Simulation Model Exchange Process Guidelines for Vehicle Development (ver.1.0)

Simulation Model Exchange Guideline Work-Package

Simulation Model Exchange Process Guideline

0. Purpose of use and notes of this guideline

1. Introduction

2. Simulation model exchange process and modeling definition approach

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Purpose of use and notes of this guideline

This model exchange process guideline (GL) was developed by summarizing the achievements of research in simulation model exchange for model-based development which have been discussed in the “Research Committee of Model Usage in the Automotive Industry". This committee has been funded by the Ministry of Economy, Trade and Industry since 2016 in Japan.

“Plant Modeling I/F Guidelines for Vehicle Development” has been rereleased by above research committee, however, in order to exchange the simulation models between Japanese and oversea automotive companies, Japanese and oversea related guidelines need to be compatible with each other.
Therefore, a new guideline which defines the relationship between conventional Japanese and oversea model based development guidelines and summarizes the items to be considered for simulation model exchange among Japanese automotive companies is required to develop.

This GL investigates other guidelines and recommendations such as recommendations for SmartSE working of Prostep iViP, and shows examples of how the conventional guidelines can be linked in simulation model exchange. This GL does not inhibit other guidelines and recommendations.

Purpose of use and notes of this guideline

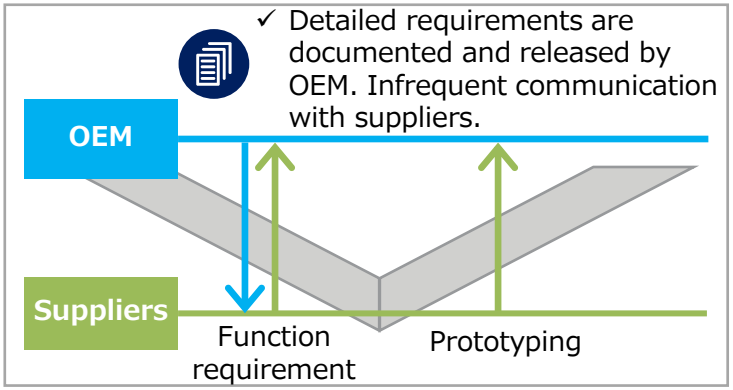
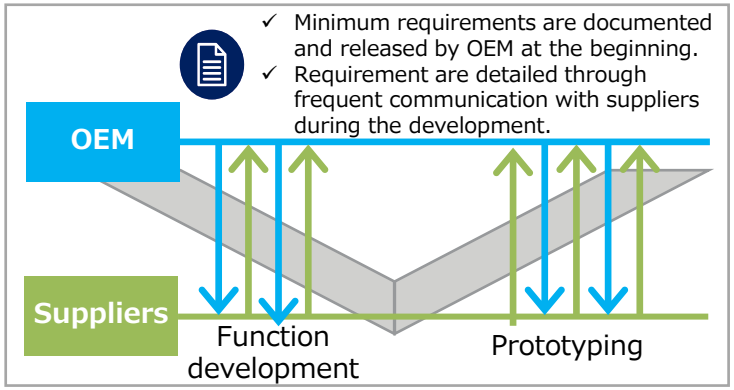
- In order to apply this GL to development process, purpose of use and notes of GL have to be shared among collaborated partners.

Purpose of use	• Improving communication efficiency between collaborated partners by applying this GL as a example of procedures in simulation model development. • Promote simulation model exchange by having a common understanding of the model through reference use cases and reference architectures at each timing of each procedure.
Notes	• This GL only defines the physical principles and references in model-based development. • This GL does not enforce a strict definition of the vehicle architecture of each automotive company.

Differences in important items in MBD in Europe and Japan

- The items that European and Japanese OEMs place importance on in MBD are different due to the clear differences in development culture that exist in Europe and Japan.

Differences in important items of MBD between OEM development culture by region/country.

OEM development culture by Region/country	Europe	Japan
	■ **Contract based development** ➢ Making suppliers to develop components according to the contract.	■ **SURIAWASE based development** ➢ Developing individual performance of components by OEM and suppliers working together to the end.
Pros/Cons	■ Pros : Short development terms due to clear scope of development responsibilities. ■ Cons : Undescribed requirements in the contract may not be developed in the components.	■ Pros : The quality of individual component performance is high because the content of development is agreed upon. ■ Cons : Long development terms due to need of understanding many requirements and flexible response.
Important items in development	■ **Accurate requirements, standardized rules**	■ **Suppliers who understand background and previous product requirements of OEM.**
Specification exchanges during development between OEM and suppliers		

Simulation Model Exchange Process Guideline

0. Purpose of use and notes of this guideline

1. Introduction
   1) The objective of this guideline
   2) The differences in priority items of MBD in Europe and Japan
   3) Concept of SURIAWASE2.0
   4) Vision of SURIAWASE2.0
   5) Deeping of SURIAWASE2.0

2. Simulation model exchange process and modeling definition approach

The objective of this guideline

- This GL contributes to promote world wide simulation model exchange by having a common understanding of the model development platform among approximately 600 European and Japanese automotive companies.
  - ➢ This GL enables suppliers to make proposals based on systems thinking, and contributes to create collaboration opportunities with new business partners.

ProSTEP iViP : 180

:

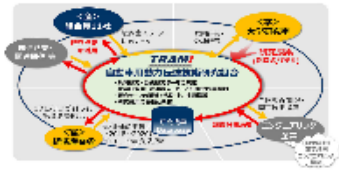
SystemX : 70

- Improving development capability for OEM/Supplier
- creating opportunities for collaboration with new partners

METI : 11

AICE : OEM 9, Organization2
Supporting company: 74

TRAMI : OEM 11
Supporting company: over26

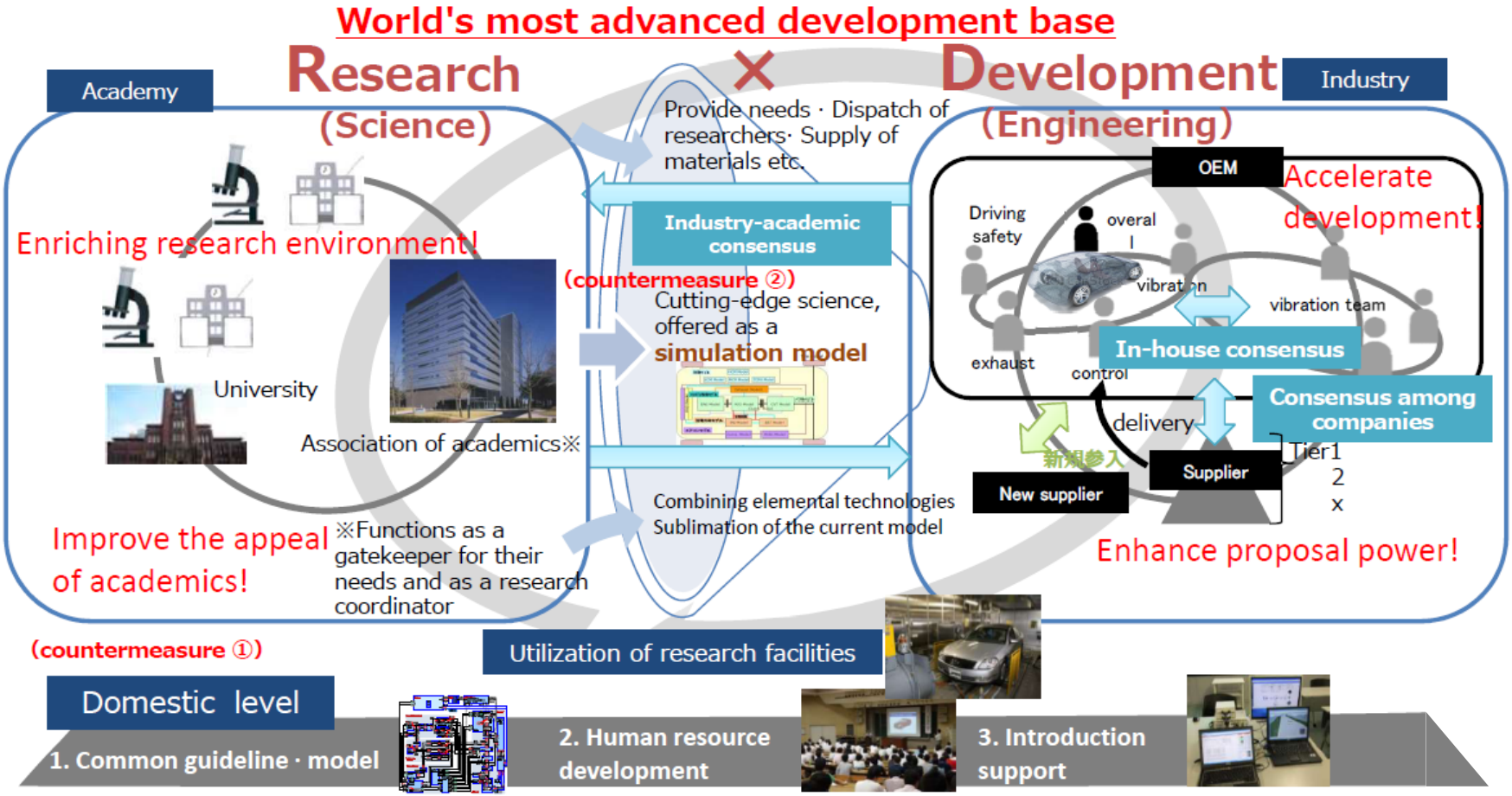


JasPar : 237
(Secretary member: 5)

※METI : 11 has been taken over by the new organization JAMBE from 2021.

Concept of SURIAWASE 2.0

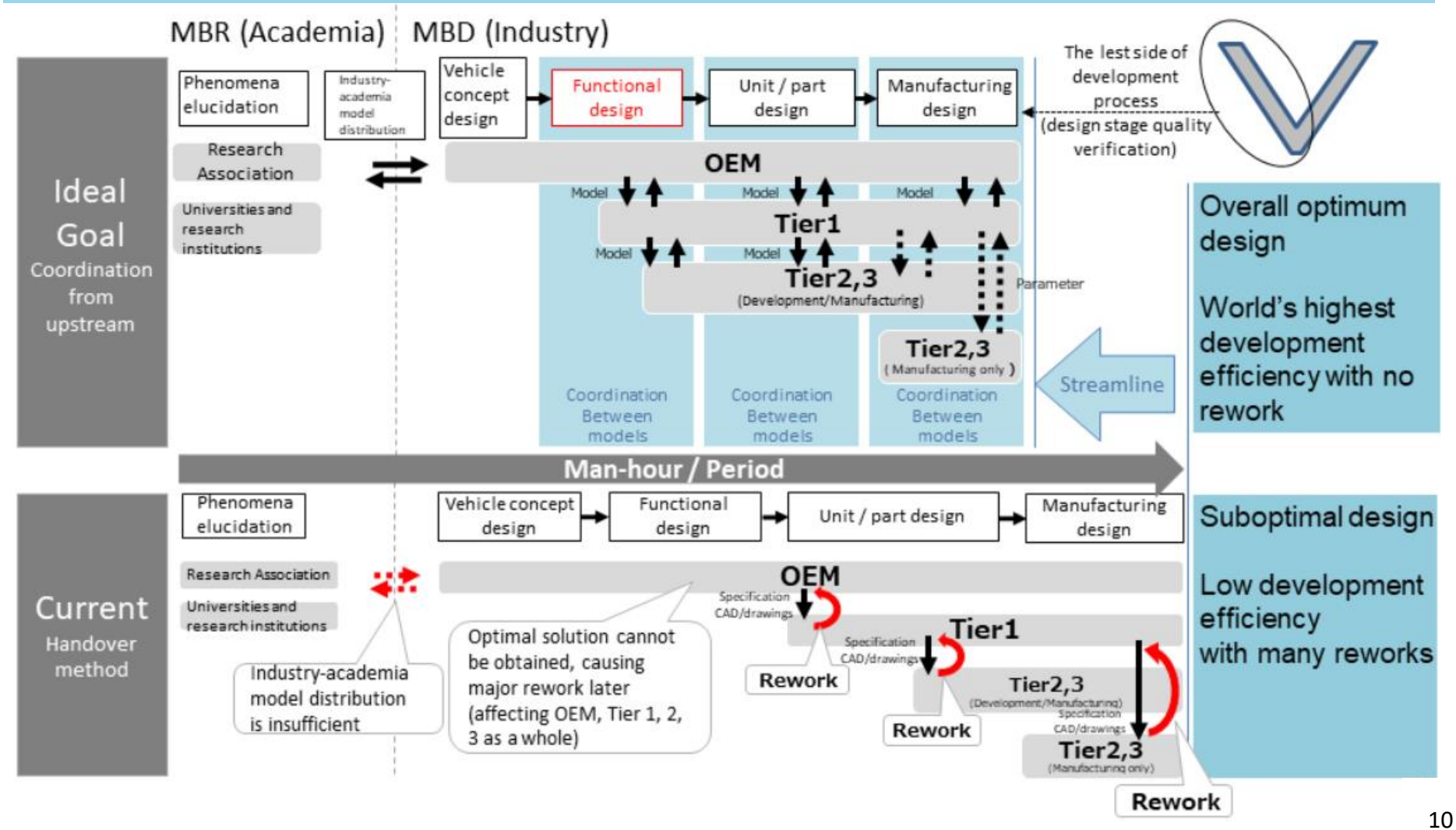
- In order to enhance Japanese development capability, the speed and accuracy of collaboration between industry and academia, companies, and within companies are improved by “thorough utilization of simulation” and “fusion of science and engineering”.
- World’s most advance development base will be realized by achieving human resource development by improving the productivity of suppliers and deepening industry-academia collaboration at the same time.



***1) SURIAWASE : Consensus or mutual agreement**
https://warp.da.ndl.go.jp/info:ndljp/pid/10341576/www.meti.go.jp/press/2016/03/20170331010/20170331010.html

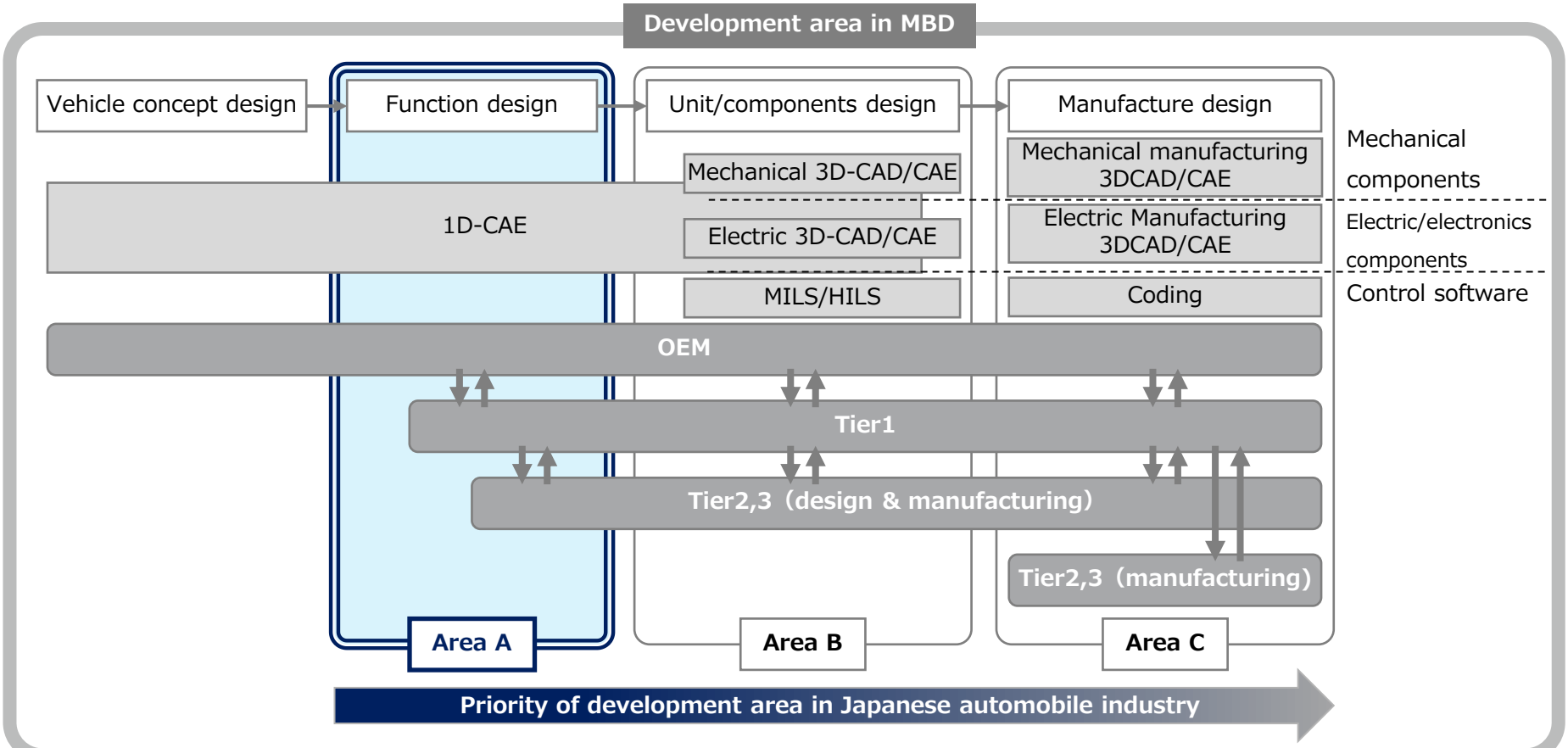
Vision of SURIAWASE 2.0

- Achieve coordination throughout the industry aiming to achieve “the world’s highest development efficiency” set by SURIAWASE 2.0.
- Prioritize functional design as the starting point for model dissemination / distribution, while also targeting other areas, including manufacturing design.



Vision of SURIAWASE 2.0

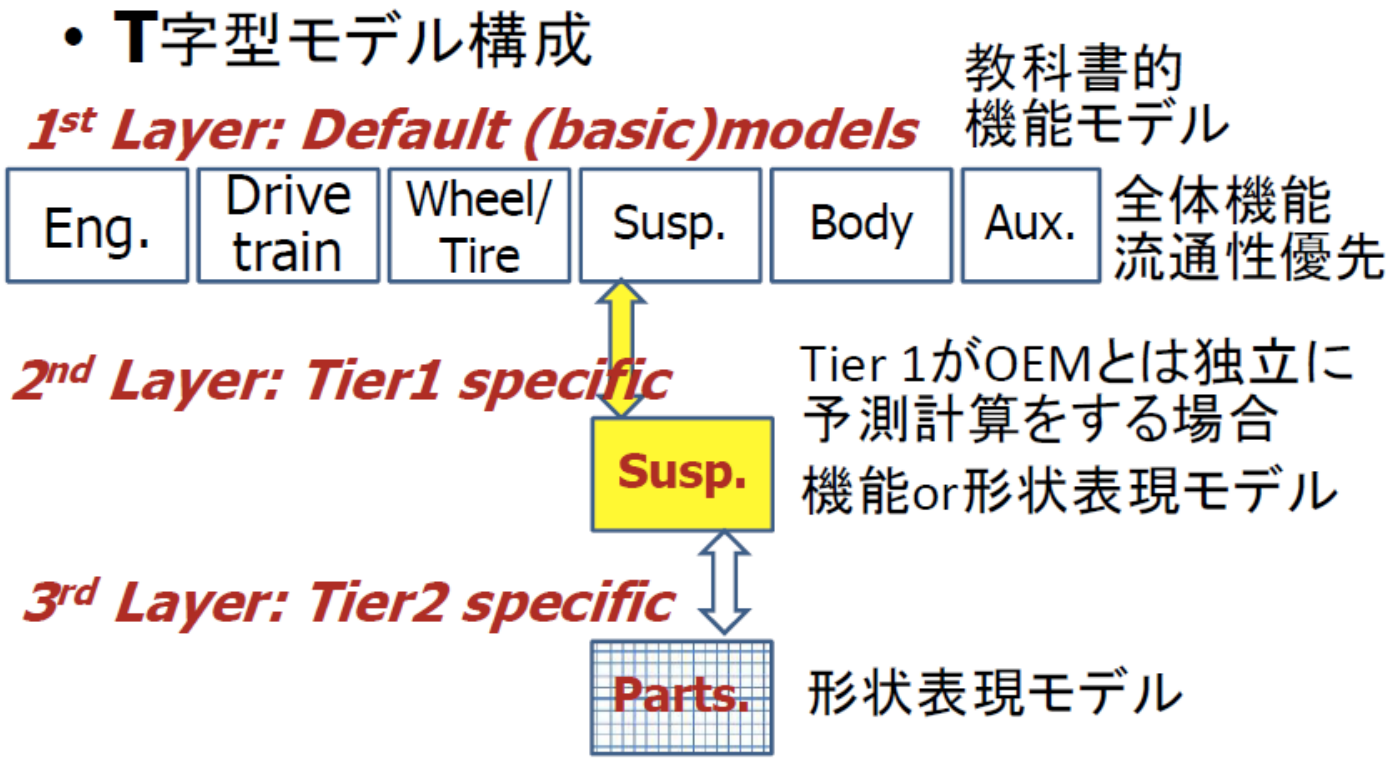
- Development items in MBD need to be prioritized (area A→area B→ area C) according to Japanese engineering development culture.
- Area A (function design) which is an important development item in Japan is set to priority No.1.
- Small and medium-sized enterprises that manufacture machine parts have a low applicability rate of 3D-CAD and CAE, and there is a high need to promote their dissemination in manufacturing design (Area C).



Deeping of SURIAWASE 2.0

Modelling other areas are difficult in systems thinking.
T-shape model creation is an important point for SURIAWASE development especially.

Concept of simulation models in MBD in Automotive industry :
layer, purpose of use, security policy for confidential information…



Deeping of SURIAWASE 2.0

From 2018Year to 2020Year, the simulation model has been developed through industry-academia collaboration focusing on expansion of the performance area according to the Japanese conventional guidelines and the layer of vehicle simulation model.

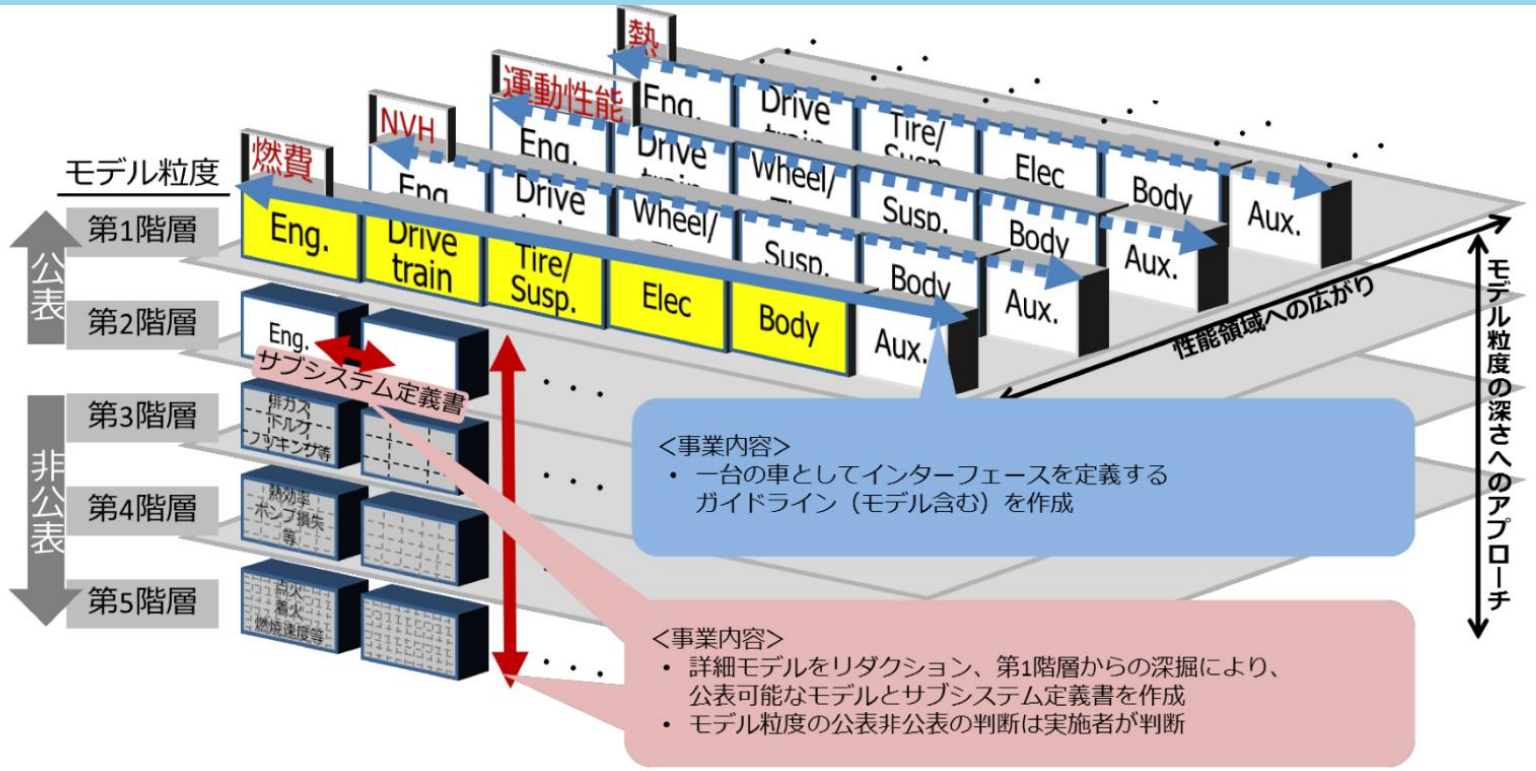


図 6 3ヵ年事業のイメージ

0. Purpose of use and notes of this guideline
1. Introduction
2. Simulation model exchange process and modeling definition approach
   - Outlines
     ①Definition of overall process
     ②Definition of interaction scenarios and use cases
     ③Definition of model architecture
     ④Definition of model type
     ⑤Definition of exchange model development process
     ⑥Definition of evaluation environment of model
     ⑦Risk and action of model modification(IP protection)
   - Summary of outlines

Technical issues in model exchange

In order to exchange the models in systems development, it is necessary to define the model architecture, layer and interface (I/F). The efficient communication method between the model developer and the user also needs to be considered.

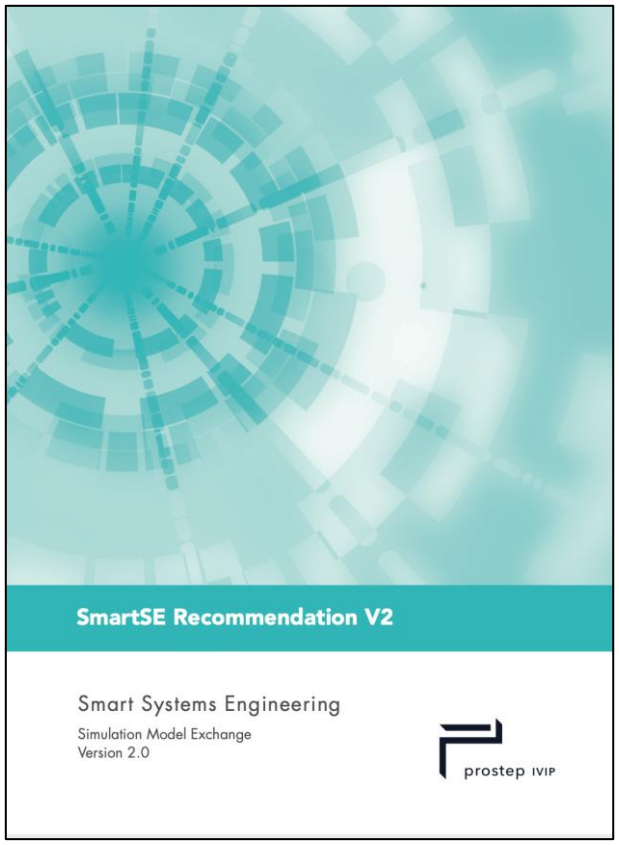
In order to exchange the simulation model between OEM and suppliers, the following technical issues which cause the huge burden of man-hours across companies are required to solve.

1）Definition of process for simulation model development
(Significantly different in each company)
2）Definition and sharing of purpose of use of simulation models
3）Definition of optimum layer of simulation models
4）Definition of evaluation environments[utilized(exchangeable) of simulation models
5）Definition of optimized I/F for model layer
6）IP protection of simulation model exchange

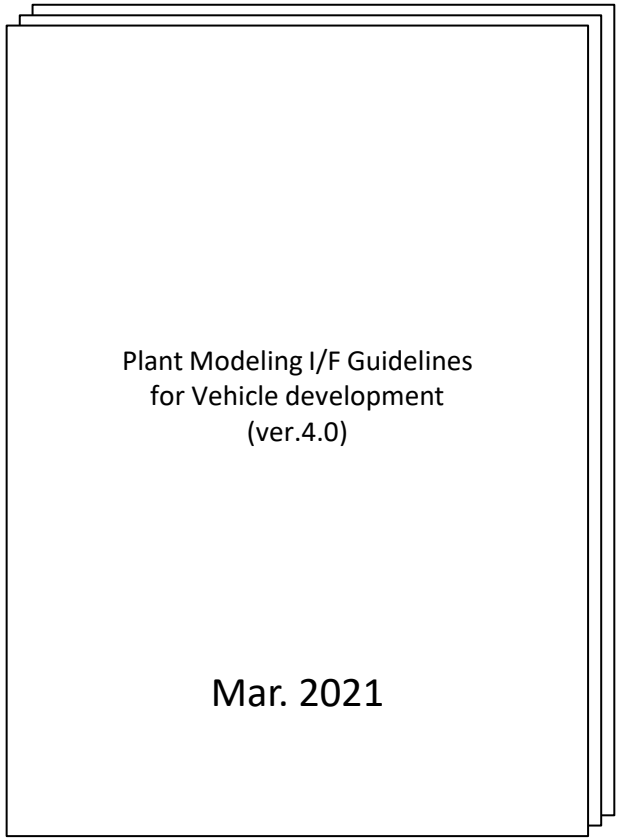
The viewpoints of the model exchange process utilizing "PSI GL" and "Plant I / F GL" are described on the following pages, based on the manners, reference architecture and I/F for model exchange which are shown on the next page.

Outlines of referenced guidelines

Smart linkage of various conventional guidelines is necessary in order to exchange the simulation models. In this GL, examples of simulation model exchange are described based on two conventional guidelines are shown below.



SmartSE Recommendation V2
Simulation Model Exchange Version 2.0
(PSI GL)

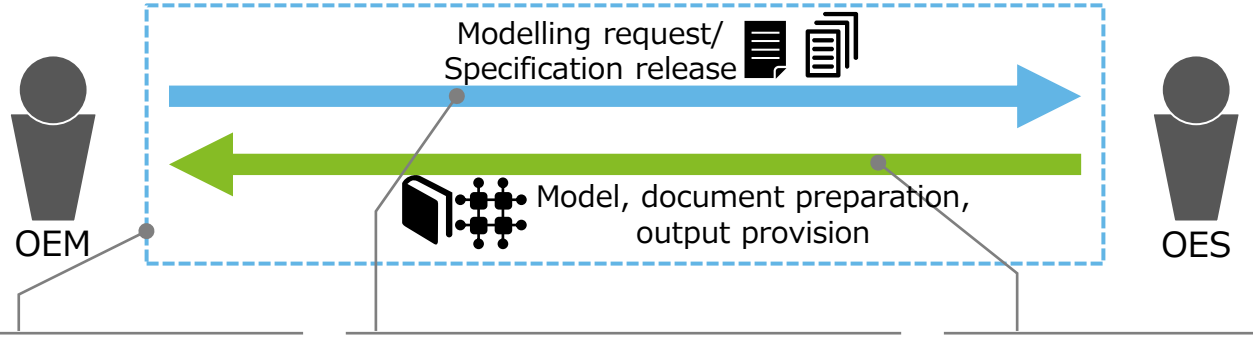


Plant Modelling I/F Guidelines
for Vehicle development ver.4.0
(Plant I/F GL)

Outlines of referenced guidelines

Promoting common understanding of model exchange and models by defining ares in Japanese MBD that are mainly problematic in model transfer between collaborated partners from the three perspectives of manners, architecture, and I/F.

Image of model exchange



Issues

- The responsibilities of OEM and suppliers which occur during the exchange of simulation model is unclear.
- Since each company has a different concept of hierarchy and layer, the area of division at the component/system level when creating a model is unclear.
- Since the I/F is set individually for each company, problems may occur when connecting models.

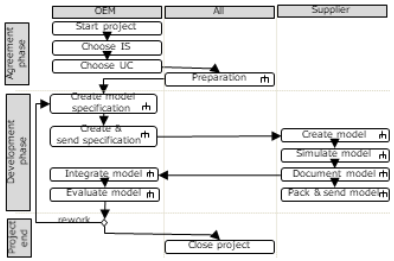
In order to clarify the division of responsibilities manners are required

A reference map which is clarify the area of model requested to create is needed to have common understanding.

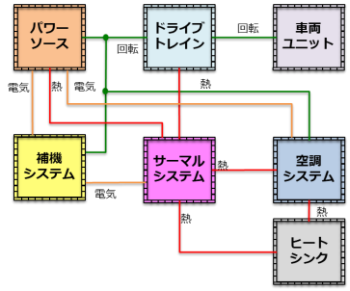
A common understating for I/F which secures connecting directions and units of each model is needed.

Measures

A Definition of manners



B Budling of reference architecture



C Definition of I/F

METI Model ガイドラインの事例		INPUT		OUTPUT	
		I/F名	From	I/F名	To
パワーソース	回転	回転数	ドライブトレイン	トルク	ドライブトレイン
	熱	温度	サーマルシステム	熱流量	サーマルシステム
	電気	電圧	空調システム	電流	空調システム
	電気	電圧	補機システム	電流	補機システム
ドライブトレイン	回転	トルク	パワーソース	回転数	パワーソース
	回転	回転数	車両ユニット	トルク	車両ユニット
	熱	温度	サーマルシステム	熱量	サーマルシステム

⋮

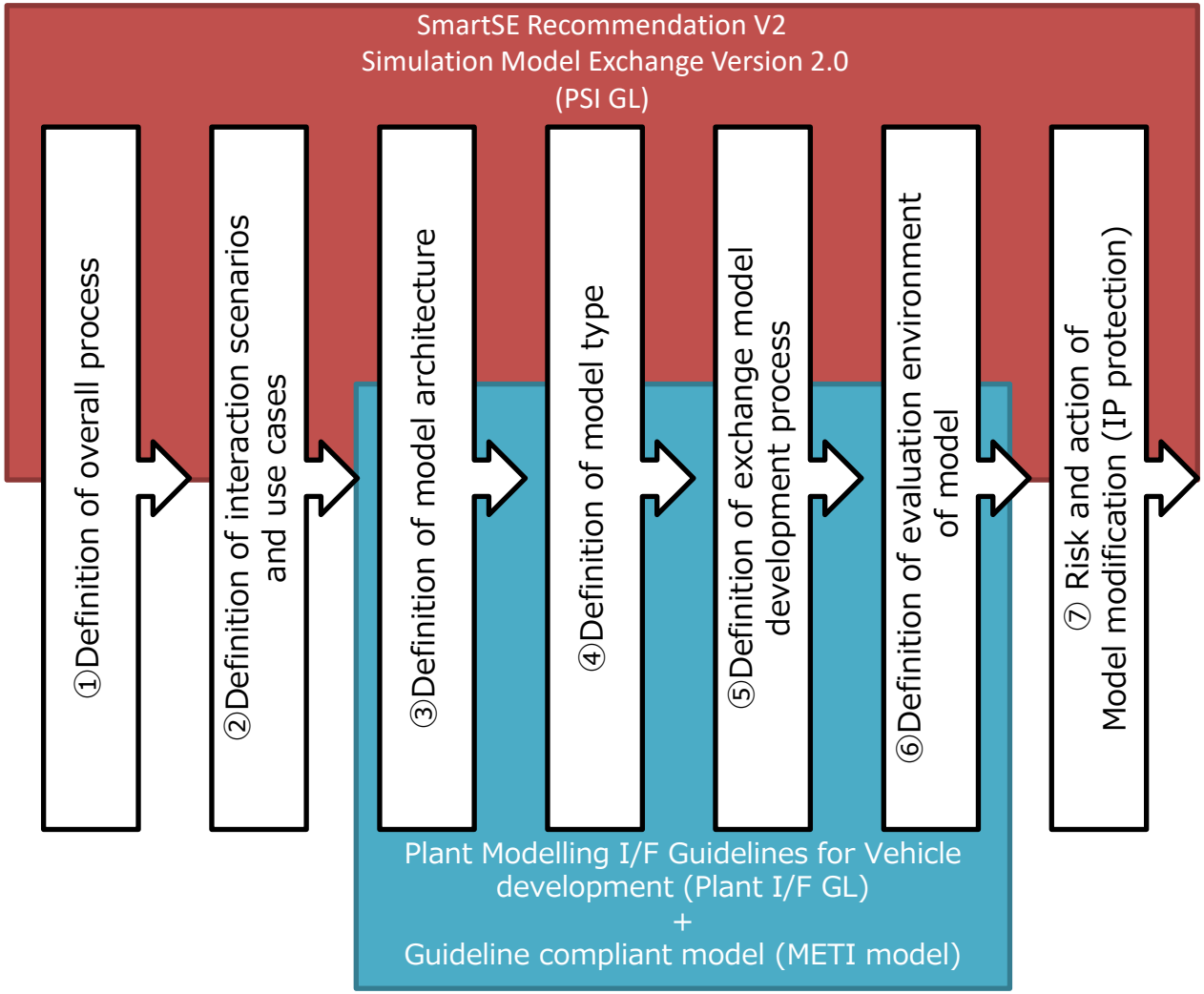
SmartSE Recommendation V2 Simulation Model Exchange Version 2.0

Plant Modelling I/F Guidelines for Vehicle development ver.4.0

Reference : Pre-GL Building Committee Meeting No.2, METI:11（12, Sep., 2019）

Outlines of referenced guidelines

The simulation model exchange guideline to be integrated this time links two reference guidelines in the following process.



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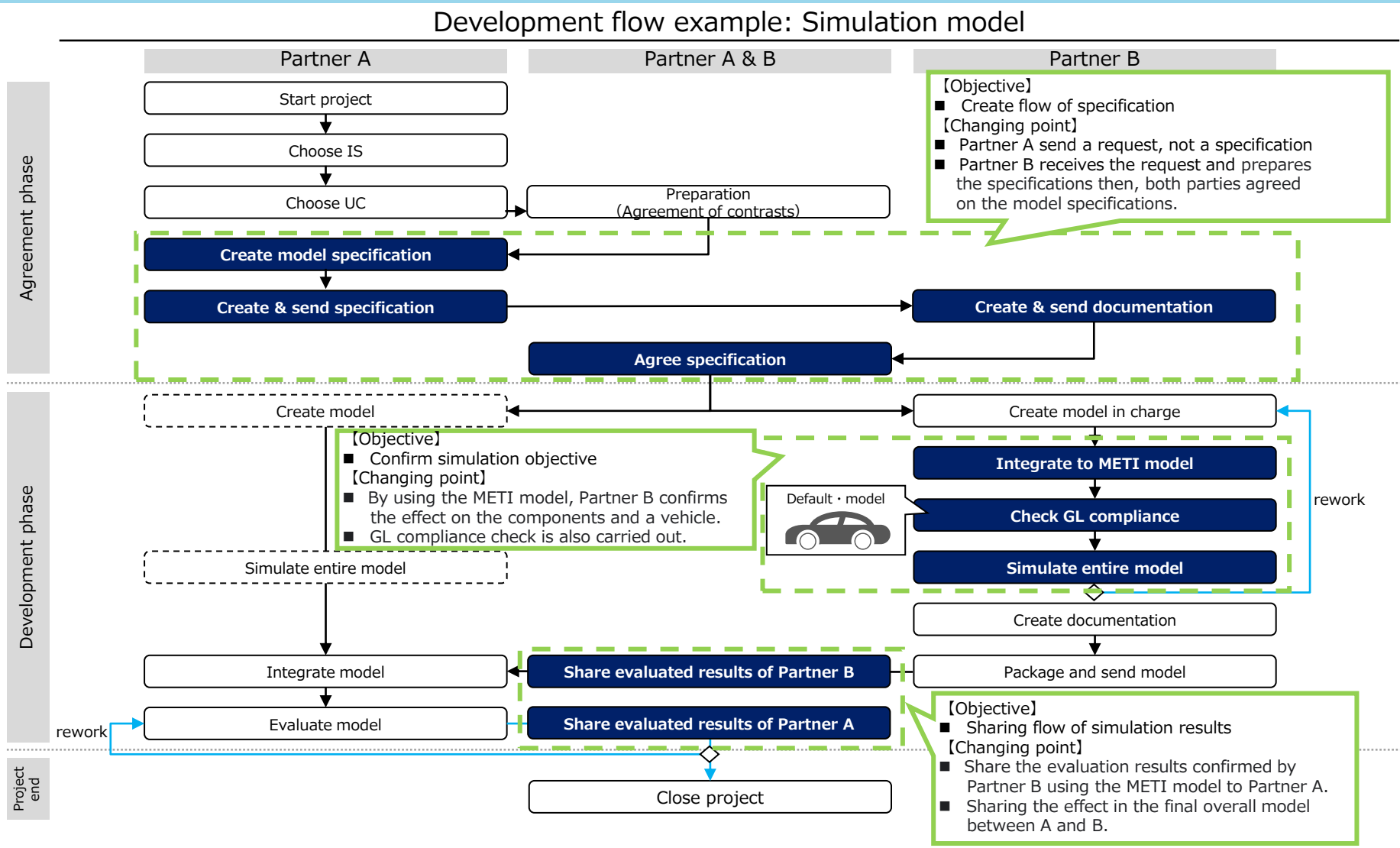
2. Process of simulation model exchange and modeling definition approach

①Definition of overall process：Development flow example using METI model

- The process of exchanging models such as the METI model between companies is described using PSI GL.
- The points of change corresponding to Japanese SURIAWASE development are summarized in the following three points.



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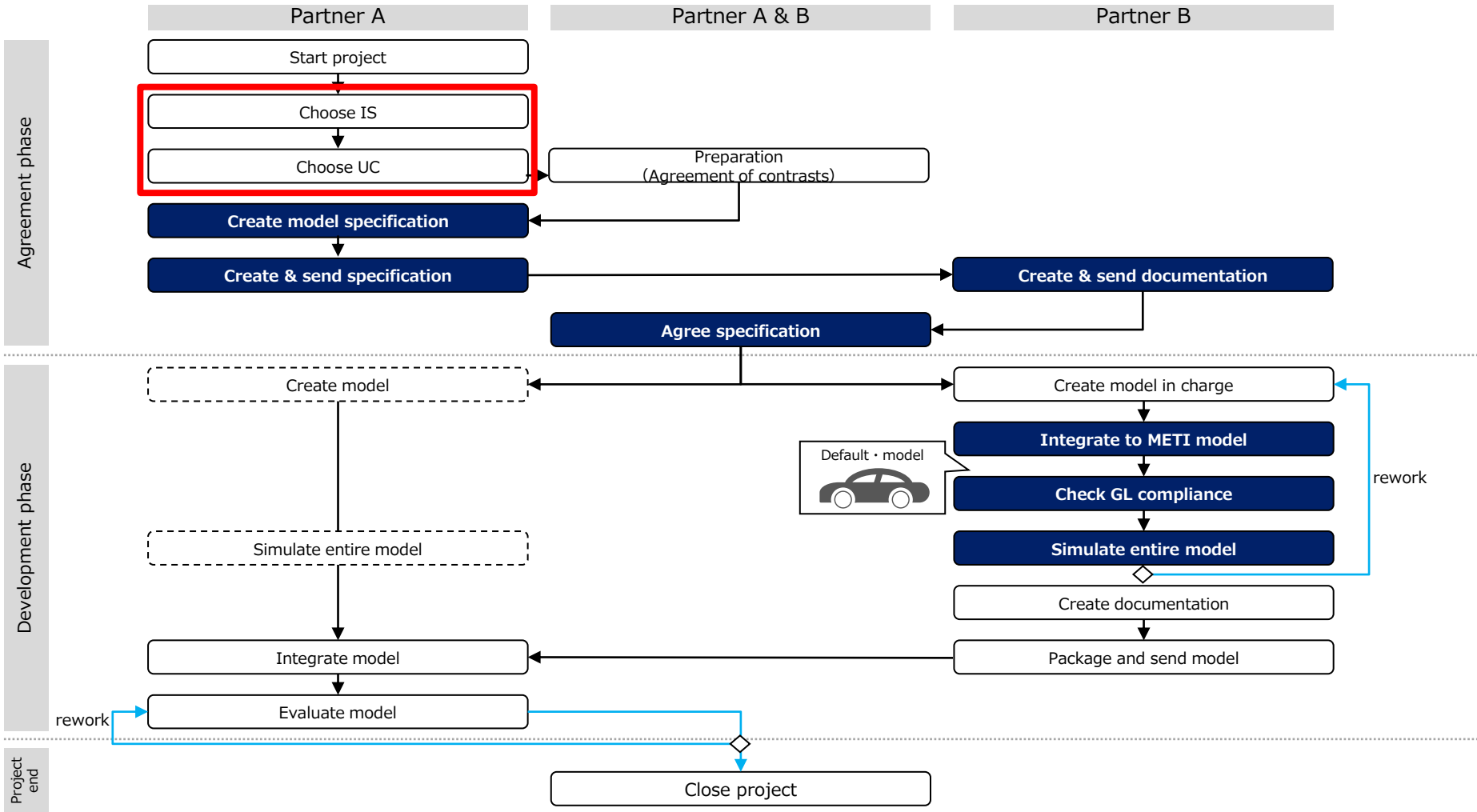
②Definition of interaction scenarios and use cases

As one of the important points in the process, it is necessary to clarify the interaction scenario (IS) and use case (UC) for model exchange. Useful for understanding requirements, IP settings, model layer, etc. among partners.

Development flow example: Simulation model

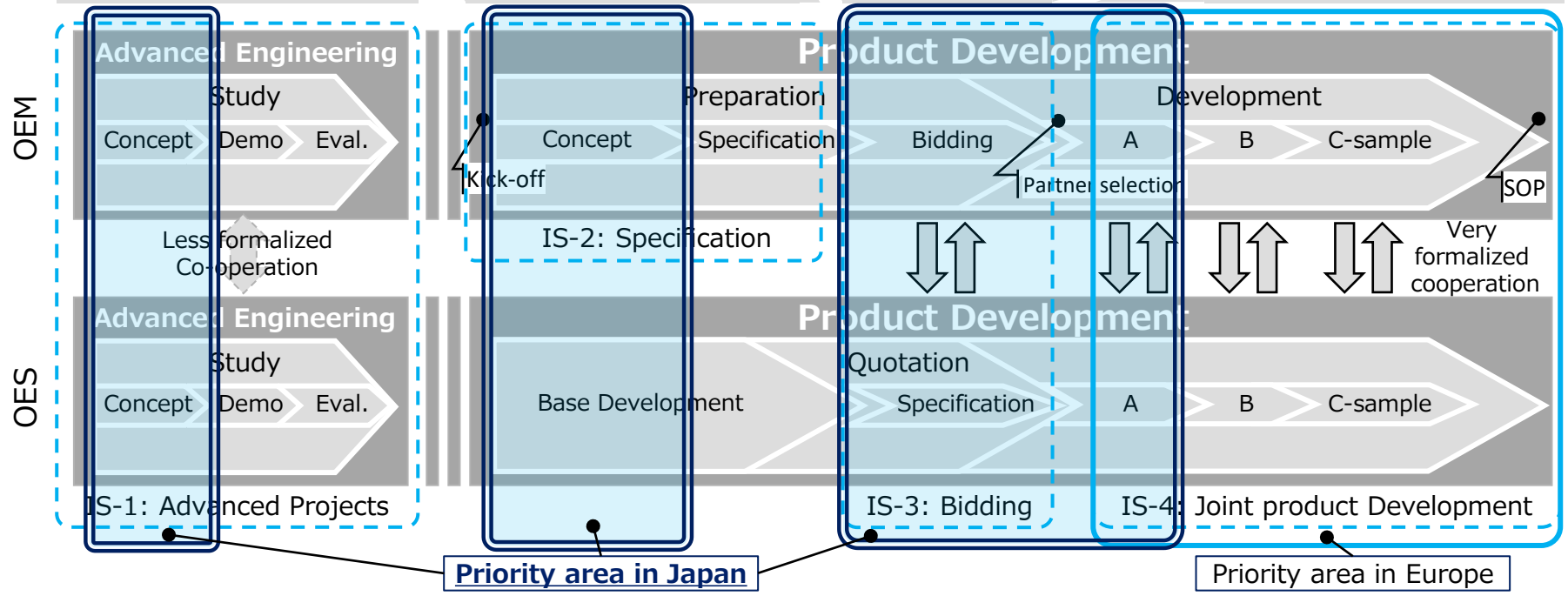


② Definition of interaction scenarios and use cases

Choose of interaction scenario

A common understanding between the partners is promoted by applying the model change process in the supplier selection and initial development phase, in order to emphasize the design area of the system / functional level in line with the Japanese SURIAWASE development culture during the interaction development phase between OEM and supplier.

	IS-1 : Advanced project	IS-2 : Specification	IS-3 : Instruction (bid/public announcement)	IS-4 : Joint Product Development
Contents	Information and data transfer flow in the early phase of system advance development, and collaborate between partners.	Organizing information and data for IS-3 to clarify the system.	Information and data transfer flow at the time of proposal, and the process until the system contract is given to the system supplier.	Flow of input and output information and data (especially simulation model) until the final production of the product.



Reference : RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

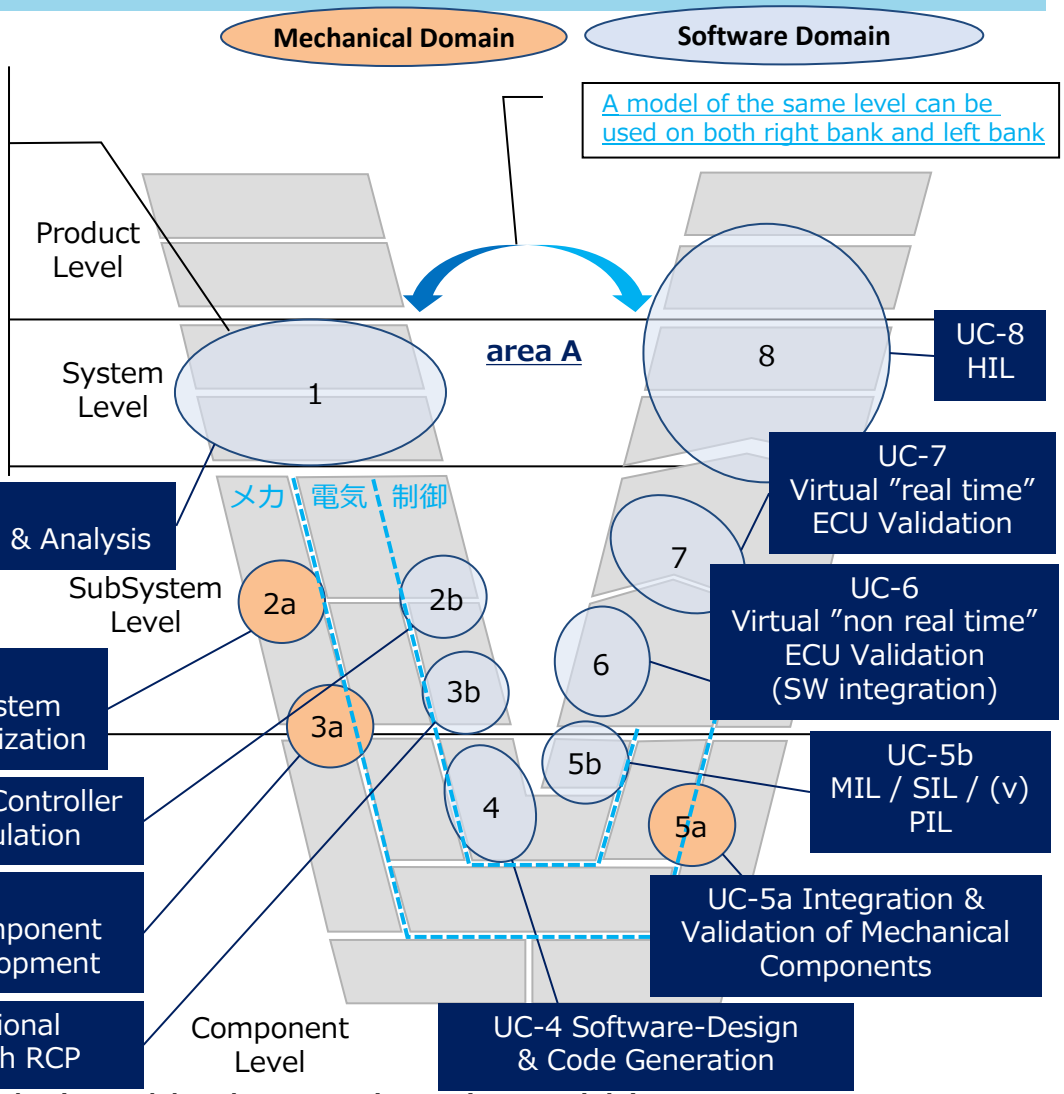
Representative use case in V shape process

Promote common understanding among collaborated partners by prioritizing area A, which is a system/ functional level design area, which is an important item in line with Japanese SURIAWASE development culture in the V-shaped development process.

○Use Case (UC)

Outline Template for each Use Case

UC-X (1~8)	Use Case Name	V
Use Case Outline		
Input	Process/ Implementation Contents	Output
Tools・Environment		



Example：Use Case (UC)

UC-1 System Modeling & Analysis
UC-2a Components/System Analysis & Optimization
UC-2b Function/Controller Design & Simulation
UC-3a Mechanical Components Design & Development
UC-3b Function Evaluation with RCP
UC-4 Software Design & Code Generation
UC-5a Mechanical Components Integration & Evaluation
UC-5b MIL / SIL /(v)PIL
UC-6 Virtual "non-realtime" ECU Validation (SW integration)
UC-7 Virtual "realtime" ECU Validation
UC-8 HIL

Reference： RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

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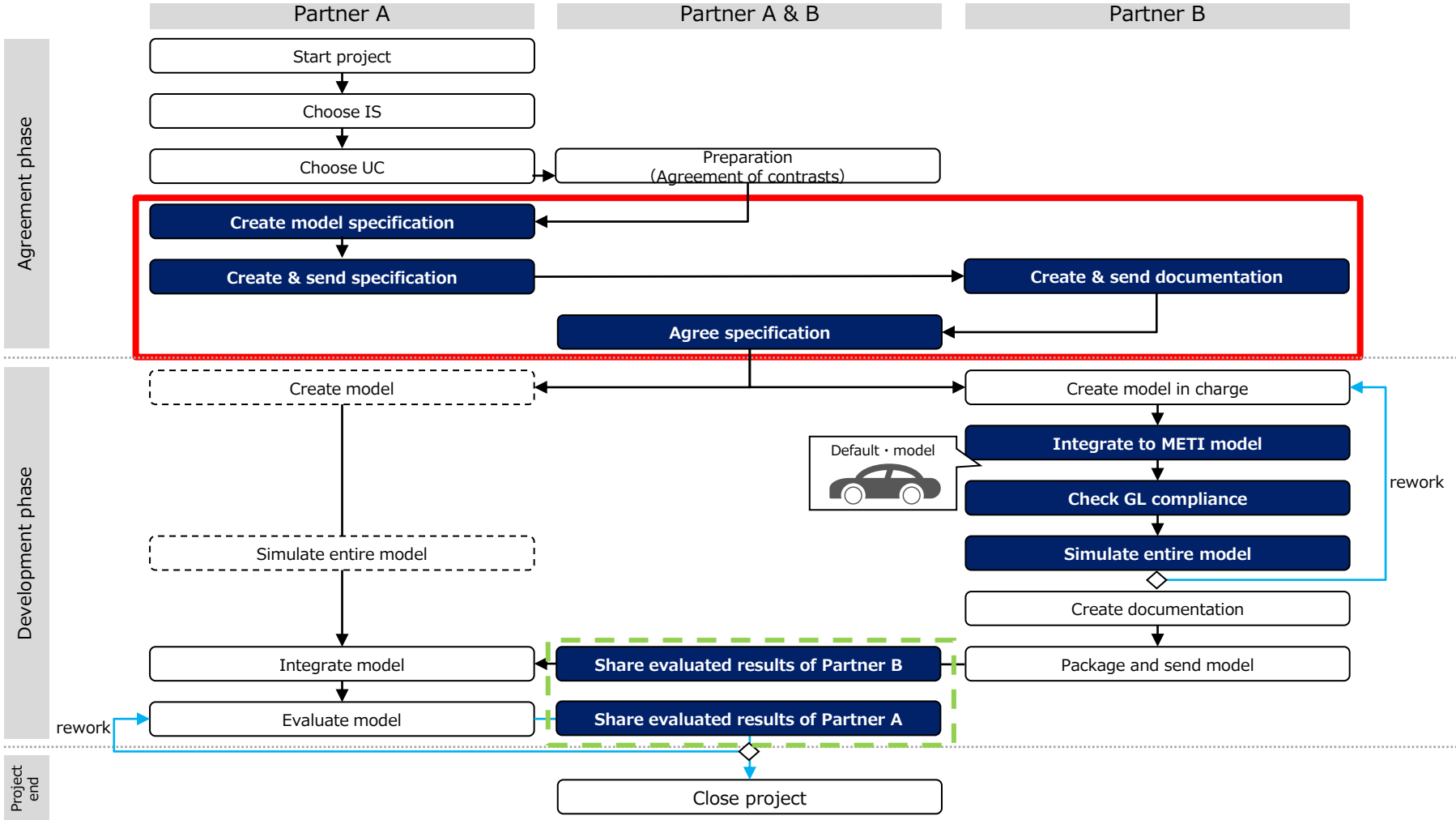
③Definition of model architecture and I/F

- areas and layer of simulation model are required to define for modeling.
- Standardized process and examples can be help to have common recognition between collaborated partners in order to define areas and layer of simulation model.

Development flow example: Simulation model



2. Process of simulation model exchange and modeling definition approach

③ Definition of model architecture and I/F :

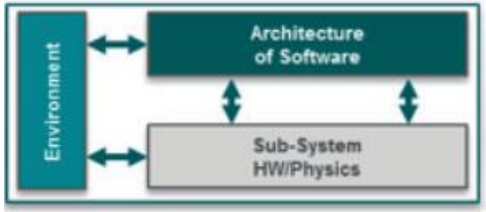
4 Layer approach

- PSI GL recommends a layered approach that divides the process of determining the scope and layer of modeling into four levels of abstraction.
- Set the required area and I/F according to the purpose of model development, and decide the type of model is required.

Degree of abstraction: Low → Models → Degree of abstraction: High

Simulation Models

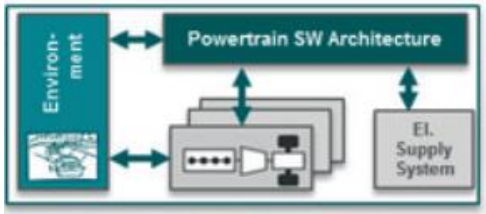
1st layer Overall System



Rough overall system architecture for engineering problems (HAD, CO2, drive dynamics, …)

- *Purpose: Coordination with OEM about functional and physical architecture*
- *Benefit of standardization: Well-defined system borders and determination of responsibilities in case of collaborative engineering*

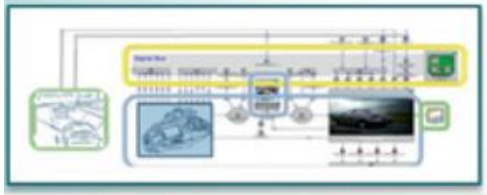
2nd layer Topology



Topologies of relevant sub-systems with couplings (energy & information flows)

- *Purpose: Specification of topologies and cause-effect-chains of the regarded system*
- *Benefit of standardization: Clearing of system understanding and requirements; reuse of knowledge*

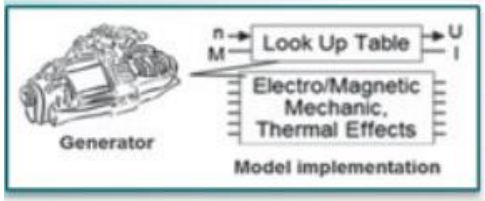
3rd layer Simulation



System model with input/output behavior of component models (granularity, interfaces with potential flow variables and signals)

- *Purpose: Specification of models and simulation tools, probably coupled simulations for main simulation tasks, simulation execution*
- *Benefit of standardization: Comparability of simulation results; interoperability of simulation models*

4th layer Model



Implementation/selection and parameterization of component models and numerics (effects, model equation, solver, …)

- *Purpose: Provision of component models including IP protection for collaborative model-based engineering with customers*
- *Benefit of standardization: Efficiency through reuse and if necessary, tailoring of models; enables comparability of simulation results*

12, Sep., 2019
Pre-GL Building Committee Meeting No.2

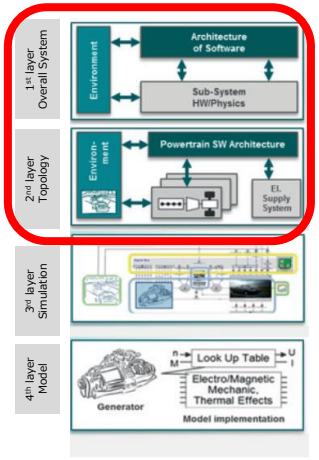
Reference : RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

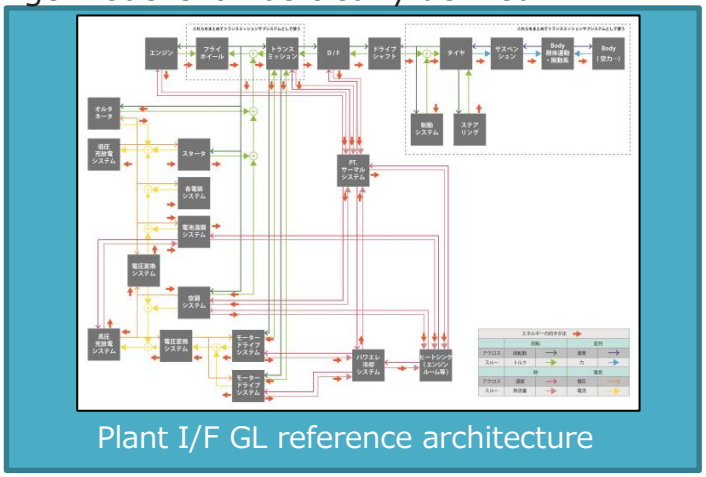
2. Simulation model exchange process and modeling definition approach

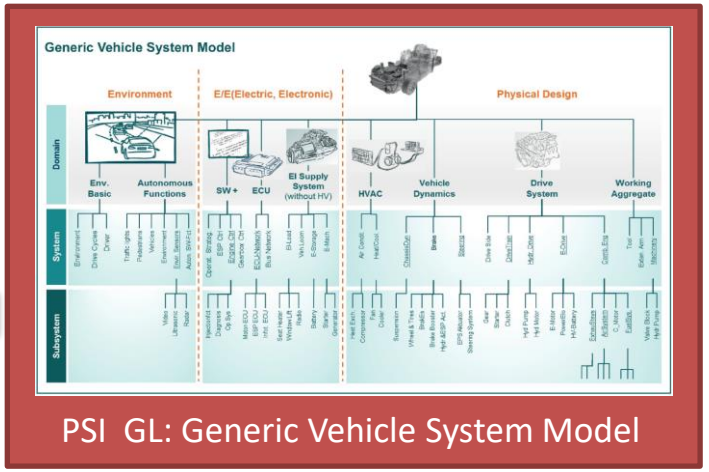
③ Definition of model architecture and I/F ：

Definition of referenced architecture case example

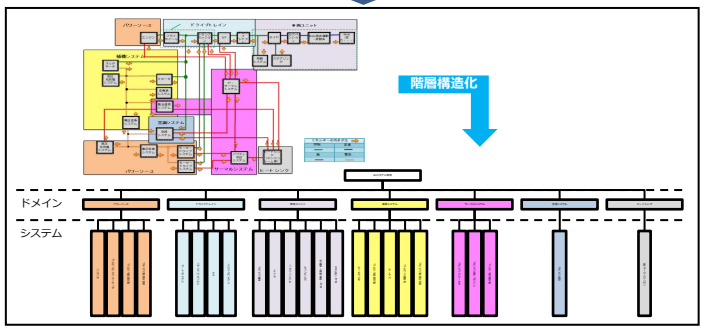
- Optimal model layer can be determined by customizing based on the reference architecture to create a model and by recognizing the required model hierarchy in common.
- In the plant I/F GL, the architecture of a general model that takes a certain performance as an example is defined. The architecture which is required to model in this time is build according to the Plant I/F GL as a reference. In addition, by clarifying the hierarchy of each system with reference to PSI GL's Generic Vehicle System Model, the layer of the exchange model shall be clearly defined.




Plant I/F GL reference architecture



PSI GL: Generic Vehicle System Model

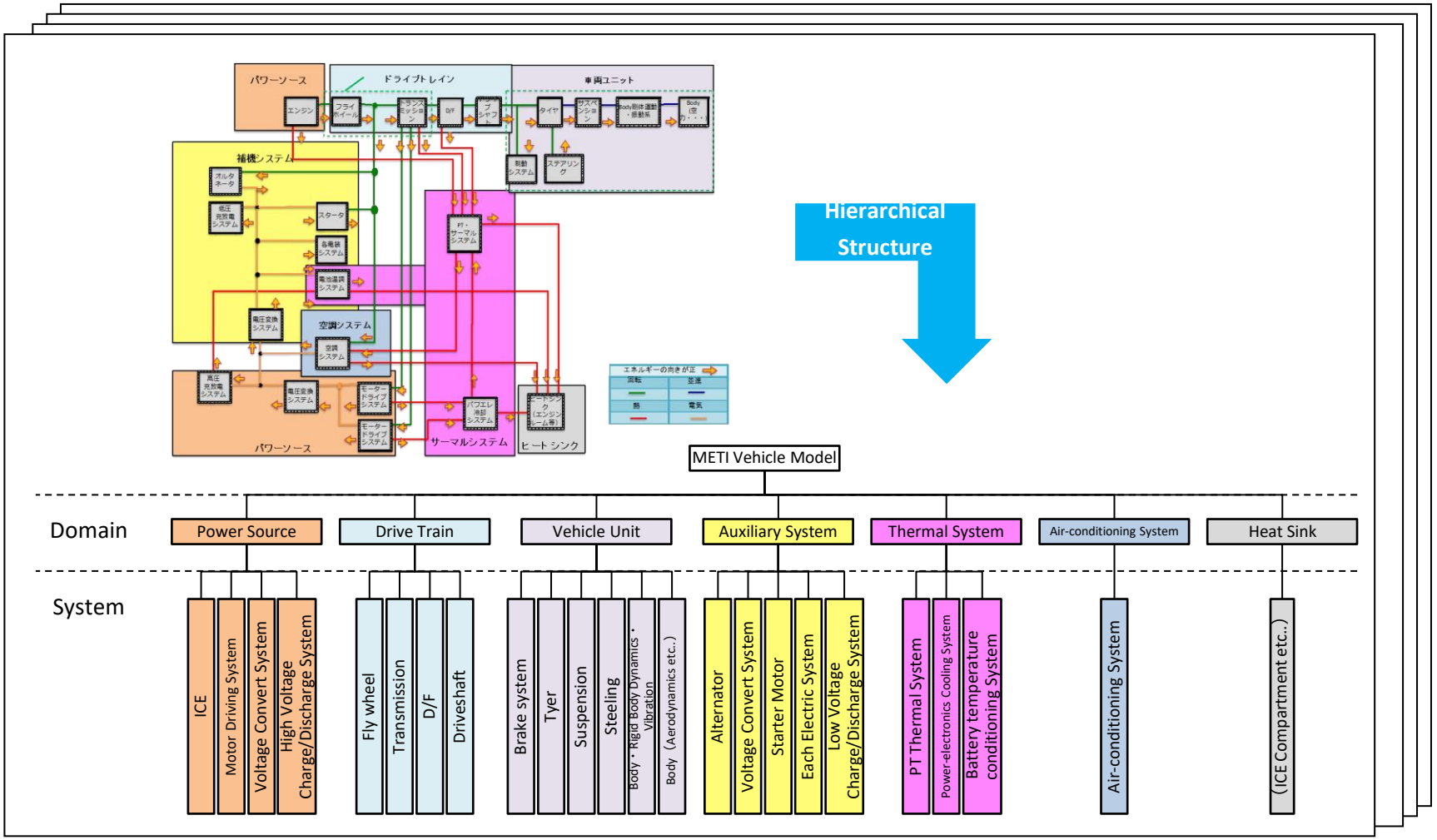


The architecture and hierarchy is required for modeling this time

③ Definition of model architecture and I/F：

Definition of Reference Architecture

By defining using the Generic Vehicle System Model with reference to the plant I/F GL compliant model (METI model), A common understanding of The layer of the model is developed.



2. Simulation model exchange process and modeling definition approach

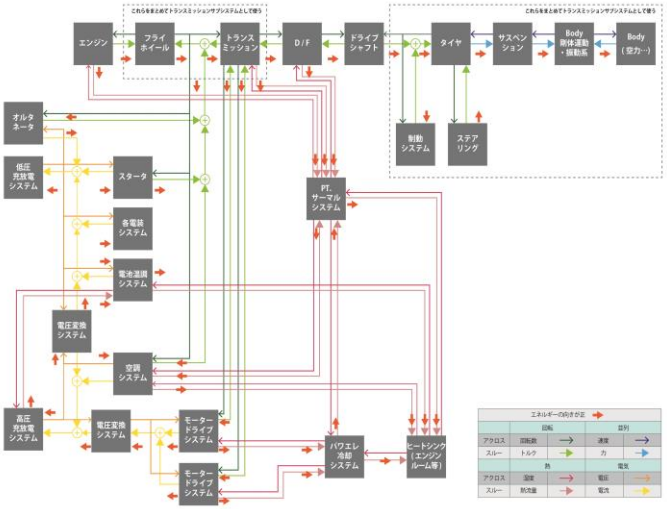
③ Definition of model architecture and I/F：

Definition of Reference Architecture

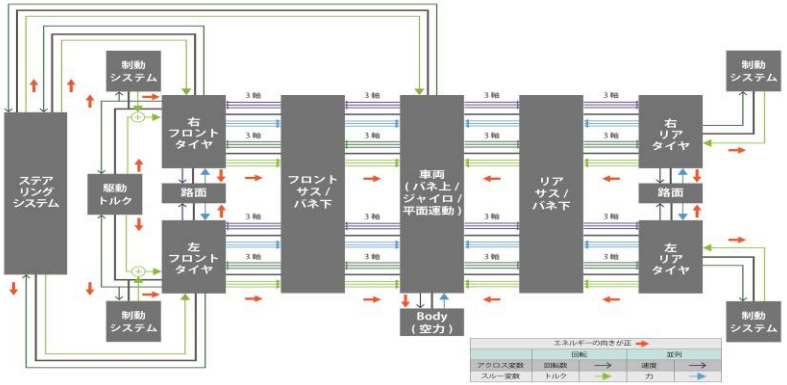
The Plant I/F GL presents the first-layer architecture and I/F cases as guideline for vehicle performances, which can contribute to the improvement of common understanding during the simulation model development.

Example: Performance of vehicle system

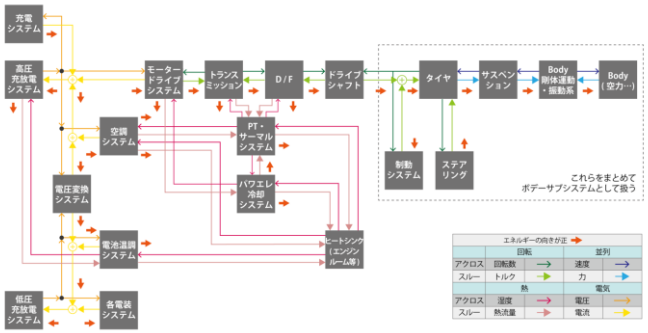
Example: Vehicle fuel efficiency system use case



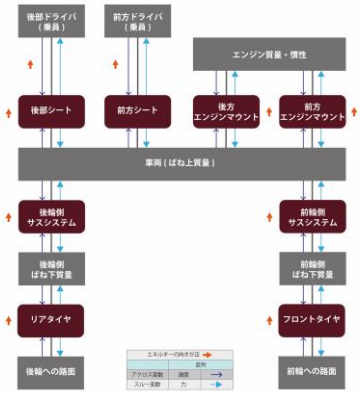
Example: Vehicle dynamics use case



Example: Electrification use case



Example:
Vehicle vibration
Use case



2. Simulation model exchange process and modeling definition approach

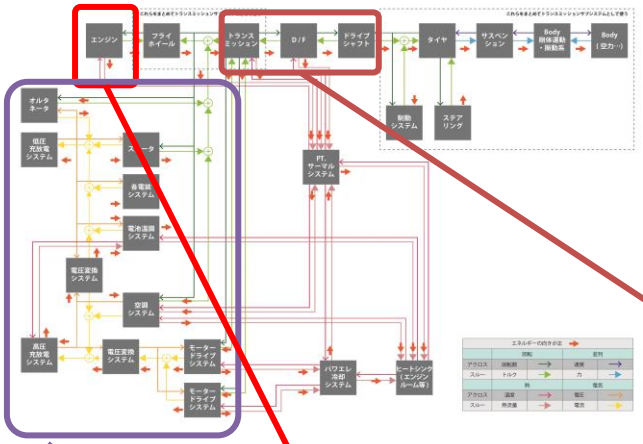
③ Definition of model architecture and I/F：

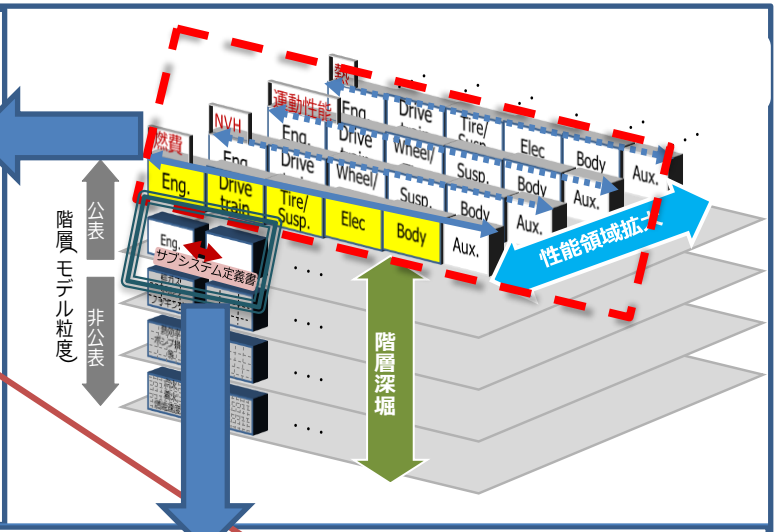
Definition of Reference Architecture

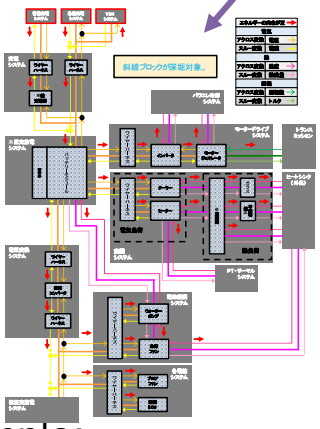
The guidelines for the deep moat part are created by Plant I / F GL. It is necessary to define the architecture of the reference model depending on evaluation objective according to the purpose of the simulation.

Examples:

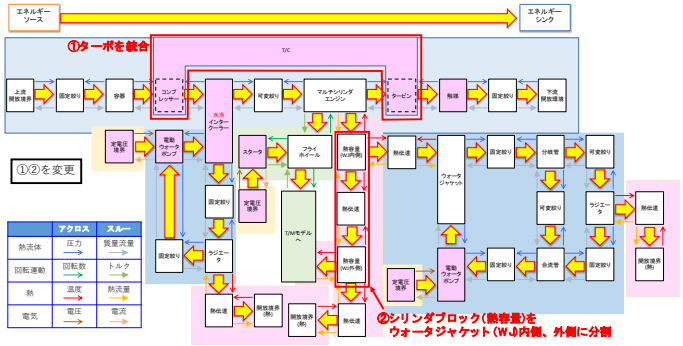
Example: Vehicle System



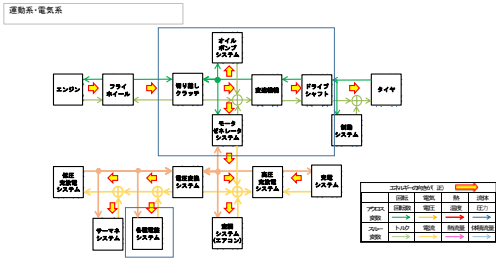




Example: Vehicle Electrification



Example: ICE



Example: Transmission

2. Simulation model exchange process and modeling definition approach

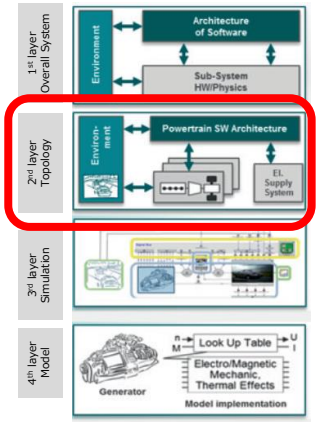
Manners | Architecture | I/F

JAMBE Japan Automotive Model-Based Engineering center

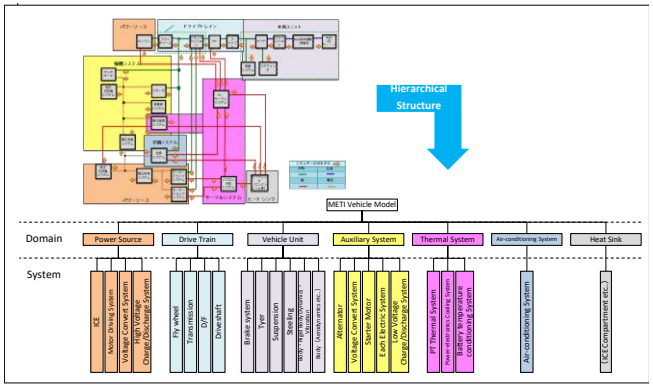
③ Definition of model architecture and I/F：

Definition of Model I/F

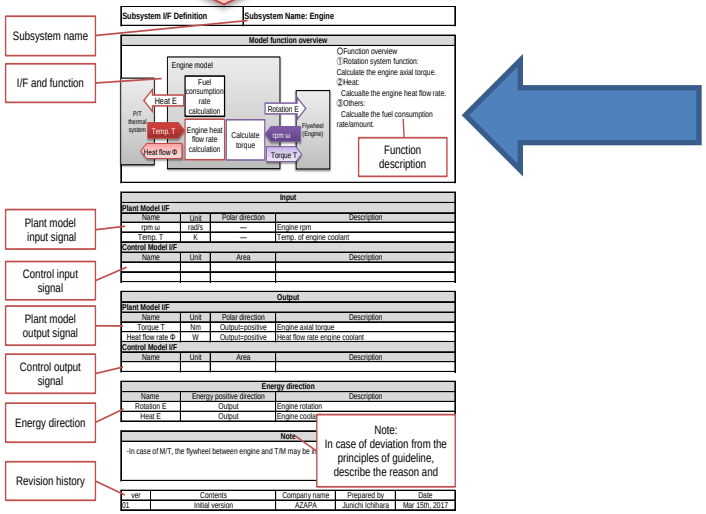
The physical I/F and the information I/F for the I/F of the distributed model are required to defined. Regarding physical I/F, there are some parts that can be defined by referring to the basic principles of plant I/F GL and model I/F examples of each layer. Regarding information (control, etc.) I/F, it is necessary to investigate and build guidelines as a future work.



Study for Topology definition



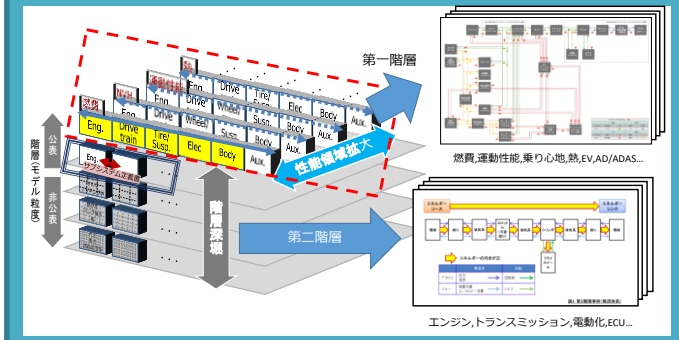
Definition of architecture layer



Definition of I/F for each architecture of model

	Basic principles
1st	Plant models shall be connected using across variables and through variables. Across variables and through variables shall be in the opposite direction.
2nd	The direction of flow from energy source to energy sink shall be considered as the positive direction of energy flow.
3rd	The overall Interface will be defined based on the Interface of elements which store through and across variables.
4th	A Through variable shall be regarded as positive when its input/output is in the same direction as the positive flow of energy.
5th	For input/output, the SI units system and the SI derived unit system shall be used. For the quantifiers, the JIS standard shall be applied.

Plant I/F GL Basic Principal



Example: I/F at each layer

Plant I/F GL

③ Definition of model architecture and I/F：

Definition of Model I/F and Domain

- In the plant I/F GL, the following energy domain are defined for the physical domain of the plant. By Defining the I/F of the exchanged model in each physical domain, it becomes easier to define the I/F of the plant model. Domain that have not been set need to be discussed in the future.

■ **List of across variables and through variables for each physical domain**

Physical Domain	Across Variables	Through Variables
Electrical	Voltage	Current
Translational	Velocity	Force
Rotational	Angular velocity	Torque
Heat	Temperature	Heat flow
Incompressible flow	Pressure	Volume flow
Thermal fluid	Temperature	Enthalpy flow
	Pressure	Mass flow/ Specific enthalpy

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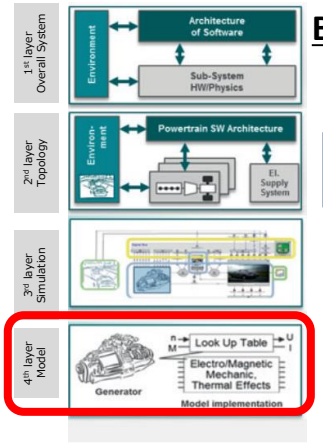
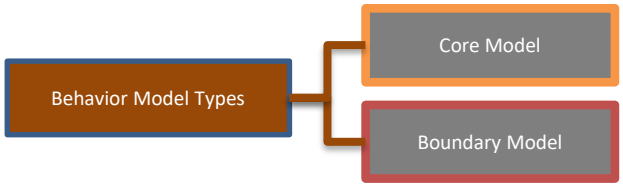
④Definition of model type :

Definition of behavior model type

For the model type to be used, a core model that can understand the design value of each system and a boundary model created with the layer that can understand the boundary conditions are set. It is necessary to set each model as a core model / boundary model according to the purpose of the simulation and optimize the layer of the model.



Behavior Model Types

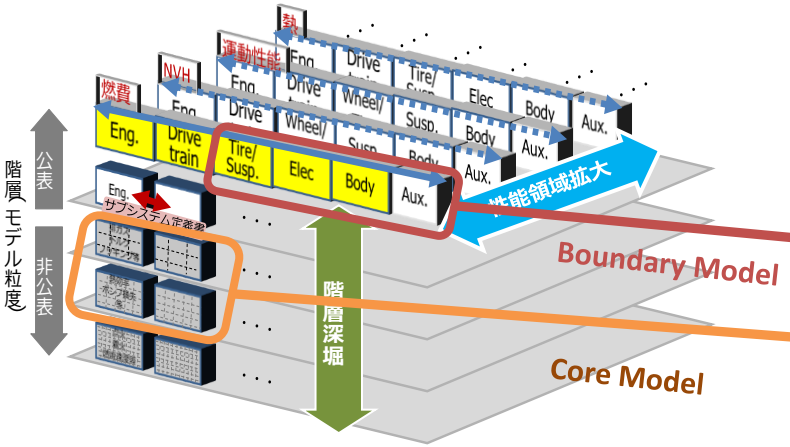


Core Model :

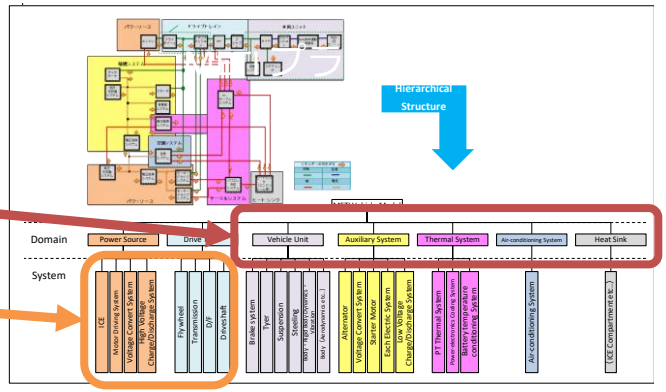
- Defined within the scope of direct development
- A model with very detailed layer
- Highly specialized
  (created by the specialist in charge of each department)

Boundary Model :

- Reduction model tailored to a specific case
- Used for other systems or other domains
  (more often replaced than the core model)
- Mainly a simple component model with rough content



Example: Definition of simulation model layer



Architecture and hierarchy of simulation model

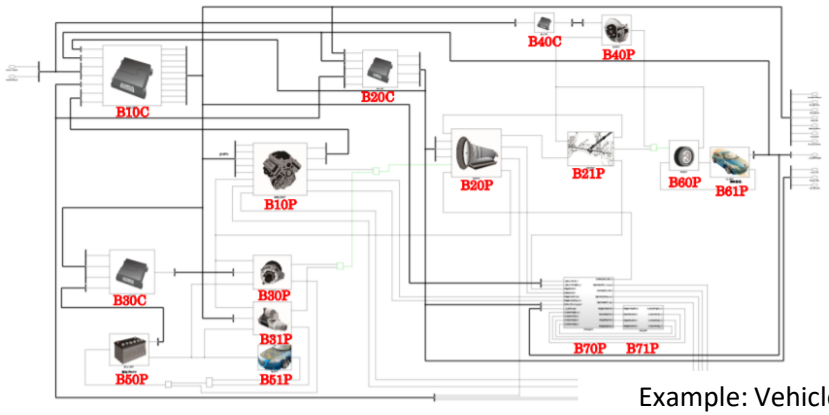
Reference : RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

2. Simulation model exchange process and modeling definition approach

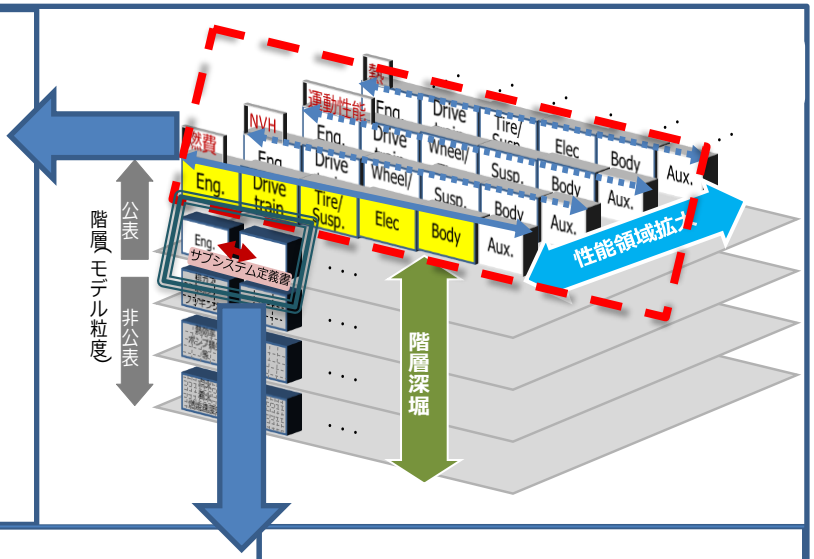
④Definition of model type :

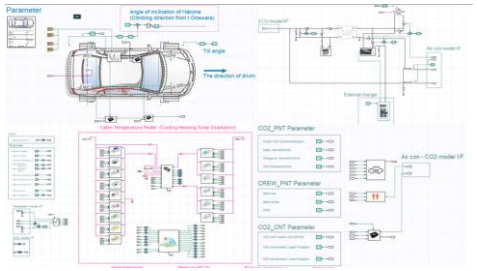
Utilization of guideline compliance model （Generic Model）

In Plant I / F GL, it can be used to have common understanding of model architecture, I / F, and model detail among business partners before starting model development by publishing a guideline-compliant model developed with general functions (generics).

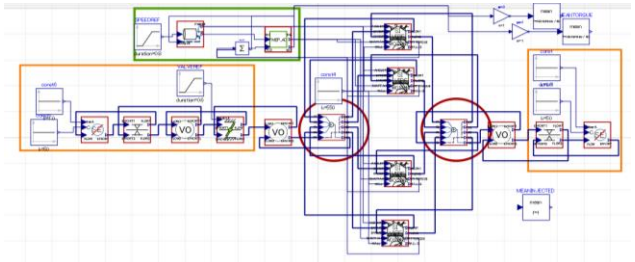


Example: Vehicle fuel efficiency system use case Matlab Simulink Model

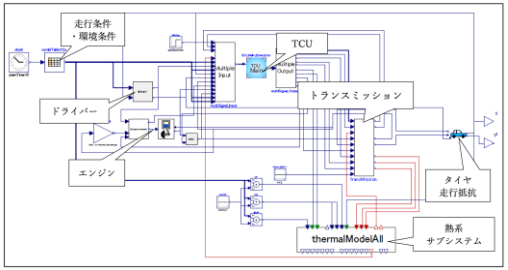




Example: Electrification use case (VHDL-ams Model)



Example: Engine use case (Modelica Model)



Example: Transmission use case (Modelica Model)

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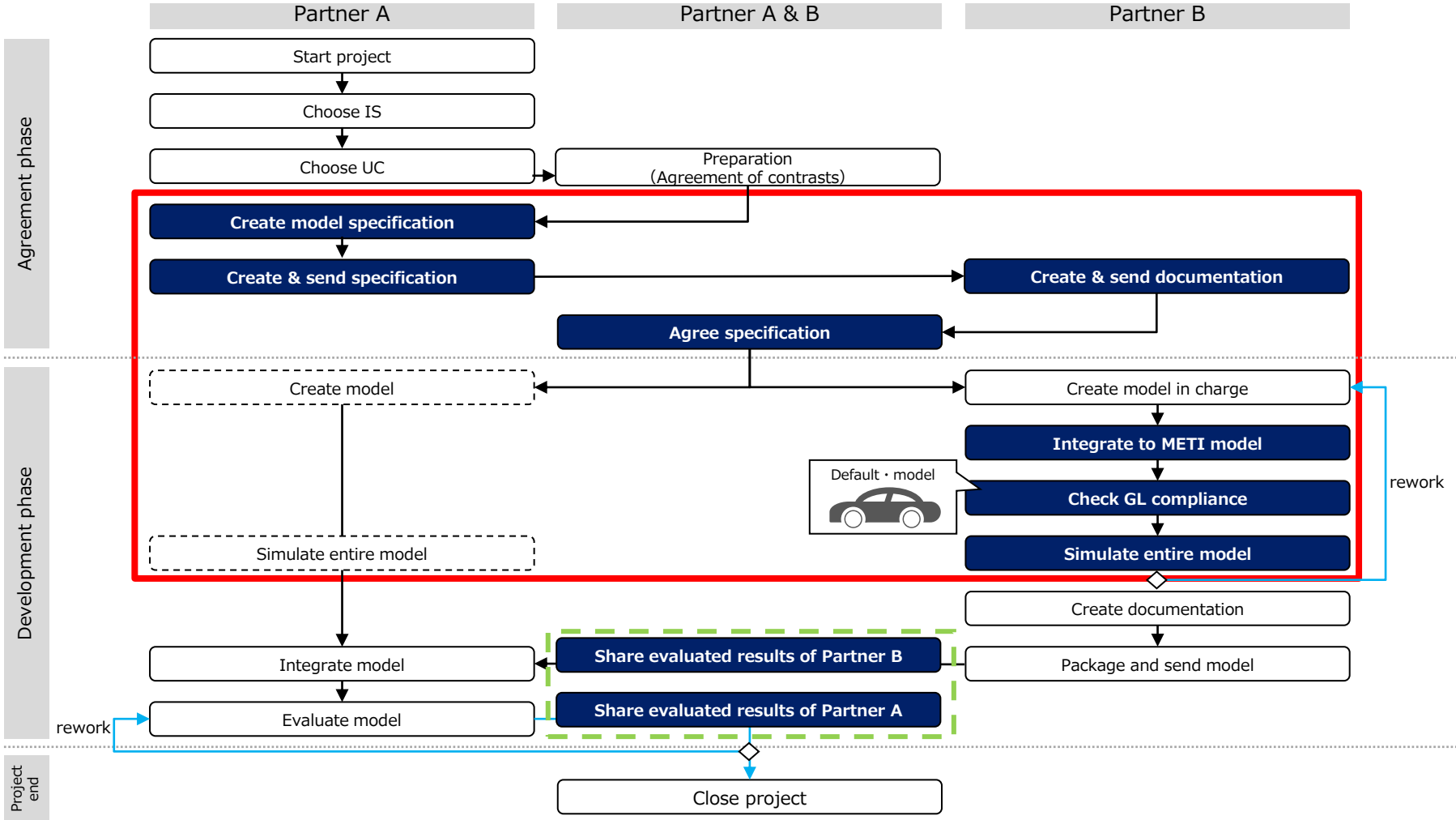
⑤ Definition of exchange model development process

In PSI GL, the development process of the model to be exchanged is defined.

Development flow example: Simulation model



⑤ Definition of exchange model development process

PSI GL defines 10 steps as a model standardization use case.
By using the plant I/F GL and the compliant model, it is possible to have a common understanding.

Step Y **Specification Steps**
Step Y **Implementation Steps**

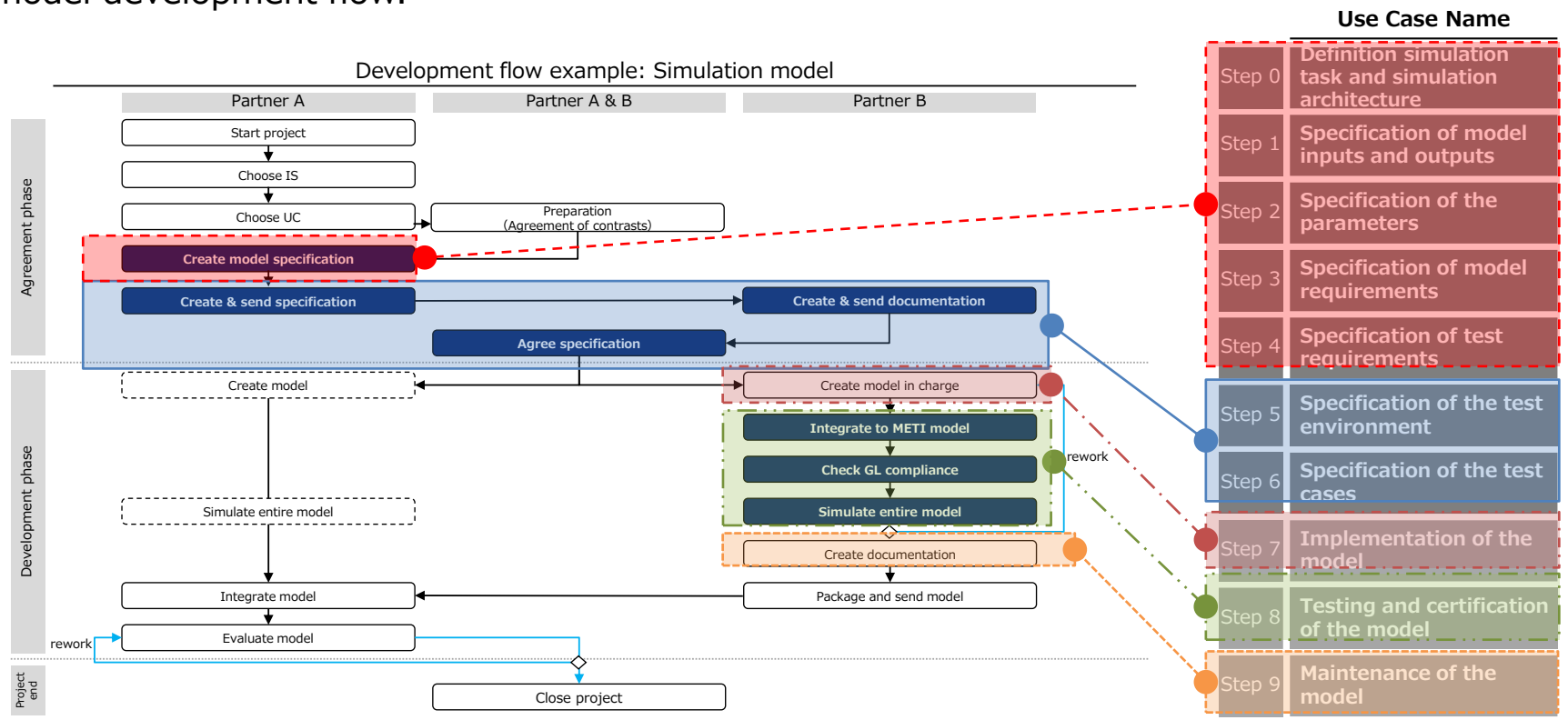
		Use Case Name		Example case
Requirement	Step 0	Definition simulation task and simulation architecture	Describe & decide simulation task & simulation architecture	Define model configuration and I / F I n the plant model guideline (control I/F and individual components in the development request form + α)
	Step 1	Specification of model inputs and outputs	Describe technical I/F (input value & output value)	
	Step 2	Specification of the parameters	Glossary of parameter which is required to define in the model	Described in development request / external specifications / manual It is also possible to utilize the guideline compliant model
	Step 3	Specification of model requirements	Identification of model requirement, documentation, and specification	
	Step 4	Specification of test requirements	Specifications of test requirements that serve as model acceptance criteria	
	Step 5	Specification of the test environment	Determining a test environment for model acceptance	
	Step 6	Specification of the test cases	Description and definition of acceptance conditions in the form of test cases performed to validate the model being developed	
Implementation	Step 7	Implementation of the model	Model development with IT supplies based on pre-specified elements	Create a manual
	Step 8	Testing and certification of the model	Actual evaluation of simulation results and testing of previously specified requirements	Describe the operation check result in the manual Guideline compliant model can also be used
	Step 9	Maintenance of the model	Model maintenance and simulation, including bug fixes (fixing patches) from a quality control perspective	Regarding support, describe in the development request / external specifications / manual

Reference : RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

⑤ Definition of exchange model development process

An example of the relationship between "an example of a model development flow" and "a standardization process for jointly used models" is shown below. It is necessary for Partner A and B to collaborate and make decisions at the following timing.

Example of relationship between distribution model development process and model development flow.



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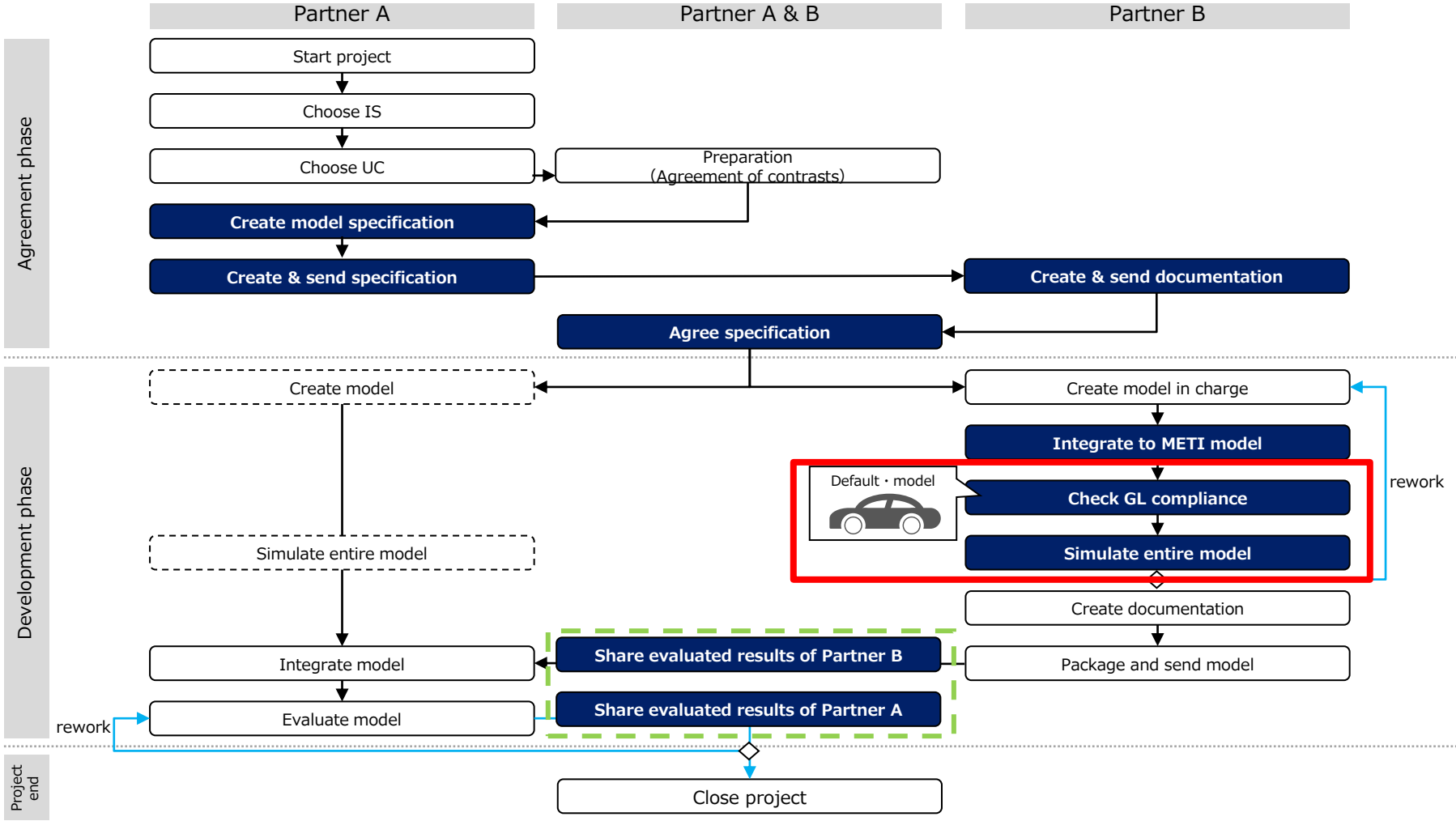
⑥ Definition of evaluation environment of model

In order to evaluate whether the model to be distributed matches the I/F of the plant model of the vehicle model of Partner A, Partner B can verify the connection with a METI GL-compliant (generic) model.

Development flow example: Simulation model



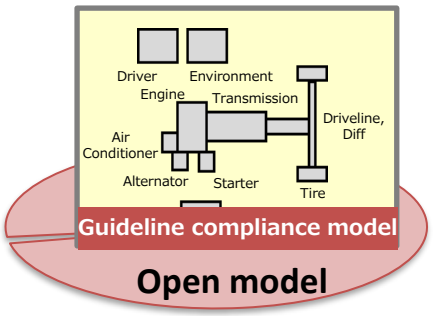
2. Simulation model exchange process and modeling definition approach

⑥Definition of evaluation environment of model :

Guideline check using guideline compliance model

By utilizing the guideline compliant model for the distributed parts model, it is possible to check the I/F, check the behavior when putting it in the vehicle model, and estimate the effect, and trouble after handing the model to the model user. It is also expected to have the effect of being able to check in advance.

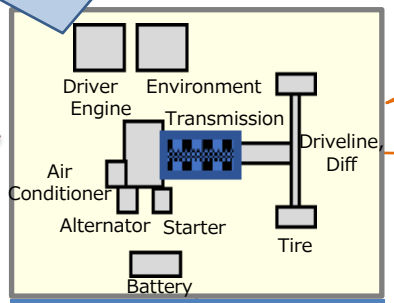
Guideline compliance model
(Fuel economy, Electric economy etc.)



Modelling | Model use

1. Vehicle level evaluation is possible by the supplier.

1. The effect on the vehicle to some extent before considering it in-house can be found.



Component model

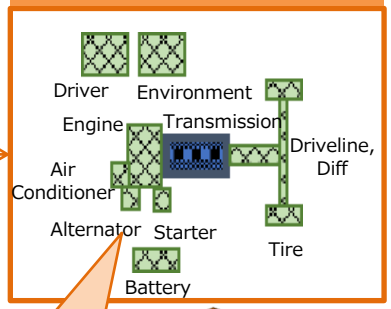
Component model

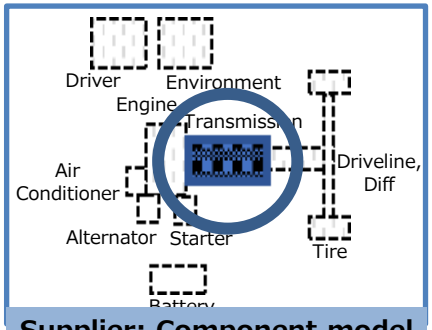
Vehicle Evaluation of component model
(Check the model architect, I/F, and market price as a vehicle)

2. The work to match the individual I / F of each manufacturer can be omitted.

2. The in-house vehicle model and the supplier parts model are immediately connected. (I / F match or difference is clear)

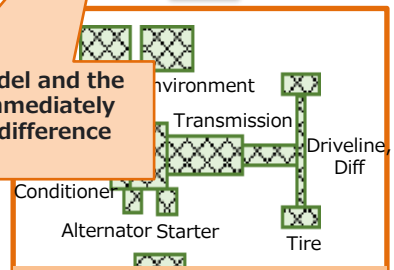
Distribution model Vehicle model for combination evaluation





Supplier: Component model
(Each company has its own uniqueness
. Whether or not there is an e.g.
T / M vehicle model as a whole)

1'. F/B for in-house parts development by suppliers is possible.



OEM: Vehicle model
(Each company has its own uniqueness)

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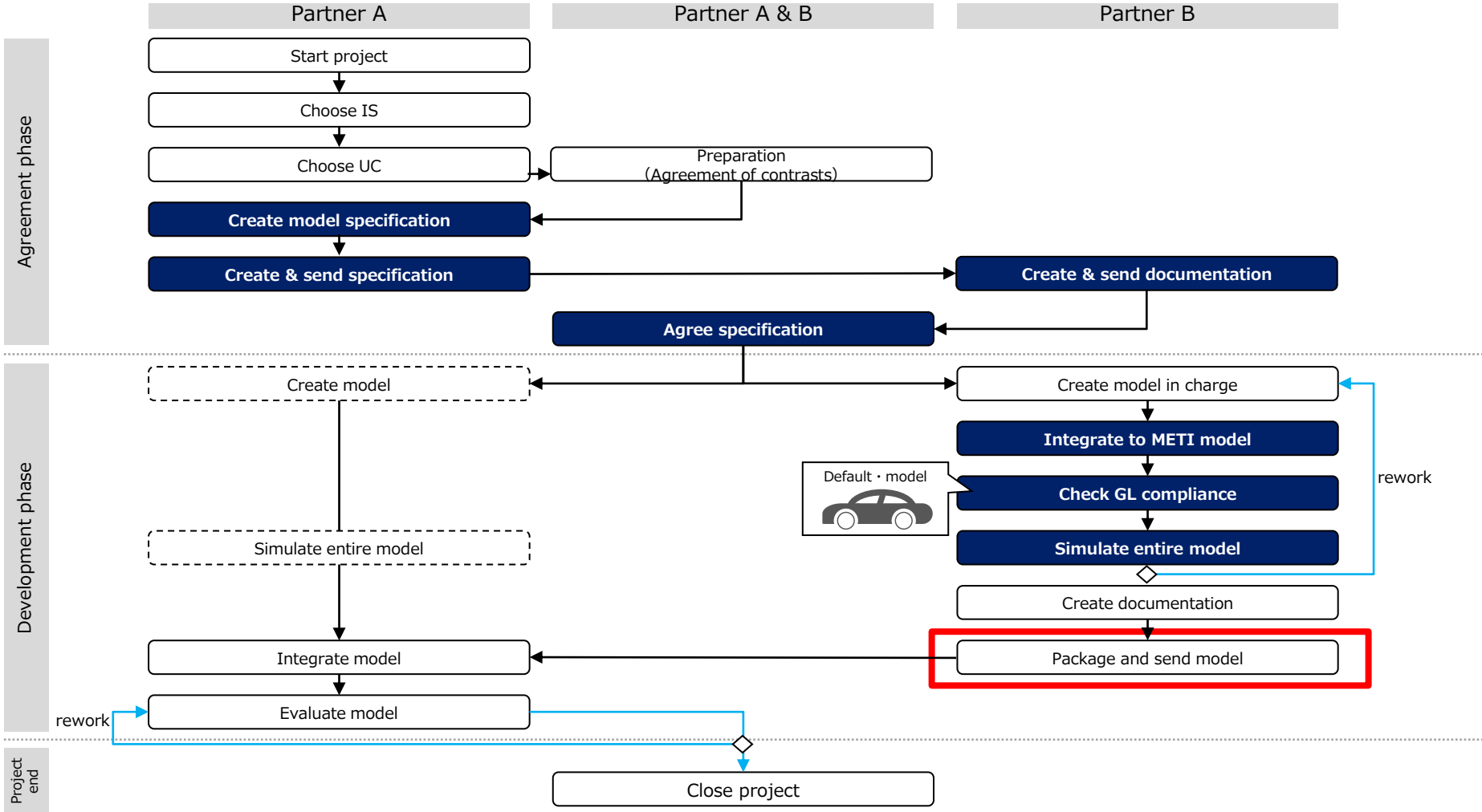
⑦Risk and action of model modification(IP protection)

Definition of exchange process of simulation model is required. PSI GL describes the actions in terms of IP protection.

Development flow example: Simulation model



⑦Risk and action of model modification(IP protection)

Ensuring transparency of model distribution by defining threats that can occur when exchanging models between partners and countermeasures.

Flow of threat for IP and measures

- Identify intellectual property (IP)
- Classify security level / Classify usage
- Identify threats
- Apply measures
- Review applied
- Monitoring

Clarification of threat for IP and measures

Legend

✓	Can be dealt with
(✓)	Can only be dealt with in a specific environment
×(✓)	Contributes to specific measures (cannot be a single measure)
×	Can not be dealt with

Threat for model exchange	Measures for threat: No model protection at all	Source code obfuscation	Only complied models without source code	Hard-Coding of parameters	Model Order Reduction and other Approximative Techniques	Integrity test of model	License-mechanisms	Encryption of all model-internal information	Remote Execution of FMUs without trusted third party	Access and Execution via Trust-Center	No model delivery all
Unintentional modification of models	×	×	×	✓	×	✓	×	×	(✓)	(✓)	✓
Unauthorized modifications of models	×	×	×	✓	×	✓	(✓)	×	(✓)	(✓)	✓
Disregarding terms of use or uncontrolled dissemination of models	×	×	×	×	×	×(✓)	✓	×	✓	✓	✓
Insight into model structure	×	✓	✓	×	✓	×(✓)	×(✓)	×	×	×	✓
Overcoming terms of use	×	×	×	×	×	×(✓)	✓	✓	✓	✓	✓
Applied Measures	×	✓	×	✓	×	✓	×	×	×	×	×

Reference : RECOMMENDATION Smart Systems Engineering Behavior Model Exchange Version 2.0(Prostep iViP)

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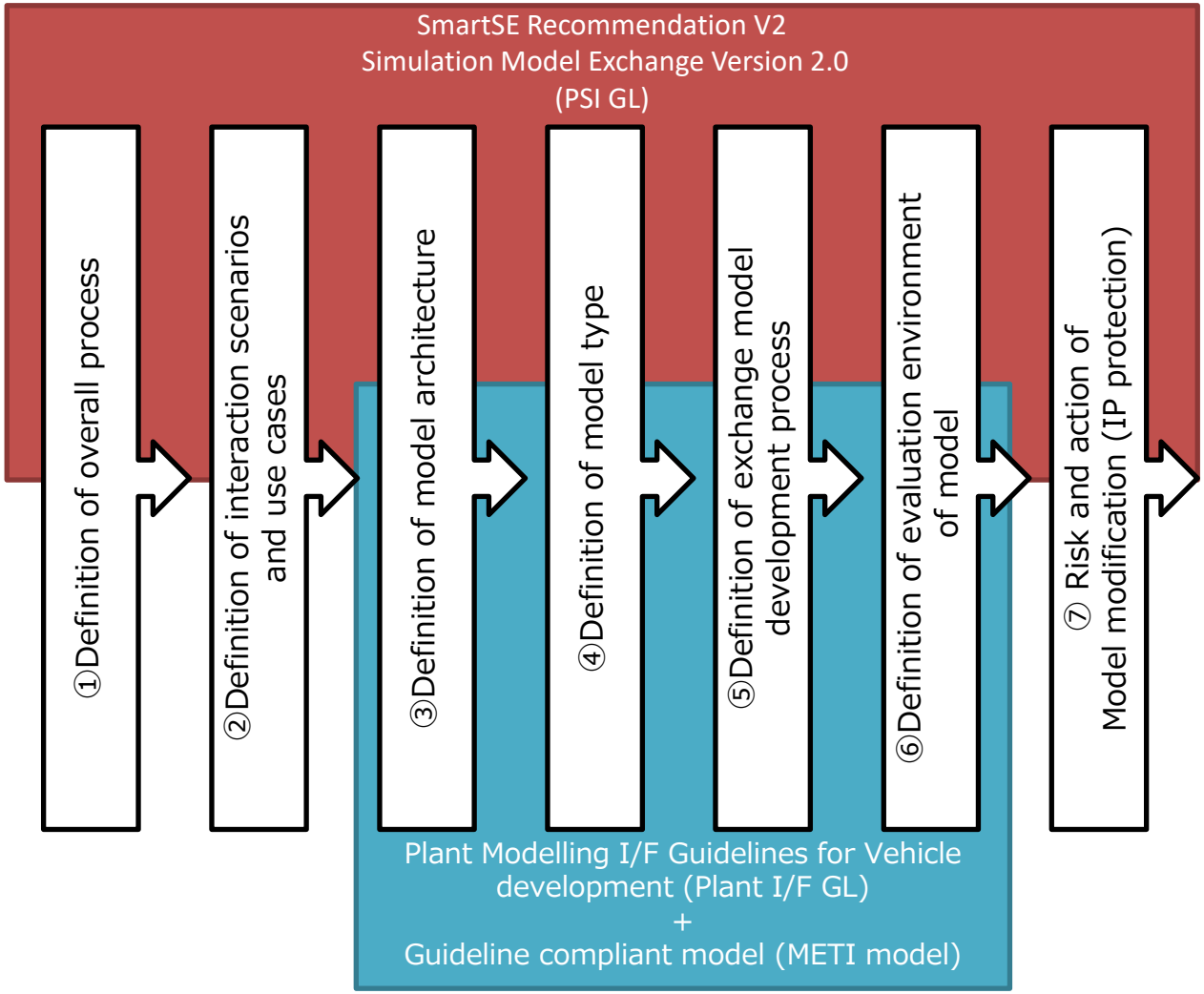
Outlines of referenced guidelines

In Japanese automobile development, how each GL can cooperate this time based on the following points in model exchange has been described.



Summary of simulation model exchange outline

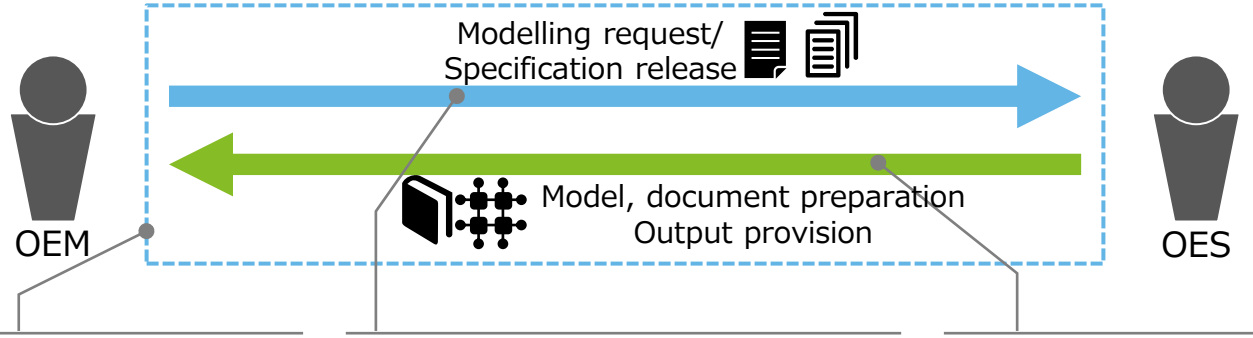
It was found that it is possible to approach the problem by utilizing PSI GL and plant I / F GL, but further study is still needed. By setting further guidelines and sharing specific examples in the future, we will promote model exchange.

Issues	Application example	
1)Definition of modeling process	①⑤	Setting the process using the METI model by referring to the process for model development described in PSI GL.
2) Definition and sharing of target usage of model	②	Share the purpose by setting mutual scenarios (IS) and use cases (UC) and clarifying in which scene to use.
3)Definition of optimum layer of model for model exchange	③④	Set the model architecture and distribution model type based on the 4-layer approach, and set the boundary model and custom model that suits the purpose.
4)Definition of evaluation environment[standard (exchange)model]	⑥	By utilizing the METI model, I / F check, behavior confirmation when putting it in the vehicle model, estimation of the effect are examined, and trouble check after handing over the model to the model user.
5)Adjustment of I/F suitable for model layer	③	Set the I / F that suits each level. Consider between plant models based on plant I / F GL. GL such as control will be considered in the future.
6) IP protection in model exchange	⑦	The viewpoint for considering IP protection is written, and further specific methodologies will be examined in the future.

Summary of simulation model exchange outline

Examples of smooth model sharing below using PSI GL, plant I / F GL, and METI models, including the background when distributing models has been described. For the details of the guidelines, refer to each guideline, deepen the understanding, and hope that they can contribute to the expansion of the collaborative areas and the efficiency of each individual function development.

Image of model exchange



Issues

- The responsibilities of OEM and OES which occur during the exchange of simulation model is unclear.

In order to clarify the division of responsibilities manners are required

- Since each company has a different concept of hierarchy and layer, the area of division at the component/system level when creating a model is unclear.

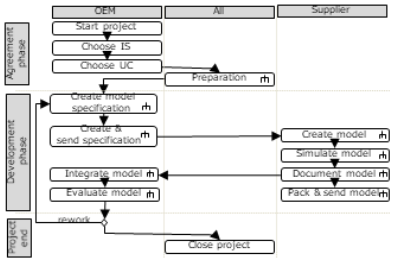
A reference map which is clarify the area of model requested to built is needed to have common understanding.

- Since the I / F is set individually for each company, problems occur when connecting models.

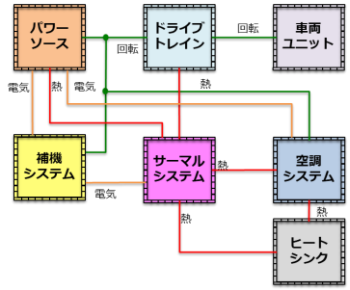
A common understating for I/F which secures connecting directions and units of each model is required.

Actions

A Definition of manners



B Budling of reference architecture



C Definition of I/F

METI Model ガイドラインの事例		INPUT		OUTPUT	
		I/F名	From	I/F名	To
パワーソース	回転	回転数	ドライブトレイン	トルク	ドライブトレイン
	熱	温度	サーマルシステム	熱流量	サーマルシステム
	電気	電圧	空調システム	電流	空調システム
	電気	電圧	補機システム	電流	補機システム
ドライブトレイン	回転	トルク	パワーソース	回転数	パワーソース
	回転	回転数	車両ユニット	トルク	車両ユニット
	熱	温度	サーマルシステム	熱量	サーマルシステム

⋮

SmartSE Recommendation V2 Simulation Model Exchange Version 2.0

Plant Modelling I/F Guidelines for Vehicle development Ver.4.0

Reference : Pre-GL Building Committee Meeting No.2, METI:11（12, Sep., 2019）

Abbreviation

ECU	Electronic Control Unit
F/B	feedback
FMI	Functional Mock-up Interface
FMU	Functional Mock-up Unit
HAD	Highly Automated Driving
HIL	Hardware in the Loop
HILS	Hardware in the Loop Simulation
I/F	Interface
IP	Identity Protection
IS	Interaction scenario
MBR	Model-based research
MBSE	Model-based Systems Engineering
METI	Ministry of Economy, Trade and Industry
MIL	Model in the Loop
MILS	Model in the Loop Simulation
OEM	Original Equipment Manufacturer
PIL	Processor in the Loop
RCP	Rapid Control Prototyping
SE	Systems Engineering
SIL	Software in the Loop
SOP	Start Of Production
SW	Software
T/M	transmission
UC	Use Case

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