# Cross-company Collaborative Model-Based Development using FMI3.0 and SSP2.0

Dai Araki - Toshiba Digital Solutions Corporation

with the cooperation of

JAMBE (Japan Automotive Model-Based Engineering center)

FMI Utilization and Deployment WG, JSAE (Society of Automotive Engineers of Japan)

3V-SG (Virtual Verification & Validation using vECU Study Group)



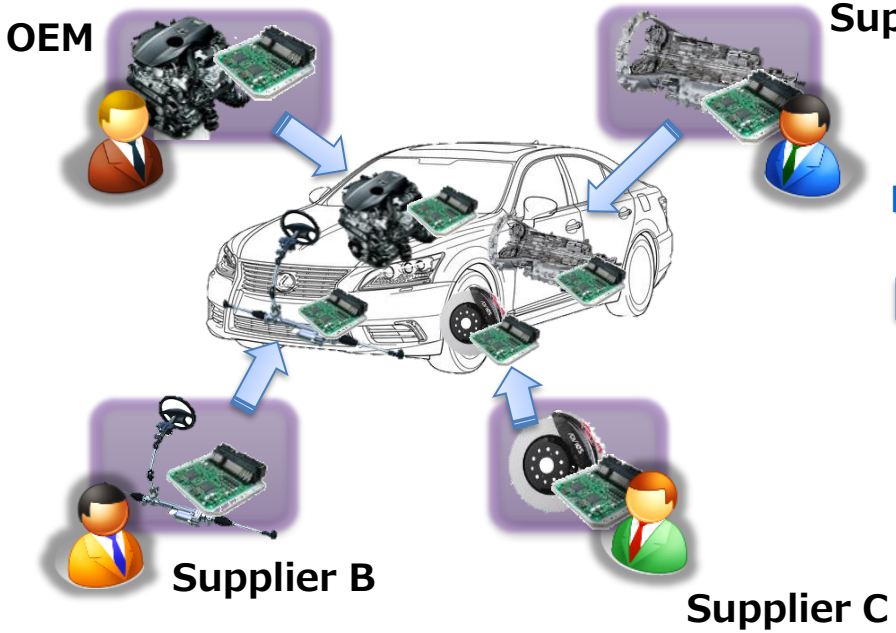
# Issues in the Vehicle Performance Planning

## Collaborative MBD between OEMs and suppliers should resolve these issues

### Current

Individual development with MBD

- OEM : Large reworks due to mainly relies on individual optimization with many individual simulations
- Suppliers : Verifying requirement fulfillment with only a limited set of evaluation conditions

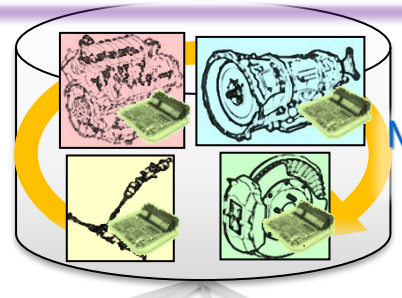



Model exchange and sharing of vehicle and components

### What we aim for

Collaborative MBD using common vehicle model

- OEM : Global optimization using integrated vehicle-level co-simulation using OEM and supplier's model
- Supplies : Participate in co-simulation with other parties to validate own part under various driving conditions

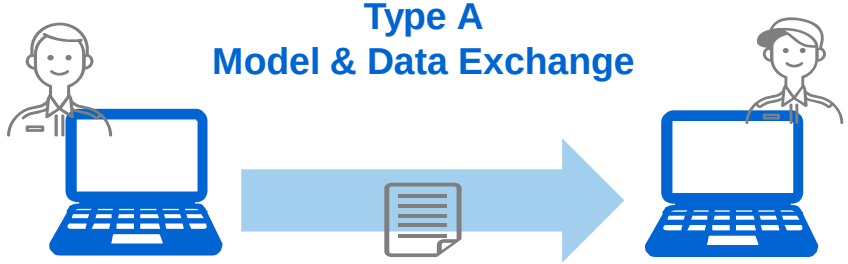


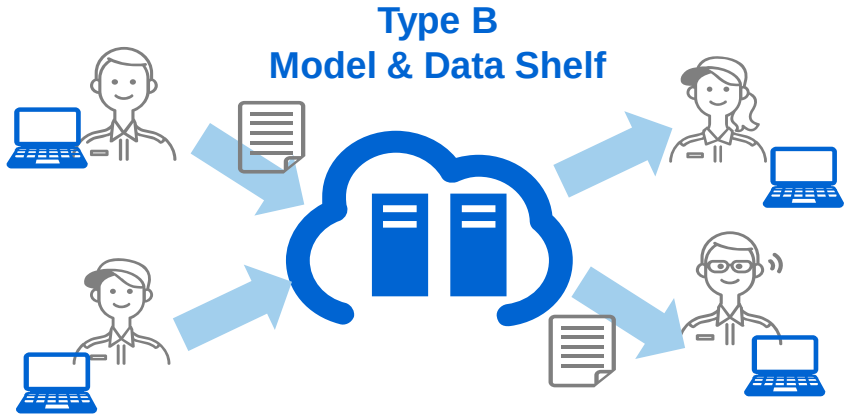
Model Management and Co-simulation

Vehicle simulation model integration by combining (confidential) component models

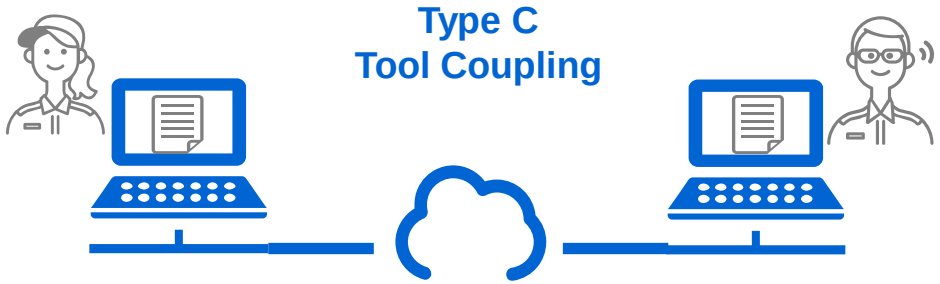
# Four Ways to Achieve Collaborative MBD

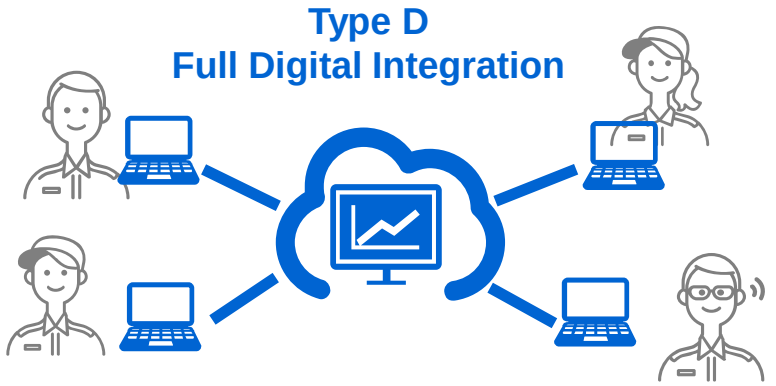
Model & Data




Co-simulation




**Interoperability is important so that methods can be changed at any time**

# Towards cross company collaboration - Simulation based product development
# Industrial Activities in EU and Japan

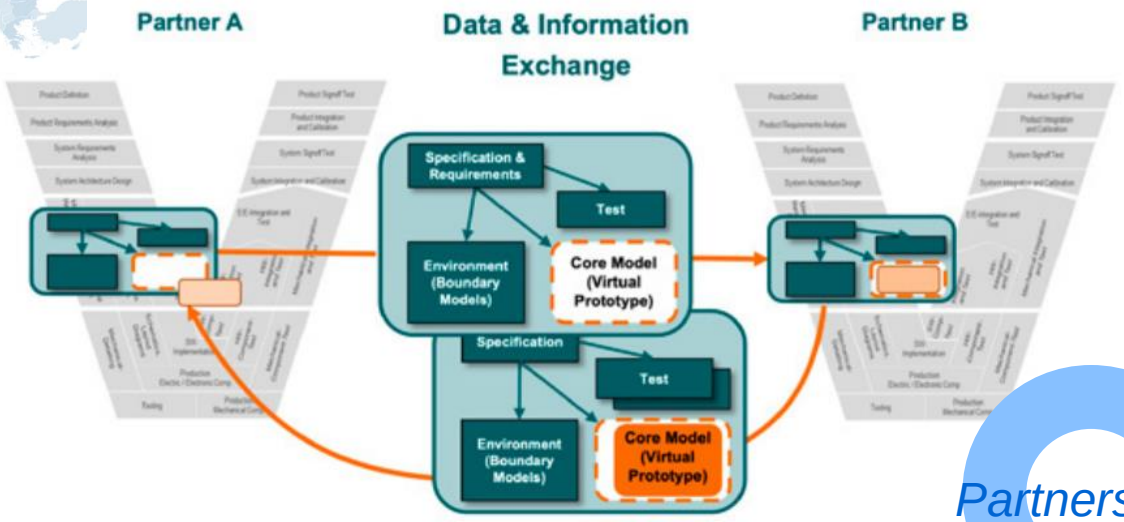
Tool independent model & data interoperability standard

ssp System Structure & Parameterization

fmi Functional Mock-Up Interface



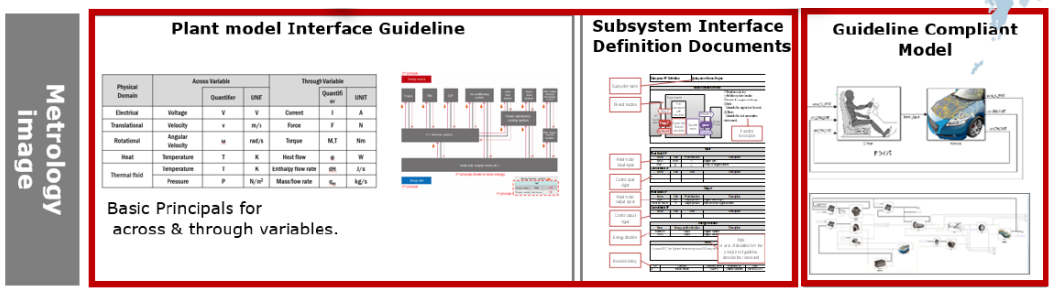
prostep IVIP

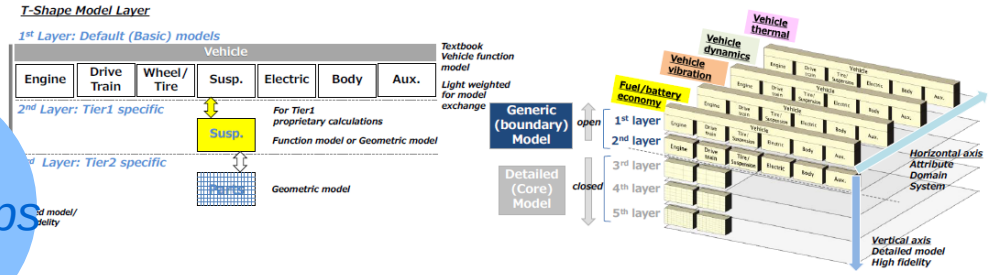



https://www.prostep.org/en/projects/smart-systems-engineering/

Partnerships

JAMBE Japan Automotive Model-Based Engineering center




https://www.jambe.jp/

# Towards cross company collaboration - Simulation based product development

# FMI & SSP Activities in Japan

Tool independent model & data interoperability standard

Japan Automotive Model-Based Engineering center
***https://www.jambe.jp/***

Partnerships

FMI Utilization and Deployment WG
Automotive Control and Modeling Division Committee
JSAE (Society of Automotive Engineers of Japan)
***https://www.jsae.or.jp/assoc/activitie/tech/page37/*** (in Japanese)

3V-SG : Virtual Verification & Validation using vECU Study Group
***https://www.3vsg.org/en/home-en/***

# FMI Utilization and Deployment WG, JSAE

Objectives :

1. Exploring methods for utilizing FMI and publishing application guidebook
2. Examining Technical Challenges When Utilizing FMI for Actual Model Connections
3. Educational seminar

Activities :

a. Feasibility Study on Applying FMI to 3D-CAE Models
b. Feasibility Study on Applying FMU Hierarchization (utilize SSP standard)
c. Expansion of Domains Eligible for FMI Application
d. Research on FMI 3.0 and eFMI
e. Collaboration with partner organizations in Japan (JAMBE, AICE)

Participants : 16 Companies (3 Observers)

MAZDA, HONDA, NISSAN, DENSO, MathWorks, Dassault Systems, Ansys, Siemens, IDAJ, Hexagon, Mitsubishi Electric Software, dSPACE Japan, Toshiba Digital Solutions, AZAPA, DENTSU SOKEN, HIRANO Research Lab
(Applied Intuition , Nagoya Univ. , RIGO Tech )

**https://www.jsae.or.jp/assoc/activitie/tech/page37/ (in Japanese)**

# FMI Application Guidebook (version 2.0.1 in 2024 Jun)

**Chapter 1. About This Guide**

**Chapter 2. FMI Basics**

- FMI operating modes and FMU file structure
- Model Exchange (ME) Structure and Features
- Co-Simulation (CS) Structure and Features
- Scheduled Execution (SE) Structure and Features
- General note on FMI compatibility
- General Notes on Information Hiding for FMIs
- General notes on tool environments using FMI
- About FMI Official Website
- Technical activities and events related to FMI

**Chapter 3. FMU Operation Mode Selection Guide and Operation Flow**

- Guideline for selecting the operating mode of FMU
- Flow from FMU creation to replacement and simulation execution
- Possible problems and countermeasures in each process (Model Exchange)
- Possible problems and countermeasures in each process (Co-Simulation)

**Chapter 4. What You Need to Know for Practical Application**

- Guidelines for determining plant model inputs and outputs
- Notes on model splitting
- FMI and Errors

**Appendix 1: Introduction of FMI Supporting Tools**

- Dassault Systèmes Dymola
- ANSYS Twin Builder
- MathWorks Simulink
- Altair Twin Activate
- dSPACE SystemDesk and VEOS
- ESI SimulationX
- Gamma Technologies GT-SUITE
- ETAS VECU-BUILDER
- Modelon Modelon Impact
- Toshiba Digital Solutions VenetDCP
- OpenModelica
- FMPy

**Appendix 2: FMI Application Examples**

**Appendix 3: Tutorial**

**Japanese version is available below**
https://www.jsae.or.jp/files_publish/page/330/FMI_guide.2.0.1.pdf
https://www.jsae.or.jp/files_publish/page/330/FMI_guide_appx.2.0.1.pdf
**English version coming soon**

# 3V-SG Overview

1. Investigation, verification, and validation of common technologies and standard technologies related to virtual verification methods.
2. Proposal and verification of new methods related to virtual verification methods, standardization proposals.
3. Dissemination and enlightenment of virtual verification.

## Participating organizations (26 organizations as of April 2025)

- ASAM Japan G.K.
- Australian Semiconductor Technology Company
  *) Now, Cadence Design Systems
- Bosch Corporation
- Cadence Design Systems, Japan
- ETAS K.K.
- GAIO Technology Co., Ltd.
- Hirano Research Laboratory
- Hitachi Industrial Equipment Systems Co., Ltd.
- Interbuddy Inc.
- MODEC Inc.
- Marble Co., Ltd.
- Marelli Corporation
- Mazda Motor Corporation
- Nissan Motor Co., Ltd.
- RYODEN Corporation
- Renesas Electronics Corporation
- Syncom Co., Ltd.
- Synopsys Japan G.K.
- T2 Laboratory Inc.
- Toshiba Digital Solutions Corporation
- Toyota Technical Development Corporation
- Witz Corporation
- ZeroSoft Co., Ltd.
- dSPACE Japan K.K.
- eSOL Co., Ltd.
- TechnoPro, Inc. TechnoPro Design Company

**https://www.3vsg.org/en/home-en/**

# 3V-SG Activities

| TF name | Short name | Description | TF reader (affiliation) |
|---|---|---|---|
| 4V-AI[*1] Rapid prototyping<br>*1) 4V (Virtual Verification & Validation for Vehicle) Installation Artificial Intelligence Rapid Prototyping | 4VAI | Develop samples of deep learning applications using rapid prototyping systems and virtual ECUs.<br>ラピッドプロトタイピングシステムと仮想ECUを使用して深層学習アプリケーションのサンプルを開発する。 | Masanori Otake<br>大竹 雅則<br>(Gaio Technology) |
| FMI[*2] Collaboration TF<br>*2) FMI : Functional Mock-up interface | FIM | Study the FMI standard and tools supporting the standard. Investigate how to utilize the standard.<br>FMI標準およびその標準をサポートするツールに関する研究。その標準をどのように活用するかを調査する。 | Dai Araki<br>荒木 大<br>(Toshiba) |
| ASAM Collaboration TF<br>(to resume 再開予定) | ASAM | Study ASAM XCP applying to virtual ECUs through proof-of-concept. Examine if the standard is applicable as well as in physical environment, study merits, if there are any notices.<br>ASAM XCPを仮想ECUに適用するためのPoCを行う。XCPが物理環境と同様に適用可能かどうかを調査、検証する。 | Akira Watanabe<br>渡邉 晃<br>（Nissan） |
| VirtIO for vECU study TF<br>(under preparation<br>活動準備中) | VirIO | Investigating and evaluating the application of VirtIO, a proven hardware-software separation standard in cloud servers, to the automotive industry.<br>クラウドサーバで実績のあるHW vs. SW分離規格VirtIOの自動車業界への適用の調査、検証する。 | Akira Watanabe<br>渡邉 晃<br>（Nissan） |

# JAMBE Organization Overview


**Committees**

**4**

**Working Group**
**Working Packages**
**Task Forces**

**15**

**Companies**

**187**

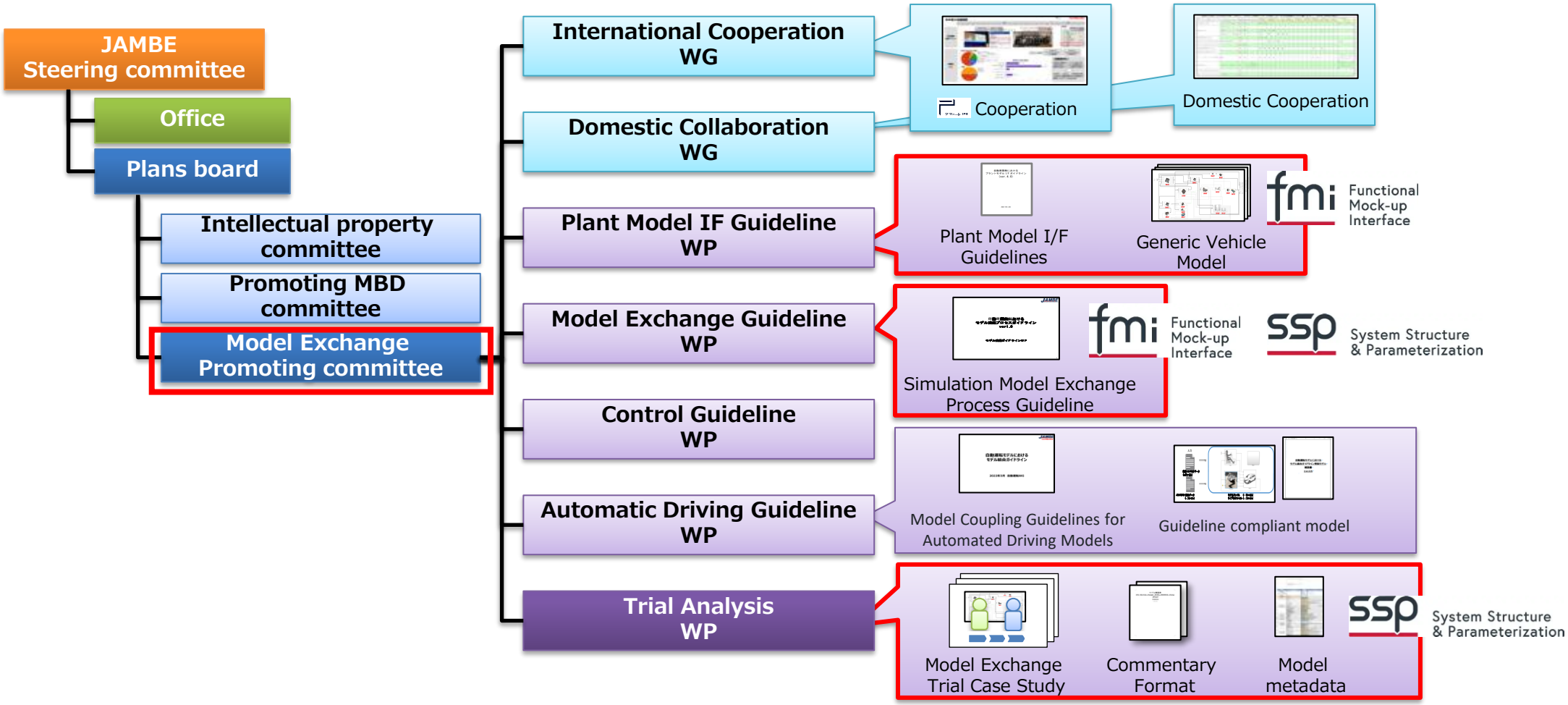
**Members**

**720**

- **14** Automobile OEM
- **62** Parts suppliers
- **54** Tool venders
- **30** Engineering service providers
- **3** Engineering associations
- **7** Trading companies and staffing agencies
- **8** Universities/ research institutes
- **8** Regional promotion organization

# Activities of JAMBE's Committee

Introducing the FMI and SSP activities of the SubWPs in JAMBE.



# JAMBE Main Activities

JAMBE Japan Automotive Model-Based Engineering center

Result of JAMBE survey

OEM

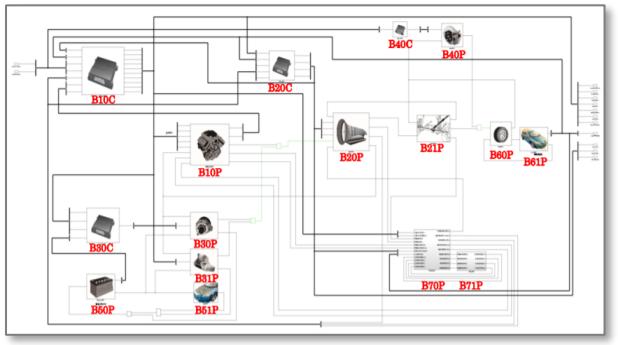
① **Many IP protection** disrupt model Exchange

② **No common Interface guideline**.

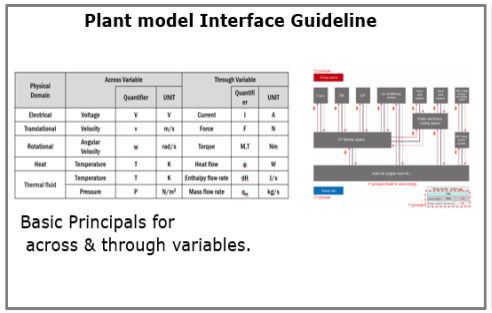
③ **Unclear requirements** for model exchange.

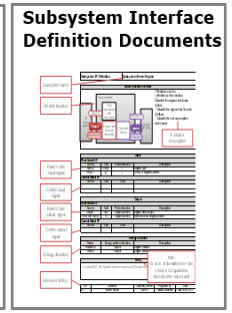
Supplier

## ① IP free Generic vehicle Models

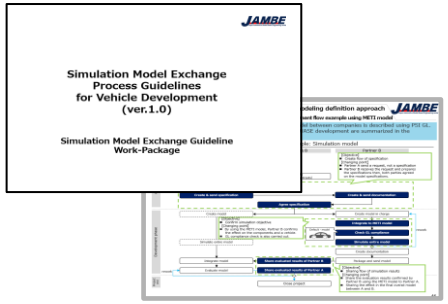



## ② Plant Model I/F guideline

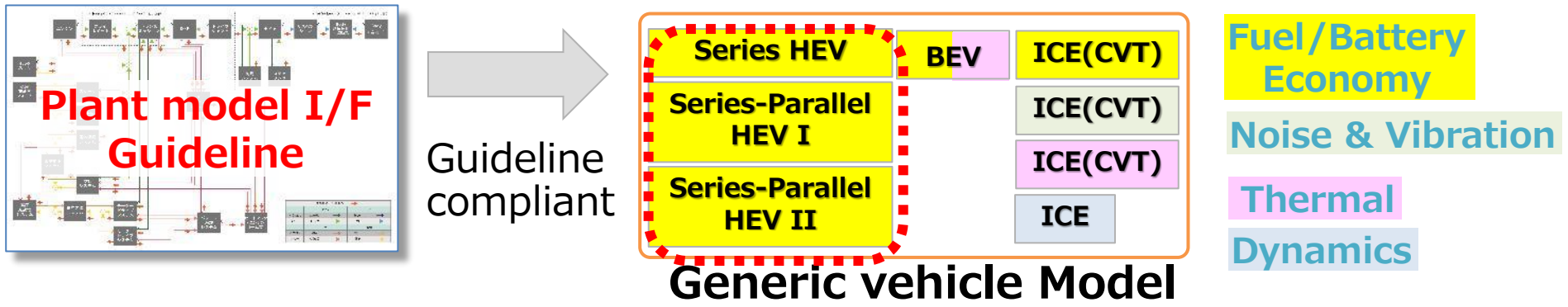



## ③ Process guideline for Model Exchange



# JAMBE Generic Vehicle Model (I/F guideline compliant model)



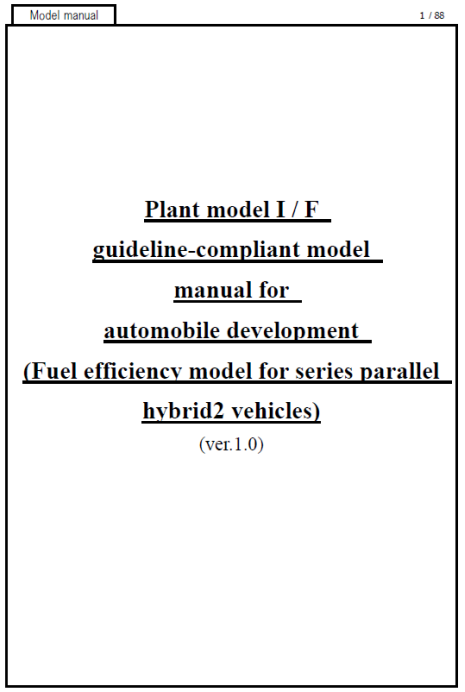

| No | Title |
|---|---|
| 200071 | Fuel efficiency model and manual for series-hybrid vehicles |
| 200081 | Fuel efficiency model and manual for series parallel hybrid vehicles (Type 1) |
| 200091 | Fuel efficiency model and manual for series parallel hybrid vehicles (Type 2) |
| 200101 | Fuel efficiency model and manual for CVT |
| 200111 | Electric Vehicle Electricity Consumption Model |
| 200121 | Electric Vehicle Electricity Cost Model |
| 200131 | Thermal model Guideline-compliant model |
| and more | |

**Available at https://www.jambe.jp/system/download**

# JAMBE Generic Vehicle Model (I/F guideline compliant model)

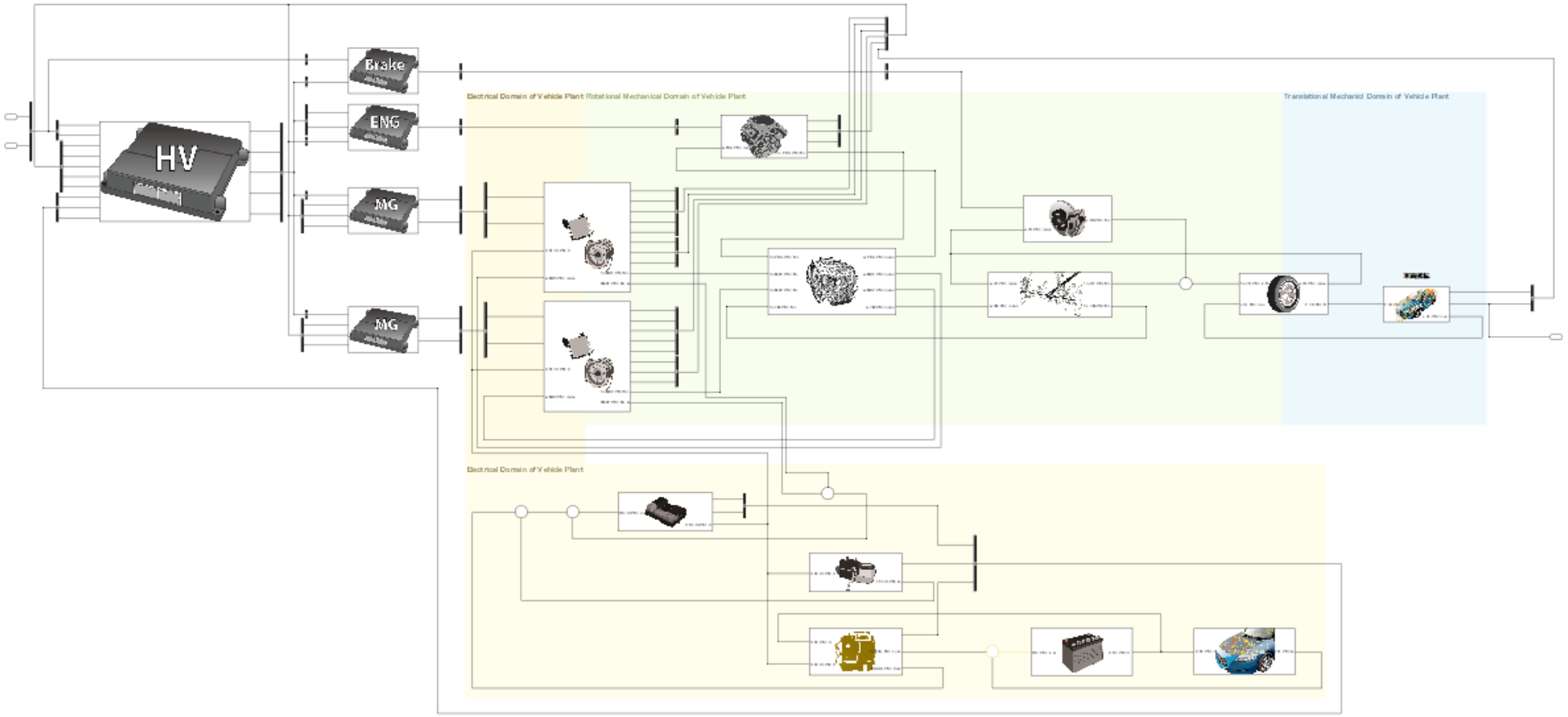
JAMBE Japan Automotive Model-Based Engineering center

## Ex. Fuel efficiency model for series parallel hybrid vehicles


Model manual 1 / 88

Plant model I / F guideline-compliant model manual for automobile development (Fuel efficiency model for series parallel hybrid2 vehicles)

(ver.1.0)

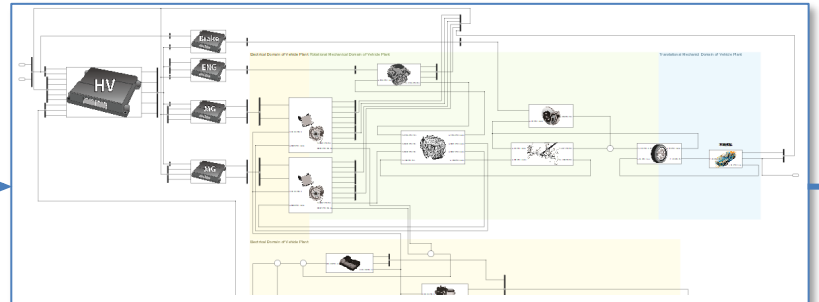



- Set of open license free simulation model created with Simulink and detailed manual
- Simulation model is divided into components such as the ECU, engine, motor, transmission, brakes, battery and etc.
- Component characteristics can be modified using parameters
- Many component models are common with other generic vehicle models.

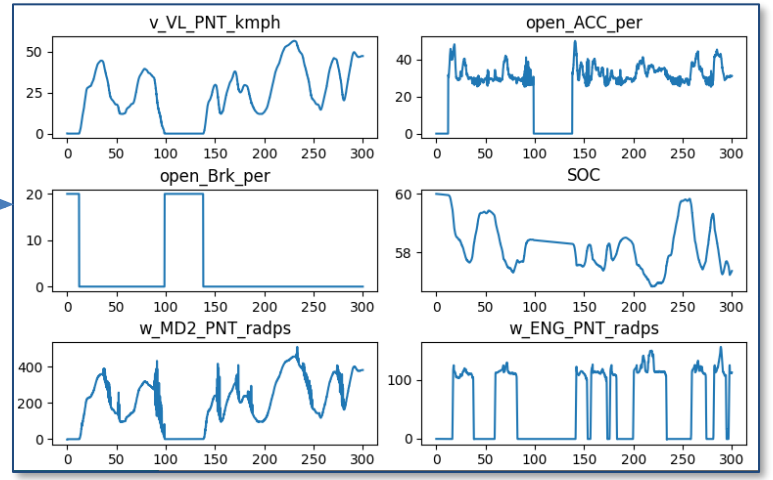
# Experiments on FMI with JAMBE model

JAMBE
Japan Automotive Model-Based Engineering center

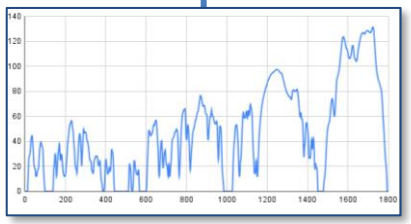
Simulink




Series parallel hybrid vehicle




Test scenario



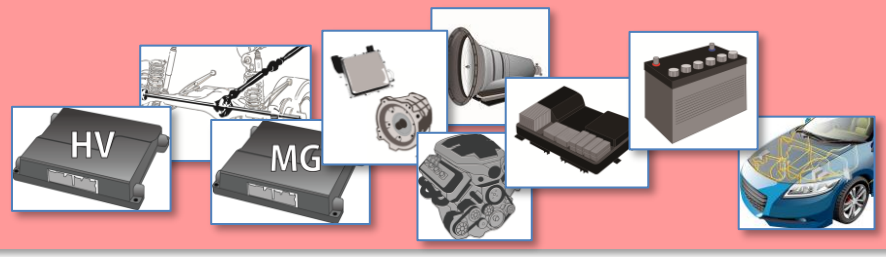
WLTC-Class 3b
driving cycle

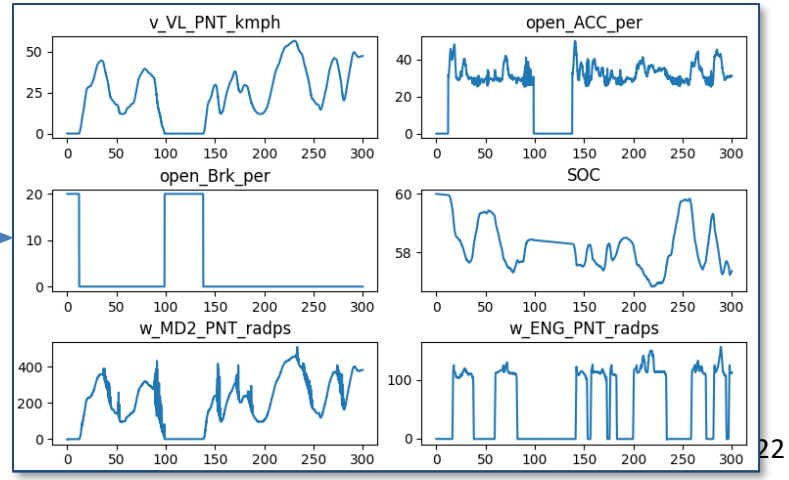
Decompose original Simulink reference model into FMUs

21 FMUs


Simulation results are largely consistent
though some issues exist depending on the tool used

Co-simulation of FMI models



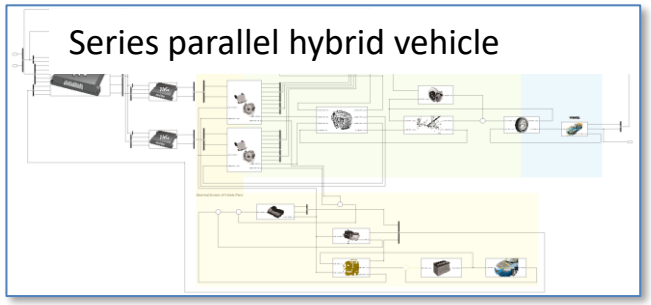



# Experiments on SSP with JAMBE model

JAMBE Japan Automotive Model-Based Engineering center

## Model

Simulink

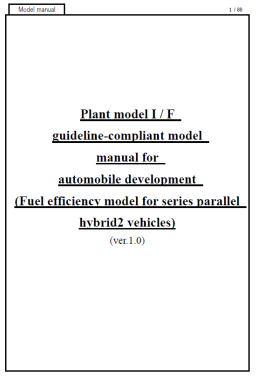


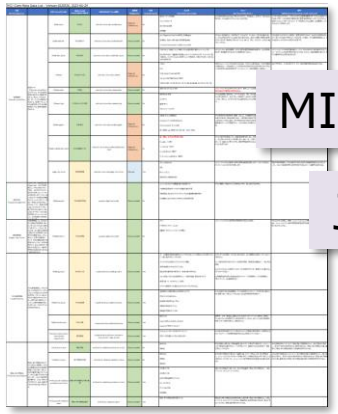

Decompose original Simulink reference model into FMUs

21 FMUs


IO and parameters


## Manual



MIC-Core meta data

JAMBE meta data extensions

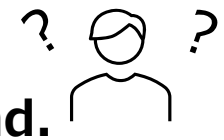
SSP System Structure & Parameterization

orchideo | easySSP

# JAMBE Motivation in Model Exchange

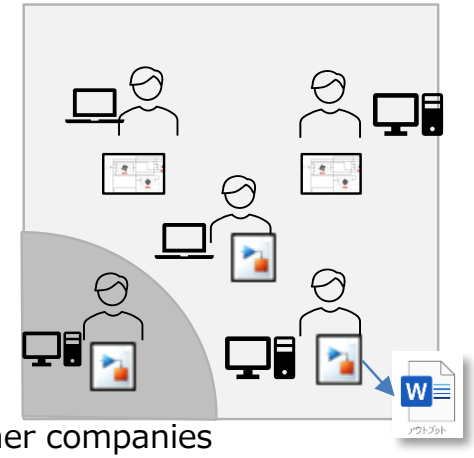
## Status quo

### Model Search



- **Cannot be found.**

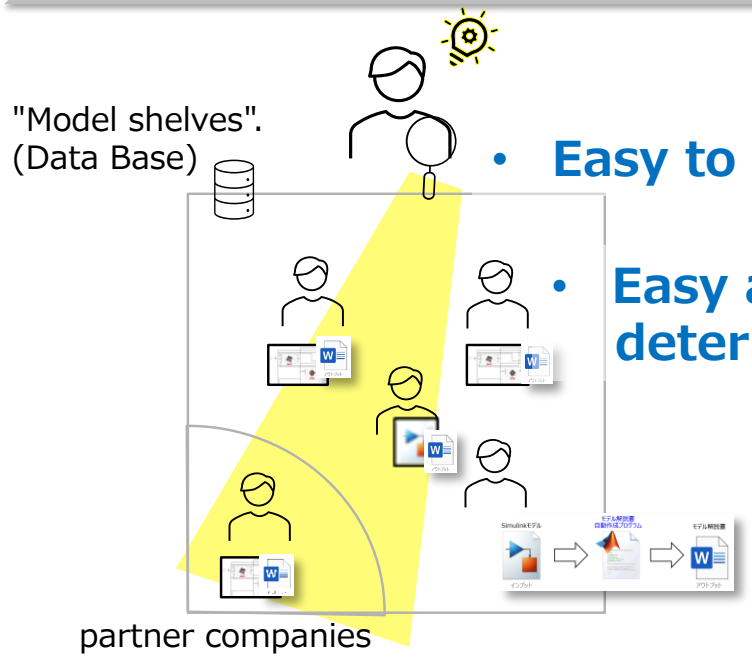
- **Difficulty in understanding the model**




- **Searching models developed by partner companies is even more difficult.**
- **Difficulty in preparing explanatory documents**

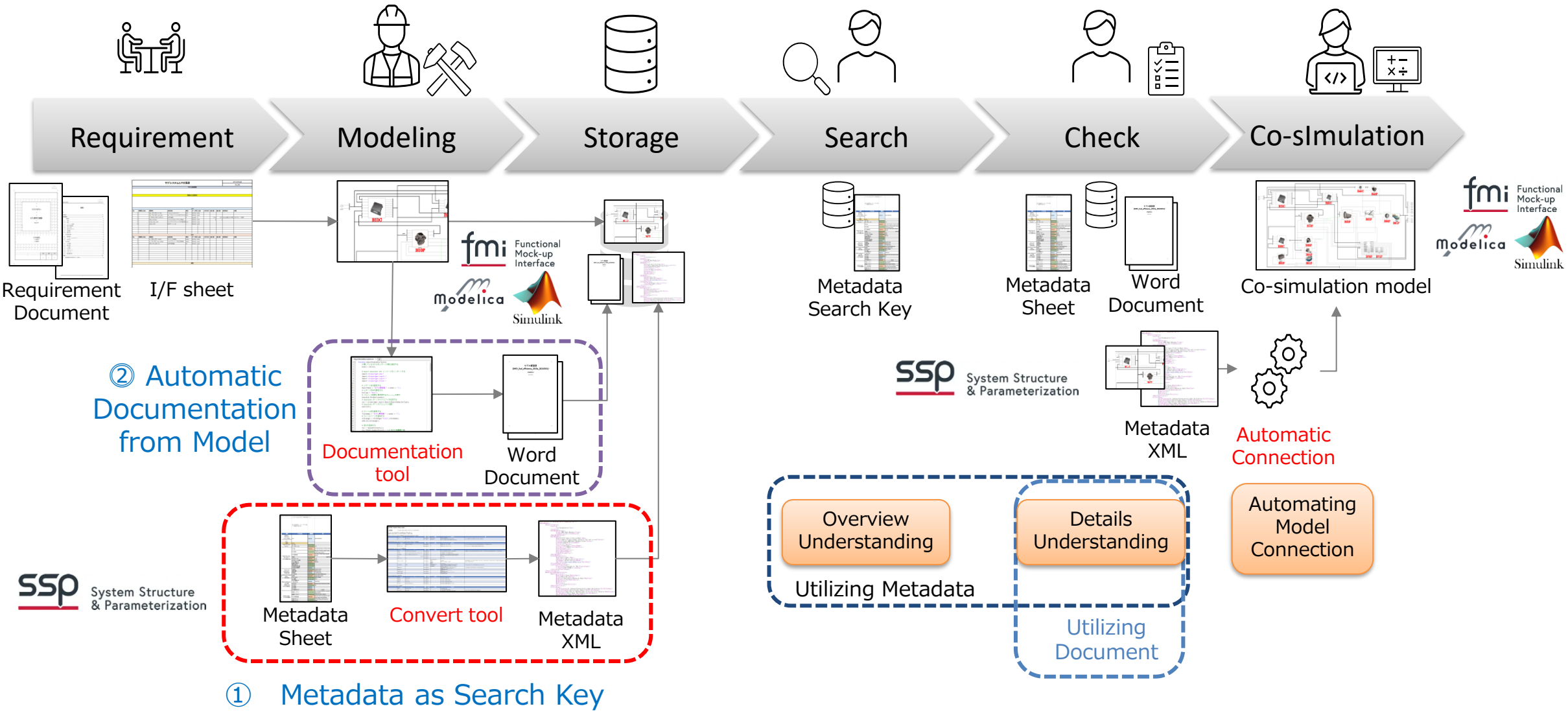
## To be

### Model Search



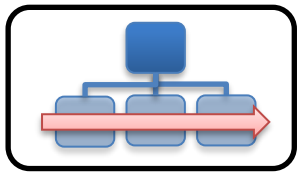
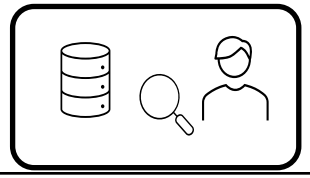
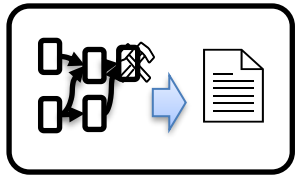
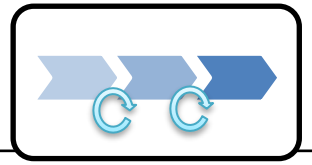

- **Easy to find**
- **Easy applicability determination**
- **Easily search for the models developed by partner companies**
- **Easy documentation**

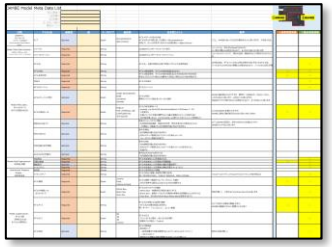
# JAMBE Solutions in Model Exchange

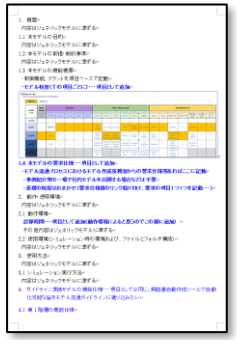


# Metadata Study in JAMBE

- In the JAMBE trial analysis working group (WP), we are examining three major common issues related to metadata.

| Topic | | Overview | Output |
|---|---|---|---|
| **SWP overall activities** |  | Management | Overall Summary Report |
| ① | **Model search**  | MIC-CORE-based item review | ・META DATA format (Excel、 SSP) |
| ② | **Automatic output of the manual**  | Automatically create instruction manuals from models | (Simulink)<br>・Manual automation tool<br>(Simulink)<br>・Manual format |
| ③ | **Traceability**  | Integration/trial with SmartSE/SystemX | ・Activity Report |





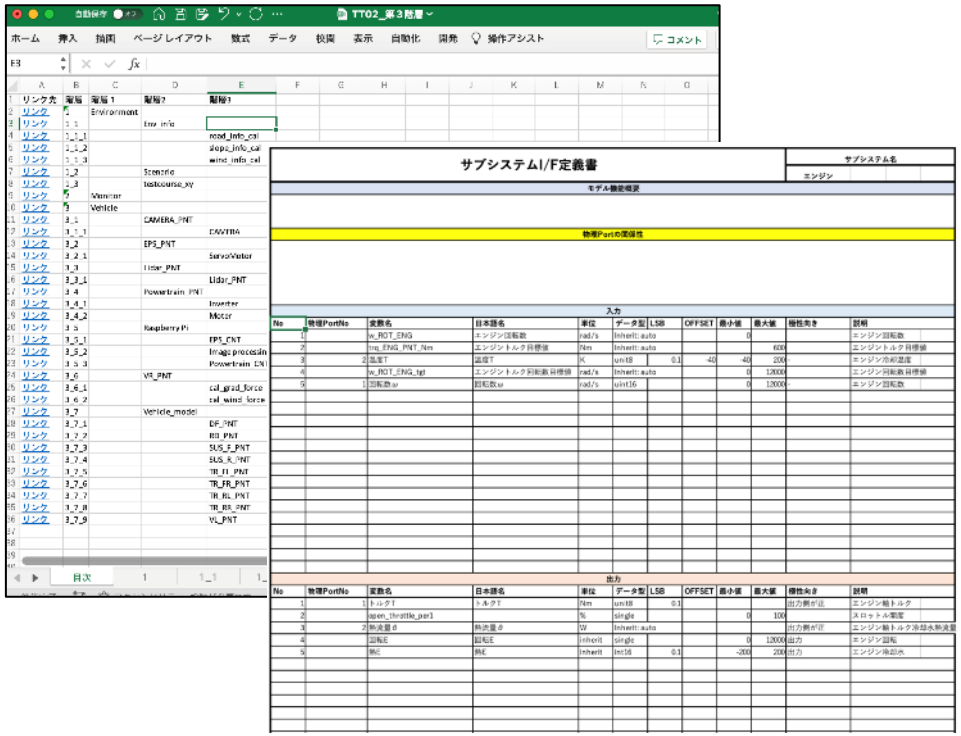
# I/F Generator Tool

Tool helps modelers understand the importance of the process of defining model I/F.

## I/F Definition Sheet

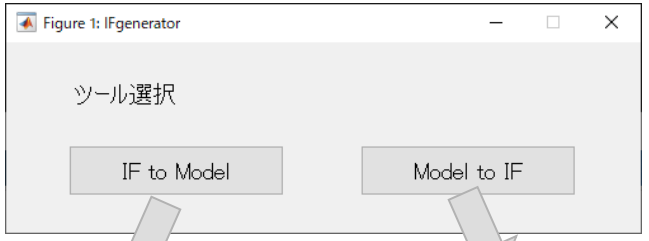
Excel

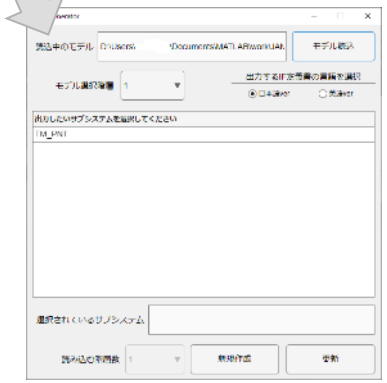
・Excellent GUI




conversion

## I/F Generator Tool



## model template

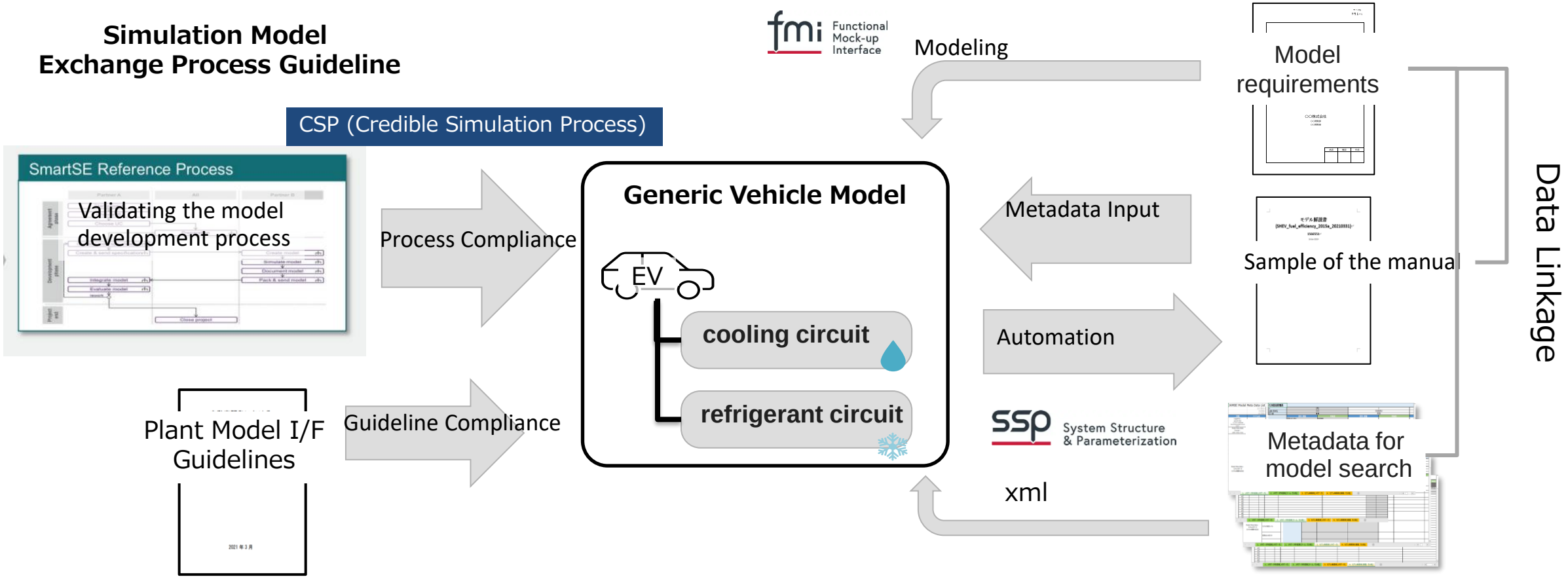
MATLAB®/Simulink®

Support for multiple blocks

※ Open to JAMBE members

# Envisioned activity 1. Use Case Creation utilizing FMI + SSP

- In fiscal year 2025, we plan to develop a thermal-fluid model for an electric vehicle in accordance with the JAMBE Plant Model IF Guidelines.
- Based on this model, we will create examples of metadata usage.
- Furthermore, we will examine where and what types of metadata should be incorporated in the development process, and compile these examples accordingly.

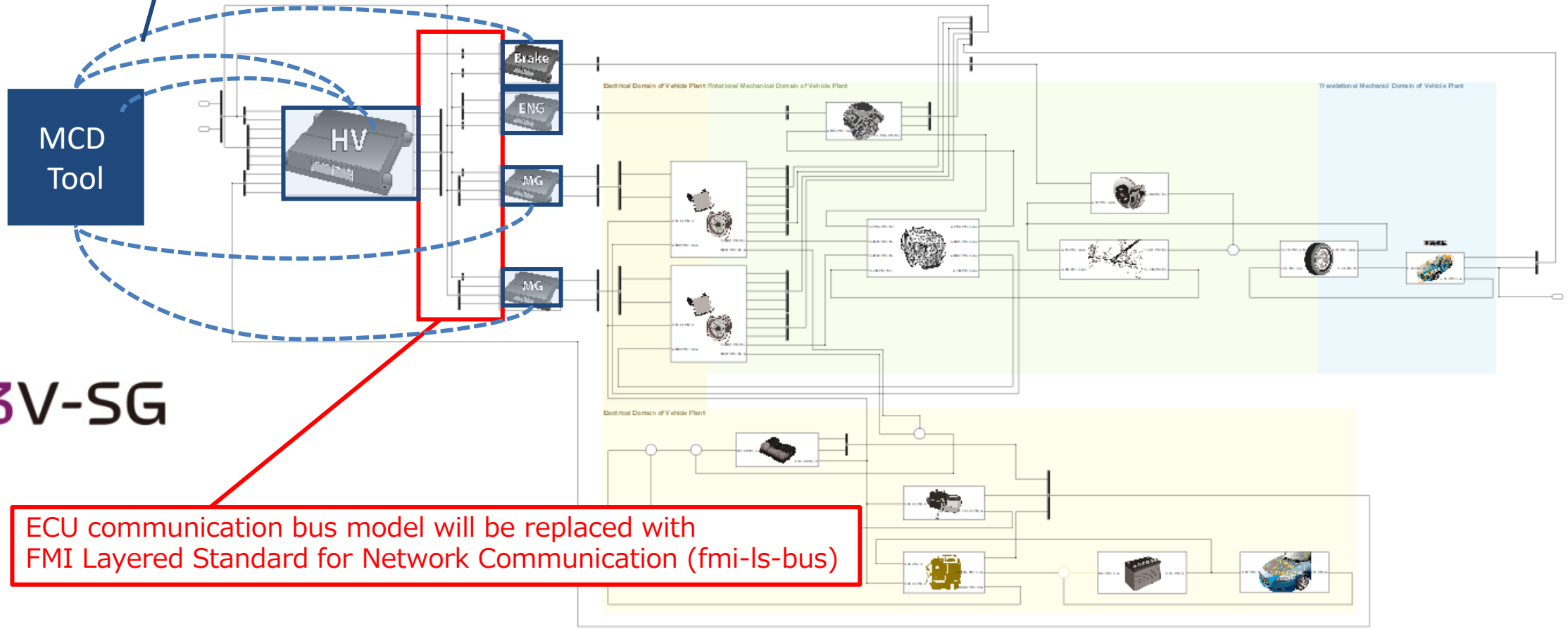


# Envisioned activity 2. Evaluation of FMI Layered Standard

- We plan to evaluate FMI Layered Standard for “Network Communication” and “XCP” with JAMBE generic vehicle model.
- This work will be conducted jointly with 3V-SG and JAMBE.

Multiple ECU monitor & calibration will be executed with FMI Layered Standard for XCP (fmi-ls-xcp)

Ex. Fuel efficiency model for series parallel hybrid vehicles




ECU communication bus model will be replaced with FMI Layered Standard for Network Communication (fmi-ls-bus)

# Long-term strategy

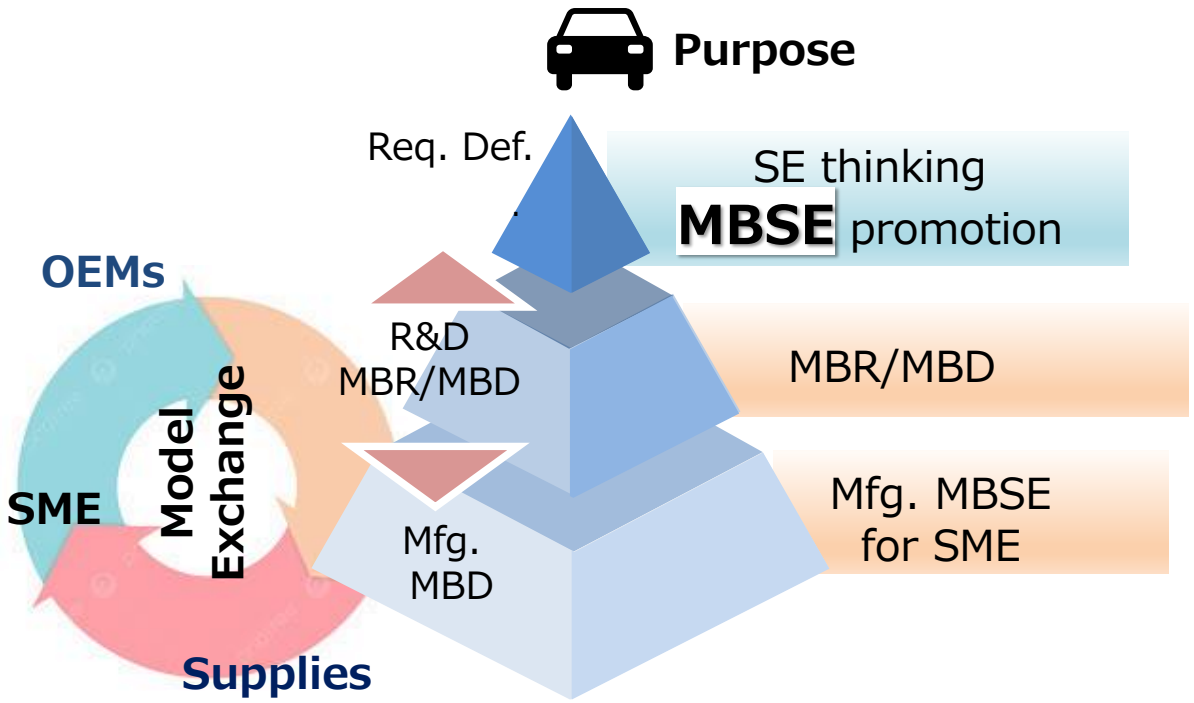
## Strengthen Cross-company Collaborative MBD to Cross-industry Collaboration

**Creating new value / Strengthening international competitiveness**

**Industry Collaboration**

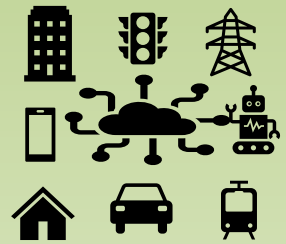
**Solving social issues / Adapting to Society 5.0**

Ecosystems with digitalization




**Mobility Systems**

SoS thinking
Cross-industry
system integration



**Purpose (System of systems)**


**Mobility system** **Power system** **traffic system**

- Medical system
- Insurance system
- Administrative system

...