Integrated Tool Chain for Model-Based Design of Cyber-Physical Systems

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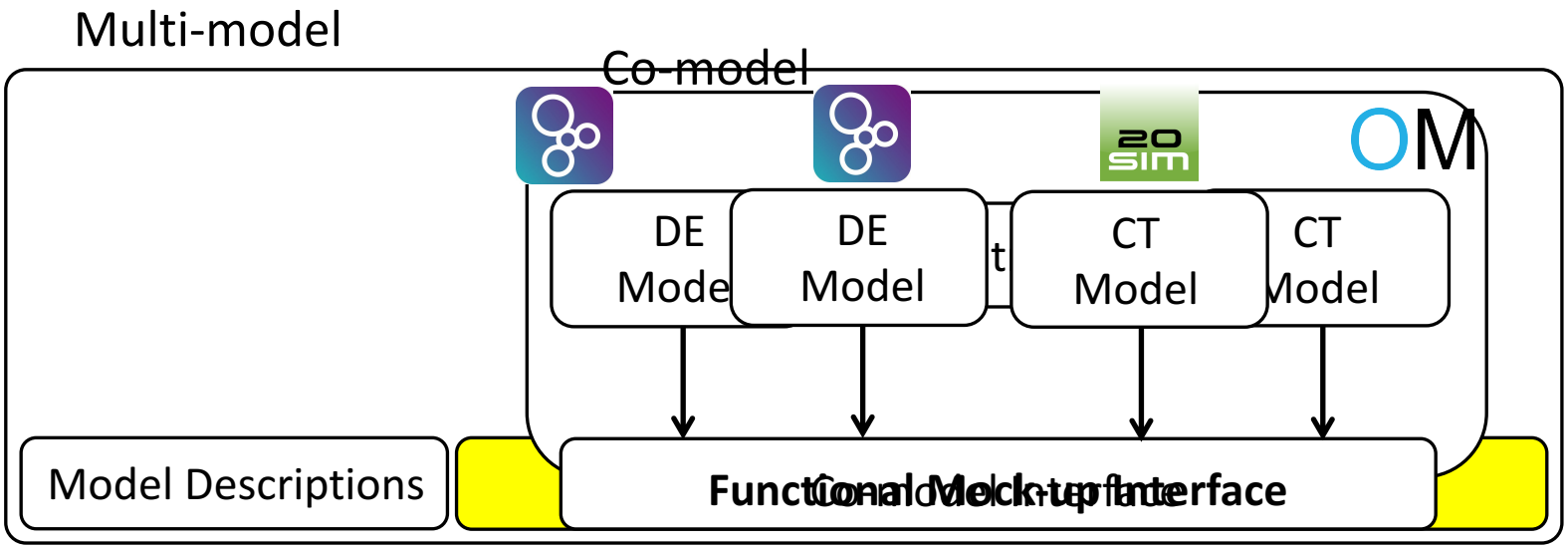
Horizon 2020 Programme

INTO-CPS Objectives

1. Build an open, well-founded tool chain for multidisciplinary model-based design of CPS that covers the full development life cycle of CPS
2. Provide a sound semantic basis for the tool chain
3. Provide practical methods in the form of guidelines and patterns that support the tool chain
4. Demonstrate in an industrial setting the effectiveness of the methods and tools in a variety of application domains
5. Form an INTO-CPS Association to ensure that project results extend beyond the life of the project

Co-modelling to Multi-modelling



Modelio — SysML modelling

Overture — Discrete-event modelling

20-sim — Continuous-time and physical-systems modelling

OpenModelica

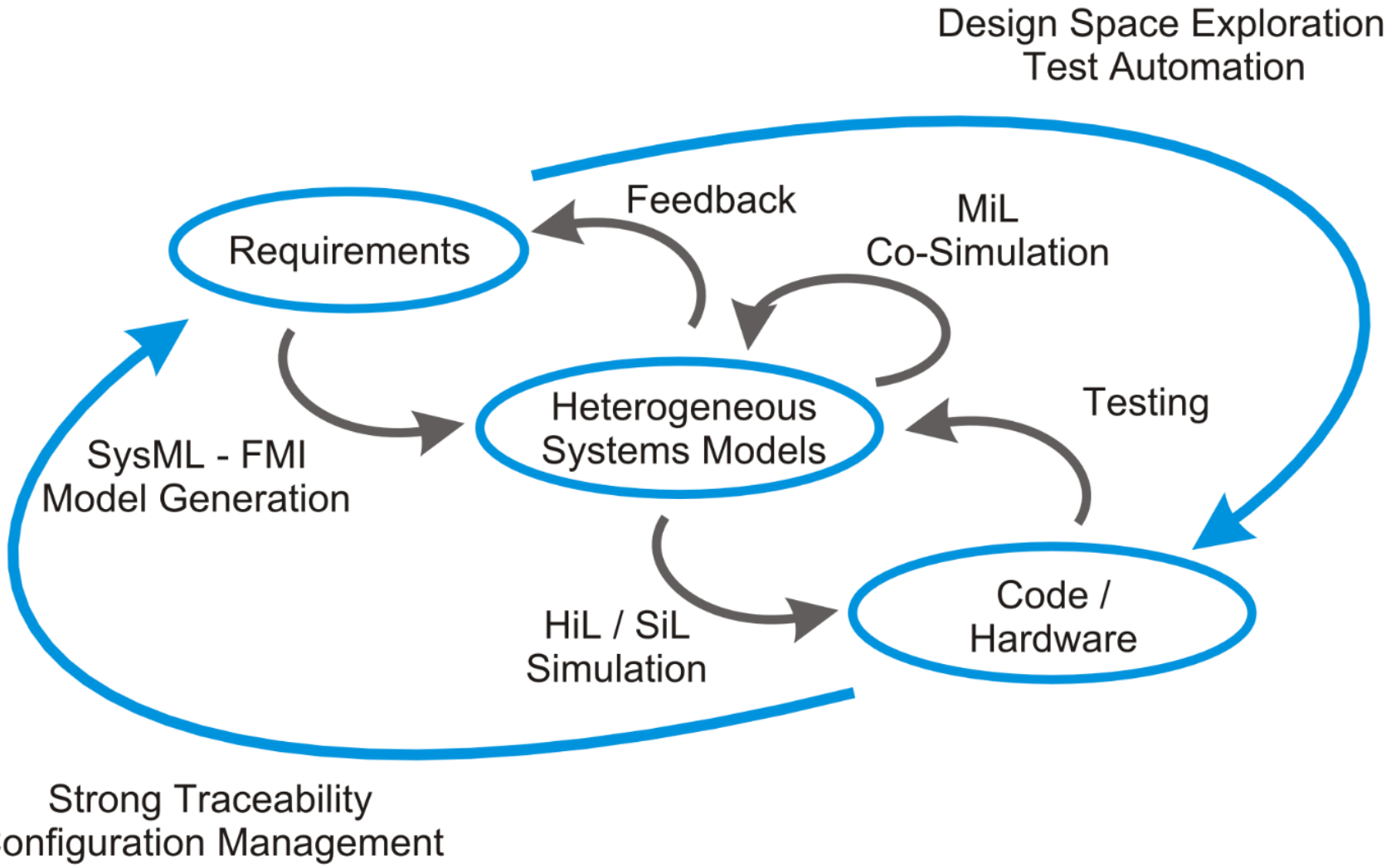
Crescendo — Co-simulation solutions

TWT Engine

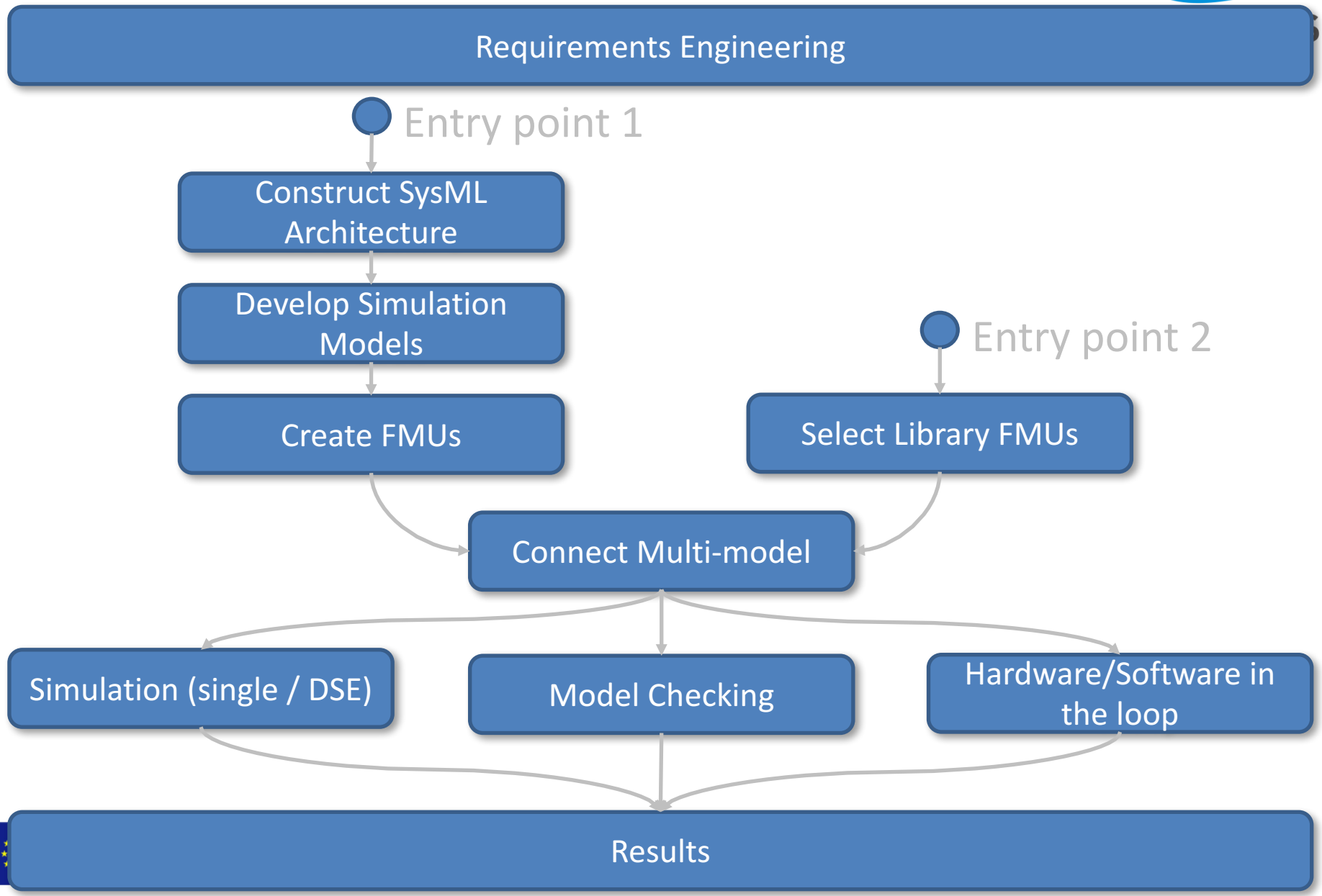
RT-Tester — Test automation / model checking

A New Toolchain for CPS Design

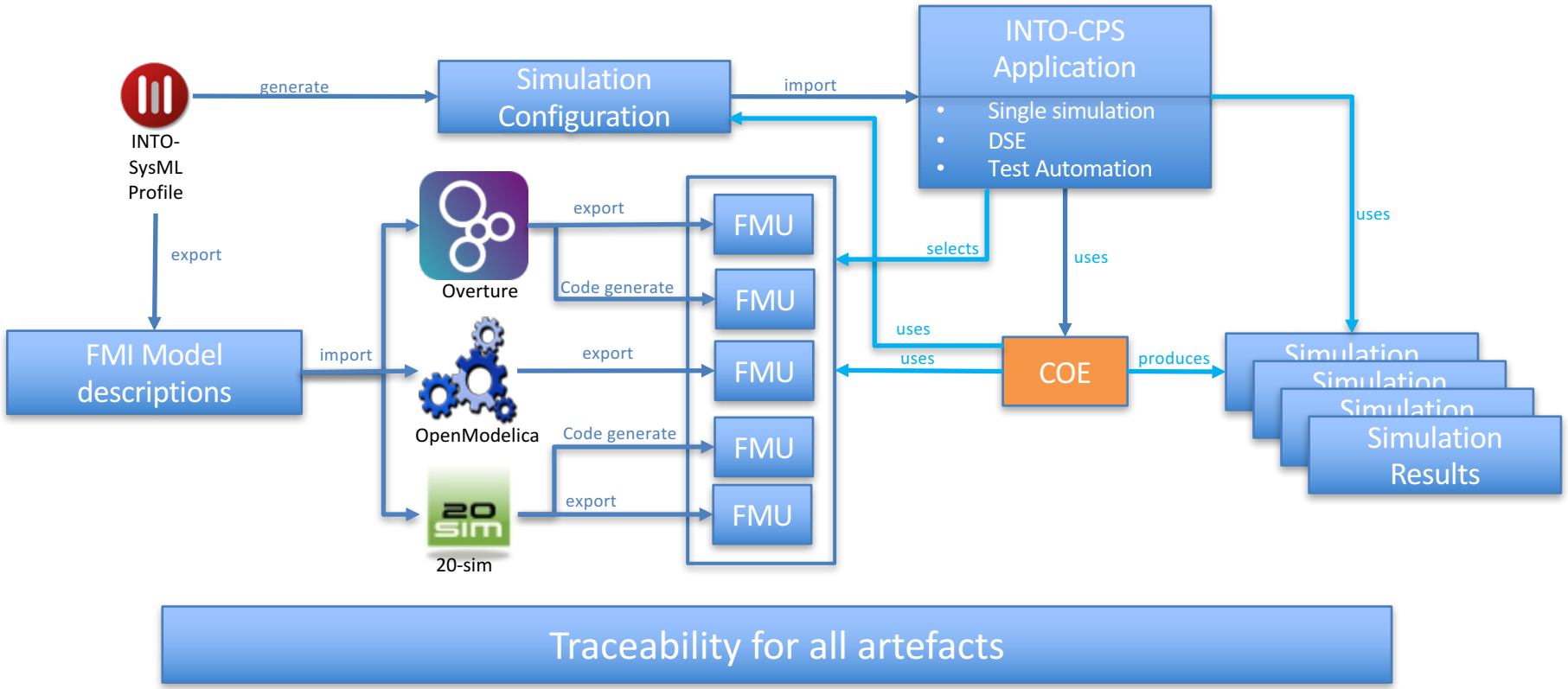
INTO-CPS



Outline Work Flow



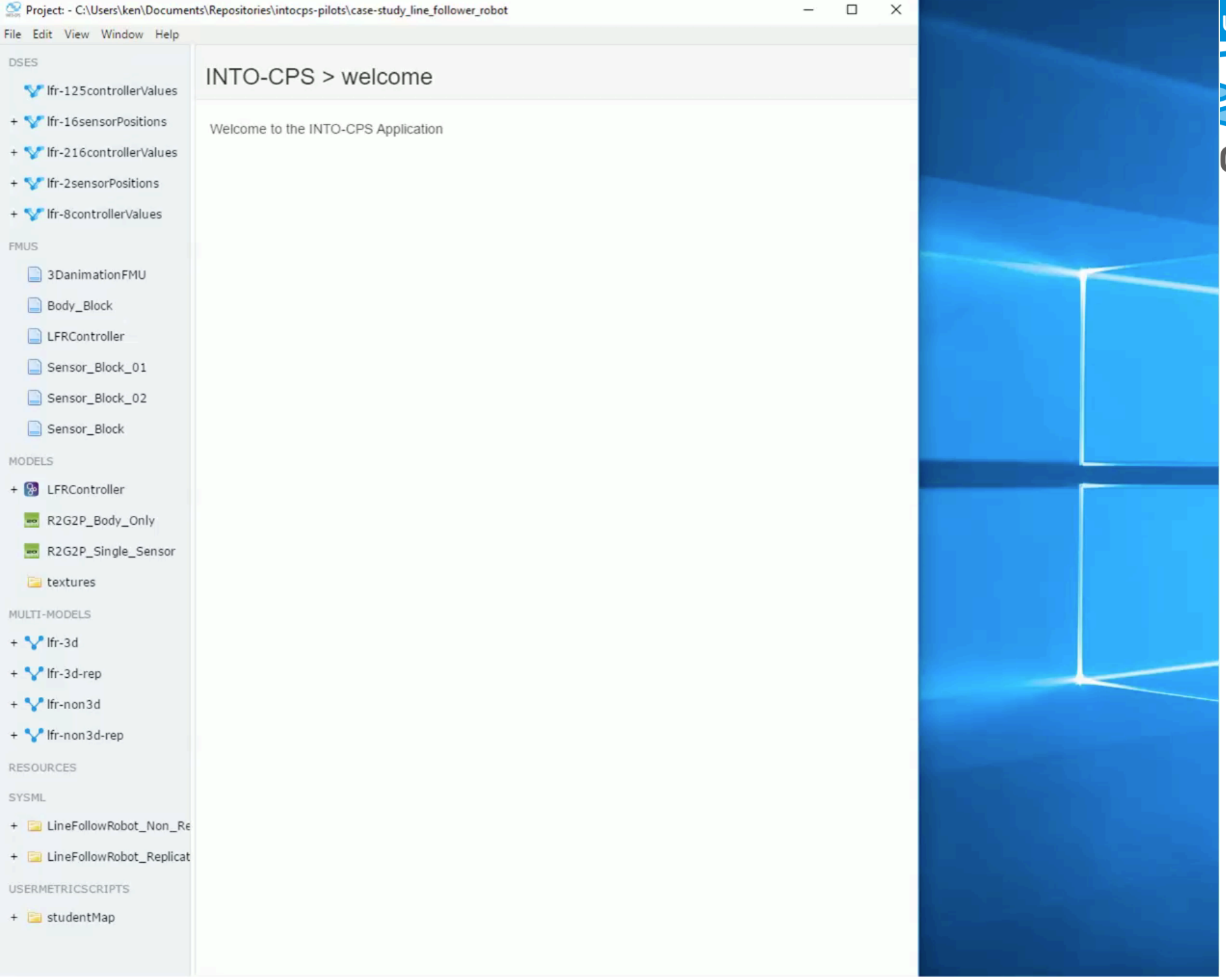
The INTO-CPS Tool Chain



The Co-simulation Engine

INTO-CPS

- Fully FMI 2.0 compliant Master Algorithm → any FMU model can be connected
- Support for discrete event (DE) and continuous time (CT) models, using proposed FMI extensions
- Multi-platform, 32/64 bit (Java-based) 
- Parallelization (using Akka / Scala) under investigation
- GUI prototype based on Modelio


Project: - C:\Users\ken\Documents\Repositories\intocps-pilots\case-study_line_follower_robot
File Edit View Window Help
DSES
lfr-125controllerValues
lfr-16sensorPositions
lfr-216controllerValues
lfr-2sensorPositions
lfr-8controllerValues
FMUS
3DanimationFMU
Body_Block
LFRController
Sensor_Block_01
Sensor_Block_02
Sensor_Block
MODELS
LFRController
R2G2P_Body_Only
R2G2P_Single_Sensor
textures
MULTI-MODELS
lfr-3d
lfr-3d-rep
lfr-non3d
lfr-non3d-rep
RESOURCES
SYSML
LineFollowRobot_Non_Re
LineFollowRobot_Replicat
USERMETRICSCRIPTS
studentMap
INTO-CPS > welcome
Welcome to the INTO-CPS Application

u.dk/

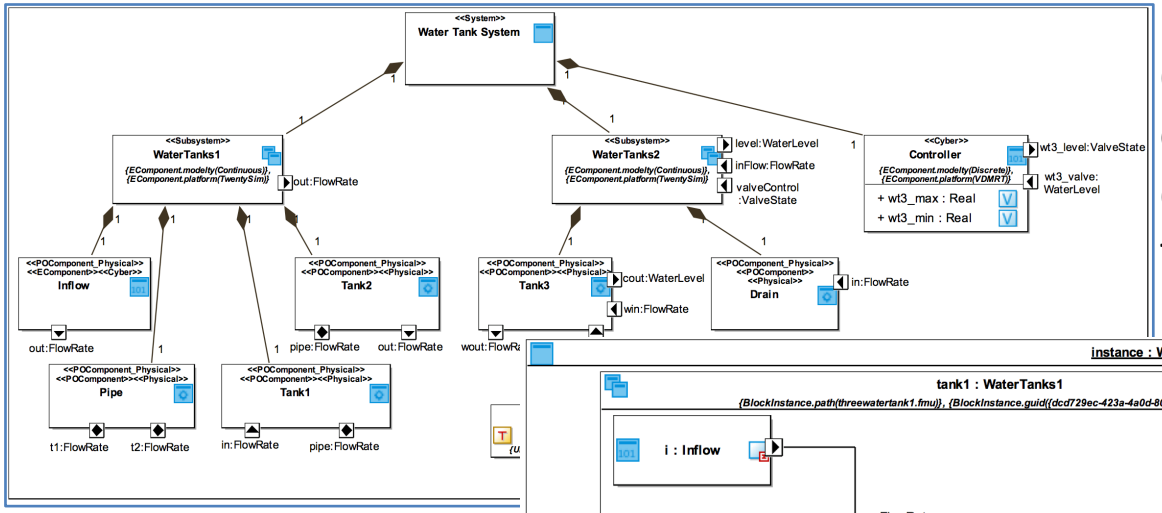
CPS

Co-Simulation Foundations

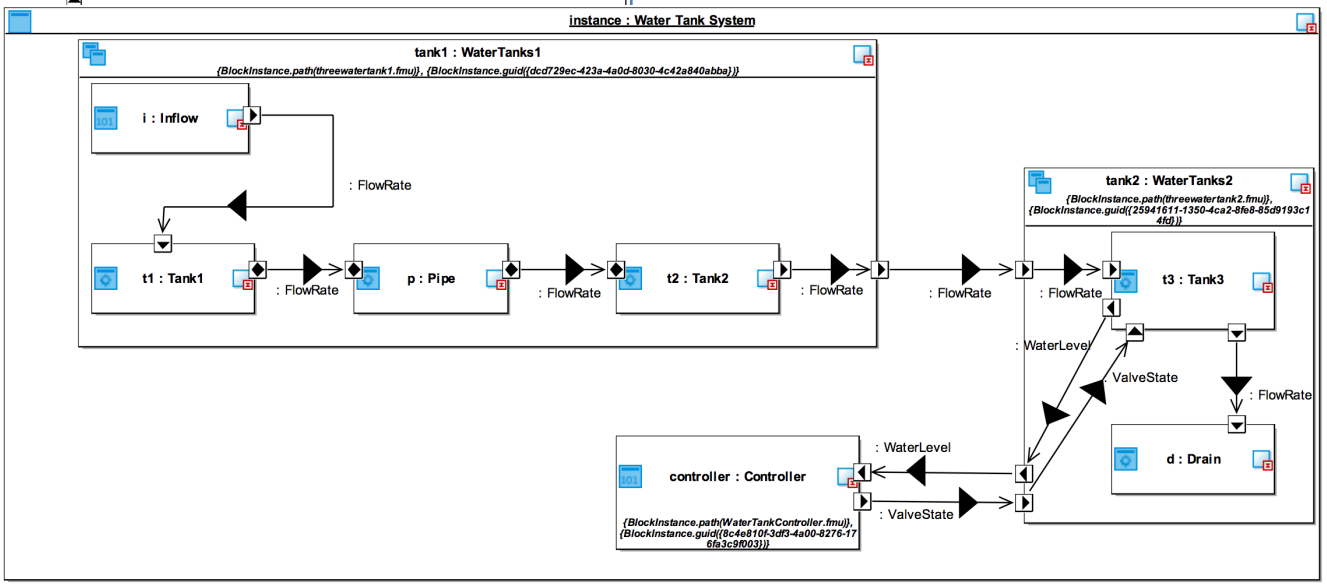
- Initial foundations developed for
  - SysML
  - VDM-RT
  - Modelica
  - FMI
- SysML CPS profile defined
  - Architecture Structure Diagram
  - Connections Diagram
  - Visualisation Diagram (TBD)
  - System Under Test Diagram (TBD)

INTO-CPS SysML CPS Profile

- Three-tank Water Tank : INTO-CPS technology
  - Design architecture using INTO-CPS profile



Architecture Diagram showing the connections between the different subsystems, and also to their interfaces in the multi-model



Industrial Case Studies

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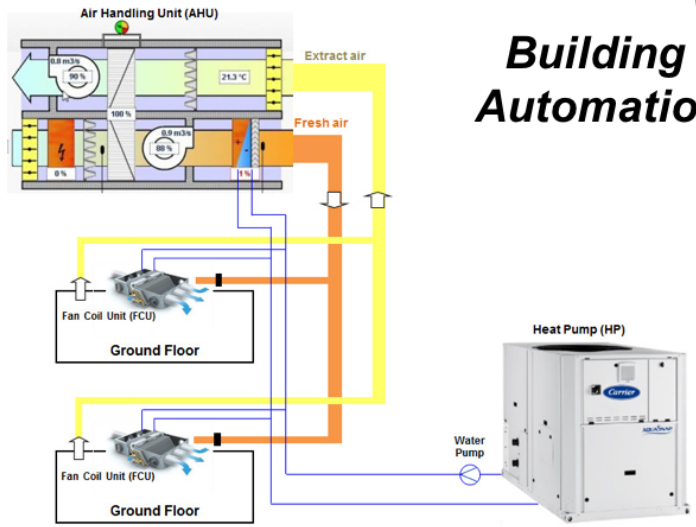
Building Automation



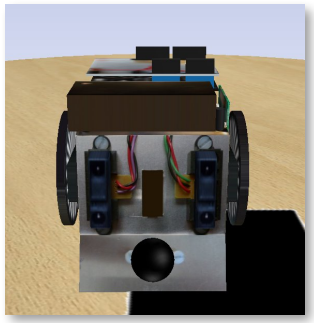
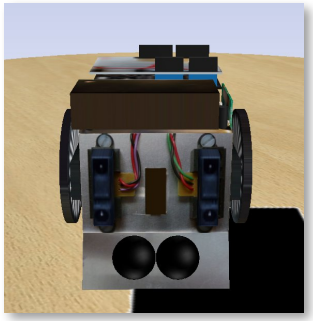
Automotive

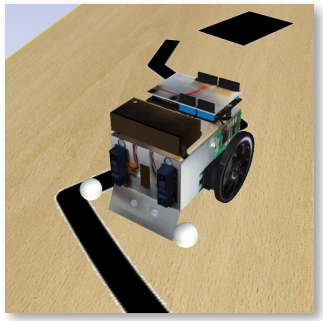
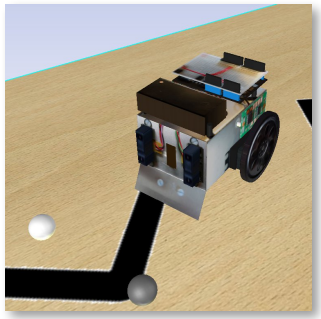
Industrial Follower Group

AGCO, Denmark
Alcatel Lucent, Ireland
Almende, Netherlands
Altran, UK
Bachmann Electronic, Netherlands
Bakker-Sliedrecht, Netherlands
Bang&Olufsen, Denmark
Bombardier, Germany
Bosch, Germany
Carrier, France
CCFE, UK
CeTIM, Netherlands
Chemring Technology, UK
Conpleks Innovation, Denmark
Continential, Romania
Critical Software, Portugal
Danish Aviation, Denmark
Delphi, Poland
Denso Corporation, Japan
Dredging International, Belgium
DSTL, UK
EDF, France
European Space Agency, Netherlands
Fortiss, Germany
Goodrich, UK
Grundfos, Denmark
GN Resound, Denmark
HADATAP, Poland
Holonix, Italy
HMF, Denmark
Huisman Equipment, Netherlands
IBM, Israel
IBM, Finland
Ikergune, Spain
Inestec, Portugal
Irmato, Netherlands
Jaguar, UK
MAN Diesel & Turbo, Denmark
MFAtech, UK
NII, Japan
Odego, Germany
ONERA, France
Oticon, Denmark
PLM Consult, Denmark
Polar Electro, Switzerland
Postech, South Korea
Prime Solutions Group, USA
Projectglobe.com, UK
Rockwell-Collins, France
Rolls-Royce, UK
Saab, Sweden
Santer Reply, Italy
Seluxit, Denmark
Siemens, Sweden
Syntell, Sweden
Tecnalia, Spain
Terma, Denmark
Thalès R&T, Germany
TTTech, Austria
thyssenkrupp Marine Systems, Germany
UTC Aerospace, UK
West Consulting, Netherlands

In total: 62

Design Space Exploration

How to Explore?

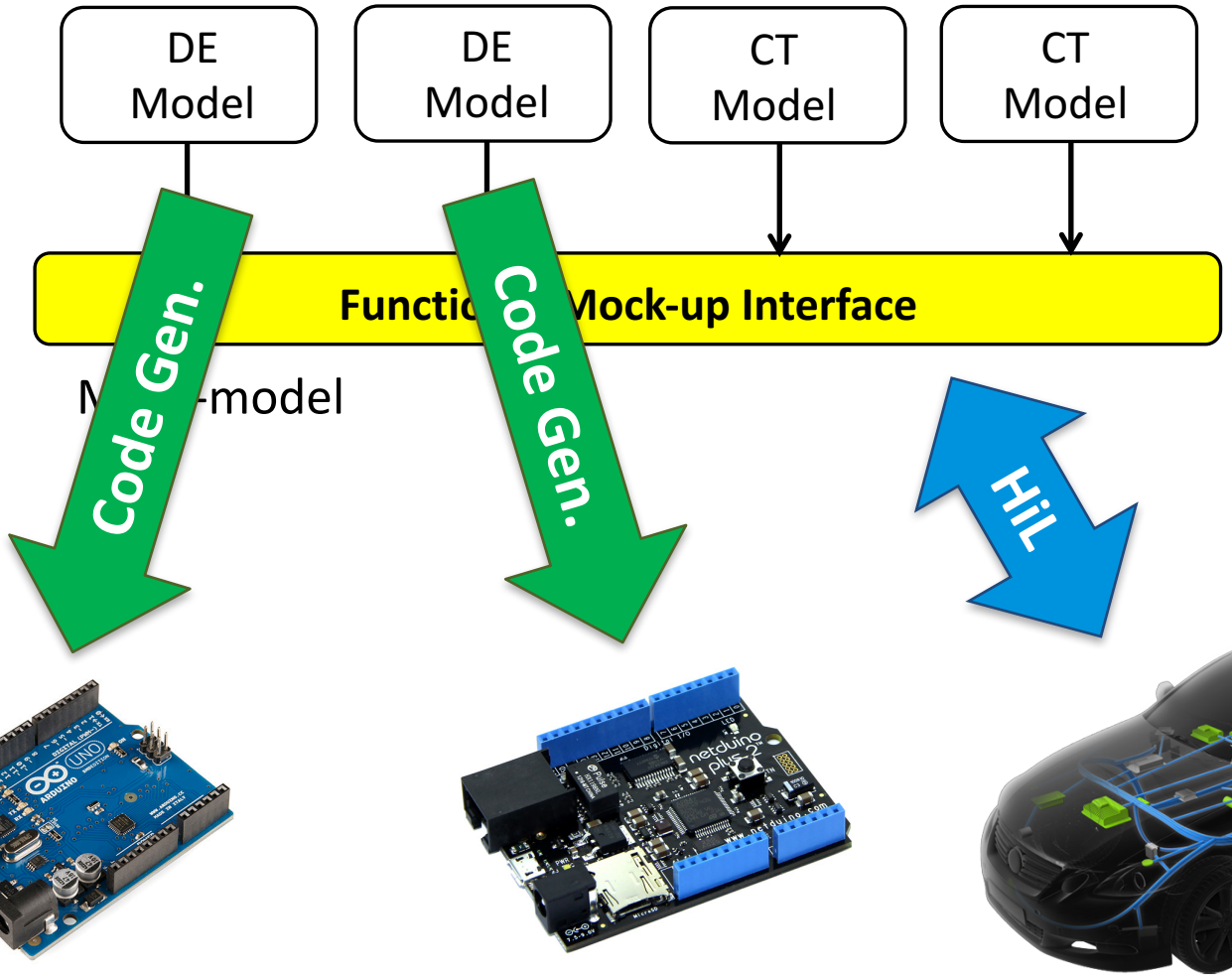
- Exhaustive
- Taguchi Methods
- Space Culling
- Genetic Methods

How to Assess?

$$V_a = w_1^a v_1^a(x_1^a) + w_2^a v_2^a(x_2^a) + ... + w_n^a v_n^a(x_n^a)$$

DSE Driver	Objective Evaluator	Ranking	Presentation
Simulation parameters, control of process	Objective measures and constraint satisfaction from raw simulation results	Ranking designs according to objective values	Display of results and search progress to the user

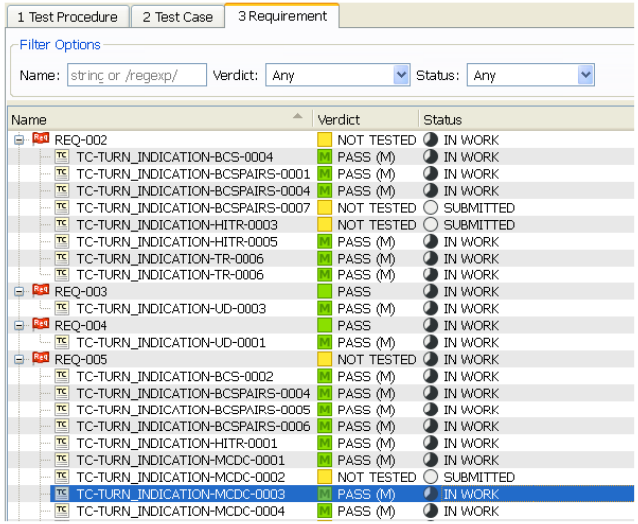
Hardware-in-the-Loop (HiL) and Code Generation



Using Generated C Code Embedded

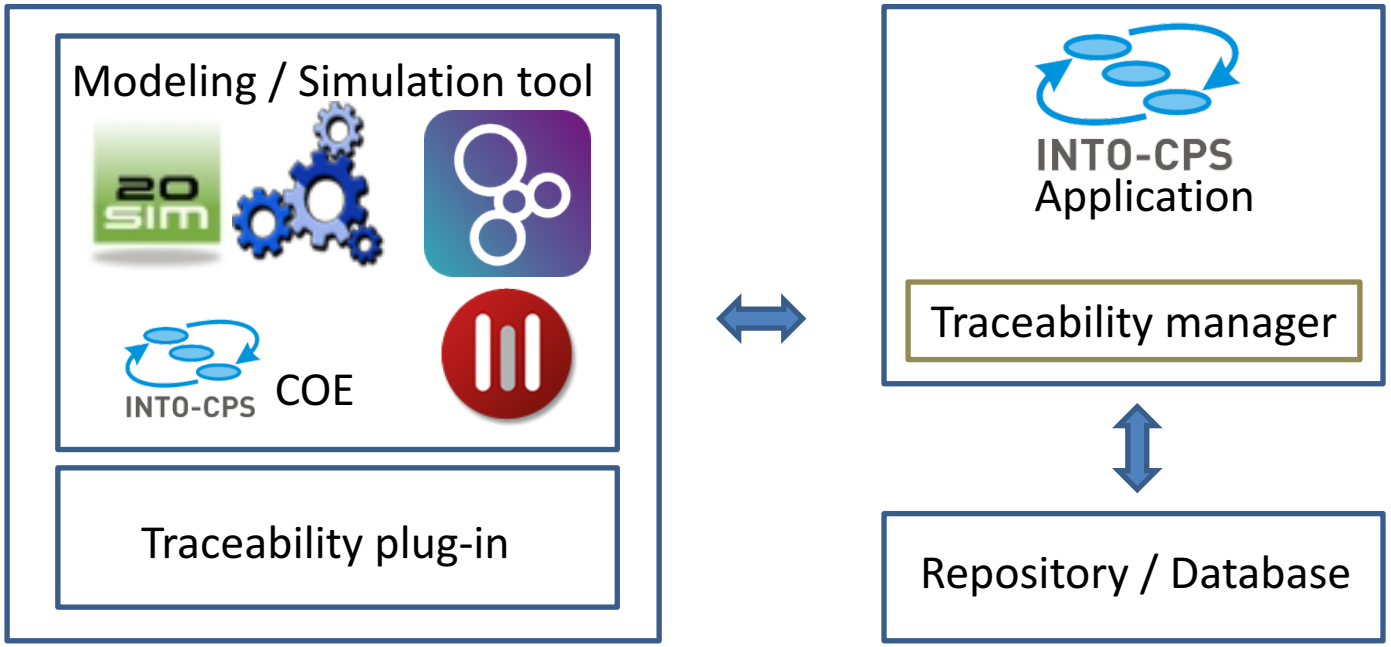
Test Automation

- Based on RT Tester tool suite
- Status:
  - Test sets generated from XMI import (from Modelio)
  - Test procedures are generated as FMUs, connected to Co-simulation
- Outlook:
  - Identify SuT in SysML profile, connect to Test Automation
  - Connect SysML requirements with LTL formulas



Traceability & Provenance

- Goal: Ensure tracing between requirements, models, results, code
- Keep track of changes
- Will use OSLC / Prov-N standards



Any questions?