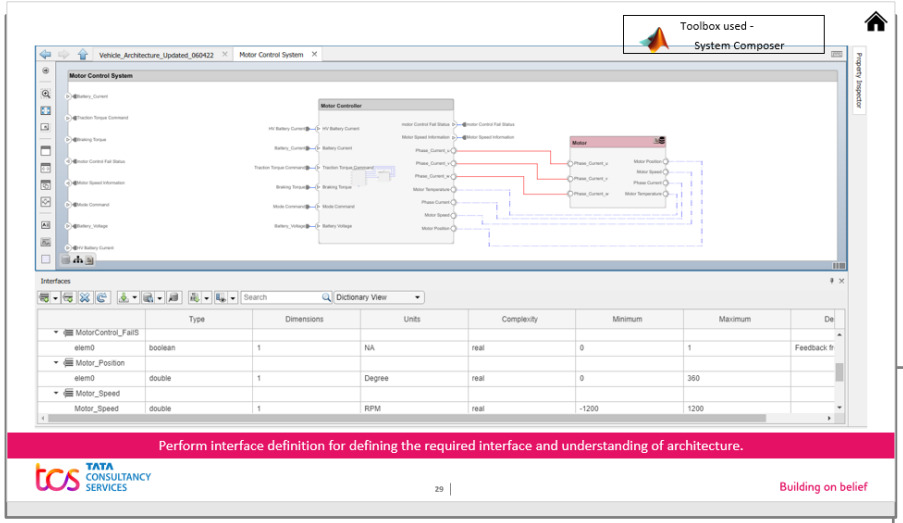
Sub System requirements Authoring

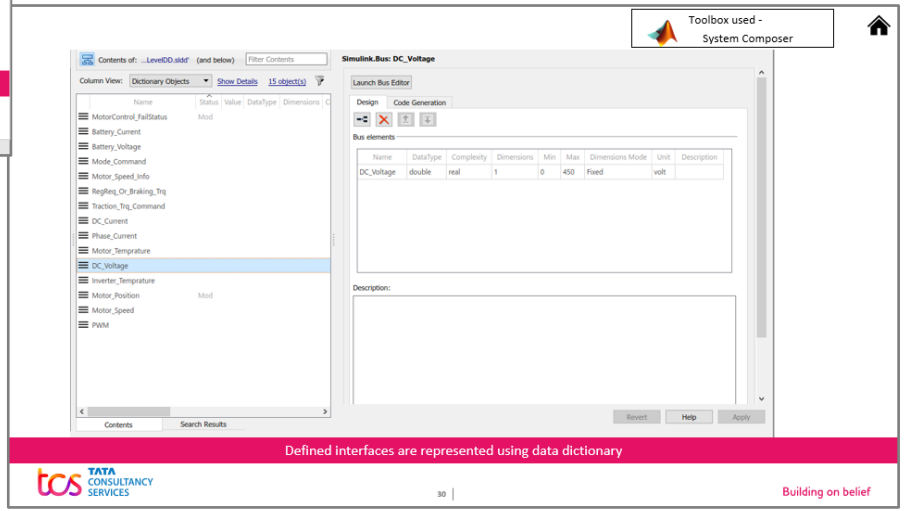
Toolbox used -
Simulink Requirements



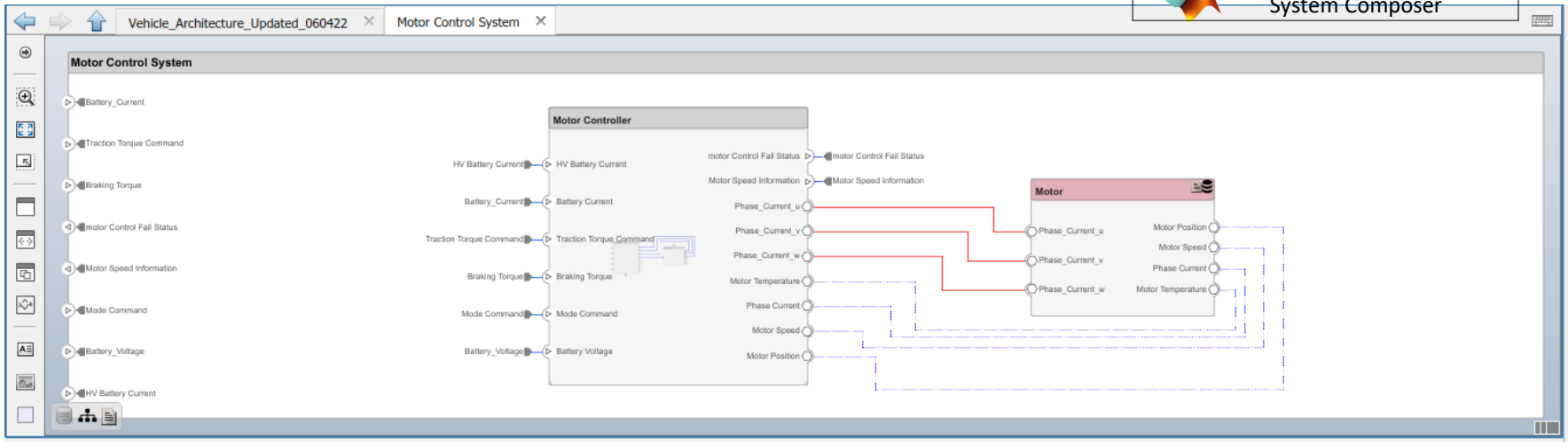
Derive Sub system requirements from System requirements. Requirement writing guidelines help to author quality requirements

Defining Interfaces





Toolbox used -
System Composer



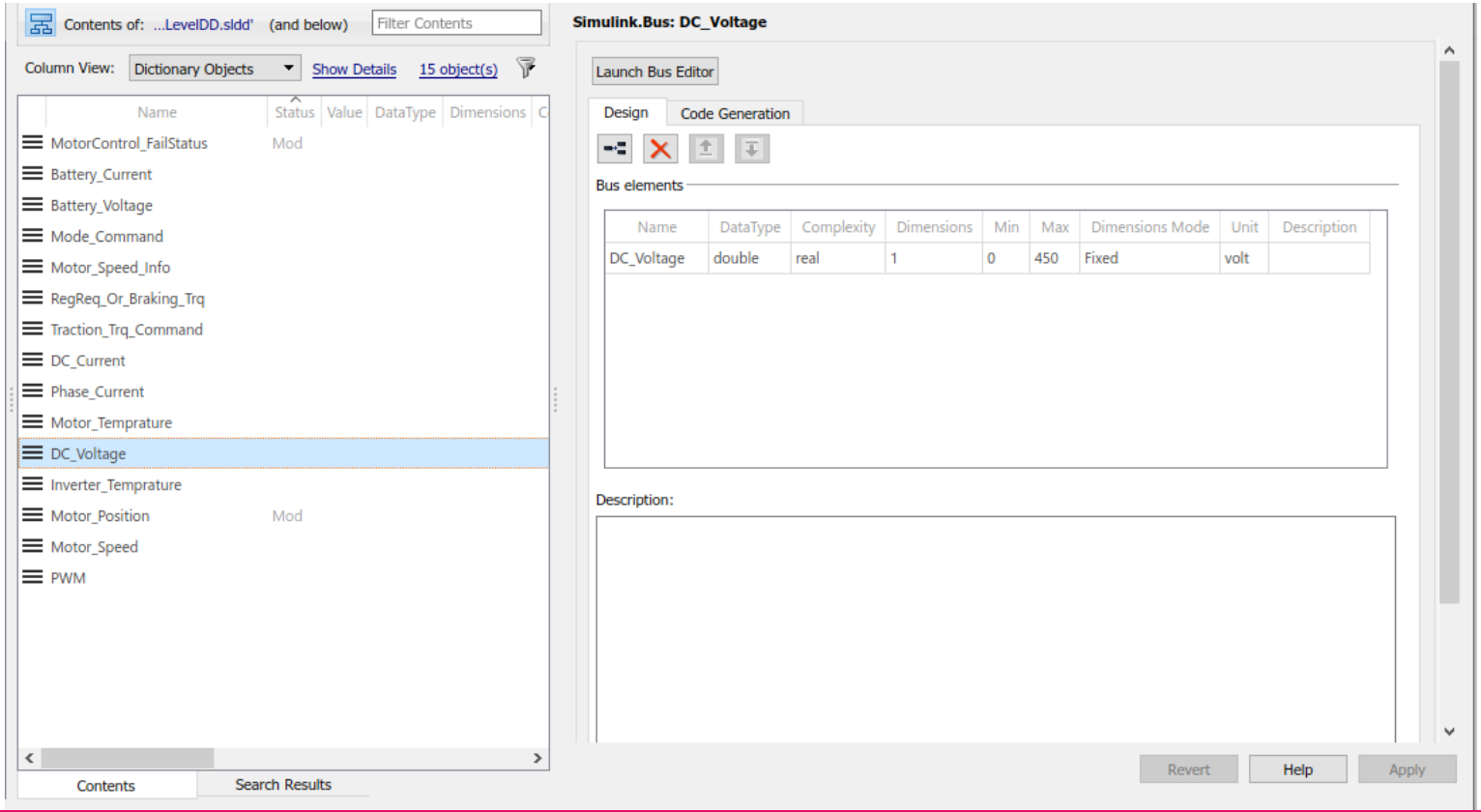
Interfaces

Search | Dictionary View

	Type	Dimensions	Units	Complexity	Minimum	Maximum	De
MotorControl_FailS							
elem0	boolean	1	NA	real	0	1	Feedback fr
Motor_Position							
elem0	double	1	Degree	real	0	360	
Motor_Speed							
Motor_Speed	double	1	RPM	real	-1200	1200	

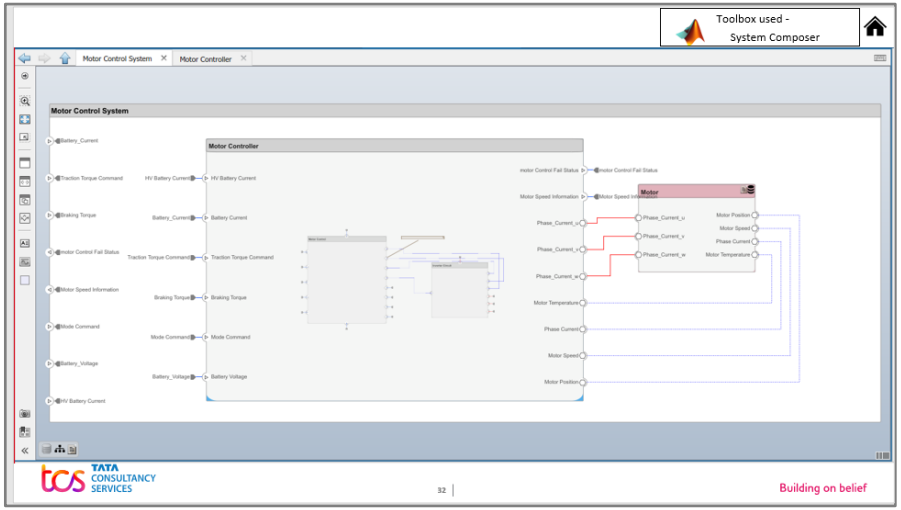
Perform interface definition for defining the required interface and understanding of architecture.

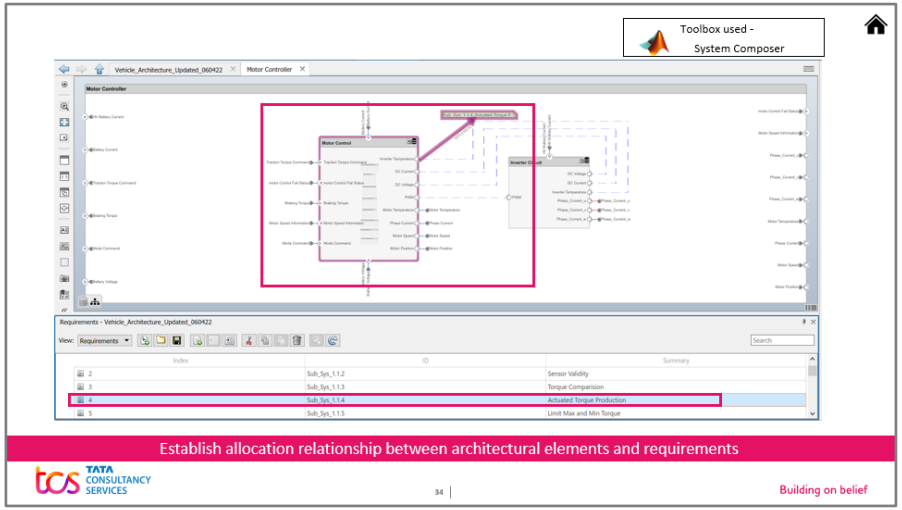
Toolbox used -
System Composer

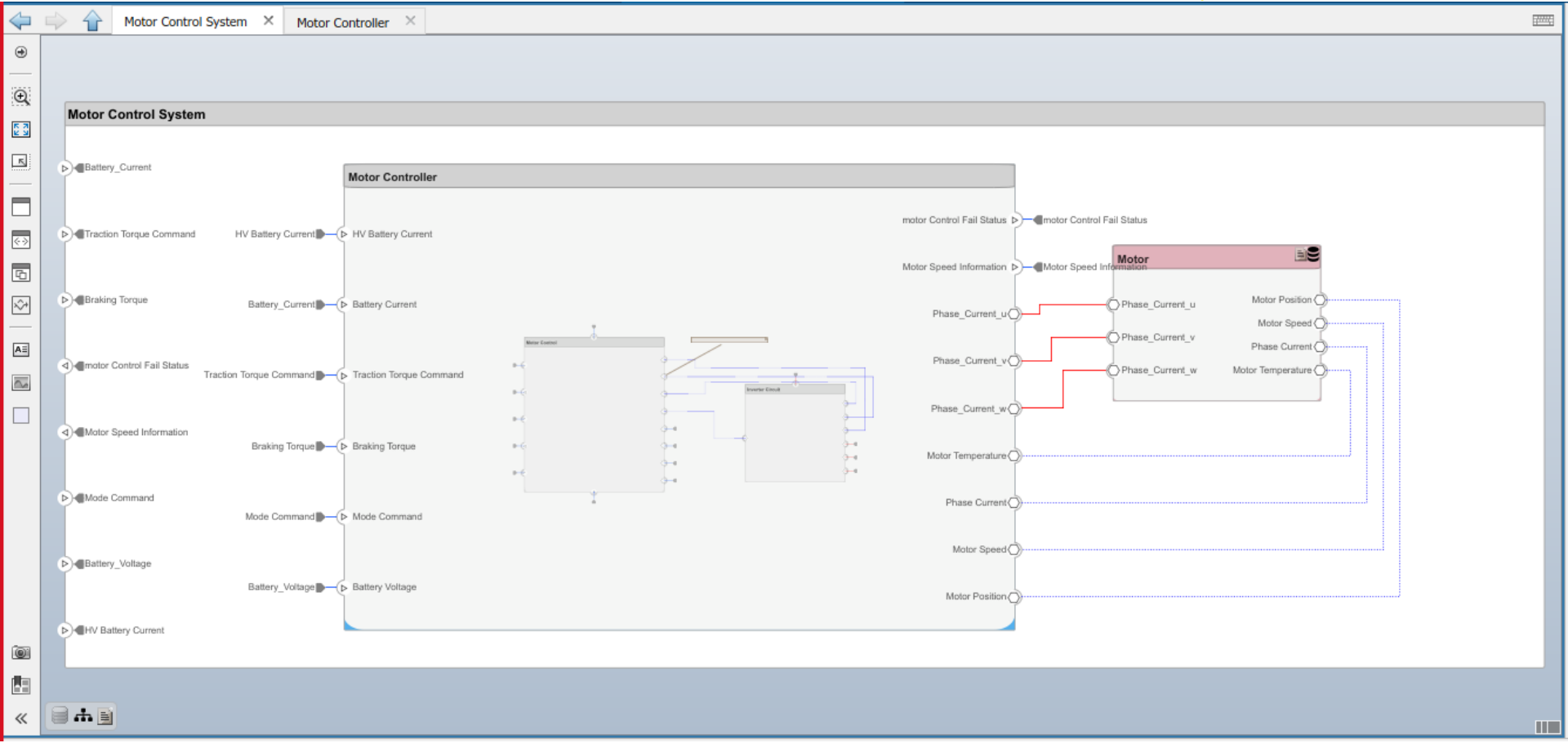


Defined interfaces are represented using data dictionary

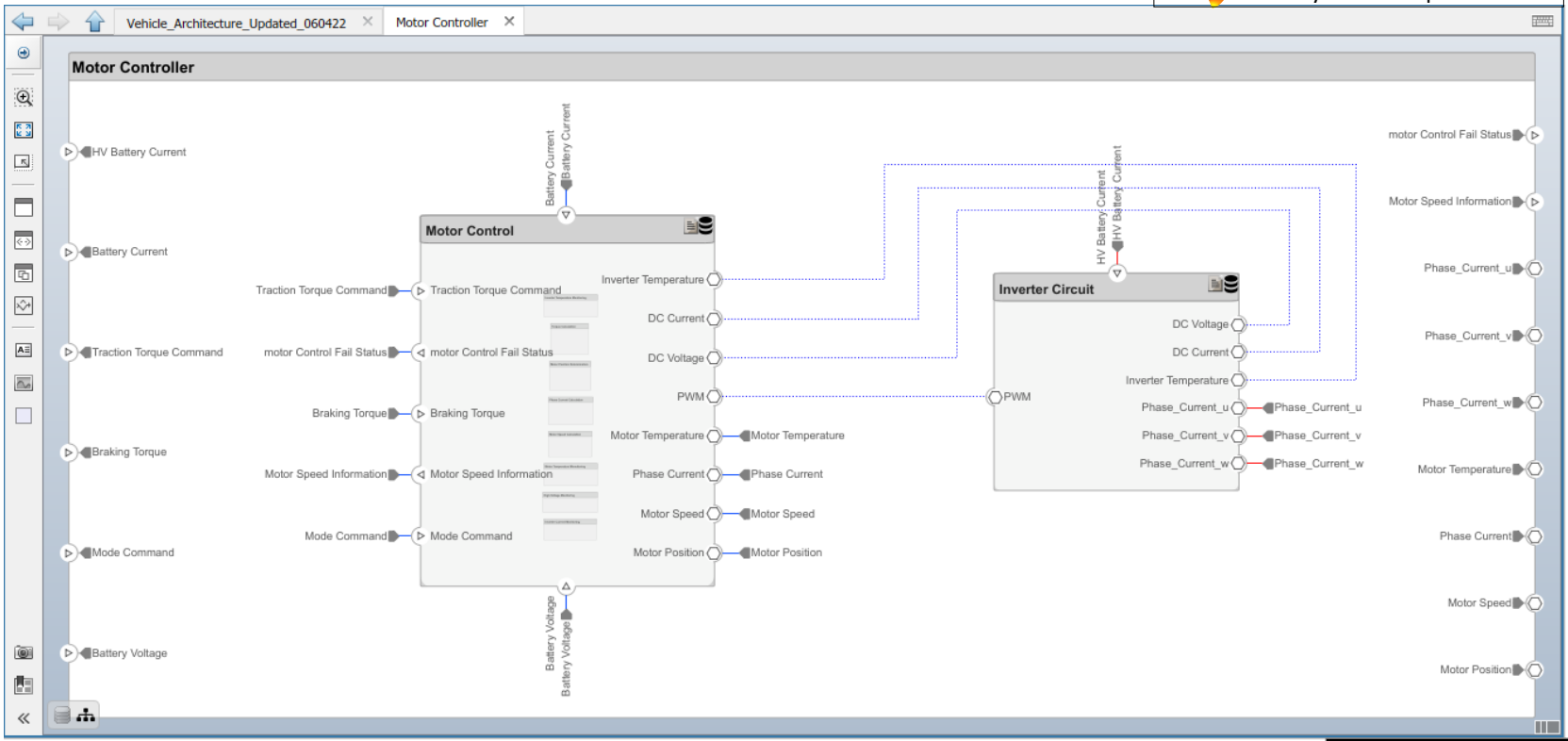
Sub System Architecture & Requirement Allocation





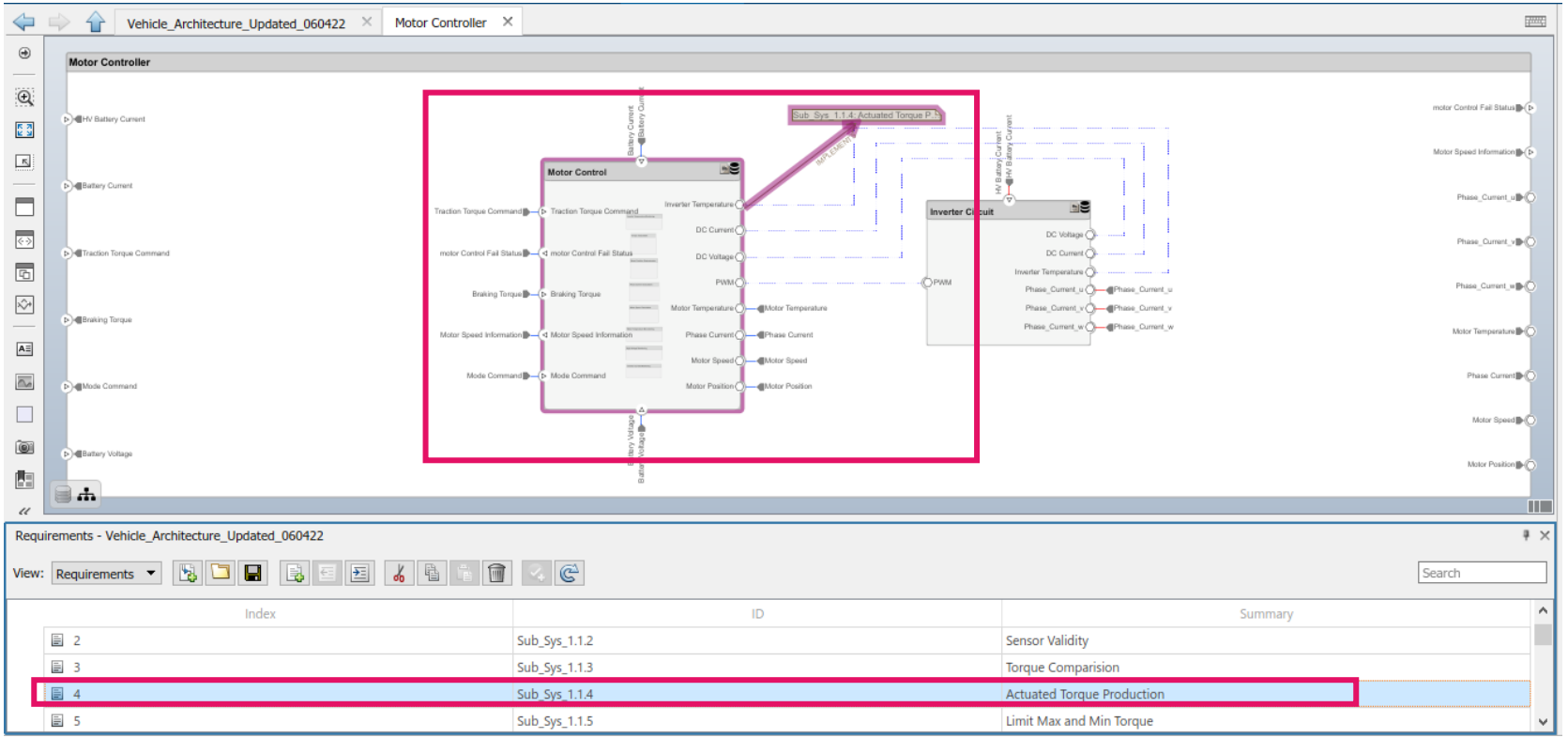

Motor Control System
Motor Controller
Battery_Current
Traction Torque Command
Braking Torque
motor Control Fail Status
Motor Speed Information
Mode Command
Battery_Voltage
HV Battery Current
HV Battery Current
Battery Current
Traction Torque Command
Braking Torque
Mode Command
Battery Voltage
motor Control Fail Status
Motor Speed Information
Phase_Current_u
Phase_Current_v
Phase_Current_w
Motor Temperature
Phase Current
Motor Speed
Motor Position
Motor
Phase_Current_u
Phase_Current_v
Phase_Current_w
Motor Position
Motor Speed
Phase Current
Motor Temperature

Toolbox used -
System Composer



Data Communication
High Voltage Line
Hardwired Connection

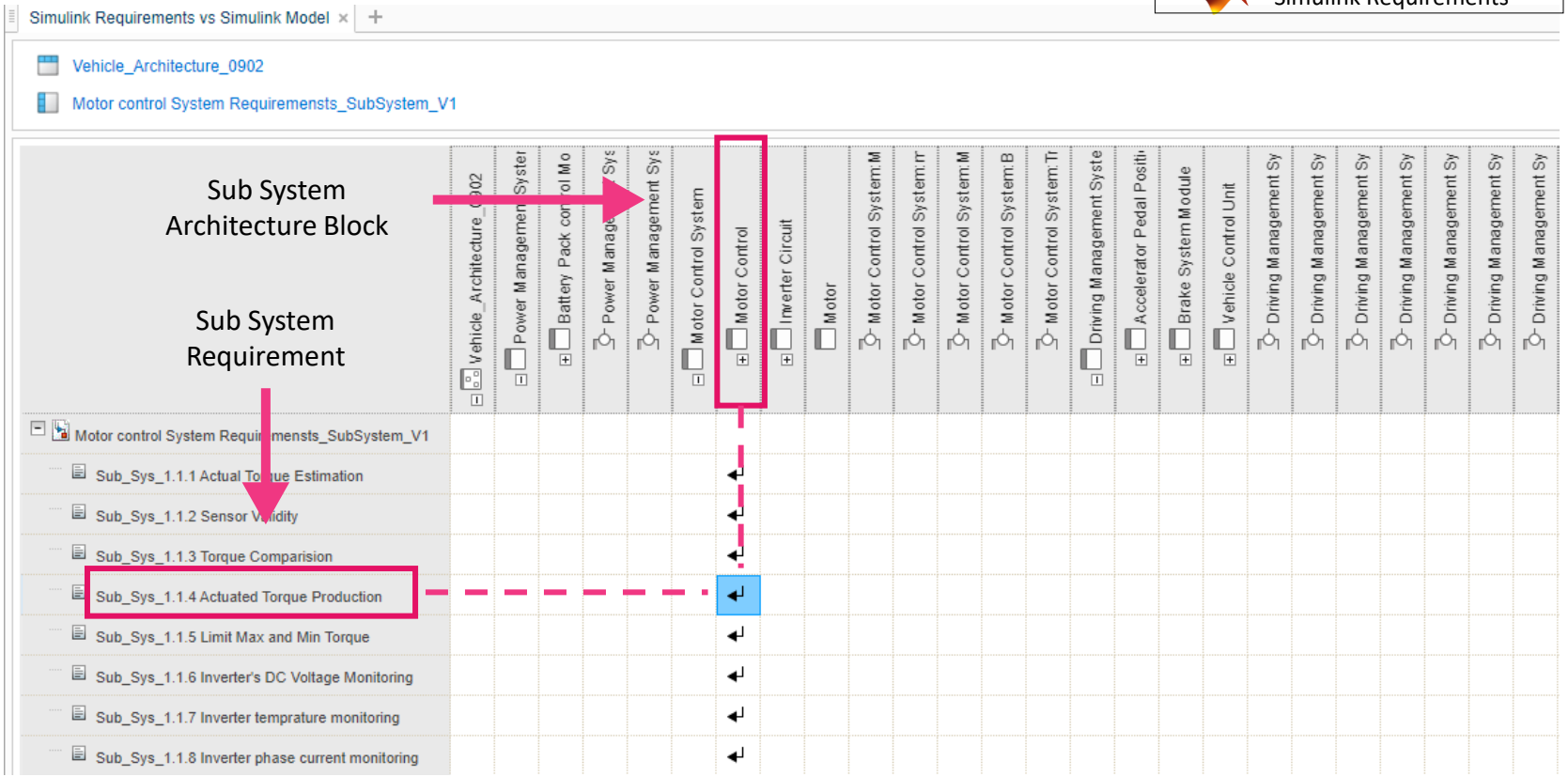
Toolbox used -
System Composer



Establish allocation relationship between architectural elements and requirements

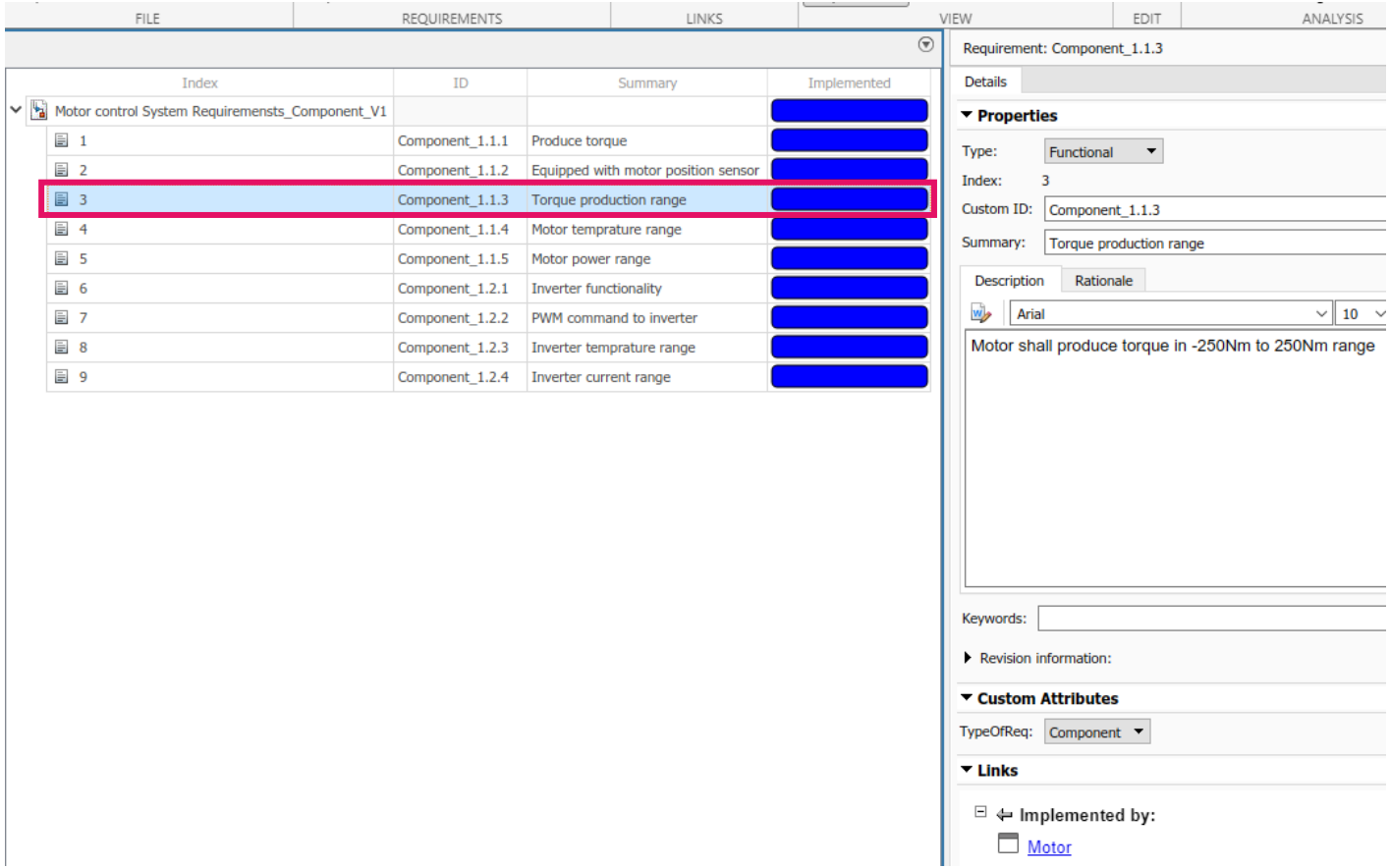
Sub System Requirement to Architecture Traceability

Toolbox used -
Simulink Requirements



Component Requirements

Toolbox used -
Simulink Requirements



Software Requirements

Toolbox used -
Simulink Requirements

Index	ID	Summary	Type	Implemented	TypeOfReq
Motor control System Requiremensts_System_V1					
Motor control System Requiremensts_SubSystem_V1					
Motor control System Requiremensts_Software_V1					
1	Software_1.1.4.1	Get Phase current	Functional		Software
2	Software_1.1.4.2	Get angular velocity	Functional		Software
3	Software_1.1.4.3	Get DC link voltage	Functional		Software
4	Software_1.1.4.4	Generate stator dq voltage	Functional		Software
5	Software_1.1.4.5	Send PWM signal	Functional		Software

Requirement: Software_1.1.4.4

Details

Type: Functional

Index: 4

Custom ID: Software_1.1.4.4

Summary: Generate stator dq voltage

Description | Rationale

Current control module shall generate stator dq voltage based on torque request, phase current, angular velocity and DC voltage.

Keywords:

Revision information:

Custom Attributes

Links

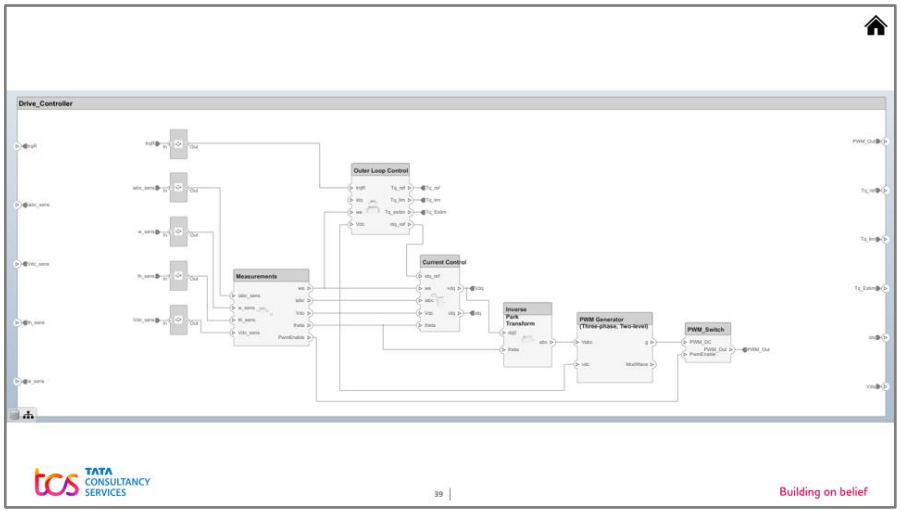
Derived from:

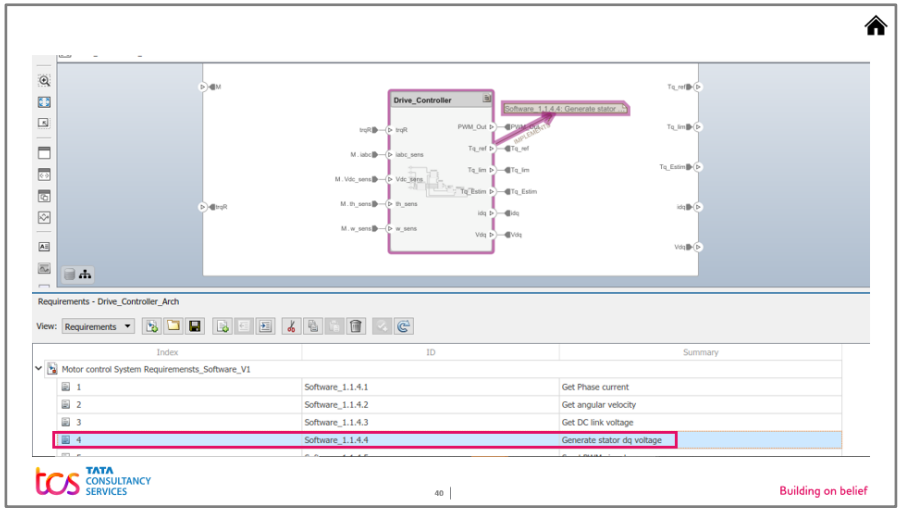
Sub_Sys_1.1.4 Actuated Torque Production

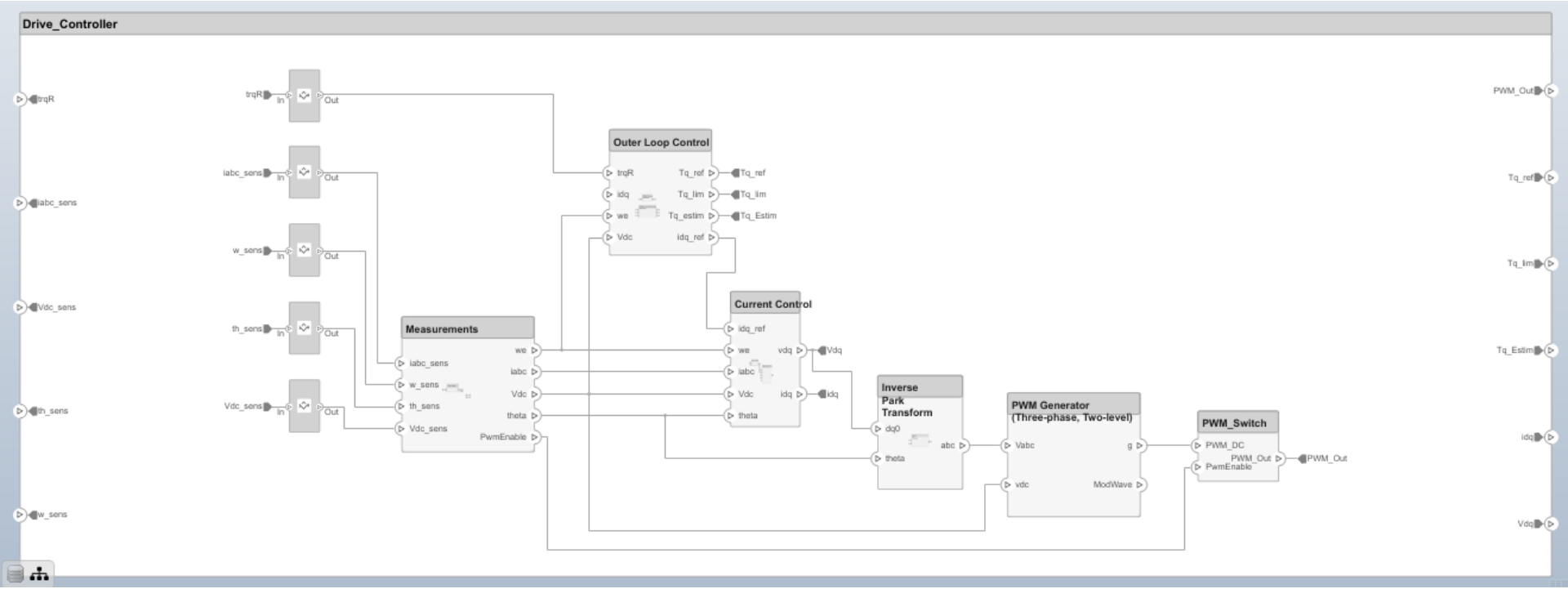
Implemented by:

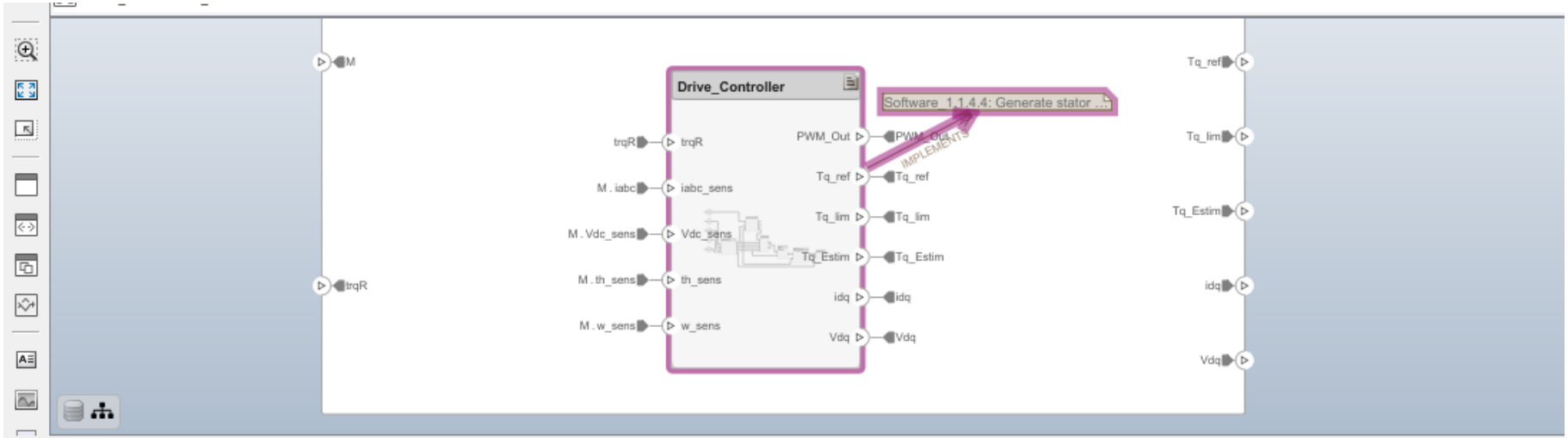
Drive_Controller

Software Architecture







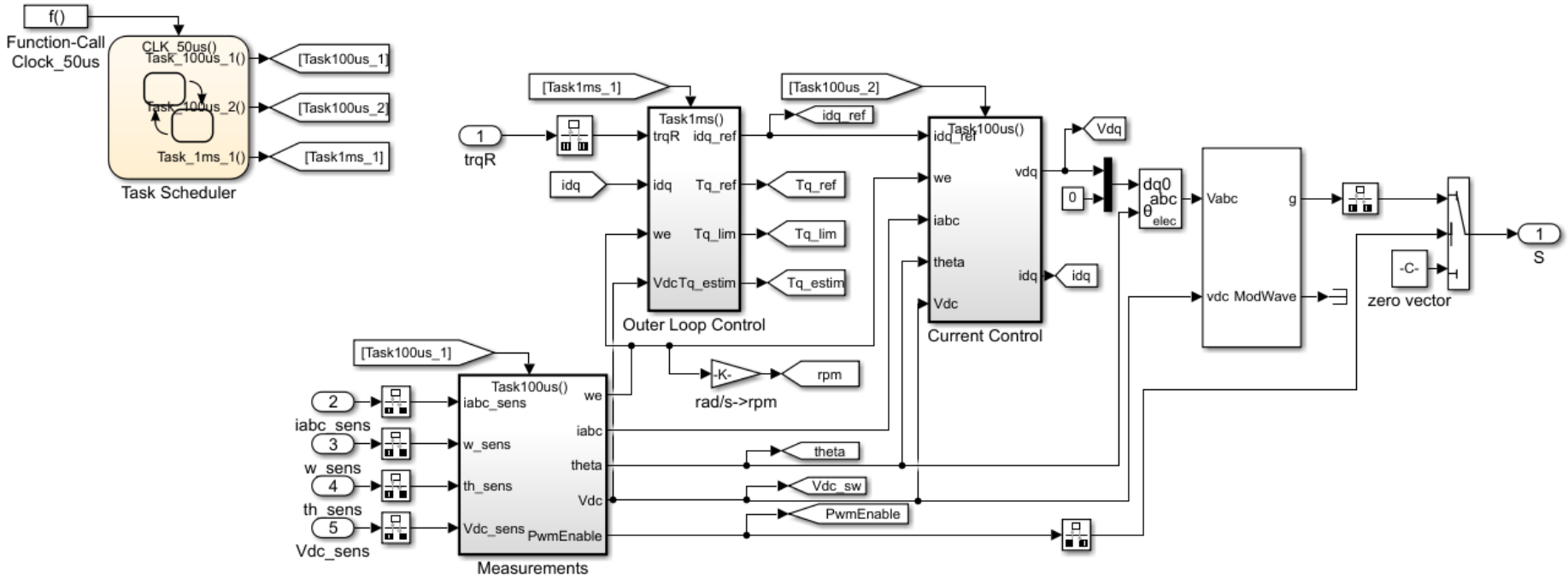


Requirements - Drive_Controller_Arch

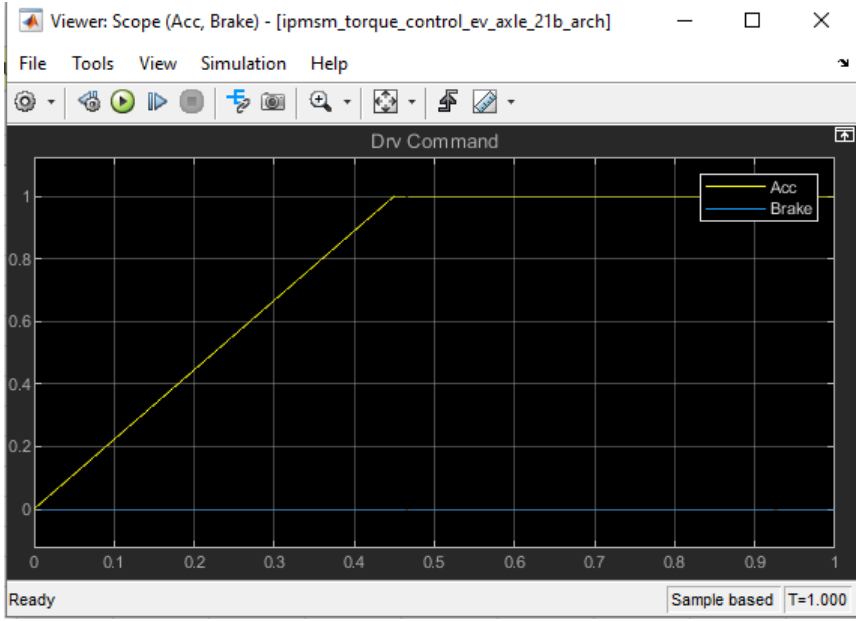
View: Requirements

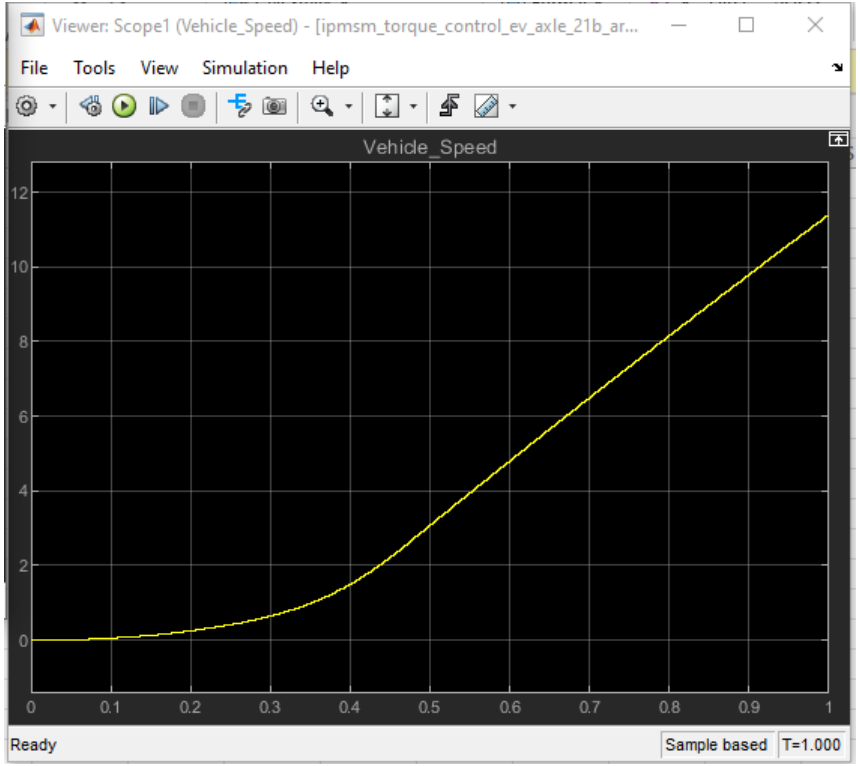
Index	ID	Summary
Motor control System Requiremensts_Software_V1		
1	Software_1.1.4.1	Get Phase current
2	Software_1.1.4.2	Get angular velocity
3	Software_1.1.4.3	Get DC link voltage
4	Software_1.1.4.4	Generate stator dq voltage

Software Design and Implementation

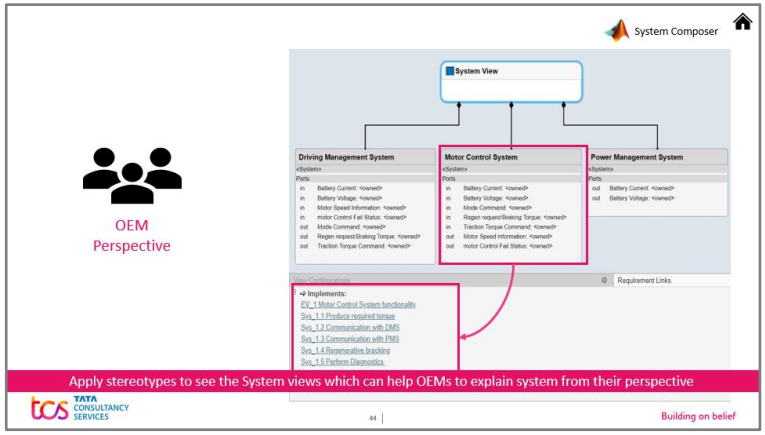


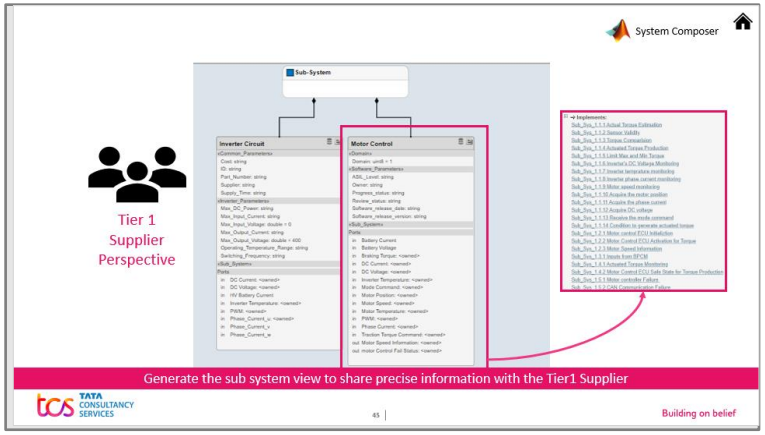
System Verification

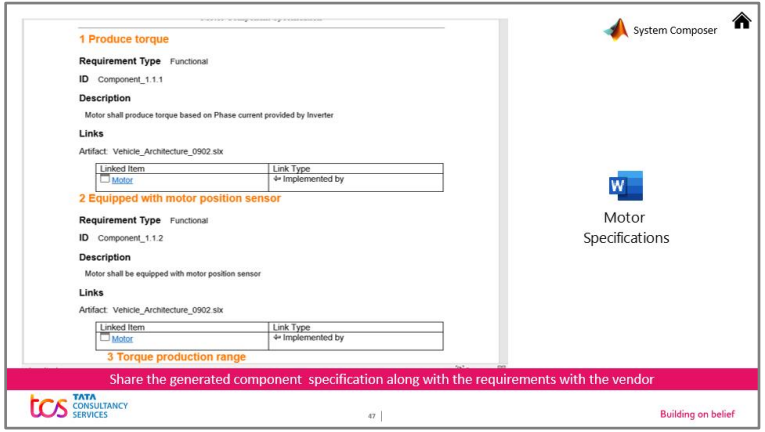


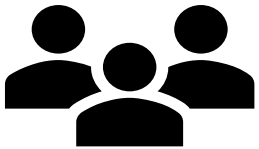


Stakeholder views

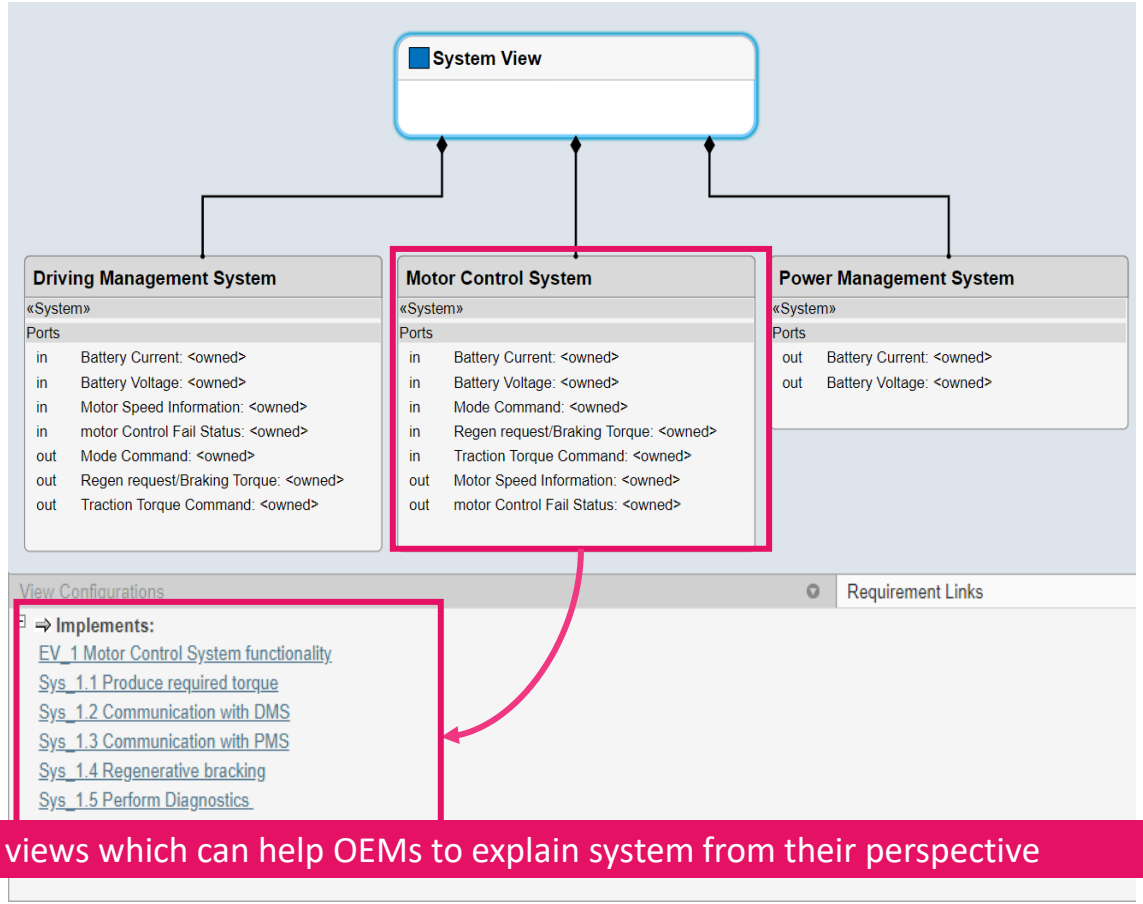




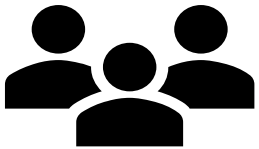




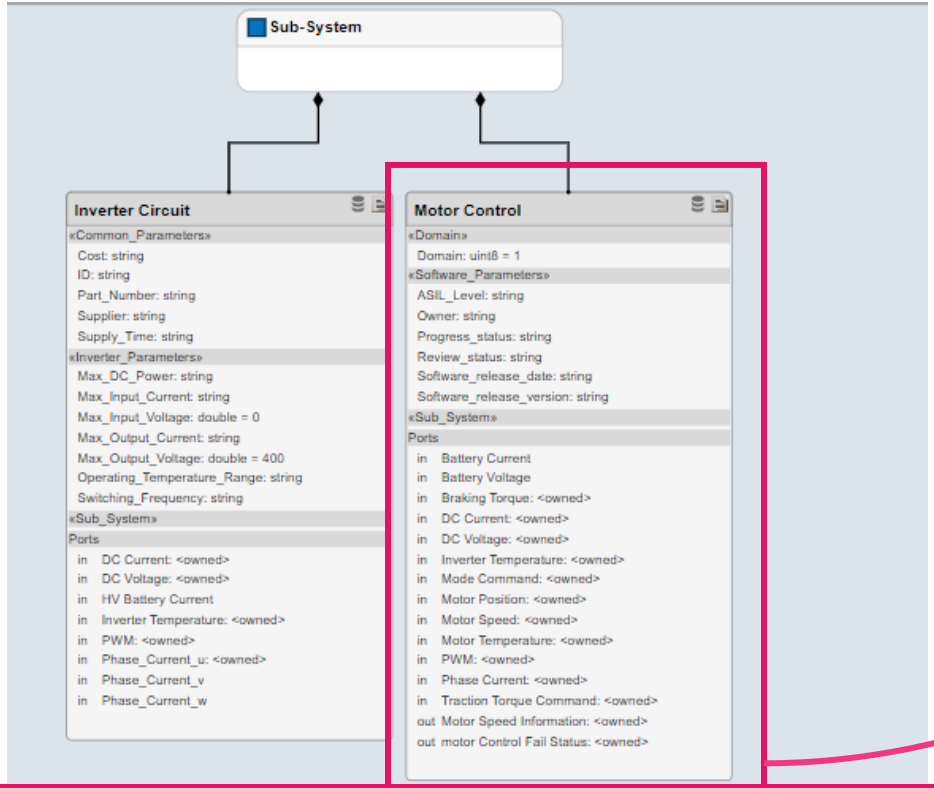
OEM
Perspective



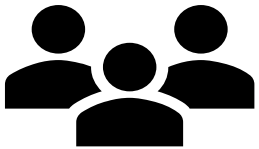
Apply stereotypes to see the System views which can help OEMs to explain system from their perspective



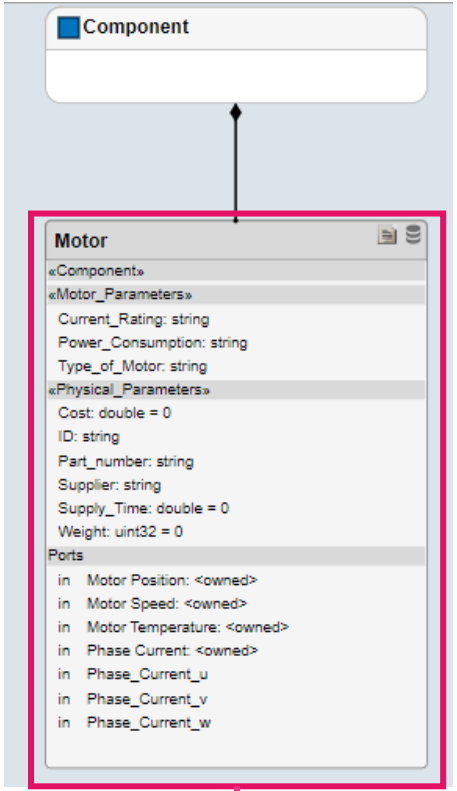
Tier 1 Supplier Perspective

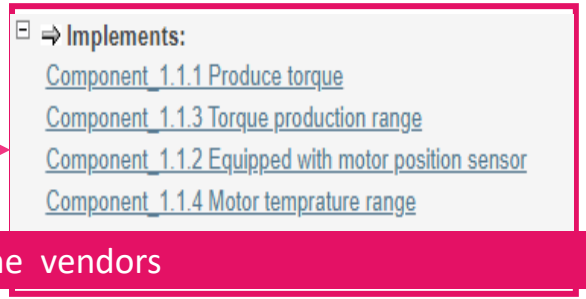


Generate the sub system view to share precise information with the Tier1 Supplier



Motor
Vendor
Perspective





Generate the component view to share with the vendors

1 Produce torque

Requirement Type Functional

ID Component_1.1.1

Description

Motor shall produce torque based on Phase current provided by Inverter

Links

Artifact: Vehicle_Architecture_0902.slx

Linked Item	Link Type
Motor	⇦ Implemented by

2 Equipped with motor position sensor

Requirement Type Functional

ID Component_1.1.2

Description

Motor shall be equipped with motor position sensor

Links

Artifact: Vehicle_Architecture_0902.slx

Linked Item	Link Type
Motor	⇦ Implemented by

3 Torque production range

Motor Specifications

Share the generated component specification along with the requirements with the vendor