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Hyundai's Modular MBSE Approach to 'Purpose Built Vehicle' Architecture Development

HYUNDAI MOTOR GROUP

SIEMENS

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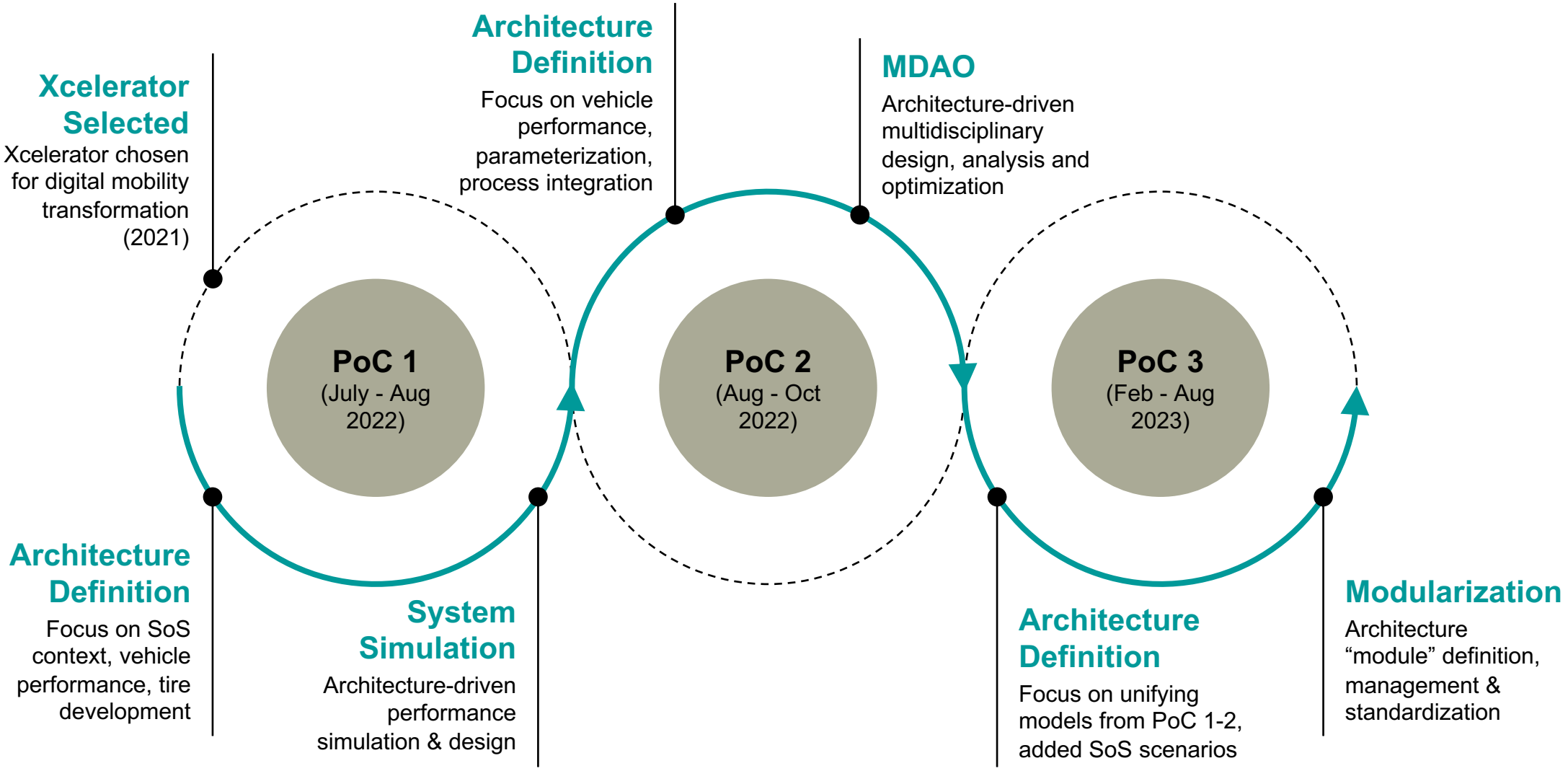
Outline

- Recap
- Introduction
- MBSE LIfecycle
- Modular MBSE
- Conclusion & Observations

Summary of Projects

Recap

Summary of MBSE Projects at Hyundai

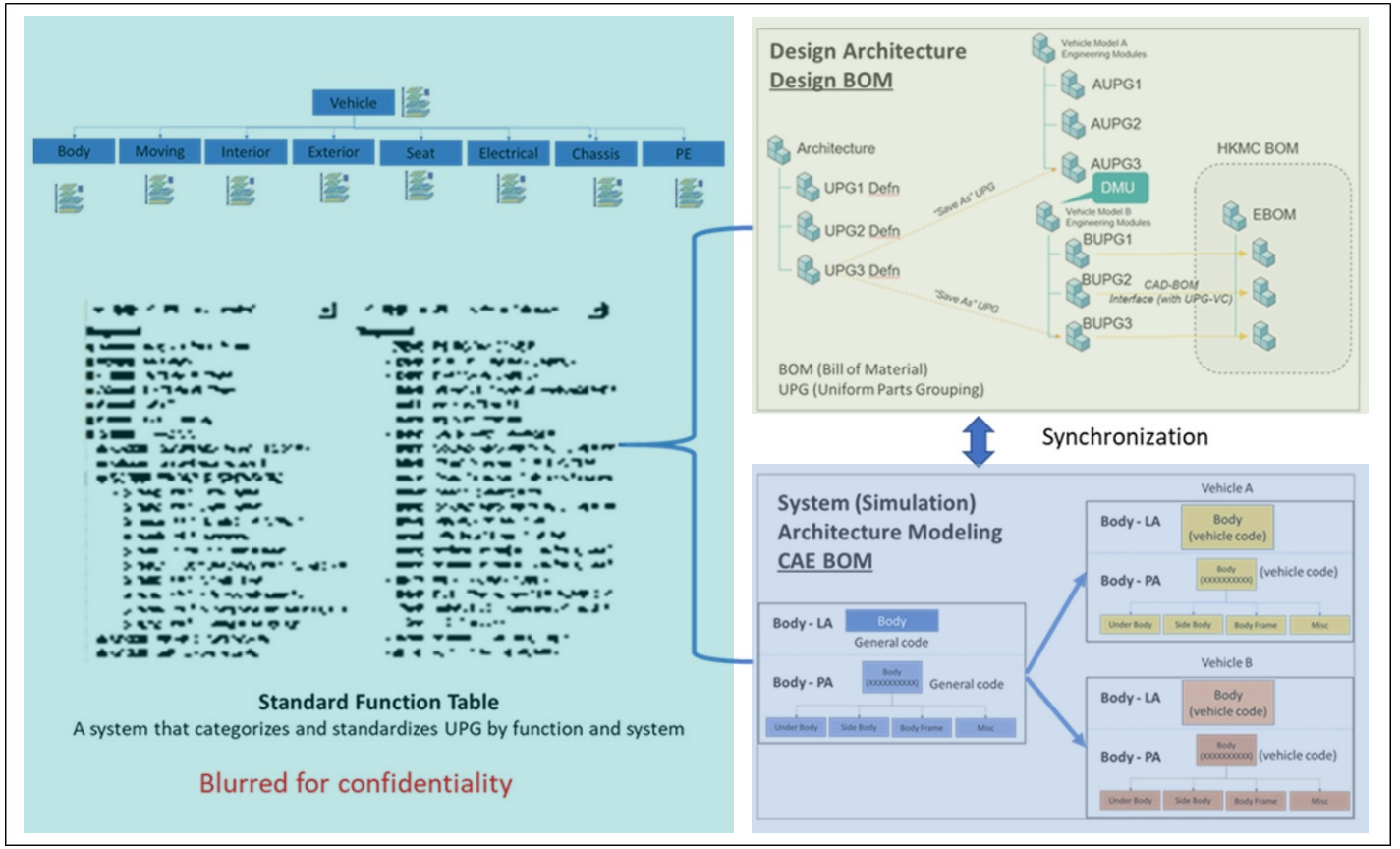


Background & Motivation

Introduction

Relevant Background

- Standard function table (UPG)
- xBOM
  - Design BOM
  - CAE BOM
- Standardized Coding



Design data management system artifacts

Motivation

Dramatic complexity explosion
Automotive systems are SoS
Emergent mobility features

Homogenous system modeling
Complicated representations of system
Limited standardization & reuse

Document-based SE
Communication challenges
Time/cost of data duplication

Lack of digital threads
Parameter/requirement traceability
Disconnect with design infra

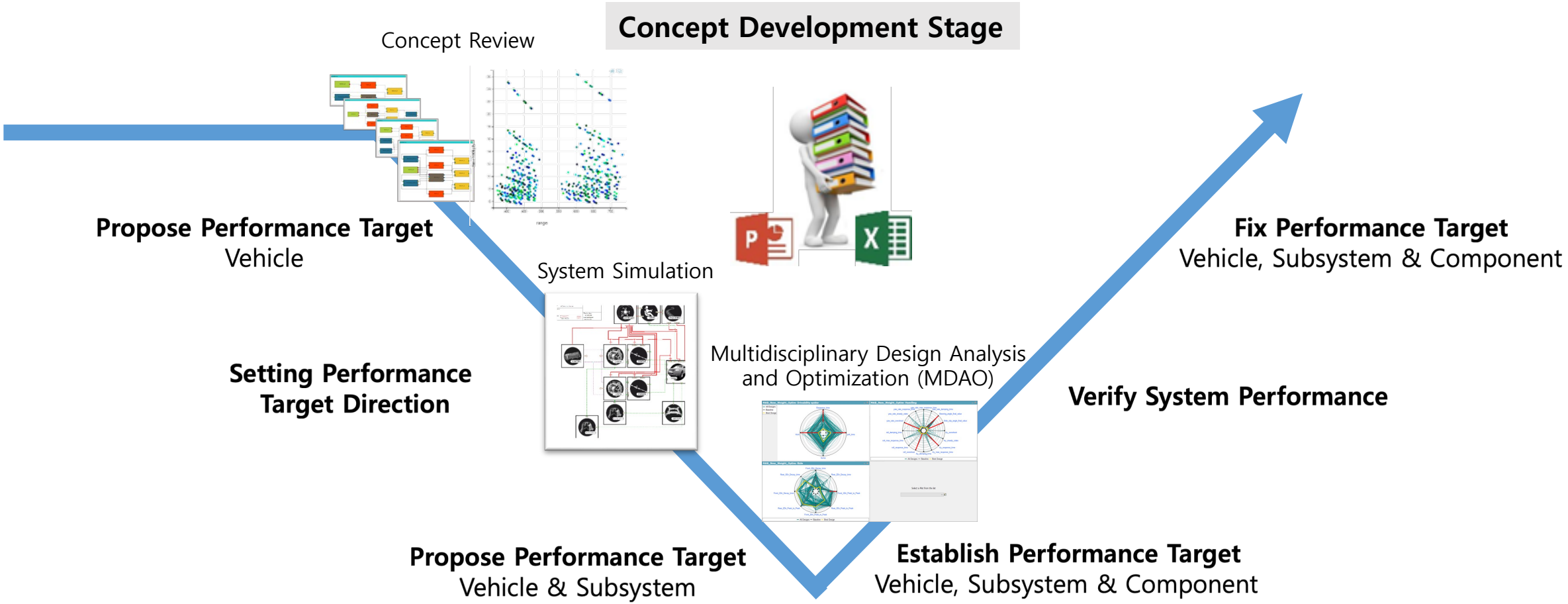
MBSE "business process"
Siloed performance development
Need for a common reference

Capturing knowledge
Legacy module design infrastructure
Legacy design models

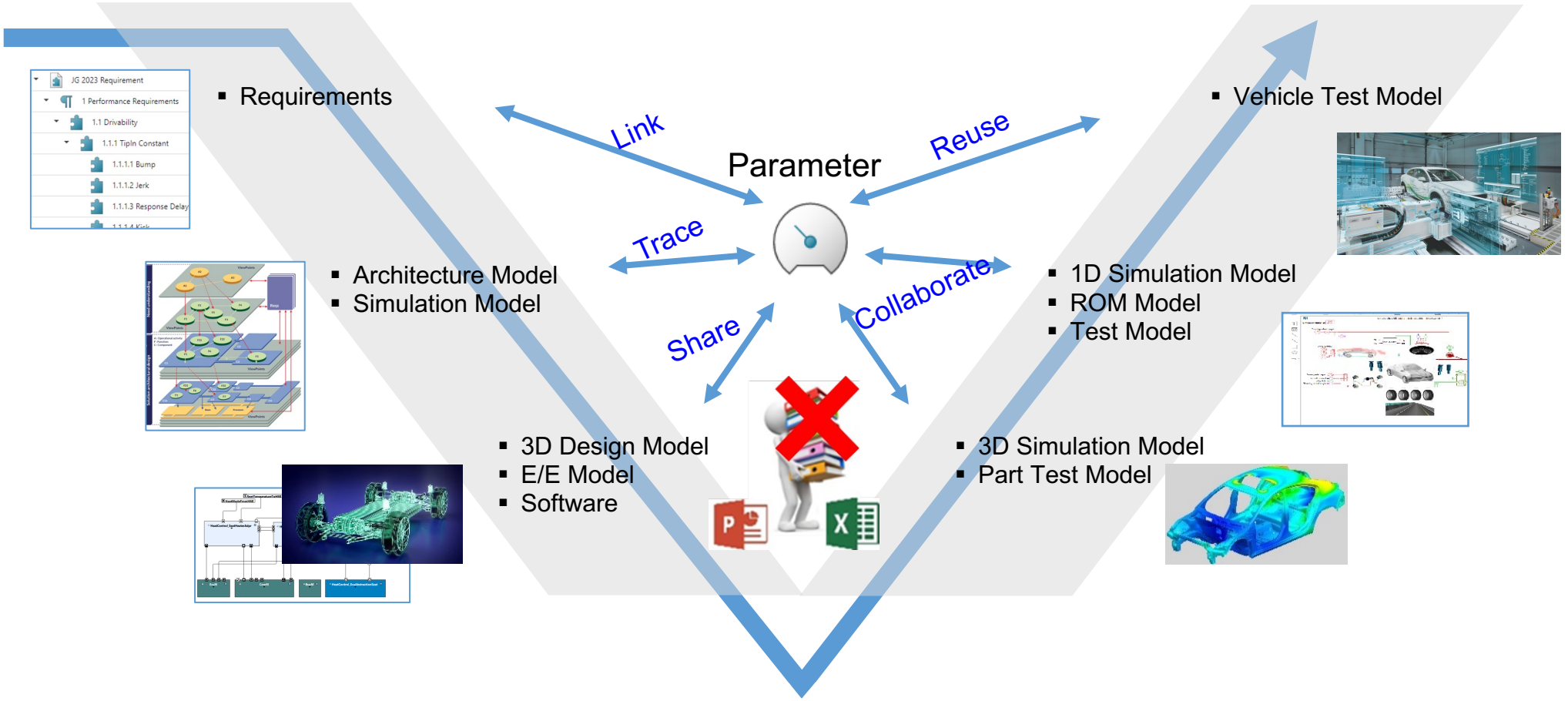
SoS Scalability

MBSE Approach

MBSE Lifecycle (as-is)



MBSE Lifecycle (to-be)



Smart Mobility System of Systems

- SoS challenges on the horizon
- Emergent mobility features
- Significantly higher product line variations
- Faster market response
- Potential for cross-enterprise MBSE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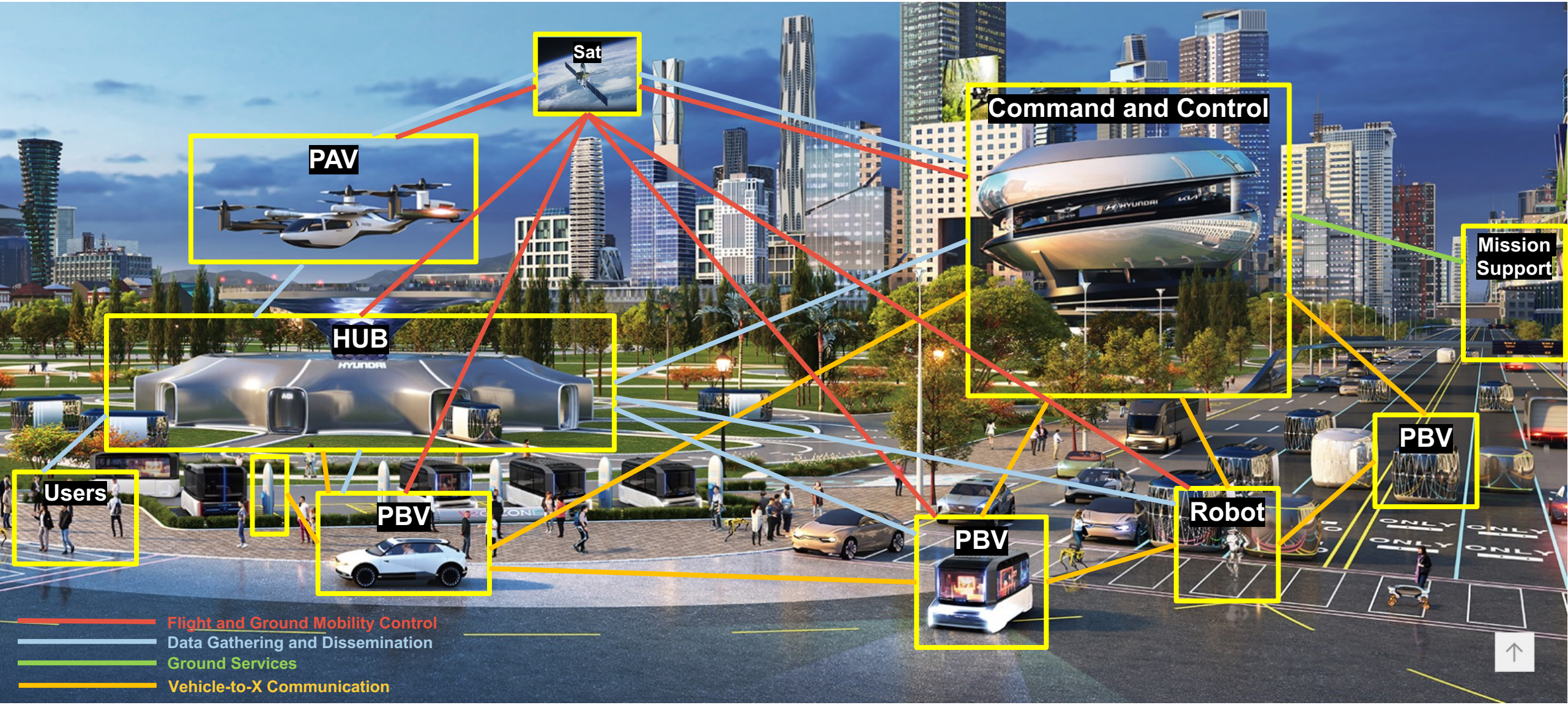
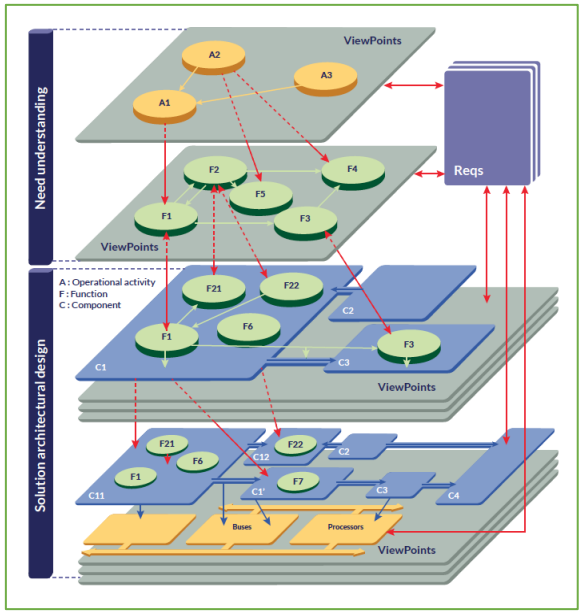
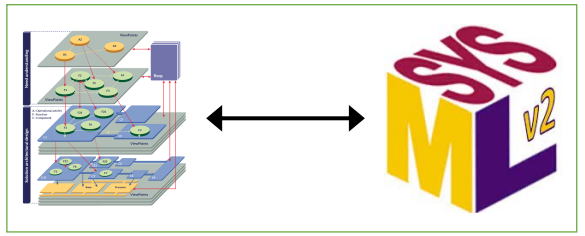

Sat
PAV
Command and Control
Mission Support
HUB
Users
PBV
PBV
Robot
PBV
Flight and Ground Mobility Control
Data Gathering and Dissemination
Ground Services
Vehicle-to-X Communication

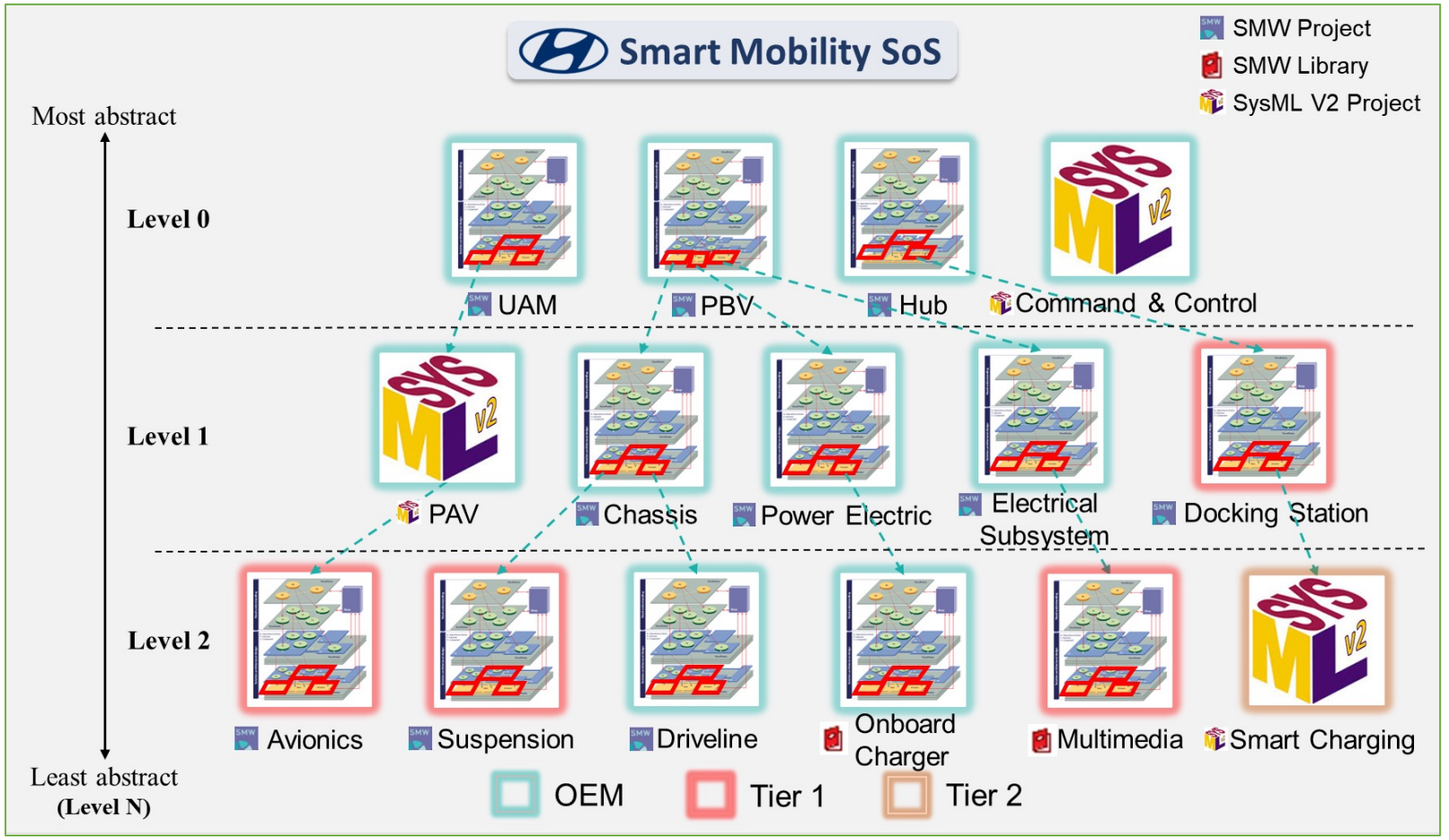
Modularization in MBSE (Vision)



The Arcadia method



Interoperability



Smart Mobility SoS model organization vision

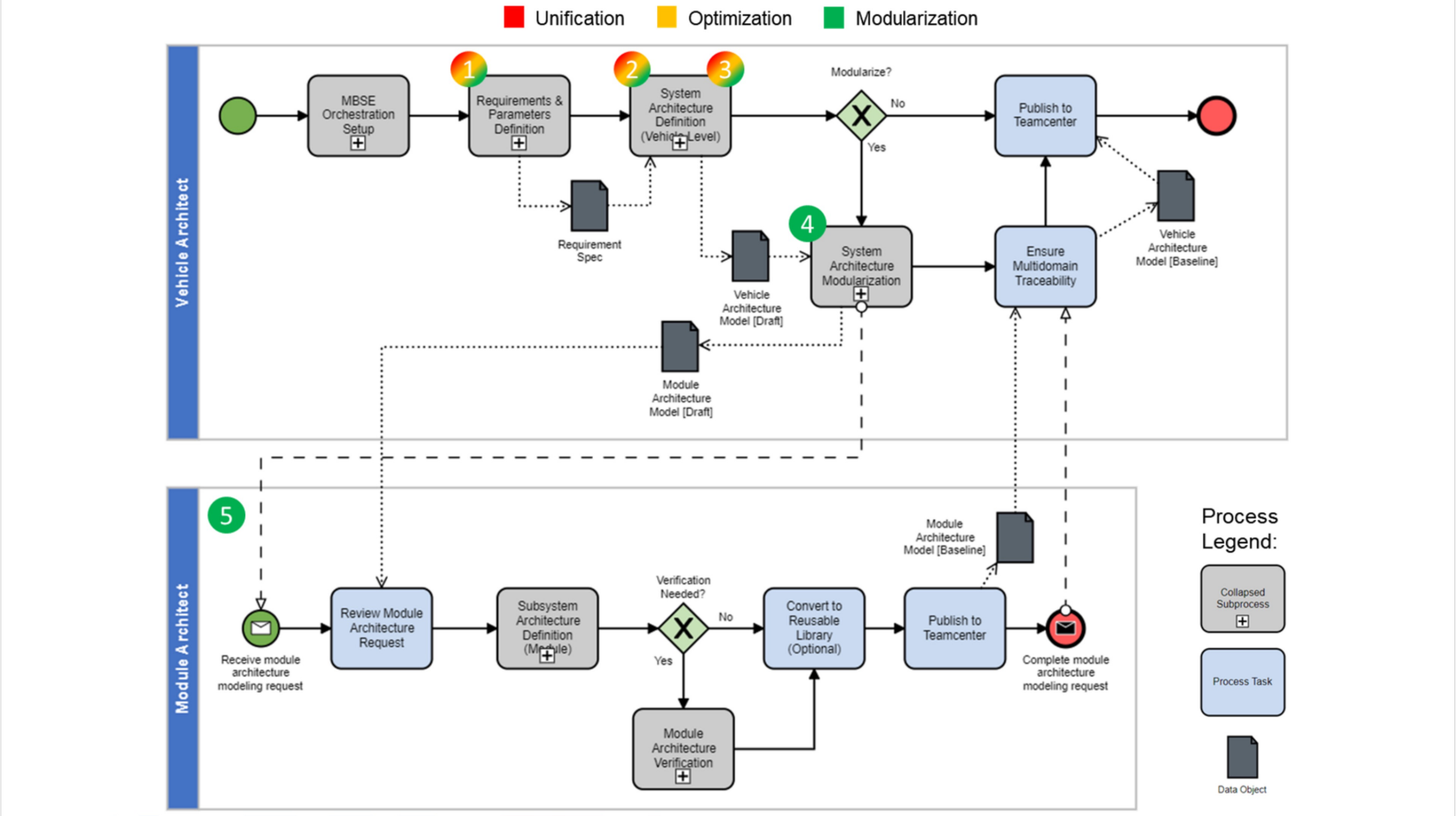
Project Objectives

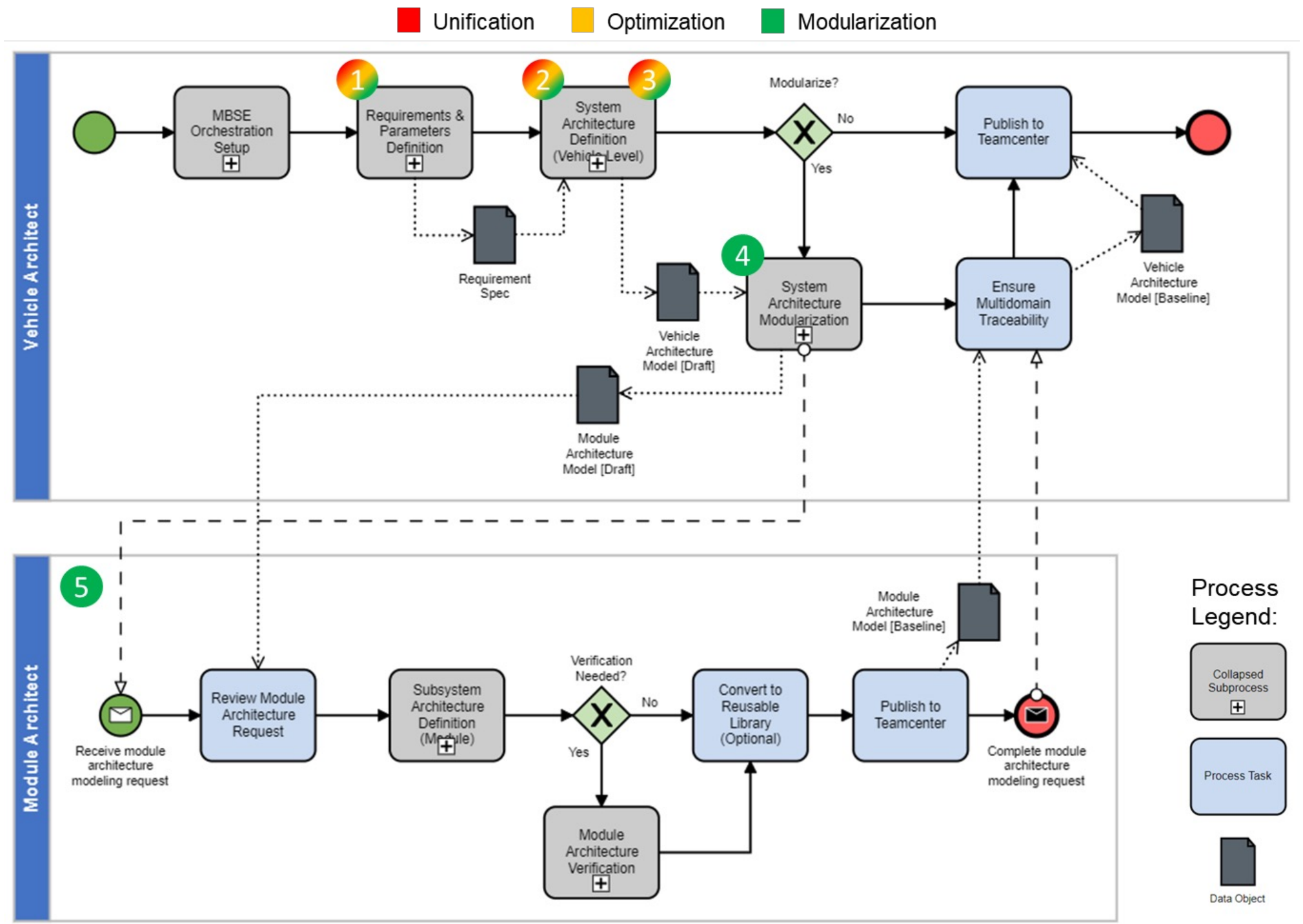
- **Unification**: Unify electric vehicle concept architecture models from the previous two PoCs and model additional operational capabilities required by the smart mobility SoS,
- **Optimization**: Optimize vehicle performance architecture for *drivability*, *ride comfort*, and *handling* and,
- **Modularization**: Modularize levels 0 and 1 of the smart mobility SoS hierarchy.

Business Process

Modular MBSE

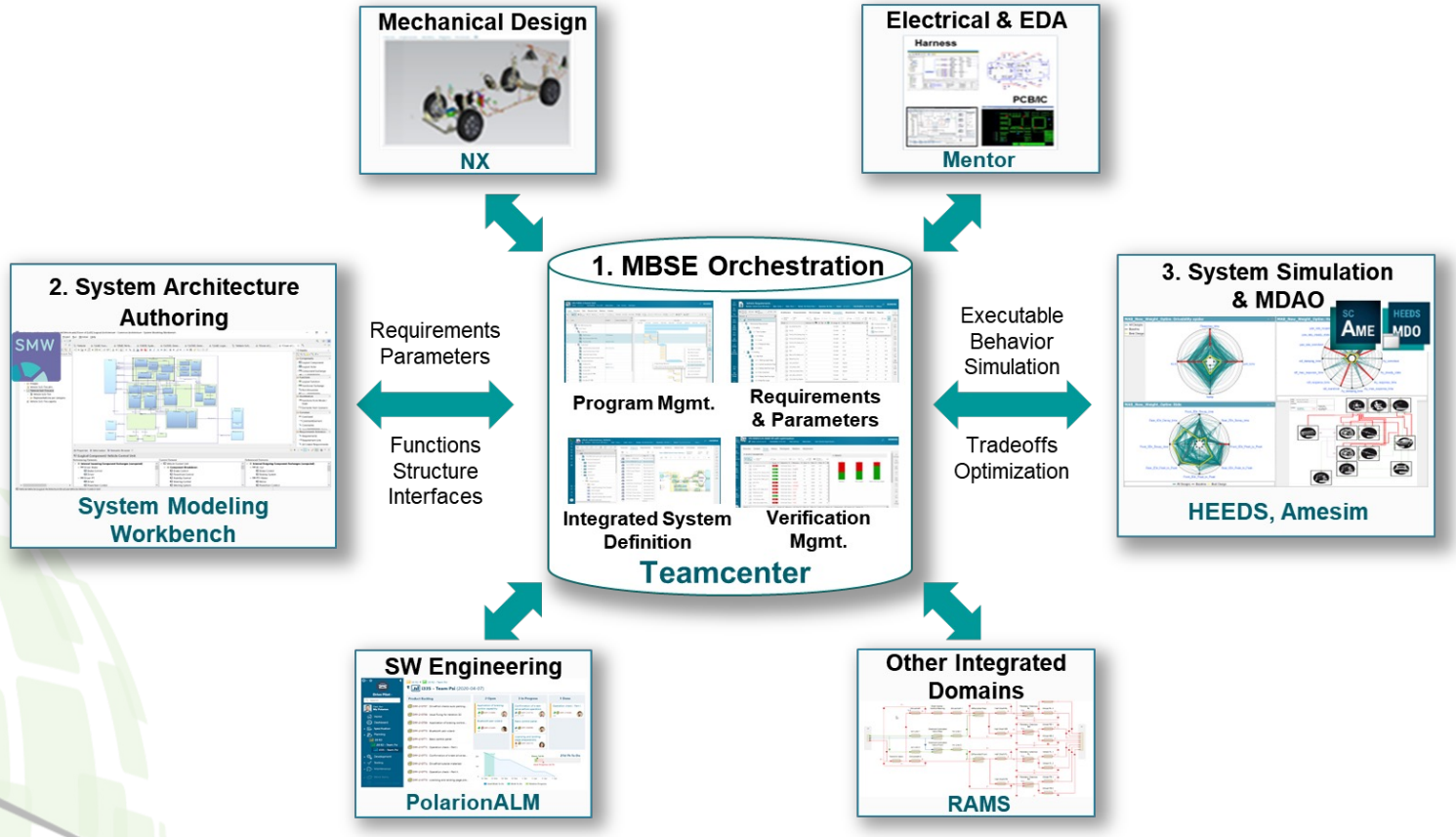
Business Process



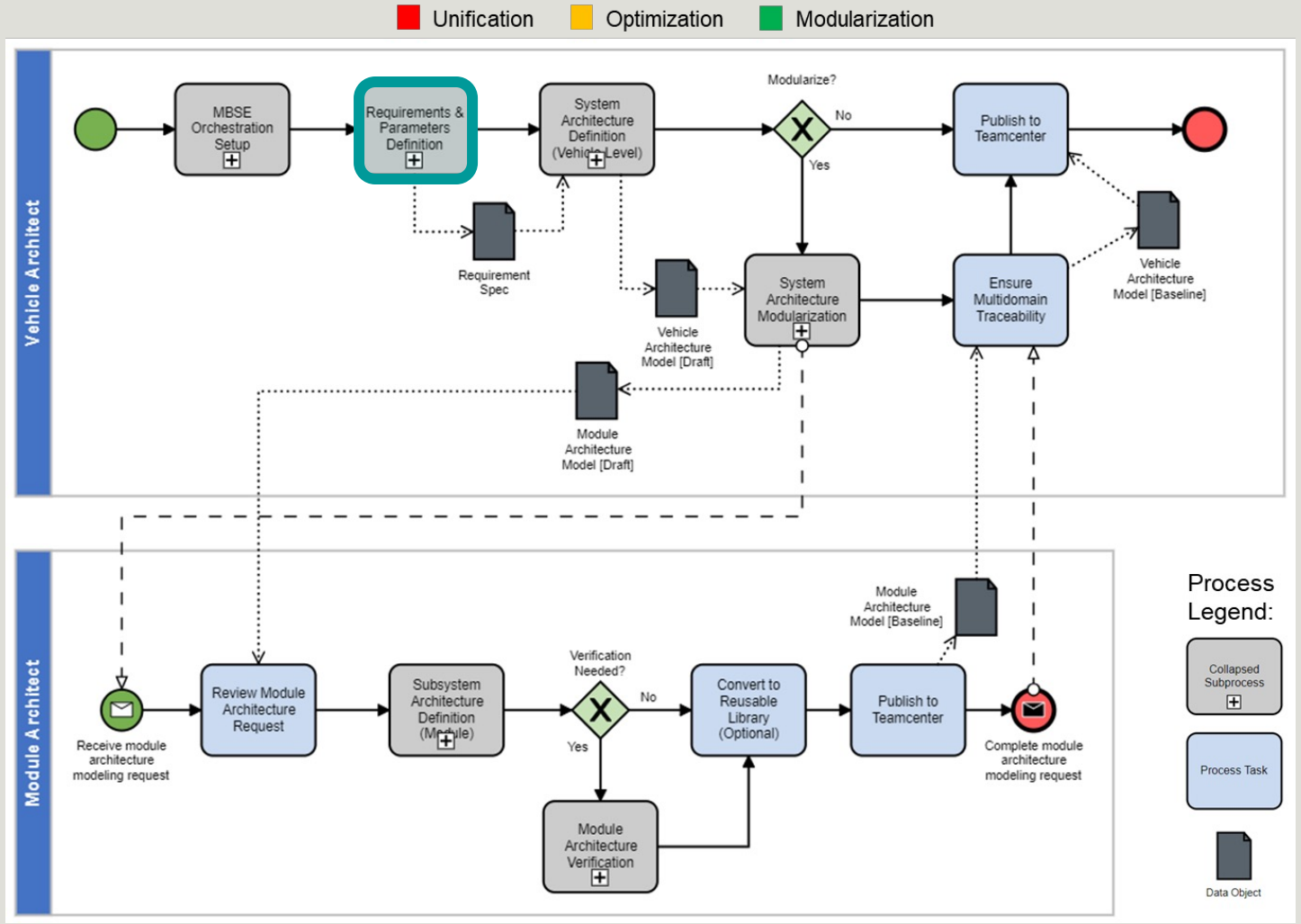

Unification
Optimization
Modularization
Vehicle Architect
MBSE Orchestration Setup
Requirements & Parameters Definition
System Architecture Definition (Vehicle Level)
Modularize?
No
Yes
Publish to Teamcenter
Requirement Spec
Vehicle Architecture Model [Draft]
System Architecture Modularization
Ensure Multidomain Traceability
Vehicle Architecture Model [Baseline]
Module Architecture Model [Draft]
Module Architect
Receive module architecture modeling request
Review Module Architecture Request
Subsystem Architecture Definition (Module)
Verification Needed?
No
Yes
Convert to Reusable Library (Optional)
Module Architecture Verification
Module Architecture Model [Baseline]
Publish to Teamcenter
Complete module architecture modeling request
Process Legend:
Collapsed Subprocess
Process Task
Data Object

Process Tools

1. **MBSE Orchestration:** Teamcenter
2. **System Architecture Authoring**: System Modeling Workbench
3. **Multidisciplinary Design, Analysis & Optimization**: Simcenter HEEDS, Amesim



1 Requirements and Parameters Definition



Inputs:

- SoS vision, problem / opportunity statements, strategic targets
- MBSE orchestration environment readiness

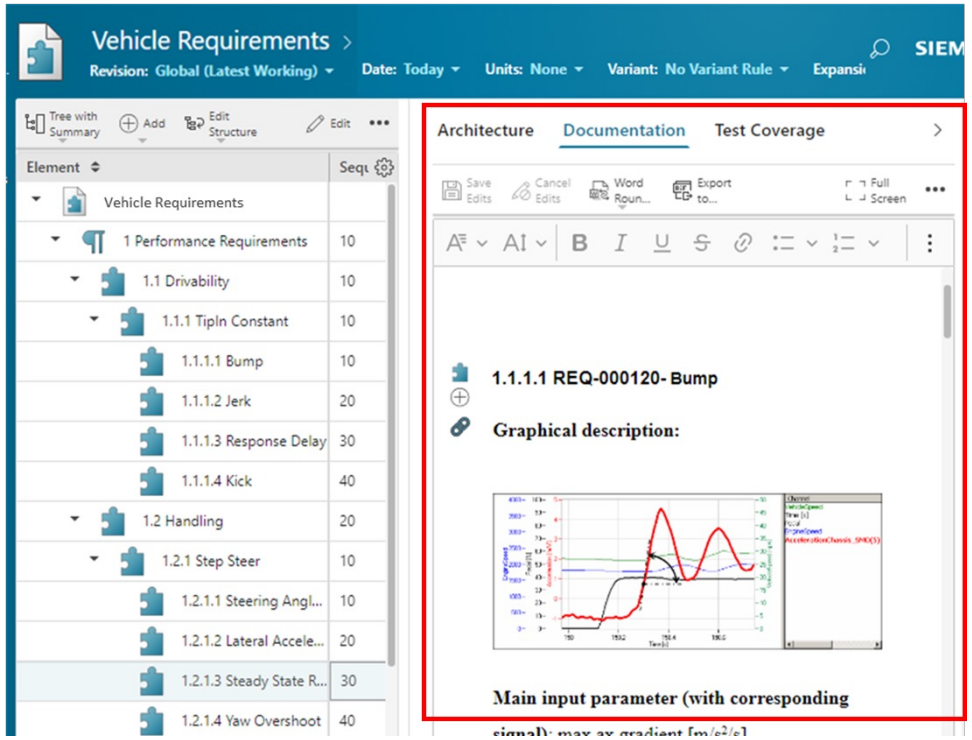
Activities:

- Multi-stakeholder requirement definition
- System / component requirement definition
- Configurable requirements with linked configurable parameter objects
- Traceability to various stages of development

Outputs:

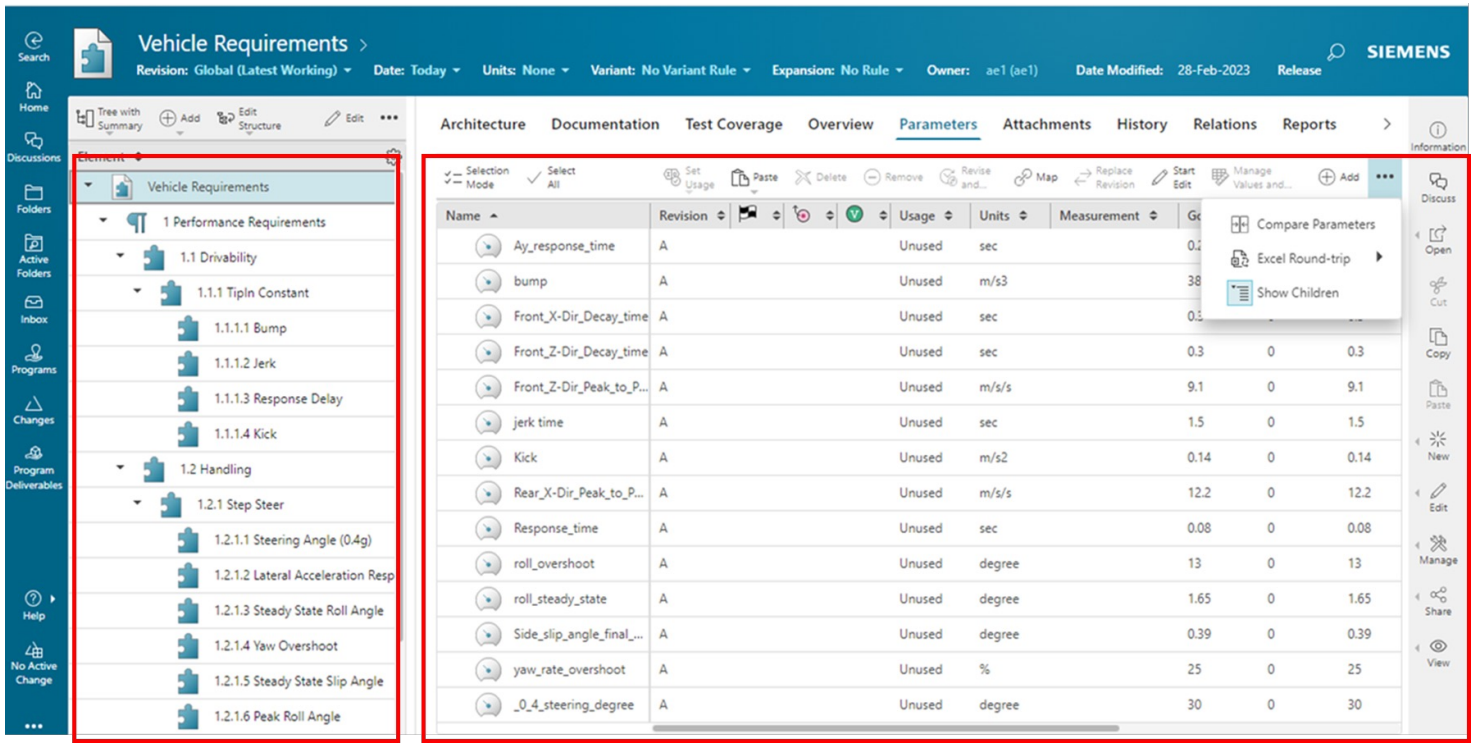
- Multi-level requirements specification
- Parameter definitions
- Requirement text - parameter mapping

Requirements and Parameters Definition



Requirement Specification Tree

Rich-text Description

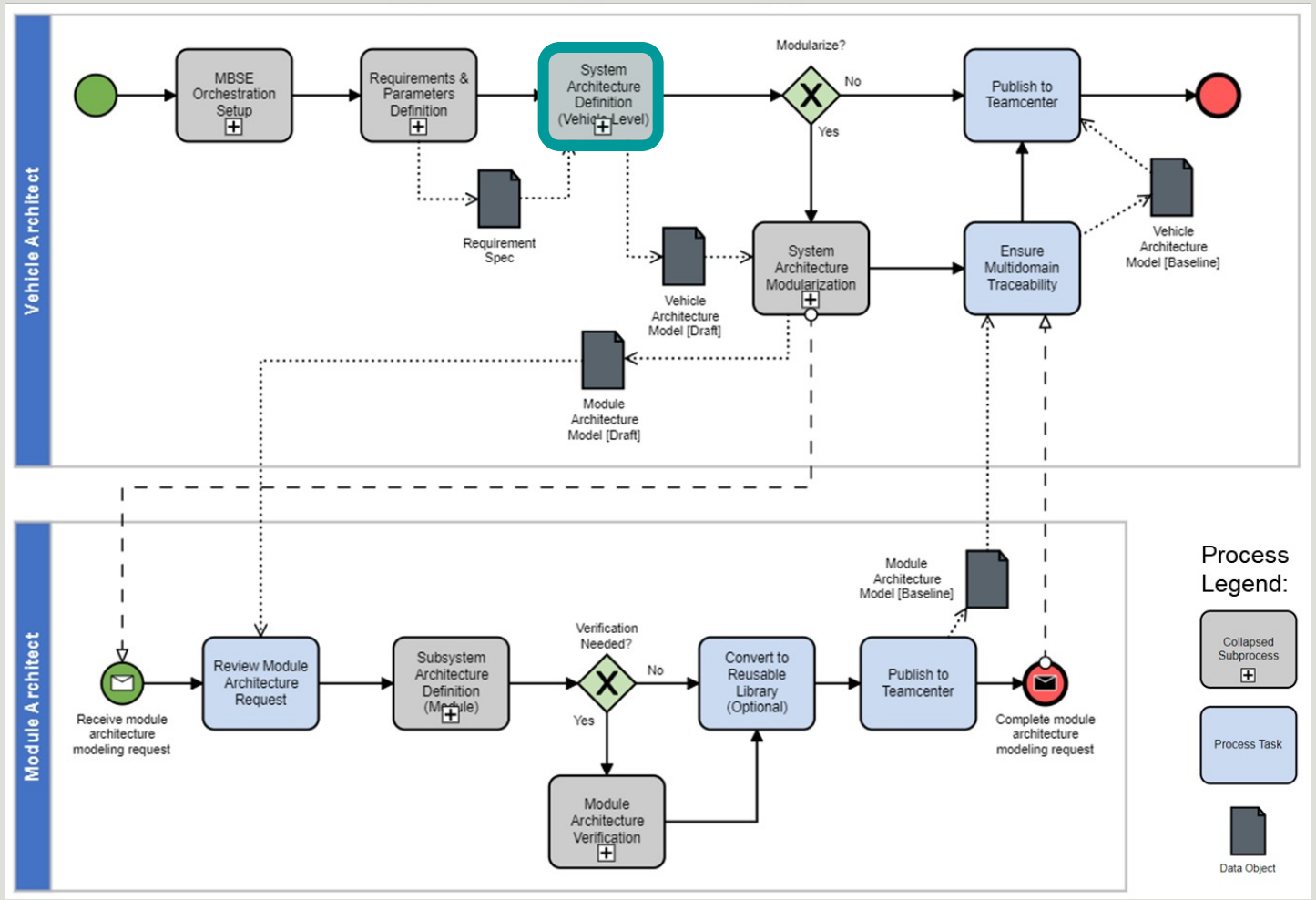


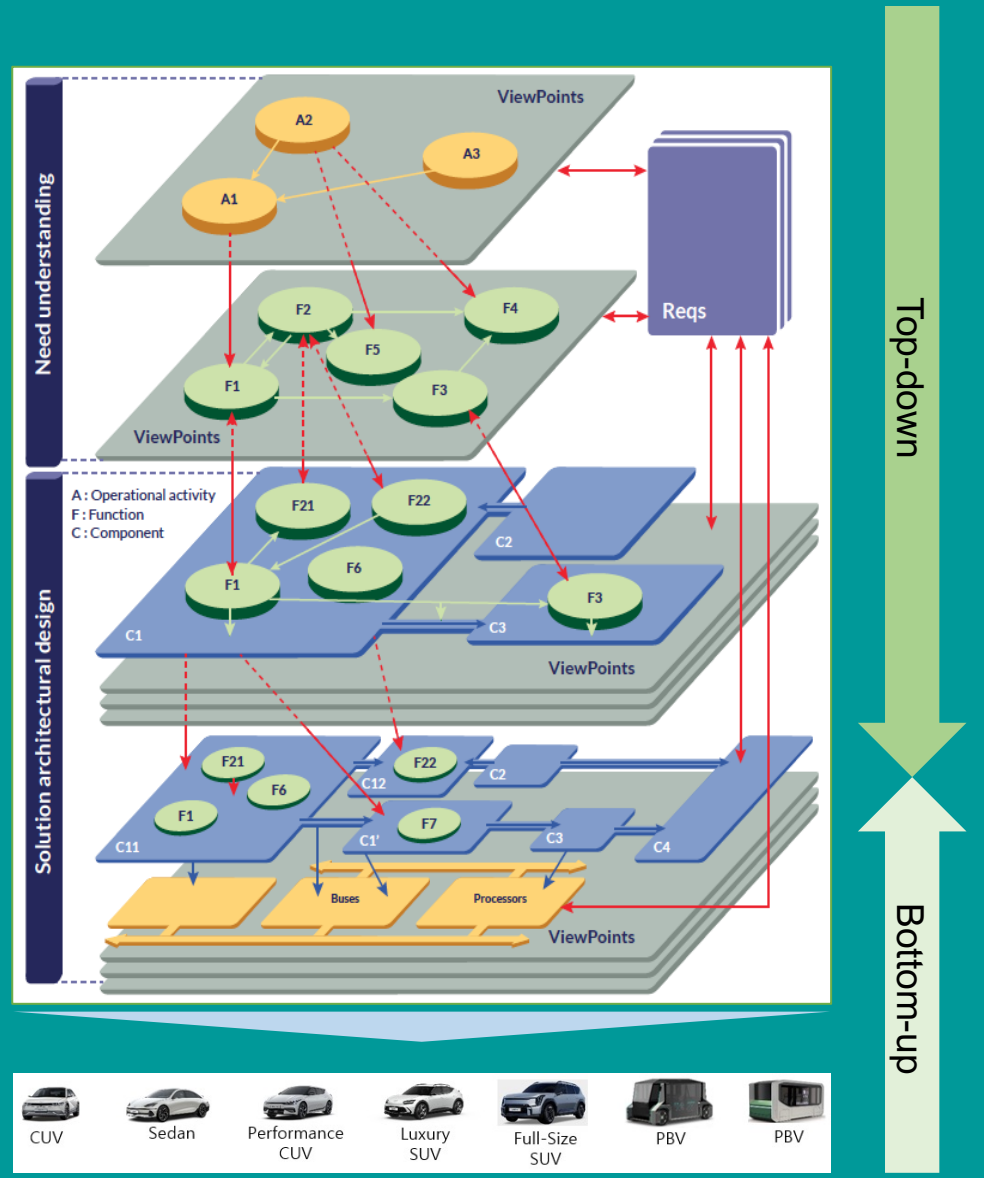
Requirement Specification Tree

Requirement Parameters

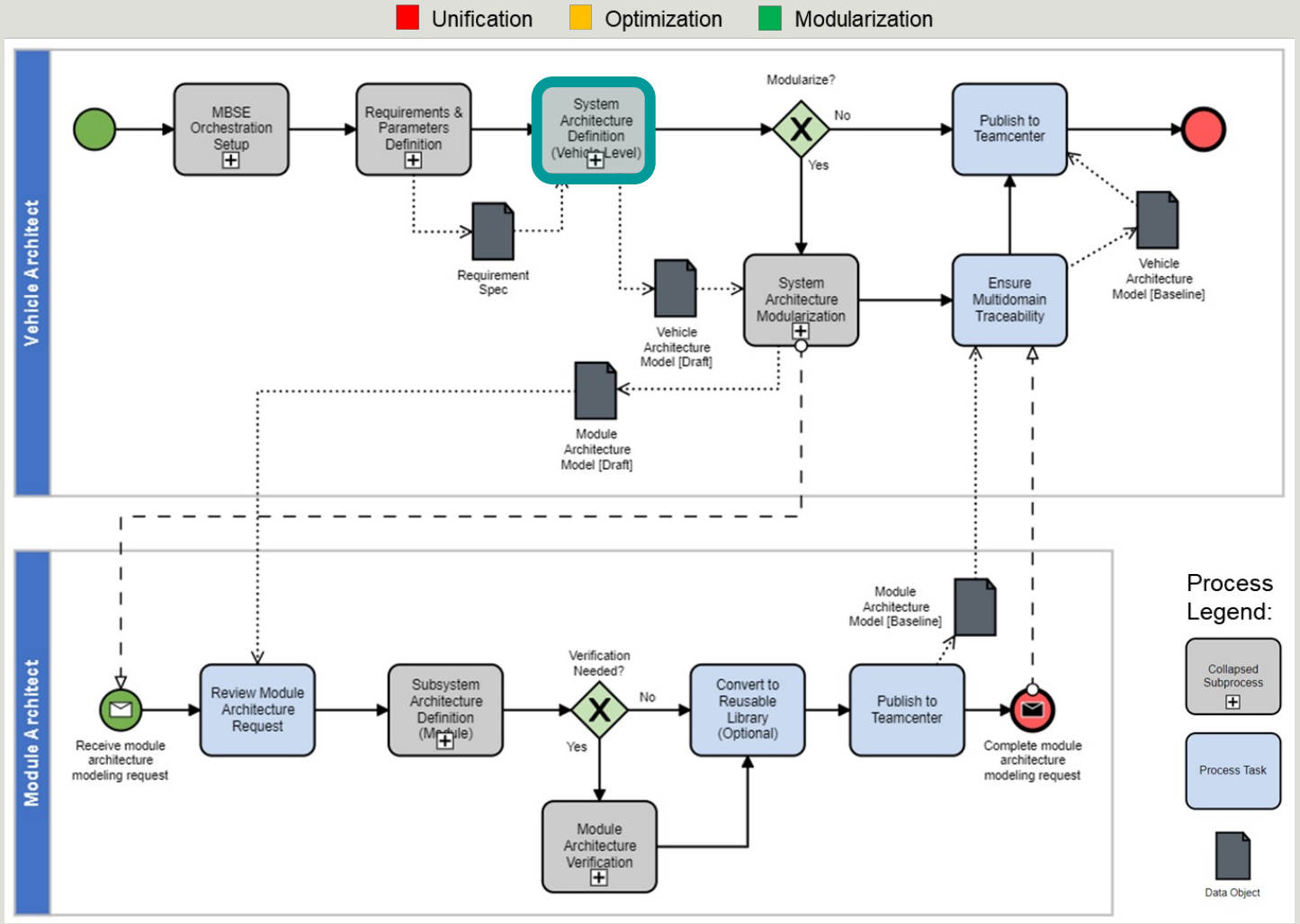
2 System Architecture Definition

Unification Optimization Modularization





2 System Architecture Definition (Operational Analysis)



Inputs:

- SoS needs and constraints
- Preliminary system needs

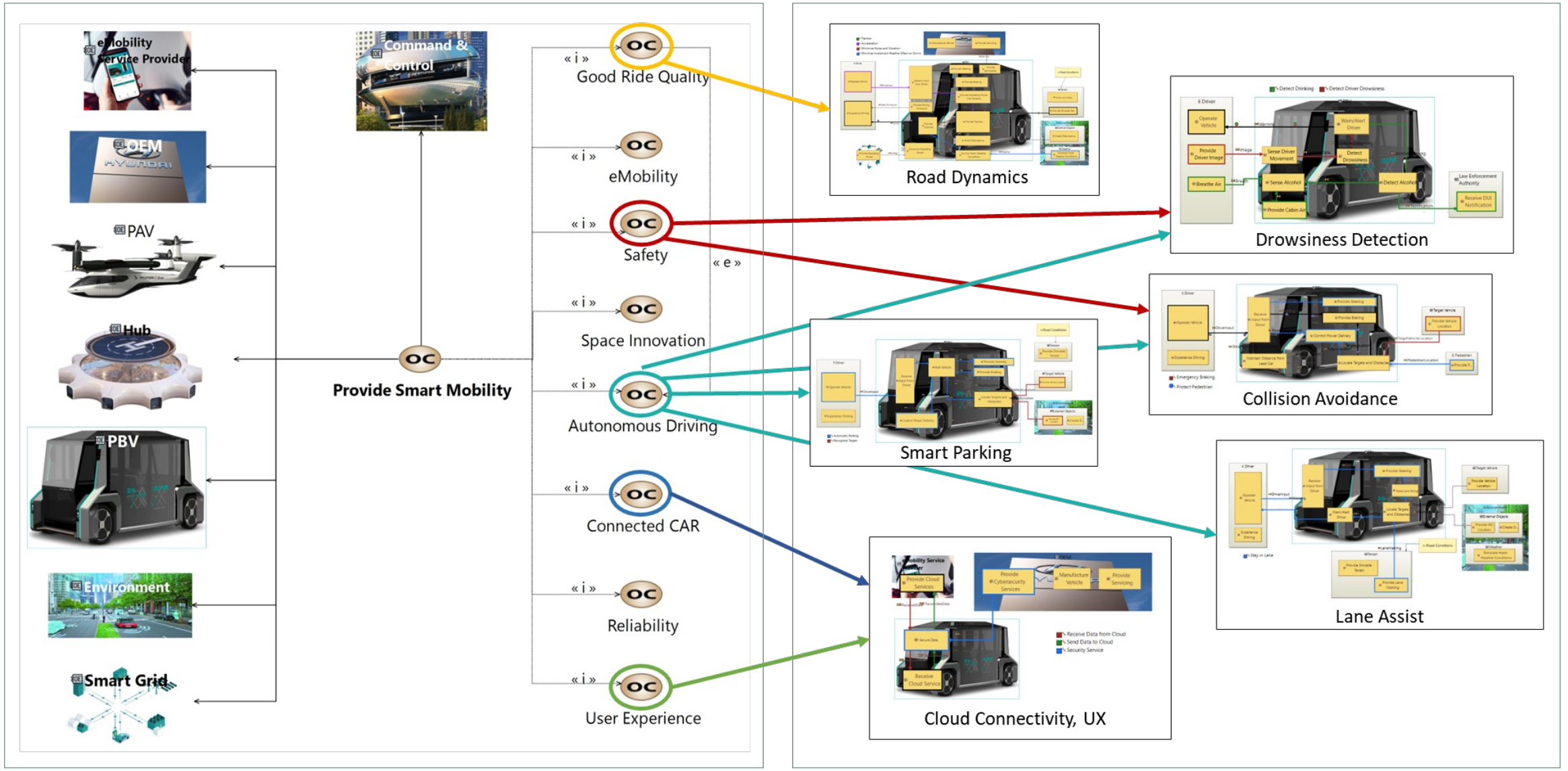
Activities:

- Model SoS mission capabilities
- Define operational behavior
- Define operational architecture
- Refine / allocate stakeholder needs
- Analyze operational model

Outputs:

- SoS interface constraints
- Refined SoS requirements
- Preliminary functional model

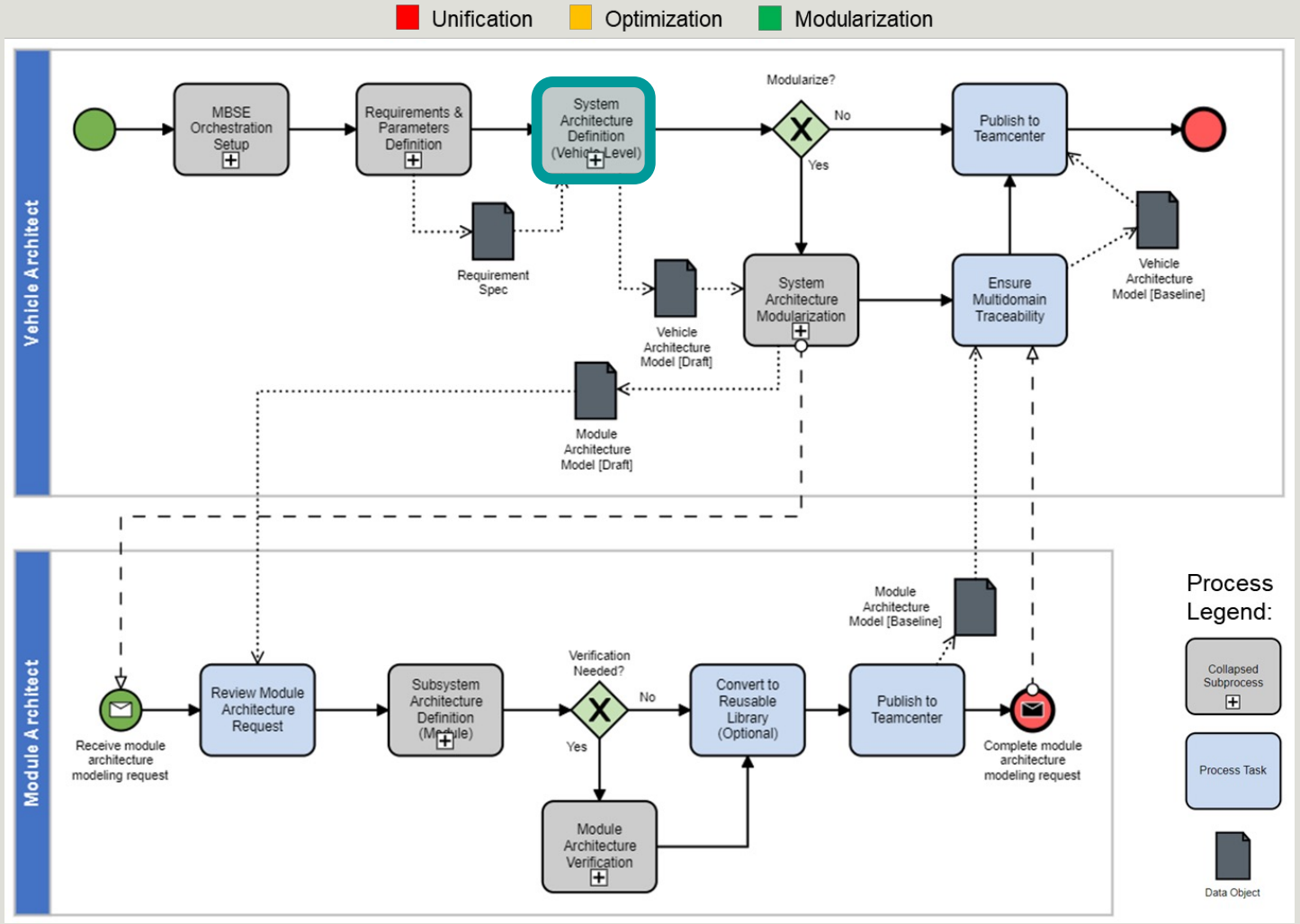
Operational Analysis



SoS Operational Capabilities

SoS Operational Scenarios

2 System Architecture Definition (System Analysis)



Inputs:

- Stakeholder requirements spec
- Operational architecture
- System capabilities

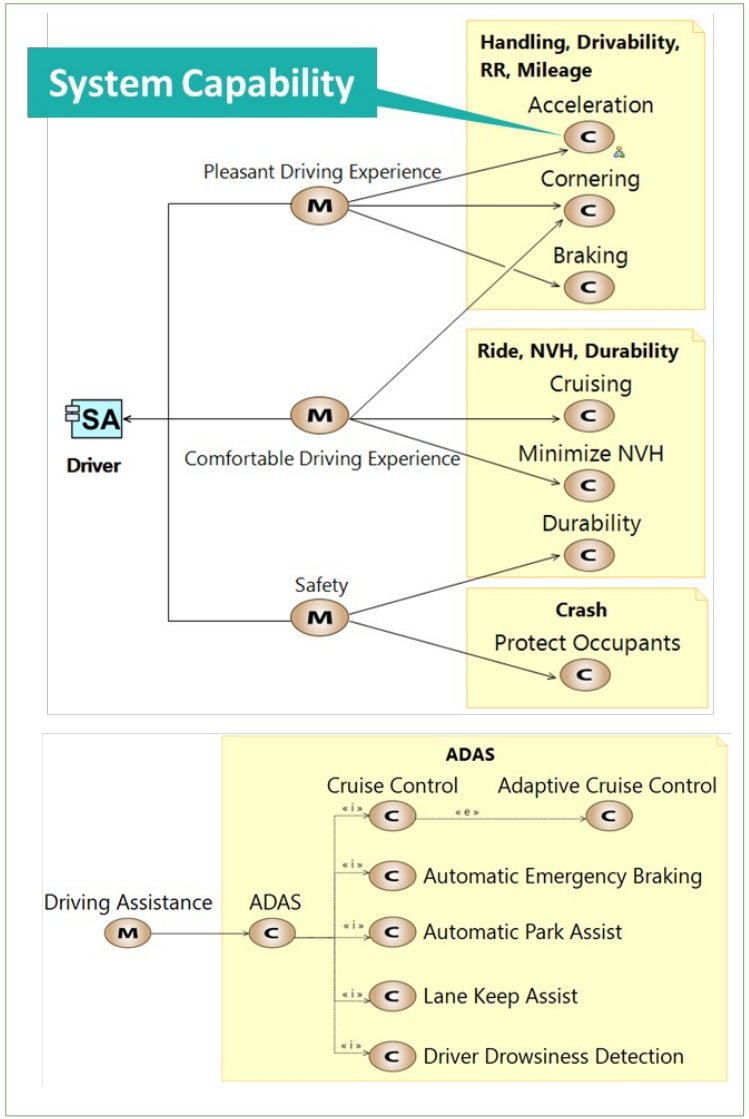
Activities:

- Model system capabilities
- Define and allocate system/actor functions
- Contextualize system-of-interest

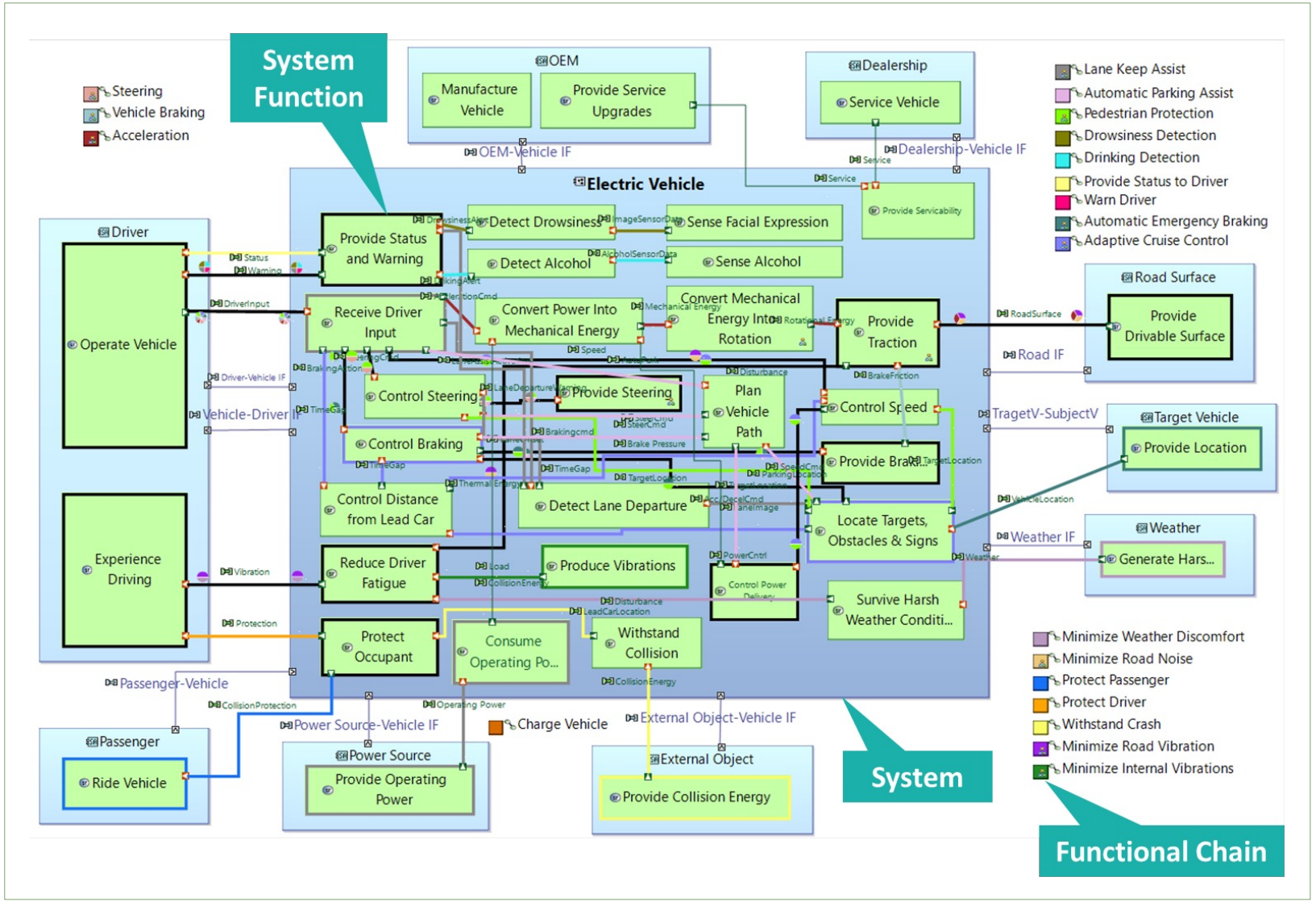
Outputs:

- Blackbox architecture model (configurable)
- System requirements spec
- Functional scenarios spec

System Analysis

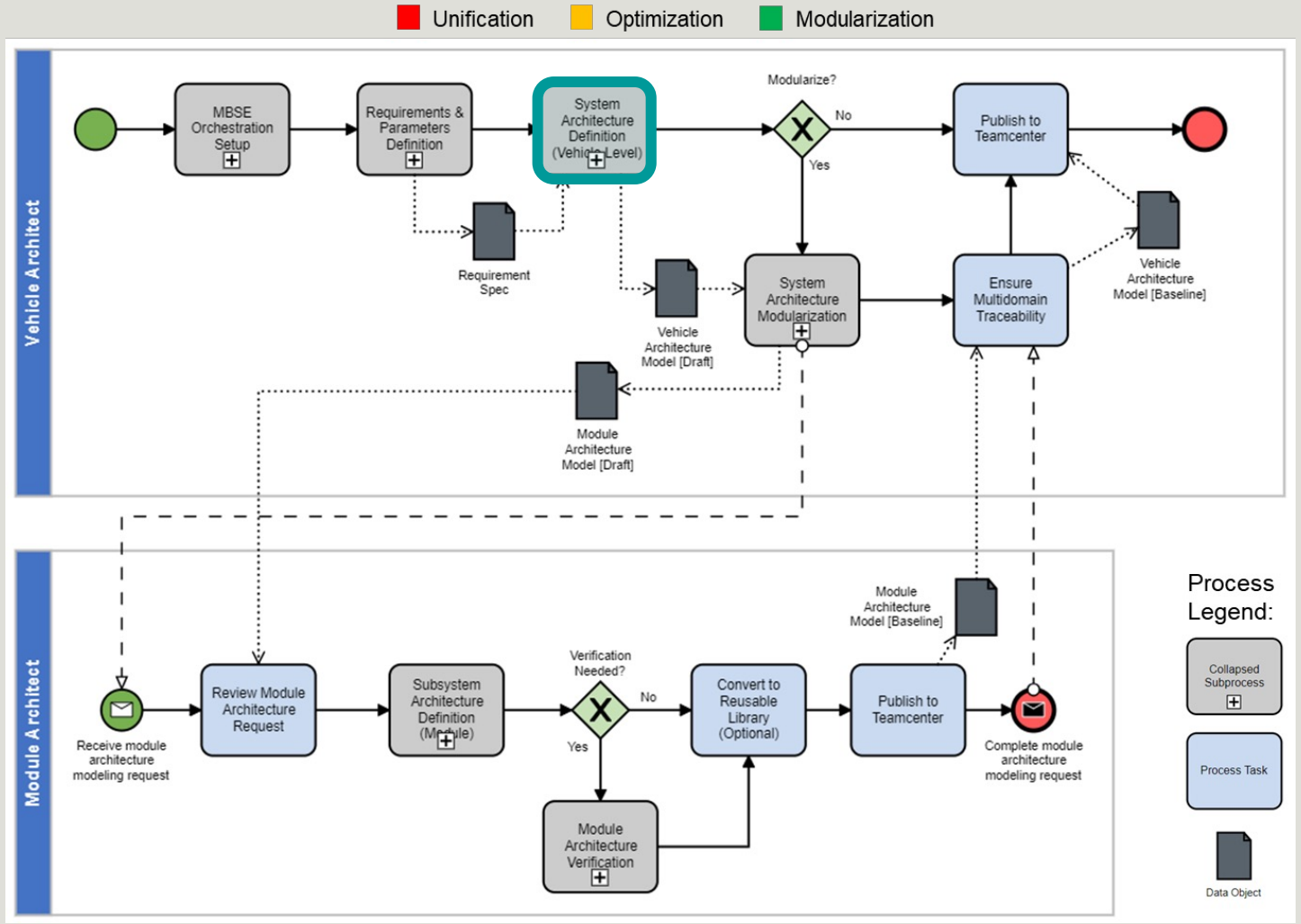


System Capabilities



System Blackbox Architecture (Integrated View)

2 System Architecture Definition (Logical Architecture)



Inputs:

- Blackbox system architecture
- Vehicle performance requirements

Activities:

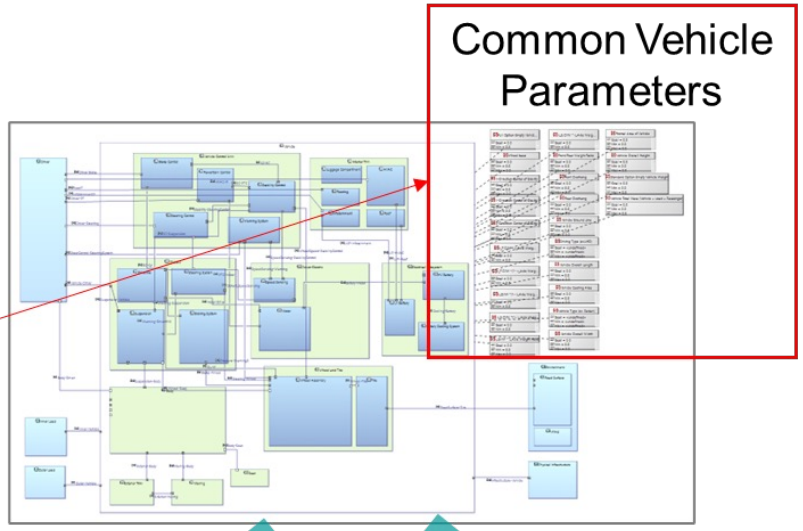
- Decompose logical system
- Allocate functions to logical components
- Define internal interfaces (white box)
- Generate stakeholder concerns (views)
- Requirement / parameter traceability

Outputs:

- Logical architecture model (configurable)
- Performance allocation & traceability
- Performance verification views

Logical Architecture

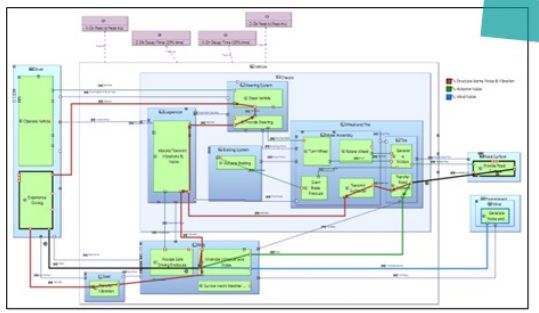
- Common Parameters
  - Driving Type (ex.LHD)
  - Vehicle Overall Height
  - Front Overhang
  - Wheel base
  - Y-Direction Center of Gravity
  - v_GVW *(1- v_Axle Weight Ratio)
  - Vehicle Overall Length
  - Full Option Empty Vehicle Weight
  - Vehicle Total Mass (Vehicle + Load + Passenger)
  - Standard Option Empty Vehicle Weight
  - Vehicle Ground Line
  - Vehicle Overall Width
  - Front/Rear Weight Ratio
  - Frontal Area of Vehicle
  - Rear Overhang
  - Vehicle Cooling Area
  - v_GVW * v_Axle Weight Ratio
  - v_F.CVW * v_Axle Weight Ratio
  - v_S.CVW * v_Axle Weight Ratio
  - Z-Direction Center of Gravity
  - X-Direction Center of Gravity
  - Vehicle Type (ex. Sedan)
  - v_S.CVW *(1- v_Axle Weight Ratio)
  - v_F.CVW *(1- v_Axle Weight Ratio)

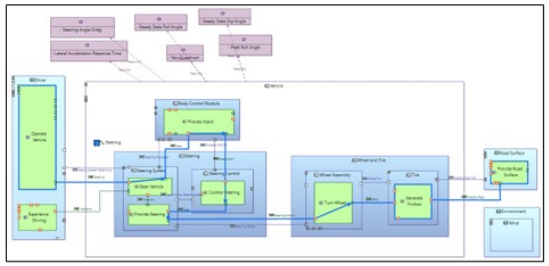


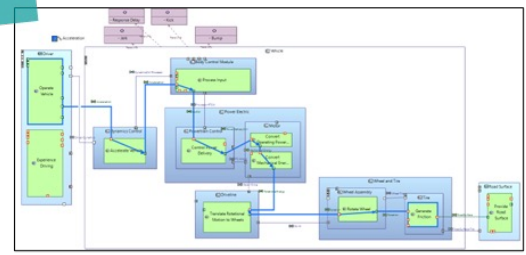
Ride Comfort

Handling

Drivability

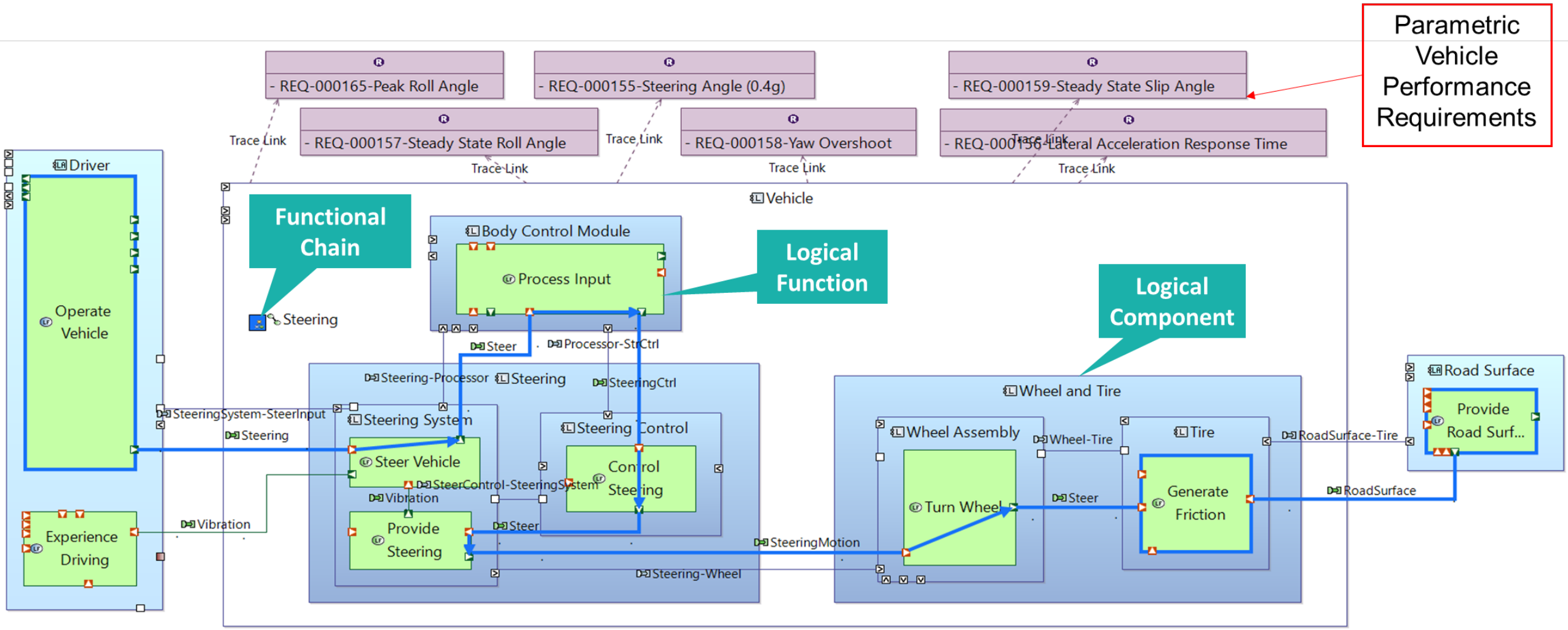






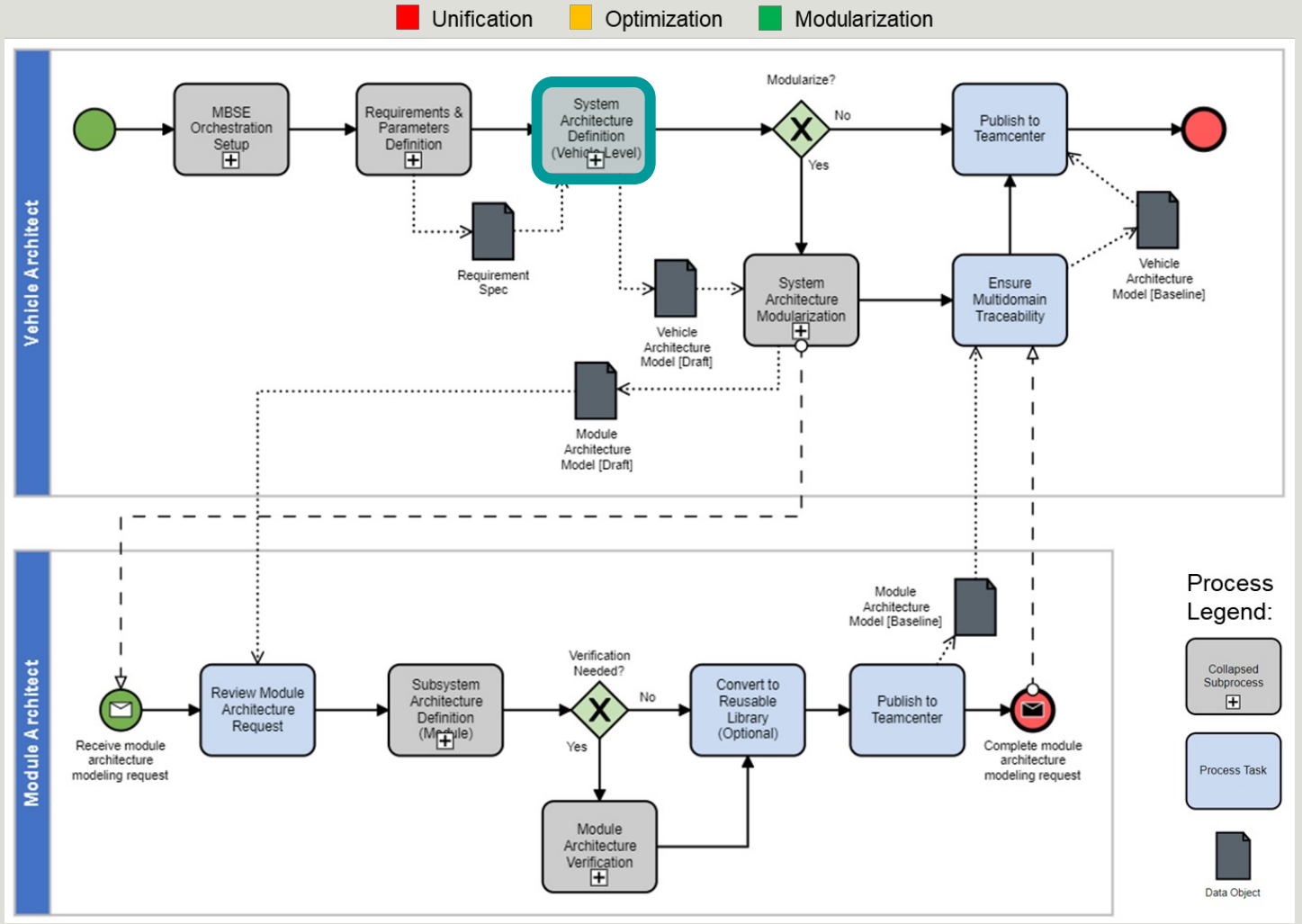
Common Vehicle Parameters, Logical Architecture Views, Traceability

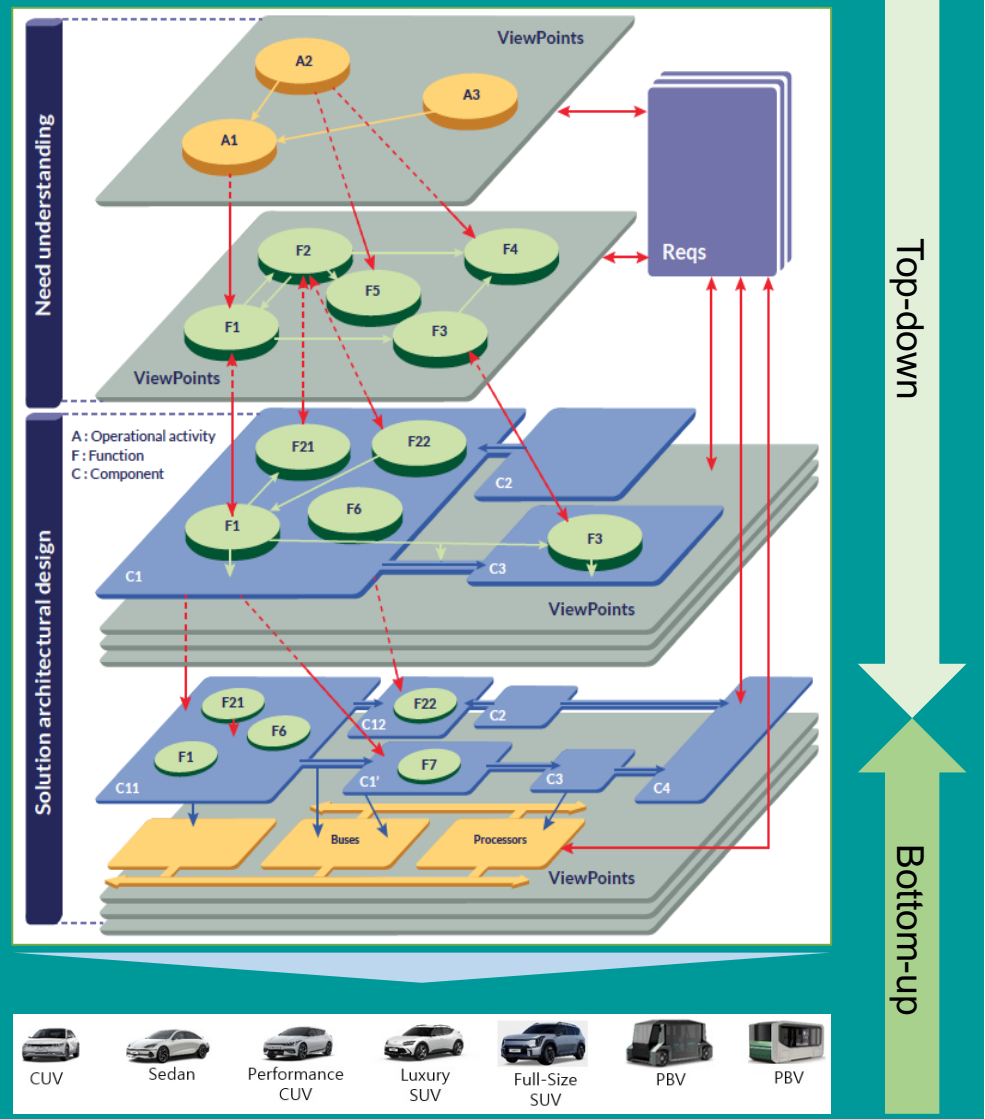
Logical Architecture



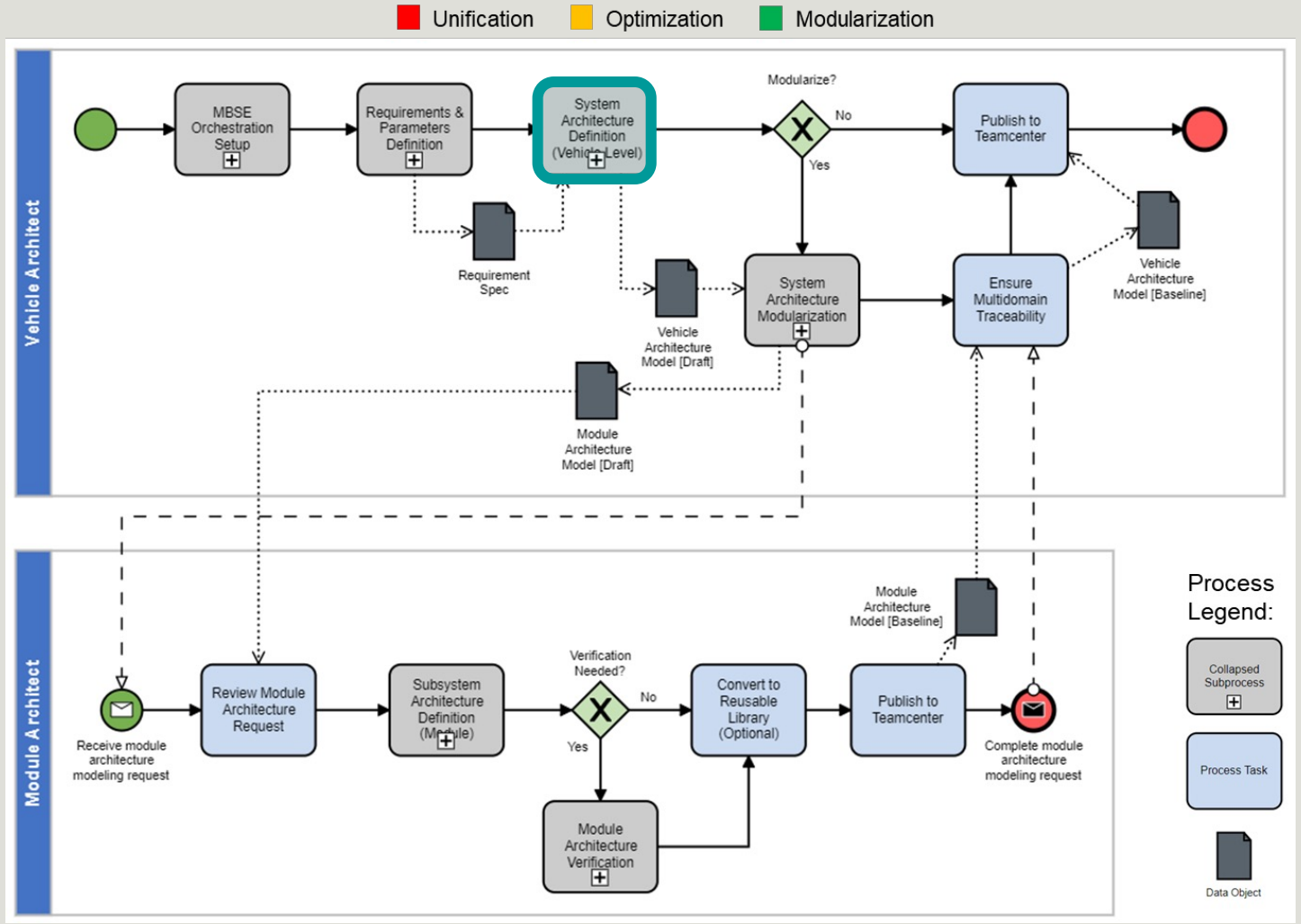
Logical architecture “view” representing handling functionality

3 System Architecture Definition (Physical Architecture)





3 System Architecture Definition (Physical Architecture)



Inputs:

- Logical architecture alternatives
- Performance analysis results
- Existing product BOM

Activities:

- Allocate logical components to physical components (from existing BOM)
- Model physical interfaces
- Orchestrate MDAO
- Evaluate logical alternatives and fix technology choices (tradeoffs, opt.)
- Trace component design requirements and parameters to architecture elements

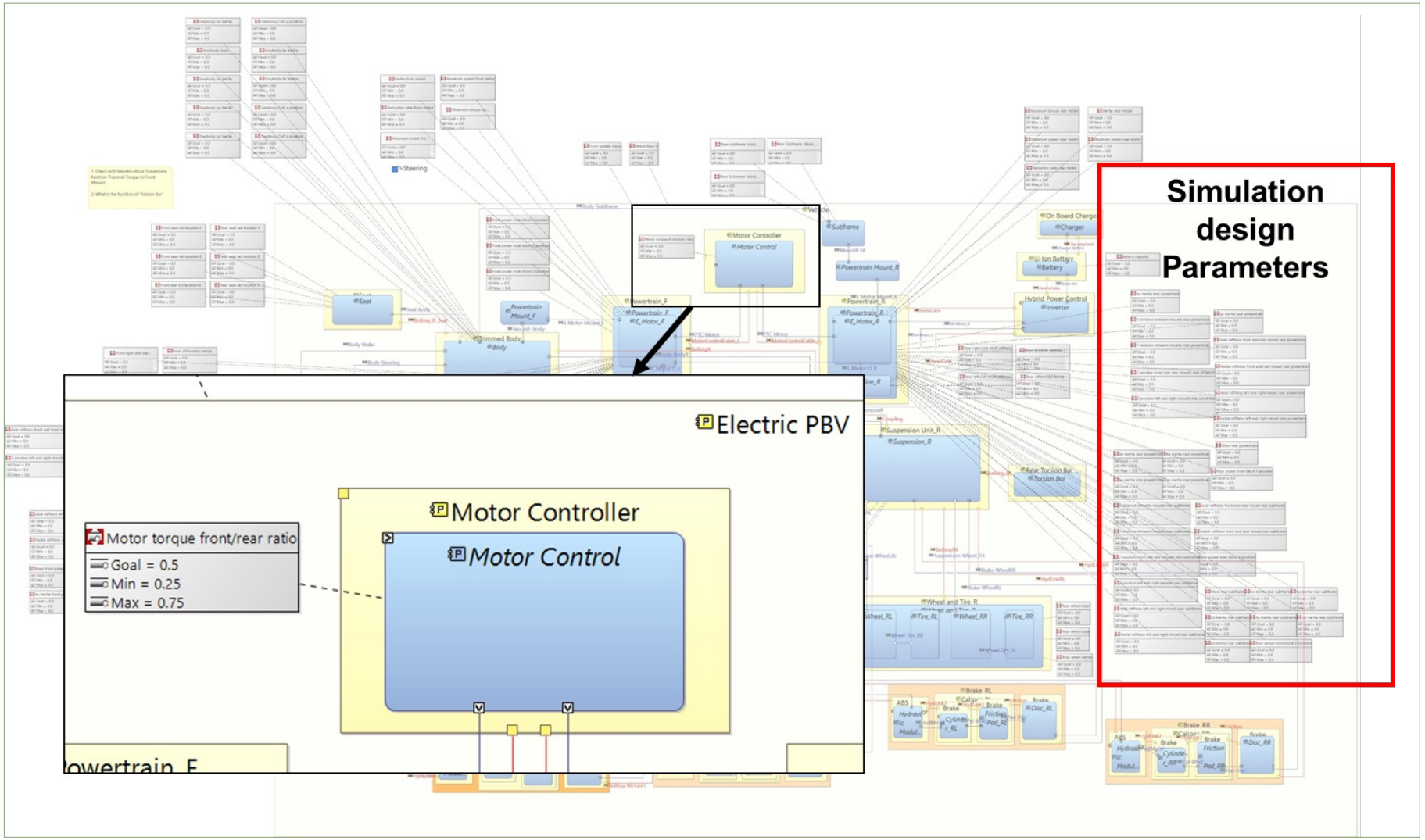
Outputs:

- Physical architecture model (configurable)
- Product breakdown structure / preliminary EBOM
- Preliminary component design specification

Physical Architecture

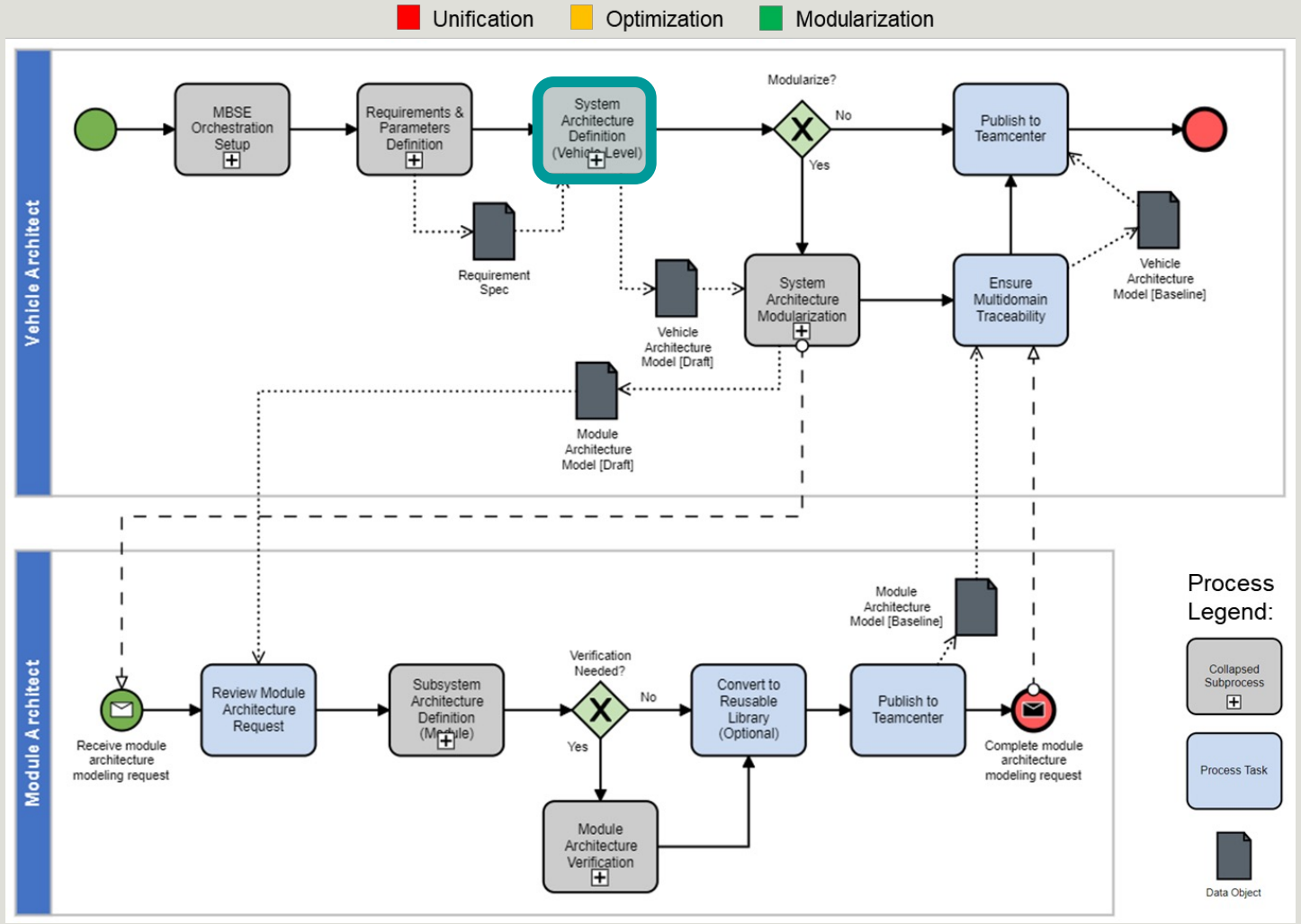
- Physical Architecture
  - Physical Functions
  - Capabilities
  - Interfaces
  - Data
  - Structure
    - Physical System
      - Vehicle Structure-Lv0
        - Body Structure-Lv1
        - Seat-Lv1
        - Power Electric-Lv1
        - Chassis-Lv1
          - General Code = G00000
          - Suspension Accessory-Lv2
          - Suspension Axle-Lv2
            - General Code = GB0000
            - Wheel and Tire-Lv3
              - General Code = GB1000
              - Wheel and Tire_R
              - Wheel and Tire_F
            - Front Axle-Lv3
            - Rear Axle-Lv3
          - Front Suspension-Lv2
          - Rear Suspension-Lv2
          - Air Suspension-Lv2
          - Muffler-Lv2
          - Brake-Lv2
          - Fuel-Lv2
          - MTG-Lv2
          - Driveline-Lv2
          - Control-Lv2
          - Cooling-Lv2
          - Steering-Lv2

Physical system breakdown



Performance simulation “view” with linked simulation parameters

3 System Architecture Definition (Performance Verification)



Inputs:

- Physical architecture model for perf. sim
- Performance verification requests
- Reusable multiphysics simulation models and libraries

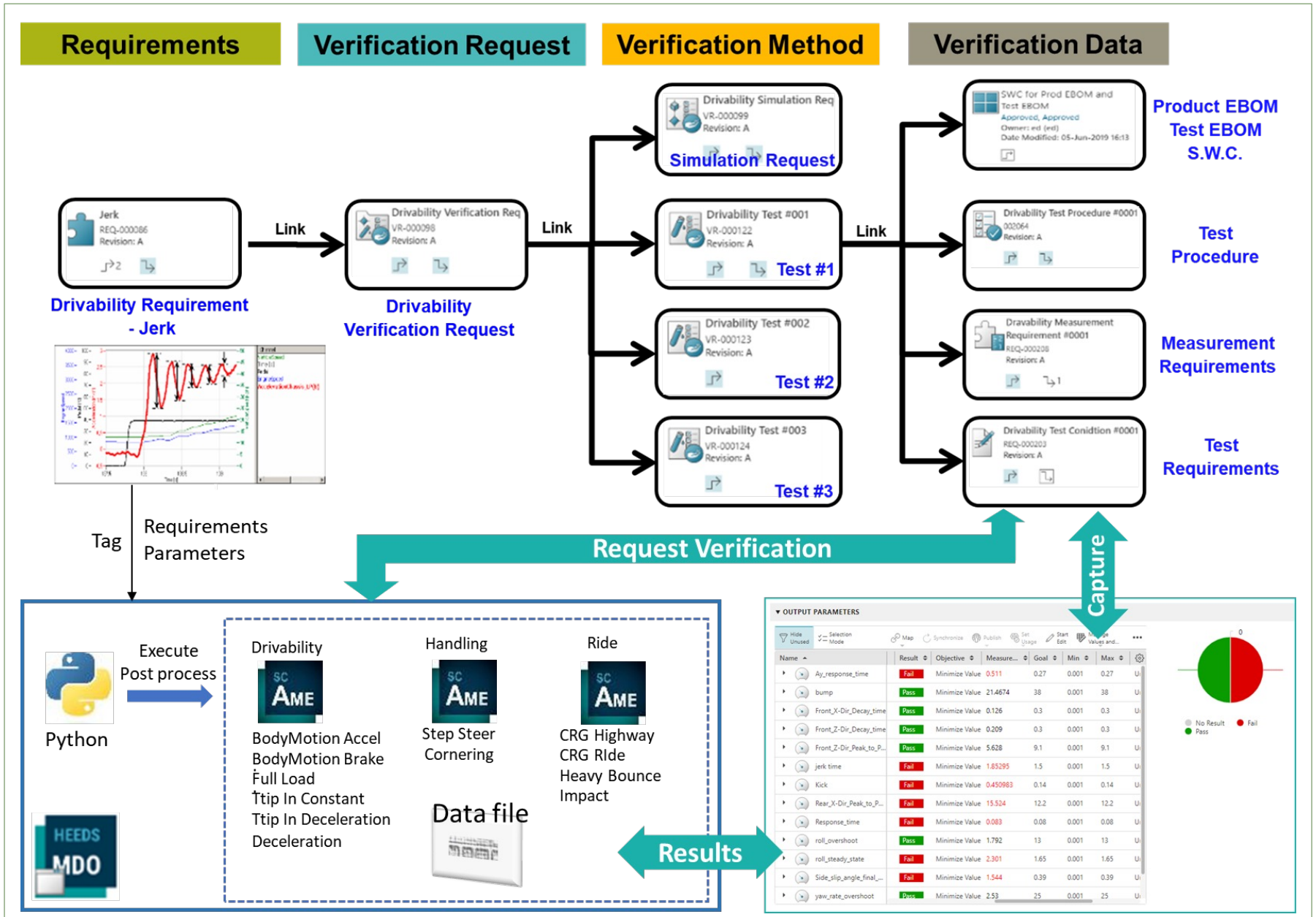
Activities:

- Initiate performance verification requests
- Tradeoff studies, optimization
- Submit verification request results
- Fix technology design parameters and baseline physical architecture
- Share granular vehicle architecture model to the LM repository (integrated system definition)

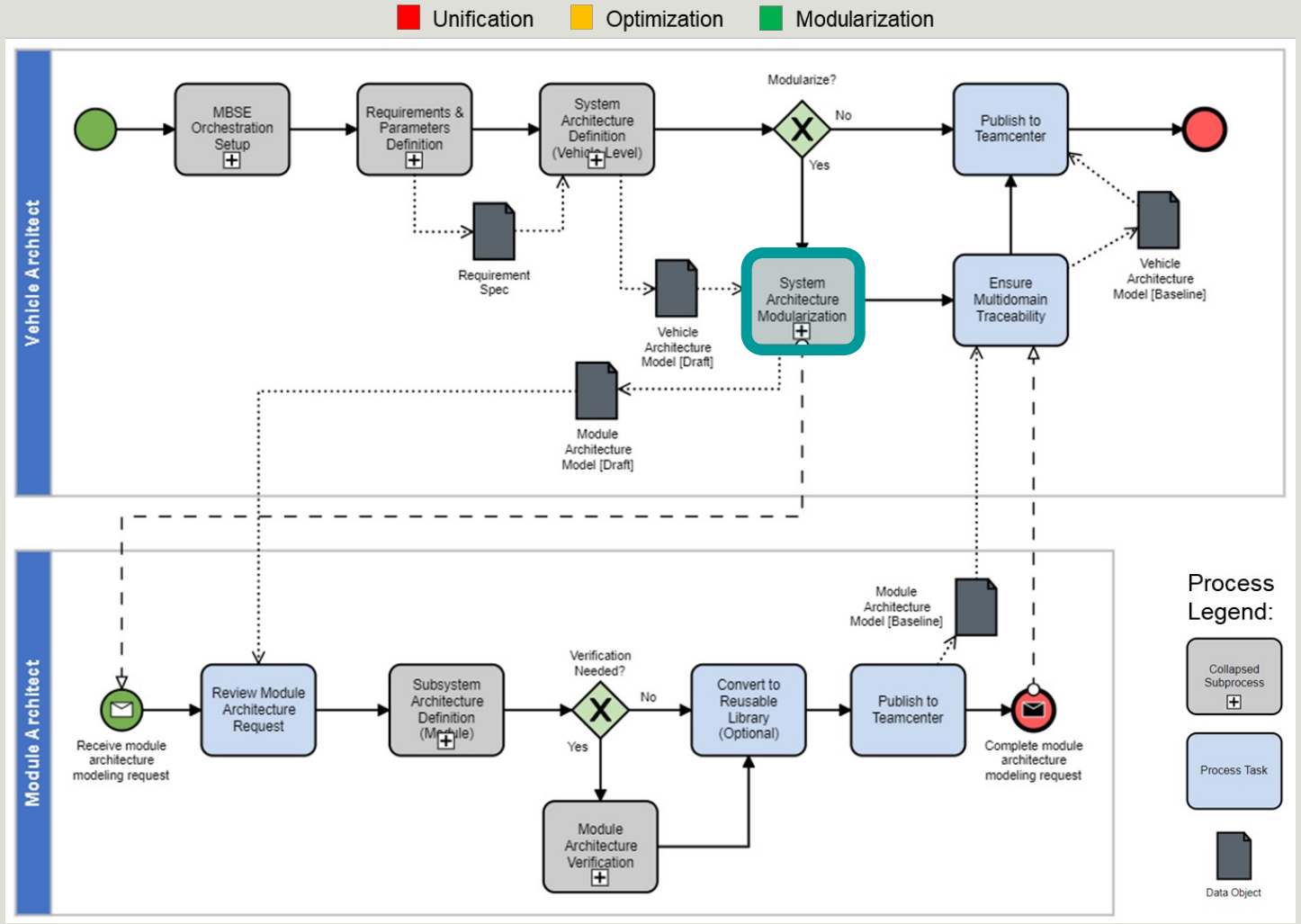
Outputs:

- Baselined vehicle architecture model (configurable)
- Product breakdown structure / preliminary EBOM
- Preliminary component design specification

Performance Verification



4 Architecture Modularization

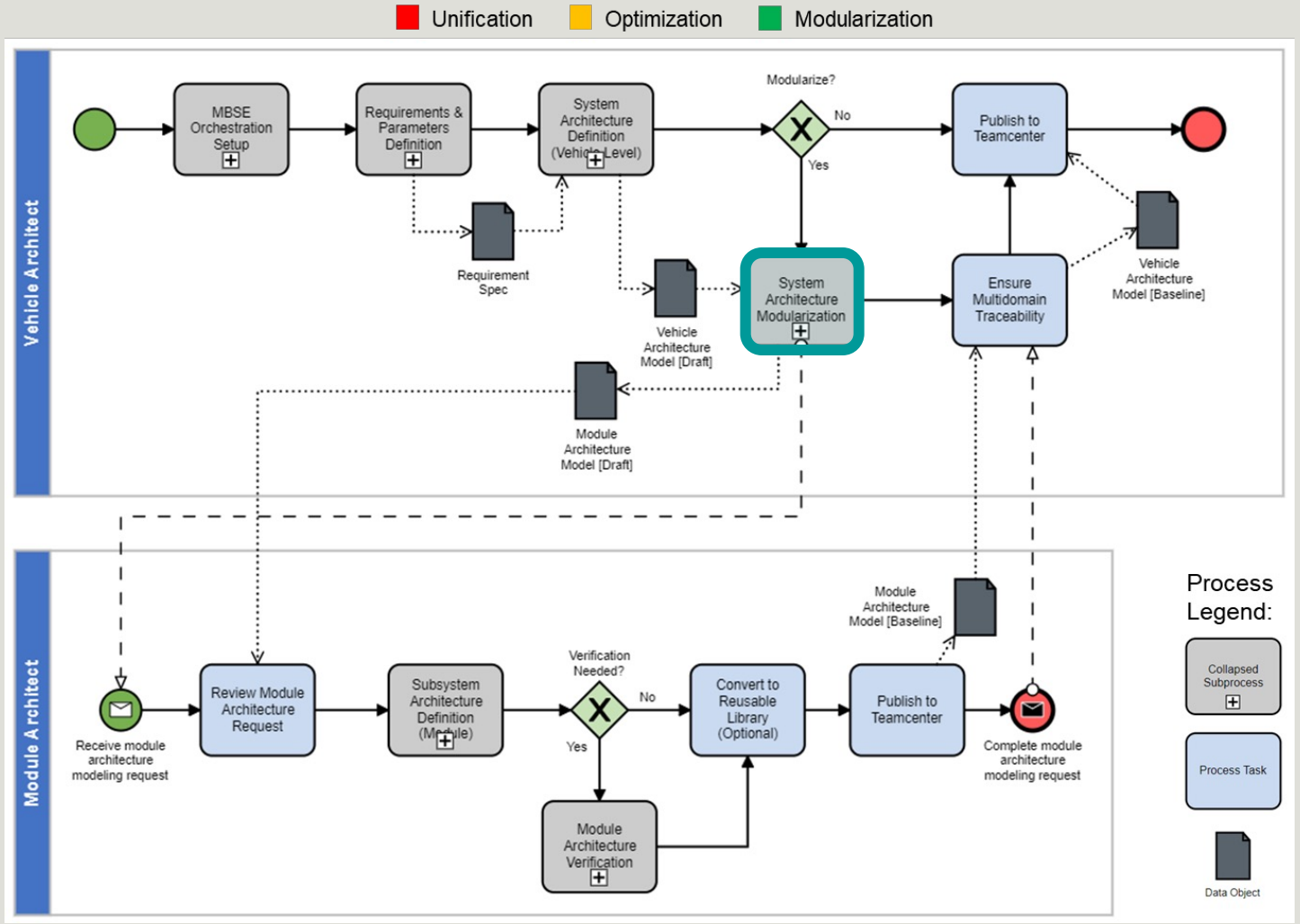


Several criteria pertaining to the development teams responsible for architecture definition are crucial for achieving modularity.

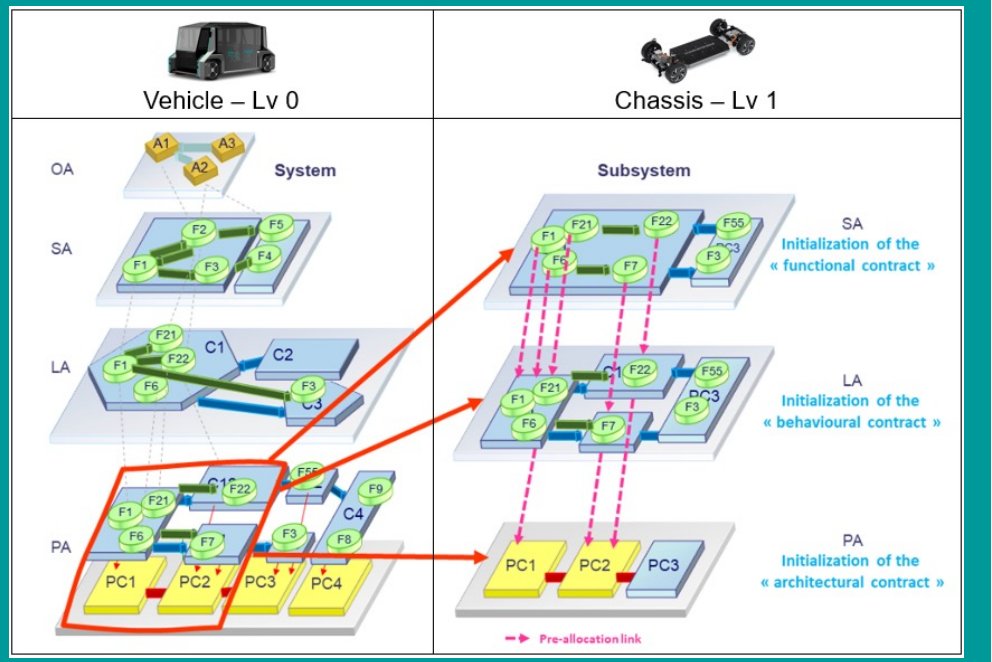
For this study, following 3 criteria are deemed essential:

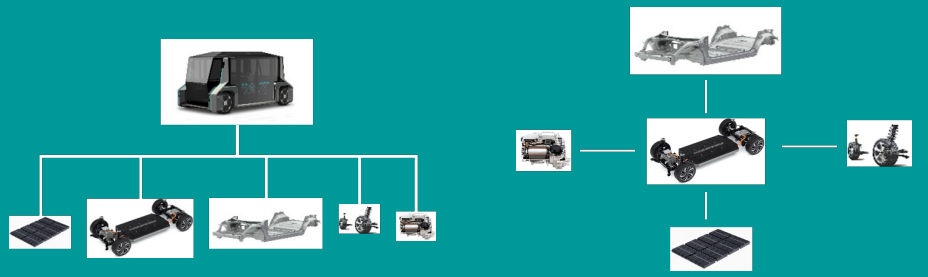
1. **Module Standardization**
2. **Interfaces**
3. **Reusability**

4 Architecture Modularization

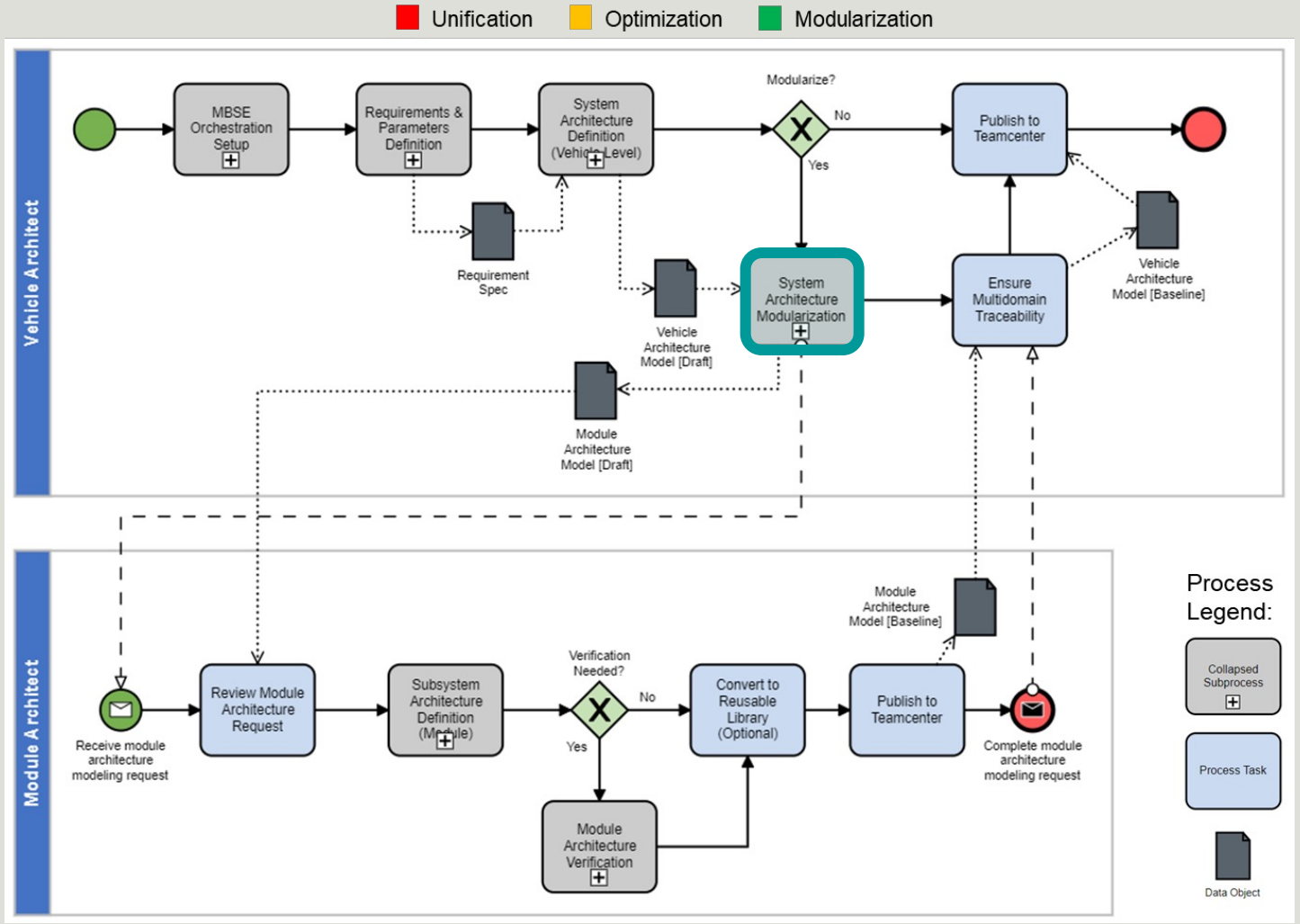


Automated system to subsystem transitions





4 Architecture Modularization



Inputs:

- Vehicle architecture model
- Requirement / parameter traceability
- Existing module classification data

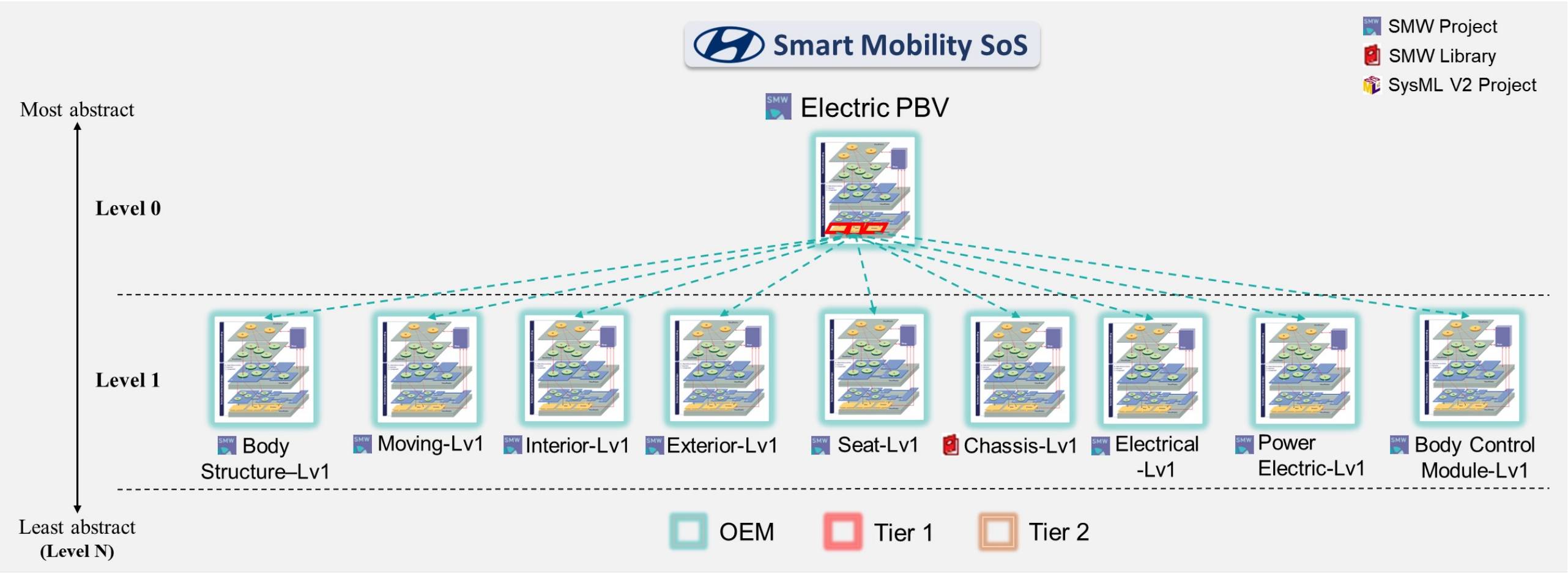
Activities:

- Assign generic vehicle coding to system breakdown
- Define module boundaries
- Generate module architecture models from vehicle architecture model
- Save vehicle / module architectures in enterprise catalog

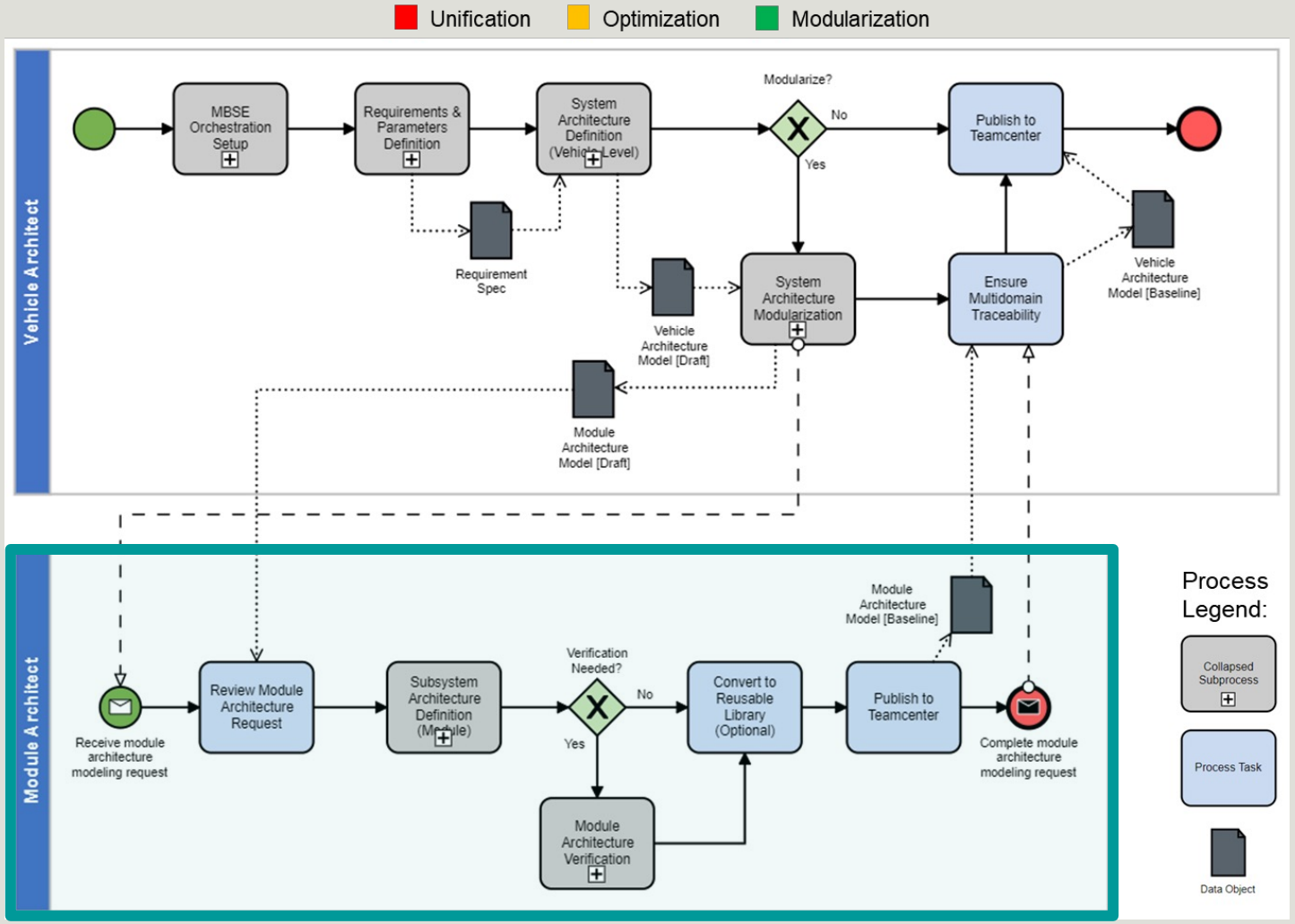
Outputs:

- Draft vehicle / module architecture models (configurable)
- Draft module requirement spec
- Traceability to domain-specific models and structures

Architecture Modularization



5 Module Architecture Development



Inputs:

- Module architecture draft
- Requirement / parameter traceability
- Module usage context

Activities:

- Refine module architectures
- Create reusable module libraries
- Define module interfaces, assign generic module coding
- Save vehicle / module architectures in enterprise catalog
- Release module architecture

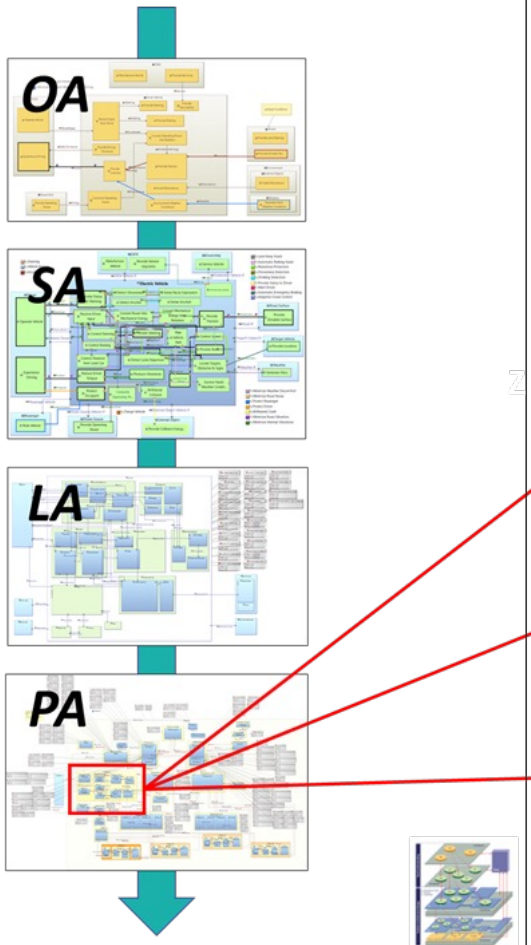
Outputs:

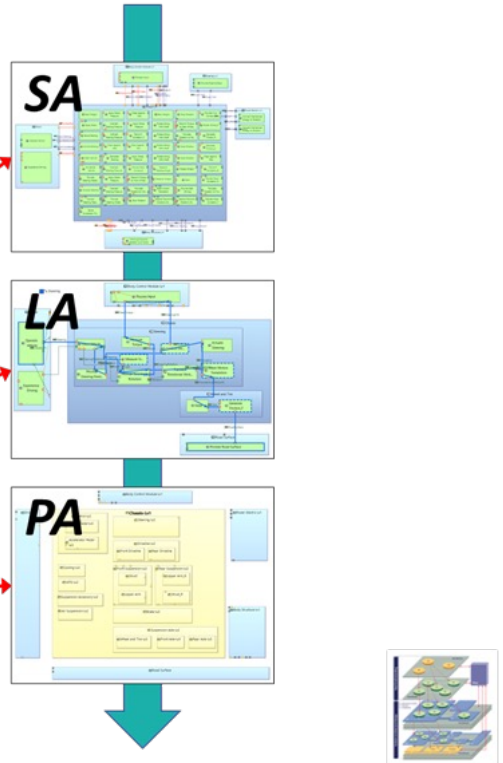
- Baselined module architecture model (configurable)
- Model-based module interface definition
- Reusable libraries of module architectures

Module Architecture Development

PBV – Lv 0

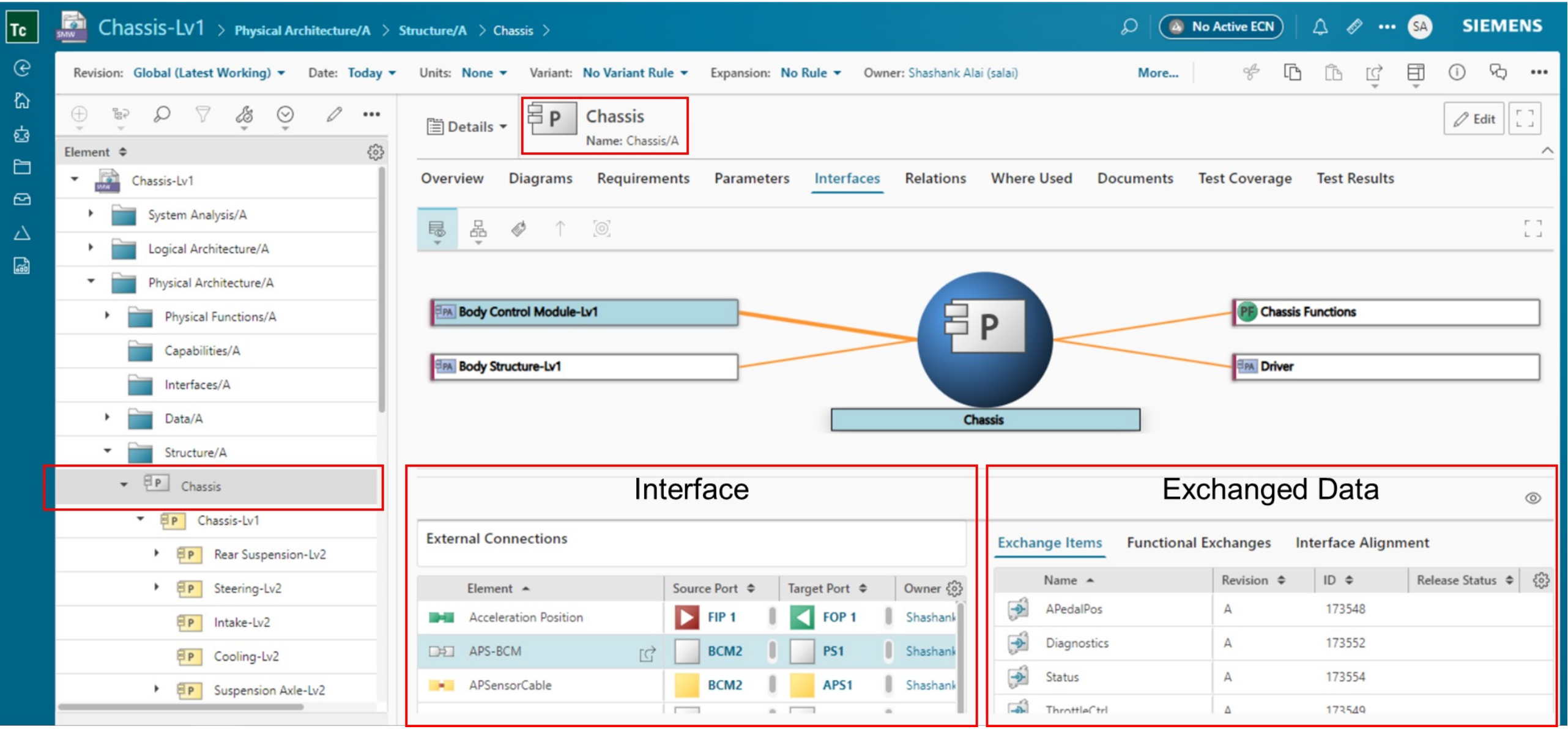
Chassis – Lv 1





Chassis module architecture definition

Module Architecture Development



Model-based module interface definition in Teamcenter

Lessons Learned

Conclusion & Observations

Conclusion

Iterative knowledge capture
Legacy product knowledge
Design evolution

Distributed development
Designated module teams
Designers and vendors

Configurability
Module standardization
Interface definition

Improved reuse
General vehicle module libraries
Program-specific usage

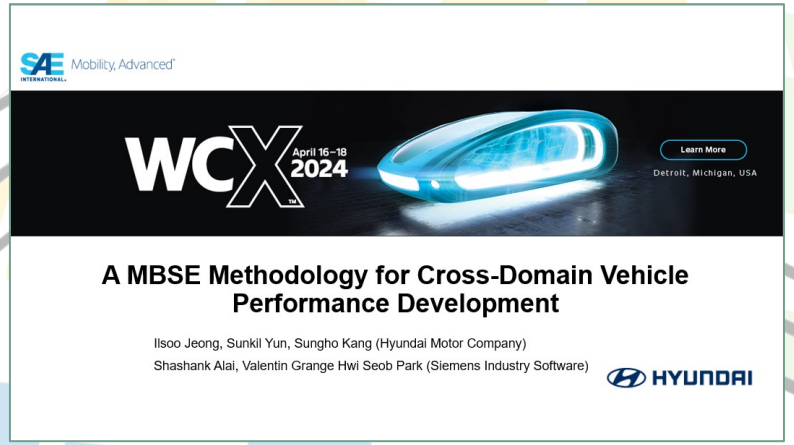
Managed complexity
Modular architecture decomposition
Granular model management

Cross-enterprise collaboration
Multi-stakeholder requirements mgmt.
Model-based supplier collaboration

Observations

- Modular architecture development a possible way to manage model development complexity
- Potential for module-based product line engineering
- Significant upfront architecture definition efforts needed for true ROI
- Pilot MBSE initiatives must extend beyond organizational silos
- When will MBSE-driven digital twins of entire product lines be a reality? Or will it?

Related Publication



1. Yun, S., Alai, S., Kim, Y., Kim, T. K., Jo, J., Lee, D., & Baloh, M. (2024). Applying a System of Systems Perspective to Hyundai-Kia's Virtual Tire Development. *INSIGHT*, *27*(1), 61-74. (Presented at INCOSE IS 2023, July 15-20, Honolulu, HI)

2. Jeong, I., Yun, S., Alai, S., Grange, V., Park, H., & Kang, S. (2024). An MBSE Methodology for Cross-Domain Vehicle Performance Development (No. 2024-01-2499). SAE Technical Paper. (Presented at SAE WCX 2024, April 16-18, Detroit, MI)

Thank you!

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