

#### Agenda

- Le projet Modelisar
- L'innovation FMI
- Les études technologiques
- Les implémentations de FMI
- Démonstration
- Perspectives sur FMI
- Initiatives automobiles
- Questions / Réponses

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#### Motivation du project

- Overall goal: Secure functionality of complex technical systems
- for customer comfort and safety
   at less costs
- "Good products at little costs"
- Aspired solution: Digital functional mock-ups substitute (late and expensive) physical mock-ups
- Challenge: Overcome domain barriers between software, electrics, mechanics, etc. in existing simulation tools & technologies
- Answer: Functional Mock-up Interface (FMI) standard
   developed in Modelisar







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Modelisar results
A new international standard
Functional Mock-up Interface (FMI)

for flexible and standardized simulator integration

- A set of open FMI specifications (Model Exchange, Co Simulation, PLM)
- More than 10 FMI prototypes for use cases
- 10 supporting scientific studies (AUTOSAR, co simulation, timing, bus)
- An evolution of Modelica language for FMI and AUTOSAR
- 24 FMI industrial Use case Proofs of concept
- 45 available or planned FMI compliant software products,
- including 34 during project course
- FMI IP & governance transferred to Modelica Association
- Cooperation with 8 European projects & 3 standard organizations
   Dissemination on the Web:

 Modelisar / FMI web site, 2) social community, 3) Wikipedia, and 4) > 100 communications & dissemination actions





#### **Technological breakthrough**

- Production and Exchange of FMUs
- Cooperation between FMUs via a master
- Independency of different types of simulator hardware and/or operating systems
- Generic approach to handle the FMU and related simulation data through PLM
- Offers standardized services
  - Control of simulation, synchronization, monitoring, visualization, documentation
     As part of one of the simulation tools or in a dedicated FMU server



#### **Overview of the Different Interfaces**







### 35 modeliser LMCS 2012 - Presentation FMI - 7 dec 2012

## Schematic view of a model in "FMI for Model Exchange"



#### Mathematical description of a FMU

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#### Implementation principles



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# Implementation details FMU distribution file

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#### Use case schematic 1/3 r Interface Step 1 – Export: Subsystem model with solver is exported from its simulation tool Subsolver added added co simulation capabilities (compared to ME) Step 2 – Import: Subsystem model is imported into simulation system for system simulation n Tool Sub-Summarized view 35 modelisar LMCS 2012 - Presentation FMI - 7 dec 2012

**FMI for Co-Simulation** 



#### FMI for Co-Simulation (tool coupling) Use case schematic 2/3



#### FMI for Co-Simulation (tool coupling) Use case schematic 3/3



#### FMU distribution in a co simulation cluster



#### Master / slave concept







#### FMI for PLM – Concepts (1/2)



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PLM system

All simulation related data including FMU life cycle management

PLM client – Authoring tool

- Tool, which needs the PLM provider information
- Modeling tool
- Simulation tool (autonomous, master, slave)
- Application tool
- Post processing tool
- ...



FMI for PLM study aims at "Product Lifecycle management" of all data needed in simulation of systems

- Functional Mock-up Units data needed for: edition, documentation, simulation, validation
- Co-simulation data needed for: edition, simulation, and Results management.

PLM syst

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- Result valuation data needed for: Post-processing, analysis, Report
  Specifications are defined through a generic approach
- Generic workflow
- Simple "link" between various authoring tools and the PLM
- Description of the FMU & data distribution between PLM and the Simulation tool (.xml for deployment)
- Shared expandable configurations

FMI for PLM – Concepts (2/2)



#### Workflow Stage 2 Example - Deploy data to all Targets



#### Summary of PLM exchange with external tools



#### **FMI Values and benefits**

#### Intrinsic FMI values

- . Stable standard interface (C, XML/XSD)
- Tool and modeling language independant ۲
- Light overhead -Openness (CC BY-SA, BSD)
- ۲ .
- Supports advanced (co-)simulation technologies
  Coupling of specialized models from various engineering domains
- daphive and convergent co-simulation rates
   Embedded software co-simulation rates
   Embedded software co-simulation (e.g. via AUTOSAR) for model-in-the-loop, software-in-the-loop and hardware-in-the-loop invaliations
   IP protection (source code optional)
- ٠ Designed for multi-industry

#### Benefits

- Fast and efficient way to **exchange and integrate** hybrid virtual prototypes between teams Efficient **frontloading** and early **integration** of suppliers and development partners into cross-domain simulation ٠
- .
- ٠
- Extension of co-development from "model definition" to "behavior simulation", i.e. from Digital Mockup to Functional Mockup



# FMI - Version 1.0 FMI for Model Exc

Specifications on the web



#### Study example - Advanced Numerical Techniques for FMI



#### Study example – Co simulation master for FMI



#### **Study example - Bus Communication Simulation**





#### FMI support in tools - December 2012





#### FMI support in tools – December 2012 (3/3)









#### Climate Control models, tools, configurations and data

- Climate Controller from Volvo ■ Controller created in MATLAB/Simulink™
- Transformed to FMU • Then to FMU with embeddable C code
- Plant Plan model created with Modelica
  - librairies
  - then transformed to FMUs
- Configurations and data stored and managed in ENOVIA V6 PLM
- Software code designed in AUTOSAR Builder
- ٠ Simulation managed in CATIA V6 and SIMULIA V6

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view of a typical HVAC





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#### **Phase 1: Supplier selection**

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Model and Co-Simulation Formats Used During MIL and SIL Phases

0	omponent	Phase 1 (MIL)	Phase 2 (MIL)	Phase 3 (SIL)
Climate C	ontrol Controller	FMI model exchange	FMI model exchange (optimized)	FMI co-simulation
	Driver	Modelica	FMI model exchange	FMI model exchange
	HMI	Modelica	FMI model exchange	FMI model exchange
Plant	Environment	Modelica	Modelica	Modelica
	HVAC	Modelica	Modelica	Modeiica
	Cabin	Modelica	Modelica	Modelica



#### **FMI Exploitation Summary**

#### Viral FMI adoption

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• 50% outside Modelisar consortium

some 10 more announced

#### Viral FMI success outside initial automotive domain

FMI tools for flow processes, railway, thermal, fluid and energy industries ...

FMI future organized in a Modelica Association Project (FMI MAP)

XITEAZ O Running & future projects to use and improve FMI : MODRIO, CORAC AME, sys2soft, CleanSky ISSE, Ebird

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HODELICA

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FMI Modelica Association Project (MAP) HODELICA The FMI content and IP have been formally transferred by the Modelisar

consortium to the Modelica Association Project (FMI MAP)

- Hosted by Modelica Association (but not dedicated to Modelica language)
- Handling of roadmap, go to standard, dissemination
- FMI specifications, enhancements, maintenance, support for implementation
- FMI MAP rules : organization between participants, compliancy rules
- Cooperation with R&D projects...
- Supporting means (see details farther)

#### Current status

- Concrete Work started 2012 Q1 (continuity with Modelisar project)
- FMI 2.0 specifications available December 2012 .



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#### FMI project members – Dec 2012

Project Leader	Torsten Blochwitz (ITI GmbH Dresden, Germany)
Steering Committee	Atego (GER), Daimler (GER), Dassault Systèmes (FRA & SWE), IFP EN (FRA), ITI (GER), LMS (FRA & BEL), Modelon (SWE), QTronic (GER), Siemens (GER), SIMPACK (GER)
Advisory Board	Armines (FRA), DLR (GER), Fraunhofer (IIS/EAS, First, SCAI) (GER), Open Modelica Consortium, TWT (GER), University of Halle (GER)
Guests	Altair Engineering (USA), Berkeley University (USA), Bosch (GER), ETAS (GER), Equa Simulation (SWE)

FMI design meetings are open to anyone Refer to MA & FMI MAP rules for roles



**FMI supporting means** 



- Supporting means:
- FMI SDK (to demonstrate & start a FMU)
- Test repository (FMU examples as reference for cross check )
- Compliance checker (check of FMI specifications)
- FMI Web site + wikipedia page
- FMI library for import of FMUs in applications
- Literature



#### For more information

FMI web pages (specifications, tools list, rules, litterature)	https://www.fmi-standard.org/
Supporting tools (SDK, checker, examples, import library)	https://www.fmi-standard.org/downloads
Wikipedia link	http://en.wikipedia.org/wiki/Functional_Mock-up_Interface
Modelica newsletters (some articles on FMI)	https://www.modelica.org/publications/newsletters
Related papers from Modelica conferences	https://www.modelica.org/events/modelica2011/Proceedings https://www.modelica.org/events/modelica2012/Proceedings
Modelica projects (including FMI project)	https://www.modelica.org/projects
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#### **FMI exploitation in Carmola project** Dream possible: the Virtual Drive Experience



#### **FMI-based Initiative in Automotive Industry**

BMW, Daimler and Ford started in Q2 2012 an initiative to establish FMI as the standard for **simulation model exchange between OEMs and suppliers** DAIMLER

These OEMs as well as Chrysler, Fiat, GM, Jaguar Land Rover, Nissan, Renault, Toyota and Volkswagen signed on Oct 23<sup>rd</sup>/24<sup>th</sup> at GAAG conference a commitment to **support this initiative**  $\underbrace{\bullet} \qquad \underbrace{\bullet} \qquad \underbrace$ 





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#### Conclusions

- Open industrial FMI standard
- Early and large adoption by tool providers
- FMI exploitation by auto industry and evaluations beyond
- FMI-based initiative of automotive OEMs for cooperation with suppliers started
- FMI future handled by FMI Modelica association project
- FMI supported by new collaborative projects



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