

# USAGE OF FMI @ BOSCH STATUS & OUTLOOK



“ FMI is the preferred model exchange and co-simulation format of Robert Bosch GmbH at system level enabling the exchange of models with internal and external partners using different modelling tools.

— Robert Bosch GmbH on ITEA3 MODELISAR

CHRISTIAN BERTSCH, BOSCH RESEARCH

# Usage of FMI at Bosch - status and outlook

## The four business sectors of Bosch

**Mobility Solutions**



**Industrial Technology**



**Energy and Building Technology**



**Consumer Goods**



- ➔ Modelling and simulation are important pillars in our development process
- ➔ >100 modelling and simulation tools in use, >10 preferred tools
- ➔ Exchange and co-simulation of models between departments, business units + external partners

**FMI is used in all business sectors of Bosch**

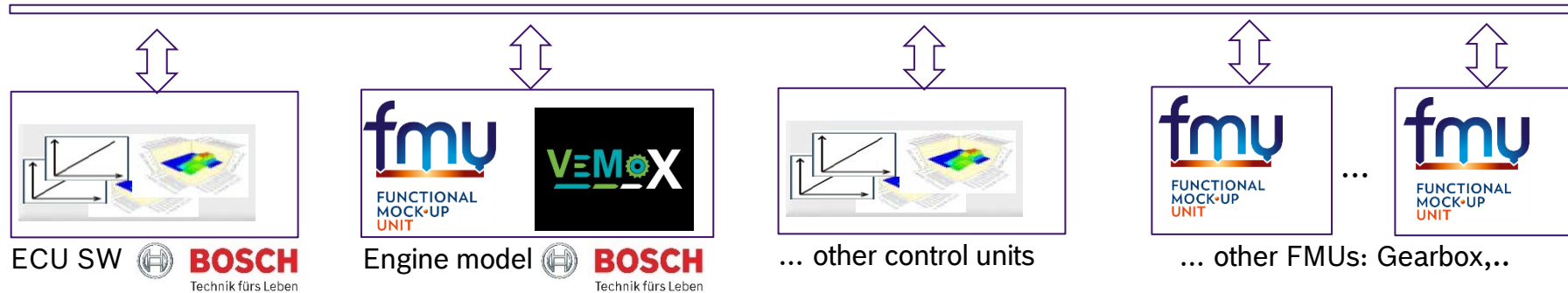
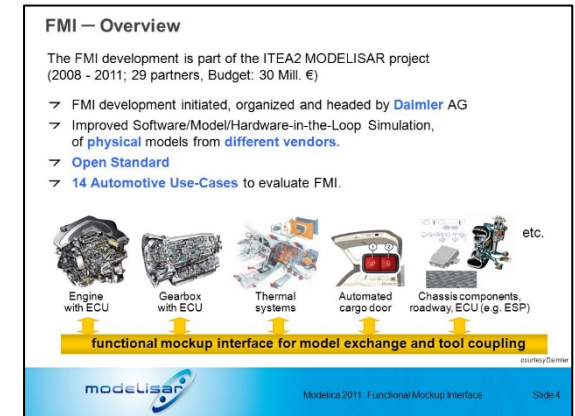
# Usage of FMI at Bosch - status and outlook

## Examples I: FMI usage in automotive

- ▶ **Vision** of MODELISAR project: Exchange models as FMUs between OEMs and suppliers
- ▶ **2019:** Collaborative engineering based on FMI is now **reality**: e.g. Software-in-the-Loop Simulation (SiL) for engine control

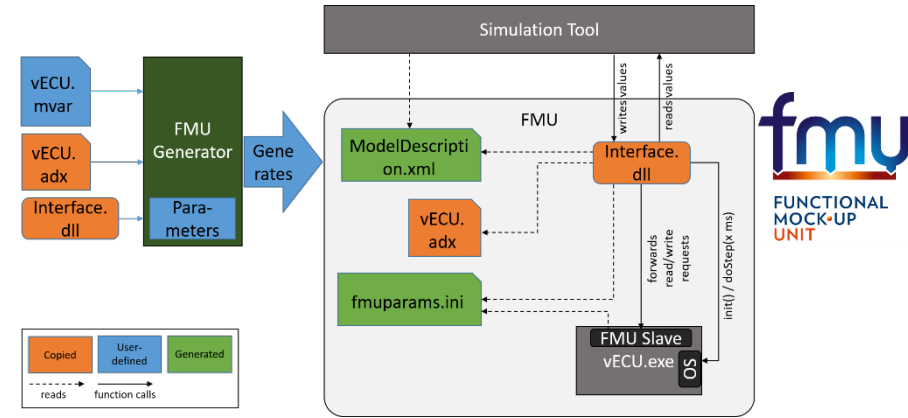
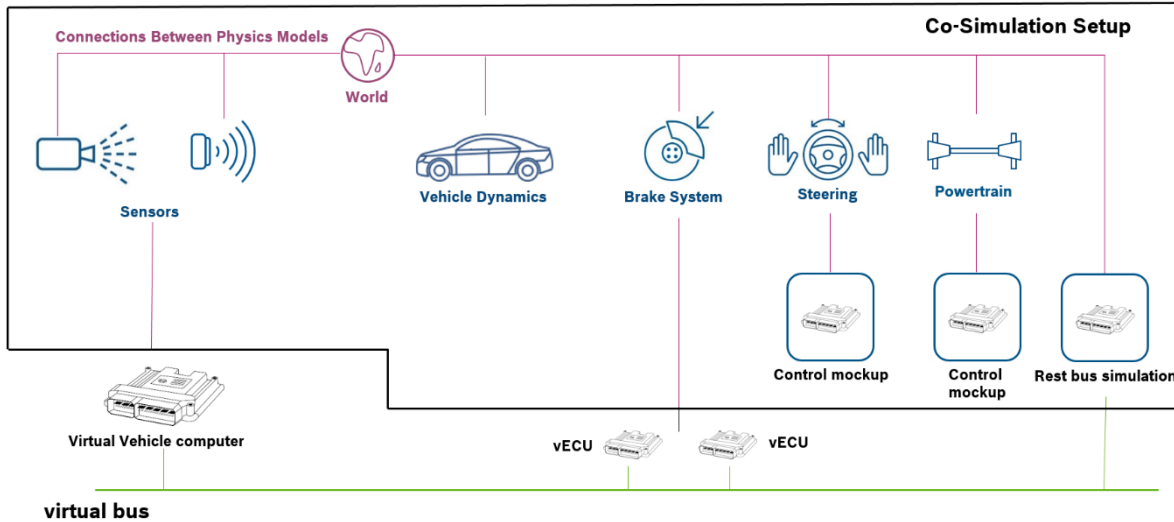


DAIMLER



## Example II: virtual ECUs, towards to connected SiL

- Next Step: from virtual ECUs to **connected SiL simulation including virtual buses**

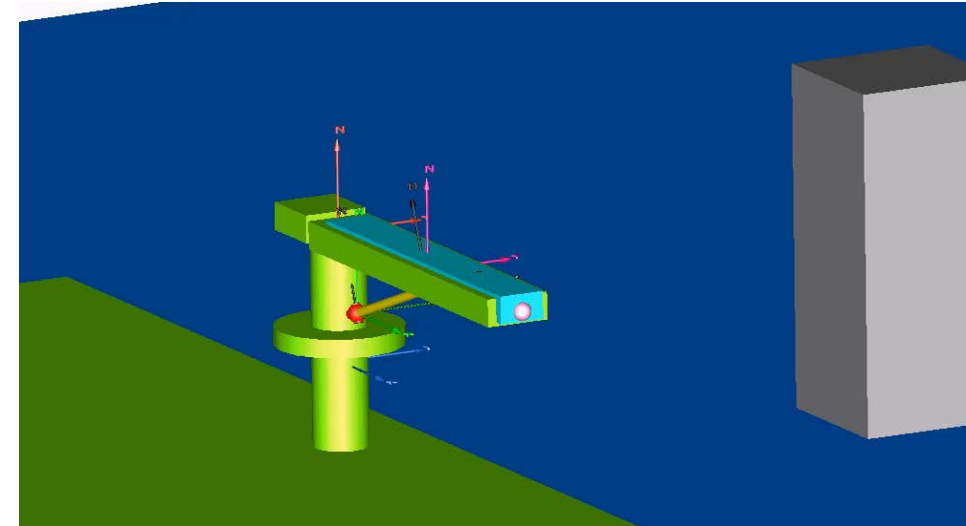


Source: P. Baumann, R. Samlaus et. al. A contribution to the simulation of networked virtual ECUs, accepted paper VDI Mechatroniktagung, Paderborn, 2019

# Usage of FMI at Bosch - status and outlook

## Example III: Motion Compensated Mobile Gangway

- ▶ Development of the drive system of a Motion Compensated Mobile Gangway
- ▶ Efficient and safe transport of service staff and loads to offshore structures (e.g. offshore wind turbines)



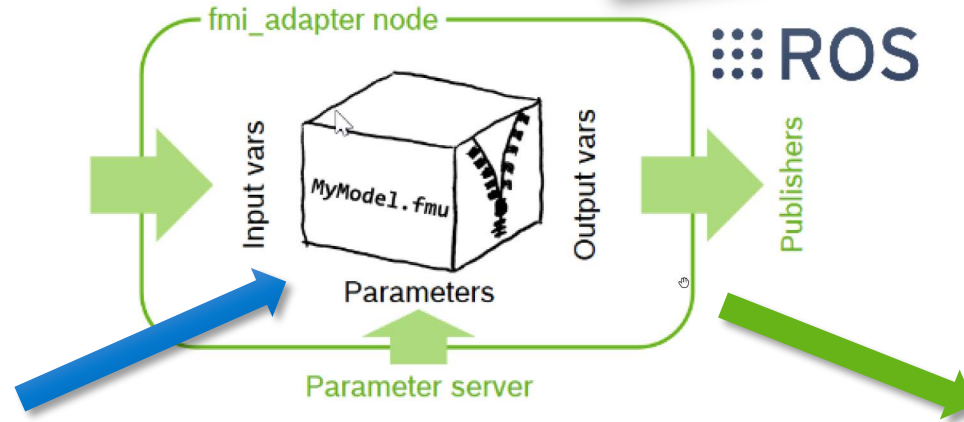
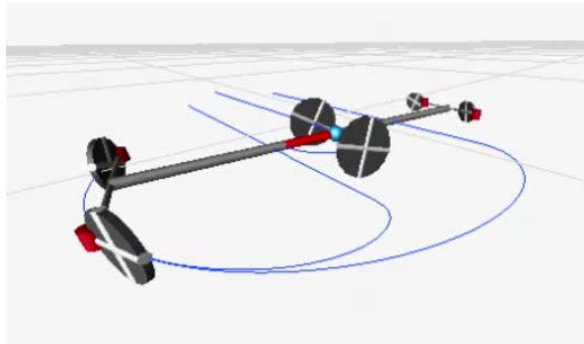
- ➔ Compensation of ship/wave movement in 3 directions (luffing, slewing, telescoping) up to 3m wave amplitude
- ➔ **International collaboration across three different locations using different simulation tools. Mechanical models as FMUs.**

# Usage of FMI at Bosch - status and outlook

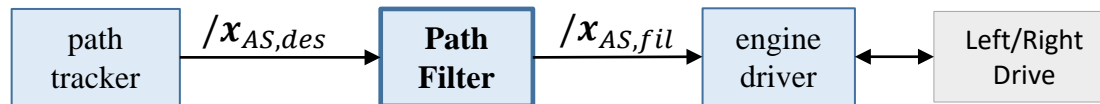
## Examples IV: Model-based Control in ROS

- ▶ Path Filter developed and tested in Modelica MiL.
- ▶ Deployed as FMU to logistic SDV<sup>1)</sup> prototype using *FMI adapter* for ROS<sup>2)</sup>.

Developed at Bosch Research  
Published on Github  
[https://github.com/boschresearch/fmi\\_adapter\\_ros2](https://github.com/boschresearch/fmi_adapter_ros2)



ActiveShuttle Dev Kit



Talk on “Enhanced Motion control of an SDV Using Modelica, FMI and ROS”, by Oliver Lenord,  
Wednesday 09:30, **Session 4B: Automotive 2**

# Usage of FMI at Bosch - status and outlook

## Internal FMI activities

### ► Bosch internal decision:

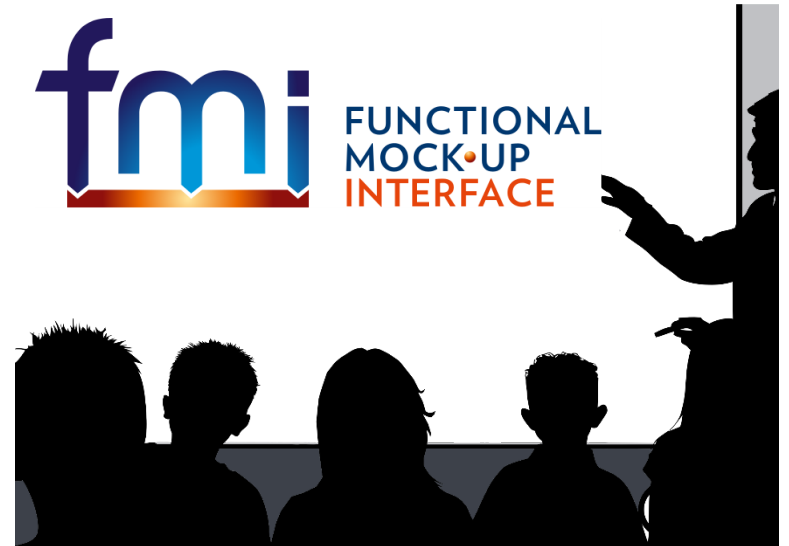
- *FMI is the preferred model exchange and co-simulation format of Robert Bosch GmbH at system level enabling the exchange of models with internal and external partners using different modelling tools*

### ► Bosch-internal FMI community with 500 members

- Internal social media group
- Regular expert meetings for exchange on FMI topics

### ► Bosch-internal FMI Trainings

- basic and specialized trainings
- >200 associates trained



<https://openclipart.org/>



# Usage of FMI at Bosch - status and outlook

## FMI support in (in-house) tools

### ► Bosch in-house tools

- FMI support in Python toolboxes (via fmpy by Dassault Systems)
  - e.g. for Uncertainty Quantification, model test automation
- TriboSim (simulation tribological contacts)
- Generators to wrap ECU-Software as FMUs
- FMU-adapter for Robot Operating System (ROS): published as open source
  - Released as open source software on Github: [https://github.com/boschresearch/fmi\\_adapter\\_ros2](https://github.com/boschresearch/fmi_adapter_ros2)



### ► Rexroth in-house tools

- Next generation sizing tools
- SiL simulation of the Bosch Rexroth precision motion control system



### ► ETAS: FMI support in many tools for embedded Software

- SCODE-CONGRA, ASCET, ISOLAR-EVE, COSYM, LABCAR, ASCMO, INCA-FLOW,





# Usage of FMI at Bosch - status and outlook

## External collaboration within FMI Project

### ► Member of FMI Steering Committee

- Robert Bosch GmbH + subsidiaries ETAS GmbH, ITK Engineering GmbH



### ► Participation in “industrialization” and “stabilization” of FMI

- E.g., Cross check, Corporate Contributor License Agreement (CCLA)

### ► Contributing to FMI 3.0 development

- Participation in working groups

### ► Close collaboration with tool vendors:

- Demanding FMI support preferred simulation tools: now almost all have (at least partial) FMI support
- Piloting FMI support in new tools

Overview Export/Import FMUs

Importing Tool	Tool A	Tool B	Tool C	Tool D + Elsewhere
Tool A				
Tool B				
Tool C				
Tool D				
Tool E				
Tool F				
Tool G				
Tool H				
Tool I				
Tool J				
Tool K				
Tool L				
Tool M				
Tool N				
Tool O				
Tool P				
Tool Q				
Tool R				
Tool S				
Tool T				
Tool U				
Tool V				
Tool W				
Tool X				
Tool Y				
Tool Z				

2012: Bosch-internal Cross-Check with 4 tools

Importing Tool	2019m	2018m	Autodesk	CATIA	D3	FMI Expert from Simulink	FMI Toolbox for MATLAB/Simulink	Mathworks	Shw	Simulink
Adams	0	0	0	5	1	7	4	1	2	0
AMEsim	0	0	0	5	4	11	2	4	3	0
ANSTIS Simplorer	0	0	0	5	0	0	0	0	0	0
AVL CRUISE M	0	0	0	10	4	16	4	1	4	1
AVL Model.CONNECT	0	0	0	2	1	10	2	4	2	0
CATIA	0	0	0	16	15	124	9	13	2	0
INTO-CPS Co-simula...	1	6	0	10	3	17	12	12	6	0
CosMote	0	0	0	0	1	0	0	0	0	1
Dymola	0	2	1	5	10	41	10	21	2	0
Easy5	0	0	0	0	0	4	0	0	0	0
FM4cpp	1	0	1	0	1	1	0	4	0	0
FM4j	1	0	1	0	1	0	1	0	0	1
FMI Bench	0	1	0	11	13	12	9	16	10	0
FMI Toolbox for MA...	0	0	0	0	0	6	1	4	1	0
FMPy	1	2	1	11	11	11	25	9	16	11
GT-SUITE	0	0	0	0	0	0	0	0	0	0
JarFMi	0	0	1	0	0	0	0	0	0	0
MasterSim	0	0	0	1	1	1	1	1	0	0
MoBa Lab	0	2	0	11	14	12	9	16	1	0
Silver	1	6	1	16	23	148	116	124	17	1
SIMPCAP	0	0	0	5	11	25	9	16	0	0
SimulationX	0	0	0	0	1	0	0	2	0	0
solidThinking Acti...	0	0	0	4	6	0	0	3	0	0

# Usage of FMI at Bosch - status and outlook

## Need for FMI feature overview of tools

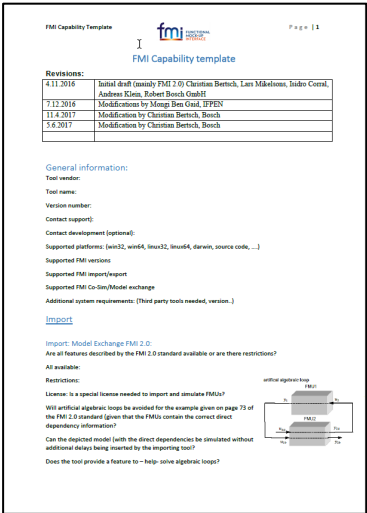
► **Problem: tools support only certain optional capabilities of the FMI standard.**

- The information about these features is **hard to find** for end users
- General tool chains can **only rely on commonly** supported subset of supported **features**

► **Proposal: Create an overview of FMU features of the tools**

- A template for FMI supporting tools to describe the supported features (proposal exists)
- Create features support tables, e.g. for FMI 2.0 CS export:

Tool	Can get and set state	Can export source code FMUs	Can export License free FMUs	Can export its standard solvers	Can export FMUs w/o tool dependency
Tool A					
Tool B	x	x	x		x
Tool C	x	x		x	
Tool D					
Tool E	x	x	x		x



Proposal: FMI Capability description template

**Not in focus of FMI project currently.**

**Involvement of industrial users needed!**

# Usage of FMI at Bosch - status and outlook

## Need for FMI 3.0 features at Bosch

## ► Array support

- E.g., be used for better support of curves and maps, e.g. in ECU Software

## ► Binary data type

- Support sensors for automated driving; clean realization of OSI
- Usage for bus simulation of connected virtual ECUs?

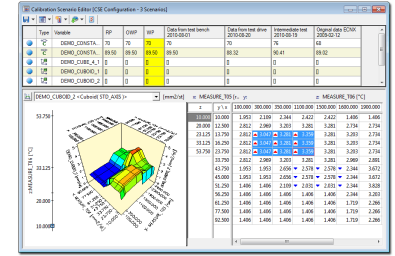
## ► Intermediate output values

- Advanced co-simulation schemes for vehicle simulation

## ► New numerical data types

## ► Clocks and Hybrid Co-Simulation

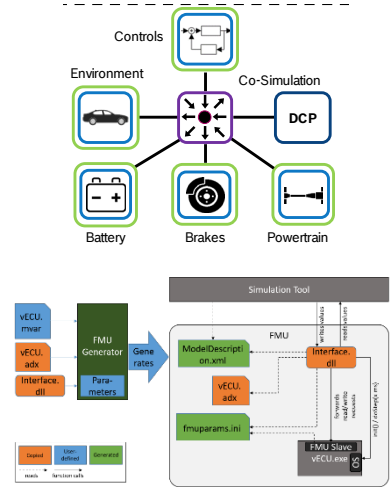
- ▶ Better support for virtual ECUs, HiL Systems
- ▶ Better support for ECU SW wrapped as FMUs



## ETAS INCA: Calibrating maps



Source: <https://www.pegasusprojekt.de/>

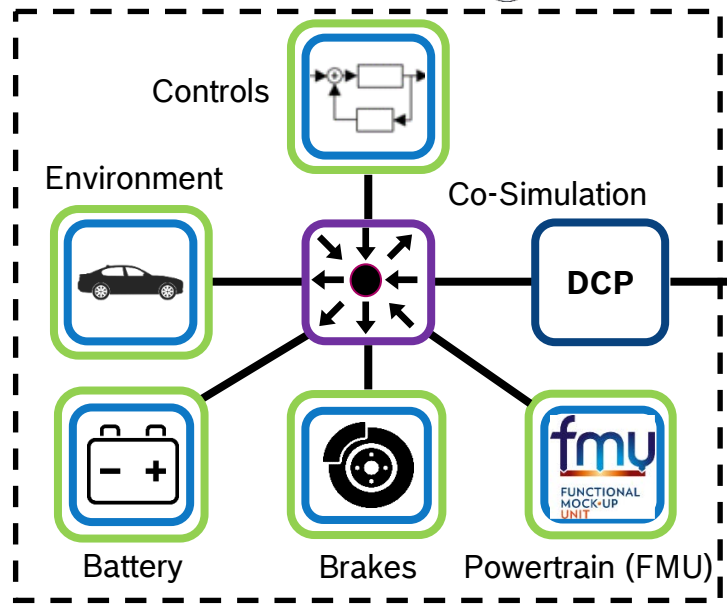


# Usage of FMI at Bosch - status and outlook

## Need for DCP: Distributed realtime simulation with FMI and DCP

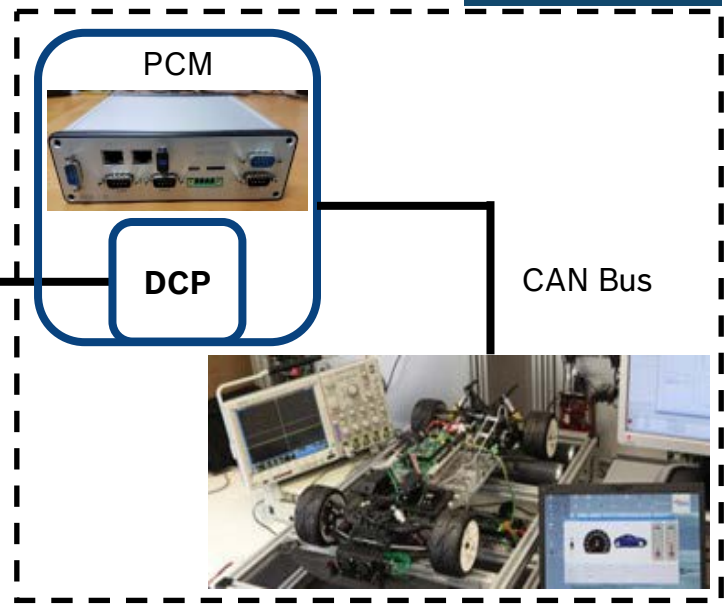
### DCP slave: Cross domain co-simulation model

Located in Renningen, Germany  **BOSCH**



### DCP slave: Small scale test bed

Located in Graz, Austria



DCP Master

UDP via internet

Peter Baumann et al., Using the Distributed Co-Simulation Protocol for a Mixed Real-Virtual Prototype, IEEE 2019 International Conference on Mechatronics, Ilmenau, 2019

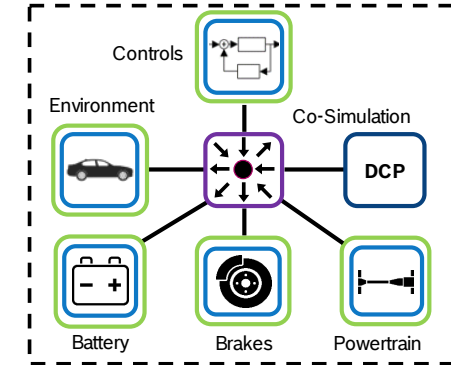
# Usage of FMI at Bosch - status and outlook

## Need for SSP standard

### ► ZF, BMW, Bosch and others initiated SSP standard

due to the need to

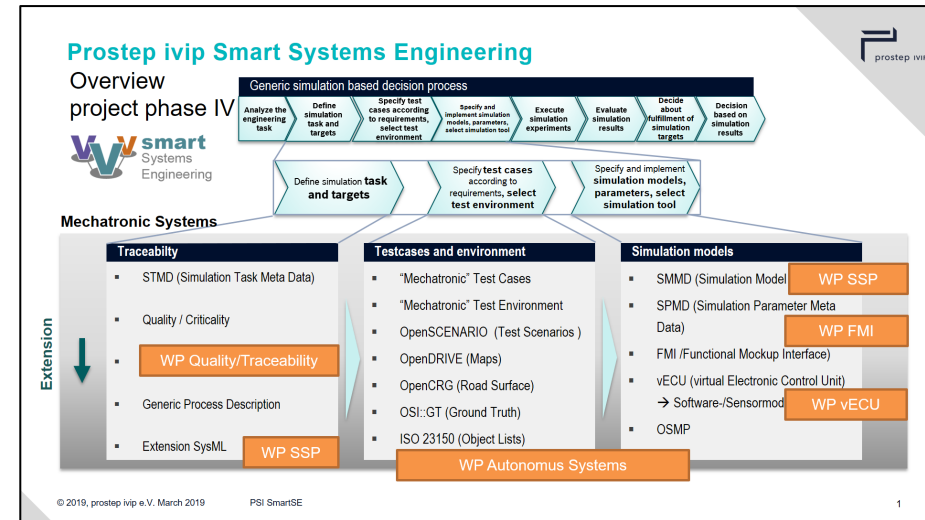
- Exchange co-simulation topologies in a tool-independent format
- Exchange and archive parameter sets



### ► Next step: broad and mature tool support needed

- SSP Compliance Checker and Cross Check Infrastructure

### ► Future work: **extend SSP towards traceability and proof of quality of simulation results** within PROSTEP Smart Systems Engineering Project



# Usage of FMI at Bosch - status and outlook

## Need to extend FMI towards usage in embedded software

### ► ITEA3 project

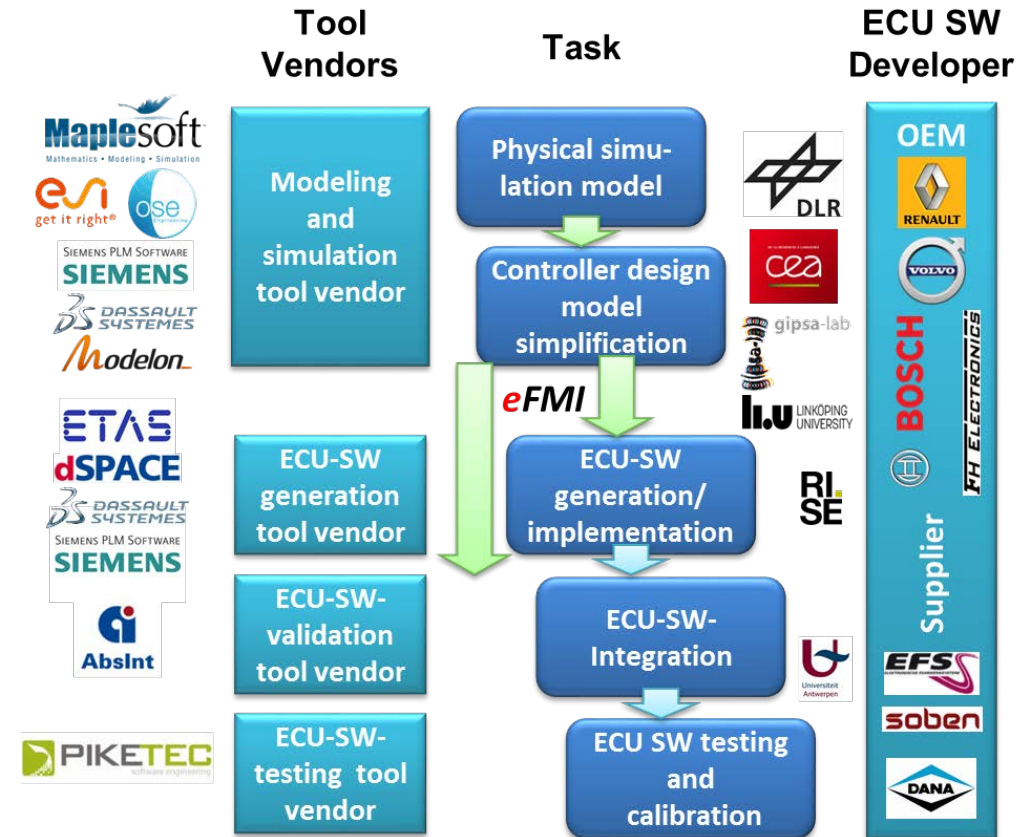


### ► Goals:

- New standard FMI for Embedded Systems (eFMI)
- Use physical models in control and diagnosis functions in production code of automotive ECUs



Contact: Oliver Lenord (Bosch), Martin Otter (DLR)



25 Partners, 5 Countries, >90PY, 2017 – 2020



# THANK YOU.



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— Robert Bosch GmbH on [ITEA3 MODELISAR](#)