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Model Interpretation for an AUTOSAR compliant Engine Control Function

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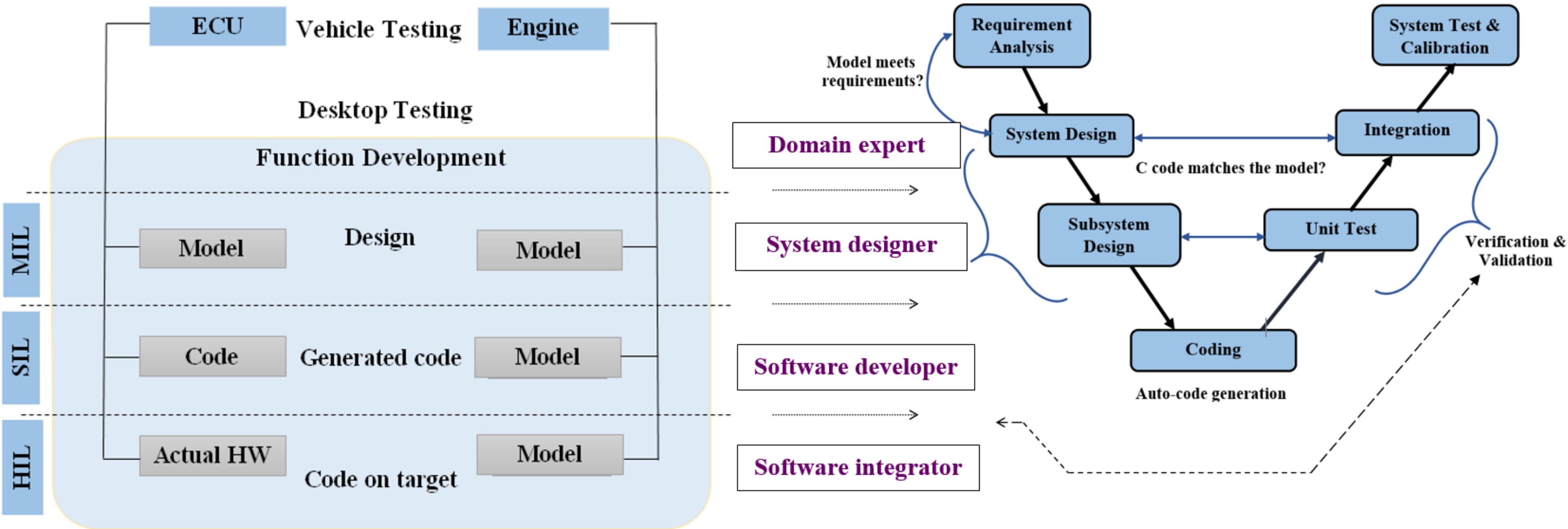
(WATERS 2016)
Toulouse, France, July 05, 2016

UNIVERSITÉ DU LUXEMBOURG

State of the art Practice



Model as the main artifact to develop the embedded software

Generative MBD – e.g., MLSL , ASCET-MD etc.

Code, other artifacts automatically generated from model

Code → binary → run on target hardware

Interpreted MBD

- Direct interpretation of design models using *interpretation engine* running on top of target
- No (optional) code, other artifacts generated
- No commercially available interpreted MBDs
- So not practiced in industrial embedded software development life cycle
- But interpretation-based runtime environments are proven (track-record) to be applied

Paper discusses…

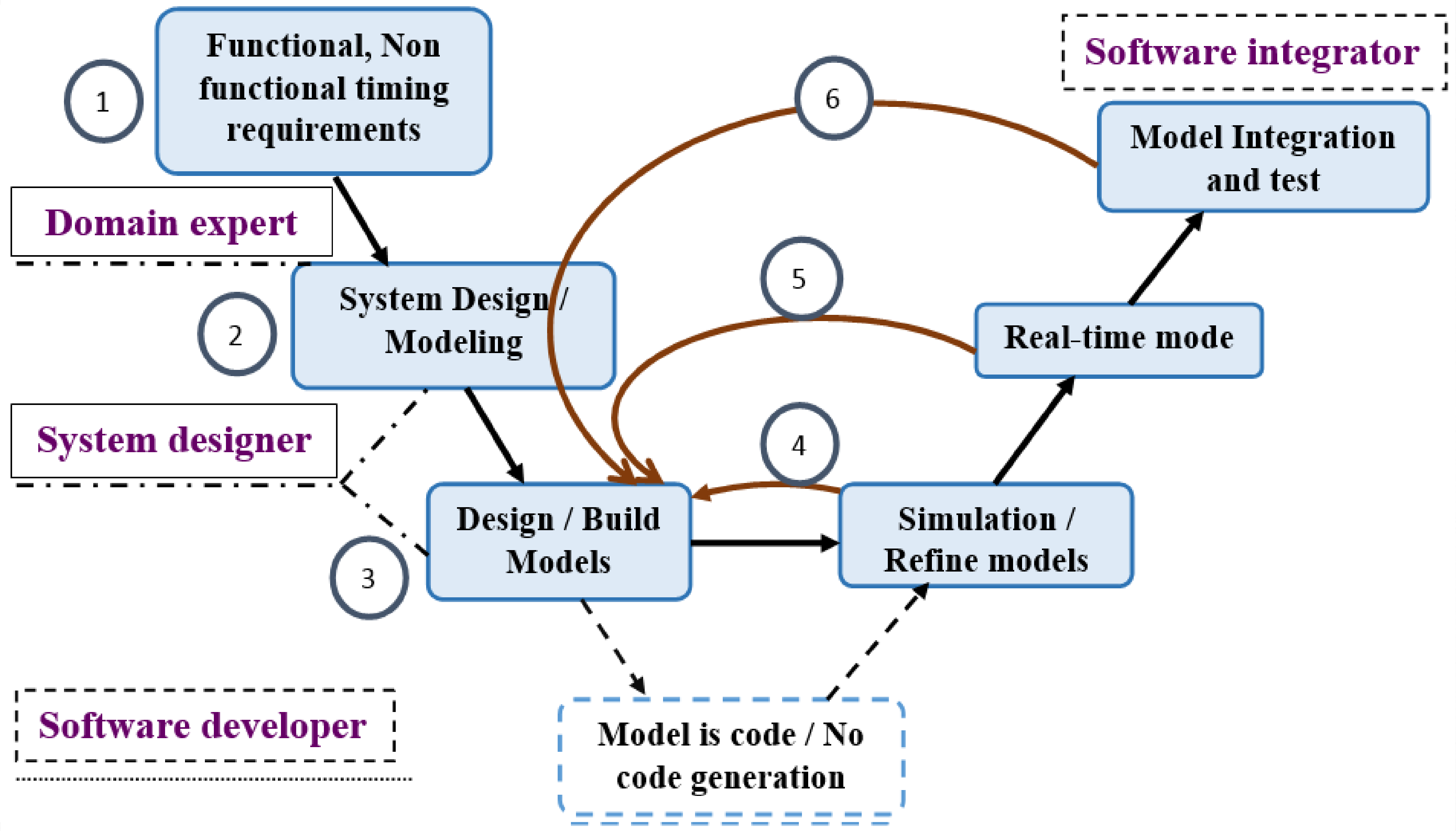
- ***Interpreted MBD*** to an industry case study to investigate it’s applicability to embedded software development cycle

  Interpreted MBD based embedded software development life cycle (proposal)

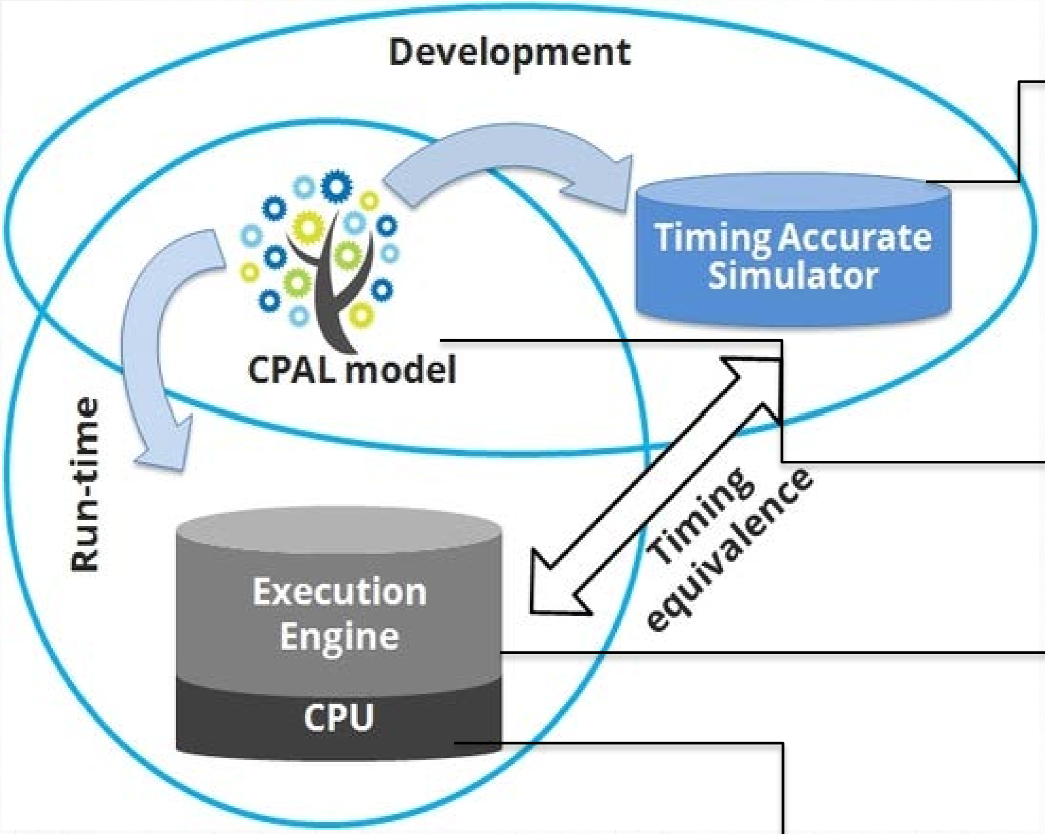
- Exploring the ***theoretical benefits*** of model interpretation with a industrial experiment

  Observations on productivity, simplicity, and performance (discussions)

Lean Development Cycle



CPAL* - an Interpreted MBD



- ✓ execute model in simulation mode or real-time mode
- ✓ timing annotation can be introduced in simulation
- ✓ simulation reflects real-time

- ✓ platform independent
- ✓ model "once"

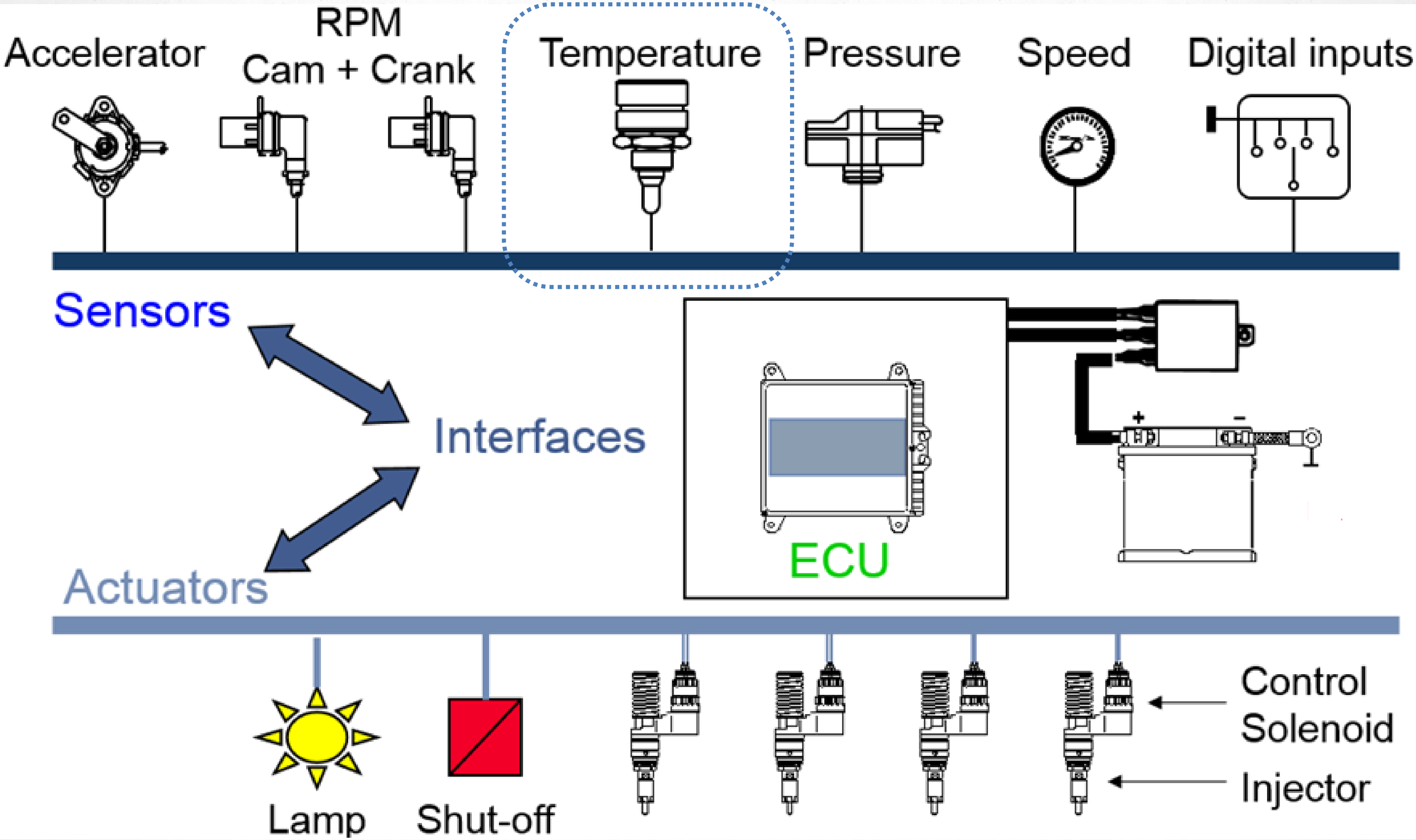
- ✓ platform dependent
- ✓ executes the model on target hardware with or without OS (BMMI)#

- ✓ Raspi, FRDM, ARM Cortex …

*** CPAL – Cyber Physical Action Language**

 # BMMI – Bare Metal Model Interpretation

Engine Control System



Engine Subsystems

Mechanical & ECU

➔ Air System

Air-Filter, Intake Manifold, Turbo-Charger / Super-Charger

Air Mass Sensor, Manifold Pressure/Temperature Sensor, Electronic Throttle

➔ Fuel Injection System

Fuel Tank, Fuel Filter, Fuel Pump, Injector

Fuel Tank Pressure Sensor, Fuel Pump, Electrical Injector, Canister Purge Valve, Fuel Rail Pressure Sensor, Rail Pressure control valve

➔ Cooling System

Coolant (Water) Reservoir, Water Pump, Radiator, Fan

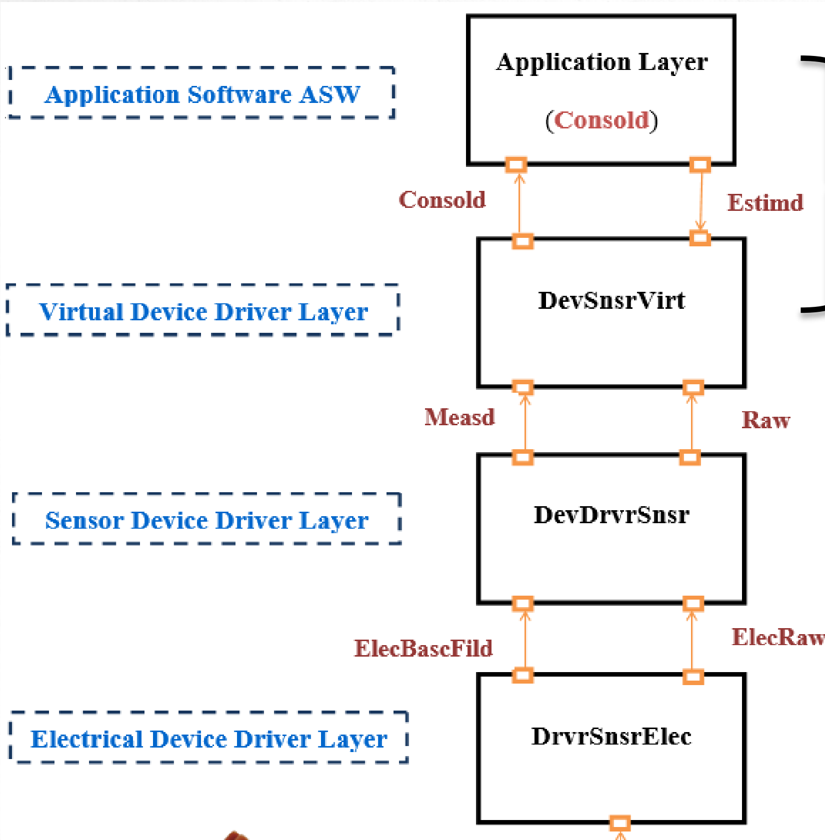
Electrical Water Pump, Electrical Fan, Water Temperature Sensor, Flow Control Valves

➔ Exhaust System

Exhaust Manifold, Exhaust Pipe, Exhaust Muffler, Catalytic Converter

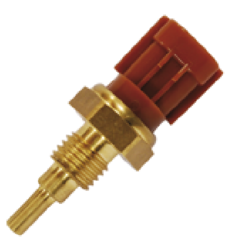
Exhaust Temperature Sensor, Lambda Sensor, NOx Sensor, EGR Valve, Secondary Air Pump, Secondary Air Valve

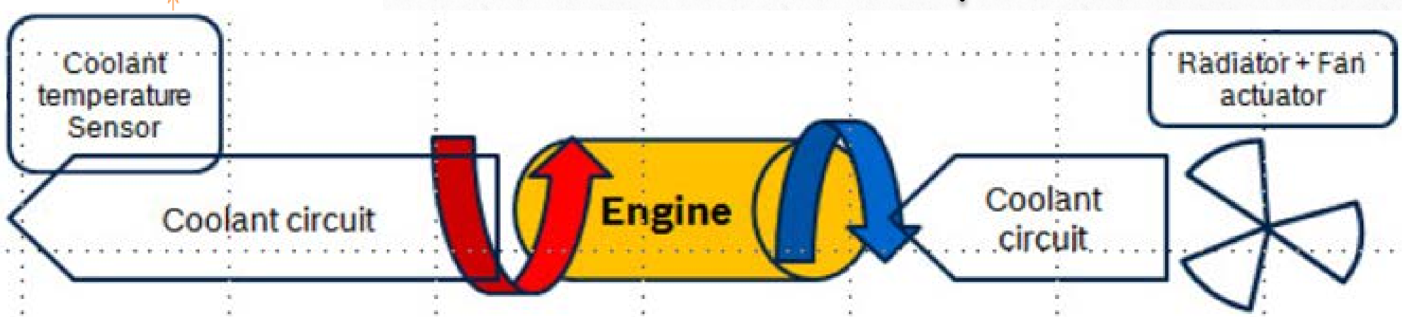
AUTOSAR Case Study



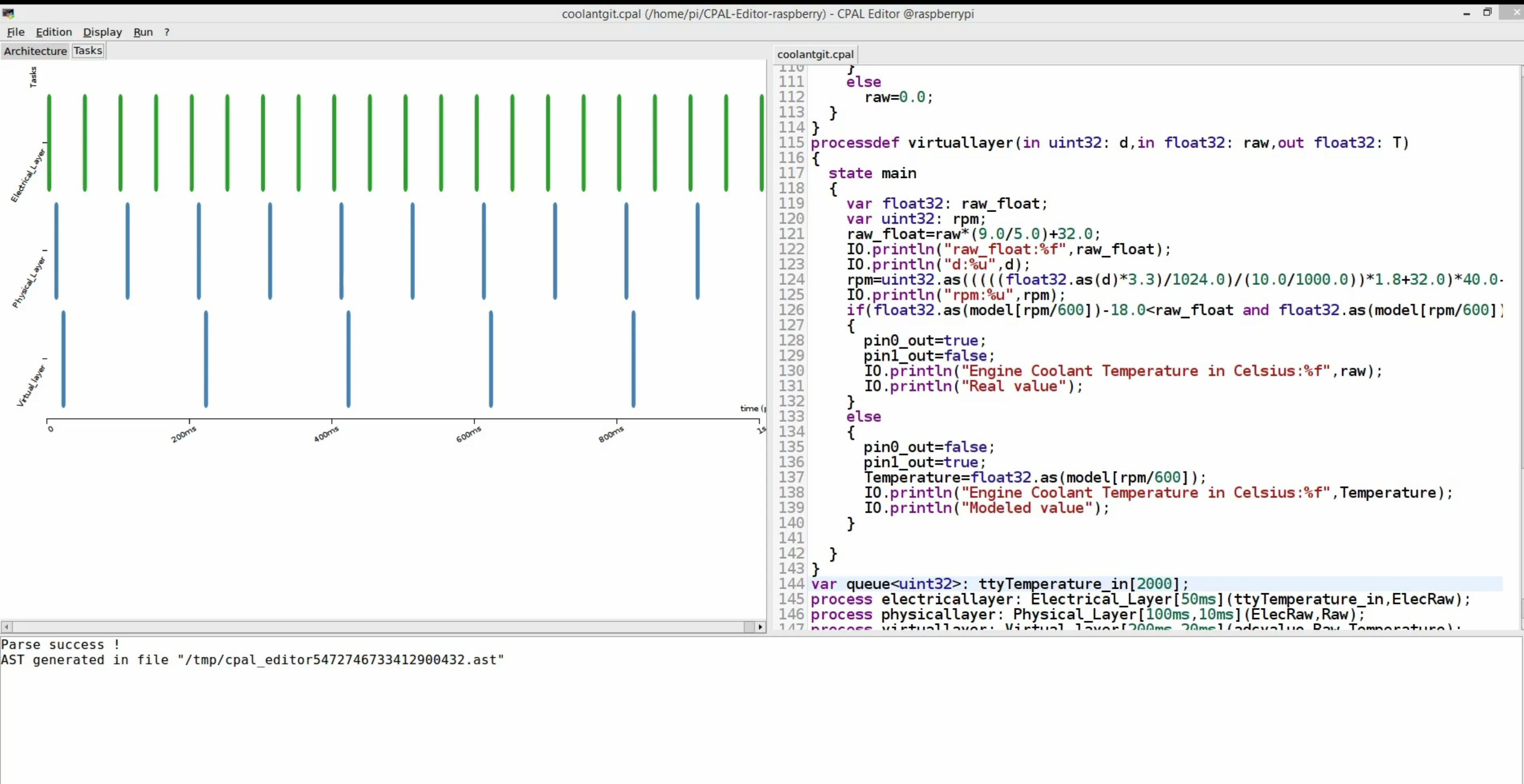
Requirement **R1**: When the difference between sensed value (*Measd*) and estimated value (*Estimd*) from application is 18 deg C, application to consider *Estimd*

Requirement **R2**: When the engine temperature changes, it has to be controlled below *200* deg C *(threshold)* value within t seconds





Let's have a look



Observation # 1 – Early stage execution

Timing accurate simulation
and real-time execution

Finding failure in model is easier (No code)

```
pi@raspberrypi ~/cpal/coolant $ sudo ./cpal_interpreter_raspberry -r git.ast
  => Digital pin found: 0, output
  => Digital pin found: 1, output
  => a serial read_only /dev/ttyTemperature
[0.000000000000:ASSIGN] Assign pin0_out new value: false
[0.000000000000:ASSIGN] Assign pin1_out new value: false
[0.000000000000:ASSIGN] Assign flag new value: 0
[0.000000000000:ASSIGN] Assign adcvalue new value: 0
[0.000000000000:ASSIGN] Assign modelvalue new value: 0
[0.000000000000:ASSIGN] Assign digit new value: 0
[0.000000000000:ASSIGN] Assign mode new value: 0
[0.000000000000:ASSIGN] Assign ElecRaw new value: 0.000000
[0.000000000000:ASSIGN] Assign Raw new value: 0.000000
[0.000000000000:ASSIGN] Assign Temperature new value: 0.000000
[0.000000000000:ASSIGN] Assign model new value: {60,65,70,75,80,85,90,95,100,105
,110,115,120,125,130,135,140,145,150,155,160,165,170,175,180,185,190,195,200,205
,210,215,220,225,230,235}
[0.000000000000:ASSIGN] Assign ttyTemperature_in new value: {}
>> step
[0.000000000000:STATE] process "electricallayer", instance "Electrical_Layer", s
tate "Main"
>> step
[0.010000000000:STATE] process "physicallayer", instance "Physical_Layer", state
 "main"
[0.010000000000:ASSIGN] Assign Raw new value: 0.000000
>> step
[0.020000000000:STATE] process "virtuallayer", instance "Virtual_layer", state "main"
```

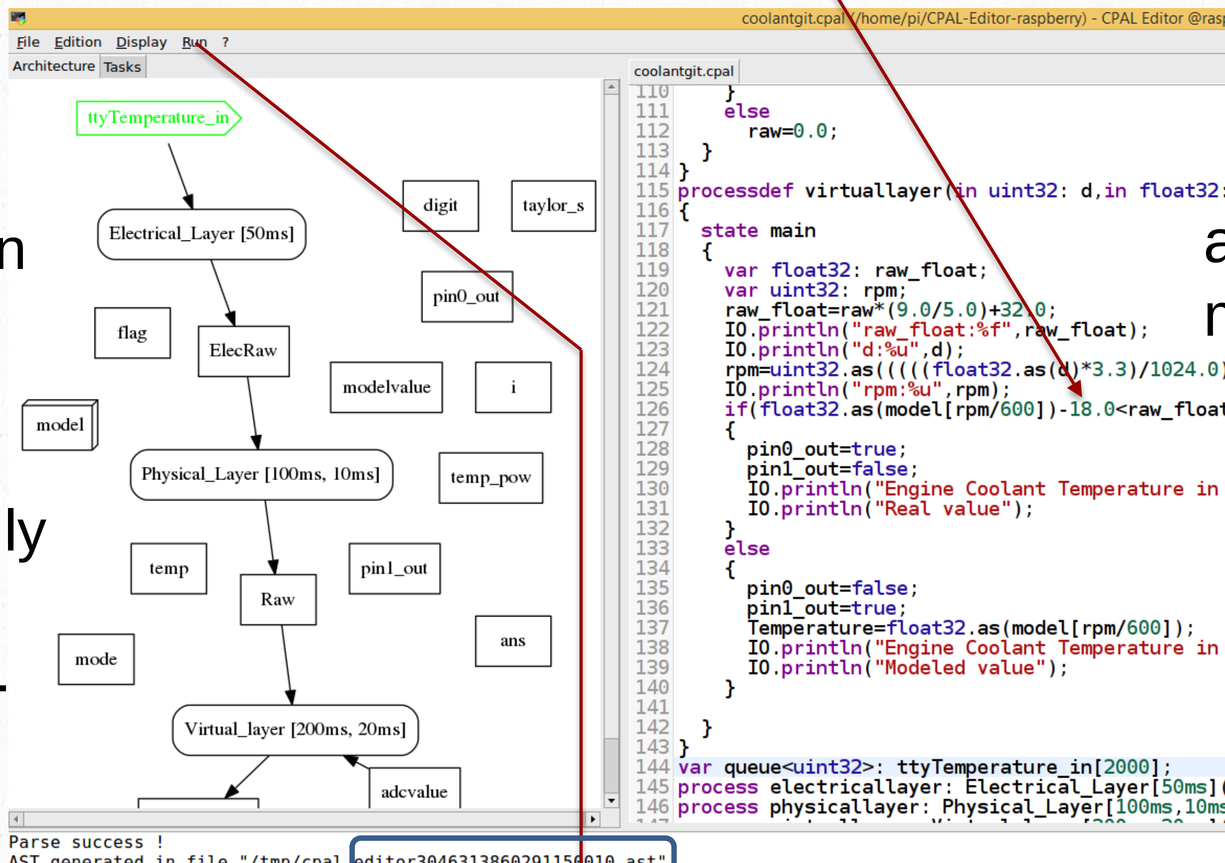
No need of tracing from code to model when failure occurs

Step by step execution – functional verification and model debugging

2 – Requirement change is easier

say **R1** (slide #9) is requested
to be changed ~~18~~ to 12 deg C

No code
No compilation
No linking
No binary
Executable model is readily available with change for **R1**

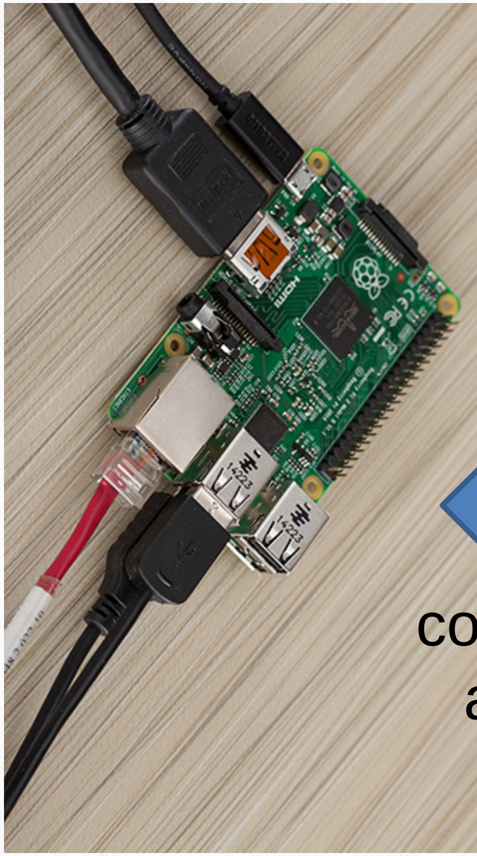


adapt the model to **R1**

Instantaneous execution of change requested

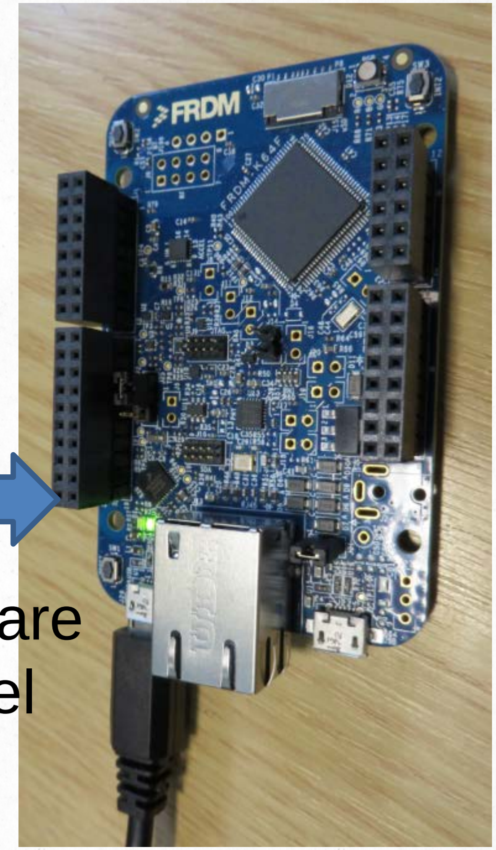
3 – Hardware Independence

CPAL model is readily portable to any hardware



coolantgit.cpal

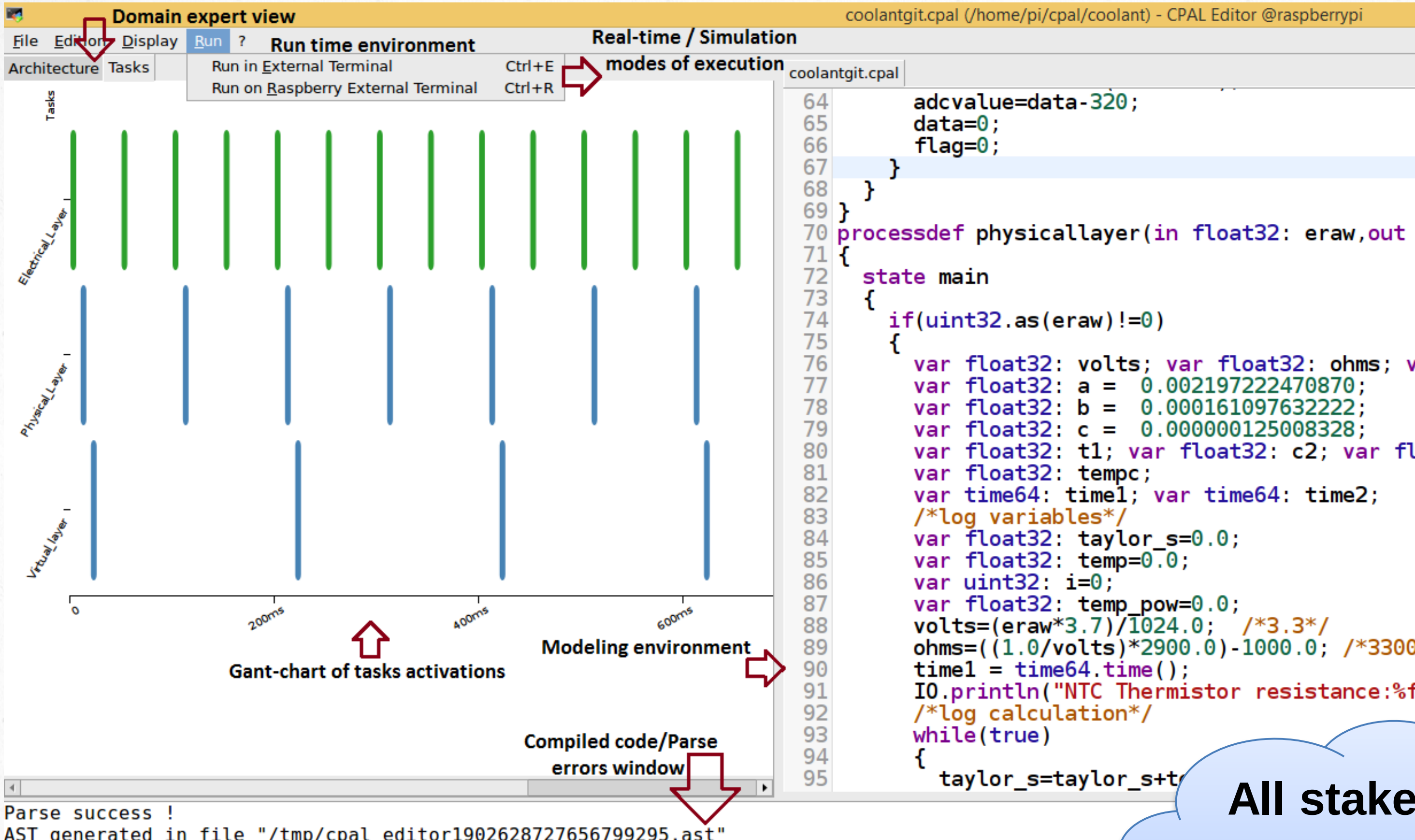
complexity of hardware abstracted in model



Interpretation engine to be adapted to HW - similar to code-generator switch to a new HW

4 – Design exploration

Functional architecture of the system – Domain expert view



Model

Developer view

All stake-holders are connected seamlessly

Scheduling of processes during simulation – timing analysis view

Our thoughts on Low-lights / Next steps

- Code generation is standard practice
- Model interpretation is **slower** than code executed – **Still**…

  calling binary code(computation-intensive portions) from interpreted code

  design phase – model interpretation to benefit productivity / easier verifiability aspects
- Production phase – Code generation to benefit faster execution capability
- Interpretation and code generation are often seen as two alternatives, not as a **continuum**