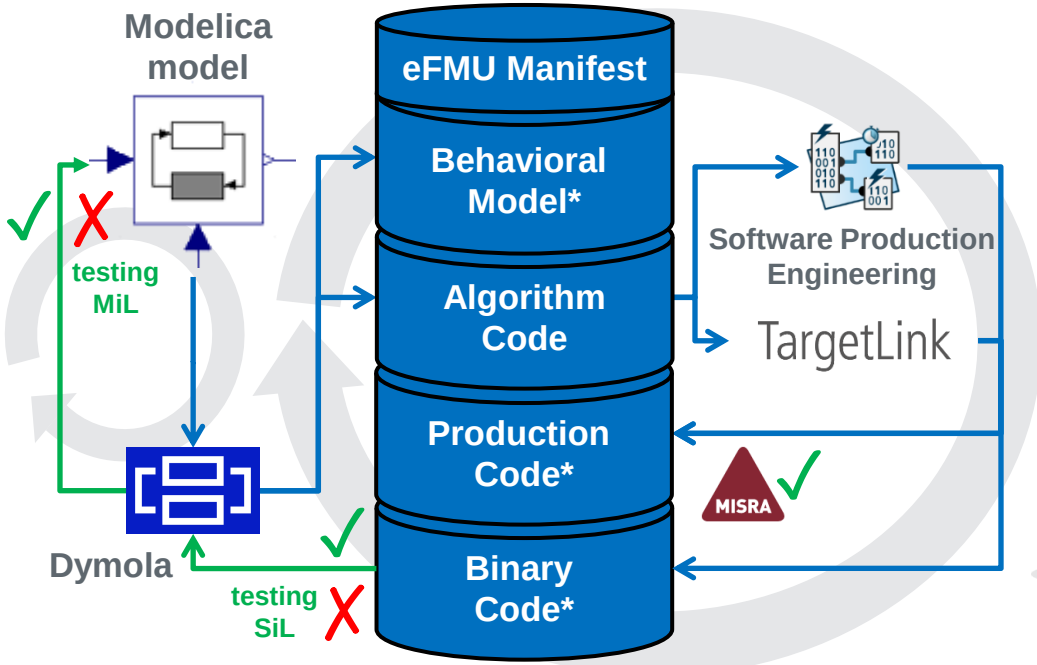

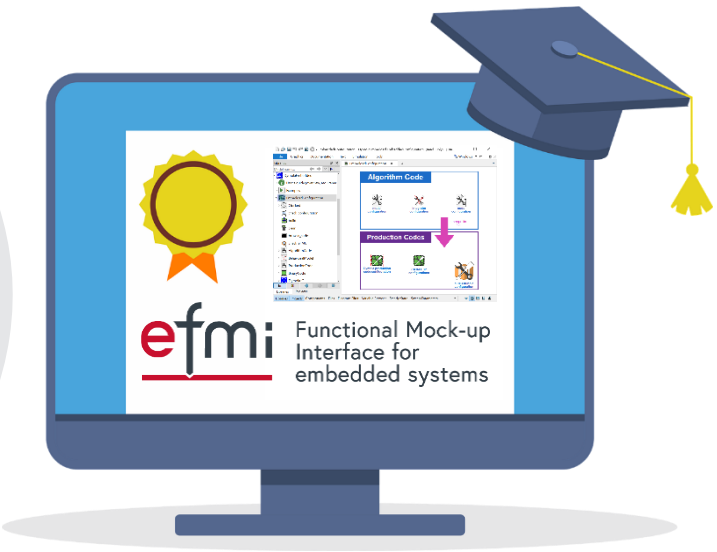

Part 4: Advanced demonstrators

eFMI®: A beginner's overview and hands-on
– 16th International Modelica Conference – 8th of September 2025 –

Christoff Bürger
Dassault Systèmes
Christoff.Buerger@3ds.com

eFMI® tutorial – Agenda

Part 1: eFMI® motivation and overview (40 min)

Part 2: Running use-case introduction (10 min)

Part 3: Hands-on in Dymola and Software Production Engineering (25 min)

Coffee break (30 min)

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Part 4: Advanced demonstrators (20 min)

Part 5 (industry case-study): eFMI based thermal management system (TMS) development for fuel cell electric vehicles (FCEV) (20 min)

Part 6: Outlook and conclusion (5 min)

Tutorial leader:
Christoff Bürger

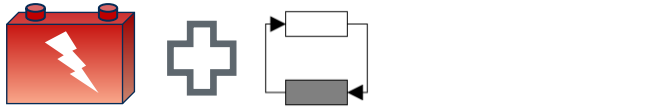
Presenter:
Daeoh Kang

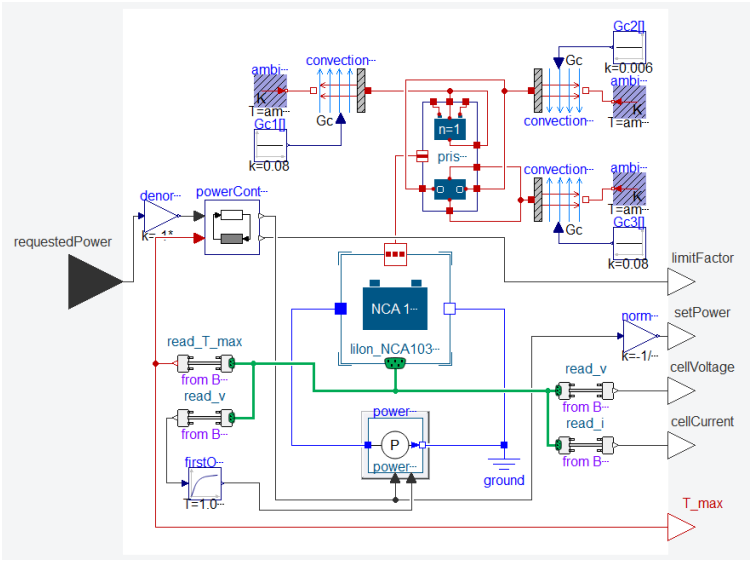
Functional Mock-up Interface for embedded systems

Simple battery management system (BMS)

BMS operating a passive-cooled battery to meet power requests as good as possible without endangering the battery due to overheating:

- BMS = battery cell model + control logic
- Battery cell model: Hard real-time simulation of electric & thermal behavior of battery (prediction model, virtual sensor)
- Control logic: Limits requested power to ensure safe operation based on simulated cell core temperature
- Inputs: Power request
- Tunable parameters: Ambient temperature
- Outputs: Actually provided power & battery status (cell core temperature, voltage, current, etc)



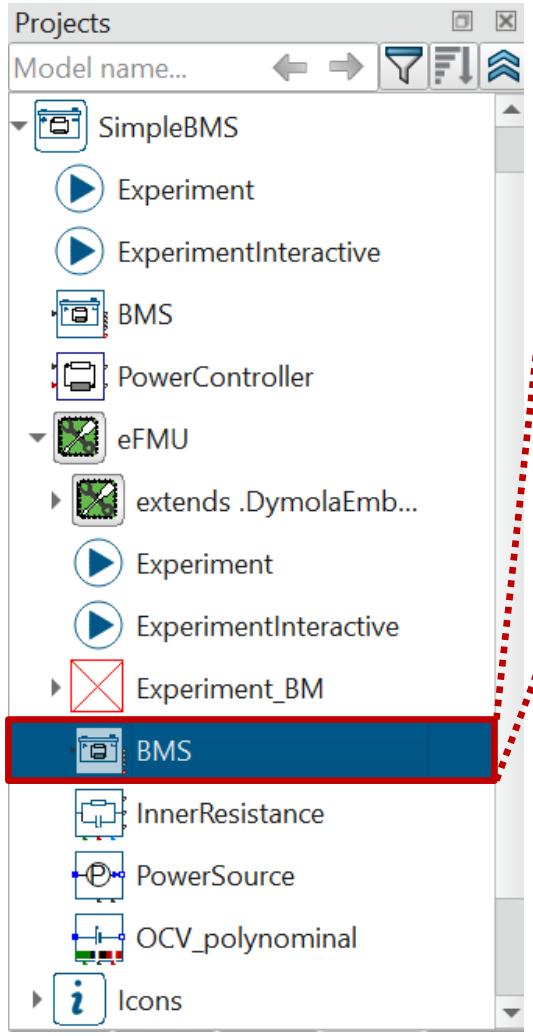


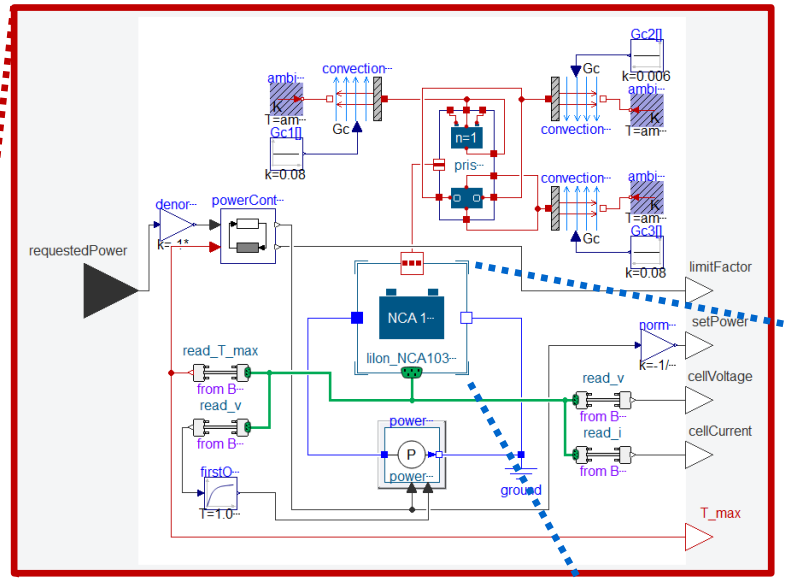
Cell model from commercial Dymola Battery library:

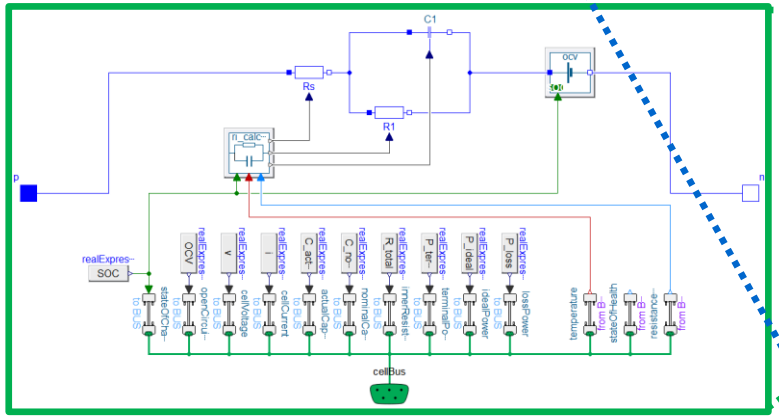
- From stock model of real battery reused (Panasonic NCA 103450 2350mAh)

efmi Functional Mock-up Interface for embedded systems

Simple BMS: Model

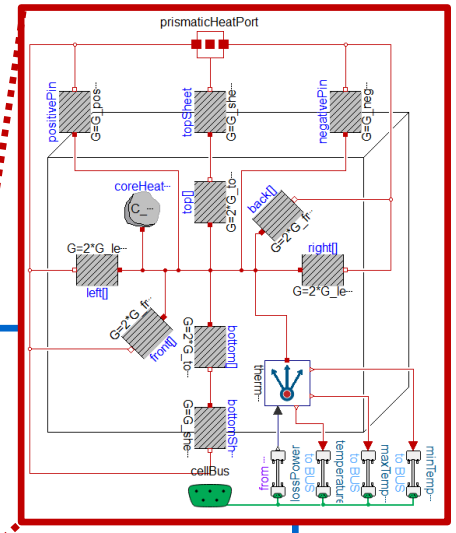


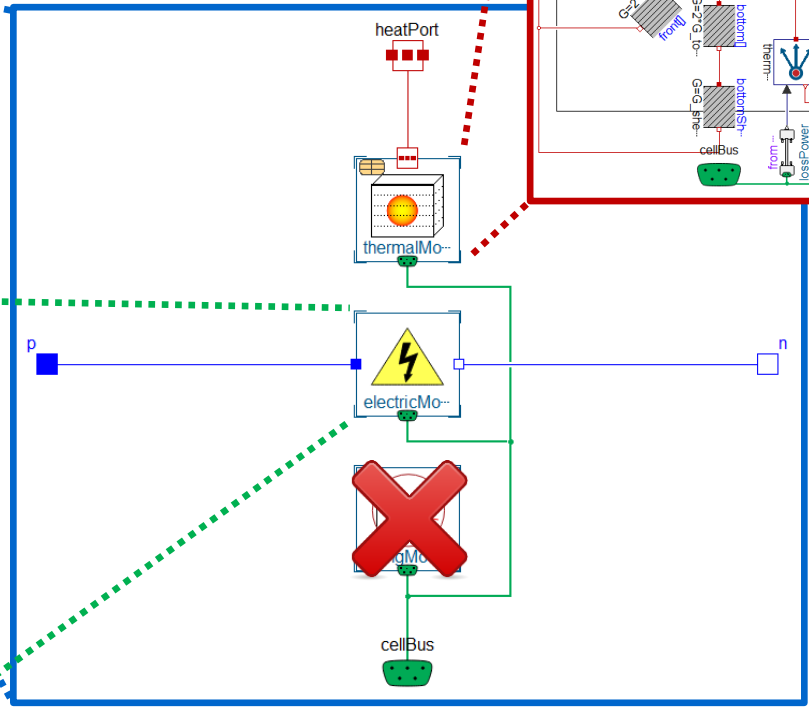




Model distributed with tutorial:

`reference-models\Part-4\SimpleBMS`





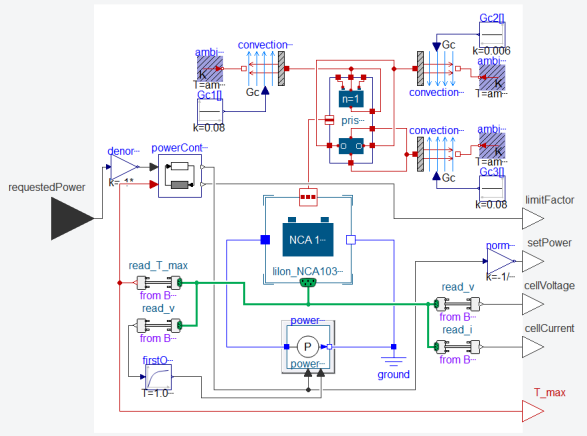
Simple BMS: Embedded target

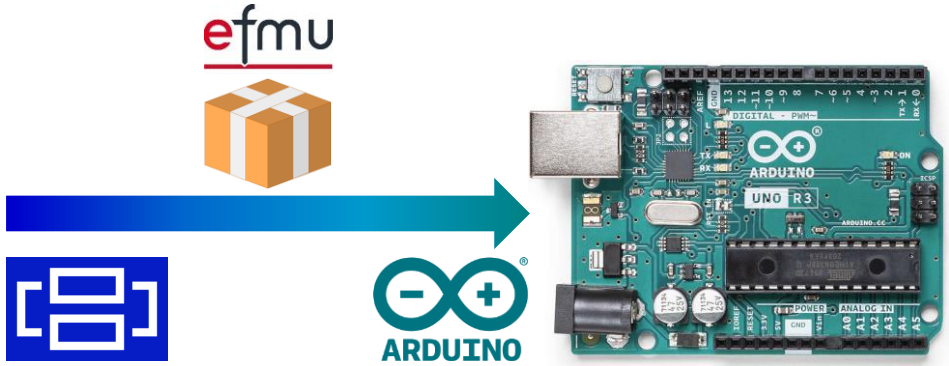
BMS deployed on Arduino® Uno Rev3:

- 32 KB flash memory, 2 KB SRAM, 16 MHz (BMS requires ~50% of program and data memory)
- Sampling period 10 ms, one DoStep() requires ~2 ms

Dymola (via eFMPy) supports export of production code container as Arduino® sketch:

- Template comments denote where in- and outputs have to be connected and recalibration is possible
- Code for scheduling and to test execution-times is generated
- Arduino® IDE can be used for further development, deployment and hardware-in-the-loop (HiL) testing





efmi Functional Mock-up Interface for embedded systems

Simple BMS: Demo

Check it out yourself at the Dassault Systèmes booth!

Christoff Bürger

DASSAULT SYSTEMES

Christopher Stromberger

DASSAULT SYSTEMES

Torsten Sommer

DASSAULT SYSTEMES

Neural quarter vehicle model (QVM)

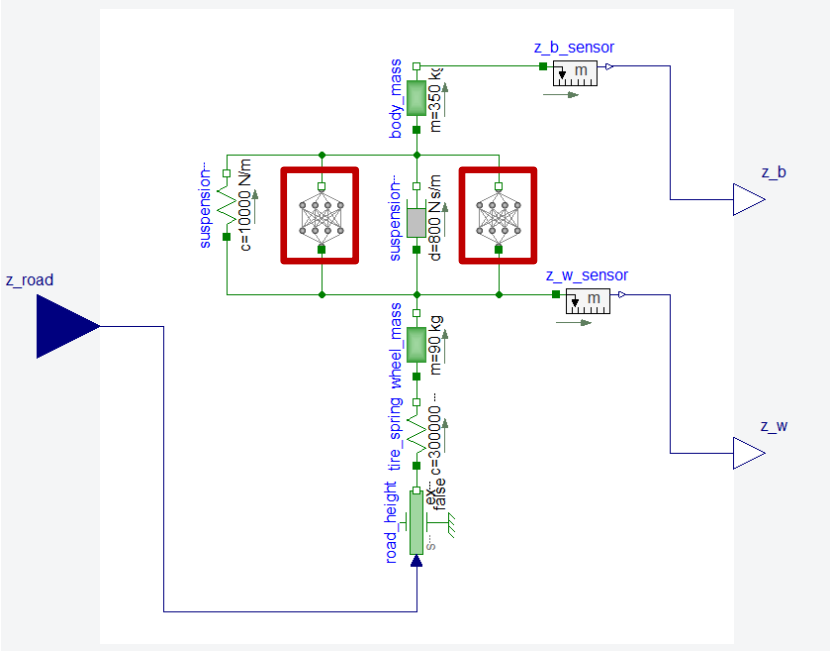
Prediction model for the vertical dynamics of a quarter vehicle model (QVM) incorporating the unknown non-linear behavior of the suspension (spring and damper) via neural networks:

- Open-source (`eFMI_TestCases.M11_NeuralQVM`)
- Trained non-linear suspension behavior additive to linear physics
- NNs as Modelica models of `eFMI.NeuralNetworks` package (open-source library for equation-based NNs, but no training)
- NN parameters (weights & biases) can be online recalibrated (eFMI tunable parameters)
- Dymola preserves multi-dimensional tensor-flows in generated GALEC code (not scalarized)

Typical use-cases of QVM predictors:

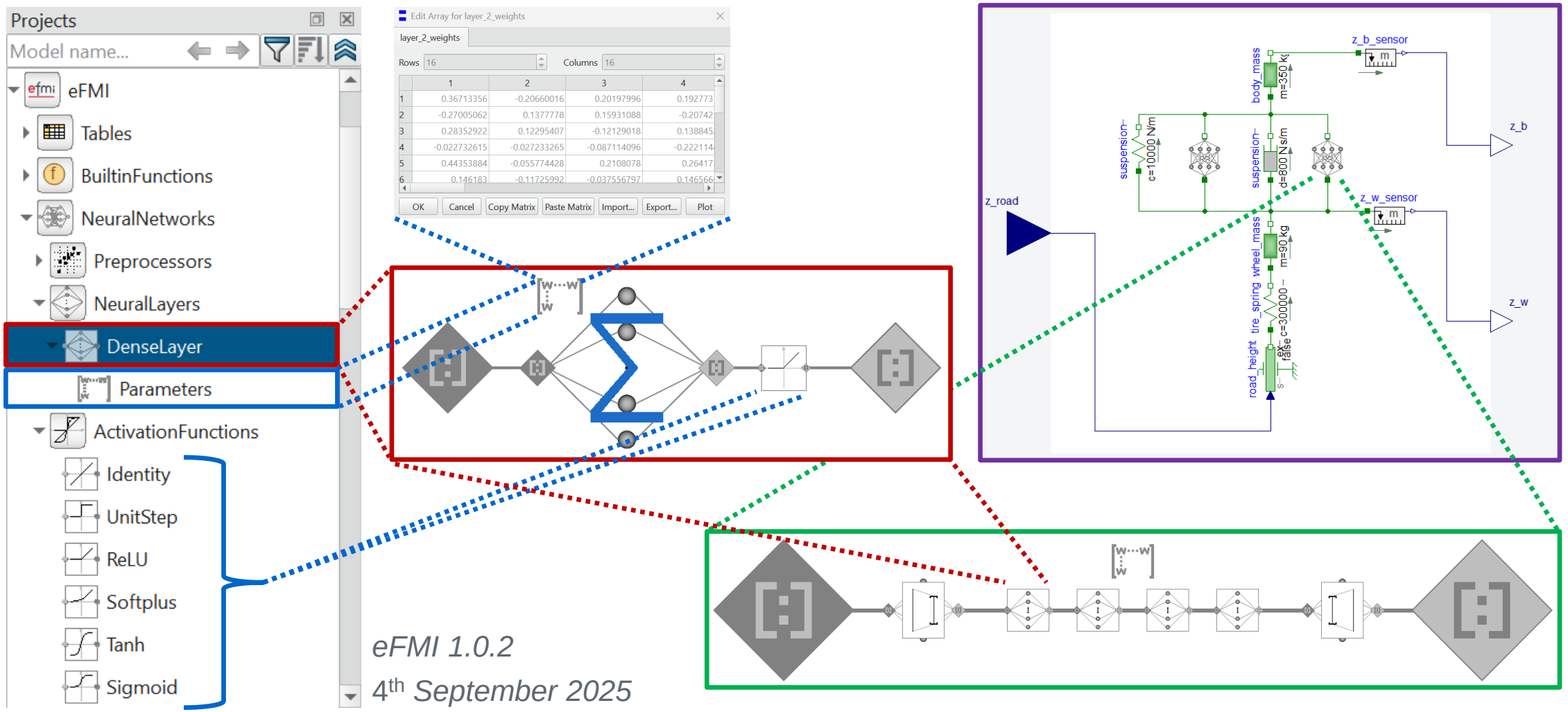
- Semi-active suspension control
- Suspension & wheel fault detection

Paper: Kamp, Bürger, Rein, Brembeck. ”*Hybrid Simulation Models for Embedded Applications: A Modelica and eFMI approach*”.
Wednesday, 9:15, Control & AI session

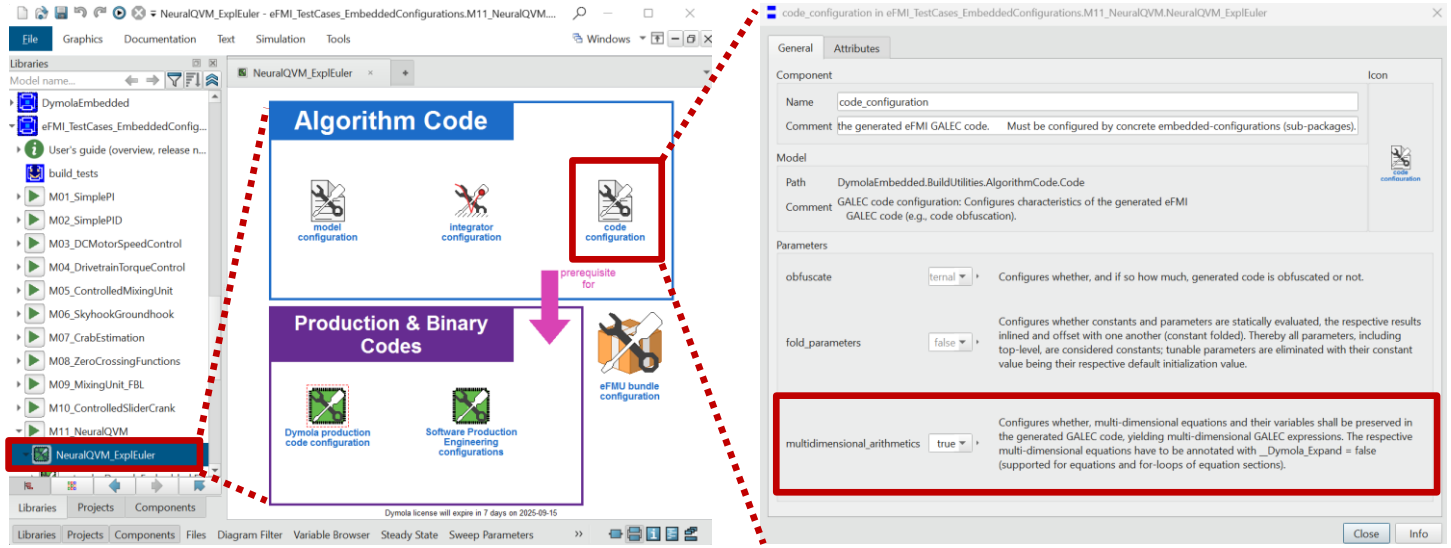


Functional Mock-up Interface for embedded systems

Neural QVM: NN modeling



Neural QVM: Tensor-flow & multi-dimensional GALEC code



Dymola 2026x prototype:
Preserve multi-dimensional equations (avoid scalarization).

NN code size dominated by weights & biases:
~29.3 KB GALEC
~4.8 KB data memory (32-Bit floating-point values)

```
'damperNN.layer_2.y[1]' := max(0.0,
    ((((((((((((((((self.'damperNN.layer_2_weights[1,1]' * 'damperNN.layer_1.y[1]')
    + (self.'damperNN.layer_2_weights[1,2]' * 'damperNN.layer_1.y[2]'))
    + (self.'damperNN.layer_2_weights[1,3]' * 'damperNN.layer_1.y[3]'))
    + (self.'damperNN.layer_2_weights[1,4]' * 'damperNN.layer_1.y[4]'))
    ...
    + (self.'damperNN.layer_2_weights[1,16]' * 'damperNN.layer_1.y[16]'))
    + self.'damperNN.params.layer_2_bias[1]'));
'damperNN.layer_2.y[2]' := max(0.0,
    ((((((((((((((((self.'damperNN.layer_2_weights[2,1]' * 'damperNN.layer_1.y[1]')
    + (self.'damperNN.layer_2_weights[2,2]' * 'damperNN.layer_1.y[2]'))
    + (self.'damperNN.layer_2_weights[2,3]' * 'damperNN.layer_1.y[3]'))
    ...
    + self.'damperNN.layer_2_bias[2]'));
...
```

Scalarized GALEC code for QVM ≈117 KB

```
'damperNN.denseLayer2.y' :=
    ((self.'damperNN.layer_2_weights' * 'damperNN.denseLayer1.y')
    + self.'damperNN.layer_2_bias');
for i in 1 : 16 loop
    'damperNN.denseLayer2.y'[ i ] :=
        max(0.0, 'damperNN.denseLayer2.y'[ i ]);
end for;
```

Multi-dimensional GALEC code for QVM ≈2.77 KB

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Functional Mock-up Interface for embedded systems

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