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Automating Model Validation

Using FMI and OMSimulator

Robert Hällqvist, Magnus Eek, Robert Braun, Petter Krus

Agenda

- Background and Introduction
  - Research projects
  - M&S of aircraft vehicle systems at Saab

- Automating Model Validation
  - Motivation
  - Enablers

- FMI-based digital twin

- Key Results and Conclusions

Background and Introduction
Research Projects

- *Open Cyber-Physical System Model-Driven Certified Development (OPENCPS)**

  - Key innovation: Development of FMI run-time and master simulation framework supporting

    - **Scalable and reliable co-simulation**

    - Open source **FMI Master Simulation Tool**

- *Compact and Efficient Platform*

  - Identified **key technology** area

    - Identify and mature new technology and methodology

    - Capability to develop and evaluate new concepts quickly

openCPS

Open Cyber-Physical System Model-Driven Certified Development
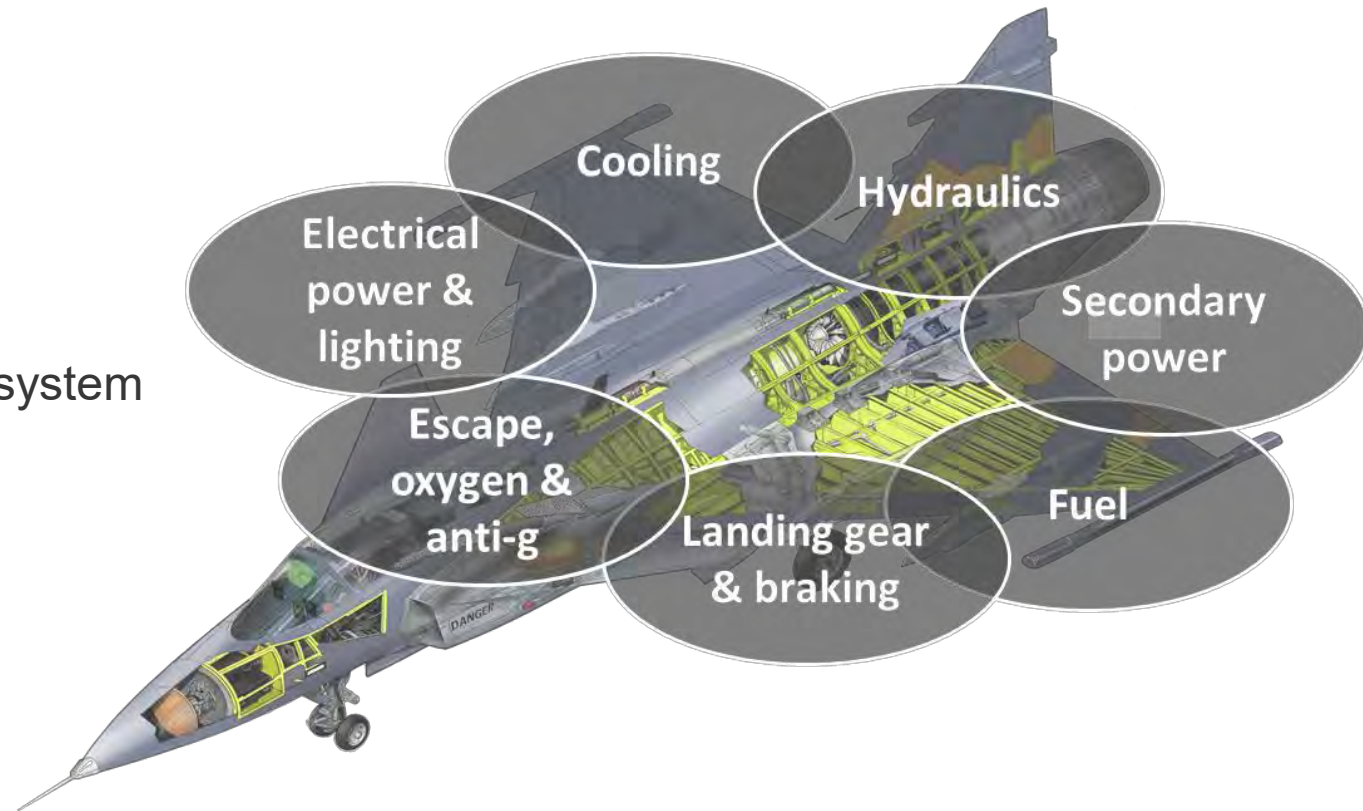
*www.opencps.eu

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Background and Introduction
## Aircraft Vehicle Systems

- In civil and military aircraft

- Complex H/W & S/W

- Tightly integrated

- Highly interconnected

- Multiple tasks per system

- Extensive use of M&S needed throughout system development

M&S of Aircraft Vehicle Systems
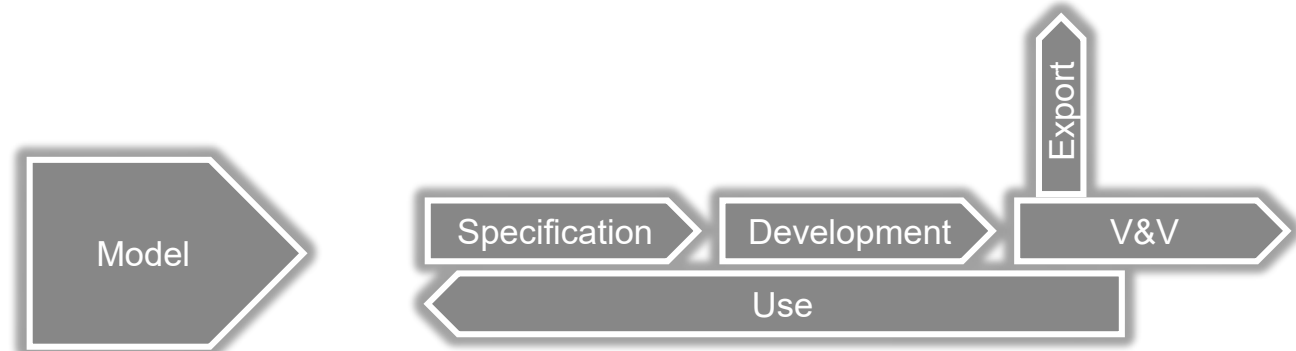## Test-Stations

- Level of Representation: measure of how well the test-station represents the unit under test

- Level of Integration: Measure of how many aircraft sub systems are represented
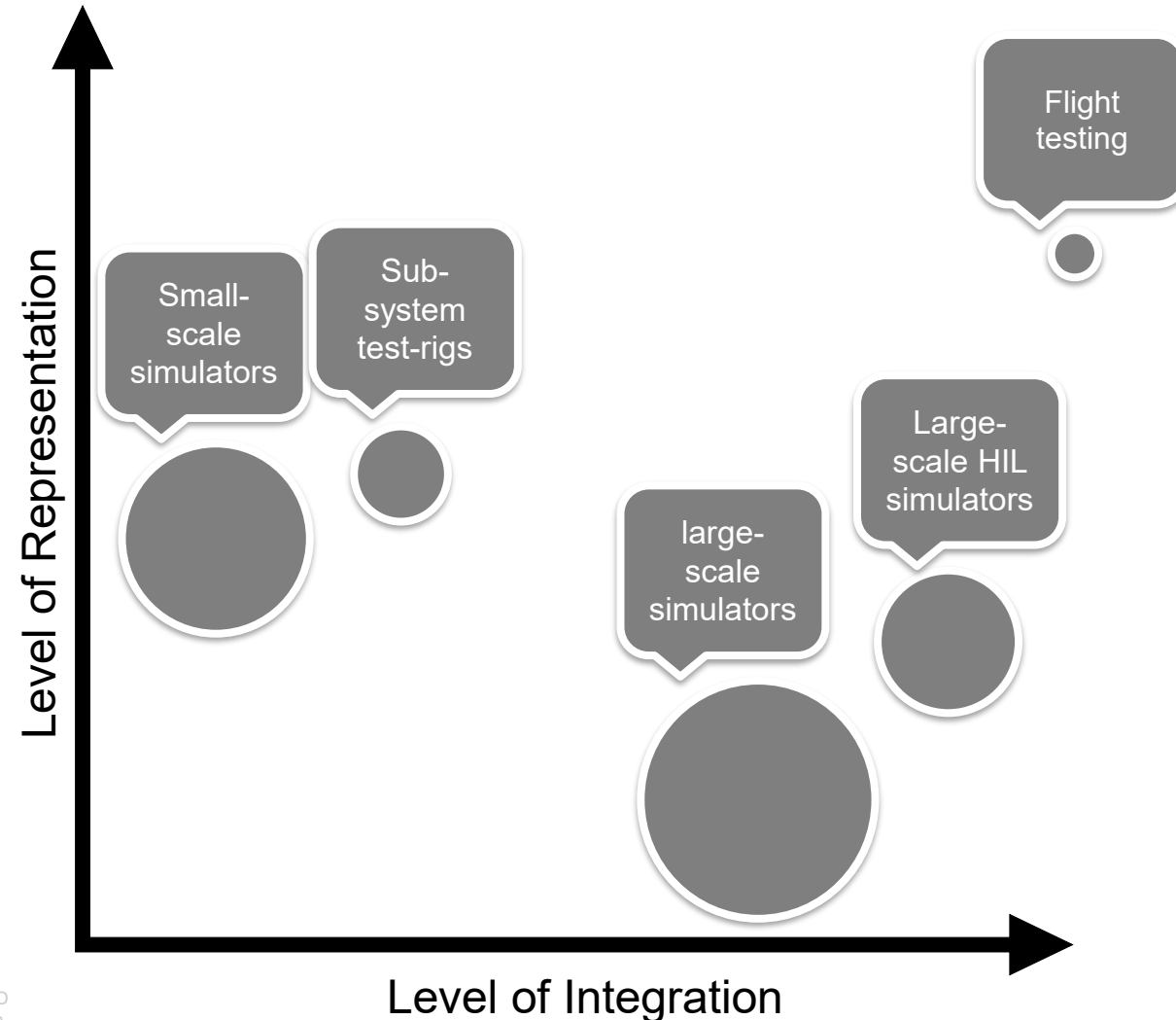
Background and Introduction
## M&S Application Development Process

- Saab Handbook for Development of Simulation Models*

  - Describes the steps needed to ready models for export to simulator applications

  - Here, the specification activity includes formulation of intended use(s), model requirements etc.

  - Development comprises the assembly of components into a simulation model

*Henric Andersson and Magnus Carlsson. Saab Aeronautics Handbook for Development of Simulation Models : Public Variant. Tech. rep. 12/00159. Linköping University, Machine Design, 2012

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Background and Introduction
## M&S Application Development Process

- General to several levels of abstraction
    - Simulators consist of multiple models or other simulators
    - Models consisting of multiple modelled sub-system components
    - Sub-system components are built up of modelling library components

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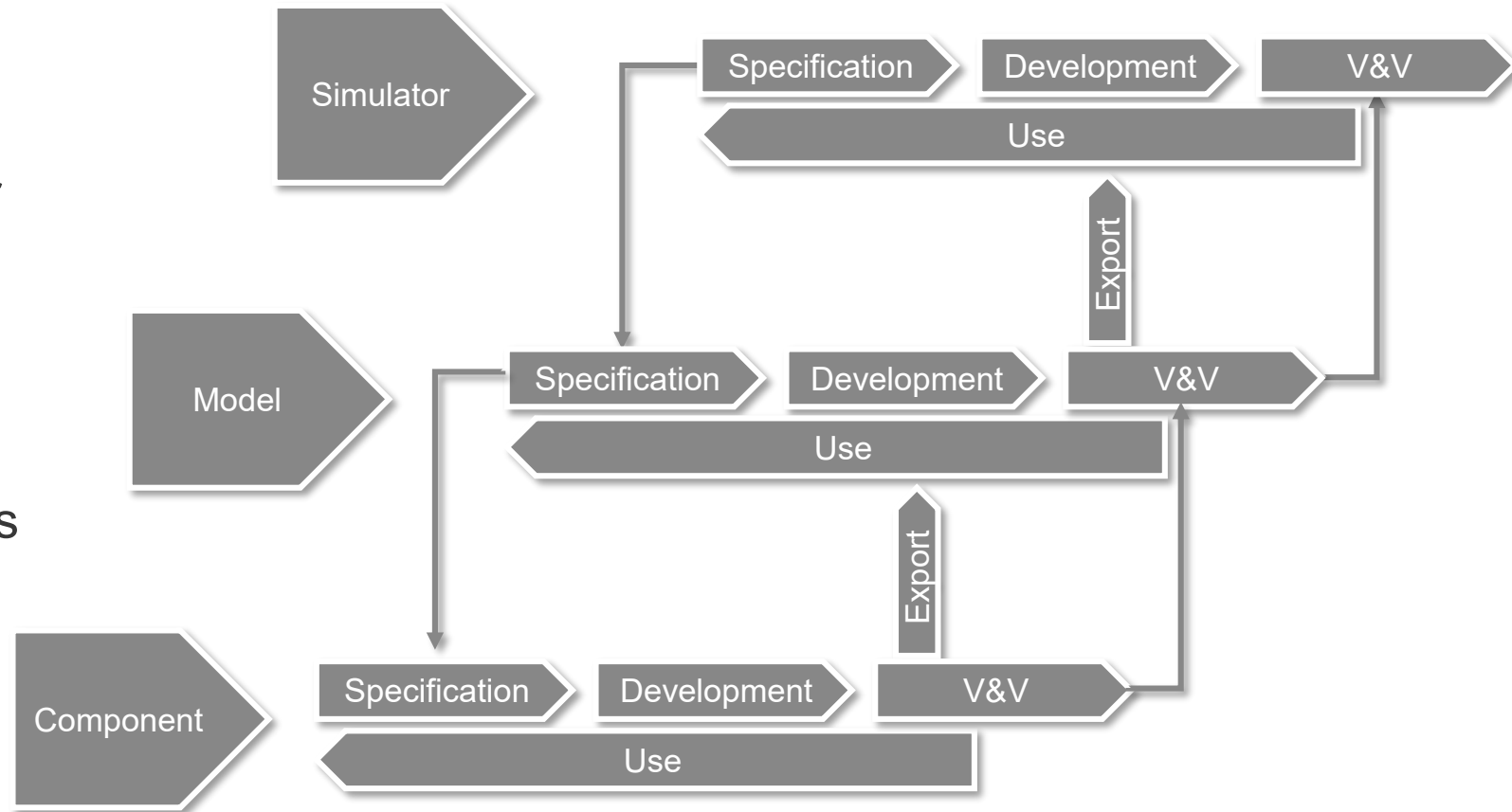
Background and Introduction
Model Validation

- Verification and Validation (V&V)
  - Verification: Is the simulation application built right?
  - Validation: Is the right simulation application built?
- Operational Domains (ODs) and how they relate to one and another
  - System of interest Operational Domain
    - System Specification
  - Model Operational Domain
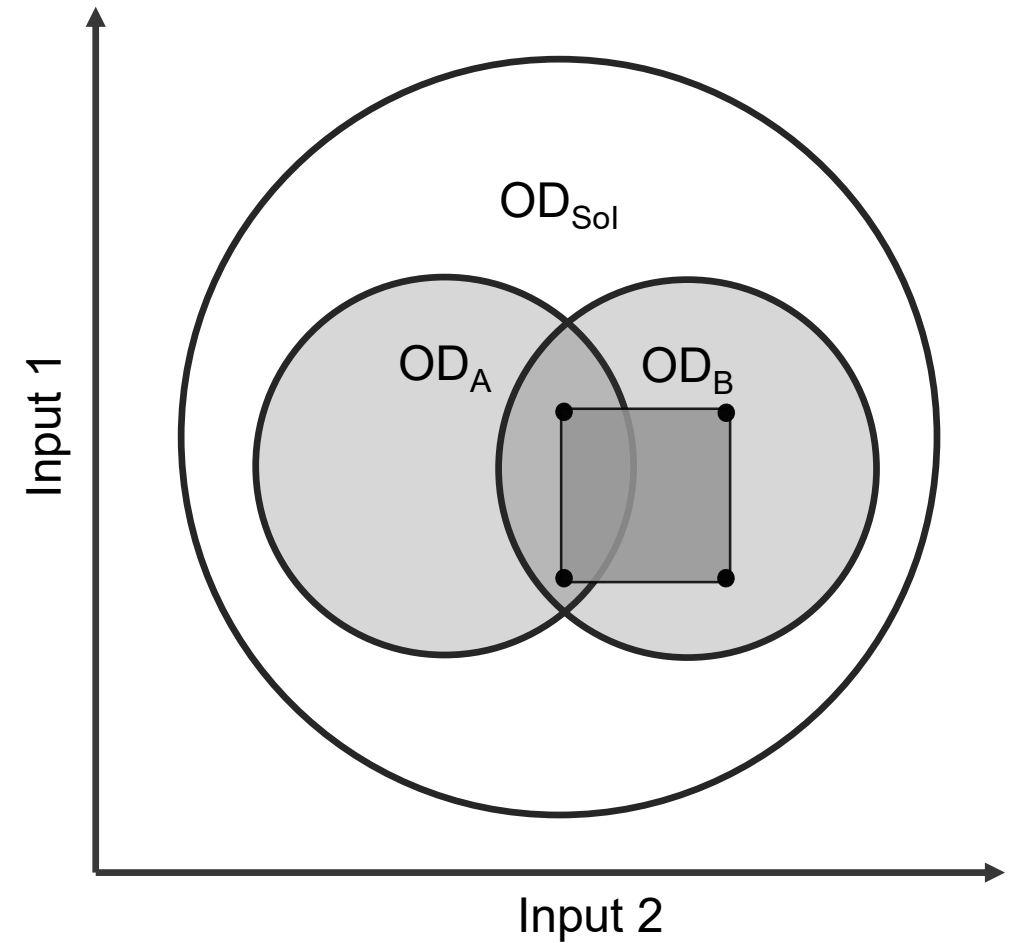   - Intended use->model specification
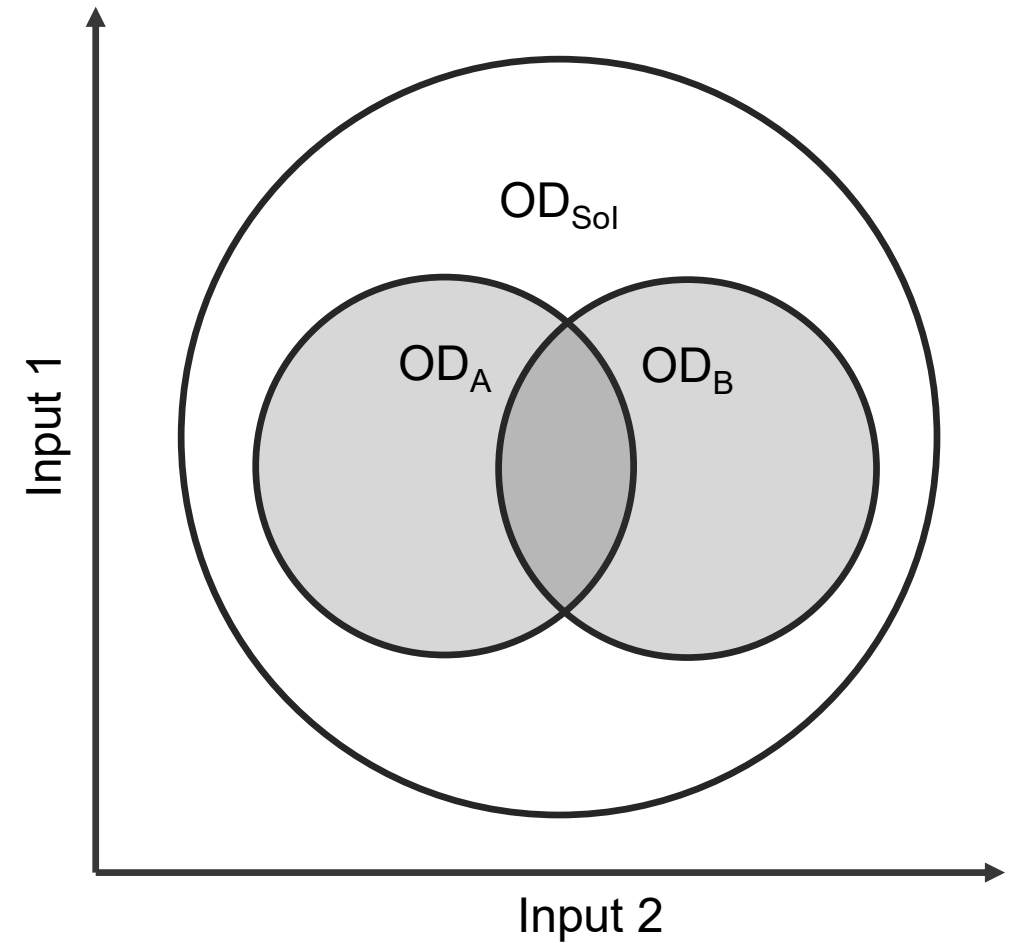
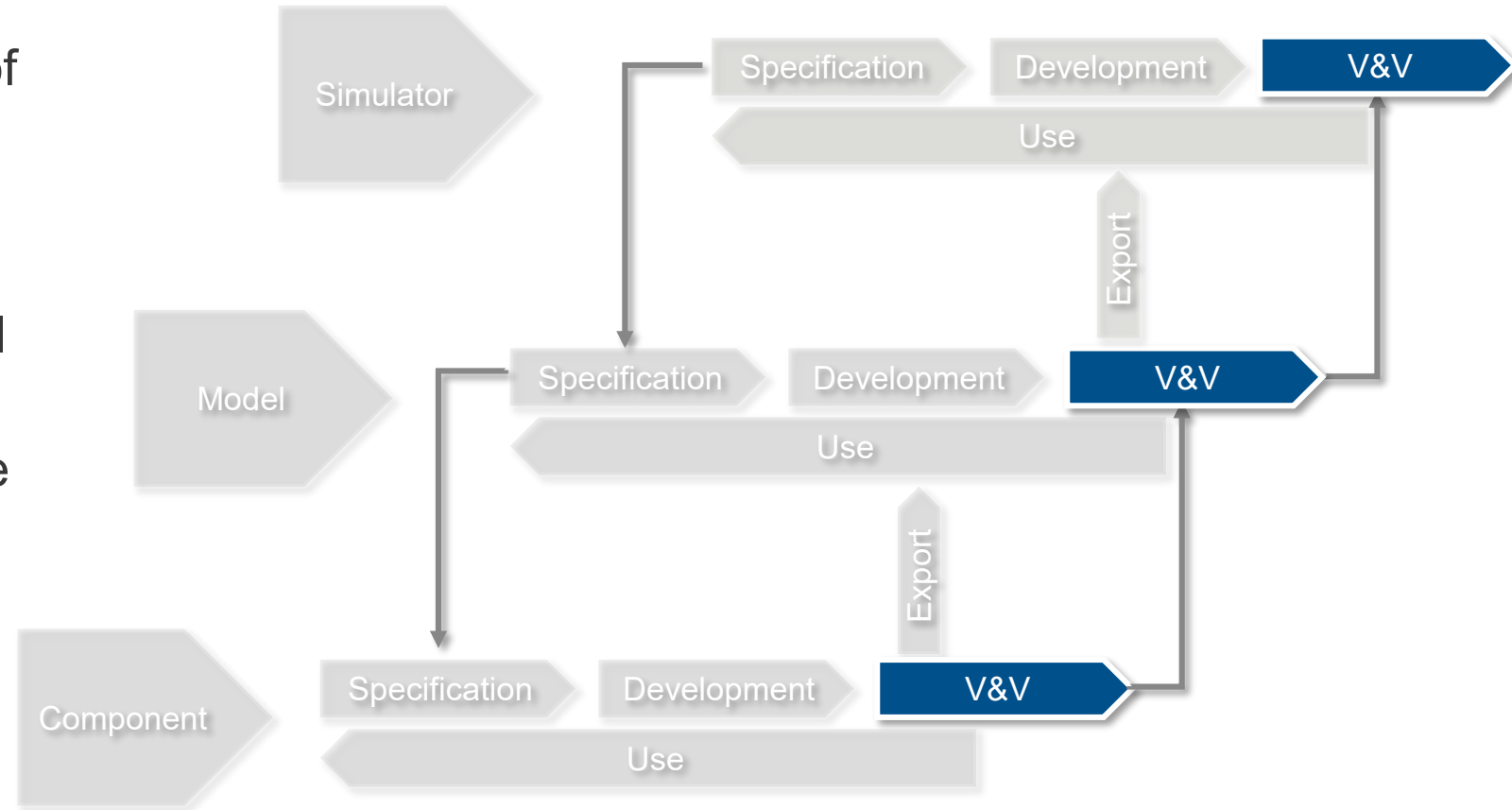# Background and Introduction
Model Validation

- Validation Experiments
  - Model validity with respect to model intended use
  - Domain of Validation (DoV)

# AUTOMATING MODEL VALIDATION
Motivation

- Reasons for automation
  - Handle large amounts of data
  - Free engineers from repetitive work
  - Enable continous model validation
  - Introduce independence and objectivity

Enablers
The functional Mock-up Interface (FMI)*

- Standardization effort commenced in the EU financed research project (*MODELISAR)*

- Specifies a generic format for export of model executables, Functional Mock-up Units (FMUs)
  - FMUs for co-simulation
  - FMUs for model exchange
  - Source code, grey box, black box

- Standardized C API for FMU execution

- Standardized interface description xml schema

- FMI 2.0 Supported by ~50 commercial and open-source tools

*FMI development group. *Functional Mock-up Interface for Model Exchange and Co-Simulation*. Report 2.0, Modelica Association, 2014
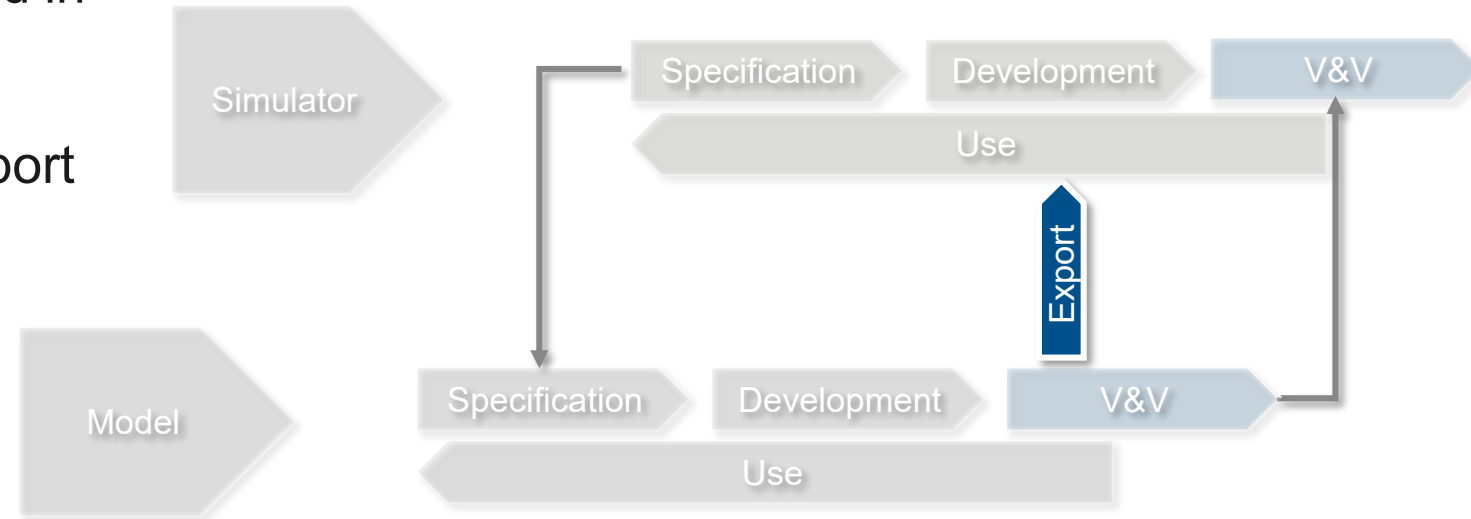
Enablers
System Structure and Parameterization (SSP)*

- Under development as a *Modelica Association Project*
  - Standardized export of simulators

- First official release in March 2019

- SSD:
  - Standardized xml schema for integration and configuration specification of connected models

- SSV
  - Standardized xml schema for specification of the parameters of connected models

- SSP
  - Package containing SSD along with its referenced resources

*Modelica Association. *System Structure and Parameterization.* Report 1.0. Mar. 5, 2019
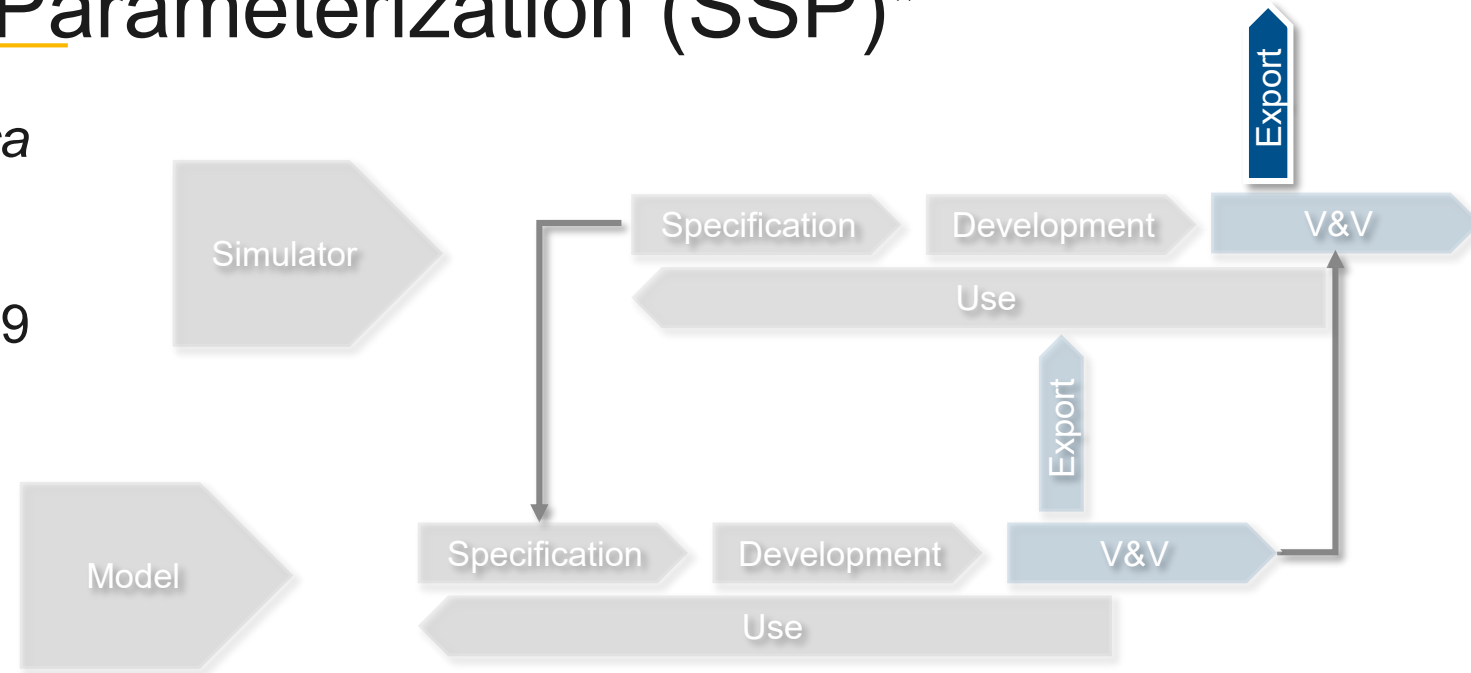
Enablers
OMSIMULATOR

- Open-source
  - Shipped with OpenModelica*
  - Available on github**

- Scripting
  - Lua, Python, C++, OM

- Graphical Editing
  - OpenModelica, Papyrus

- Information exchange
  - FMI, SSP

OMSimulator.lib/dll

OMSimulator.exe

OMTLMSimulator
- **Physical connections**
- **Delayed connections**
- **Distributed processes**

OMFMISimulator
- **Signal connections**
- **Non-delayed connections**
- **Single process**

*https://www.openmodelica.org/
**https://github.com/OpenModelica/OMSimulator

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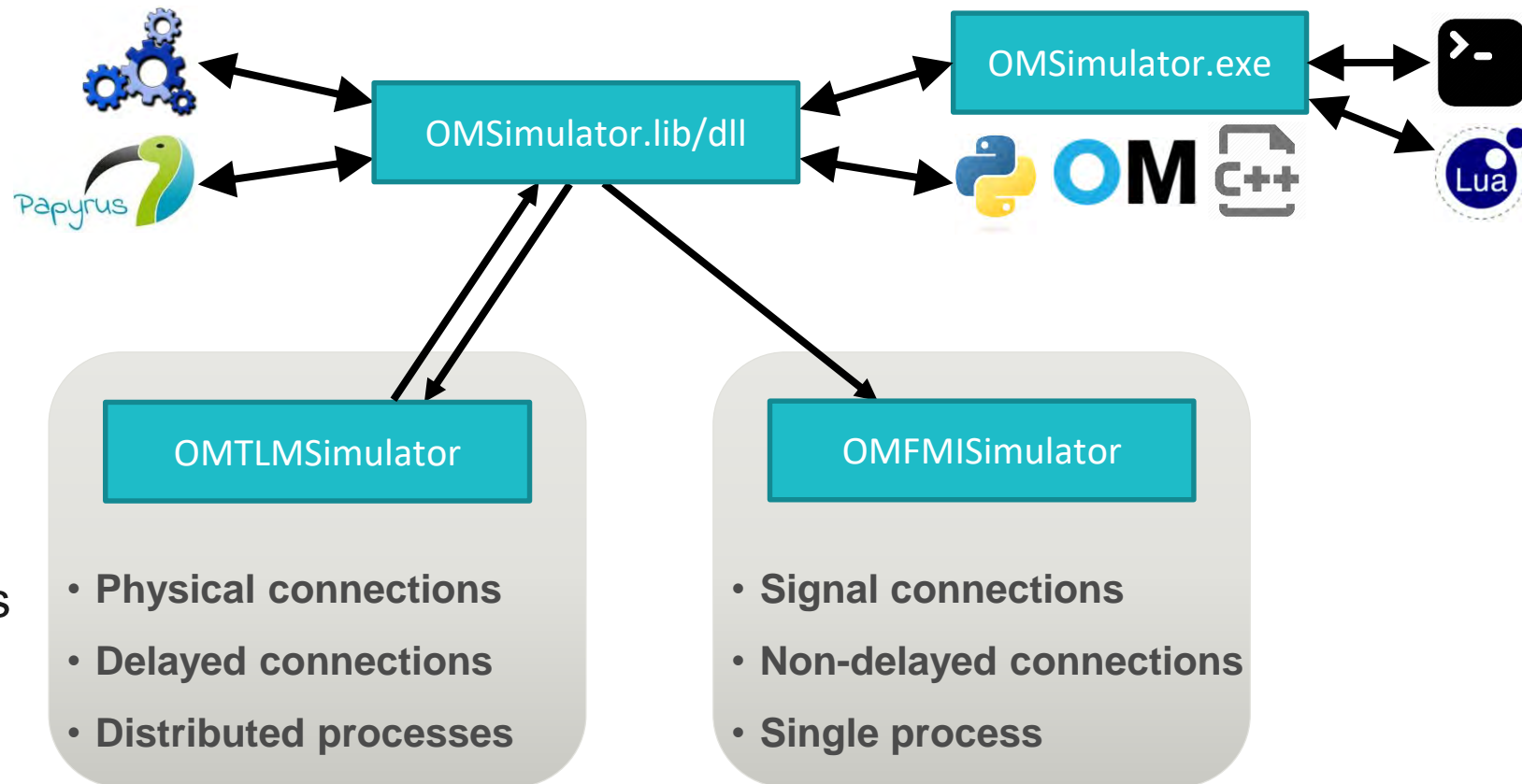
FMI-based Digital Twin
Compact and efficient platform

Test aircraft

Measurement data

Storage A

Automation & Standardization

Utilization

Test engineer support: Anomaly detection

M&S engineer support: Model validation

SE support: Identify verification methods

OMSimulator

FMUs

Simulation results

Pre-processing

Post-processing

Storage B

Analysis & report generation

Store aggregated analysis results

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Automated model validation
-Outlook

Identified areas of model improvment, functionality and representation

Export of model and sub-system V&V information

Modelling domain

V&V and model calibration

Sub-system testing platform

Central Model Storage

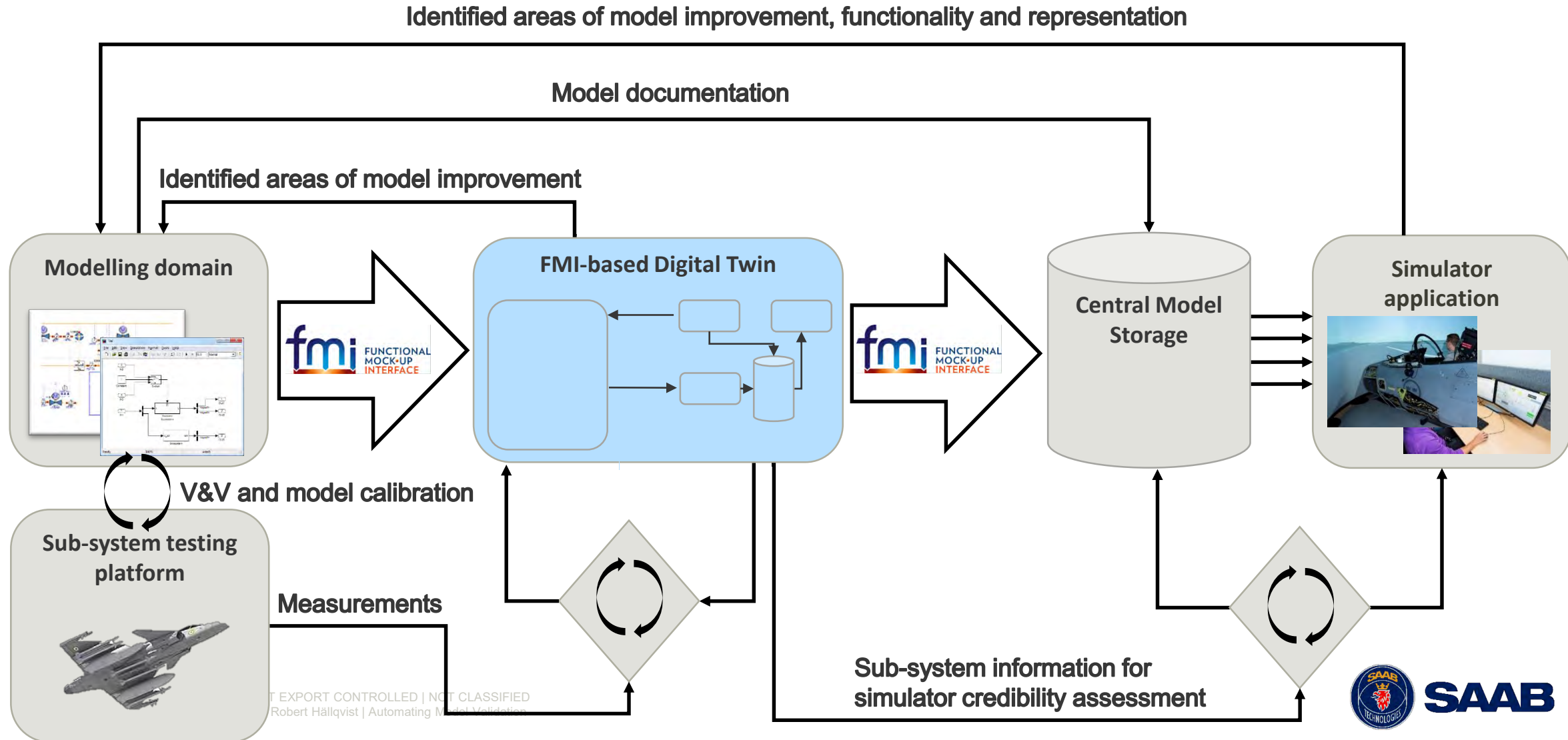**Simulator application**

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Automated model validation
-Outlook

Automated model validation
-Outlook

- Physics-based modeling
  - Standardized export and integration
- Flight test
  - Trigger V&V framework iteration
- Central model storage
  - Models are passed on to storage along with incorporated V&V info
- Simulator applications
- Simulator credibility assessment
  - On-line
  - Connection to latest info from V&V framework
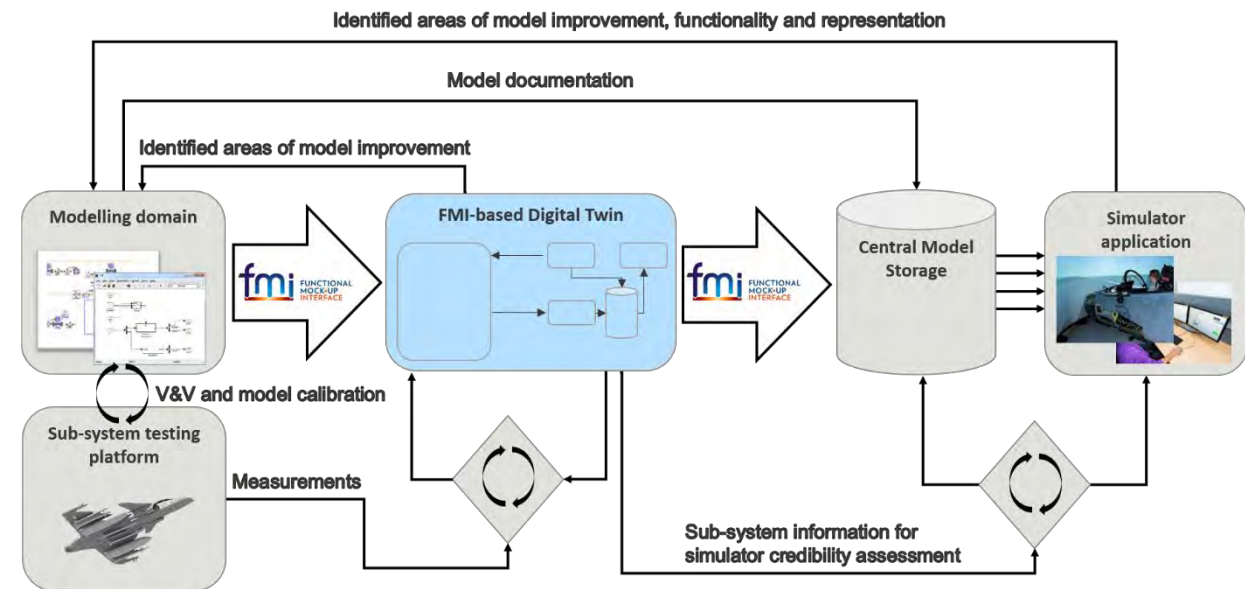
Key Results and Conclusions

- Key enablers advancing the targeted state-of-the-art in physics-based M&S have been identified, developed/progressed, and evaluated

  - OMSimulator

  - FMI standard update

  - Interoperability

- Prototype of FMI-based digital twin developed and launched at Saab

  - Successively approach automated V&V and anomaly detection

- Continuation of research established via NFFP7-Call 2 and ITEA

Thank you!!