FORD OTOSAN

Real Time Thermal Management Model Development

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17.10.2016

GT CONFERENCE 2016

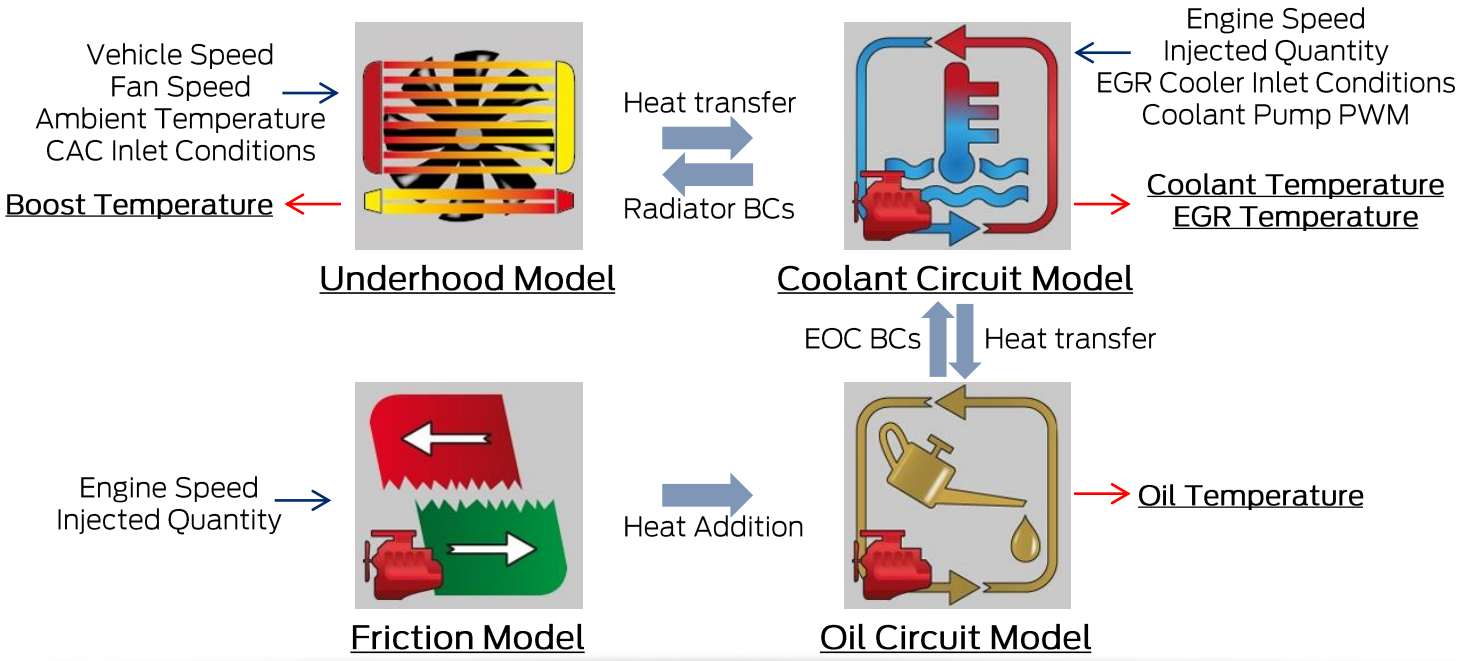
CONTENT

INTRODUCTION

- More stringent emission regulations, more complex diesel powertrains
  - Complex thermal management systems (pump, fan, AGS, etc.)
  - Increasing number of ECU calibratables
  - Increasing demand for hardware and software validation tests
  - Increasing demand for analytical tools and HIL & SIL simulators
- Plant models required for software validation on HIL & SIL simulators
  - Easy to create engine plant models (mapped, empirical, etc.)
  - Hard to create empirical thermal thermal management models
- Real time capable analytical thermal management models for HIL simulators
  - Available with the start of the project for thermal system optimization
  - Minimal effort to convert to a real time model
  - No change in results when converted to a real time model
- Various benefits
  - Reduced test requirements
  - Integration of calibration teams at early phase of the project
  - Almost no additional cost
  - Repeatable HIL simulations
  - Simulations in extreme conditions
  - Future intelligent powertrains

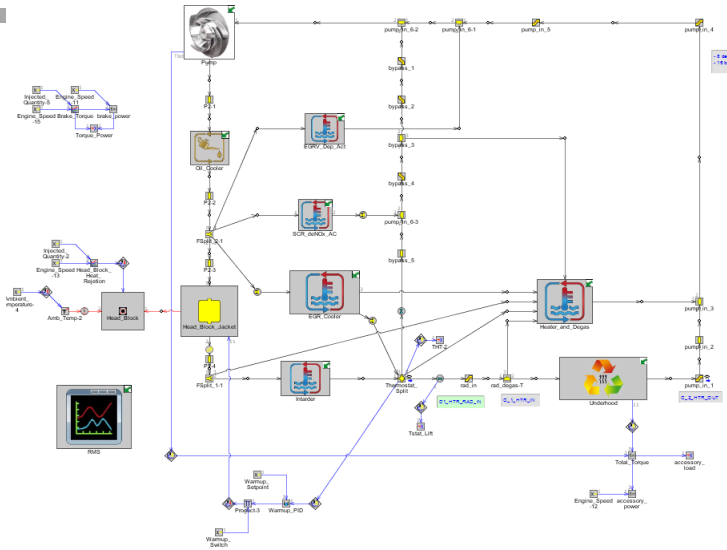
THERMAL MANAGEMENT MODEL İN GT-SUITE

- Created in GT-SUITE
- Stand alone engine & vehicle thermal management model
- Consists of four sub-models
- Predicts coolant, oil, boost and egr temperatures
- Modular, i.e. can be integrated with any type of model
- Runs faster than real time

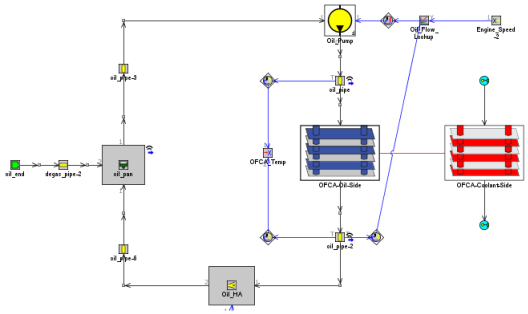


THERMAL MANAGEMENT MODEL İN GT-SUITE

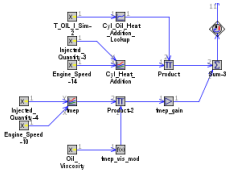
- Coolant Circuit Model
  - Consists of components in the cooling system
  - Head & block heat rejection is mapped as a function of engine speed & injection quantity
  - EGR Cooler inlet conditions are mapped as a function of engine speed & injection quantity
- Oil Circuit Model
  - Simple oil circuit model
  - Consists of oil cooler, oil sump, oil pump, and heat addition parts
- Friction Model
  - Heat addition to oil from piston cooling jets and friction is mapped as a function of engine speed & injection quantity
- Underhood Model
  - Simple 1D underhood model
  - Consists of condenser, CAC, radiator, fan and ram air parts



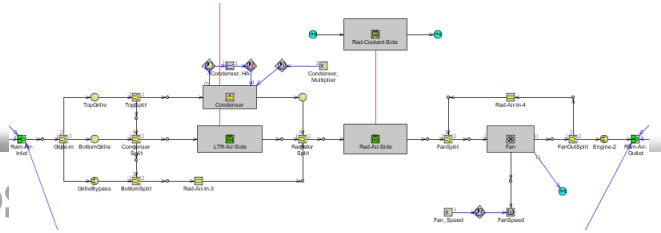
Coolant Circuit Model



Oil Circuit Model



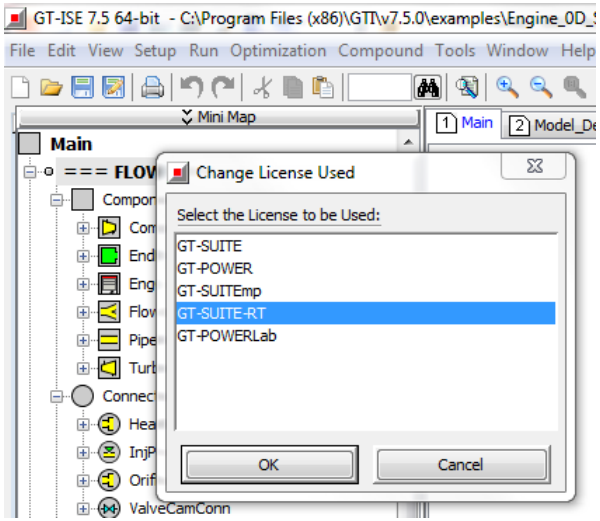
Friction Model



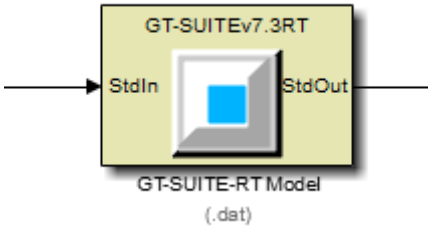
Underhood Model

GT-SUITE-RT – REAL TIME MODELING

- Thermal management model is converted to a real time model in GT-SUITE with almost no change in model
- RT model represents the plant for HIL testing
- Speed optimized special GT-SUITE-RT solver
- Identical results with the standard solver
- 30-50% faster than the standard GT-SUITE solver
- Less computational fluctuations
- Provided as an executable, dynamic library and static library
- Can be used from GT-SUITE, Simulink & SIL/HIL applications
- Run models locally on PC and HIL platforms



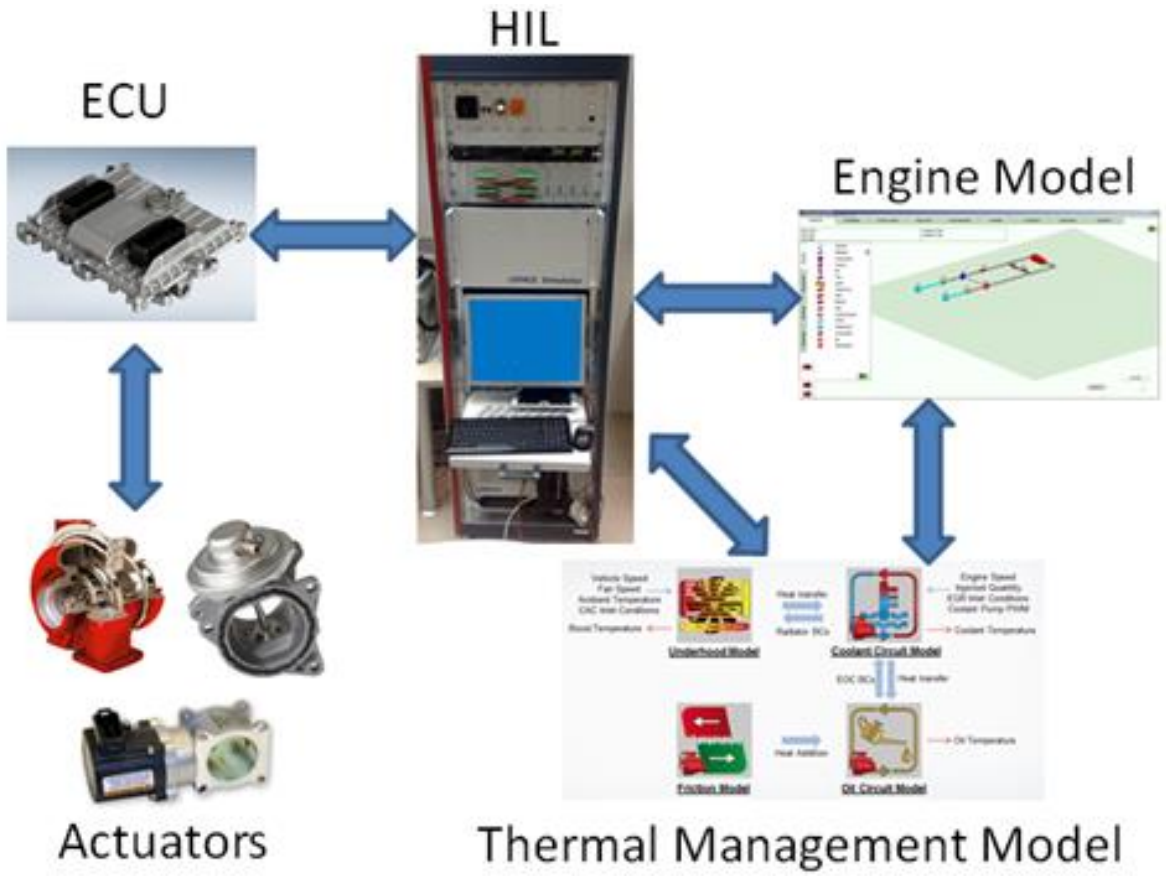
RT Model Generation in GT-SUITE



RT Model mask in Simulink

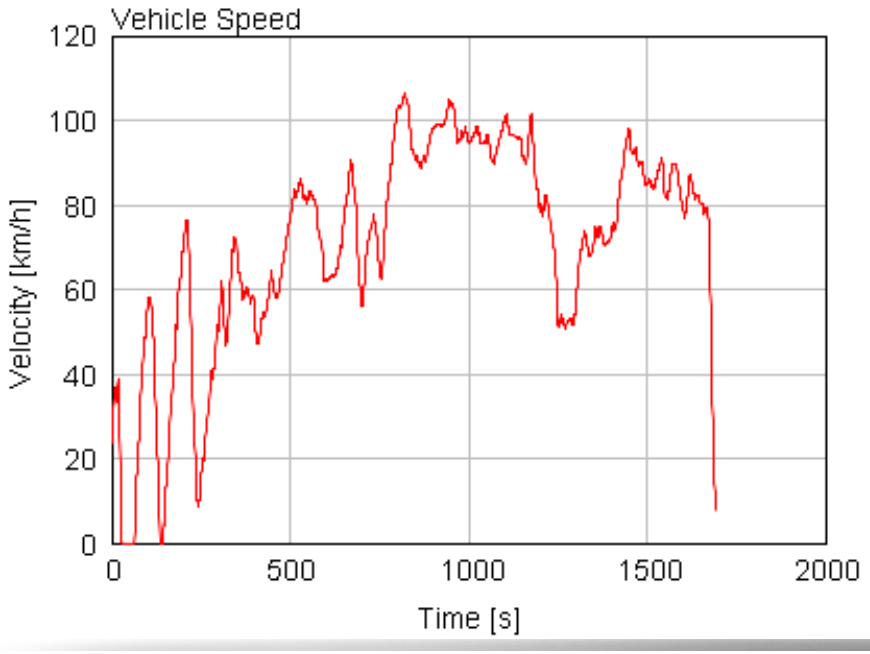
HIL SIMULATORS

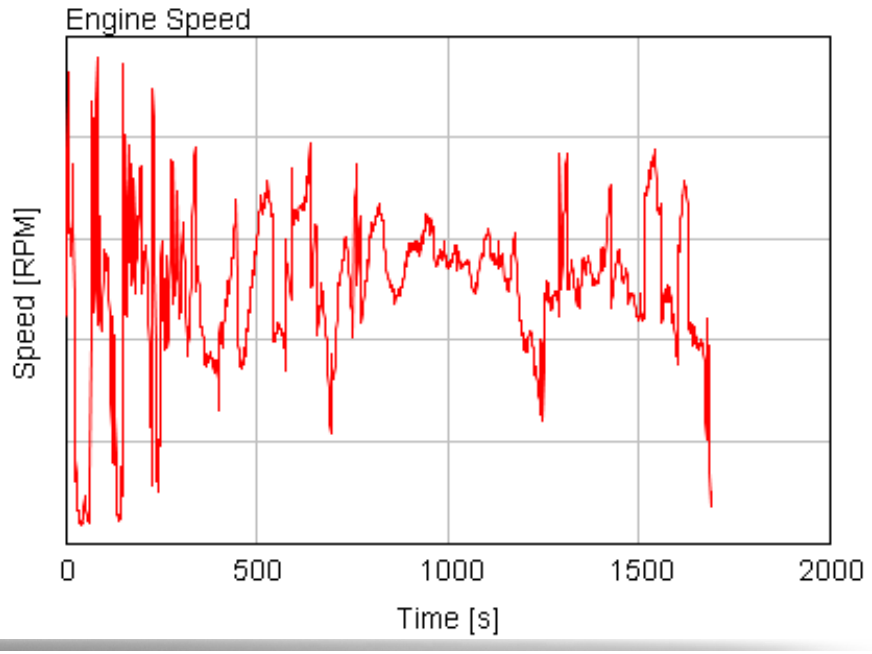
- ASP (Advanced Support Package) is required from dSPACE.
- 4th core of the DS1006 QC Processor Board is used for GT Power RT application to establish an Ethernet interface.



VEHICLE TEST CYCLE FOR MODEL VALIDATION[8]

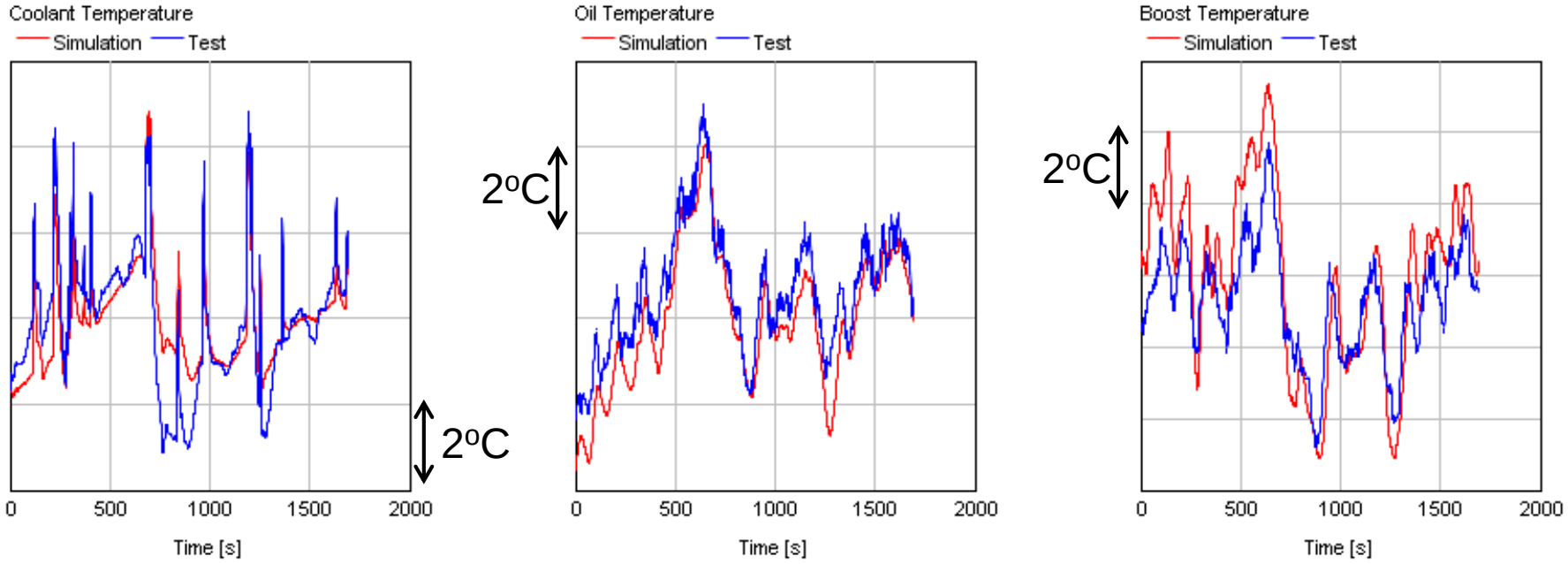
- Transient cycle from on road vehicle tests
- 1693 seconds (28 minutes) duration
- Acceleration & deccelaration at the beginning of the cycle
- Cruising at the end of the cycle
- 37 °C ambient temperature





DESKTOP MODEL VALIDATİON RESULTS

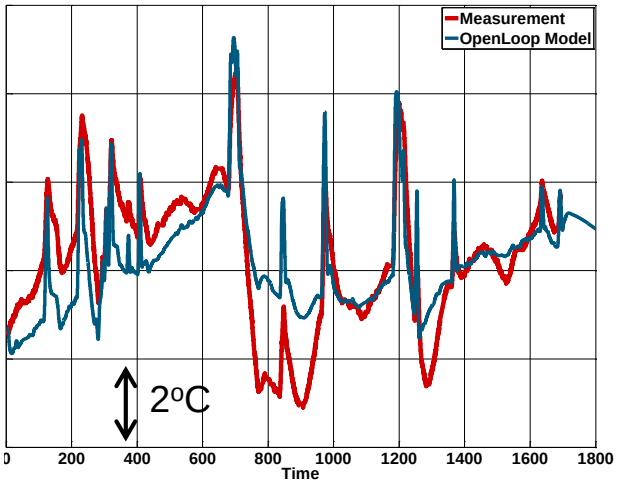
- Inupts taken from test data (engine speed, quantity, CAC & EGRC inlet conditions, etc.)
- Coolant, oil, boost temperature results are in good correlation with test results
- Peaks in coolant temperature due to intarder usage
- EGR Cooler gas outlet temperature correlation not reported due to low egr rates
- The model runs 3x faster than real time



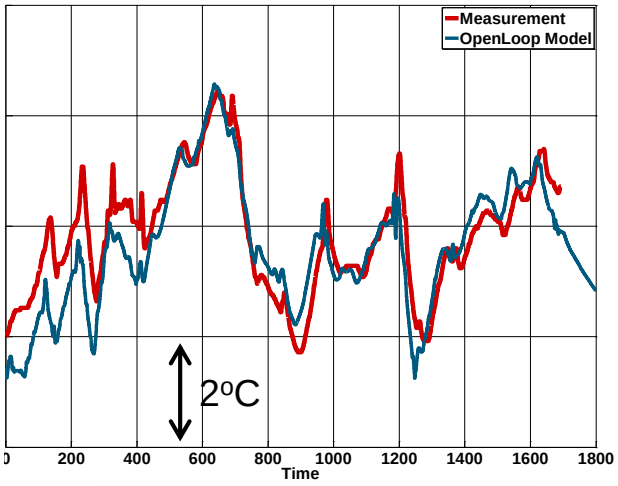
HIL MODEL VALIDATION RESULTS

- Desktop model converted to a real time model & run on HIL platform
- Inputs taken from test data (engine speed, quantity, CAC & EGRC inlet conditions, etc.) (open loop)
- The results are identical to desktop model results.
- Confirmed that GT-SUITE and GT-SUITE-RT solvers produce the same results.

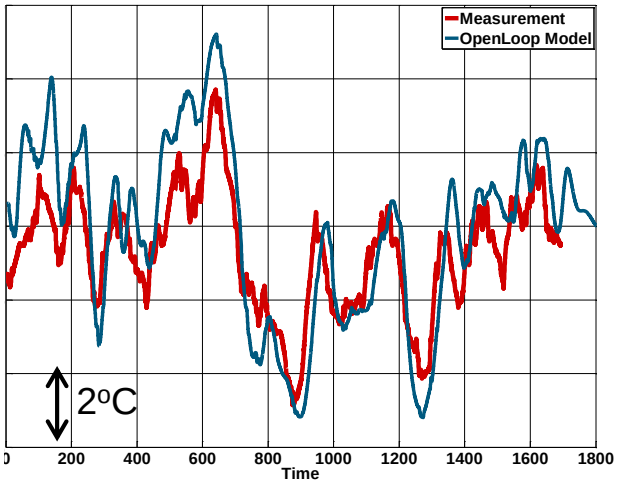
Coolant Temperature



Oil Temperature

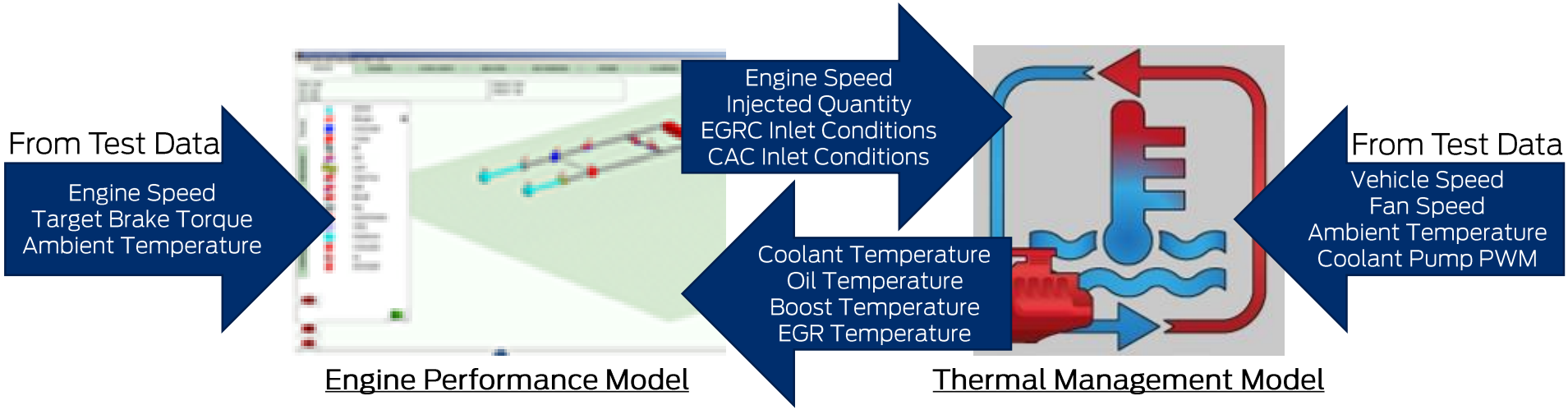


Boost Temperature



HIL MODEL WİTH İNTEGRATED ENGİNE MODEL[11]

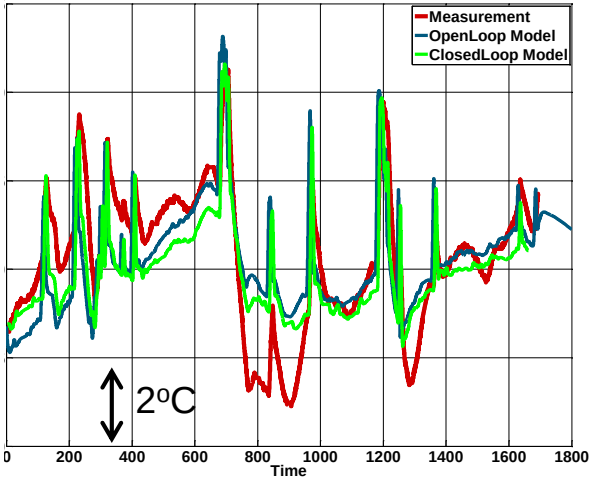
- RT thermal management model is integrated with an engine performance model
- Engine performance model is created using an in-house code.
- Some of the inputs are calculated by the engine performance model. The remaining inputs are taken from test data.



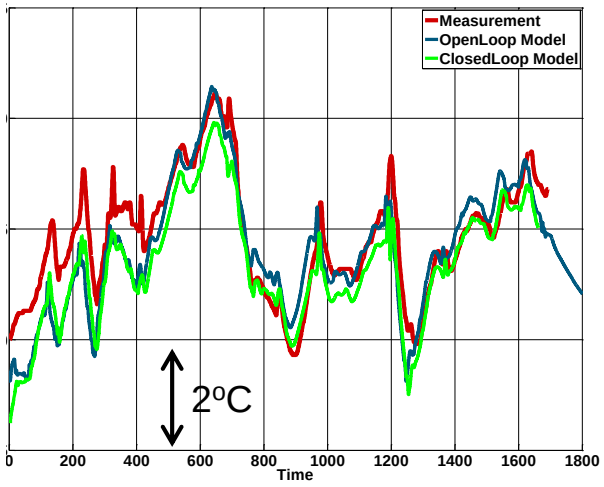
HIL MODEL WİTH İNTEGRATED ENGİNE MODEL

- The integrated model run on HIL platform (closed loop).
- Deviation in inputs calculated by the engine performance model (CAC inlet conditions, injected quantity, etc.)
- Deviation in temperature predictions at most 1 ^{o}C.

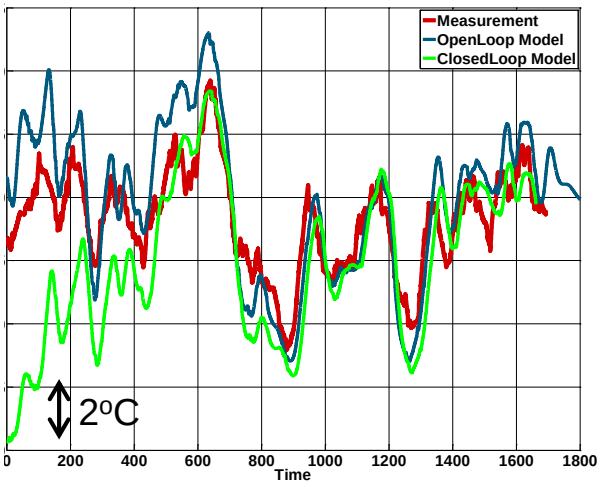
Coolant Temperature



Oil Temperature



Boost Temperature



CONCLUSION

- Real time capable thermal management model validated with desktop simulations
- The thermal model converted to a real time model with no change in results with HIL simulations
- Negligible changes in temperature predictions even when integrated with a low fidelity engine performance model
- Used for software development & calibration on HIL & SIL platforms
- Possible future use cases
  - Reduced tests for sofware validation
  - Possible to test extreme conditions (e.g. 50 ^{o}C ambient temperature)
  - Repeatable HIL simulations for software validation
  - Possible to use in conjunction with future intelligent powertrains
  - Integration of calibration teams at early phase of a project

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THANK YOU