OPENCPS Overview
Digital Twin Business Cases

MODPROD
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openCPS

ITEA3

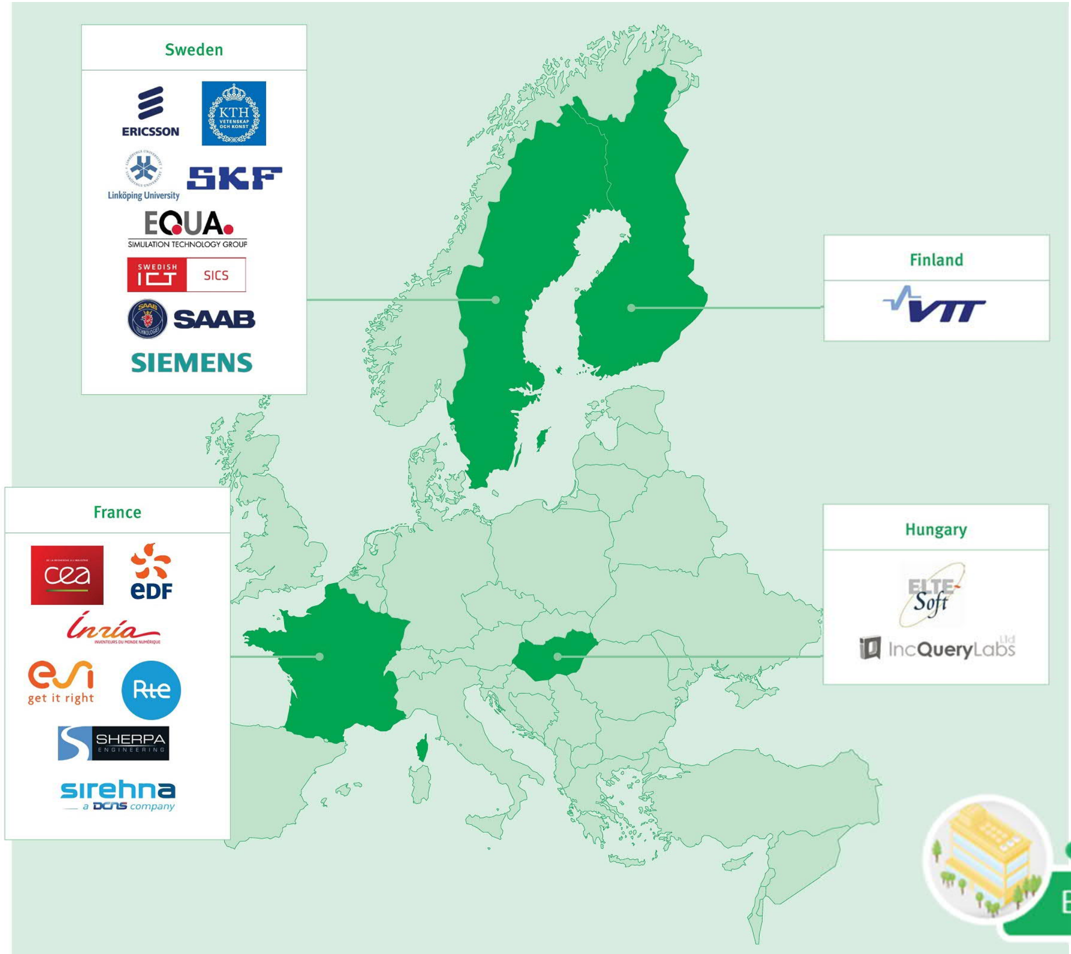
Short Overview

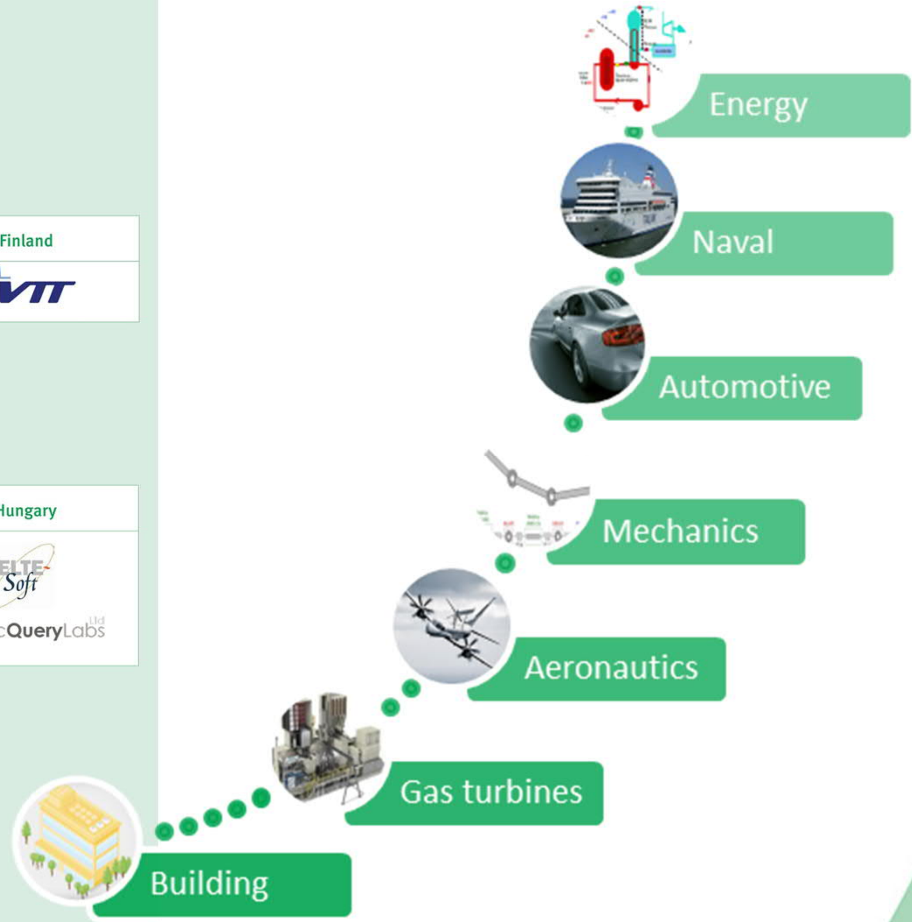
openCPS

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 Person Years, 6.3 M€, 18 partners

Project Consortium & Industry Domains

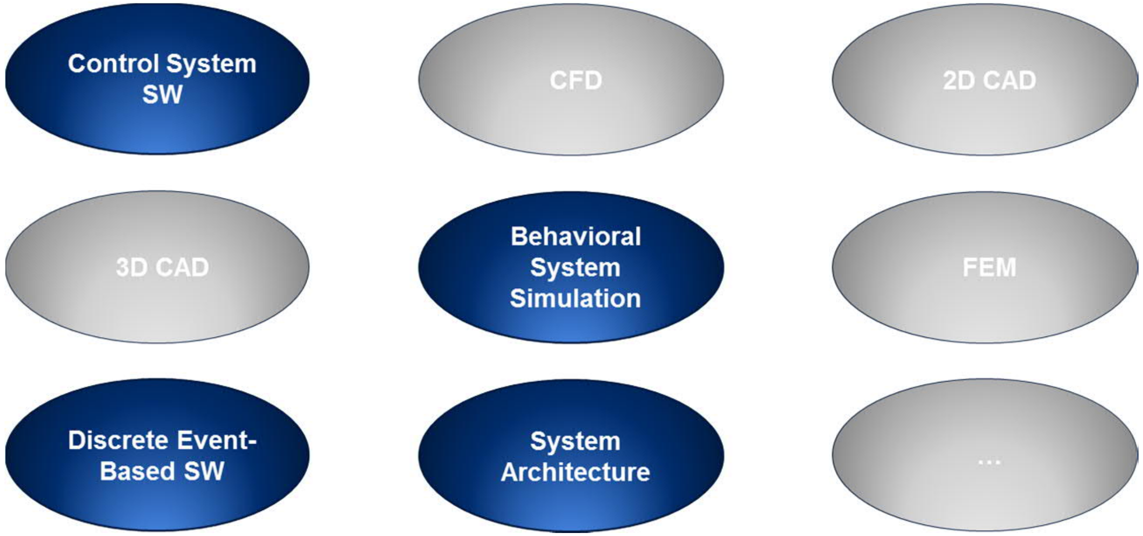




Top 3 Key Innovation Areas

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

1. FMI Master Simulation Tool including UML/Modelica Interoperability
2. State Machine and Real-Time Debugging & Validation
3. Efficient Multi-Core Simulation



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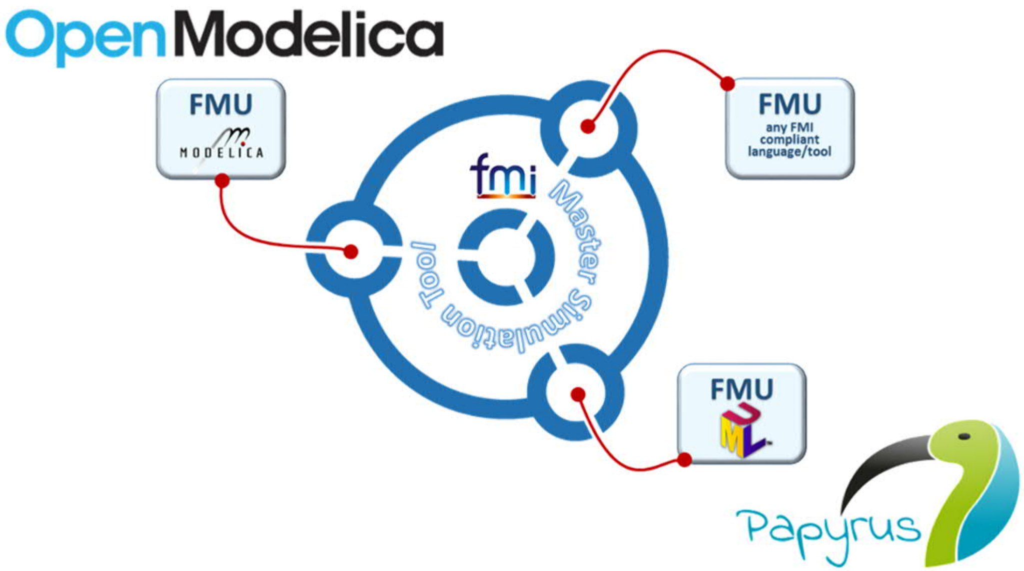
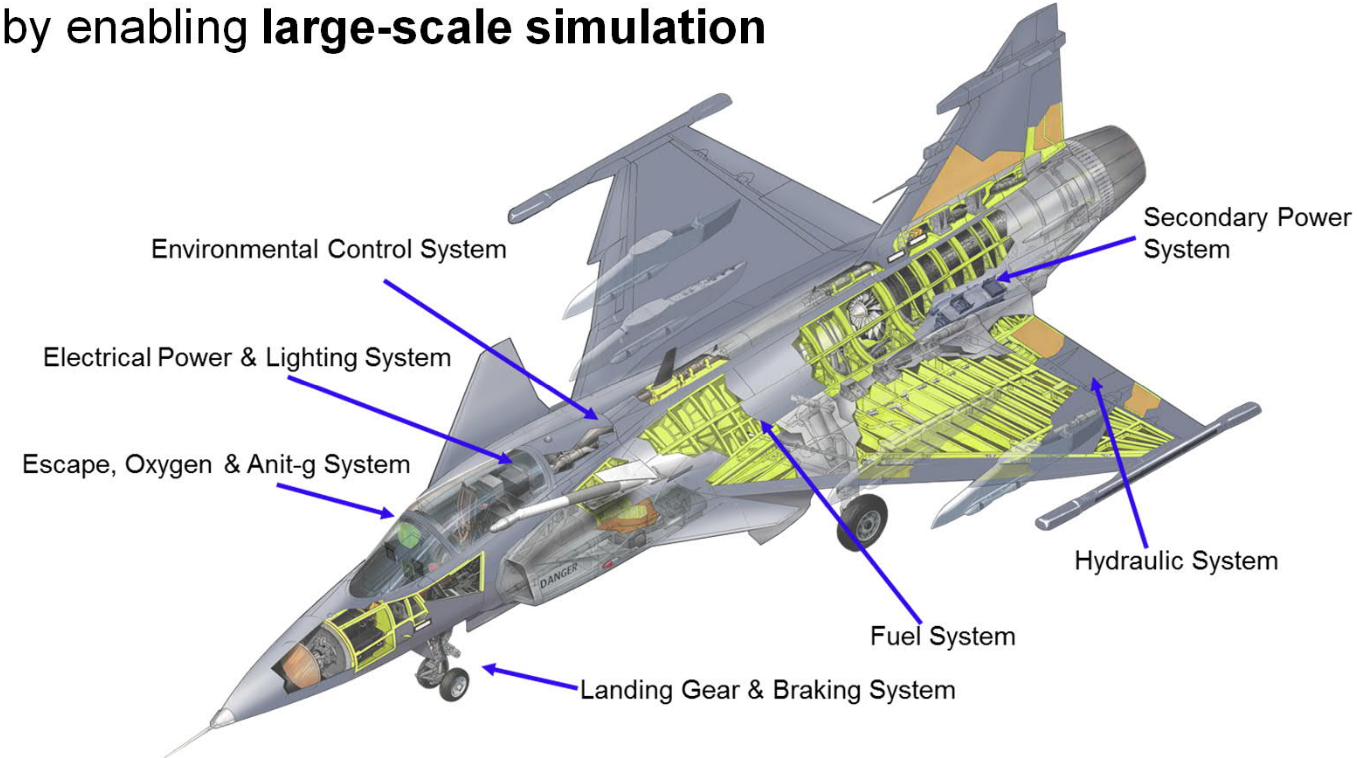


Validation of project results in advanced industrial demonstrators!

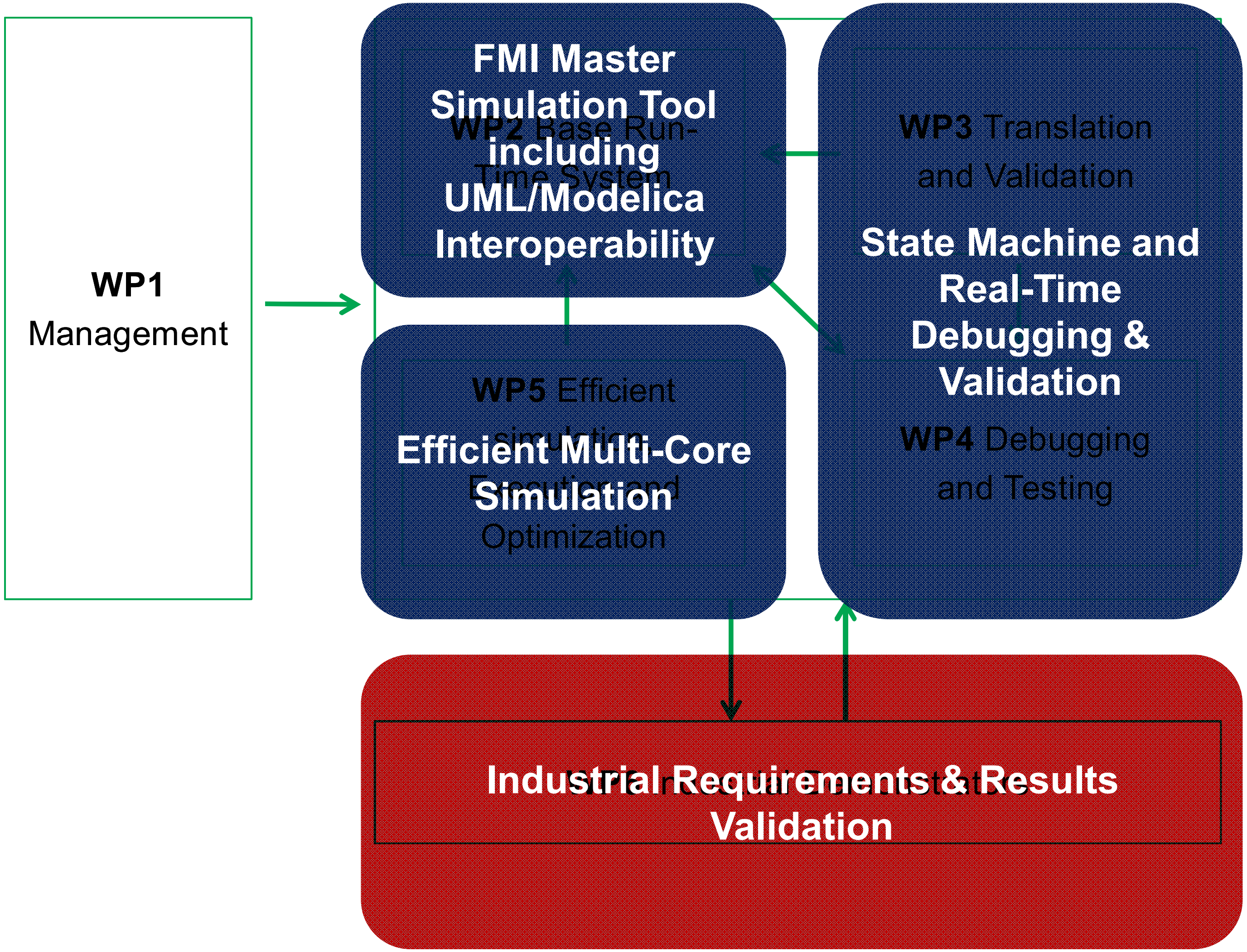
Top 3 Key Innovation Areas: Saab perspective

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



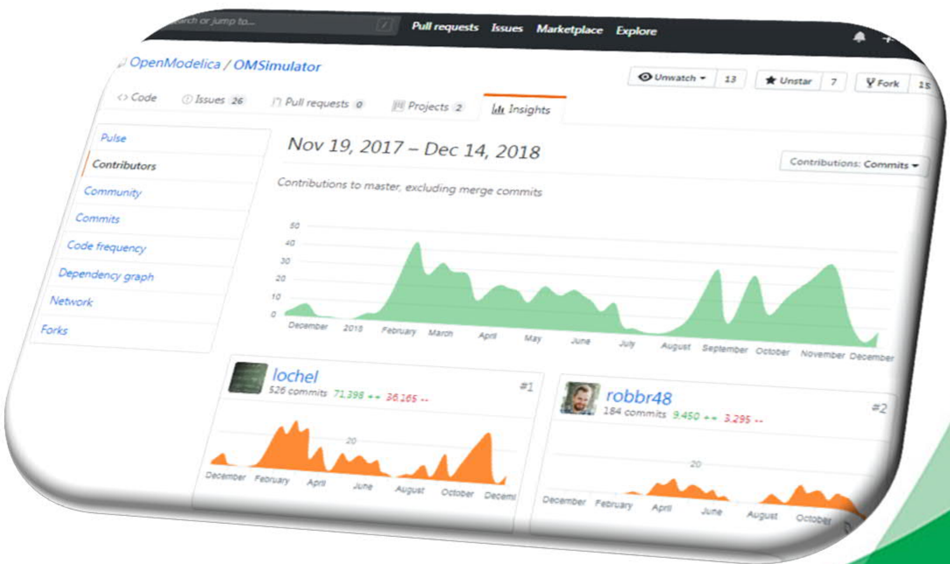
- Current SotA in M&S of Aircraft Vehicle Systems
  - Simulation of individual physical subsystems using detailed equation-based models
  - Simulation of complete aircraft using simplified models of physical systems
  - **Need: Simulation of several connected subsystems using detailed models**

Work Packages



Enabling focus on key innovations

- **Strong focus on the core collaborative development effort: OpenCPS FMI Master Simulation Tool *OMSimulator***
  - Integrated Project Team including key developers and end-users
  - Prioritized backlog linked to end-user requirements, enabling iterative development and continuous monitoring
  - Github and automated testing



- **Successful delivery of tool supporting industrial demonstrators**

Open Source & Dissemination Strategy

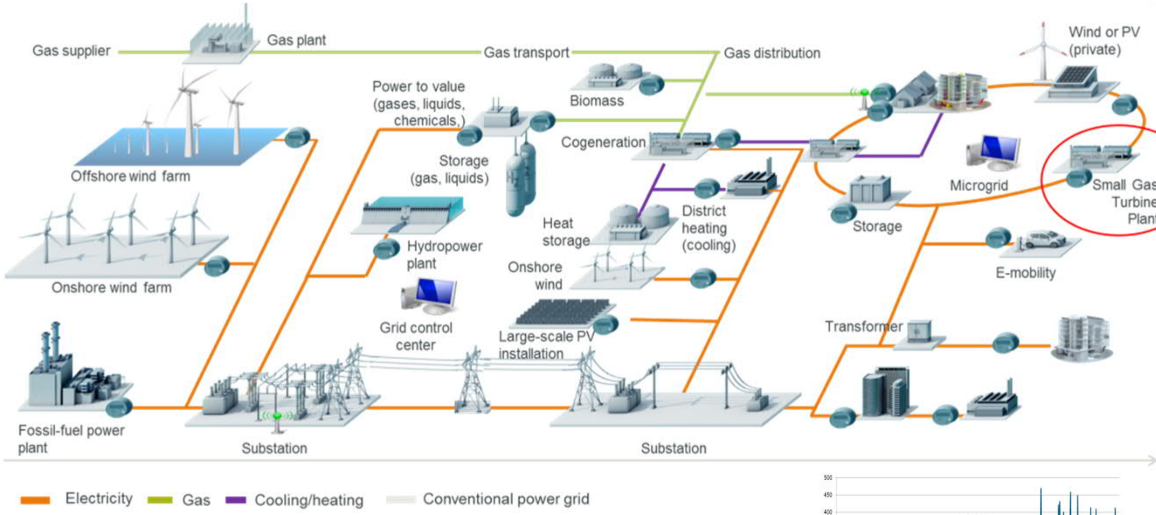
- **Well established open source consortiums including several project partners, further developing & disseminating project results**
  - Open Source Modelica Consortium (OSMC)
  - Papyrus Industrial Consortium & Eclipse foundation
  - Project results publicly available in latest versions of OpenModelica & Papyrus
- **Standardization activities**
  - OMG: Proposal on UML state-machine execution semantics accepted
  - FMI & SSP: Ongoing coordination on improved support for discrete-time systems & Transmission Line Method (TLM) co-simulation, FMI Change Proposal submitted
  - Modelica Association: Promote and standardize results related to Modelica language, e.g. code generation and V&V of Modelica models
- **Partners engaged in dissemination of project results, >70 documented papers and presentations**
  - In-house at industry partners
  - Workshops & conferences: Both in M&S communities and industrial application domains
  - Public project website

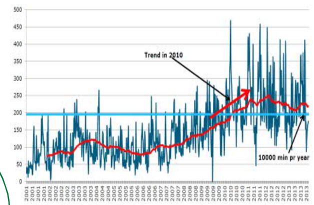
Energy Demonstrators - Business case

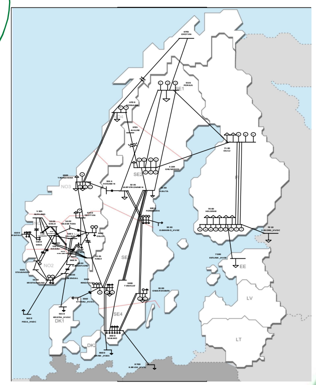
Challenges

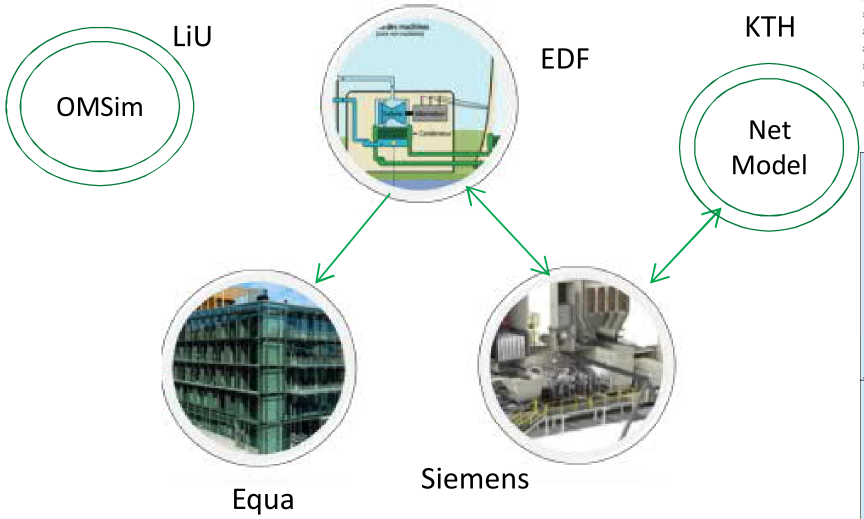
Frequency quality of Nordic Grid is deteriorating

Grid frequency variations are increasing



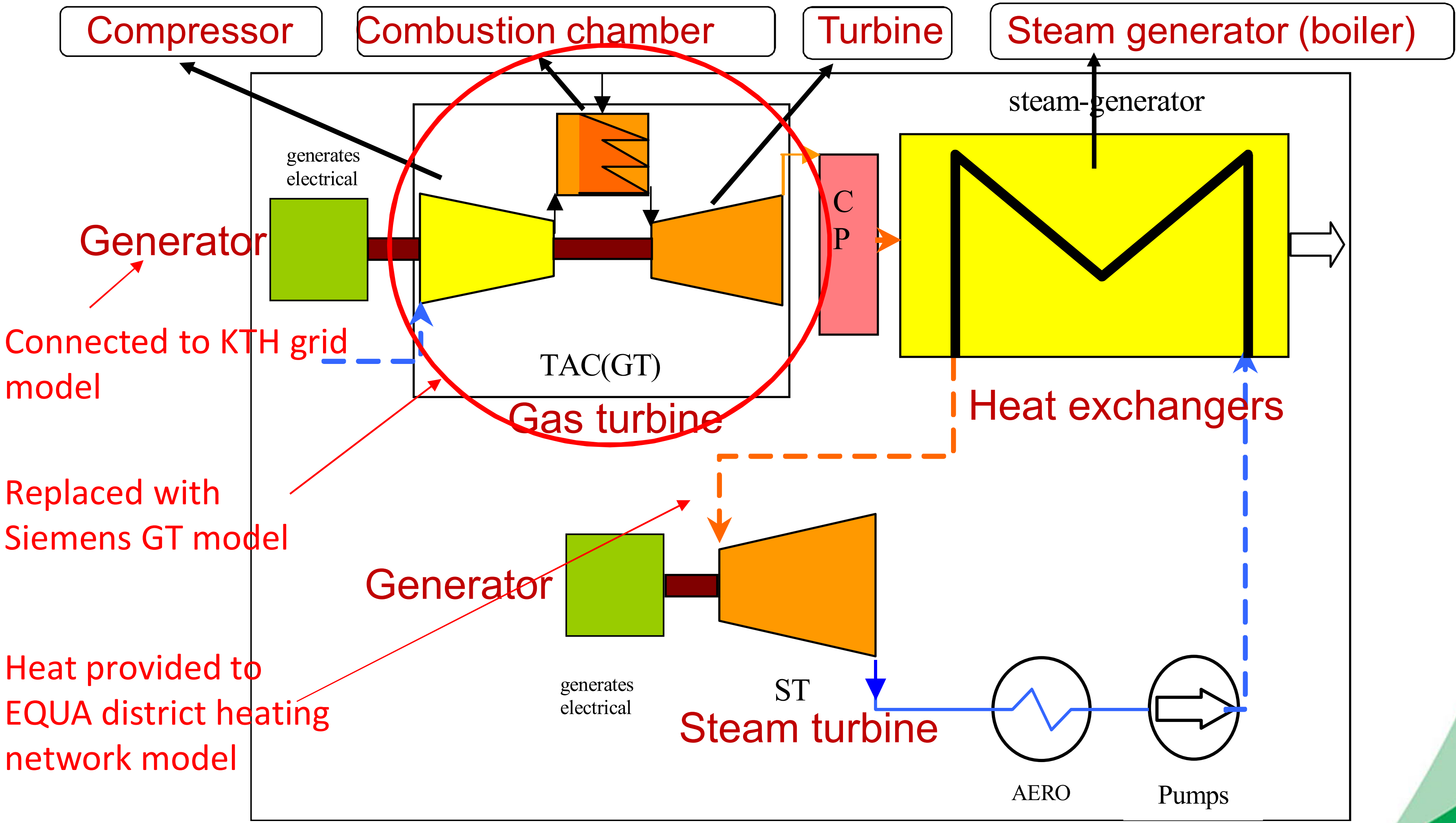




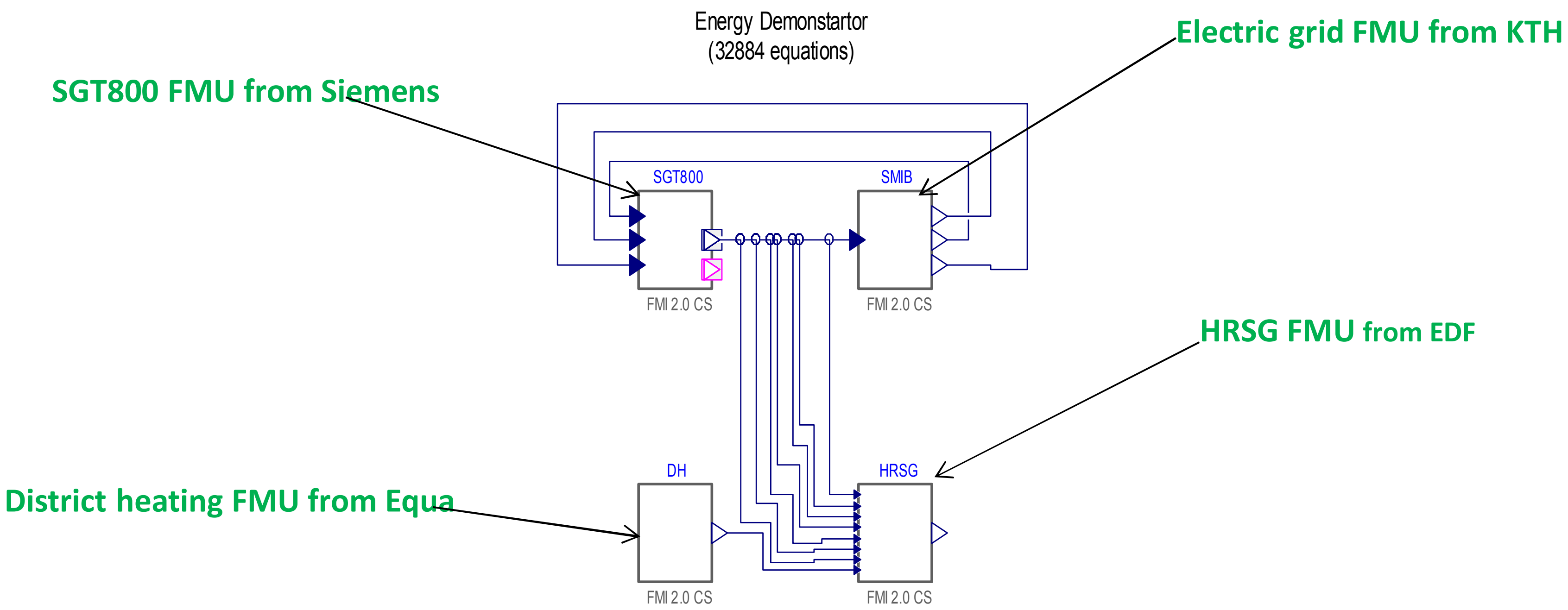


KPI Targets
Methods & tools ready for exploitation in subsystem closed-loop environment & energy system simulators
Detailed knowledge required for industrial use and further development of OMSimulator
Power energy demonstrator - OMSimulator enable promising results for efficient distributed co-simulation of several connected detailed subsystem models incl. human factors

Heat Recovery Steam Generator in the Joint Energy Demonstrator



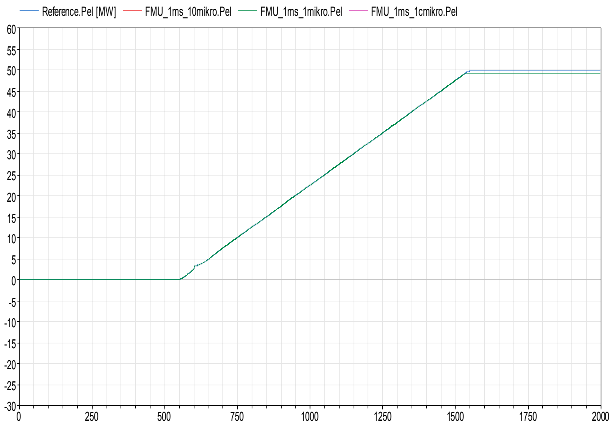
Simulation of Complex Systems
Energy Co-simulation



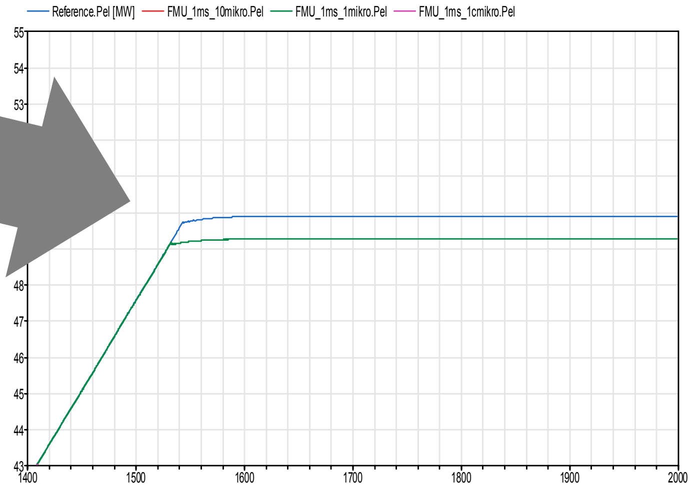
Goal

Simulate a combined cycle power station **with huge detailed accurate models from different suppliers**, provided as FMUs

Energy Demonstrator - results



Generator power [MW] during GT start deviates



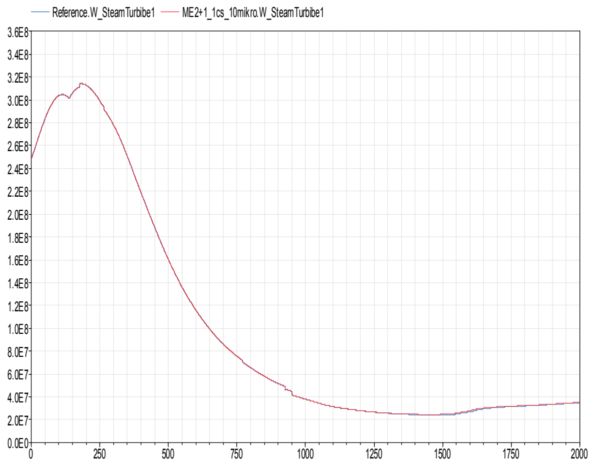
The result improves by:

- Shortening communication interval
- Reducing the error tolerance

To have an accurate result requires very long execution times due to:

- a need to set low error tolerance and use a short communication interval
- Inaccurate: 24 minutes
- Accurate: 500 h (estimated from present results)

The result depends upon application



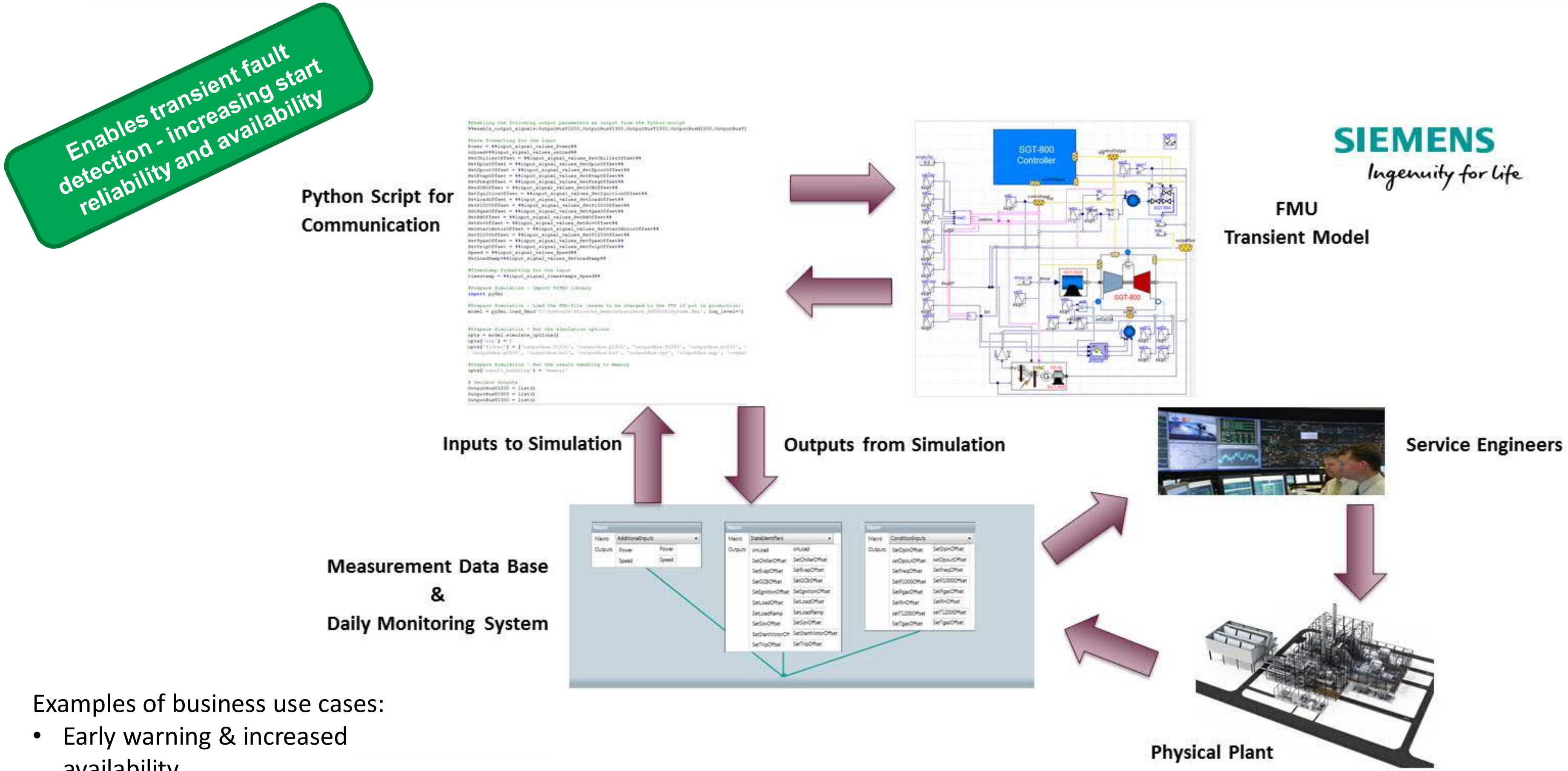
The HRSG connected to GT reveals good accuracy, deviations seen are caused by the deviation in GT power shown above

Improvements to the state-of-the-art

- Ability to use open source Modelica tool for the modelling and simulation of power plants (and energy systems at large).

- Ability to reuse verified Modelica models for data reconciliation (ability to identify faulty sensors and improve the quality of measurements by reducing uncertainties).

Cyber-Physical Simulation Application
Model interact with physical instances



Examples of business use cases:

- Early warning & increased availability
- Fault detection & diagnostic
- Predictive maintenance
- Increased customer value
- …

Cyber-Physical Simulation Application
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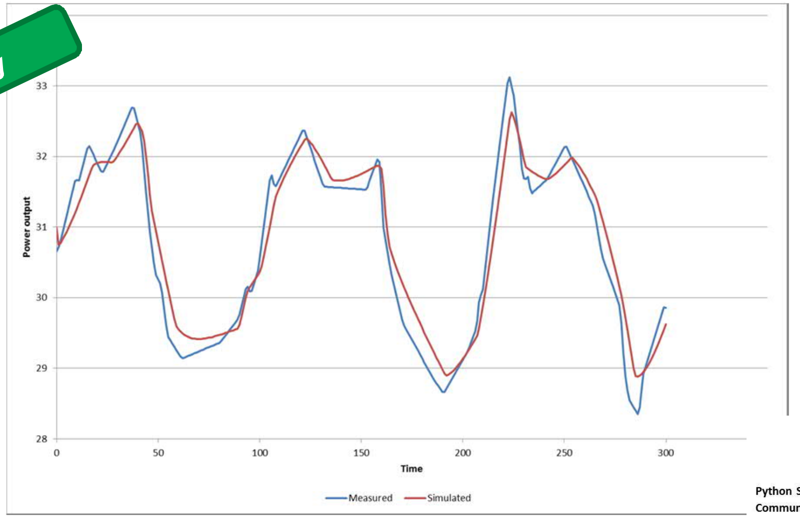
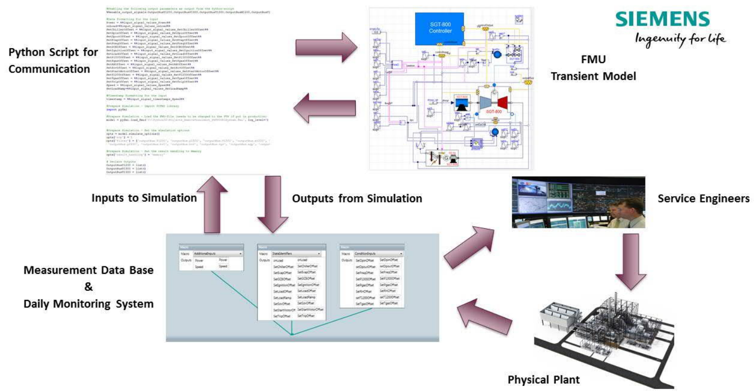
Successful User Story



1. Problem:
Continuous load variation at site tears out guide vane

2. Detection:
Complains from customer
Mimic the behavior with model



3. Solution:
New control feature to be implemented
New control tested and adjusted before implementation

4. Result:
Positive response from customer
Guide vane operation more smooth preventing tear out

5. Closing the Loop:
Agent implemented in supervision system
Supervision system detects and warns at similar operation

Joint Energy Demonstrator OPENCPS - Summary Highlights

- The Demonstrators is an example of good collaboration between Universities and Industry.
- It’s the first large scale multi-FMU test of complex energy systems
- The FMU technology enable wide spread use of advanced simulation at low cost
- Good behavior models based on algorithms is fundamental for e.g. Machine Learning and AI technology