15th Modlica Conference

prostep SmartSE

Building Blocks for Simulation based Cooperation between Partners

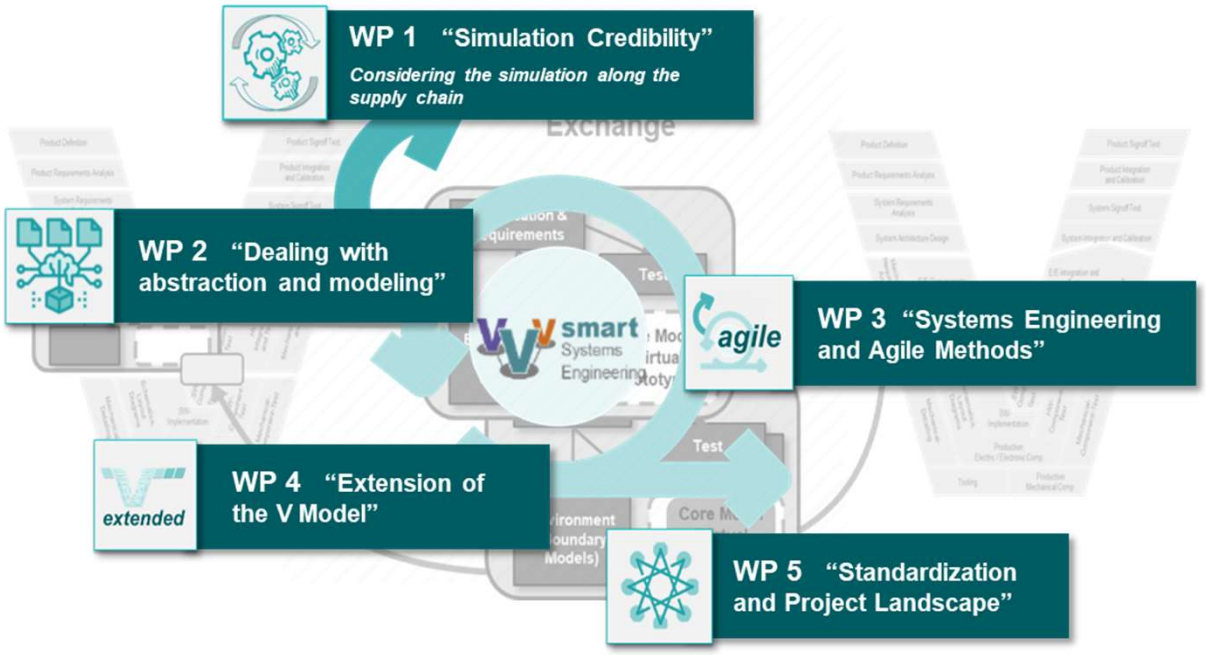
Aachen, October 2023
Hans-Martin Heinkel, Bosch
Pierre Mai, PMSF
Martin Geissen, Unity

Prostep SmartSE Project Consortium 2023

Project phase 5: Work Packages and Fields of Action

Mission Phase 5 *(2022-2024)*

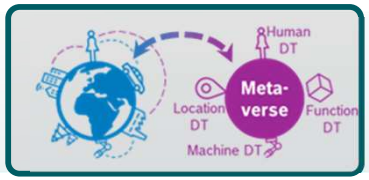
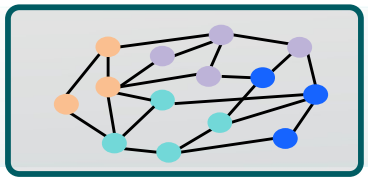
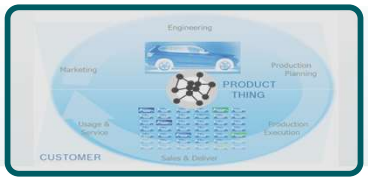
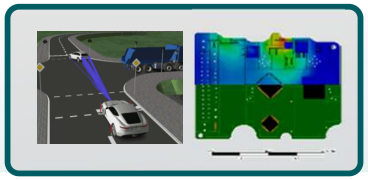
Enabling collaborative development and validation of complex products by simulation along a multi tier supply chain.



25+ project participants

Prostep Smart Systems Engineering (SmartSE)

Building Blocks for Simulation based Cooperation between Partners

Metaverse		*Floating transition between real and virtual world*
Collaboration Networks		*Heterogeneous changing networks, collaboration models*
Company internal Digitalization, Virtualization		*Continuous use, enrichment of information, knowledge evaluation*
Simulation supported Development		*Alignment with reality, prediction of reality basis for virtualization*
Real Products, Components		*Development of reliable and sustainable components and products*

From Digitalization to Virtualization
From Documentation to Prediction

What does virtualization mean

- We make prediction, statements about properties, behavior based on simulation, models and their parameterization.
- These statements can have far-reaching consequences
- We must be able to trust them

Prostep Smart Systems Engineering (SmartSE)

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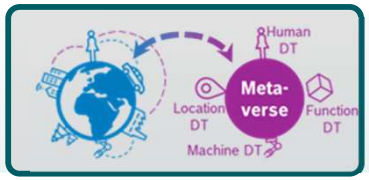
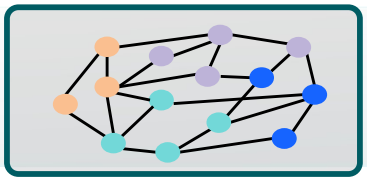
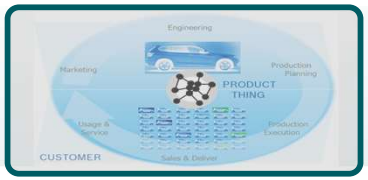
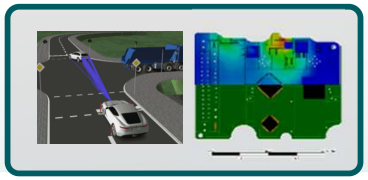
Metaverse		*Floating transition between real and virtual world*
Collaboration Networks		*Heterogeneous changing networks, collaboration models*
Company internal Digitalization, Virtualization		*Continuous use, enrichment of information, knowledge evaluation*
Simulation supported Development		*Alignment with reality, prediction of reality basis for virtualization*
Real Products, Components		*Development of reliable and sustainable components and products*

Strong involvement, interaction with users (people)

Availability of Information in heterogeneous IT environments,

Traceability, Simulation Credibility

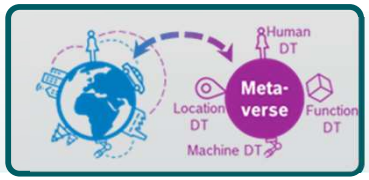
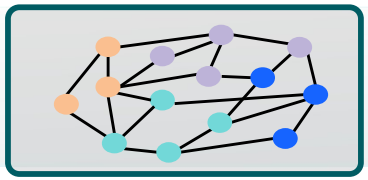
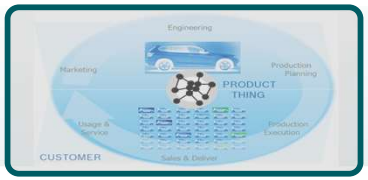
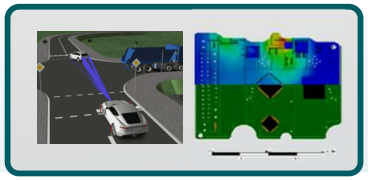
Verification Validation of Models, Parameters, Simulation

Reduced number of real prototypes

We need Building blocks to support these challenges

Prostep Smart Systems Engineering (SmartSE)

Building Blocks for Simulation based Cooperation between Partners

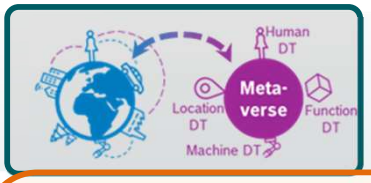
Metaverse		*Floating transition between real and virtual world*
Collaboration Networks		*Heterogeneous changing networks, collaboration models*
Company internal Digitalization, Virtualization		*Continuous use, enrichment of information, knowledge evaluation*
Simulation supported Development		*Alignment with reality, prediction of reality basis for virtualization*
Real Products, Components		*Development of reliable and sustainable components and products*

We need the experts for establish and maintain the automatization (Expert knowledge within workflows)

Prostep Smart Systems Engineering (SmartSE)

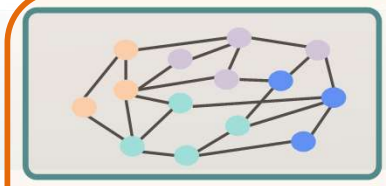
Building Blocks for Simulation based Cooperation between Partners

Metaverse



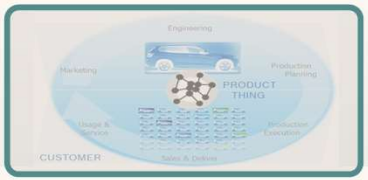
Floating transition between real and virtual world

Collaboration Networks



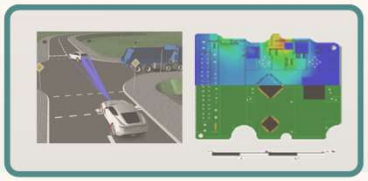
Heterogeneous changing networks, collaboration models

Company internal Digitalization, Virtualization



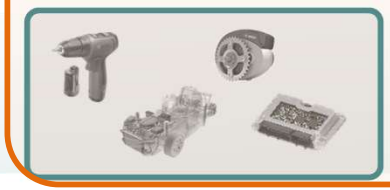
Continuous use, enrichment of information, knowledge evaluation

Simulation supported Development



Alignment with reality, prediction of reality basis for virtualization

Real Products, Components



Development of reliable and sustainable components and products

Focus of prostep Smart SE project

Strong involvement, interaction with users (people)

Availability of Information in heterogeneous IT environments,

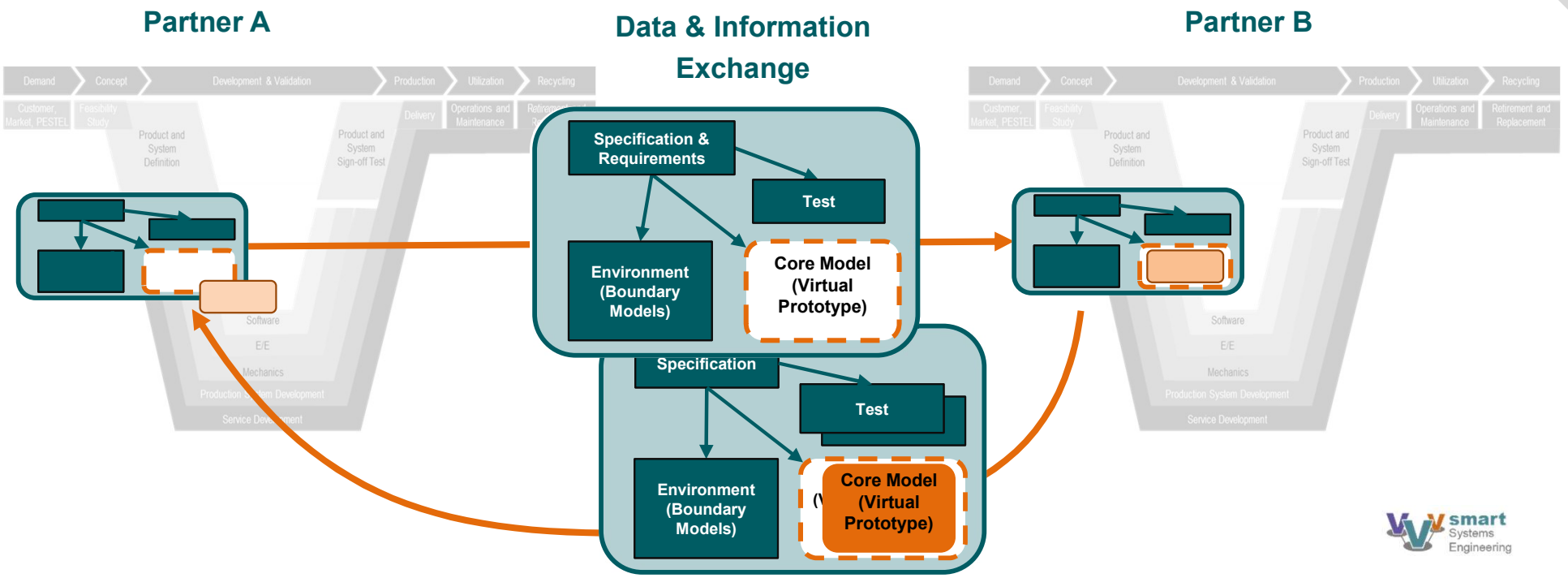
Traceability, Simulation Credibility

Verification Validation of Models, Parameters, Simulation

Reduced number of real prototypes

We need Building blocks to support these challenges

Motivation Smart Systems Engineering (SmartSE)
Collaborative Simulation-based Engineering



In Scope: Exchange of all artefacts required for an efficient, cross-company simulation-based engineering like specifications, requirements, test cases, simulation models and model meta data.

Building Blocks for Simulation based Cooperation
Agenda

prostep IVIP

Process

Structuring, assignment responsibilities

Standards and Recommendations

Simulation credibility, abstraction and modeling

Information

Harmonization metadata, semantics

Data formats for exchange

heterogeneous IT environments, collaboration

smart Systems Engineering

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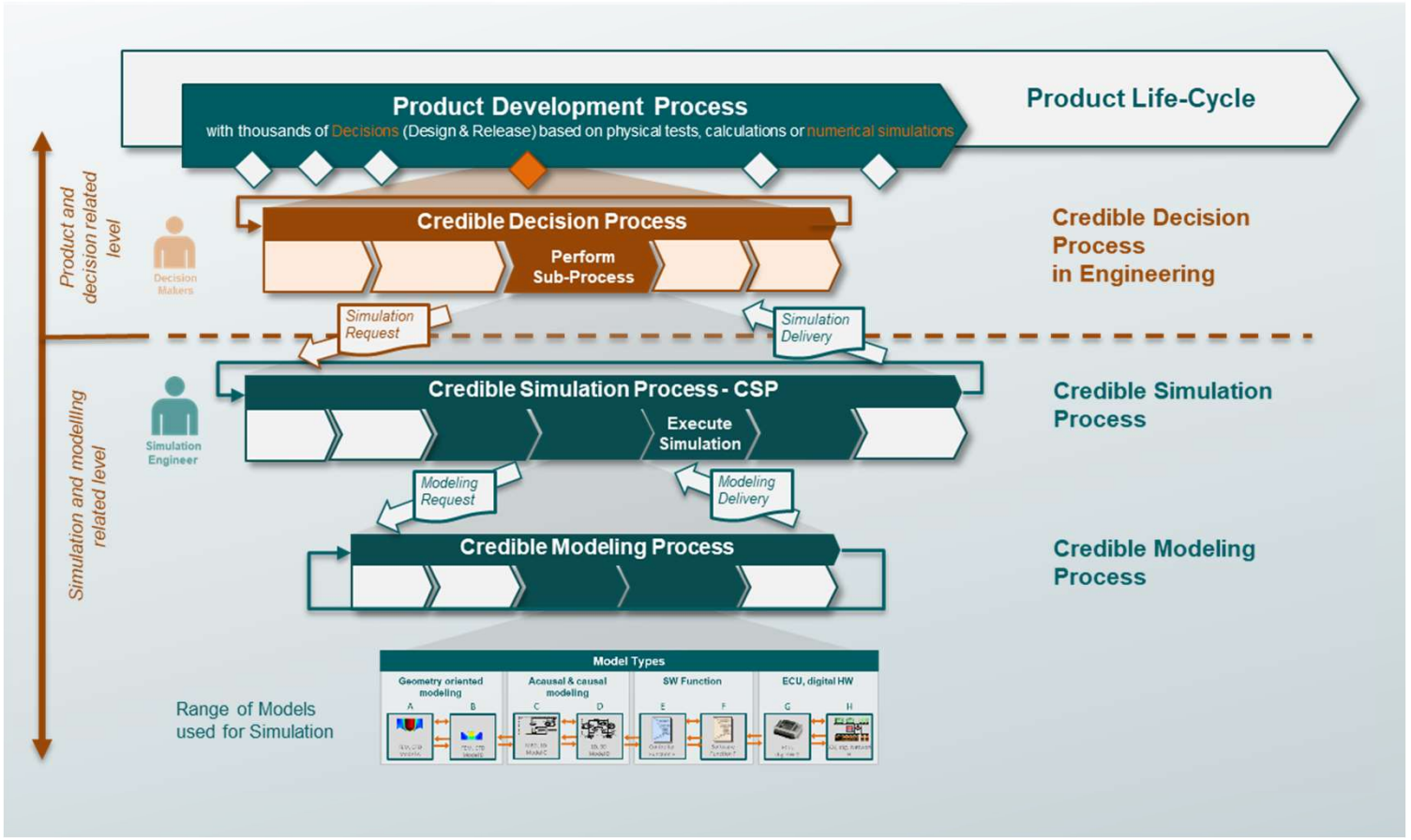
Building Blocks for Simulation based Cooperation

Structuring, Assignment Responsibilities

Process hierarchy with clear information structuring

- ***Sub-processes can be integrated into specific company processes***
- ***Clear assignment of responsibilities***



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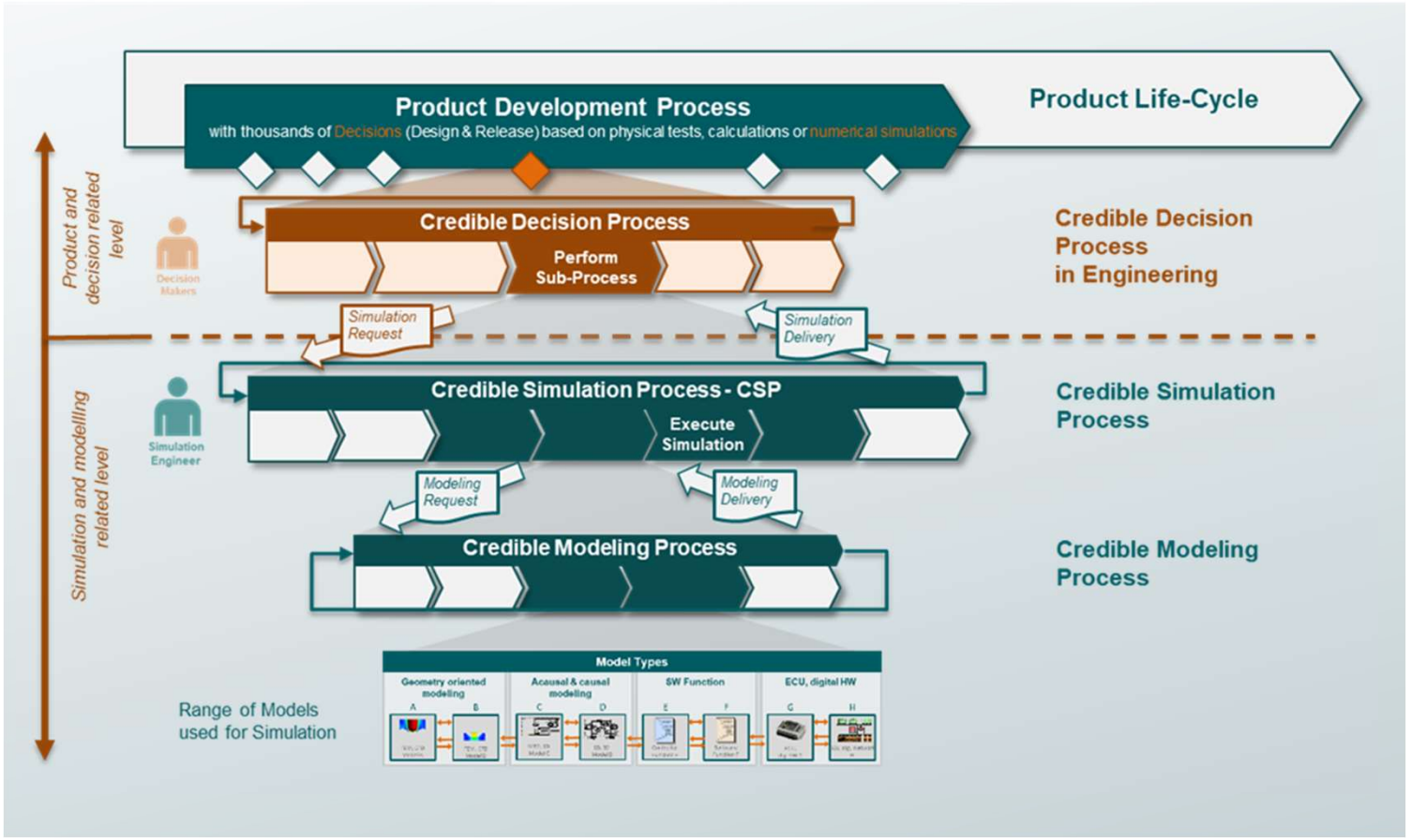
Building Blocks for Simulation based Cooperation

Standards and Recommendations for Simulation Credibility

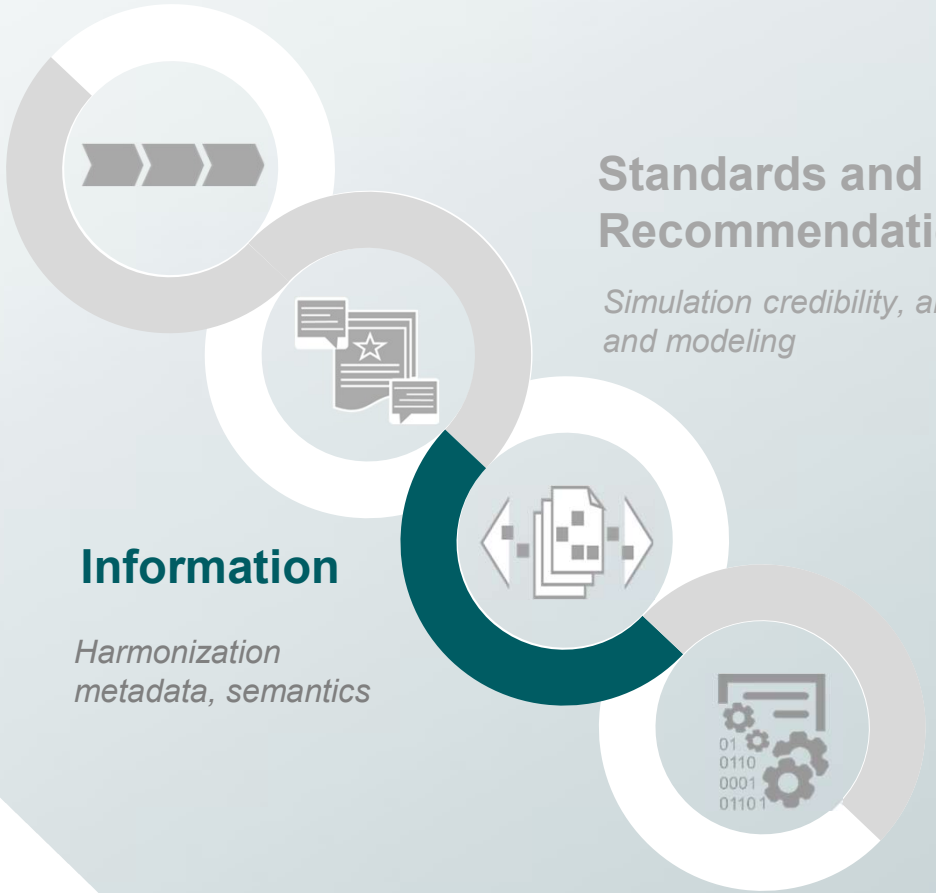
Currently meetings for alignment "Big Picture and core terms" for Credible Decision Process Framework in Engineering with

ASME INCOSE NAFEMS

as basis for domain specific credibility standards.



Building Blocks for Simulation based Cooperation
Agenda



Process

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Building Blocks for Simulation based Cooperation

Harmonization Metadata, Semantics

Alignment of Model Metadata for Simulation and Traceability

The exchange and reuse of simulation models within the company and with external partners is becoming increasingly important.

For efficient exchange and reuse

- Information, metadata about the properties of the models is required (what does the model represent, which effects are implemented)
- as well as administrative information (name, owner, version,...).

Currently there are several standards for model metadata, or they are being developed from these organisations

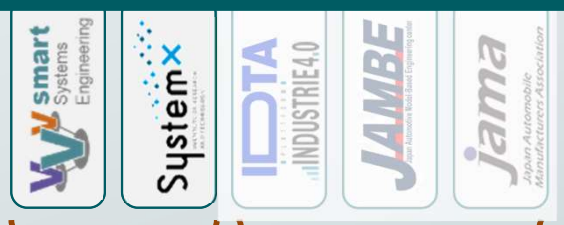
Building Blocks for Simulation based Cooperation

Alignment of Model Metadata for Simulation and Traceability

The standards from these organizations are input for alignment

MIC Core
Attributes for Model Meta Data
i.e. Model name, Release, Identifier,..

V1.0 release
July 2023



Fully aligned

Alignment ongoing

Goal: not to have one standard

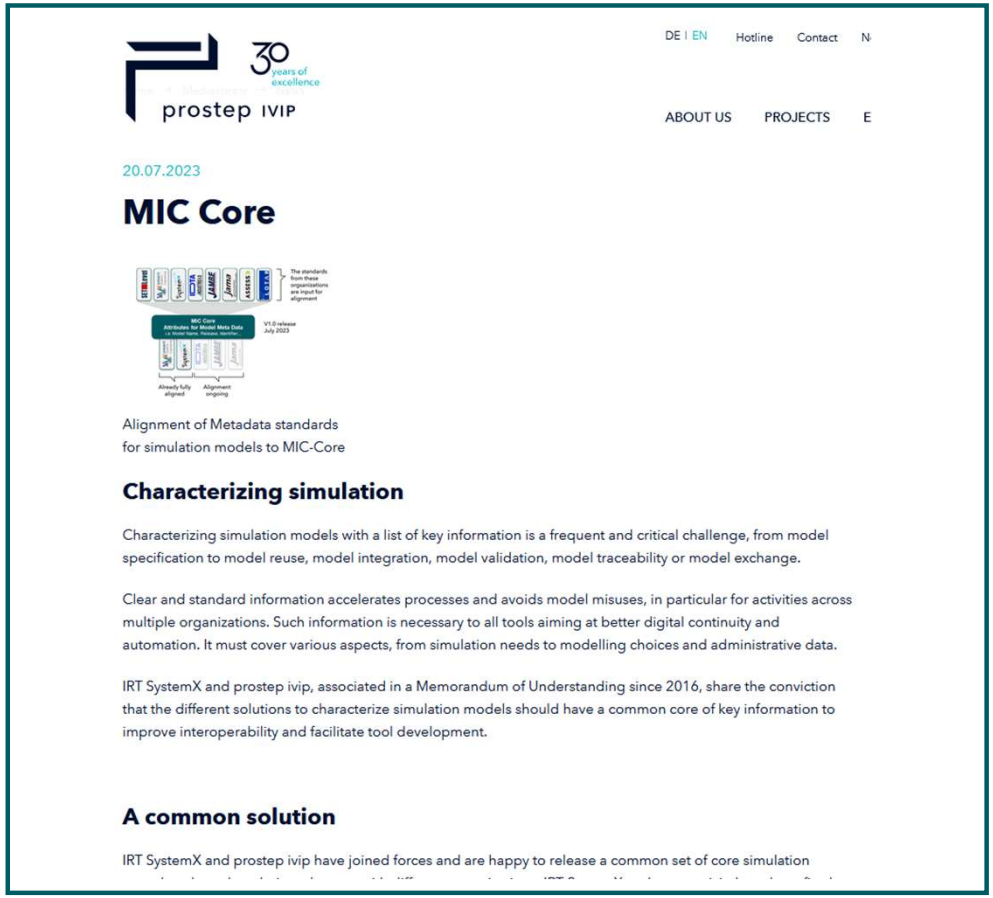
But:

- to identify and harmonize the overlapping attributes
- so, there will be a common aligned part of attributes in every standard
- also, standard specific attributes according to the different use cases, domains

The standards will stay independent but will have aligned parts

Building Blocks for Simulation based Cooperation

SRMD Data Format and MIC Core Standard for Model Metadata



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ABOUT US PROJECTS E

20.07.2023

MIC Core

Alignment of Metadata standards
for simulation models to MIC-Core

Characterizing simulation

Characterizing simulation models with a list of key information is a frequent and critical challenge, from model specification to model reuse, model integration, model validation, model traceability or model exchange.

Clear and standard information accelerates processes and avoids model misuses, in particular for activities across multiple organizations. Such information is necessary to all tools aiming at better digital continuity and automation. It must cover various aspects, from simulation needs to modelling choices and administrative data.

IRT SystemX and prostep ivip, associated in a Memorandum of Understanding since 2016, share the conviction that the different solutions to characterize simulation models should have a common core of key information to improve interoperability and facilitate tool development.

A common solution

IRT SystemX and prostep ivip have joined forces and are happy to release a common set of core simulation

Prostep IVIP press release about MIC-Core V1

Link to press release
https://www.prostep.org/en/medialibrary/news/detail/article/mic-core-1/

Link to MIC-Core specification
https://mic-core.github.io/MIC-Core/main/

Building Blocks for Simulation based Cooperation

SRMD Data Format and MIC Core Standard for Model Metadata

Contents

SystemX INSTITUT DE RECHERCHE TECHNOLOGIQUE

prostep IVIP

MIC Core Specification

Version 4528536, 2023-06-29

The MIC Core specification is a free standard that defines a set of harmonized model meta data attributes that meta-data standards can adopt to avoid ambuity and incompatibility in common attributes across domains and standards. It is maintained as a joint undertaking of IRT SystemX and prostep ivip. Releases and issues can be found on github.com/MIC-Core/MIC-Core.

1. Introduction

1.1. Why MIC Core

The exchange and reuse of simulation models within the company and with external partners is becoming increasingly important.

For efficient exchange and reuse

- Information, metadata about the properties of the models is required (what does the model represent, which effects are implemented)
- as well as administrative information (name, owner, version,...).

Currently there are several standards for model meta data, or they are being developed from several organisations

1.2. What is MIC Core

Link to MIC Core specification

https://mic-core.github.io/MIC-Core/main/

Building Blocks for Simulation based Cooperation

SRMD Data Format and MIC Core Standard for Model Metadata

An implementation of the MIC Core Specification in the SRMD Standard is already available.

Simulation Resource Meta Data (SRMD) are part of the Modelica SSP-Traceability standard

Implementation of MIC-Core in the SRMD metadata format

Introduction

In the following, an exemplary implementation of the MIC-Core standard into the SRMD metadata format will be shown. The SRMD (Simulation Resoure Meta Data) metadata format is a subset of the SSP traceability STMD (Simulation Task Meta Data) format. These formats are part of the Modelica Association Project SSP (System Structuring and Parametrization). The SRMD format allows to specify any metadata, attributes in the form of key value pairs. The format description also specifies where this metadata file should be stored in an FMU or SSP (link to SSP traceability).

Maping of MIC-Core attributes to the SRMD format

The following table shows the implementation. In the first column the attributes defined in the MIC core are listed. The second column lists the conversion of the attribute names to SRMD. For easier machine processability, clustering via presented terms separated by period is used here. No spaces are used. In column 3 an abbreviated explanation of the attributes is listed

MIC-Core Name	SRMD Mapping	Short Explanation
Model name	administrative-data.model.name	Human-readable way of referring to the model. Usually short and clear. Not necessarily unique
Model identifier	administrative-data.model.identifier	Unique identifier for the model.
Model description	administrative-data.model.description	Human-readable, textual, general overview. Highlights important information about the model.
Model supplier	administrative-data.model.supplier	The responsible body and, if applicable, organizational unit within the body, that is responsible for supplying the model.
Model confidentiality level	administrative-data.model.confidentiality-level	Protection level to apply to the model.
Legal restriction	administrative-data.legal-restriction	Defines the rules governing the distribution and usage of the simulation model, including licensing,
Release	administrative-data.release	Unique identifier, preferably human-readable (i.e. semantically meaningfull), for the release of a particular simulation model.
Release date	administrative-data.release.date	Date, and possibly time and timezone, of the release of a simulation model. Must respect ISO 8601.
Release type	administrative-data.release.type	Relates to the maturity of the model.

Building Blocks for Simulation based Cooperation

SRMD Data Format and MIC Core Standard for Model Metadata

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<srmd:SimulationResourceMetaData version="1.0.0-beta2" name="SSP-Model SRMD" generationTool="orchideo | easySSP (eXXcellent solutions GmbH)" generationDa
<!-- MIC core attributes -->
    <stc:Classification type="org.prostep.srmd.mic-core">
        <stc:ClassificationEntry keyword="administrative-data.model.name">Permanent Magnet Synchronous Machine in abc</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.model.identifier">EMPSM3E01MSEREF</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.model.description">This is a model of a Permanent Magnet Synchronous Machine - PMSM - in ab
        either in wye or delta connection, which considers linear magnetic condition
        (i.e., no magnetic saturation, hysteresis loss and spatial harmonics).</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.model.supplier">Robert Bosch GmbH, RB-CoC Simulation</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.model.confidentiality-level">C-SC 1</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.legal-restriction">BIOS License v4</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.release">20XX.Y.Z</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.release.date">May 1, 2022</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.release.type">internal-release</stc:ClassificationEntry>

        <stc:ClassificationEntry keyword="purpose-objectives.model">Requirement derivation resp. development of control strategies for electric powertrai

        <stc:ClassificationEntry keyword="subject-information.modelled-entity">Small motors (~500W), but also motors with either low magnetic saturation
        or around a given operation point (linearization)</stc:ClassificationEntry>

        <stc:ClassificationEntry keyword="implementation.modeling-choice">Refer to related user documentation, `Features` section.</stc:ClassificationEnt
        <stc:ClassificationEntry keyword="implementation.model.limitations">Refer to related user documentation, `Model assumptions and limits` section.<
        <stc:ClassificationEntry keyword="implementation.model.classification">Linear, causal.</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="implementation.software-hardware-environment-requirements">Matlab 2022b, Microsoft Visual C++ 2022 (c) on Windo

        <stc:ClassificationEntry keyword="verification-validation.verification-status">has been verified.</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="verification-validation.validation-status">has been verified.</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="verification-validation.procedure-criteria">Verification: Refer to related `test` documentation.</stc:Classific
        <stc:ClassificationEntry keyword="verification-validation.report">Verification: Refer to related `test results` documentation.</stc:Classificatio
        <stc:ClassificationEntry keyword="verification-validation.report">Validation: Refer to related library overview documentation, `Validation` secti
        <stc:ClassificationEntry keyword="verification-validation.report">This model shall not be used to design electric machines.</stc:ClassificationEn
    </stc:Classification>

<!-- MSE core attributes -->
    <stc:Classification type="de.bosch.srmd.mse">
        <stc:ClassificationEntry keyword="administrative-data.library-name">mseref.emachines.simulink</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.type">Physical principle</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.family">Electric machines</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="administrative-data.modelling-approach">Lumped-element considering only the electric part of a PMSM</stc:Classi
        <stc:ClassificationEntry keyword="administrative-data.use">Load `mseref.emachines.simulink` library in Simulink. (Optional) Set paths to `mseref.
        <stc:ClassificationEntry keyword="administrative-data.release-status">Stable</stc:ClassificationEntry>

        <stc:ClassificationEntry keyword="implementation.format">Simulink (embedded blocks),
        possibility to export model as FMU (model exchange), as .exe-file resp. as S-function via Simulink coder.
        Internal MSERef interface standard, refer to `mseref.emachines.simulink` library, section `E-machine interfaces`</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="implementation.performance-characteristics">No requirement regarding realtime capability</stc:ClassificationEnt

        <stc:ClassificationEntry keyword="development-history.feature">Link to related SSP-file</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="development-history.bug-fix">Link to related SSP-file</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="development-history.feature">Link to related SSP-file</stc:ClassificationEntry>
        <stc:ClassificationEntry keyword="development-history.creation">Link to related SSP-file</stc:ClassificationEntry>
    </stc:Classification>
</srmd:SimulationResourceMetaData>

<!-- MSE Standards | unreleased | Internal | © Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction,
editing, distribution, as well as in the event of applications for industrial property rights. -->
```

Dymola

Unnamed

SSP-Model SRMD

Key	Description
Type: org.prostep.srmd.mic-core.administrative-data	
model.name	Permanent Magnet Synchronous Machine in abc
model.identifier	EMPSM3E01MSEREF
model.description	This is a model of a Permanent Magnet Synchronous Machine – PMSM – in abc coordinates, either in wye or delta connection, which considers linear magnetic condition (i.e., no magnetic saturation, hysteresis loss and spatial harmonics).
release	20XX.Y.Z
release.date	May 1, 2022
release.type	internal-release
model.supplier	Robert Bosch GmbH, RB-CoC Simulation
model.confidentiality-level	C-SC 1
legal.restriction	BIOS License v4
Type: org.prostep.srmd.mic-core.purpose-objectives	
model.purpose	Requirement derivation resp. development of control strategies for electric powertrain.
Type: org.prostep.srmd.mic-core.subject-information	
modelled-entity	Small motors (~500W), but also motors with either low magnetic saturation rates or around a given operation point (linearization)
Type: org.prostep.srmd.mic-core.implementation	
modeling-choice	Refer to related user documentation, `Features` section.
model.limitations	Refer to related user documentation, `Model assumptions and limits` section.
model.classification	Linear, causal.

orchideo | easySSP

MIC-Core-SRMD-Example.srmd

Read

org.prostep.srmd.mic-core

- administrative-data
  - model
    - name: Permanent Magnet Synchronous Machine in abc
    - identifier: EMPSM3E01MSEREF
    - description: This is a model of a Permanent Magnet Synchronous Machine
    - supplier: Robert Bosch GmbH, RB-CoC Simulation
    - confidentiality-level: C-SC 1
  - legal-restriction: BIOS License v4
  - release: 20XX.Y.Z
    - date: May 1, 2022
    - type: internal-release
- purpose-objectives
  - model: Requirement derivation resp. development of control strategi
- subject-information
  - modelled-entity: Small motors (~500W), but also motors with either low magne
- implementation

Simulation Resource Meta Data (SRMD) are part of the Modelica SSP-Traceability standard

easySSP

Building Blocks for Simulation based Cooperation
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Process

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Standards and Recommendations

Simulation credibility, abstraction and modeling

Information

Harmonization metadata, semantics

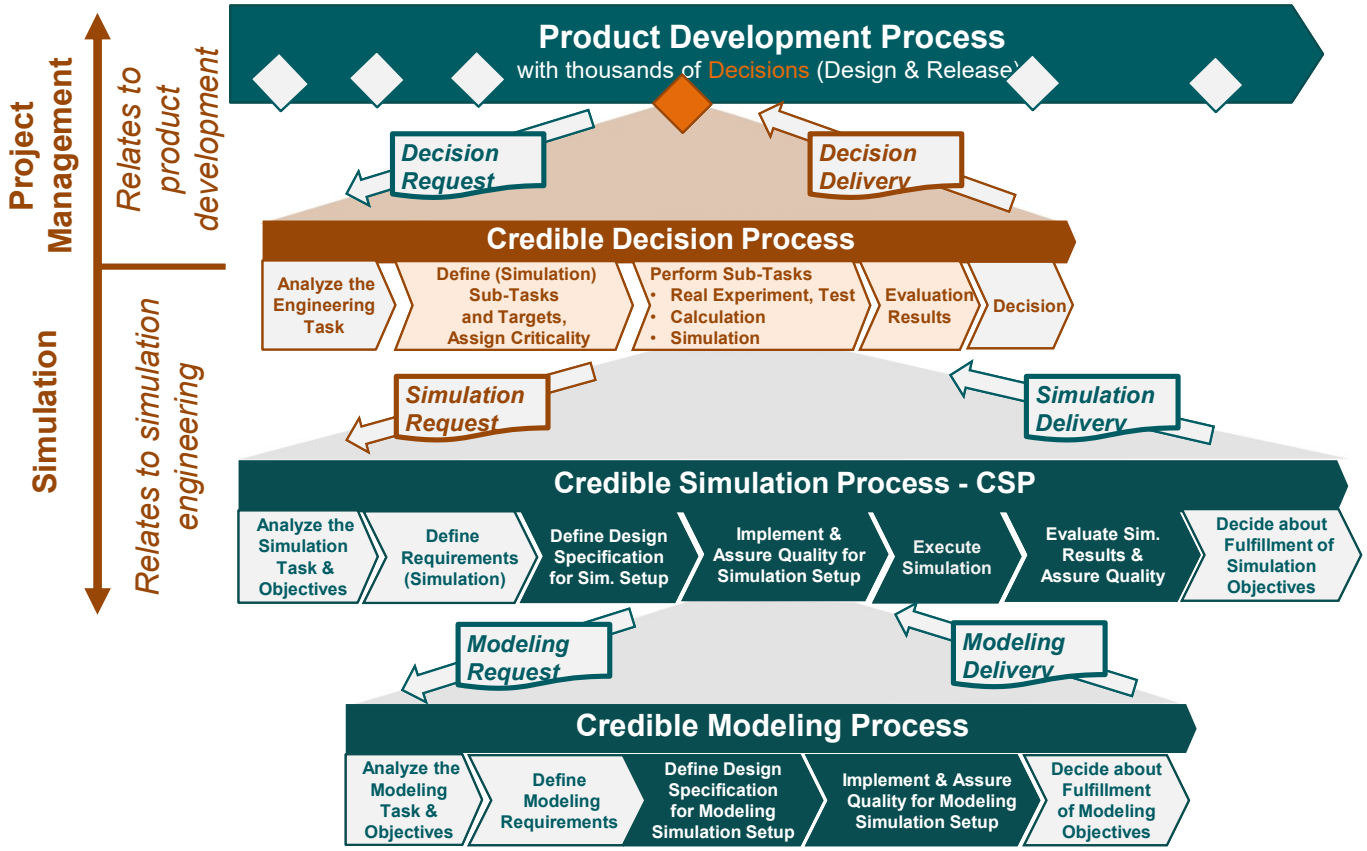
Data formats for exchange

heterogeneous IT environments, collaboration

smart Systems Engineering

Building Blocks for Simulation based Collaboration

Data Formats & Processes for Exchange: Heterogeneous IT Environments, Collaboration

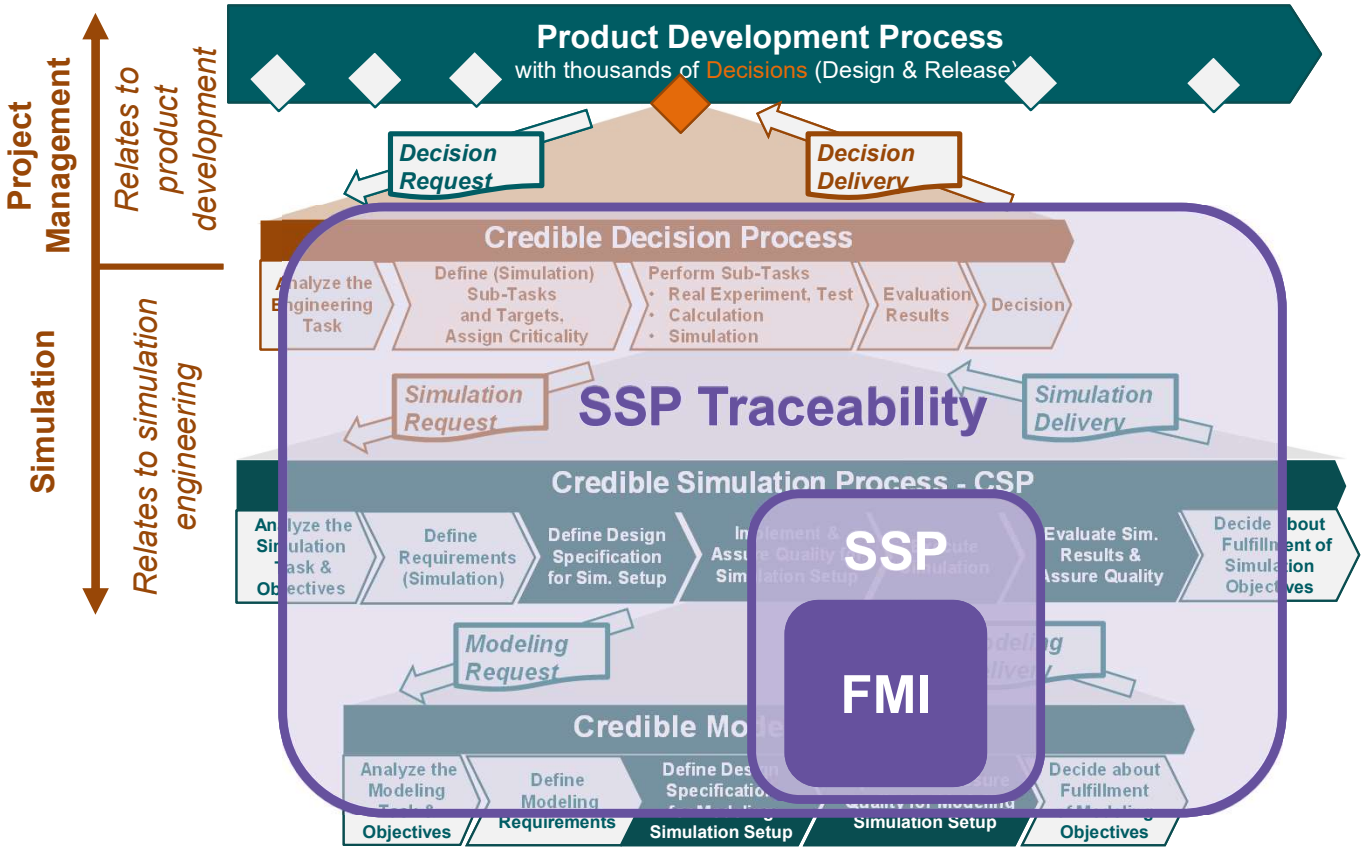


Credible Simulation Process Framework

- Process hierarchy with clear information structuring
- Sub-processes can be integrated into specific company processes

Building Blocks for Simulation based Cooperation

Data Formats for Exchange: Heterogeneous IT Environments, Collaboration



Within the Modelica Association, data standards for the exchange of simulation artifacts between tools are developed and supported.

- **FMI project**:
  - Exchange of models on system level → (FMI3.0)

- **SSP project**
  - Exchange of model architectures and parameter sets.
    → SSP1.0 with standard layer SSP Traceability (GlueParticle)

Building Blocks for Simulation based Cooperation

From Process to Traceability in Heterogeneous IT Environments, Collaboration

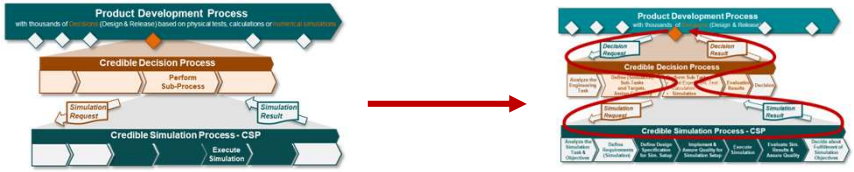
Process
- Reproducibility
- Traceability

Workflow
- Concrete implemented process
- Repeatability

Information Chain
- Process-data-modell
- **GlueParticle**

Information Artefacts
- Artefacts linked to information chain
- For traceability, reuse

From Process to **Traceability**

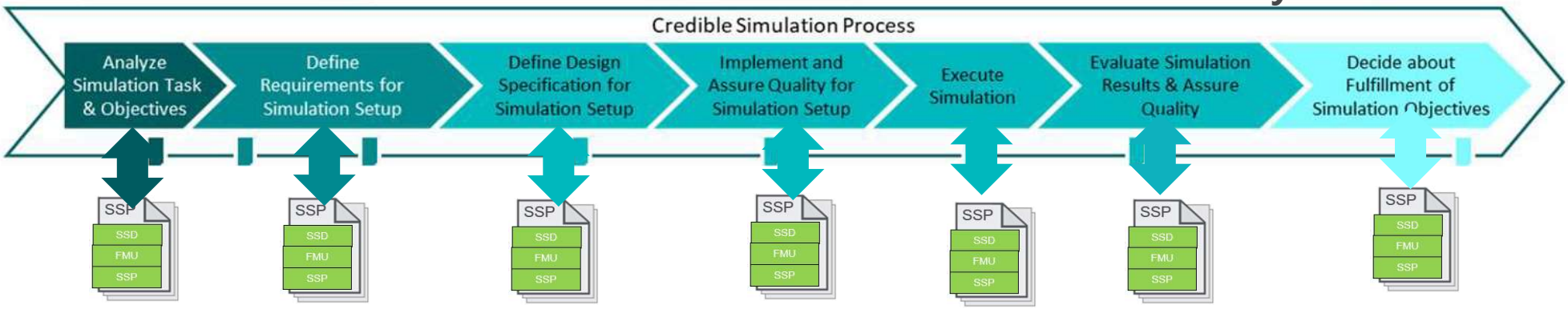


- Clear structuring of information
- Transparency of the information linkage of workflows, processes
- **With GlueParticle Approach**
  - Consistency of process chain and information chain
  - Is integrated part in workflow
  - After the workflow run, a filled information chain is available, no post documentation

Credible Simulation Process (CSP) + SSP-Traceability (GlueParticle)

The CSP is a Documentation Standard to establish Traceability

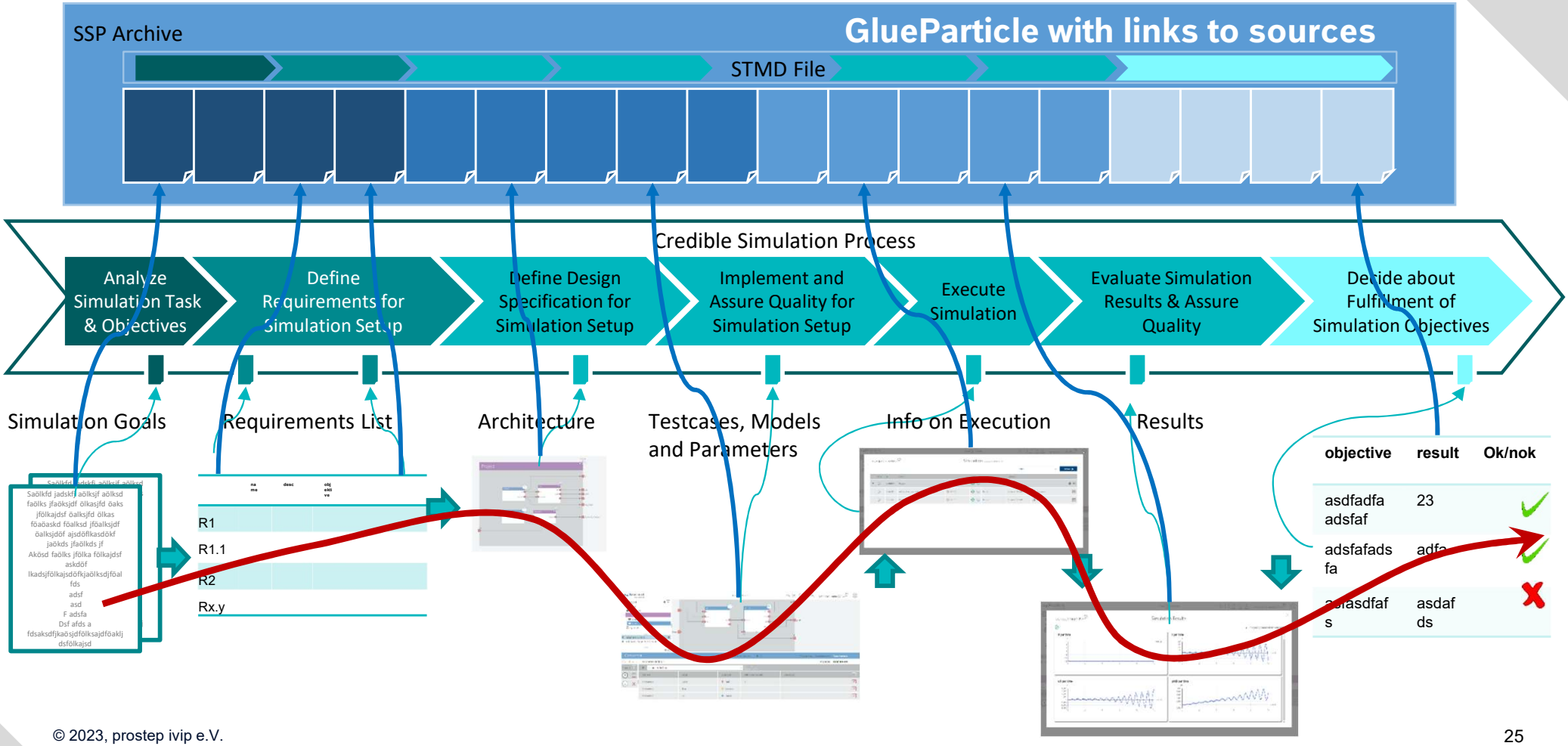
How it is documented in a traceable and standardized way…



What really happened during Development…

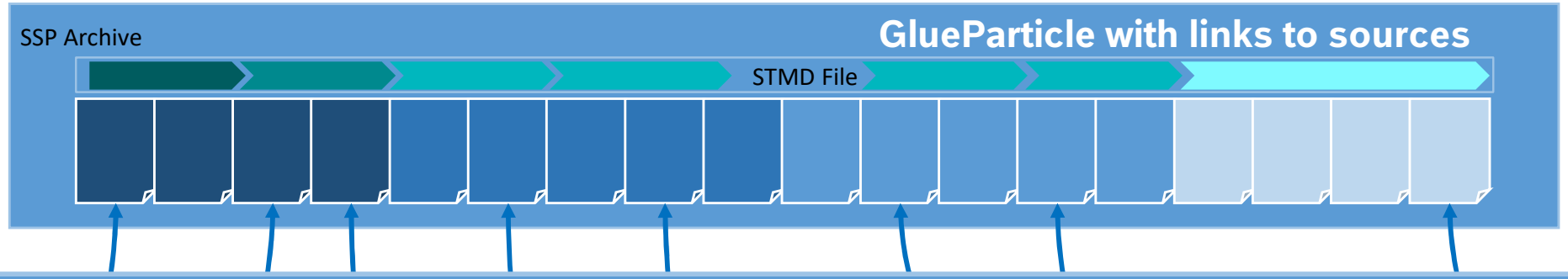
Building Blocks for Simulation based Cooperation

Traceability from Requirements to Simulation Result



Building Blocks for Simulation based Cooperation

Traceability from Requirements to Simulation Result



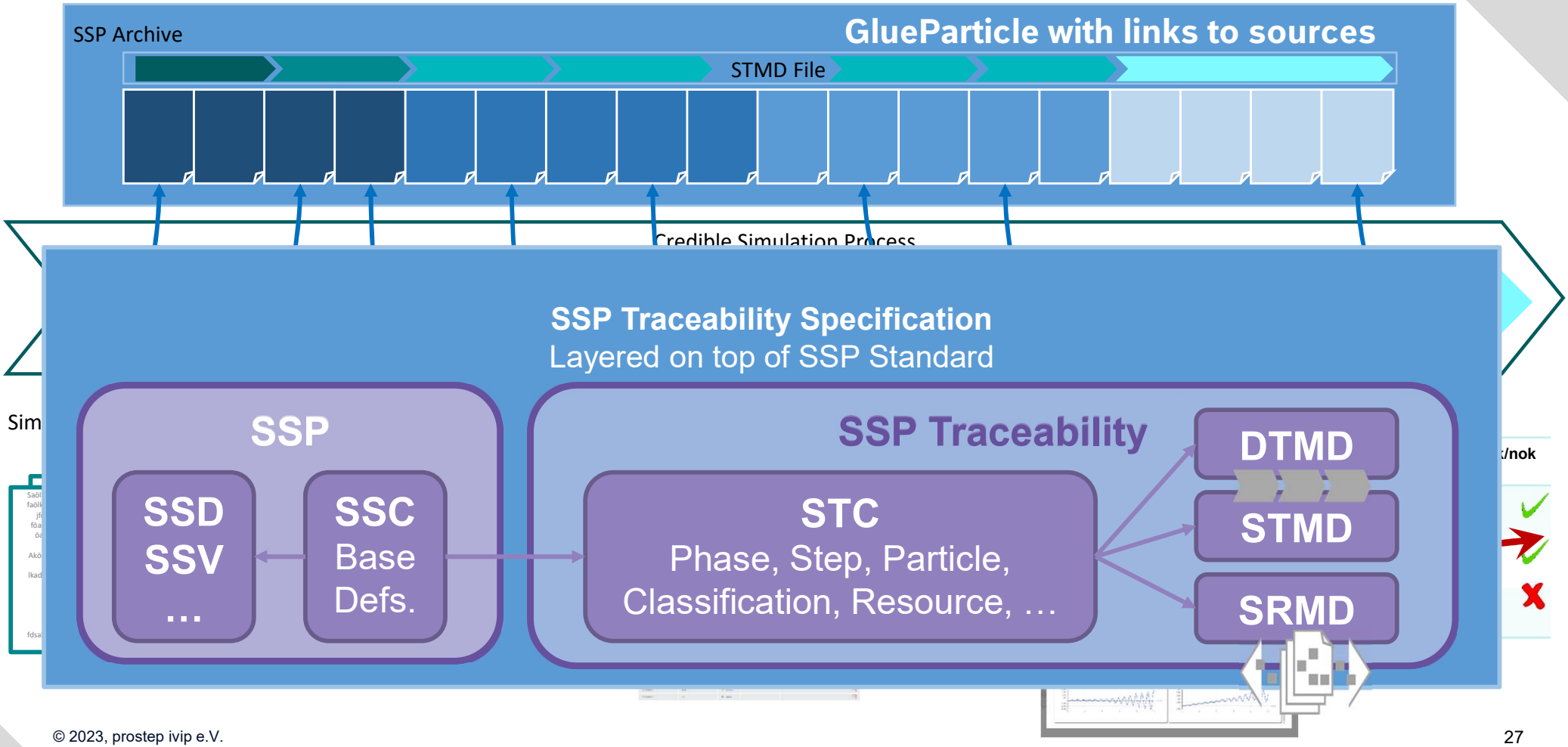
SSP Traceability Specification

Layered on top of SSP Standard

- Based on SSP formats and principles
- Generic approach of phases and steps
- Instantiated for CSP as STMD format
- Each step contains Input, Procedure, Output, Rationale information, referencing Resources
- Additional Linking, Life Cycle & Classification
- SSP ZIP packaging
- (Relative) URI references to resources
- Multi-format support for resources
- Common XML schema components
- Extensibility via annotations
- Devolves into pure SSP for pure SSP tools

Building Blocks for Simulation based Cooperation

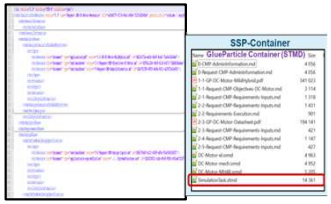
Traceability from Requirements to Simulation Result



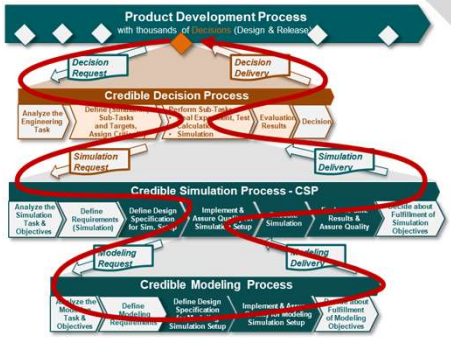
Building Blocks for Simulation based Cooperation

Data formats for exchange, heterogeneous IT Environments, Collaboration

Consistent data formats (SSP Traceability) for the Credible Simulation Framework are available. They support the cooperation between partners in heterogenous environments.

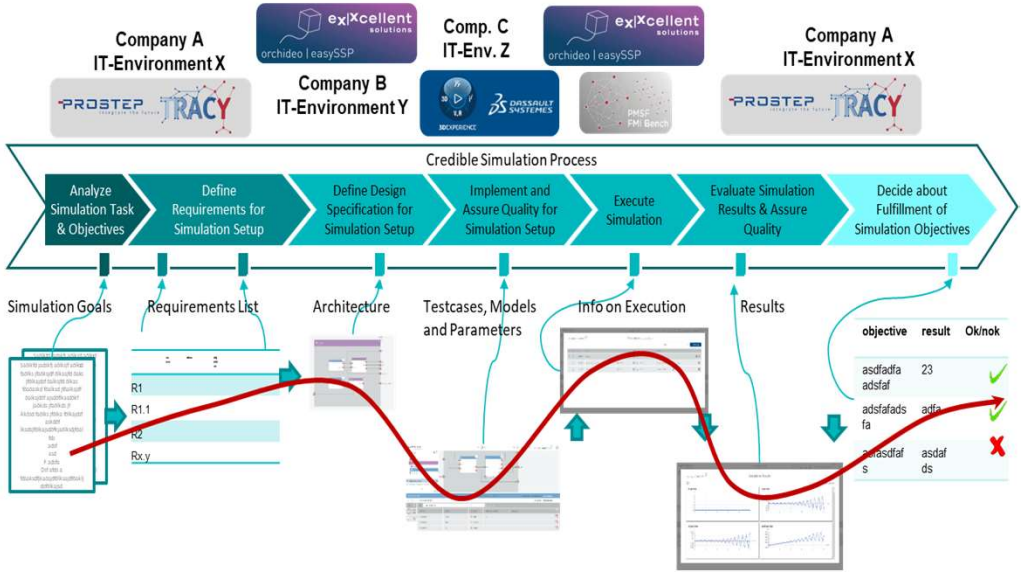


Tool support is already available.



2023-24: Establish realistic automotive use cases for SSP, CSP, traceability, meta data management

- Open to SmartSE partners to facilitate the collaborative development among us and along the value chain
- A communication medium between SmartSE and other consortia, e.g. JAMBE or CATENA-x



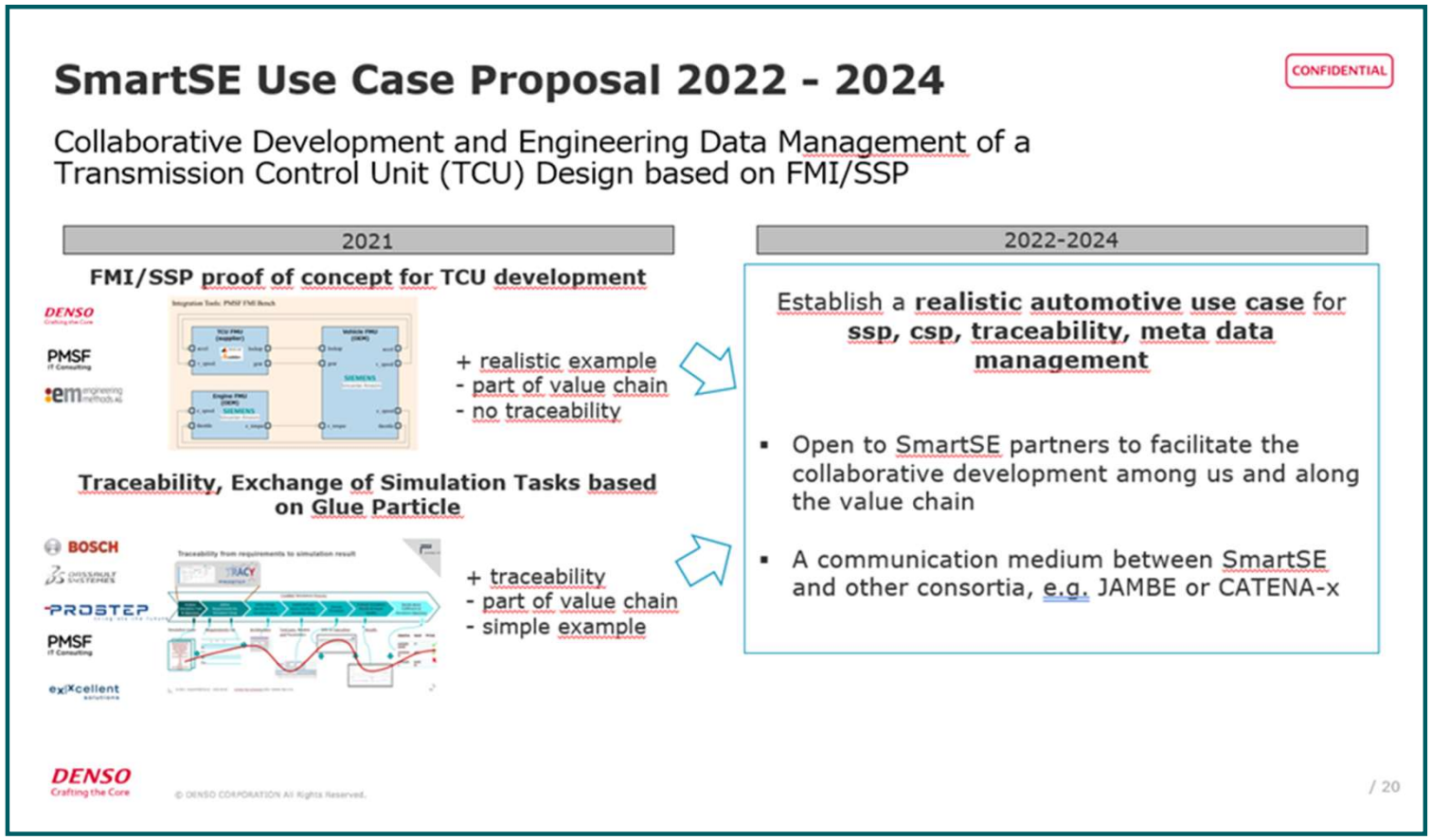
Link to Video

Building Blocks for Simulation based Cooperation

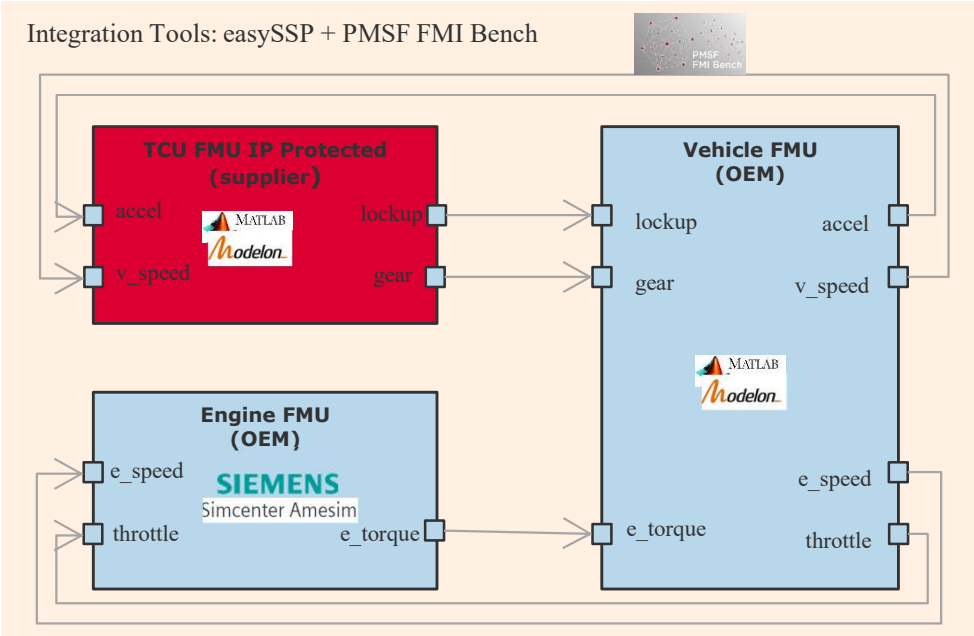
Data Formats for Exchange: Heterogeneous IT Environments, Collaboration

Consistent data formats (SSP-Traceability) for the Credible Simulation Framework are available.

They support the cooperation between partners in heterogenous environments



Collaborative Simulation-based Engineering
Use Case*: Collaborative Transmission Control Unit (TCU) Design



This is an example use case. It does not represent any real business case.

Showcase
Supplier to design, test and calibrate TCU based on OEM specs and requests.

Fokus
Usage of Credible Simulation Process (CSP), SSP-Traceability, MIC-Core Metadata

Engine Model →
Internal combustion engine

Vehicle model →
rest of the vehicle. Maintains the engine state, vehicle state; provides accelerator and throttle positions

TCU model →
provides transmission lockup and gear ratio information, based on the vehicle speed / accelaration information.

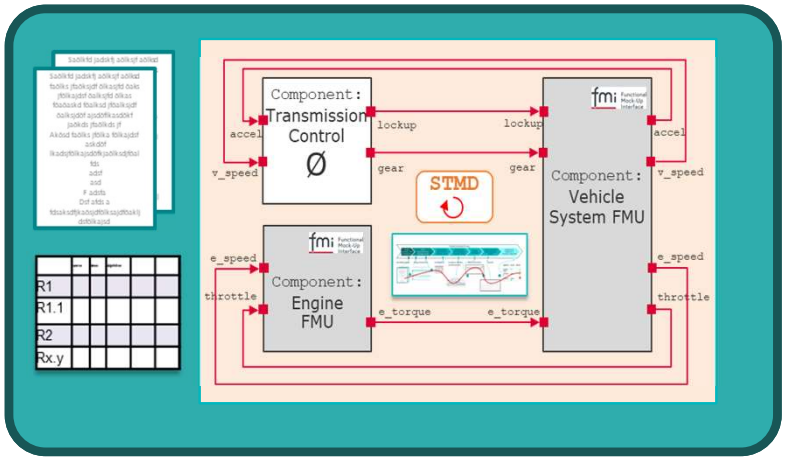
In Scope: Exchange of all artefacts required for an efficient, cross-company simulation-based engineering like specifications, requirements, test cases, simulation models and model meta data.

Collaborative Simulation-based Engineering

Use Case*: Collaborative Transmission Control Unit (TCU) Design

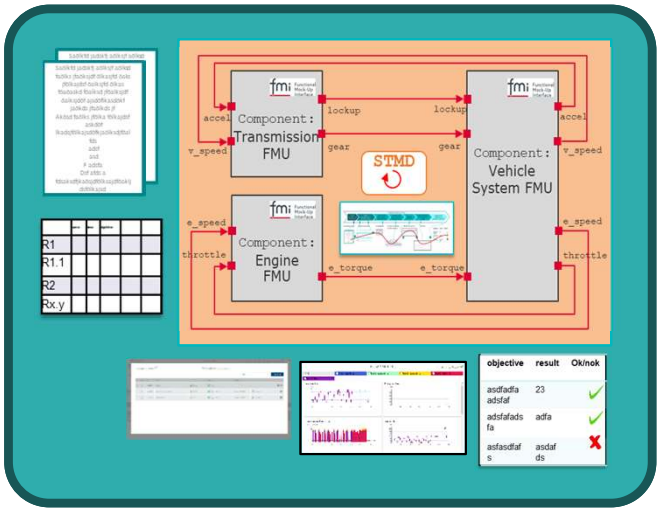
Story: Supplier to design, test and calibrate TCU based on OEM specs and requests.

Request Package



The OEM submits the TCU specification as an envelope specification, as well as the other documents as an SSP container.

Delivery Package



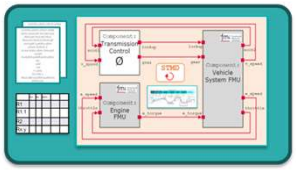
The supplier transfers the TCU model and the results as an SSP container. Here the SSP standard layer SSP-traceability (STMD format) is used.

**This is an example use case. It does not represent any real business case.*

Collaborative Simulation-based Engineering

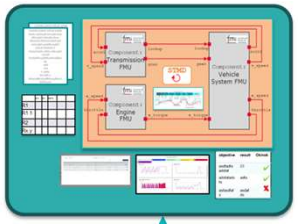
Traceability from requirements to simulation result

Request Package



Exchange between Partners and Tools

Delivery Package



Data Management

Import / Export Packages and merge Data

PIDTec. SimData Manager

Credible Simulation Process

Analyze | Define Requirements | Define Design | Implement | Execute Simulation | Evaluate | Decide

Simulation Goals

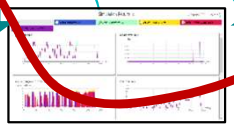
Requirements List

Architecture

Testcases, Models and Parameters

Info on Execution

Results



Link to Video

This approach is based on the Credible Simulation Process Framework and open standards like FMI, SSP, SSP-Traceability

fmi Functional Mock-up Interface ssp System Structure & Parameterization

Building Blocks for Simulation based Cooperation
Agenda

prostep IVIP

Process

Structuring, assignment responsibilities

Standards and Recommendations

Simulation credibility, abstraction and modeling

Information

Harmonization metadata, semantics

Data formats for exchange

heterogeneous IT environments, collaboration

smart Systems Engineering

Building Blocks for Simulation based Cooperation

Where does it go?

Process

SmartSE

2023/24

Standards and Recommendations

SmartSE + ASME & INCOSE & NAFEMS

2023ff

Information

MIC-Core

Q2/2023

Data formats for exchange

Modellica Assocation Prj. SSP

SSP Traceability 1.0 Q4/2023

SSP 2.0 Q4/2023

prostep ivip SmartSE Phase V

Mission Phase 5
(2022-2024)

Enabling collaborative development and validation of complex products by simulation along a multi tier supply chain.

If you are interested in these topics: **Get in contact with us during the conference**

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Pierre Mai
PMSF

Peter Lobner
eXXcellent solutions

Dag Brück
Dassault Systèmes

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Thank you

for your attention