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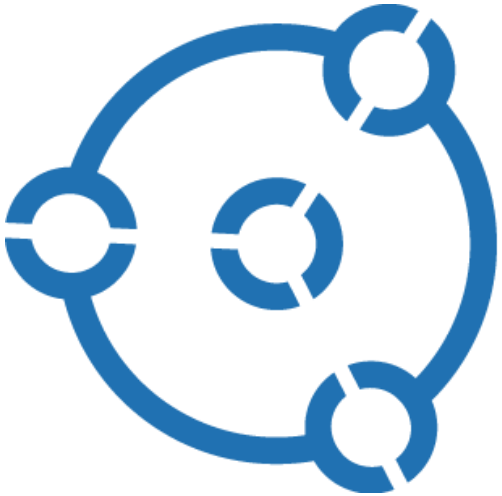
OPEN SOURCE SOLUTIONS FOR STANDARDIZED AND EFFICIENT DEVELOPMENT OF CYBER-PHYSICAL SYSTEMS

MODPROD
Linköping, 7 February 2018

Magnus Eek & Robert Hällqvist
www.opencps.eu



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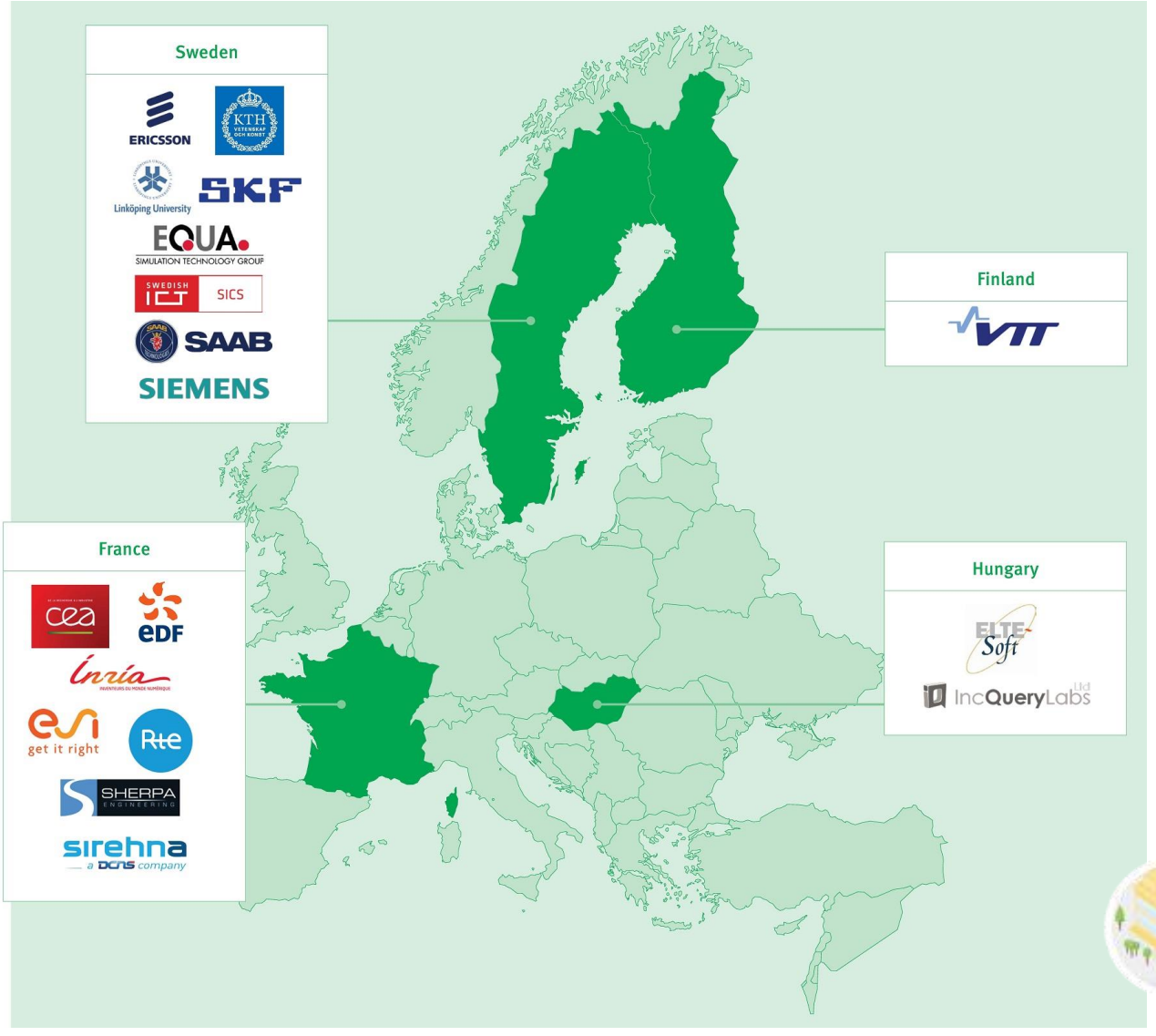
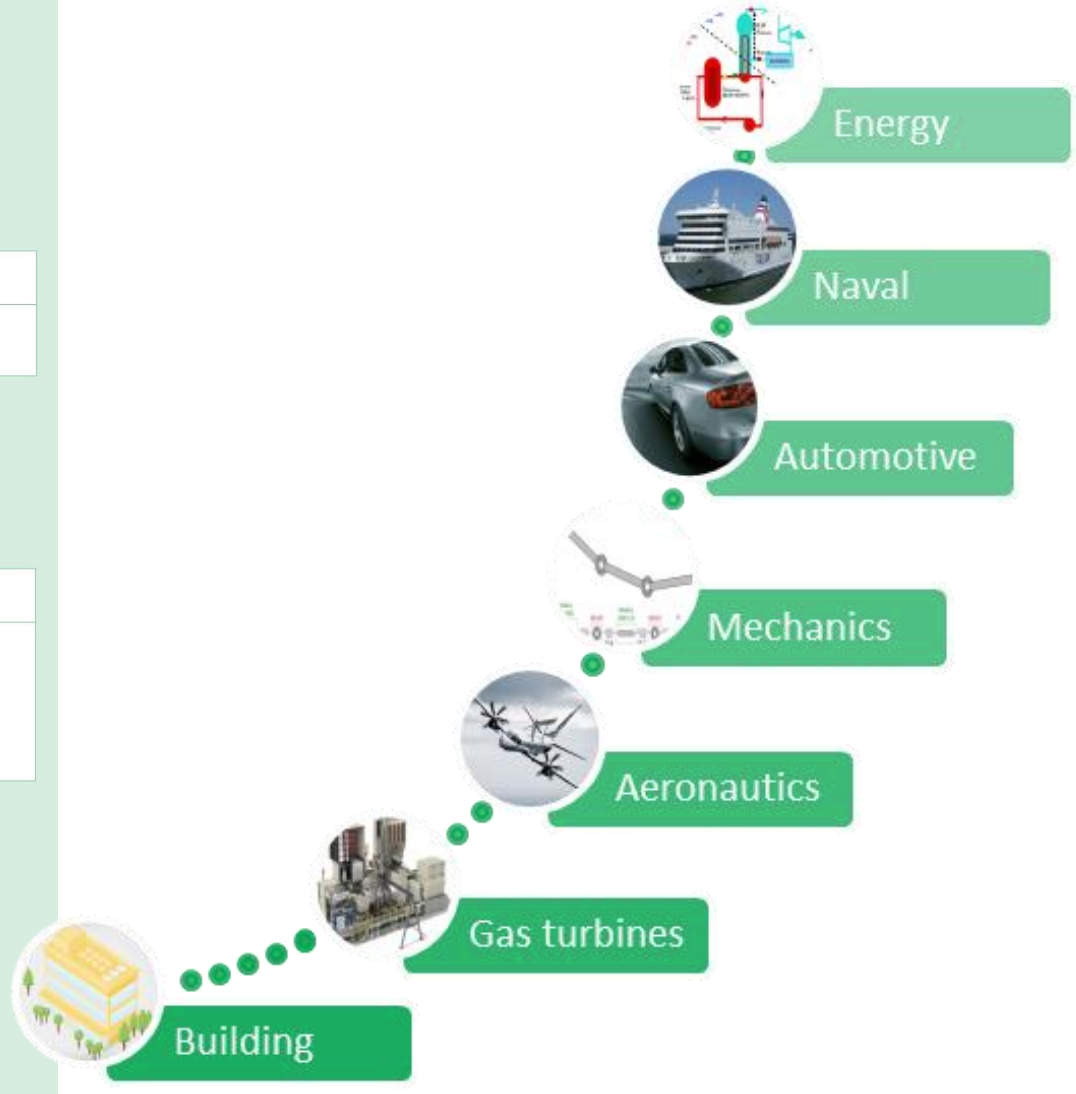
COLLABORATIVE R&D ON METHODS, STANDARDS & OPEN SOURCE TOOLS FOR EFFICIENT DEVELOPMENT OF CYBER-PHYSICAL SYSTEMS

- Duration: December 2015 to December 2018
- 4 countries: Sweden, France, Finland, Hungary
- Current status: 46.5 person-years, 6.5 M€, 18 partners
- Project coordinator: Saab

ITEA 3
EUREKA
innovation across borders

PROJECT CONSORTIUM & INDUSTRY DOMAINS





BACKGROUND

Challenges in cyber-physical system development:
- Complexity
- High demands
- Cost efficiency

Development tools are complex and critical for industry:
- Interoperability
- Tool vendor lock-ins
- Life cycle support

Great industrial interest in open source tools:
- Control of features
- Industry collaboration

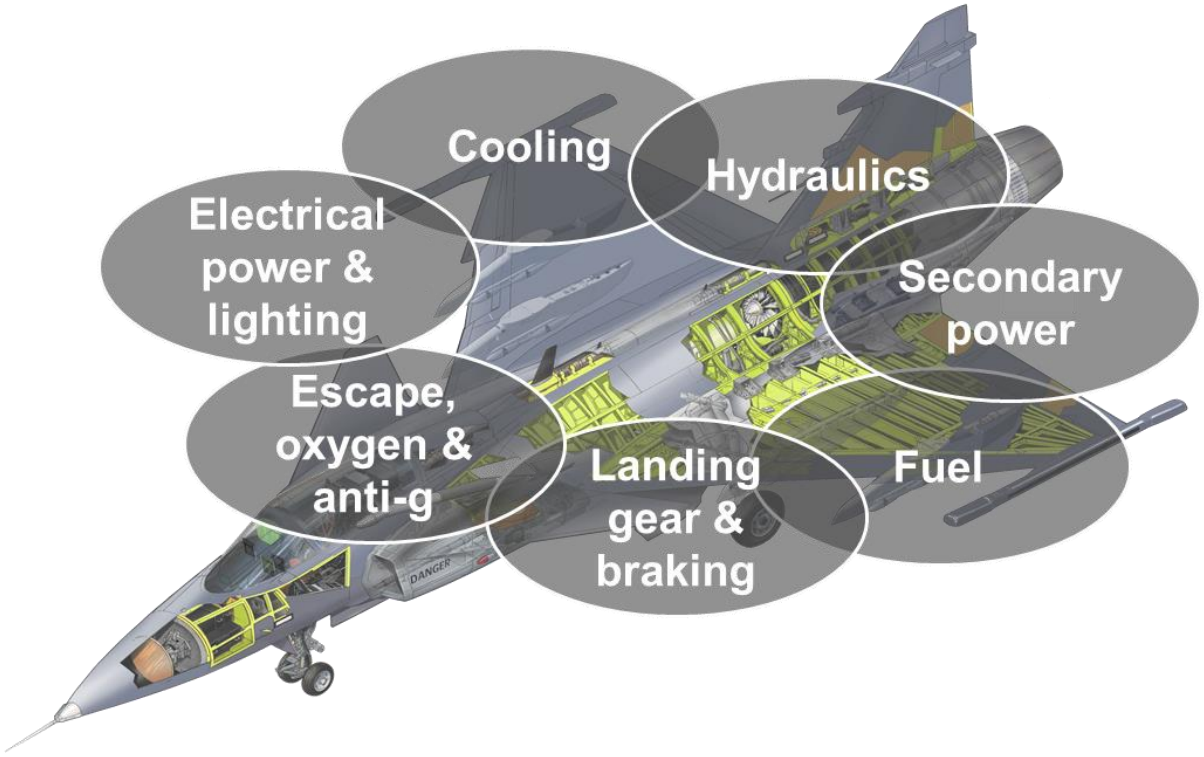
OpenModelica

Papyrus

OVERALL AIM
KEY INNOVATION AREAS

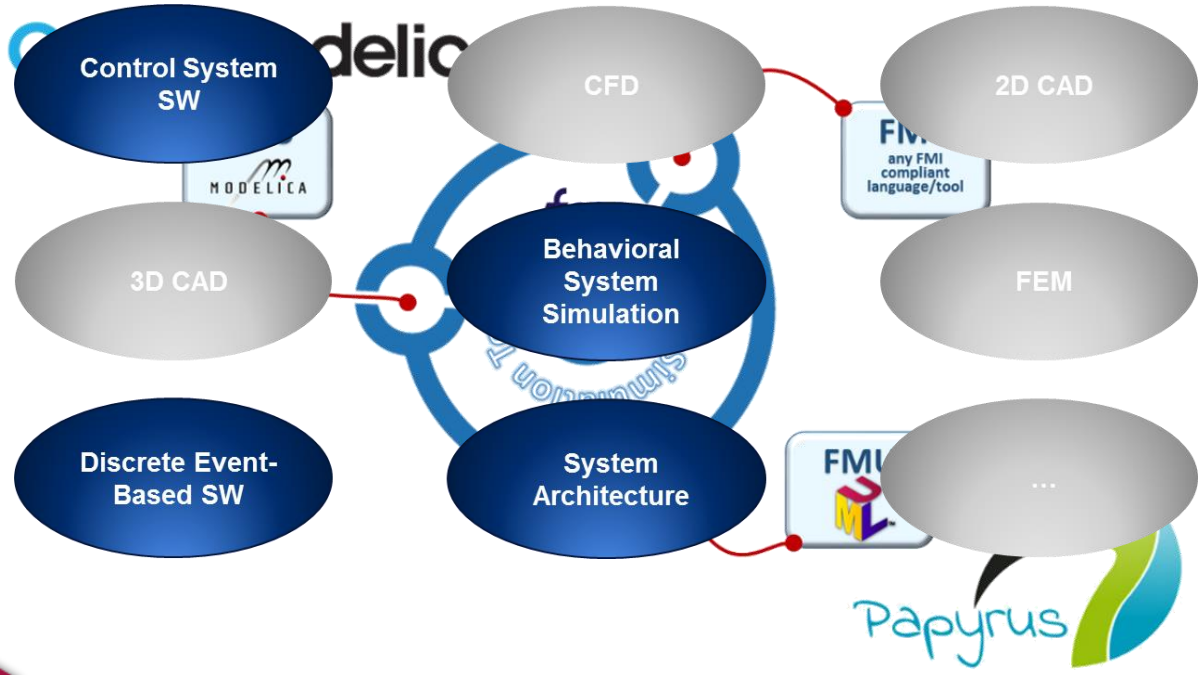
- Increase **front loading** capability in development of cyber-physical systems by enabling **large-scale simulation**

- Example: Current SotA in Aircraft Vehicle Systems
  - Simulation of individual subsystems using detailed equation-based models of physical systems
  - Simulation of complete aircraft using simplified models of physical systems
  - **Need: Simulation of several connected subsystems using detailed models**



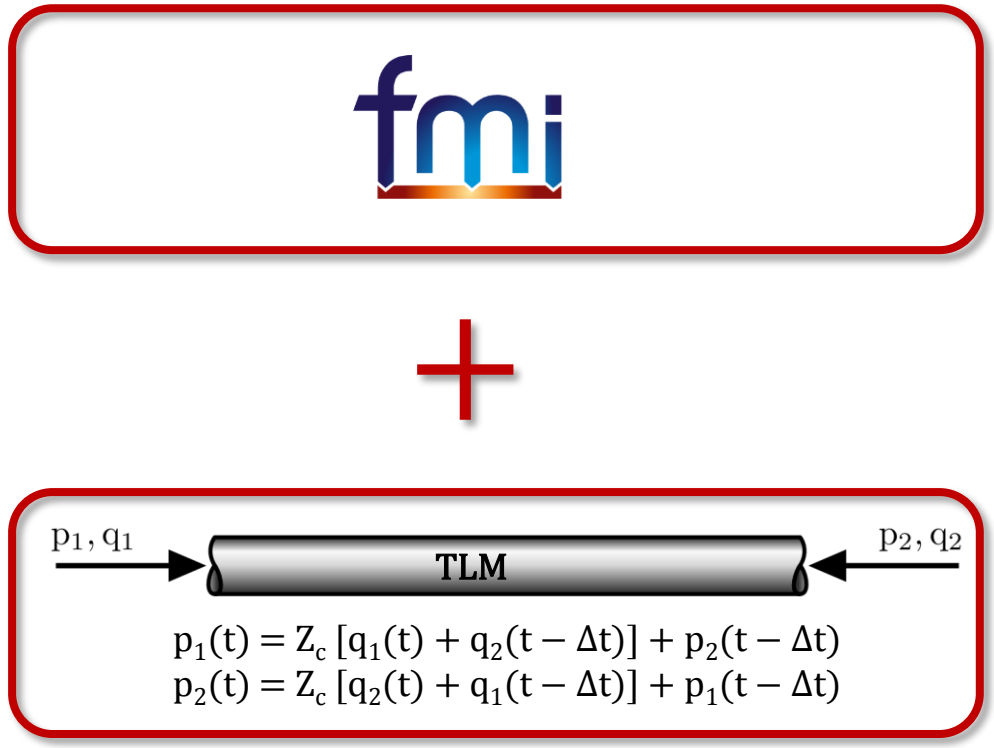
OVERALL AIM
KEY INNOVATION AREAS

- Increase **front loading** capability in development of cyber-physical systems by enabling **large-scale simulation**
- Innovation areas:
  - FMI Master Simulation Tool including UML/Modelica Interoperability
  - State Machine and Real-Time Debugging & Validation
  - Efficient Multi-Core Simulation
- Validation of project results in a range of **advanced industrial demonstrators**



OPENCPS FMI MASTER SIMULATION TOOL
OMSimulator

- Open source co-simulation tool for **standardized**, **numerically robust**, and **efficient distributed simulation**
  - Functional Mock-up Interface (FMI) 2.0 CS & ME
  - System, Structure & Parameterization (SSP)
  - Transmission Line Method (TLM)
- FMUs and external tool integration, e.g. Simulink, Adams, Hopsan, Dymola
- Integration into OpenModelica & Papyrus
- Standalone: Open for integration into scripting frameworks, third-party tools, and specialized applications, e.g. flight simulators, optimization tasks



OPENCPS FMI MASTER SIMULATION TOOL
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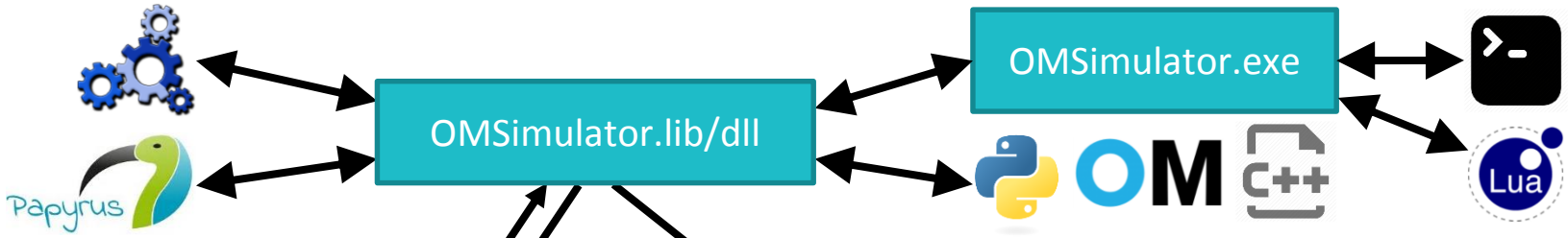


OMTLMSimulator

- Physical connections
- Delayed connections
- Distributed processes

OMFMISimulator

- Signal connections
- Non-delayed connections
- Single process

INDUSTRY DEMONSTRATORS

Buildings/Tunnels

EQUA

Gaz turbines

Siemens TU, KTH, VTT

Aeronautics

Saab AB, LIU

Mechanics

SKF, LIU

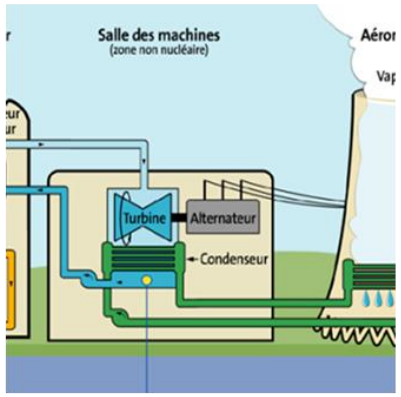
Automotive

Sherpa, CEA

Naval

Sirehna

Power plant



EDF, LIU

INDUSTRIAL USE CASE: SAAB AERONAUTICS
AIRCRAFT VEHICLE SYSTEMS

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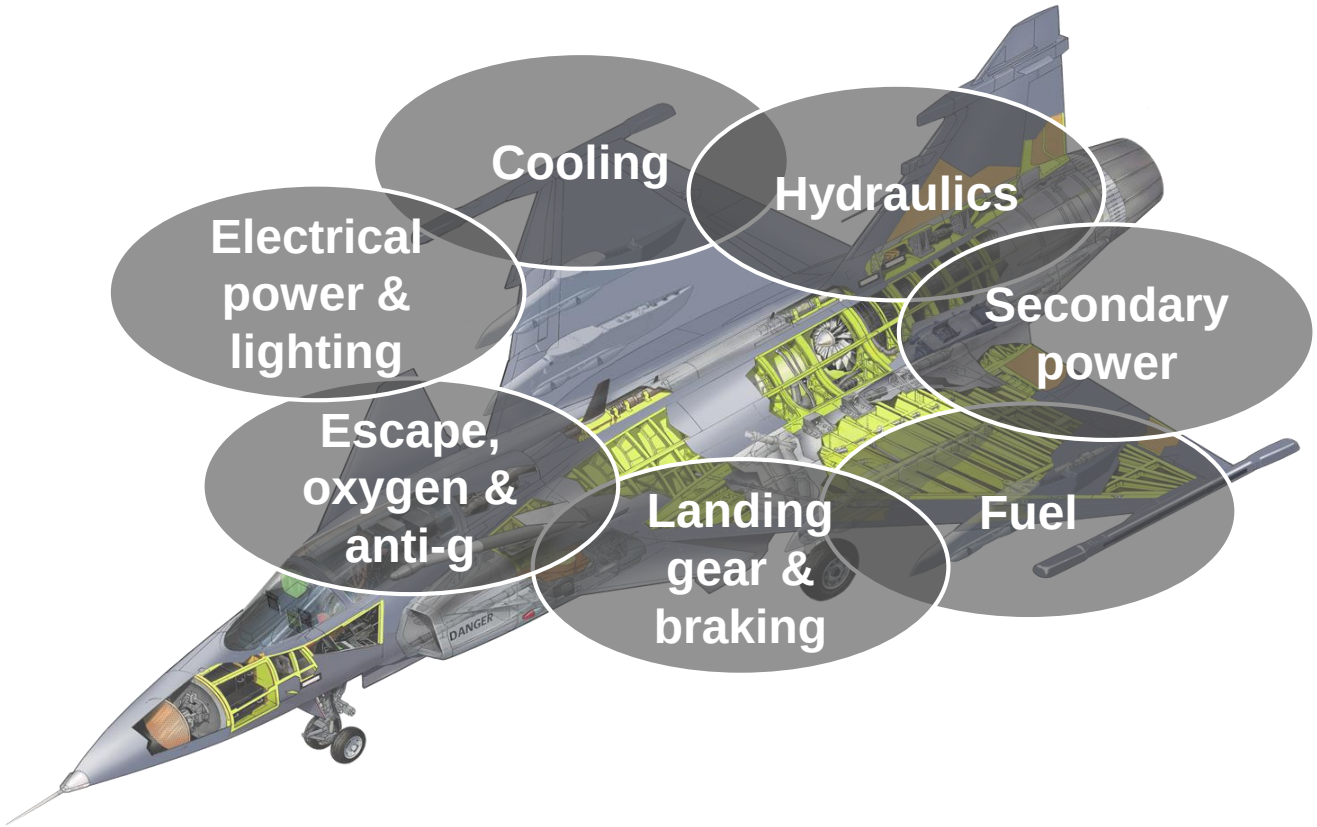
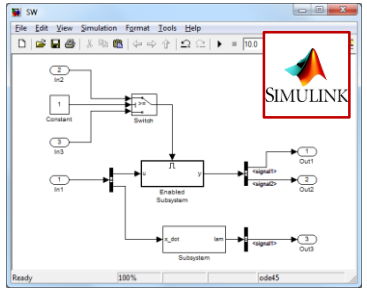
AIRCRAFT VEHICLE SYSTEMS



… | Flight mechanics | Avionics | **Vehicle systems** | Engine | Sensors | …

CURRENT MODEL-BASED DEVELOPMENT PROCESS

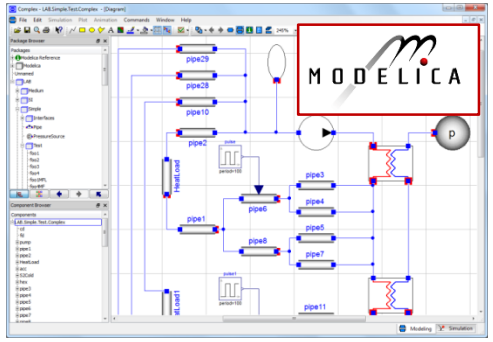
Three iterative design loops



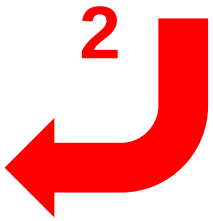
Model of S/W

Test rigs & simulators

Flight test

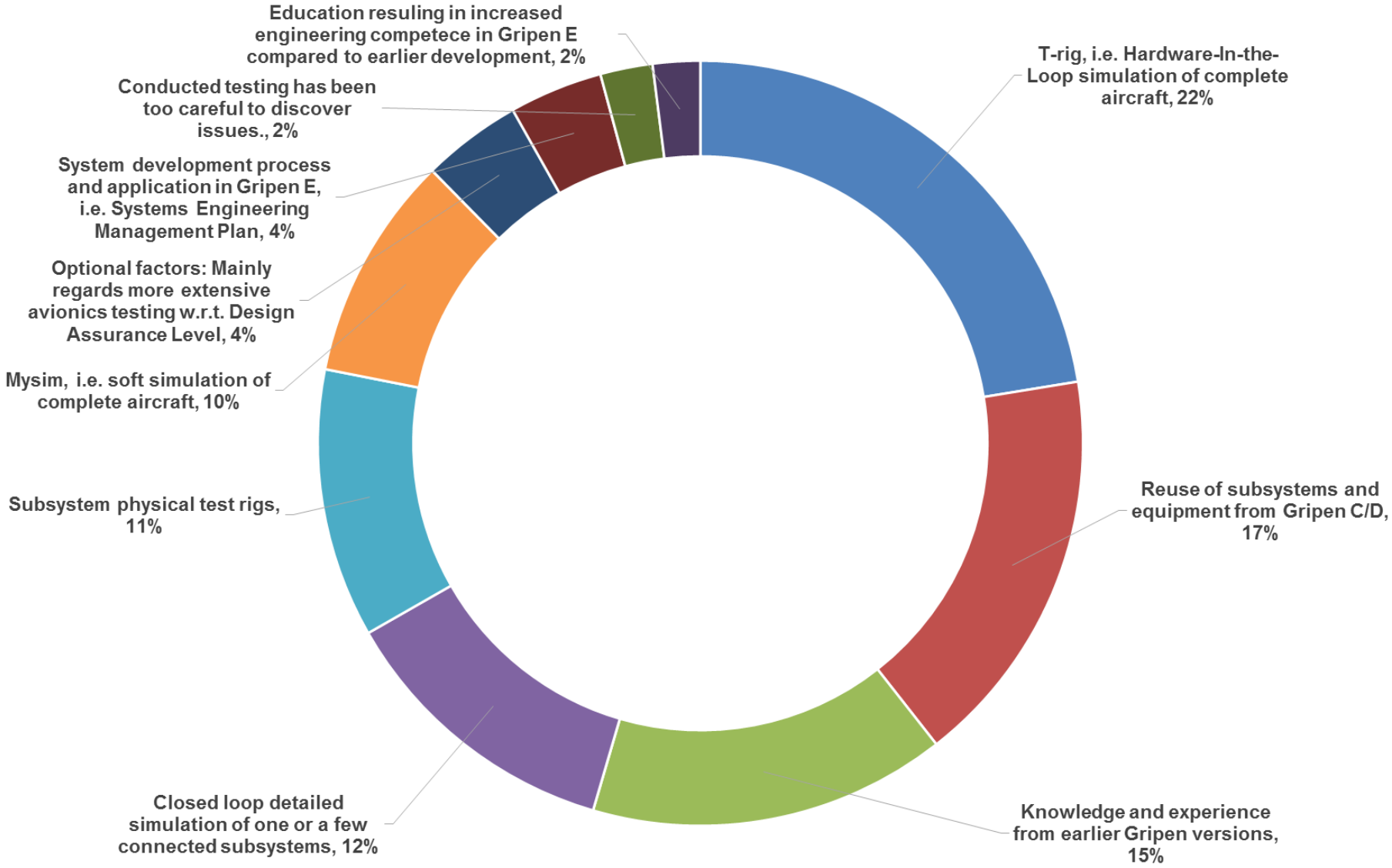


Model of physical system

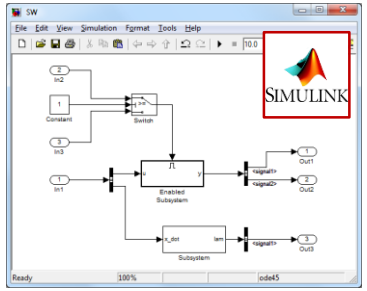


Calibration and validation of models
Minor updates of system design

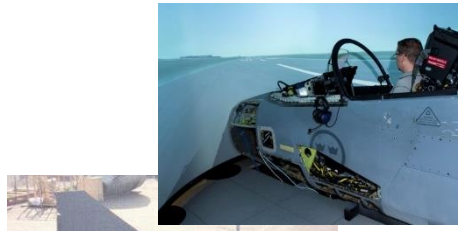
REASONS FOR LOW NUMBER OF ISSUES IN GRIPEN E EARLY GROUND AND FLIGHT TESTING



FUTURE MODEL-BASED DEVELOPMENT PROCESS
More efficient model integration & distributed simulation in 1st loop

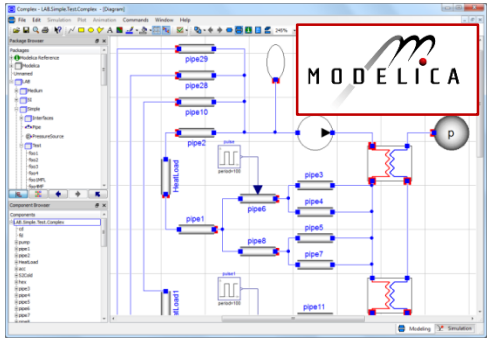


Model of S/W

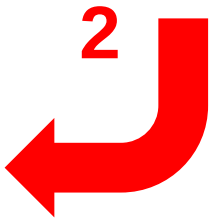


Test rigs & simulators

Flight test

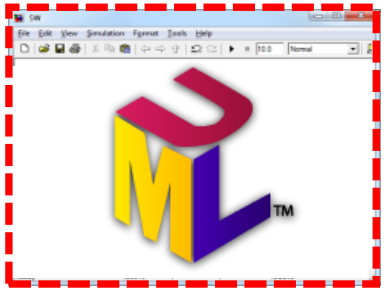


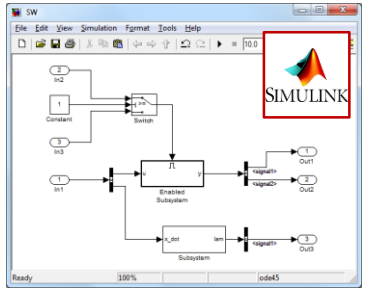
Model of physical system



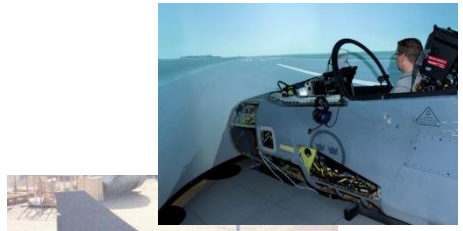
Calibration and validation of models
Minor updates of system design

FUTURE MODEL-BASED DEVELOPMENT PROCESS
Integration of discrete event-based xtUML S/W already in 1st loop



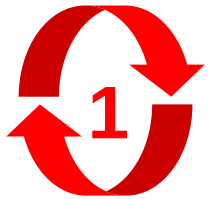


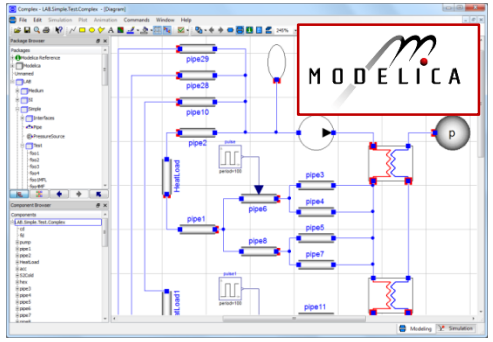
Model of S/W



Test rigs & simulators

Flight test

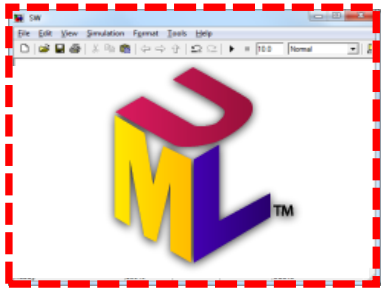


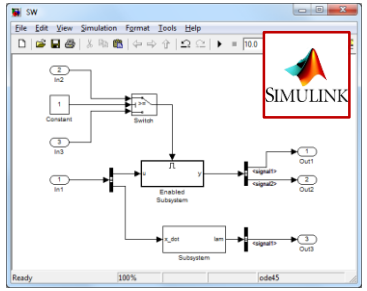


Model of physical system

Calibration and validation of models
Minor updates of system design

FUTURE MODEL-BASED DEVELOPMENT PROCESS
Standardized model exchange – internally at Saab & with partners





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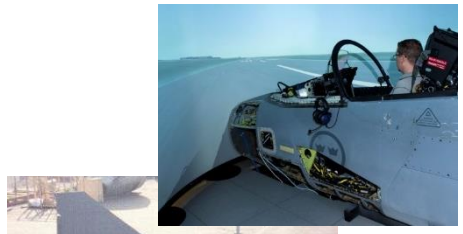
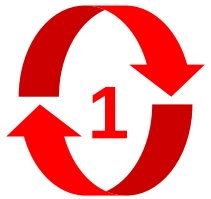
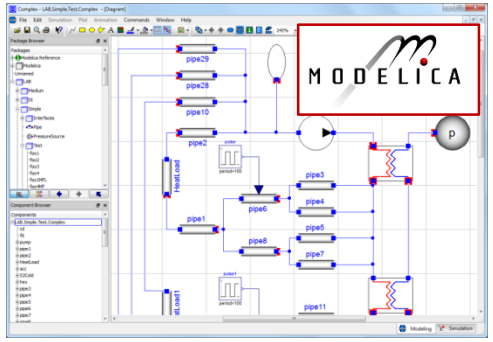


Test rigs & simulators

Flight test





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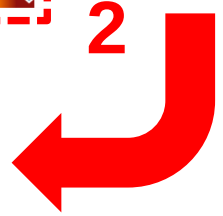
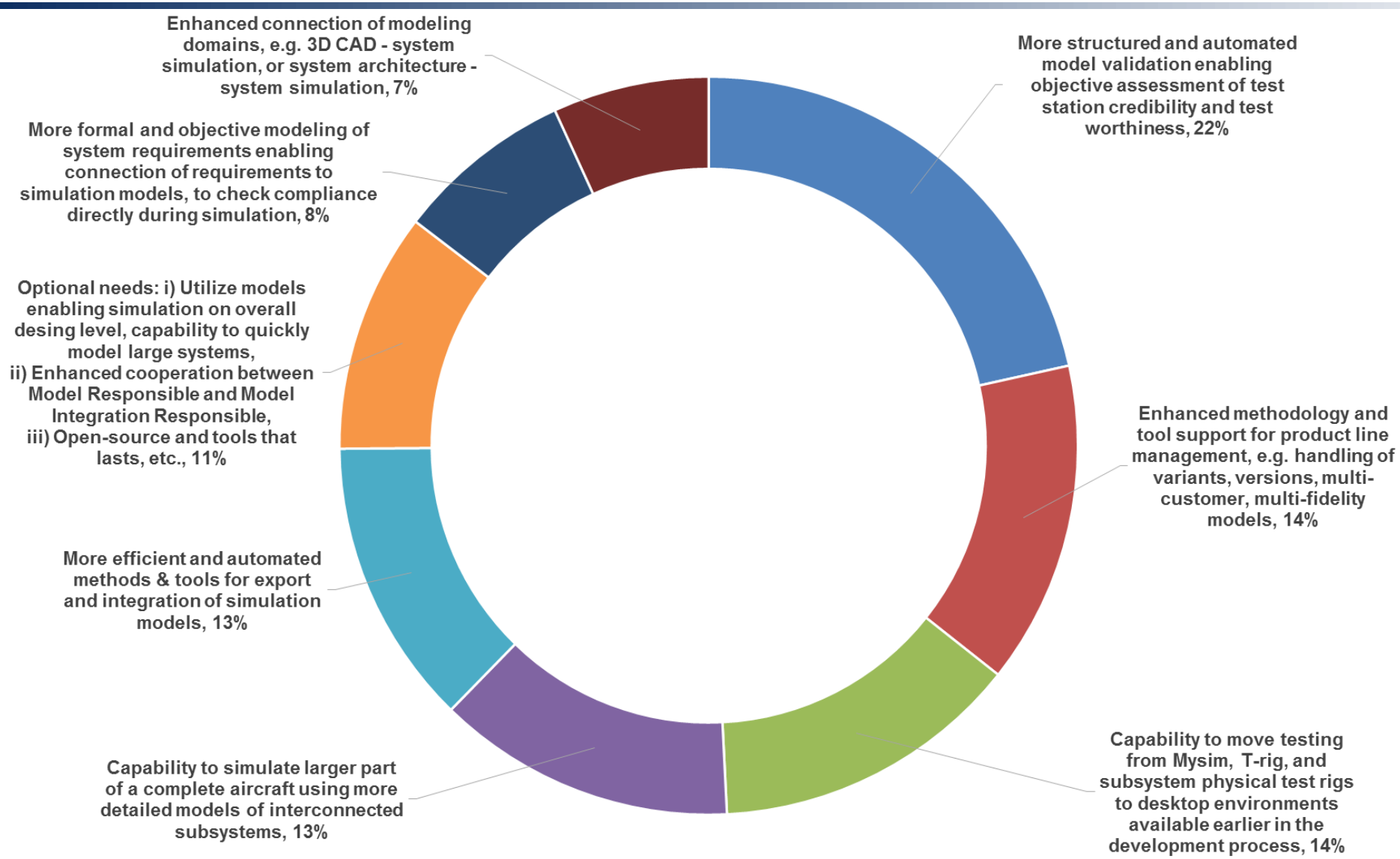


Calibration and validation of models
Minor updates of system design

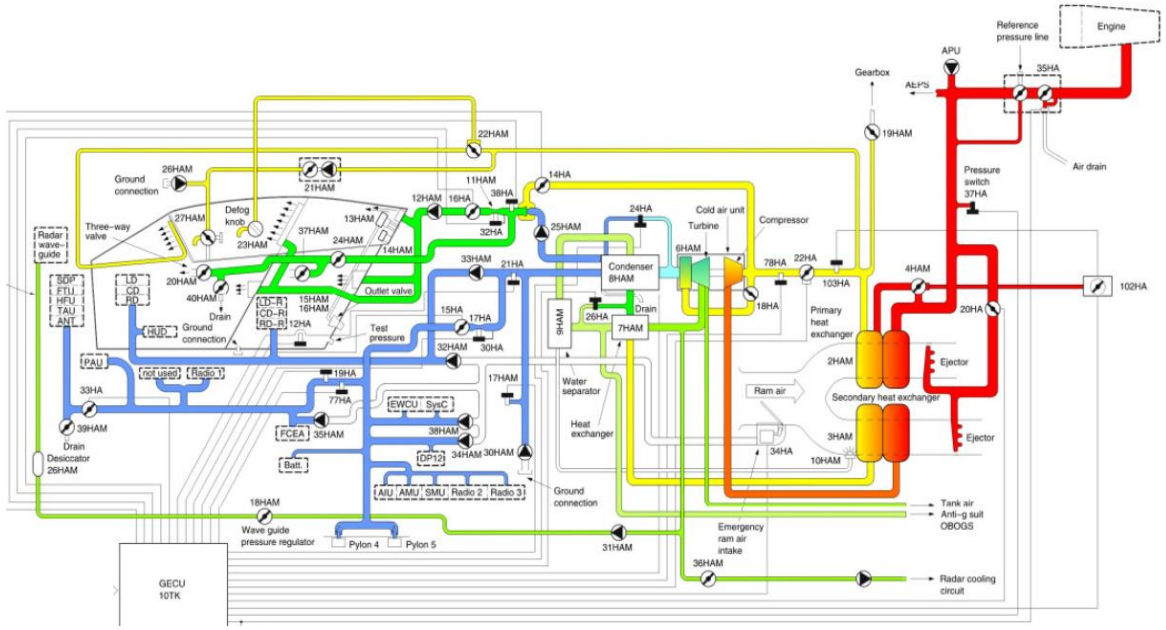
FUTURE NEEDS IN SYSTEM DEVELOPMENT



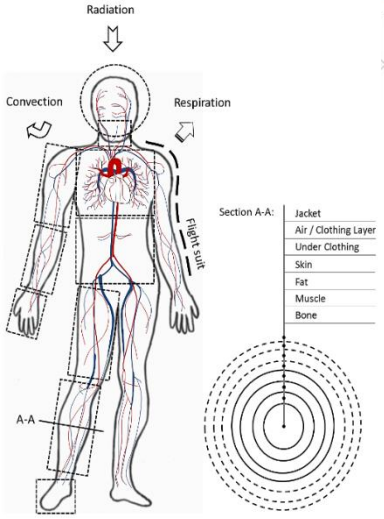
SAAB AERONAUTICS DEMONSTRATOR

FMI-based efficient distributed co-simulation of Aircraft Vehicle Systems

- Demonstrate
  - Standardized model export and simulator integration
  - Interoperability between different modeling tools/domains
  - Expansion in M&S of aircraft vehicle systems at Saab, increased scope and availability of high fidelity simulations
- OMSimulator development
  - Input to requirement specification
  - Aid in development prioritization
  - Verification in an industrial setting
- Multiple languages/tools involved
  - Modelica (OpenModelica, Dymola)
  - xtUML (Bridgepoint)
  - SysML (Papyrus)
  - Simulink

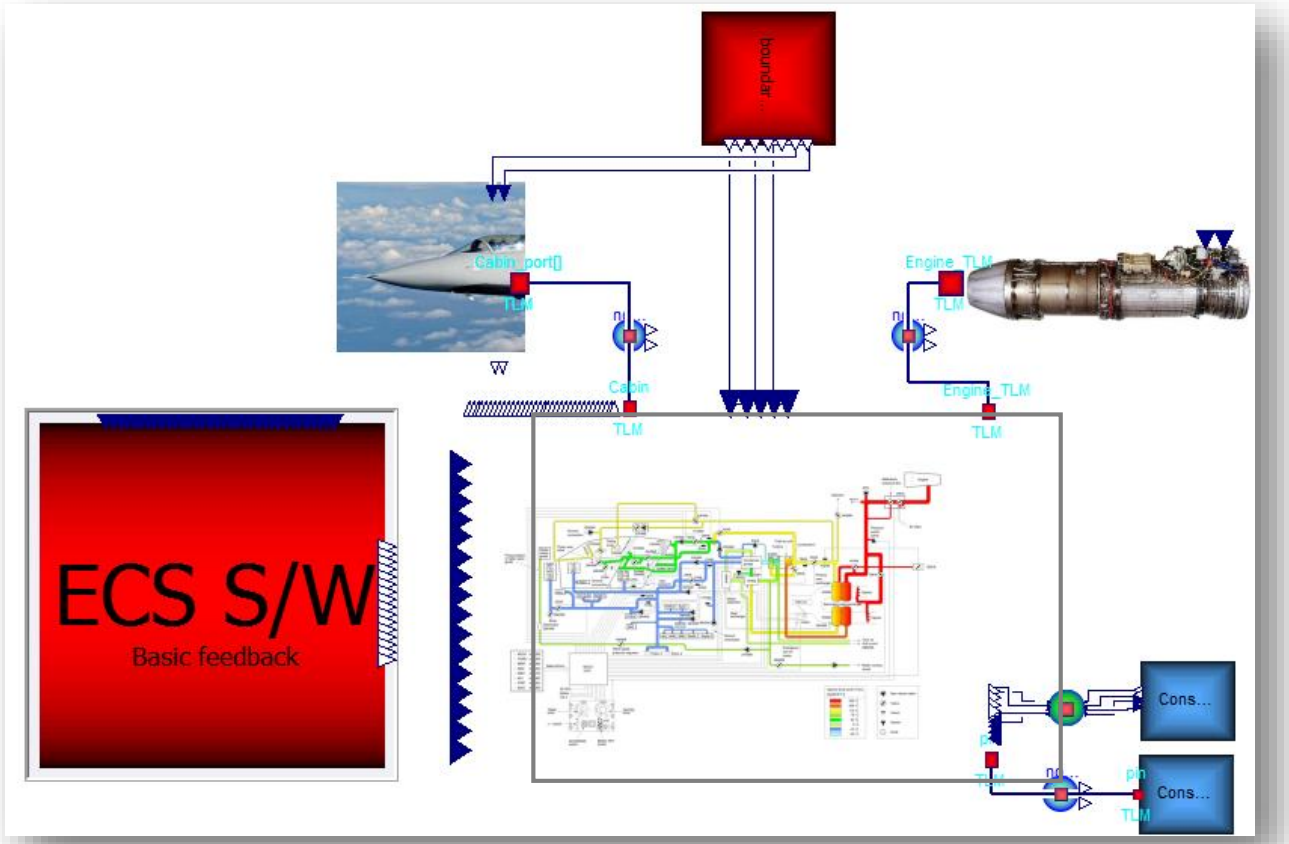


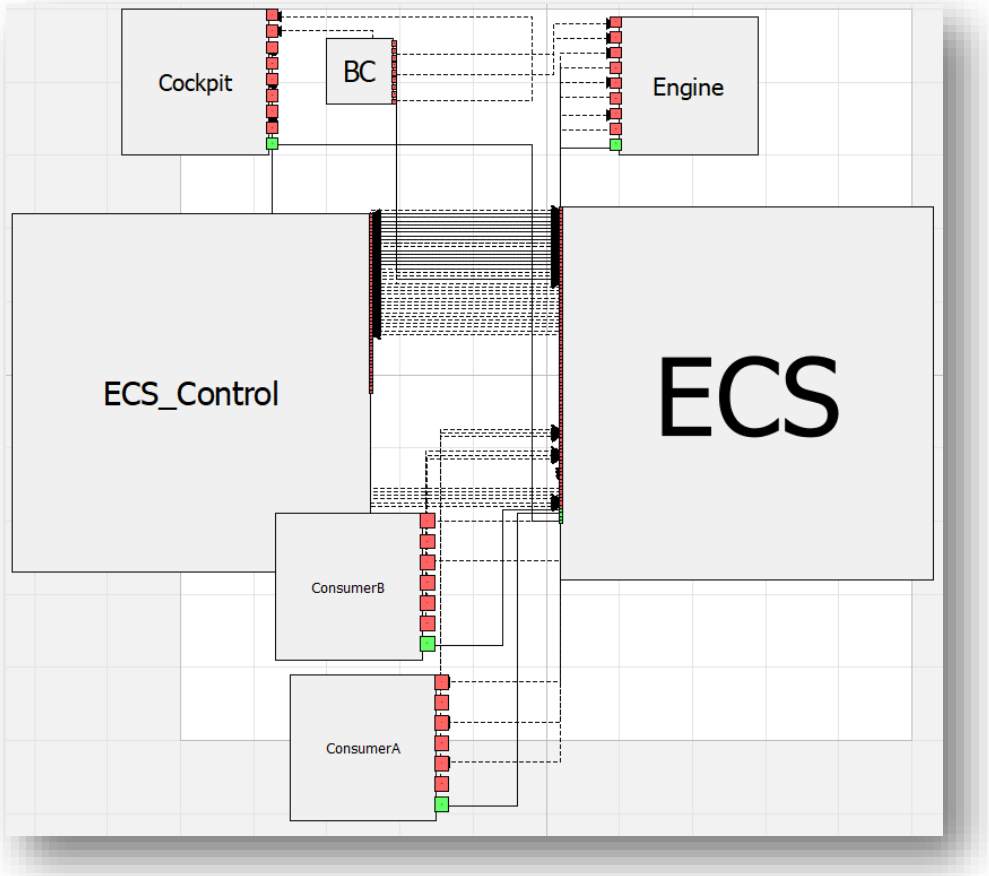
Aircraft Environmental Control System (ECS)



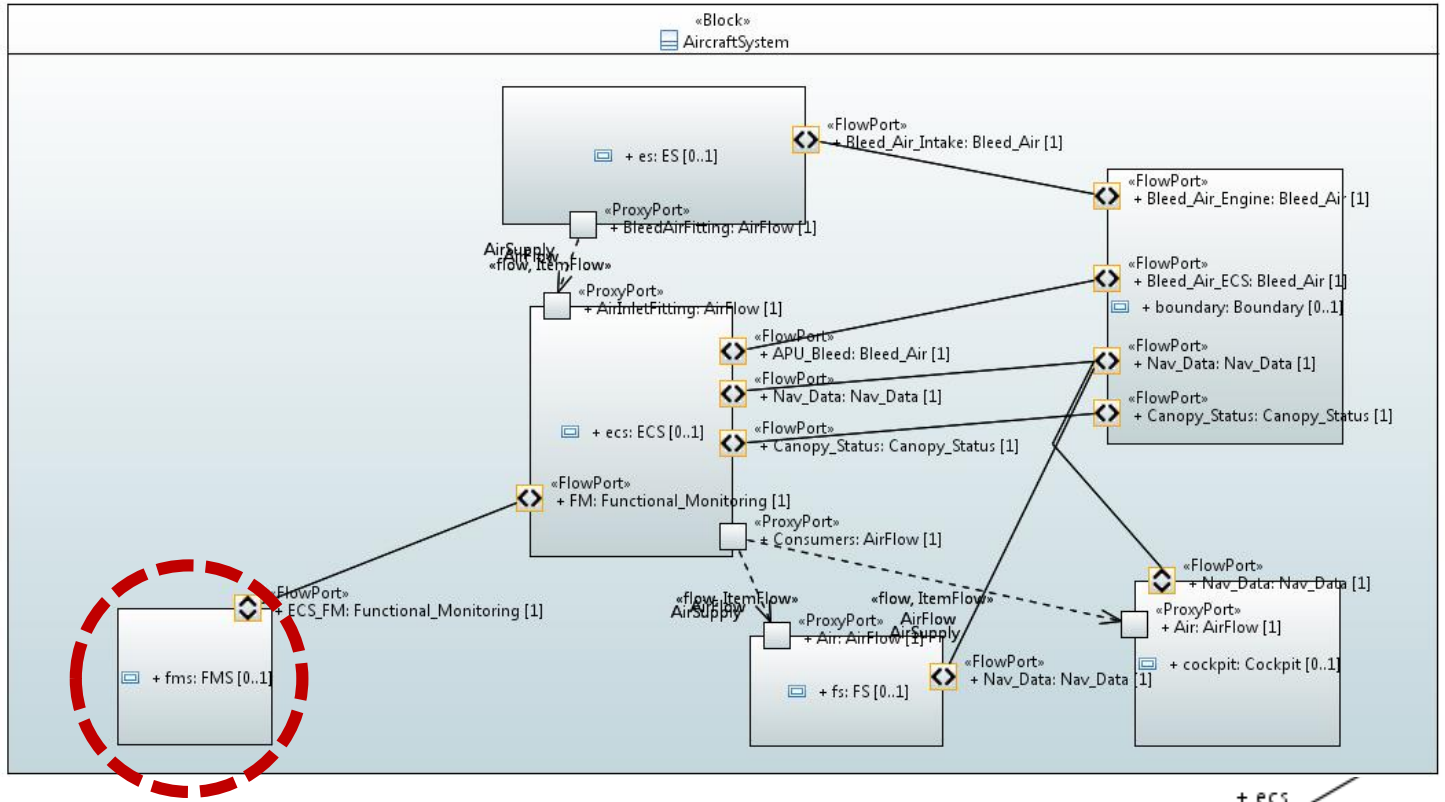
Thermal model of human

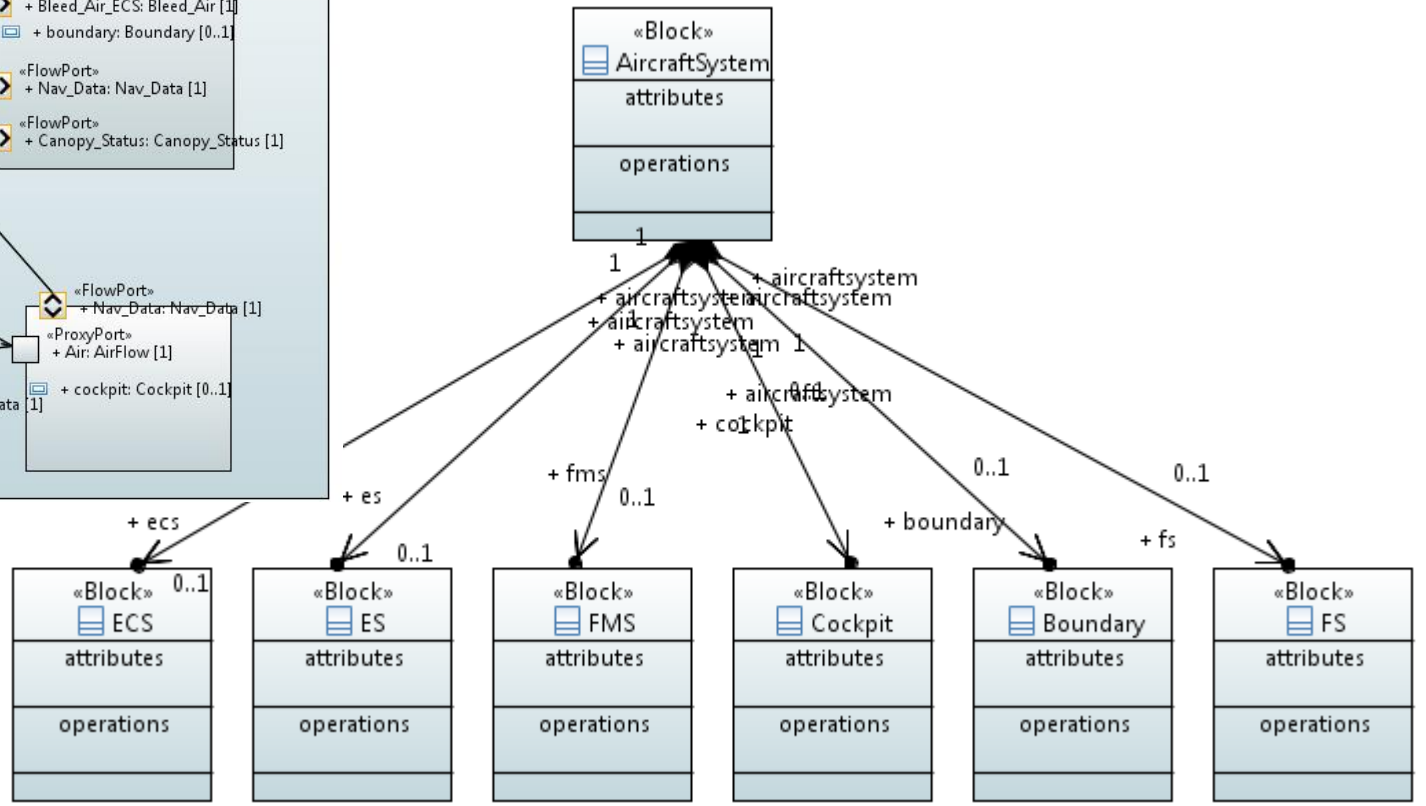
SAAB AERONAUTICS DEMONSTRATOR
Modelica & OMSimulator implementations



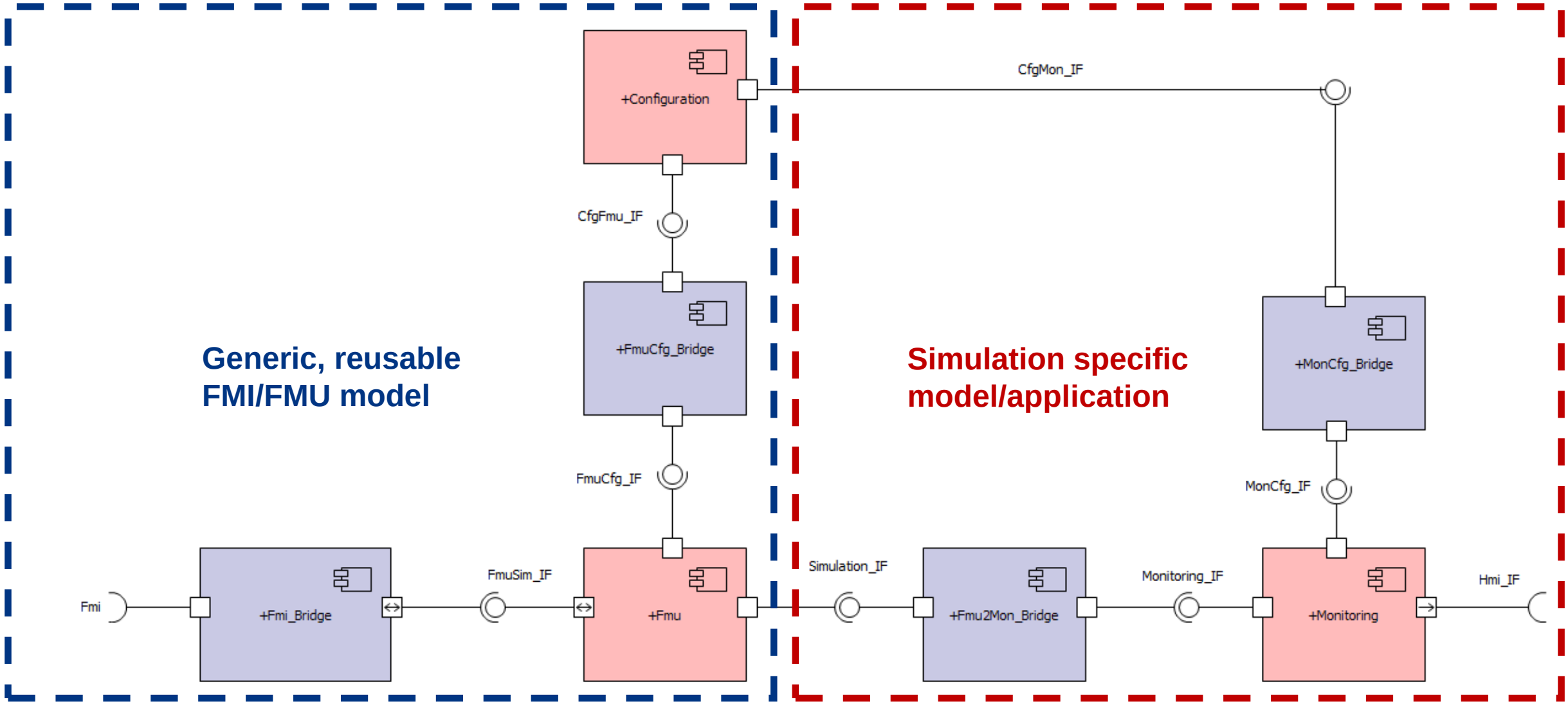


SAAB AERONAUTICS DEMONSTRATOR
System architecture view



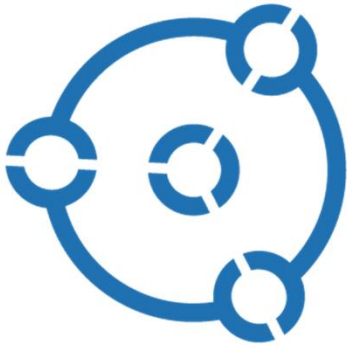


SAAB AERONAUTICS DEMONSTRATOR
xtUML → FMU



SUMMARY & CONCLUSIONS

- 2nd year industry demonstrator prototypes running, enabled by tool support developed in the project
  - OMSimulator v1.0 released
  - Prototypes available for UML-FMI-Modelica interoperability
  - First implementation of SSP support in Papyrus
- Focus for 3rd year:
  - FMI-TLM integration, parallelization, debugging
  - Maturing tools and demonstrators
- Most project results are public, open source, and distributed through OpenModelica & Papyrus
- More information: www.opencps.eu



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innovation across borders

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THANKS FOR YOUR ATTENTION!

Magnus Eek & Robert Hällqvist
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