25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

Open Standards Simulation Workflow for Heterogeneous System Models

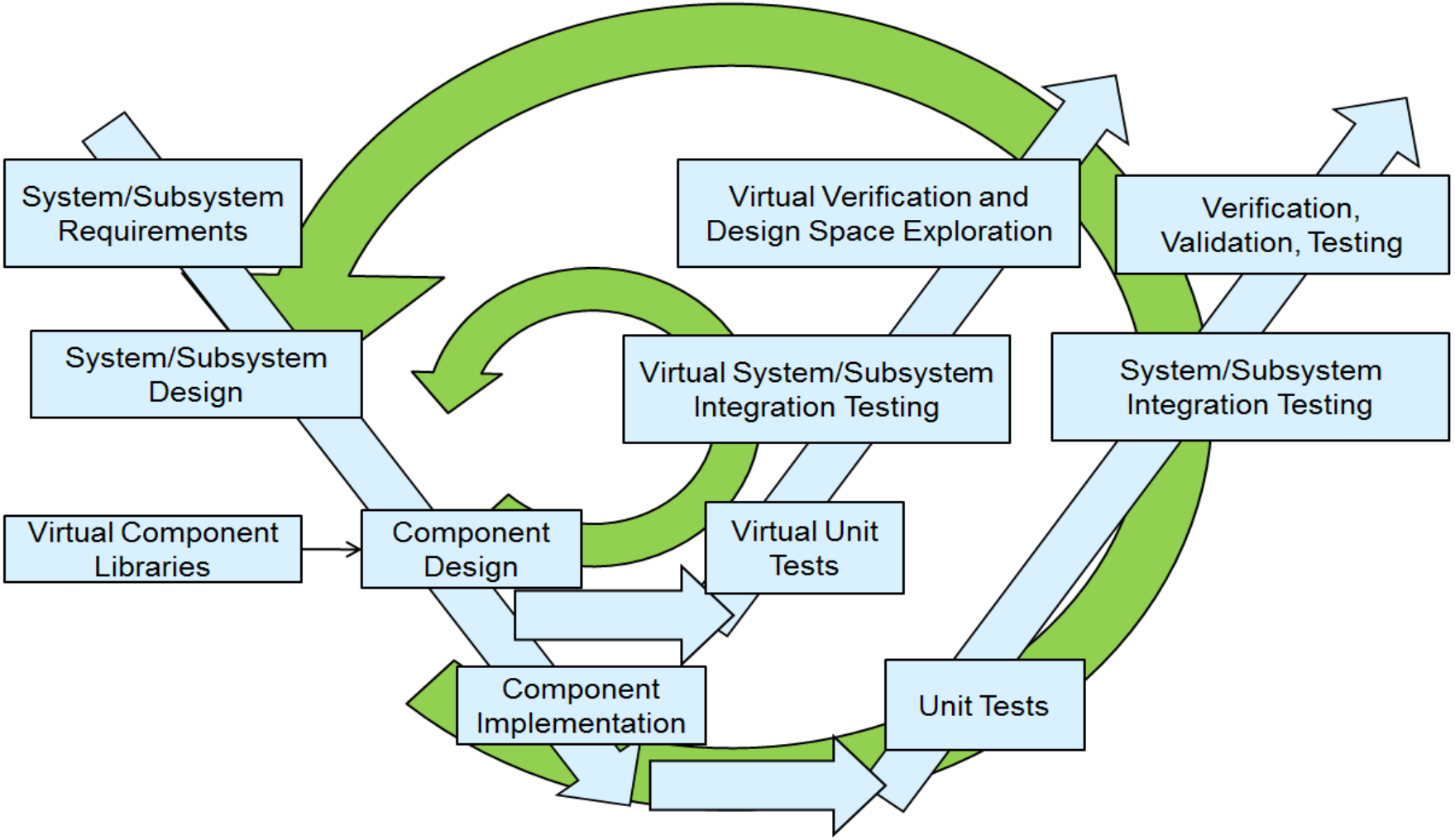
(e.g. FMI based simulation)

Henry Broodney, Lev Greenberg, Shinichi Hirose, Eldad Palachi – IBM

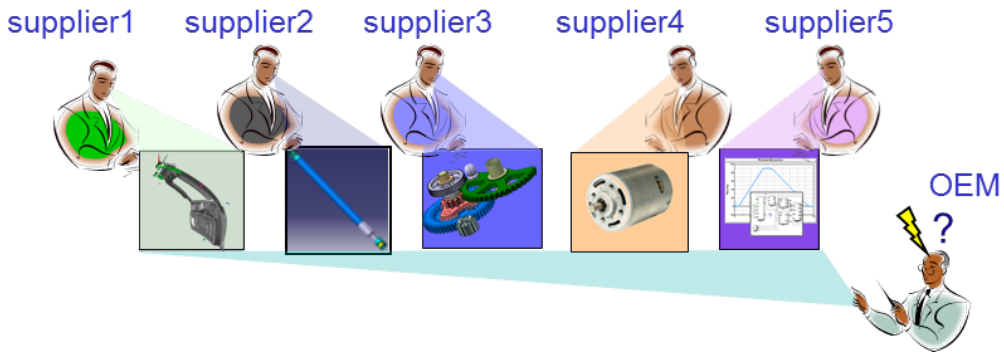
Agenda

- A bit of history
- FMI in a nutshell
- Simulation workflow
- Somewhat technical…
- Couple of use cases
- What the future holds

V-model with left shift

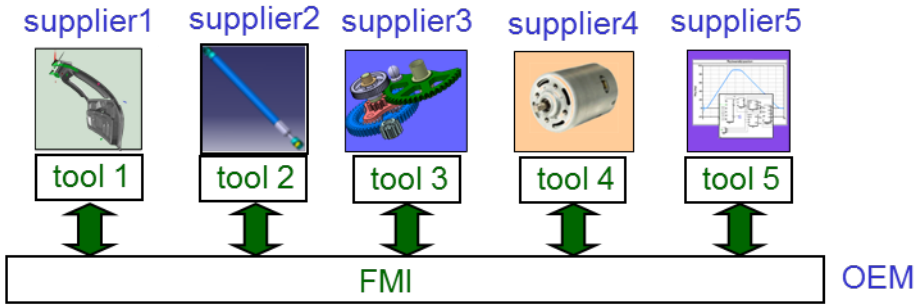


Need and solution



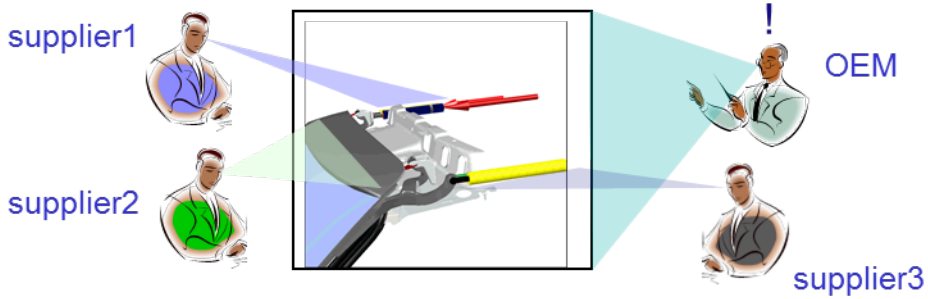
Problems / Needs

- Component development by supplier
- Integration by OEM
- Many different tools
- Supplier IP must be protected



Solution

- Industry standard for model interoperability for simulation
- Reuse of supplier models by OEM
- Protection of models' IP



Added Value

- Early verification of design
- Decreased tooling overhead
- Increased process efficiency and quality

Related work

- Models of Computation
  - Consider attending session 3.1 today (15:30)
- Cyber-Physical systems modeling
- Mathworks Simulink®
- Modelica®
- EU Framework projects
- OMG…

Functional Mockup Interface

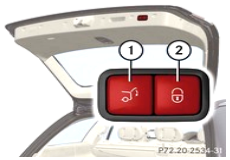
The FMI development was part of the ITEA2 MODELISAR project (2008 - 2011; 29 partners, Budget: 30 Mill. €). From 2012 FMI is developed as Modelica Association project

- FMI development initiated, organized and headed by Daimler AG
- Improved Software/Model/Hardware-in-the-Loop Simulation, of physical models from different vendors.
- Open Standard
- FMI Standard Releases
  - FMI 1.0 in 2010
  - FMI 2.0 in 2014
- Over 35 FMI compliant tools (Modelica tools, Simulink add-ons, Rhapsody, etc)
  - https://www.fmi-standard.org/tools

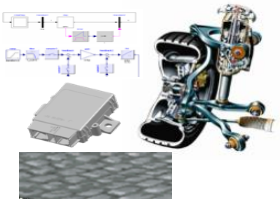

Engine with ECU


Gearbox with ECU


Thermal systems



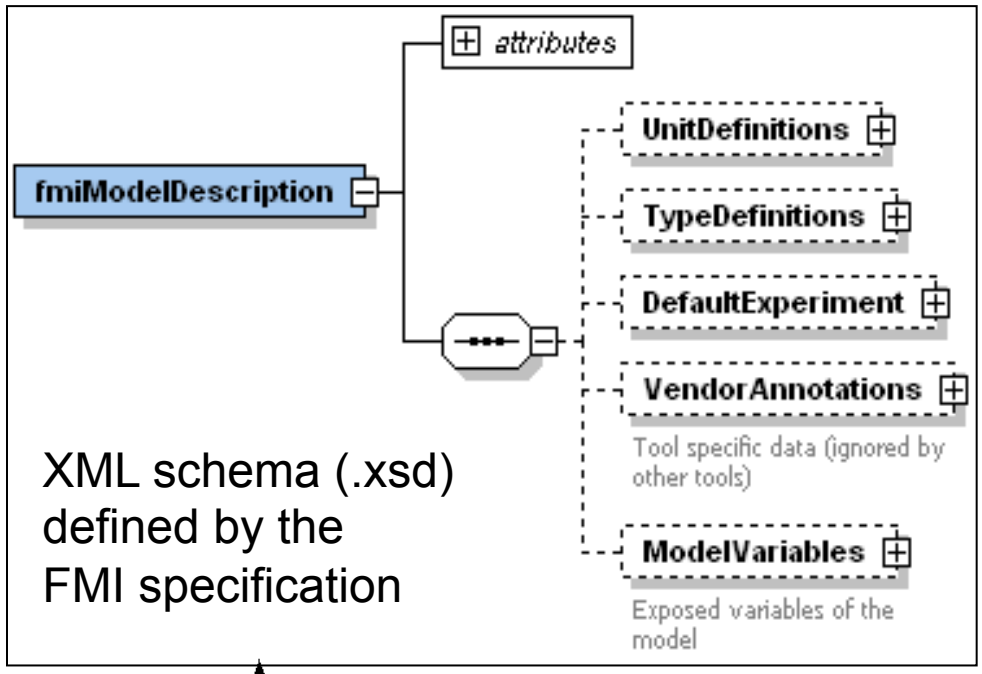
Automated cargo door


Chassis components, roadway, ECU (e.g. ESP)

etc.

functional mockup interface for model exchange and tool coupling

Functional Mockup Unit (FMU)



control

simulator GUI

reads

references

model.dll

modelDescription.xml

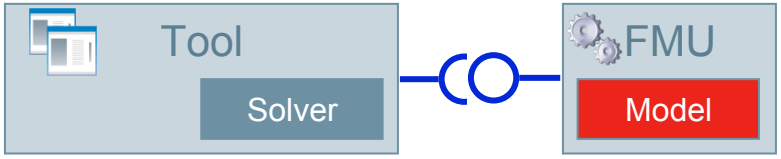
.fmu

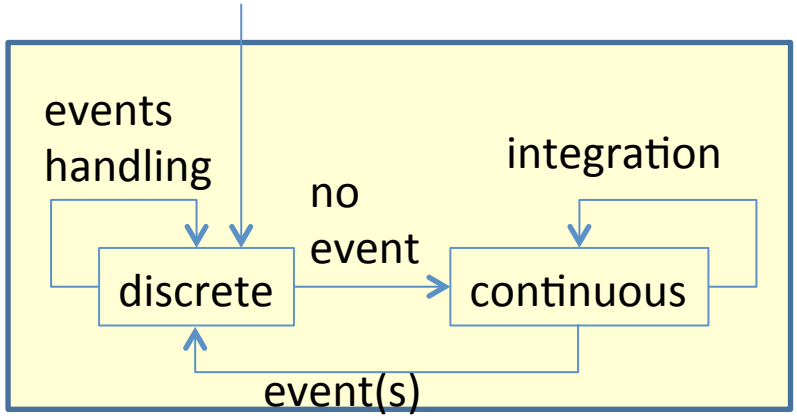
run 1 or many

simulator solver

Flavors (modes)

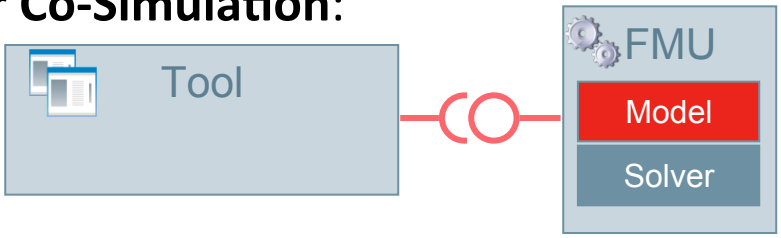
FMI for Model Exchange:

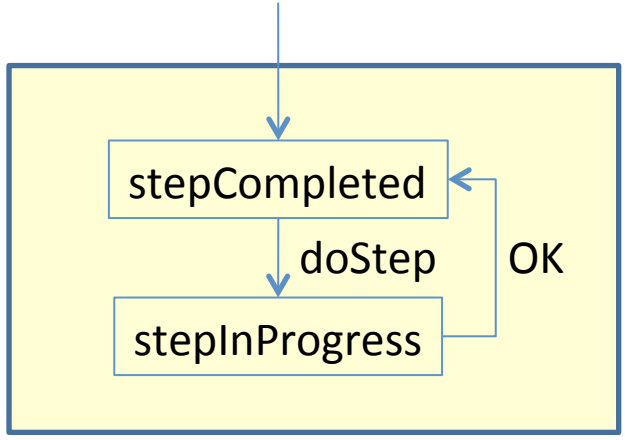




- FMU for ME doesn't contain ODE solver –hosting simulation tools need to provide it
- FMU exposes state variables and thier derivatives

FMI for Co-Simulation:





- FMU for CS includes solver – hosting tools "only" communicate signals between FMUs and select communcation step sizes

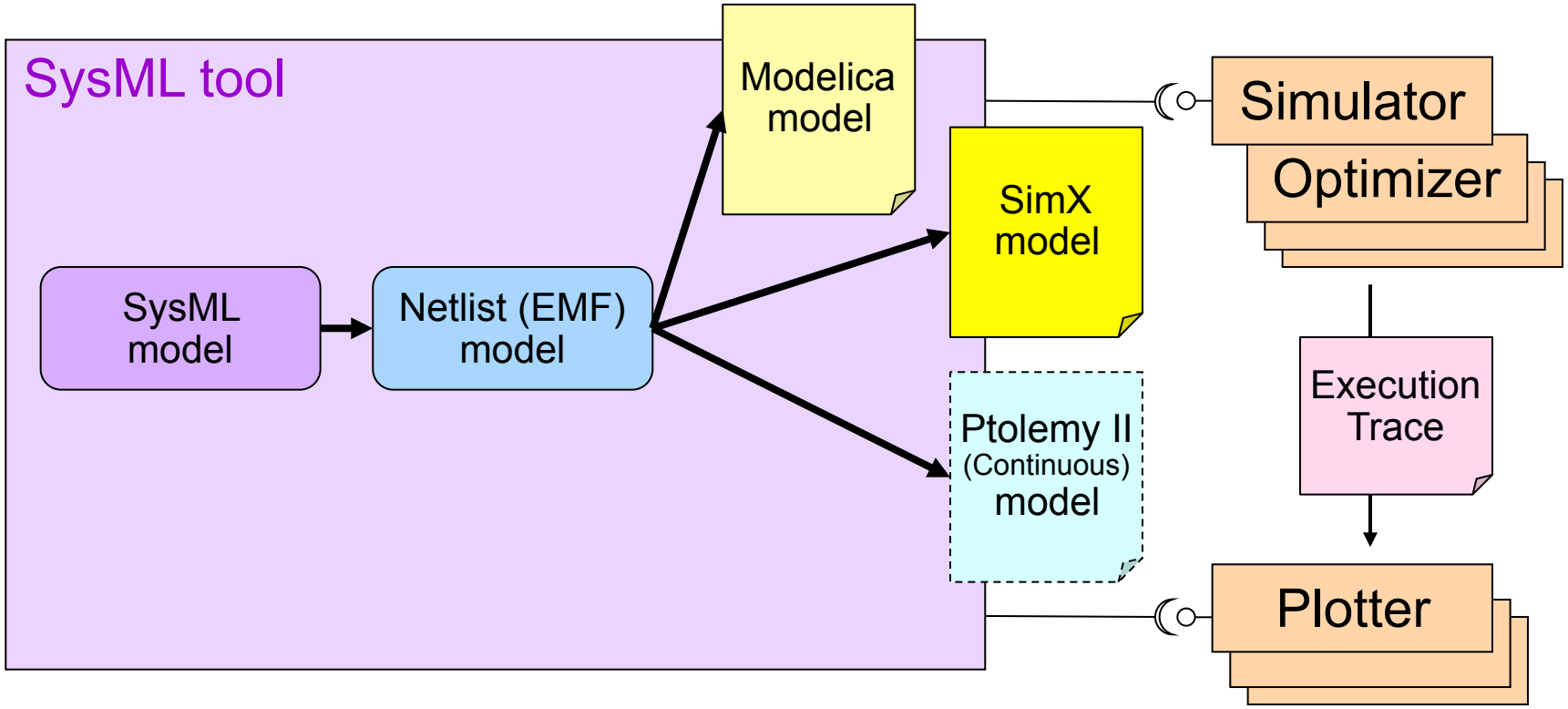
Tool availability

From www.fmi-standard.org

	Model Exchange		Co-Simulation	
	Export	Import	Slave	Master
FMI_1.0 67 (24)	22 (11)	30 (15)	31 (11)	40 (18)
FMI_2.0 20 (8)	4 (4)	5 (2)	8 (6)	14 (4)

Open Source Available!!

Hybrid Simulation Concept



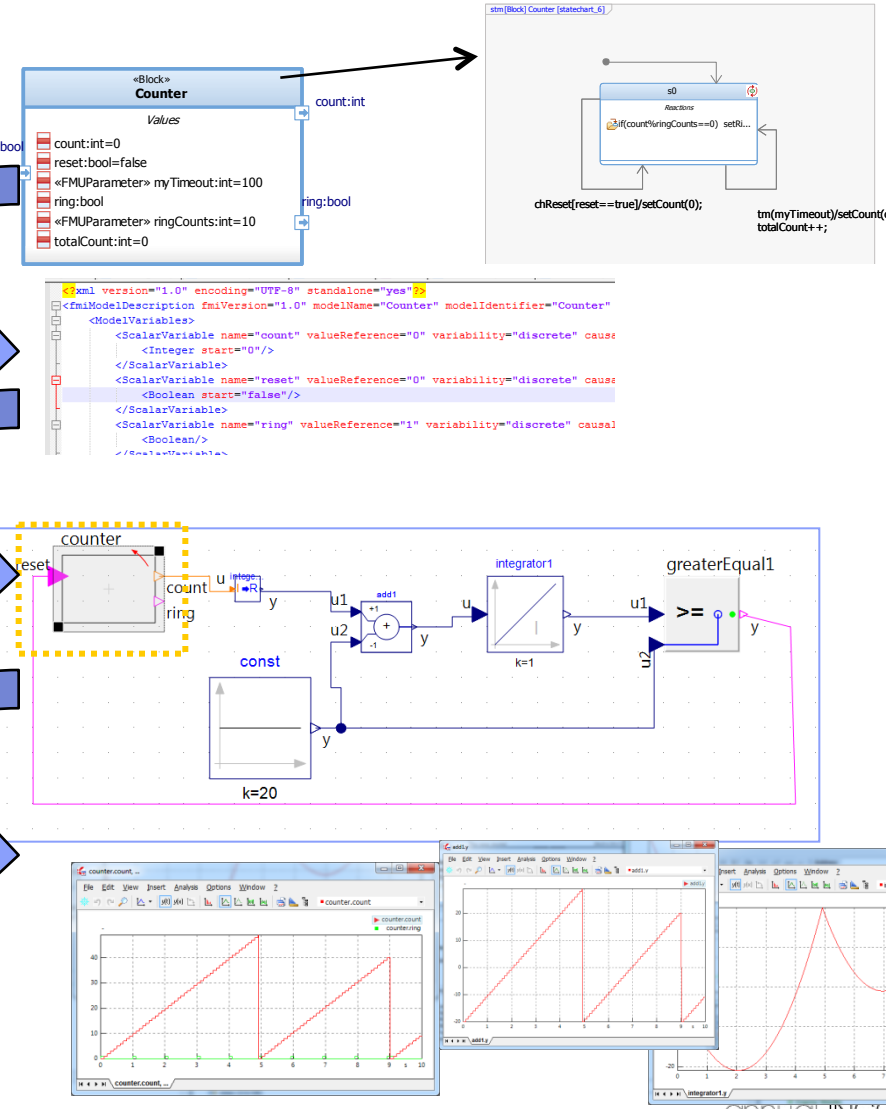
Workflow - export

Design behavioral SysML block

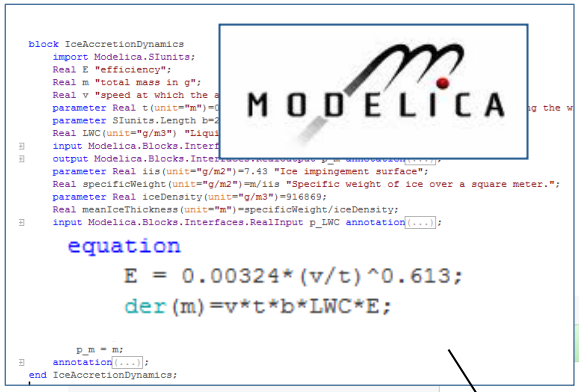
Export SysML to FMU

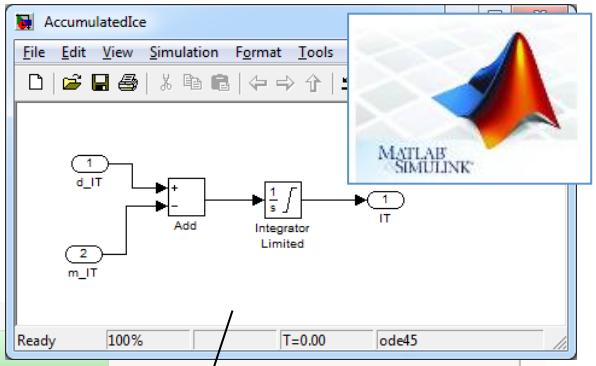
Import FMU and compose the hybrid system (SimX, Dymola, OpenModelica)

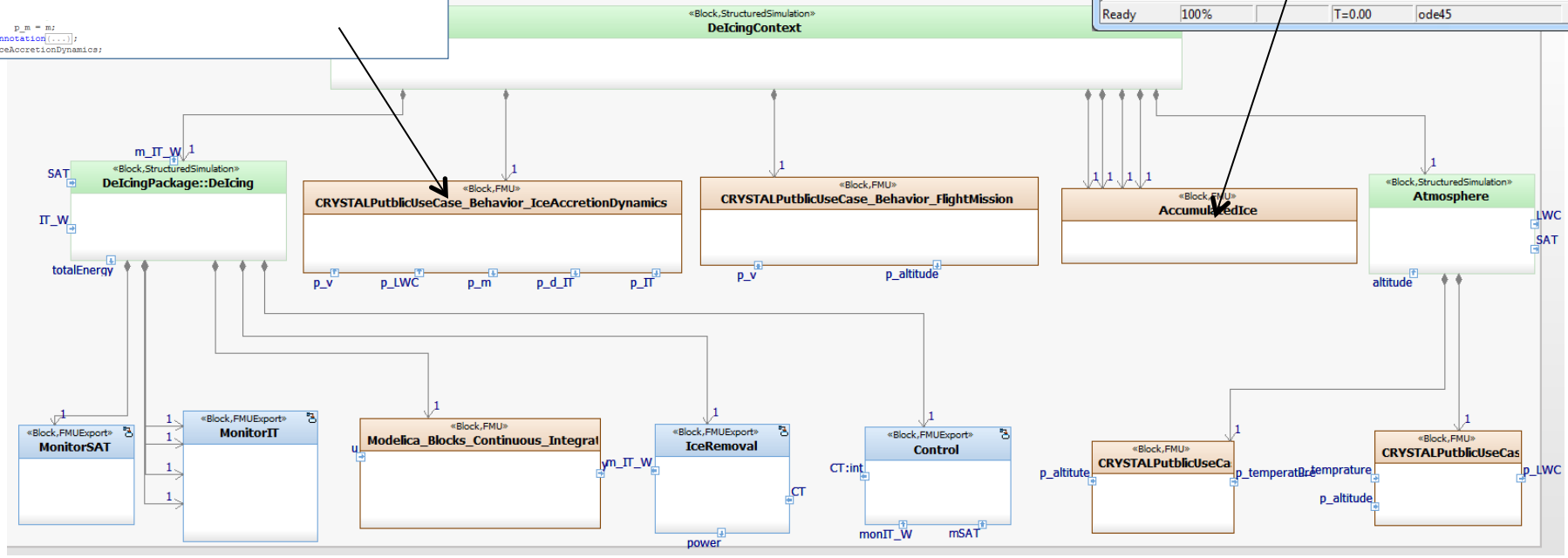
Simulate



Workflow – import

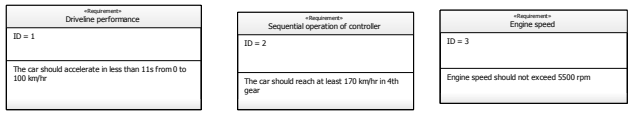


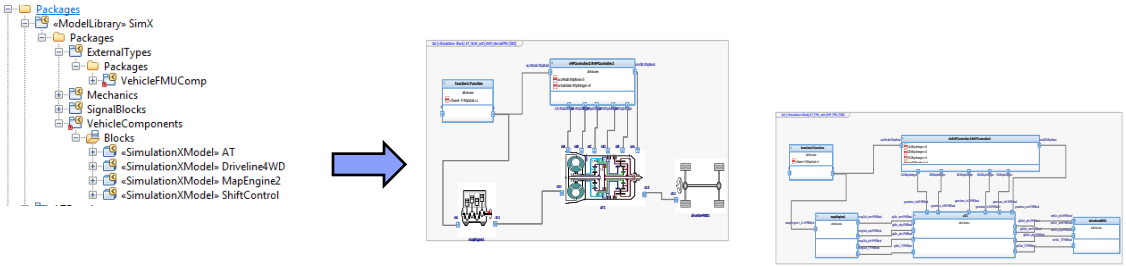




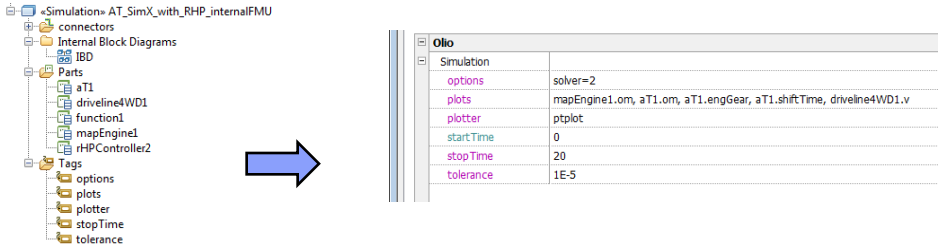
Workflow - full

Design the hybrid system in SysML, including imported FMU

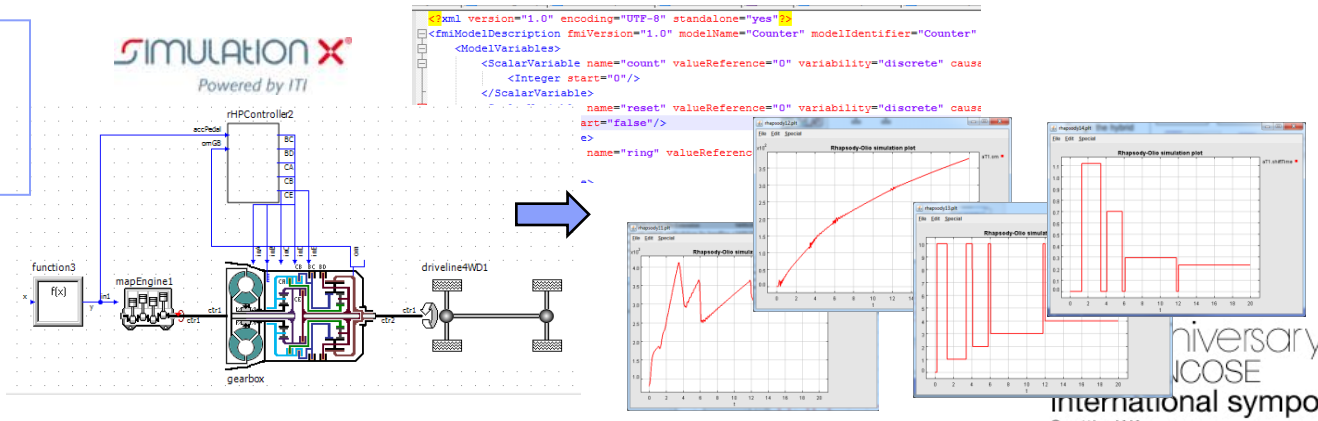




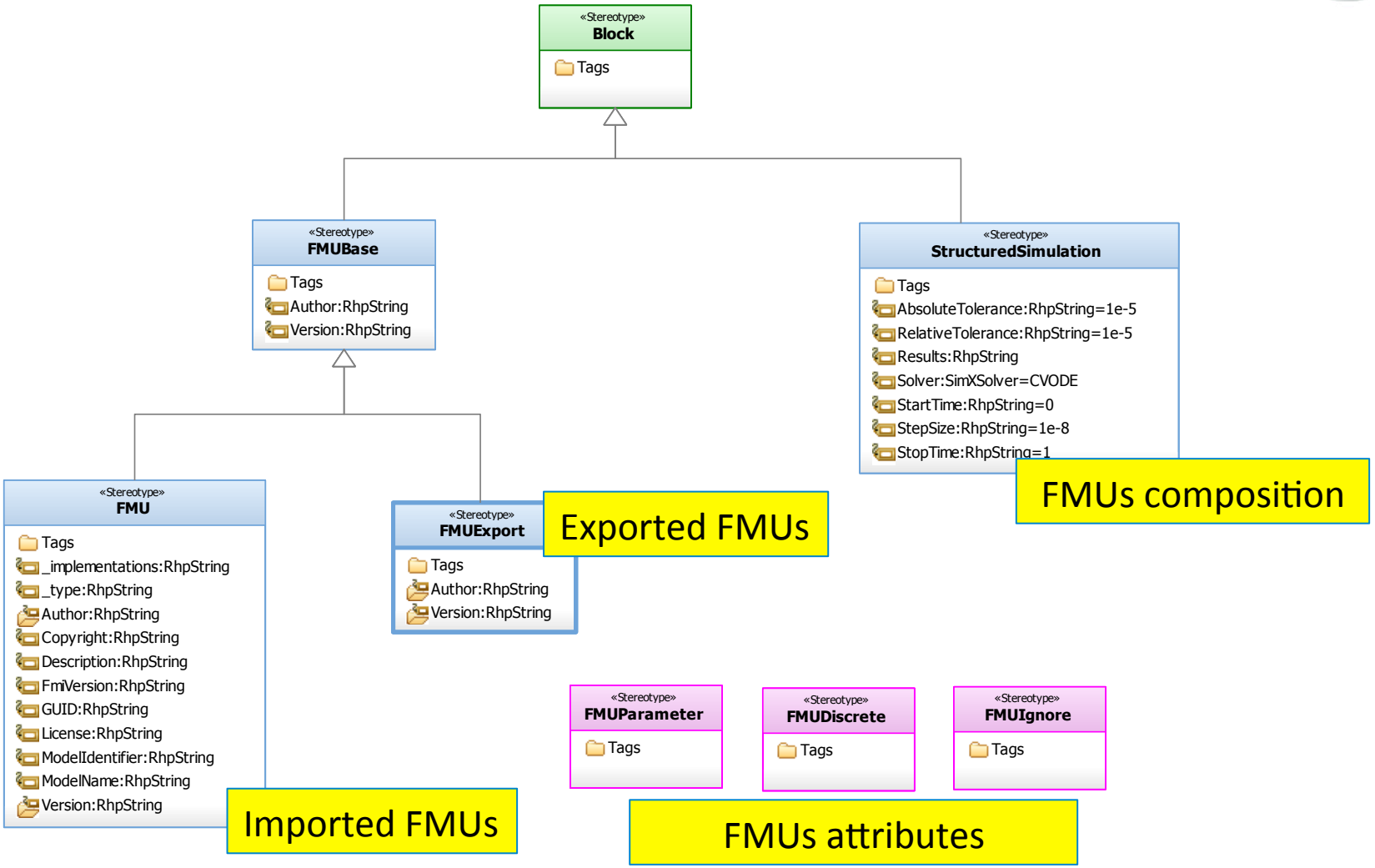
Define simulation parameters in SysML



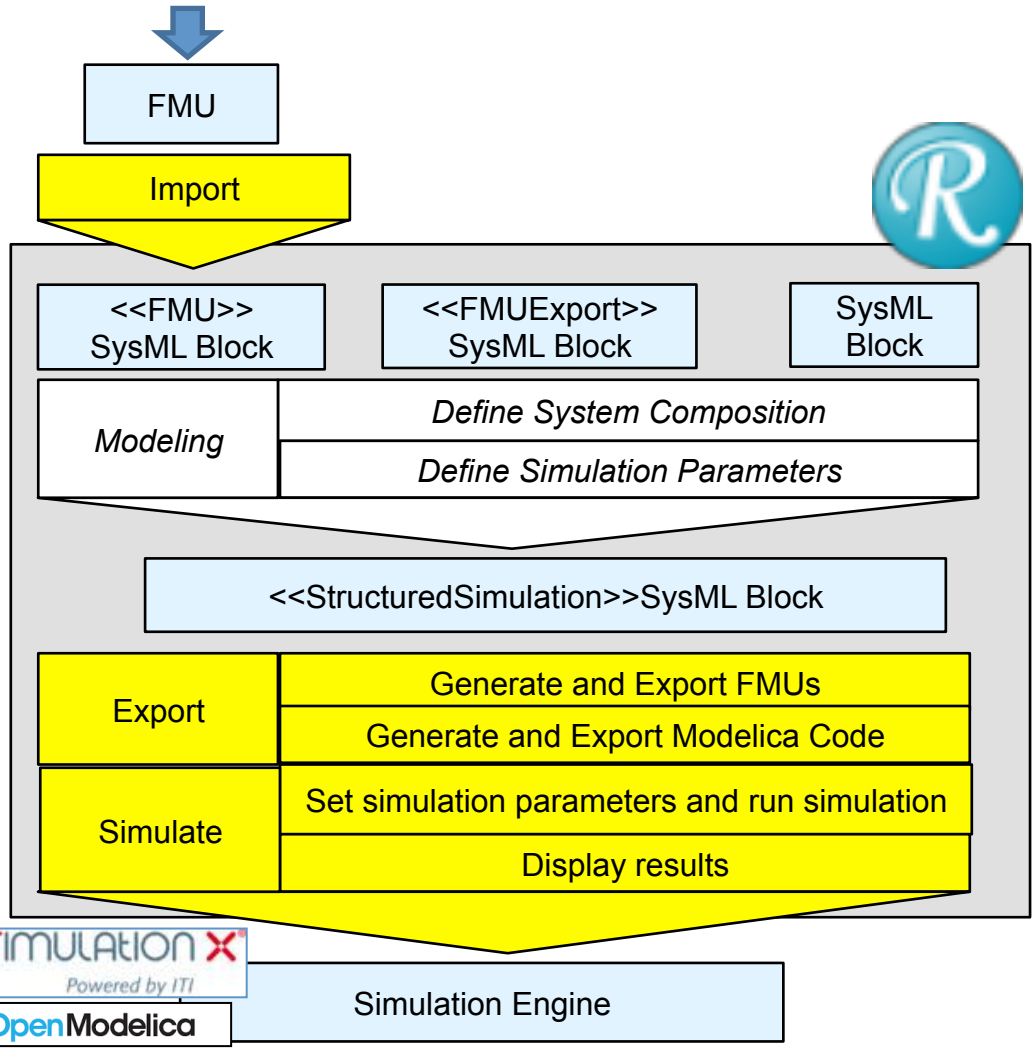
FMU generation, model export and simulation in SimX



FMI in SysML


«Stereotype»
Block
Tags
«Stereotype»
FMUBase
Tags
Author:RhpString
Version:RhpString
«Stereotype»
StructuredSimulation
Tags
AbsoluteTolerance:RhpString=1e-5
RelativeTolerance:RhpString=1e-5
Results:RhpString
Solver:SimXSolver=CVODE
StartTime:RhpString=0
StepSize:RhpString=1e-8
StopTime:RhpString=1
FMUs composition
«Stereotype»
FMU
Tags
_implementations:RhpString
_type:RhpString
Author:RhpString
Copyright:RhpString
Description:RhpString
FmiVersion:RhpString
GUID:RhpString
License:RhpString
ModelIdentifier:RhpString
ModelName:RhpString
Version:RhpString
Imported FMUs
«Stereotype»
FMUExport
Tags
Author:RhpString
Version:RhpString
Exported FMUs
«Stereotype»
FMUParameter
Tags
«Stereotype»
FMUDiscrete
Tags
«Stereotype»
FMUIgnore
Tags
FMUs attributes

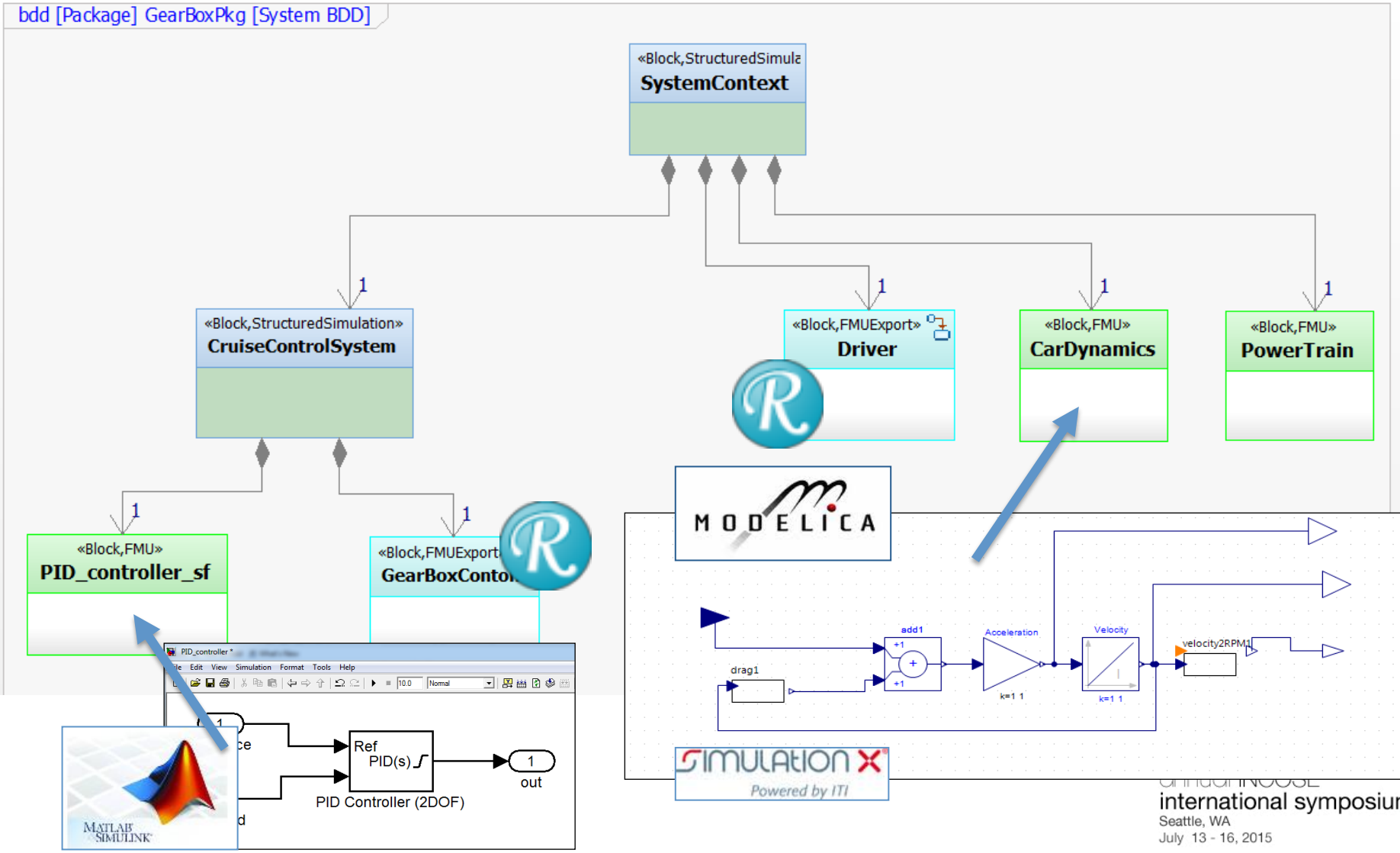
FMI in Rhapsody



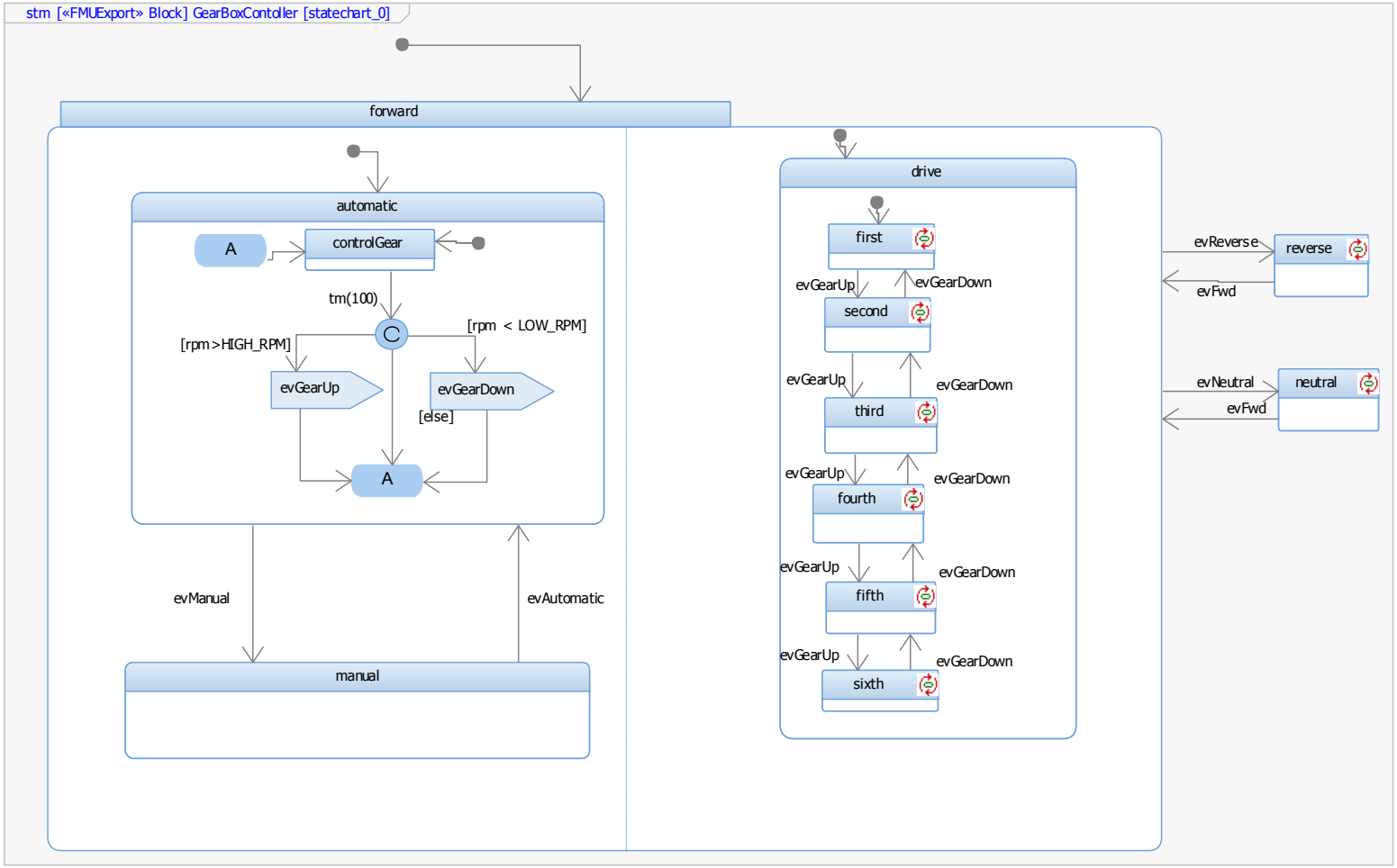
Features:

- Import FMI 1.0 (CS and ME)
- Generation FMUs from SysML
  - FMI 1.0 ME
  - no limitation on internal communications
- Hierarchical composition
- Net-list in Modelica
- Automatic plots generation

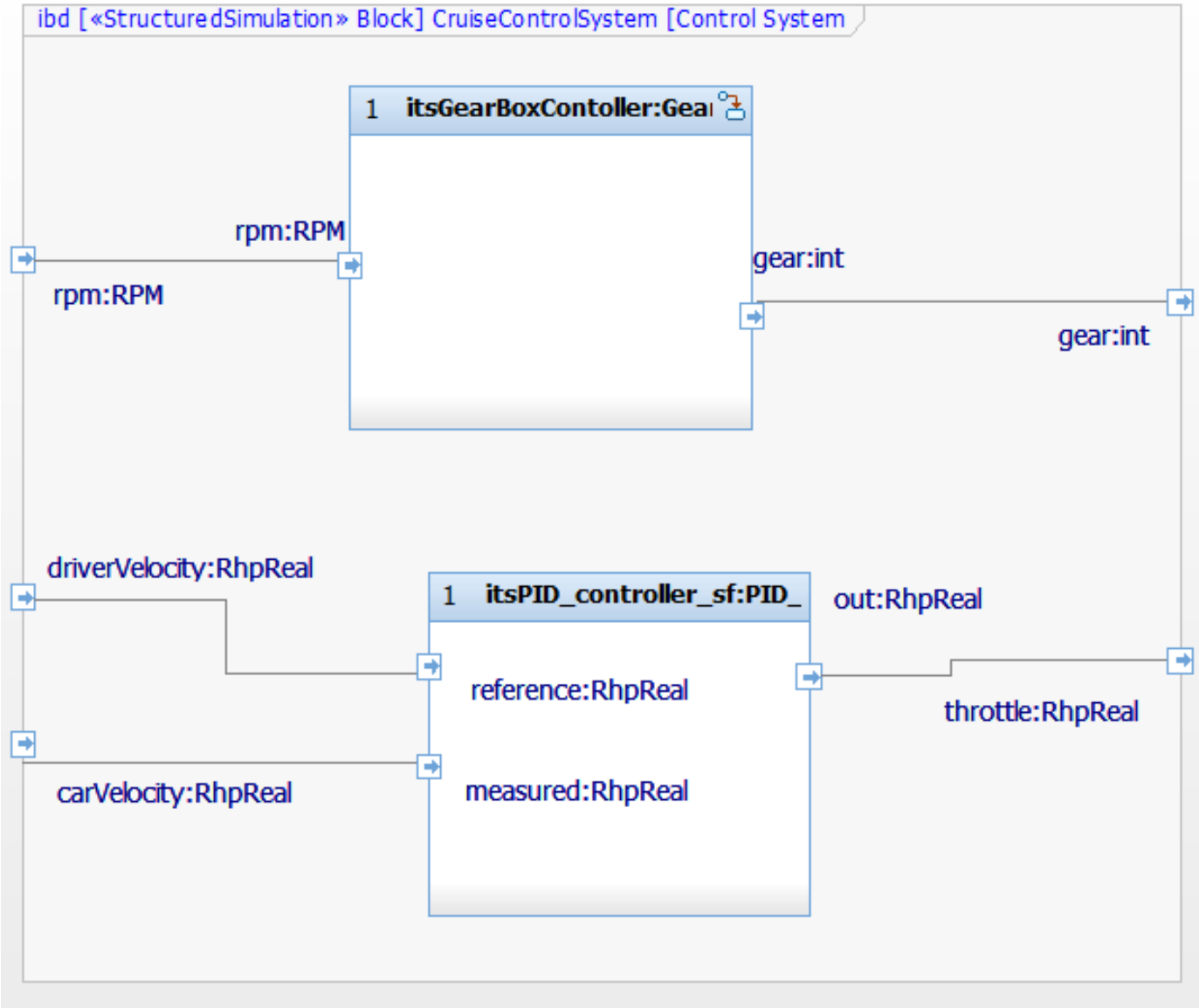
Cruise Control – block diagram



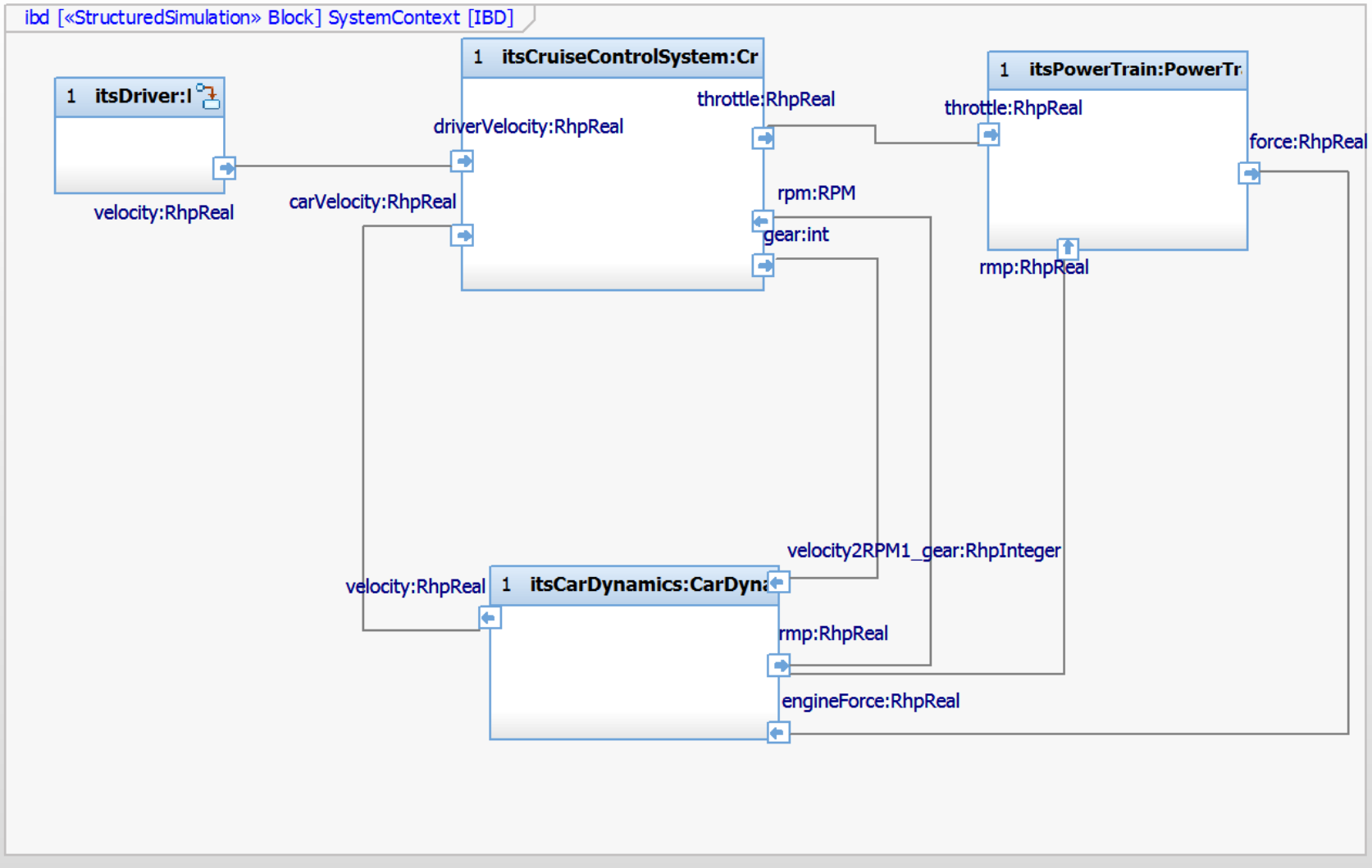
Cruise Control – Gearbox Controller



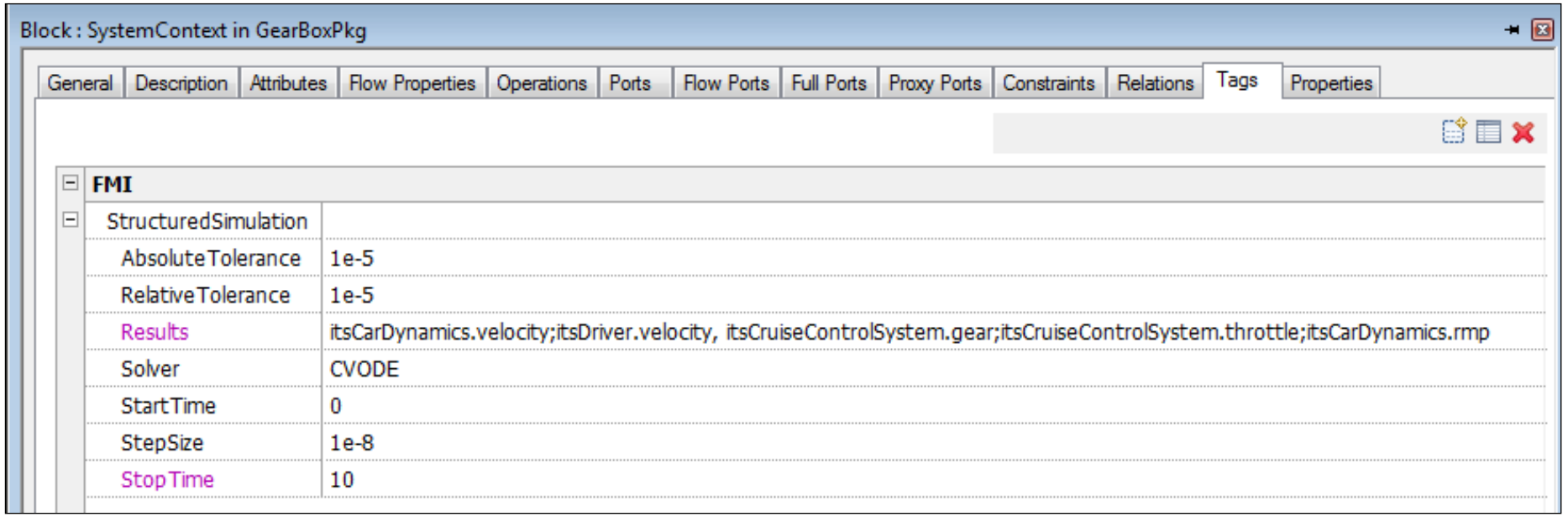
Cruise Control – internal structure



Car – internal structure

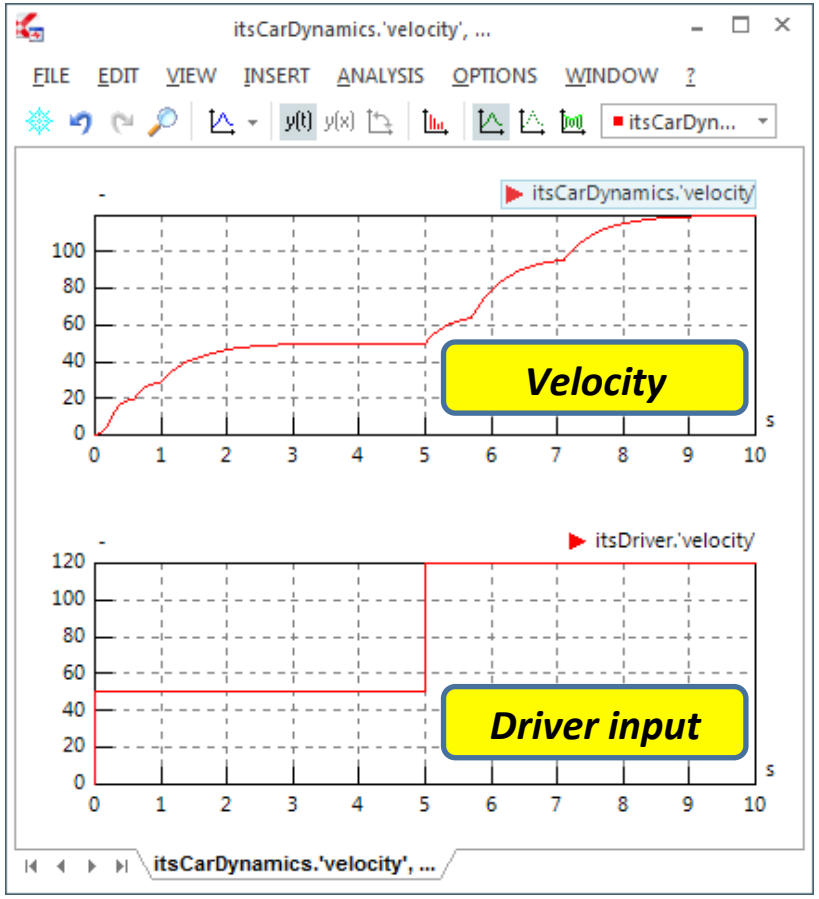


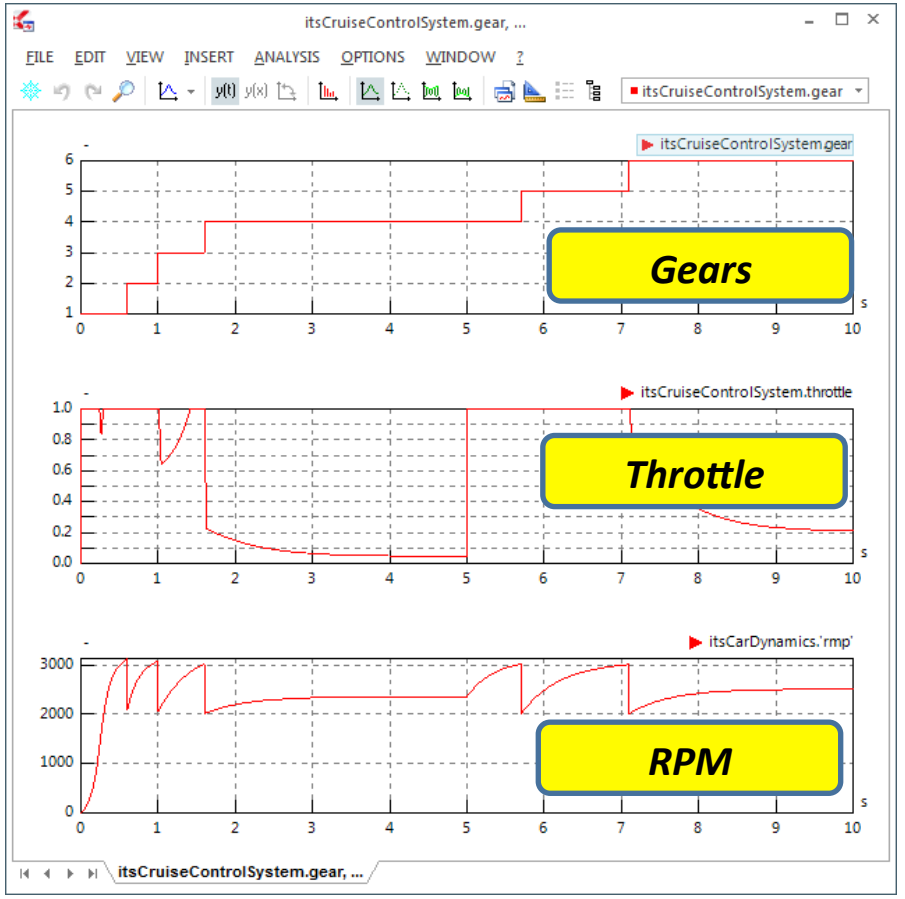
Simulation parameters



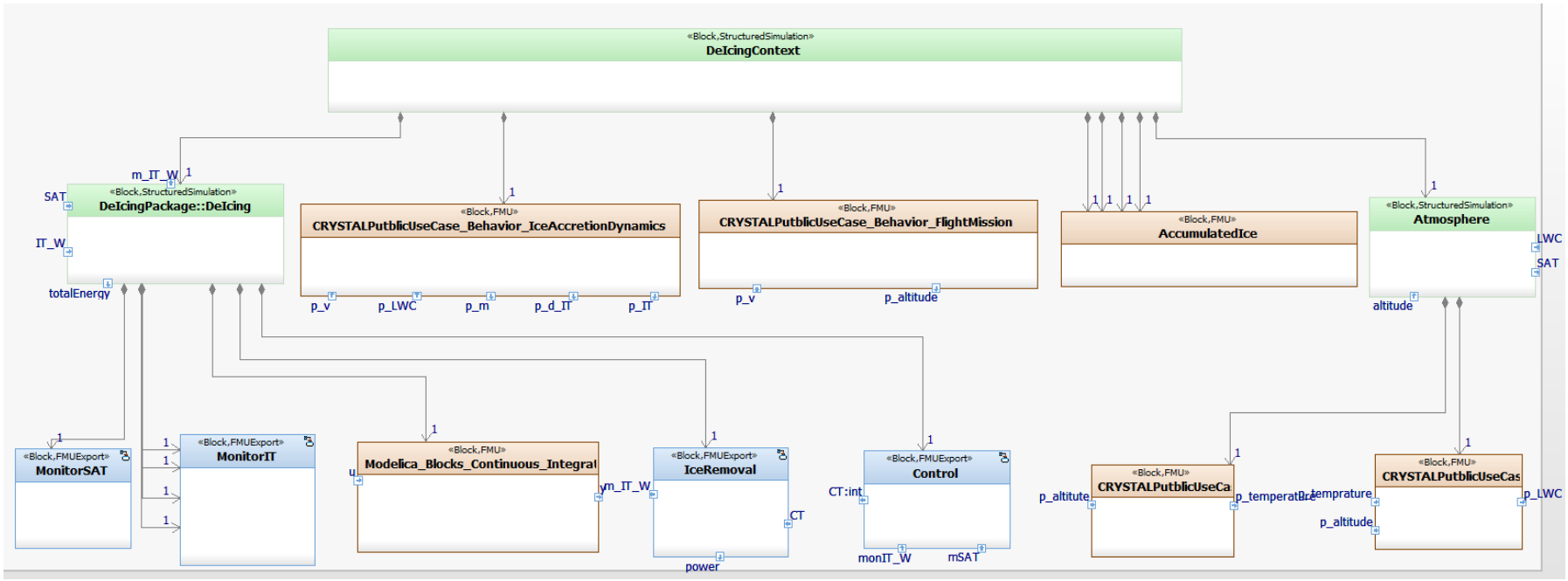
Top level block contains the simulation parameters

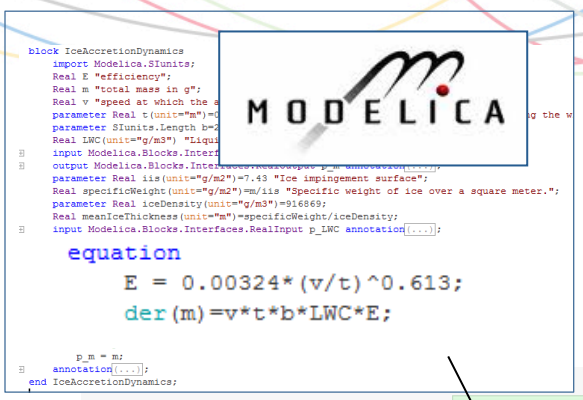
Simulation results

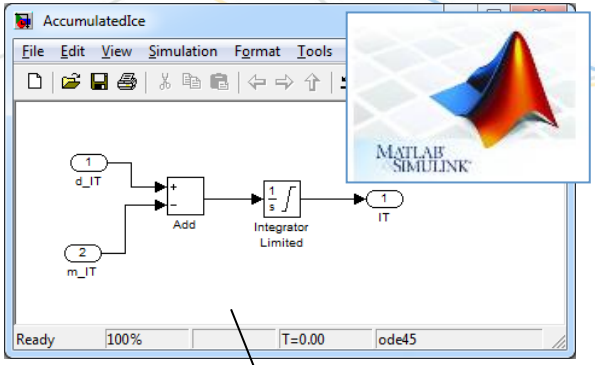


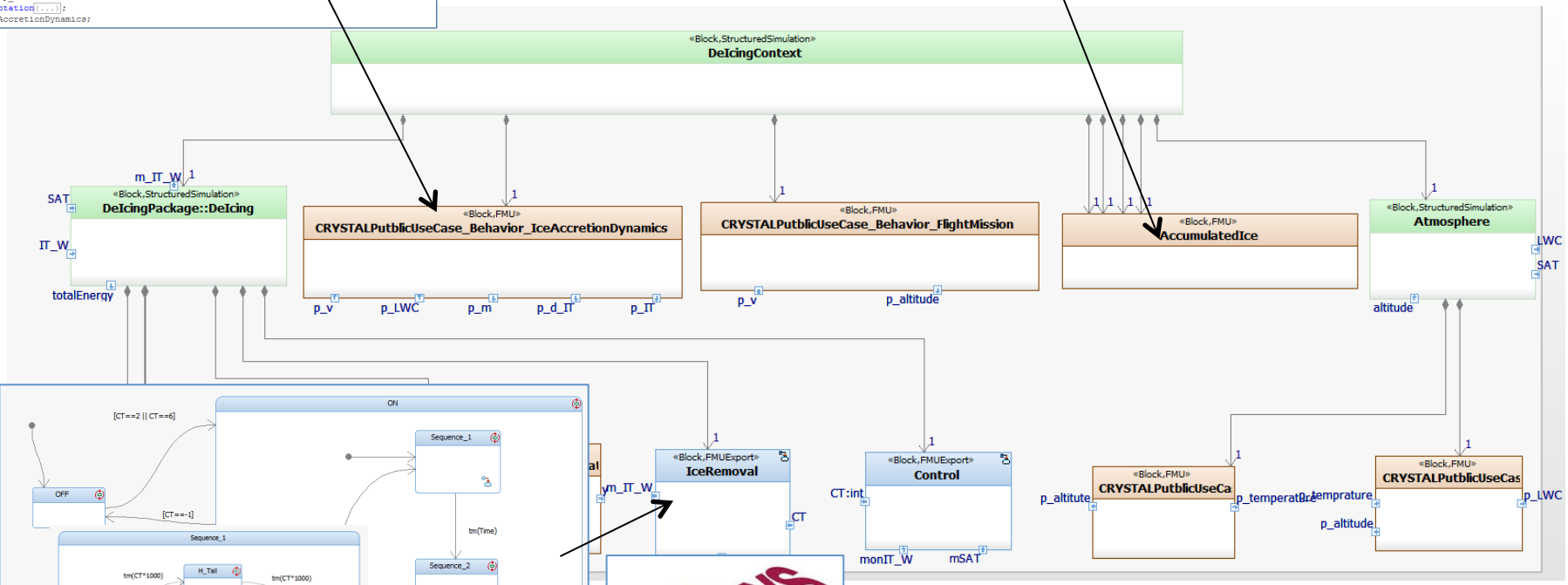


De-icing System





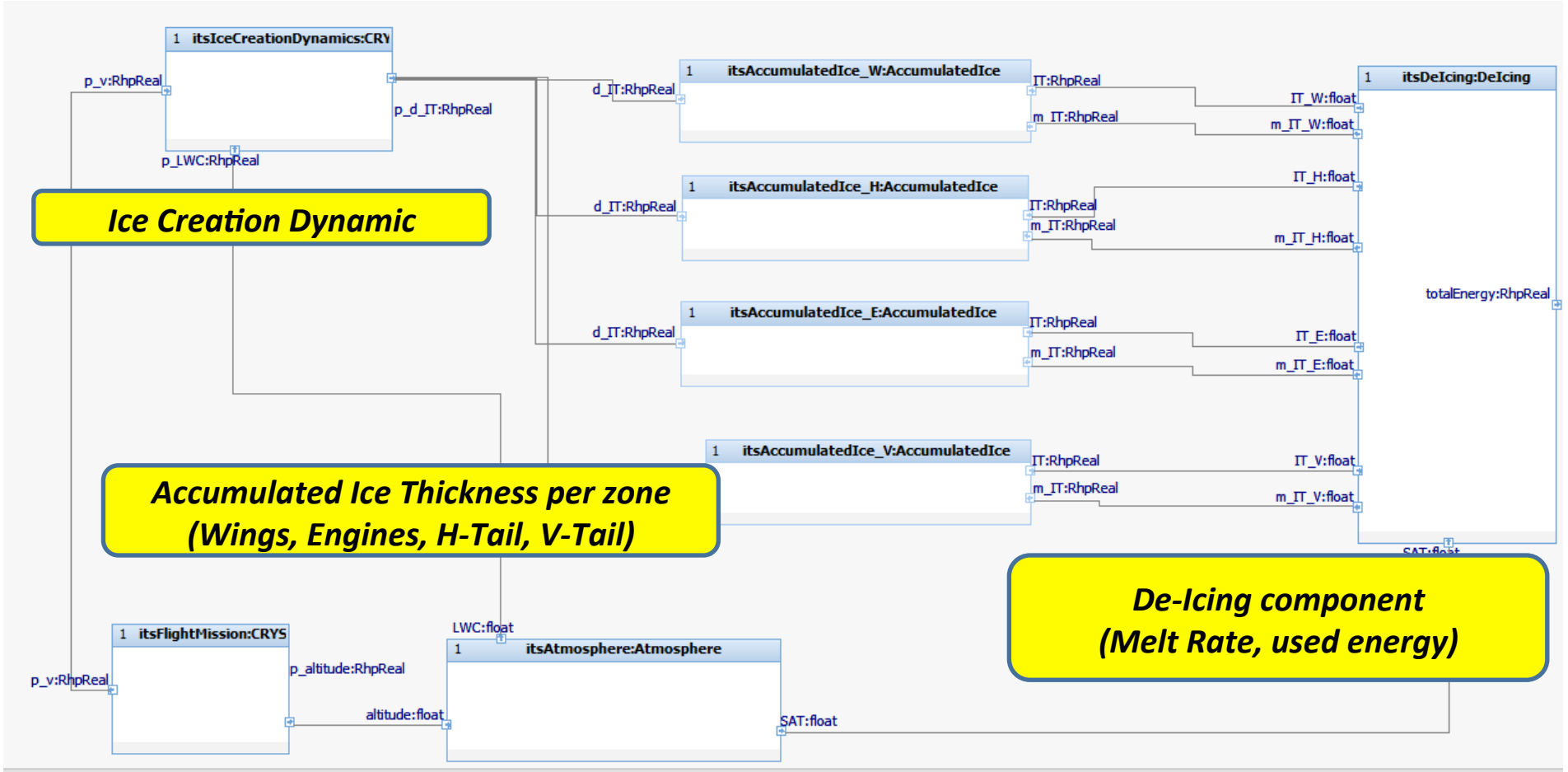




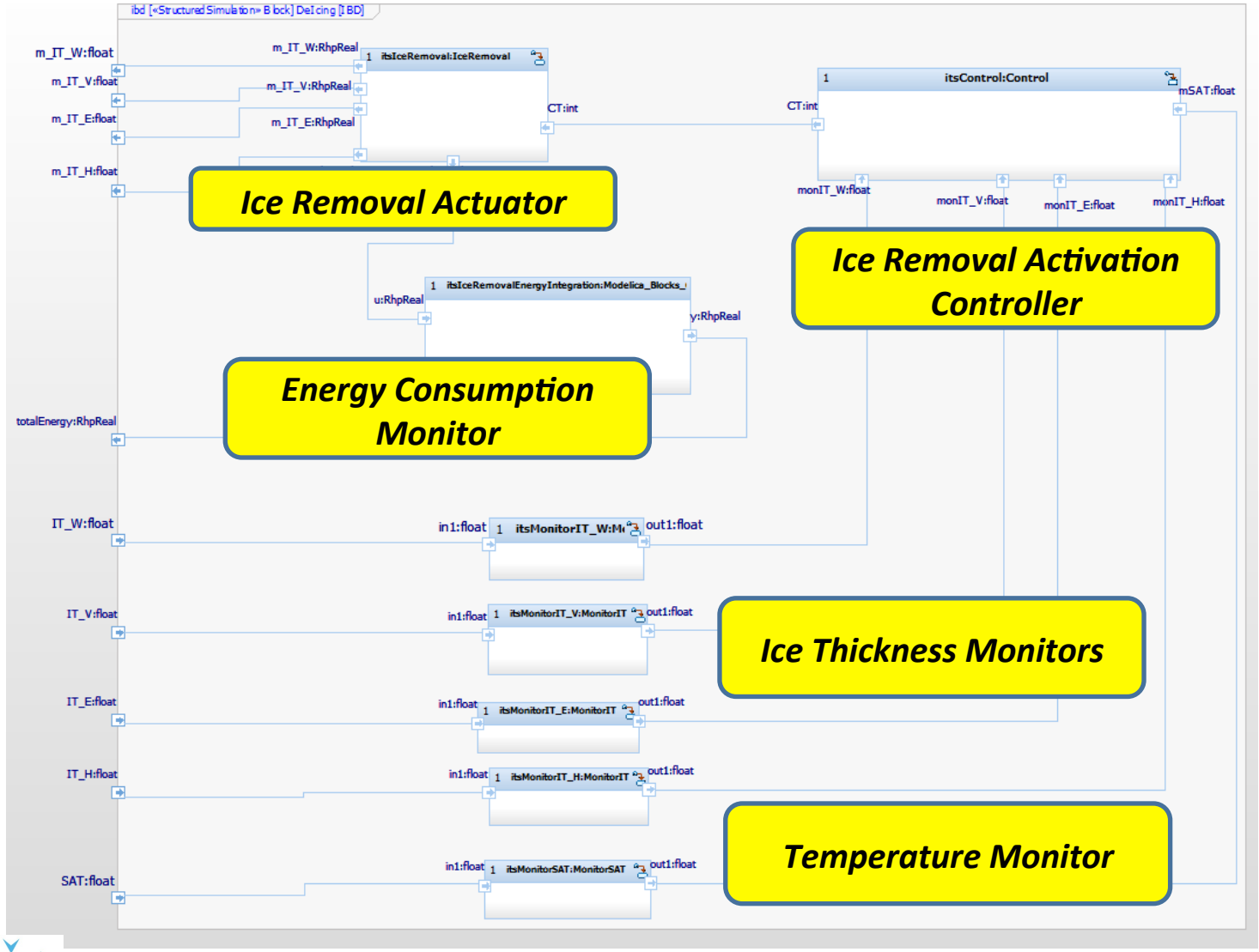
CRYSTAL

25th anniversary annual INCOSE international symposium
Seattle, WA
July 13 - 16, 2015

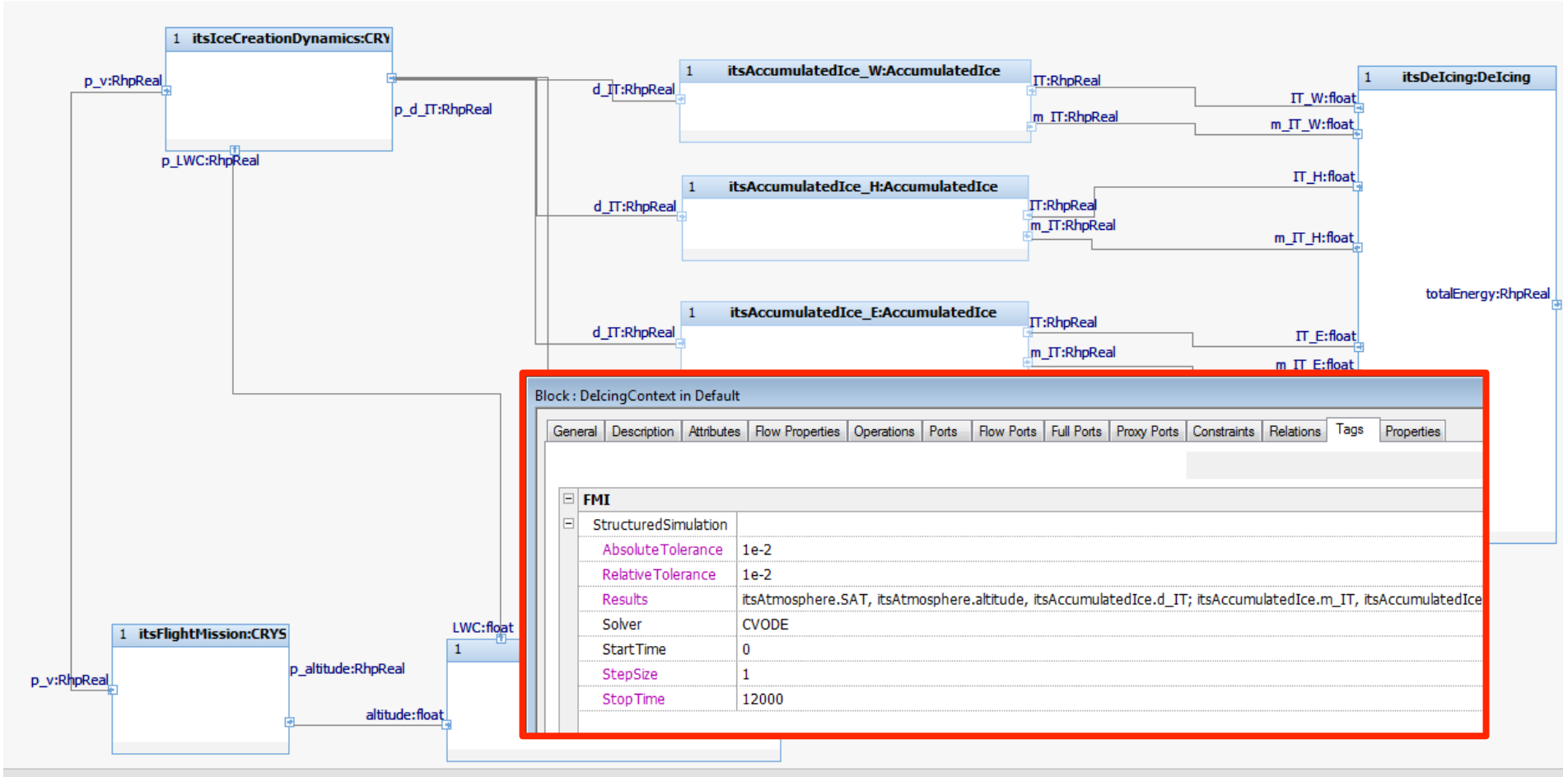
De-Icing Context IBD



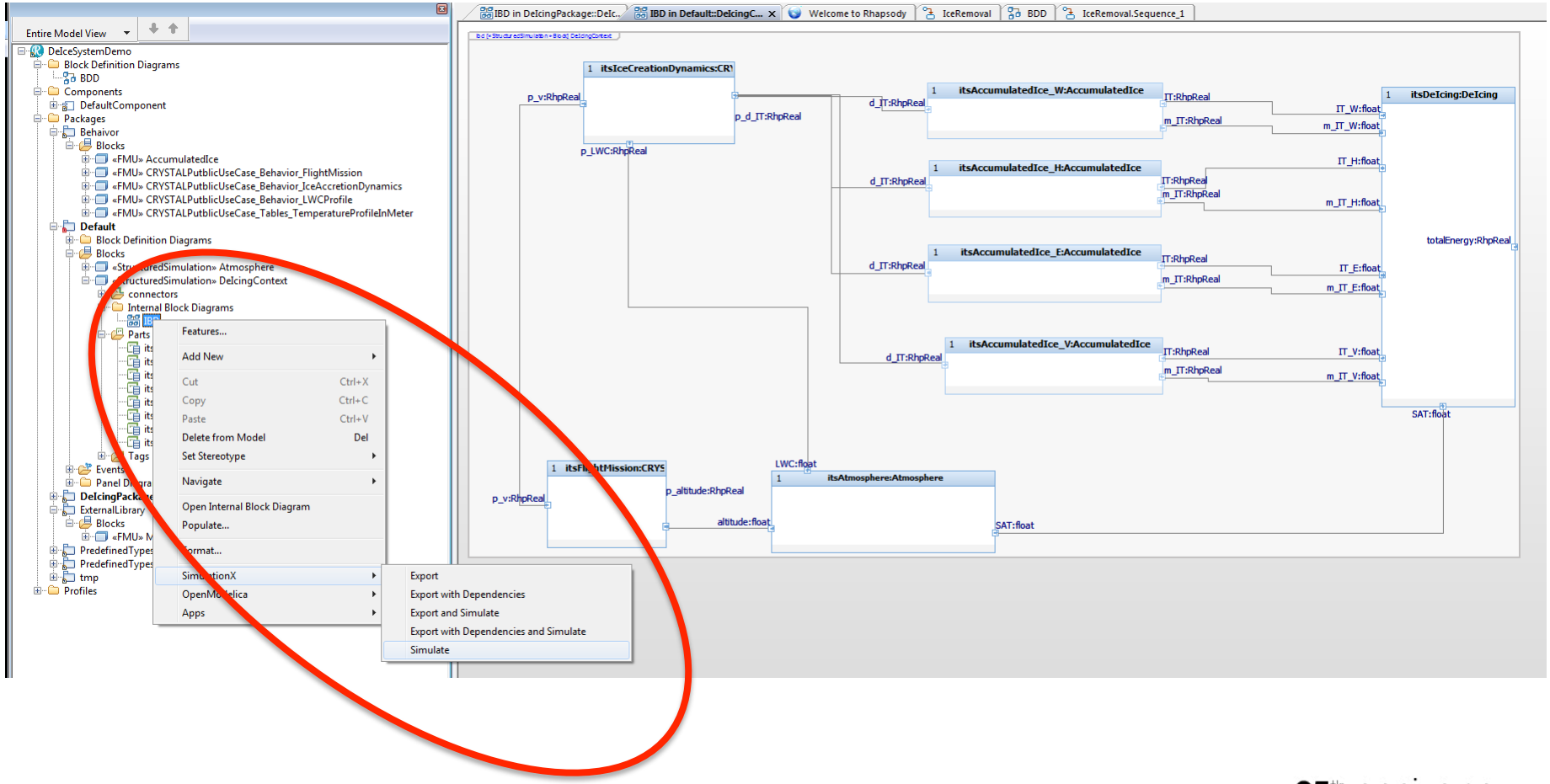
De-Icing IBD


ibd [«Structured Simulation» Block] DeIcing [IBD]
m_IT_W:float
m_IT_V:float
m_IT_E:float
m_IT_H:float
m_IT_W:RhpReal
m_IT_V:RhpReal
m_IT_E:RhpReal
itsIceRemoval:IceRemoval
CT:int
itsControl:Control
mSAT:float
monIT_W:float
monIT_V:float
monIT_E:float
monIT_H:float
Ice Removal Actuator
Ice Removal Activation Controller
itsIceRemovalEnergyIntegration:Modelica_Blocks_
u:RhpReal
y:RhpReal
Energy Consumption Monitor
totalEnergy:RhpReal
IT_W:float
IT_V:float
IT_E:float
IT_H:float
SAT:float
in1:float
out1:float
itsMonitorIT_W:M
itsMonitorIT_V:MonitorIT
itsMonitorIT_E:MonitorIT
itsMonitorIT_H:MonitorIT
itsMonitorSAT:MonitorSAT
Ice Thickness Monitors
Temperature Monitor

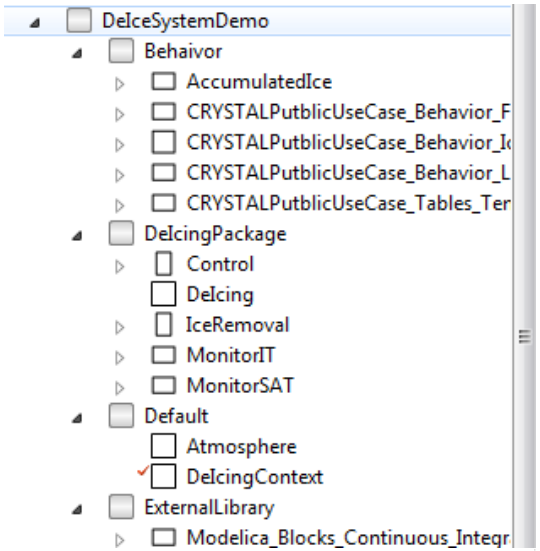
Simulation Parameters

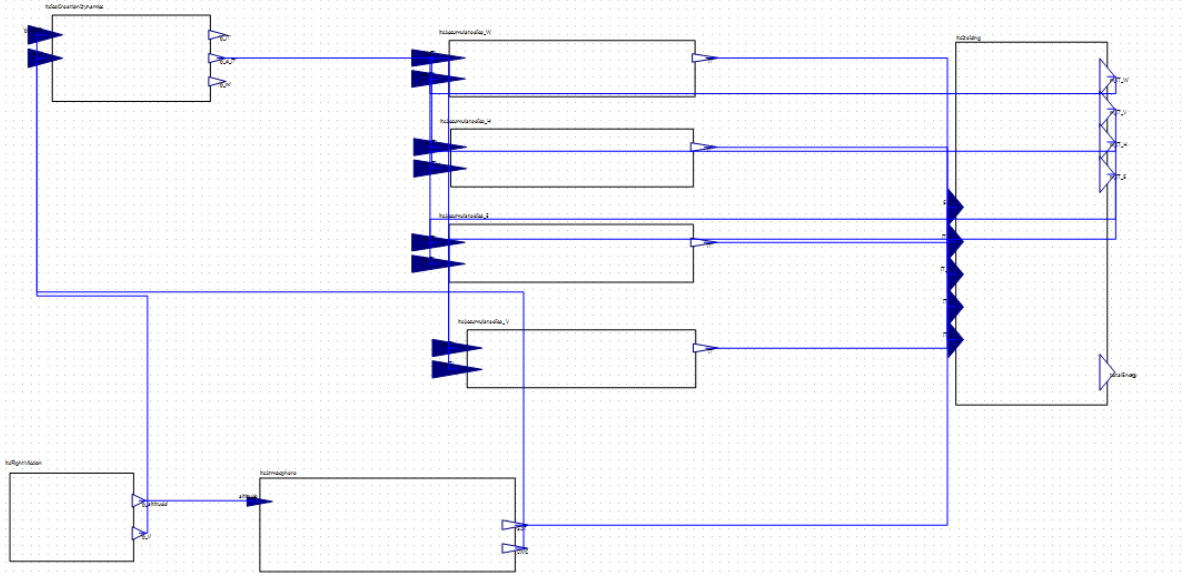


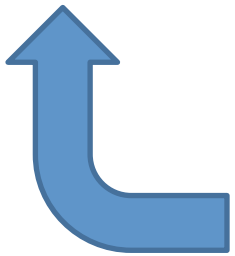
Export and simulation

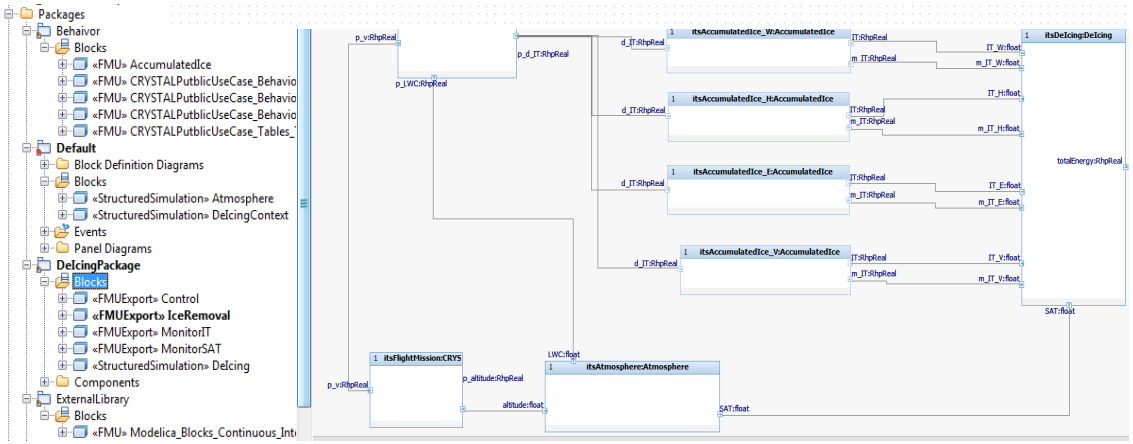


Structure in OpenModelica

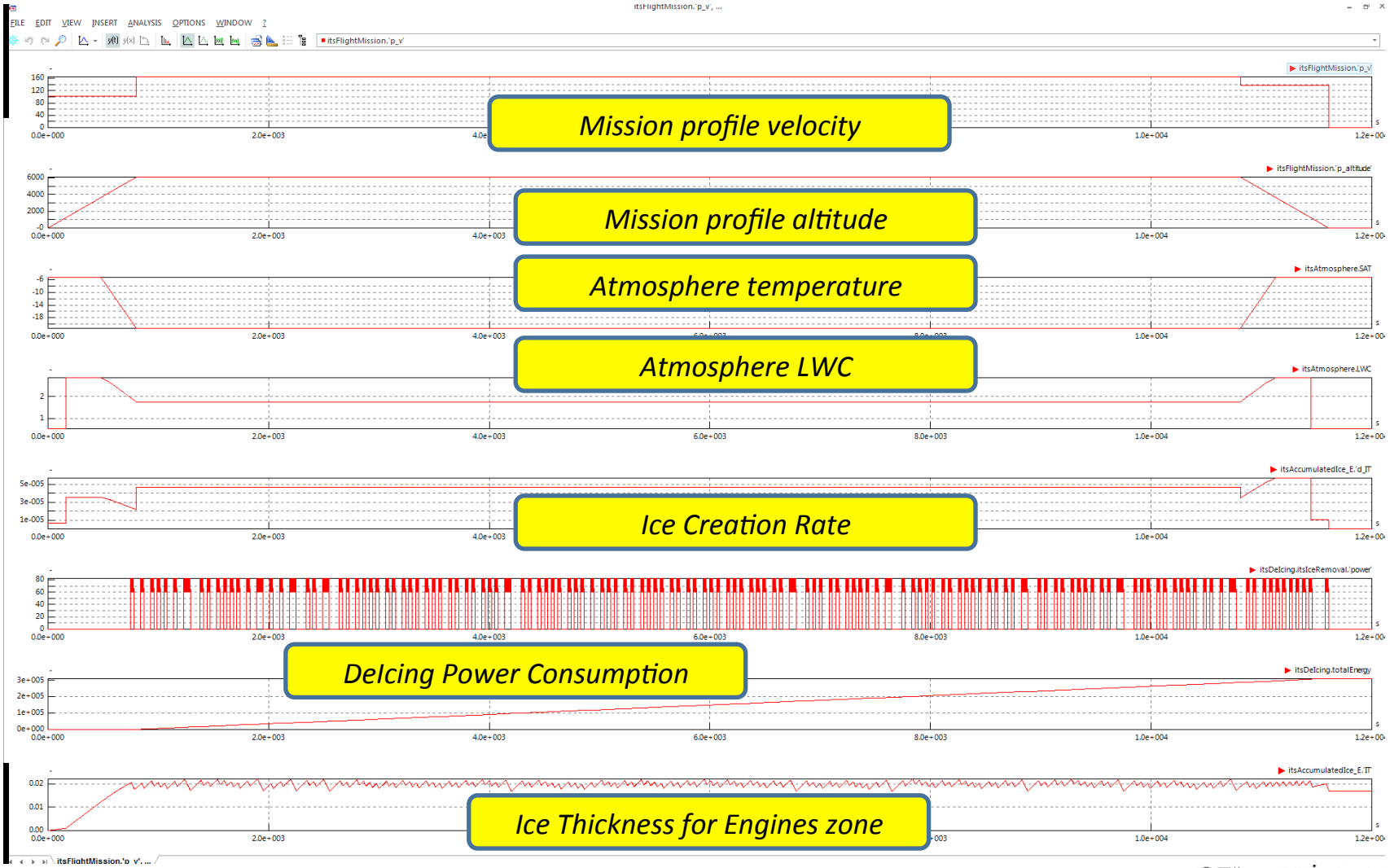








Simulation Results



FMI current drawbacks

- FMI for Co-simulation lacks event handling – a-periodic discrete models cannot be properly handled.
- No support for “absent signal” notion
- The standard does not dictate the composition method and language, thus tools use many incompatible approaches.

Future directions

- Address the above…
- Exploring FMU in-cloud execution and simulation as a service
- Distributed Simulation
- Models and IP management

Disclaimer: The materials and the messages in this presentation are unrelated to any current IBM offering or future plans and should not constitute a basis for purchasing decisions.

Thank you!!