EUROPEAN GT CONFERENCE 2018

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Set-up and Validation of an Integrated Engine Thermal Model in GT-SUITE for Heat Rejection Prediction

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Agenda

1. Motivation
2. Sub-Systems Modelling
   2.1. Engine Performance Model
   2.2. Engine Thermal Model
   2.3. Hydraulic Models
   2.4. Predictive Friction Model
3. Integrated Model
4. Conclusions

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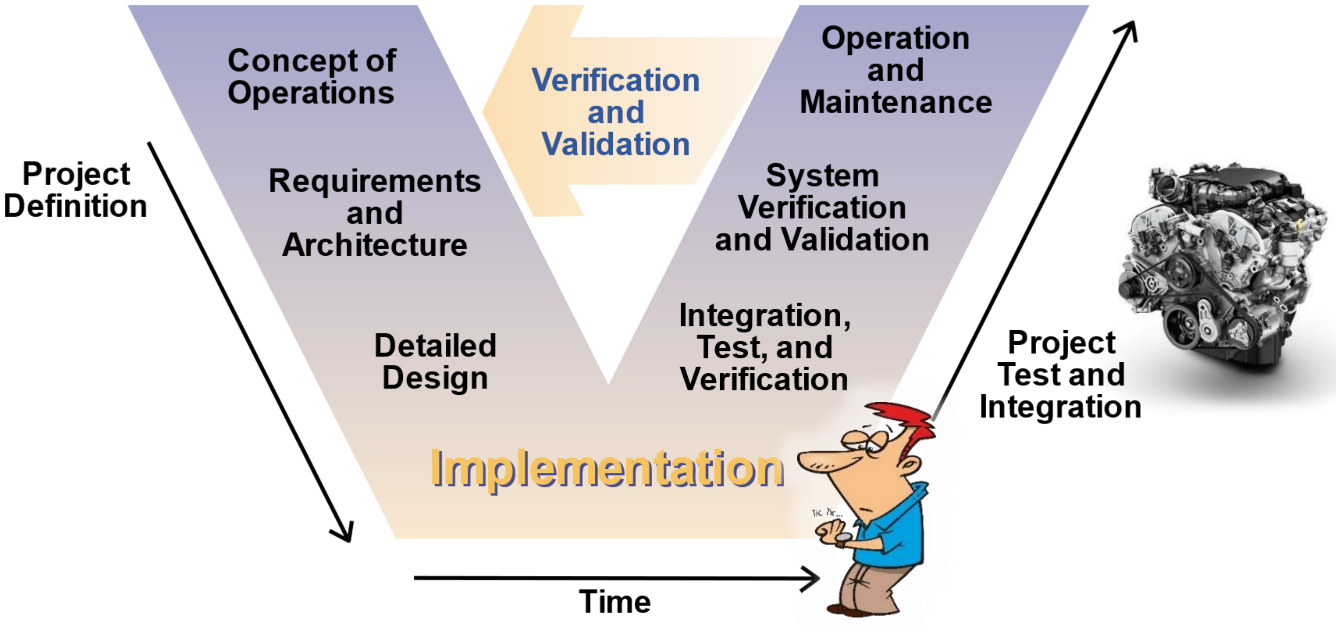
Project Scope

- Heat rejection map required since early stages of development
- Current approach consists in *empirical* heat rejection maps
  - Requires considerable experimental data from prototype engines
  - Experimental map not available until fairly late in the development process
  - Heat rejection map often not consistent with what observed later on real vehicle



Source: https://en.wikipedia.org/wiki/V-Model

→ **Improve the capabilities of engine heat rejection prediction via 1D simulation**

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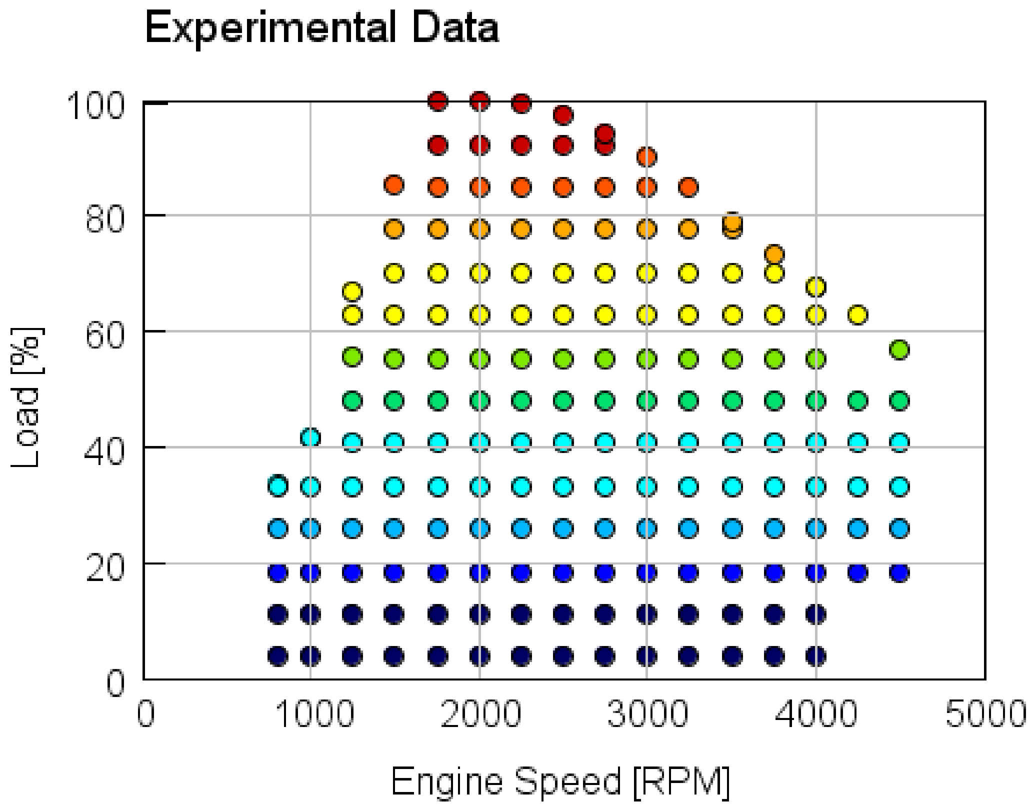
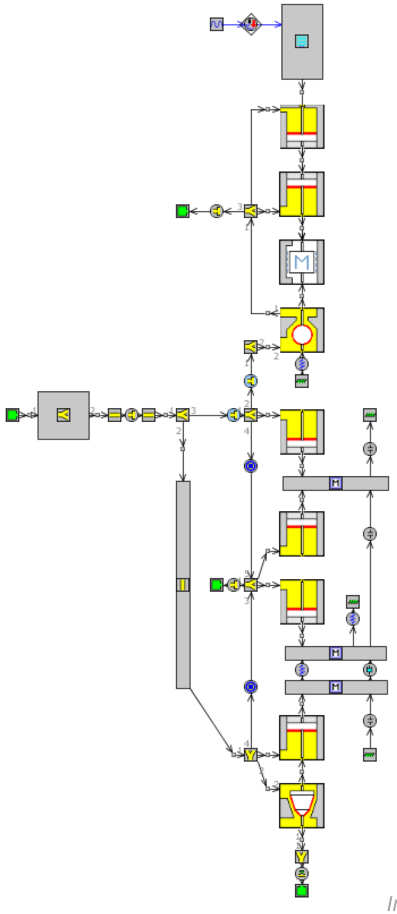
2.1. Engine Performance Model

- An existing GT-SUITE model of a 4-cylinder Diesel engine was thoroughly correlated on a steady-state mapping
  - The reference dataset included 176 points: from 800 to 4500 rpm, from 1bar BMEP to Full-Load
  - Indicating data was provided along with cycle-average measurements



2.1. Engine Performance Model

- **Injection Rate Map** and **DIPulse** predictive combustion



– Injection rates at various $\mathbf{P_{rail}}$ and **ET**
– Map characterizing injector performance
– Populated from detailed injector model provided by JLR

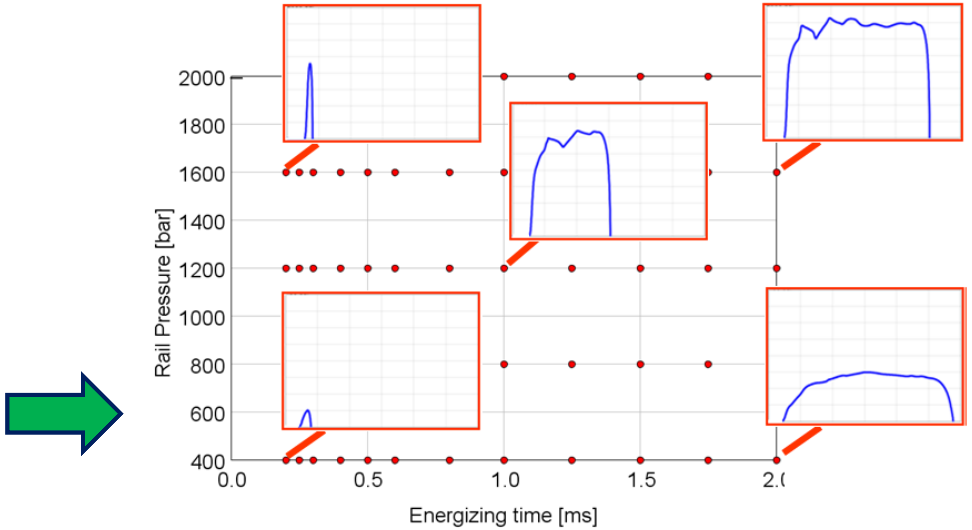
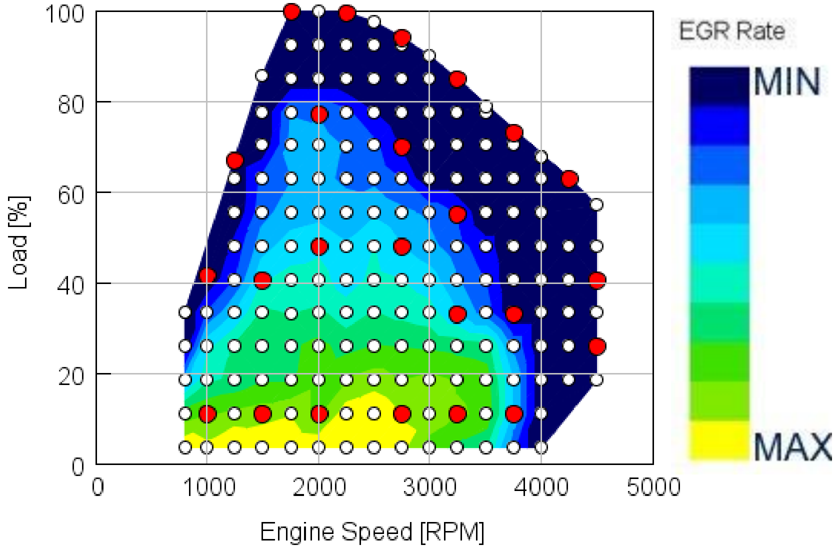


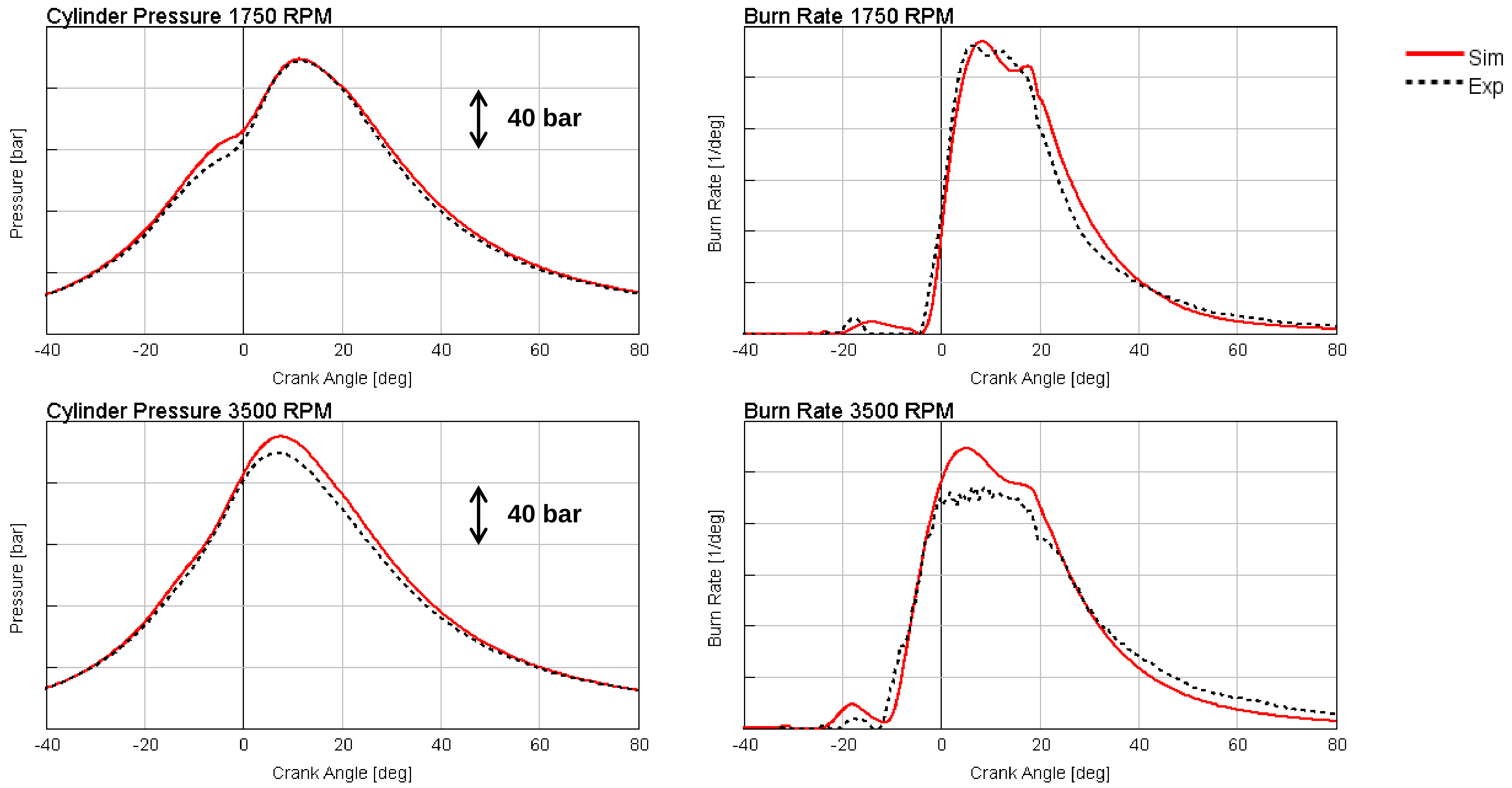
Image Courtesy of Gamma Technologies



– DIPulse burn rate is <u>predicted</u> based on:
  - In-cylinder pressure and temperature
  - Mixture composition
  - Injection timings and profiles
– 4 parameters optimized on 24 points via built-in ADO with Genetic Algorithm

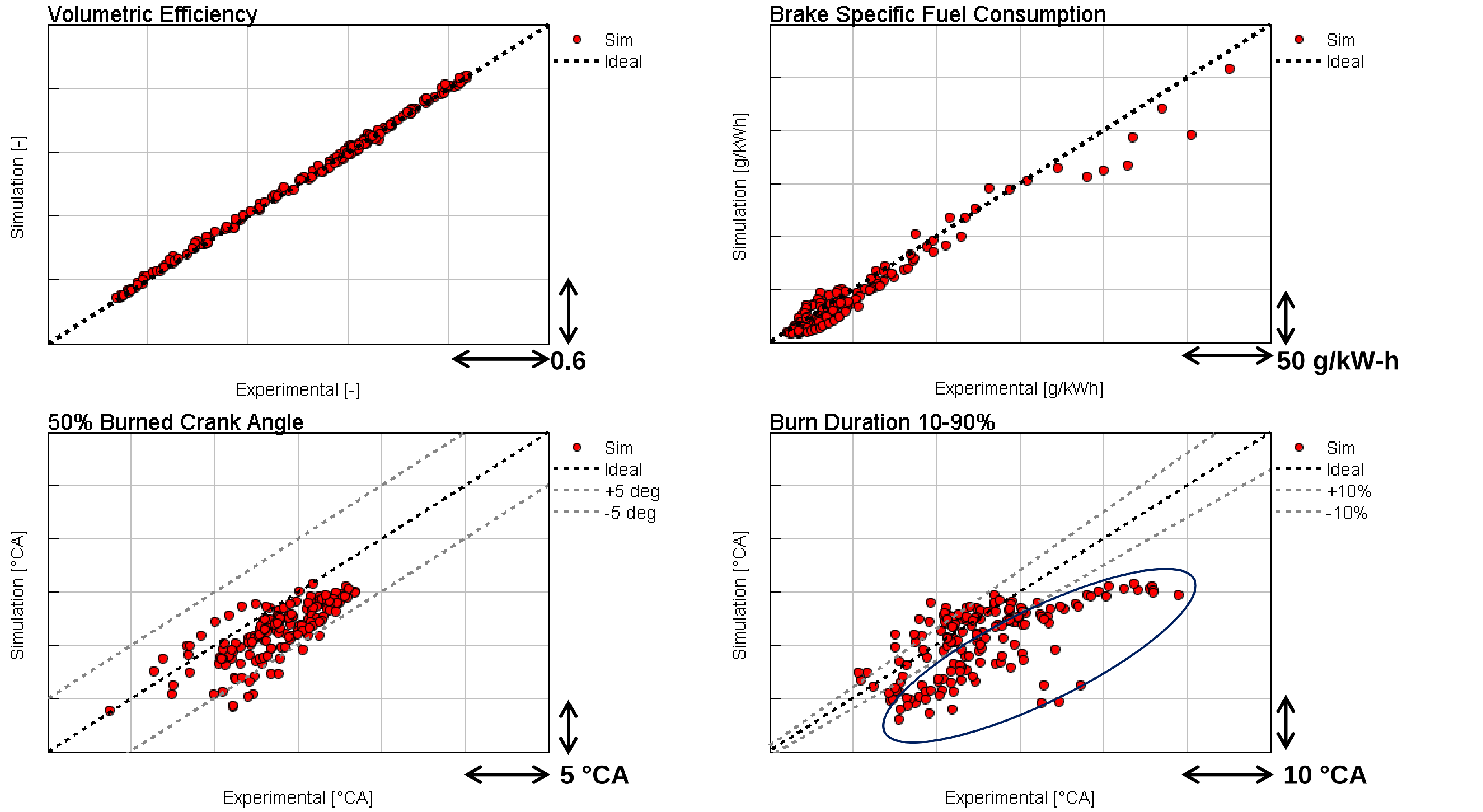
2.1. Engine Performance Model

- **Correlation Results** – Indicating (Full-Load)



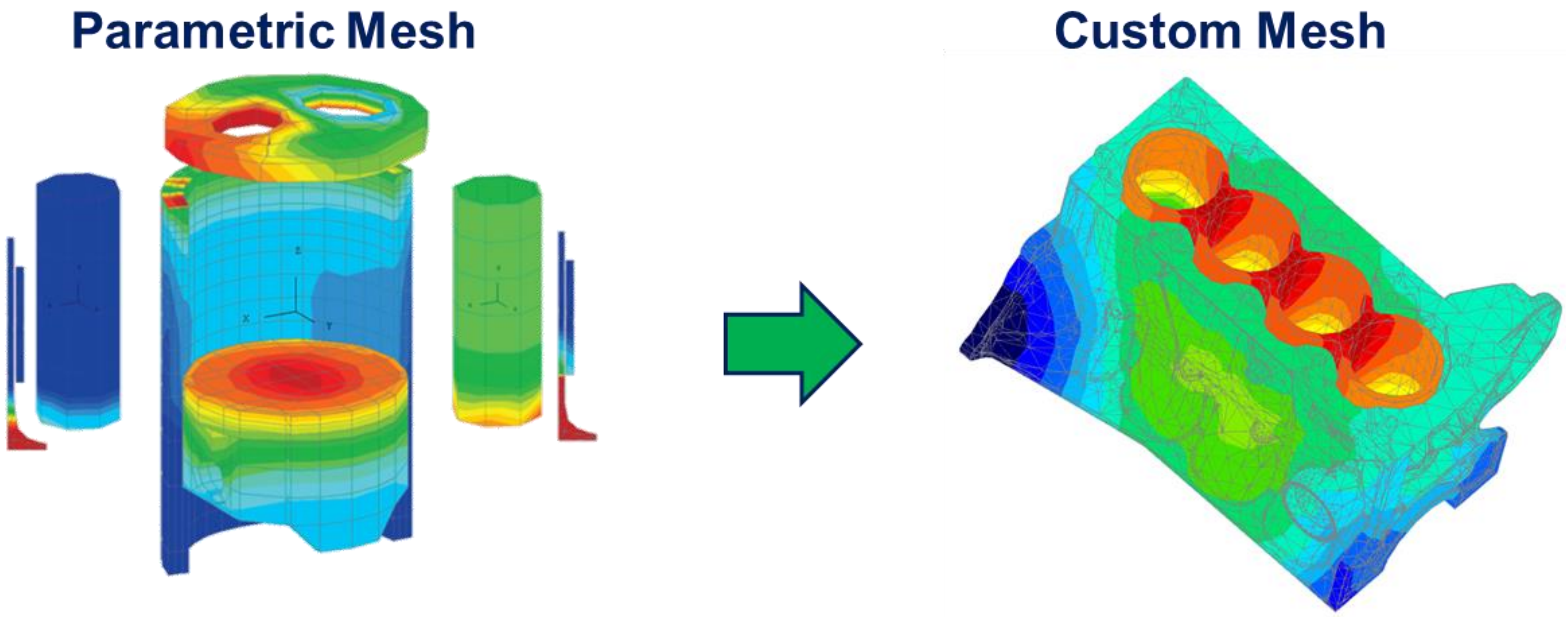
2.1. Engine Performance Model

- **Correlation Results** – Engine Map



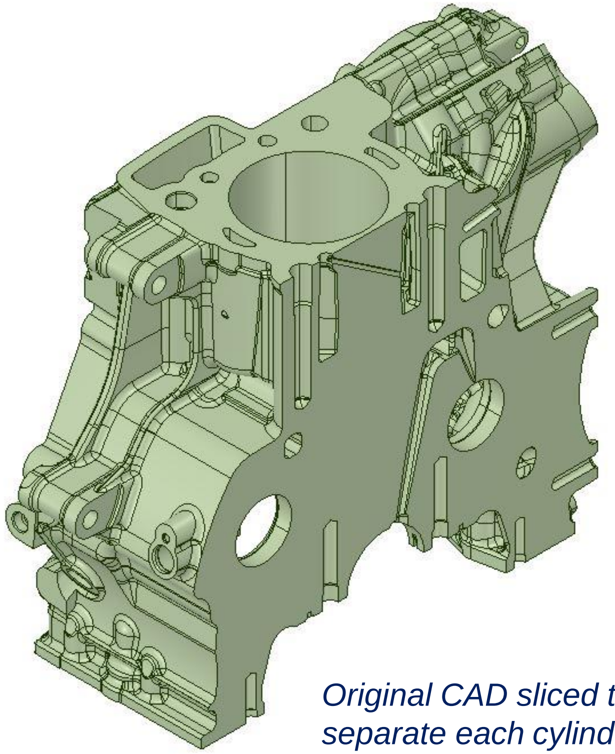
2.2. Engine Thermal Model

- *TWallSoln* FE Wall Temperature Solver historically available in GT-SUITE, employing a "parametric" (i.e. simplified) representation of the engine structure.
- Now GT-SUITE consents the user to import the actual engine structure in the form of an FE mesh → The so-called "**Custom Mesh**" approach.

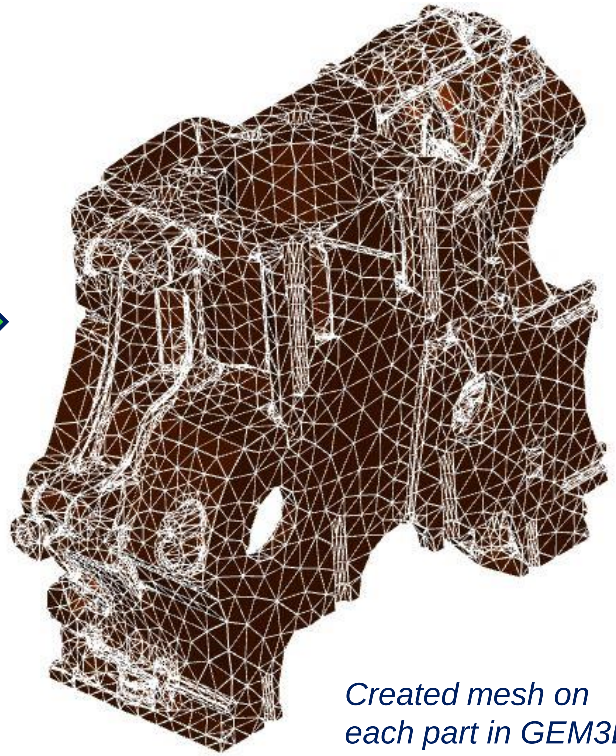


2.2. Engine Thermal Model

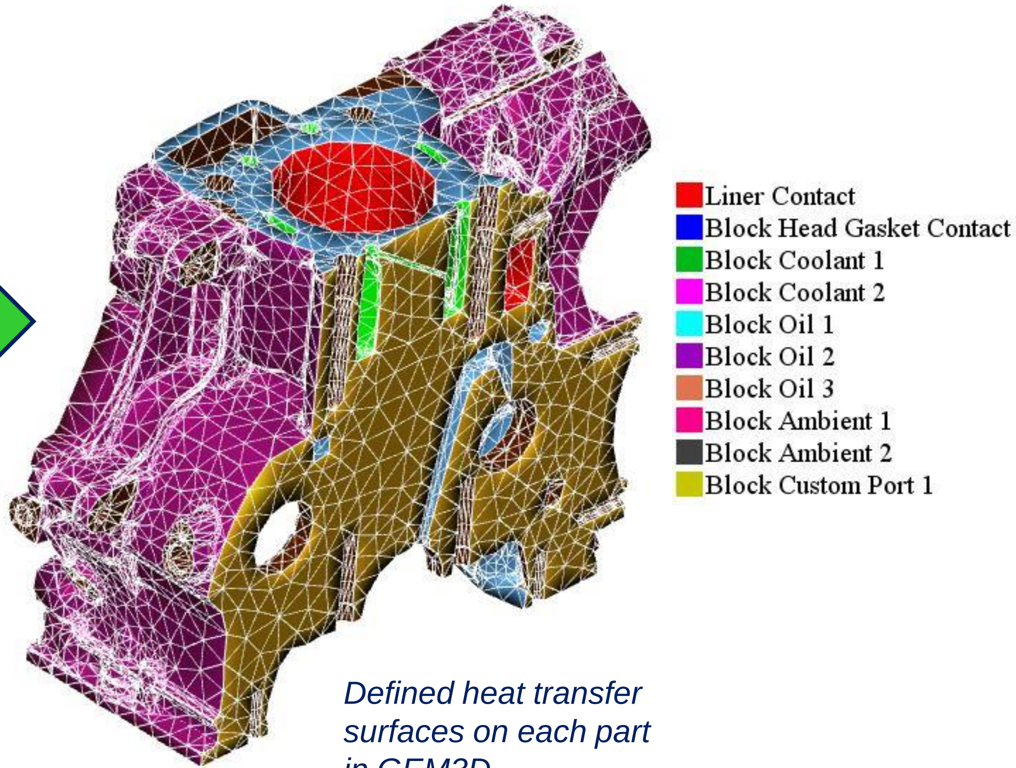
- 3D FE meshing of the engine structure in GEM3D
  - 3D FE models created on **head**, **block**, **valves** and **piston** (cylinder-by-cylinder)
  - Graphical “painting” of boundary heat transfer surfaces



Original CAD sliced to separate each cylinder in GT-SPACECLAIM



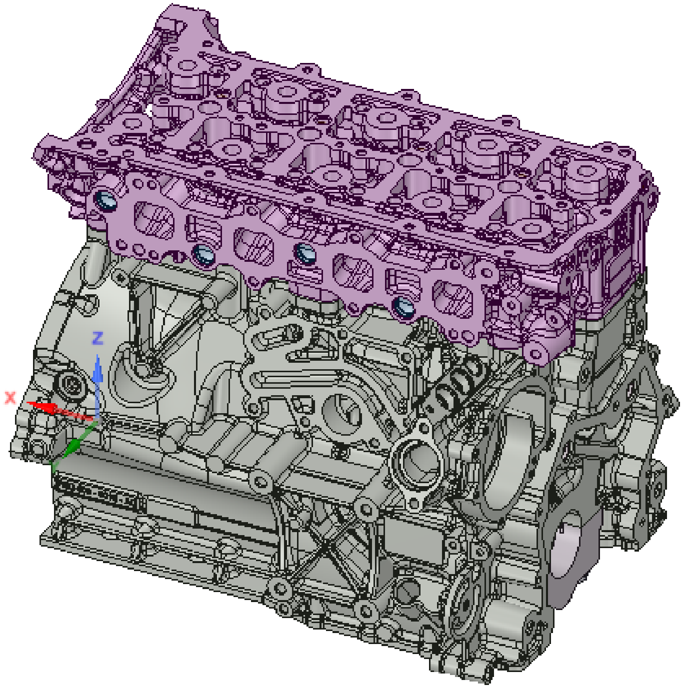
Created mesh on each part in GEM3D

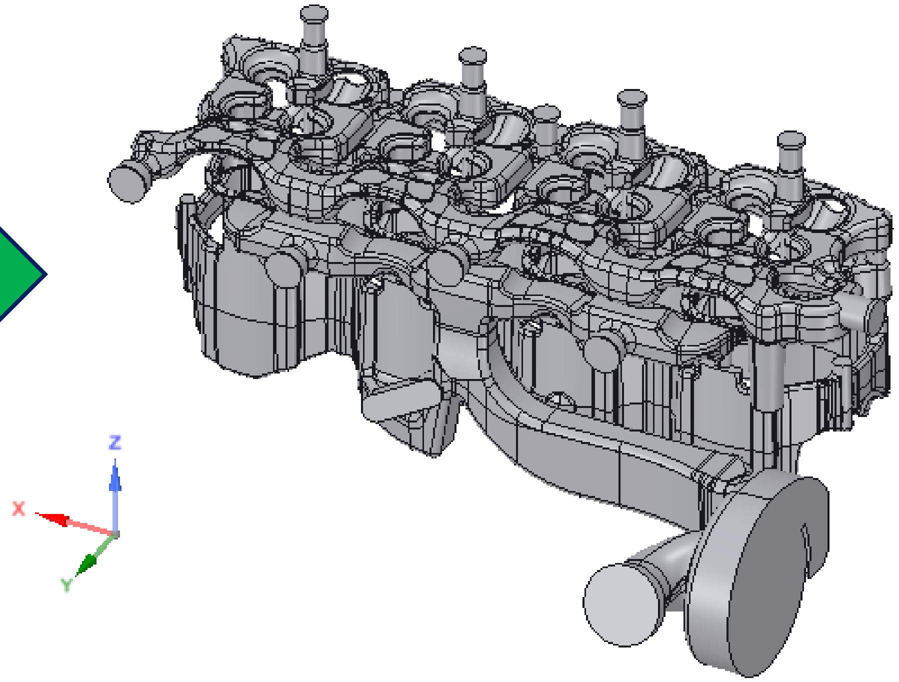


Defined heat transfer surfaces on each part in GEM3D

2.2. Engine Thermal Model

- **Water jacket** coolant volume extracted from CAD using GT-SPACECLAIM
  - Discretized into 1D primitives in GEM3D
  - Water jacket model calibrated to match flow distribution from a CHT 3D-CFD analysis



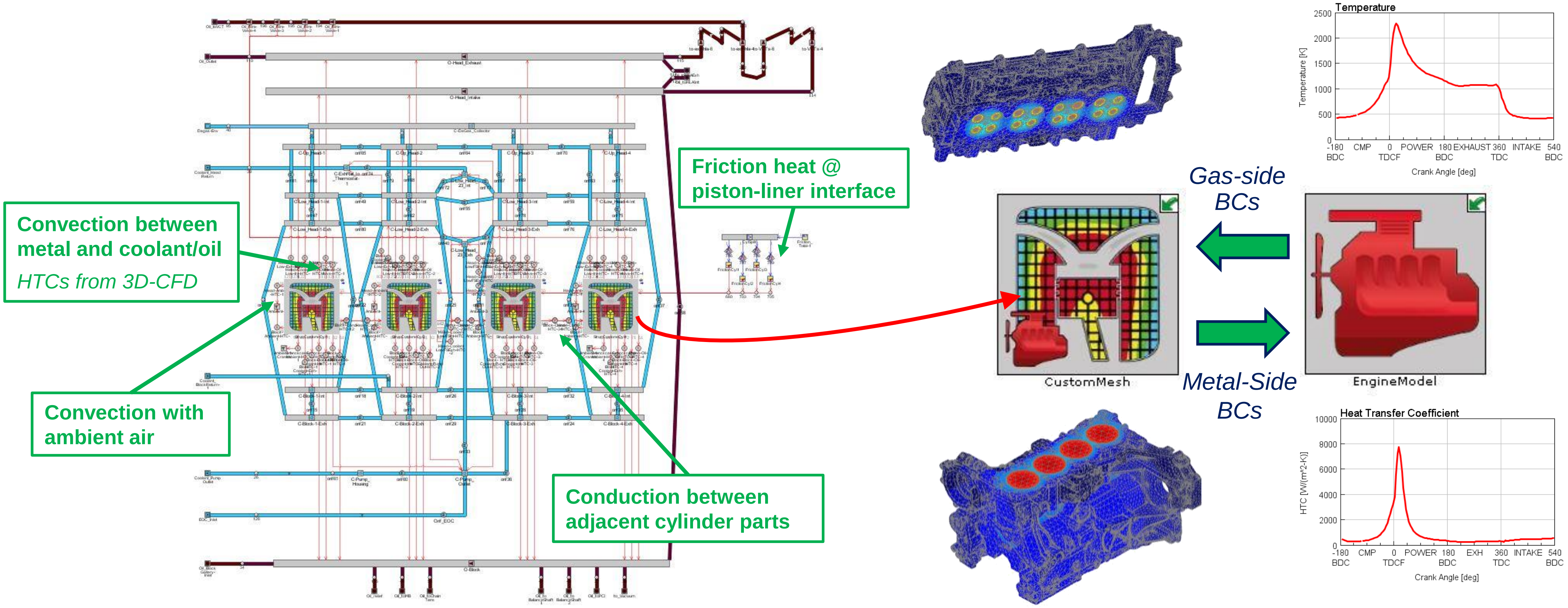


Water jacket fluid domain

- A detailed 1D **lube model** already available was used

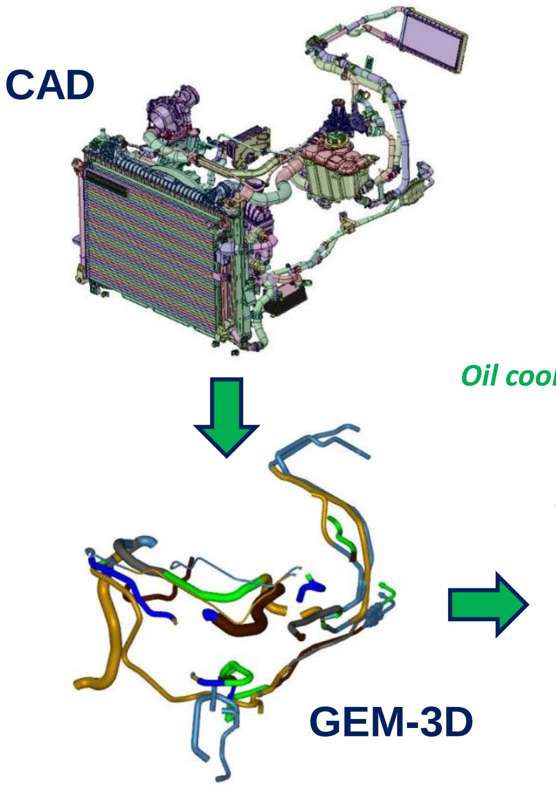
2.2. Engine Thermal Model

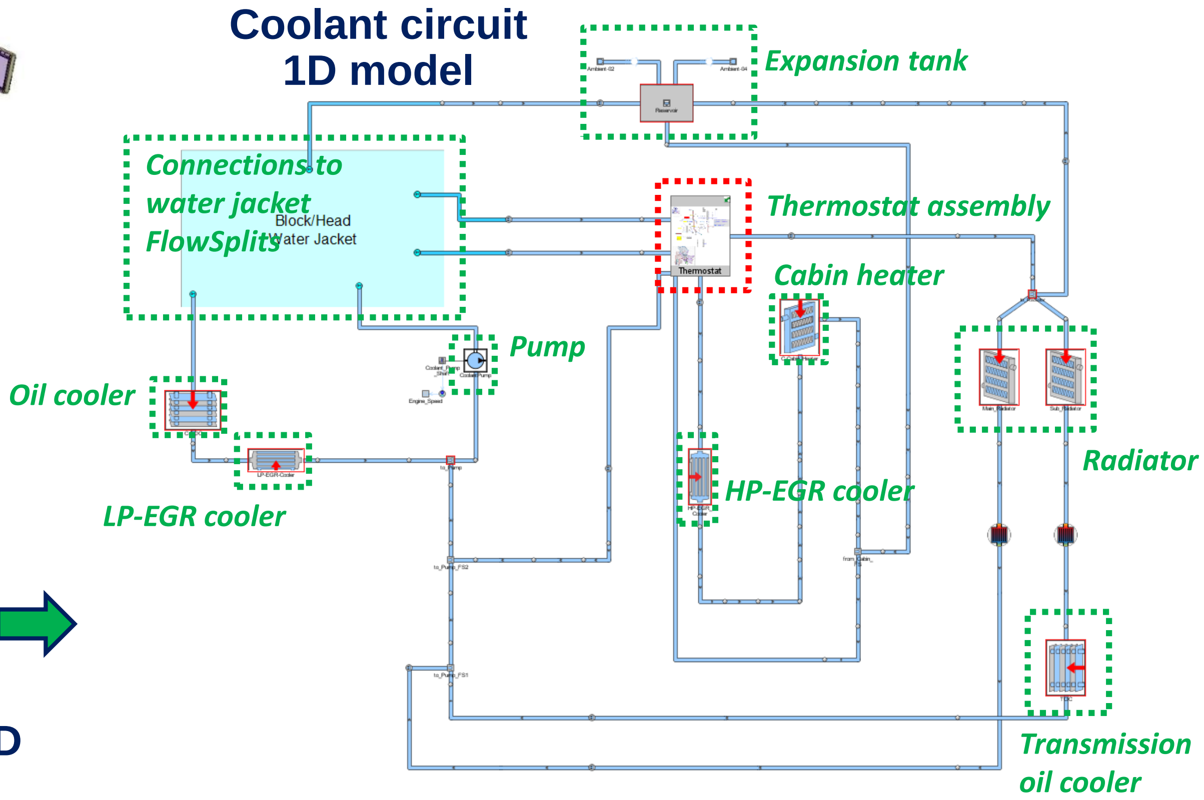
- The "Custom Mesh" of the engine structure and the coolant/oil passages were integrated in a single 1D model, thermally connected to the performance model.

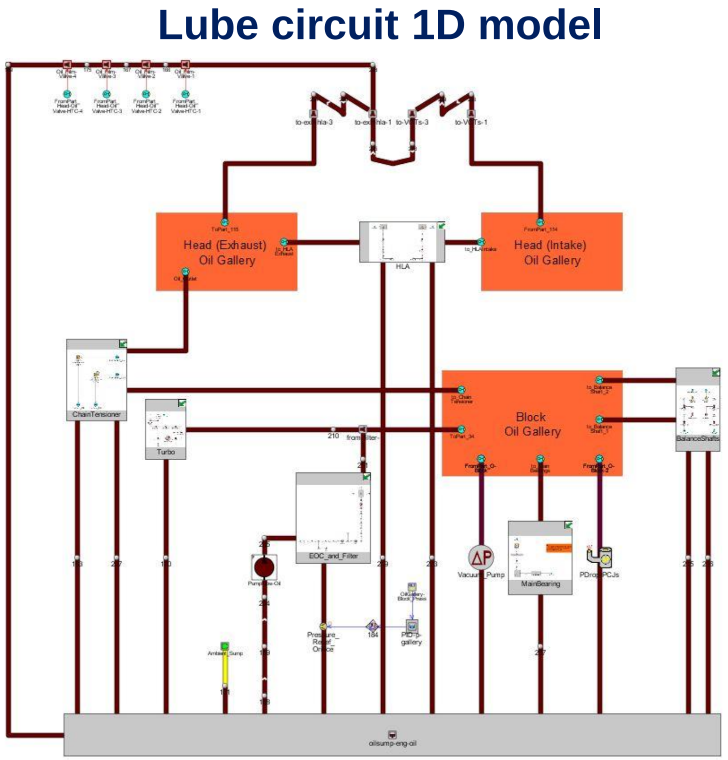


2.3. Hydraulic Models

- The complete **coolant circuit** 1D model was built from CAD
- Heat exchangers, pump, thermostat, expansion tank, etc. were added
- An already calibrated **lube model** was used for the integration

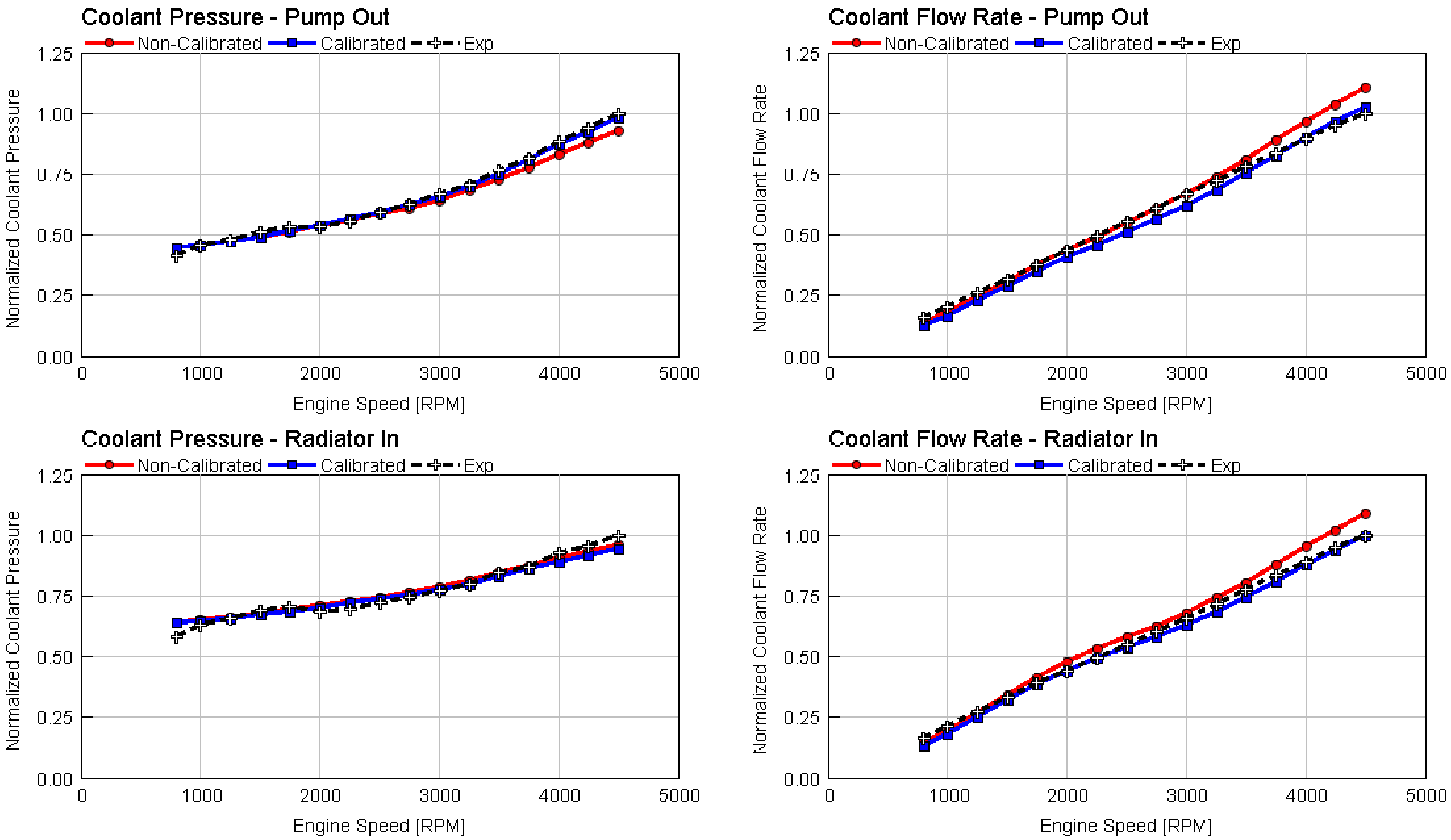






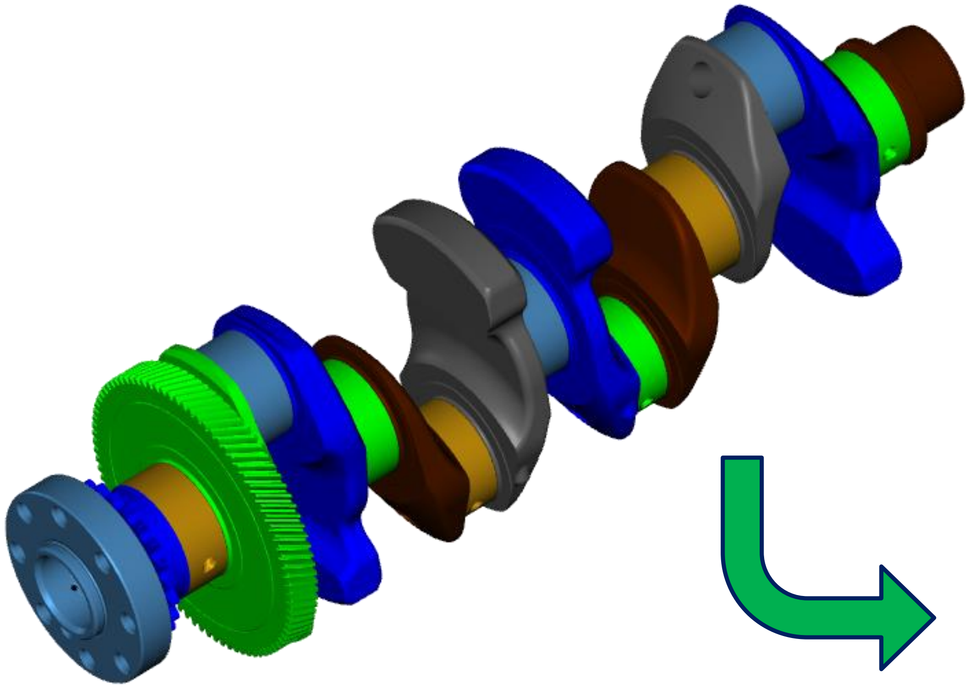
2.3. Hydraulic Models

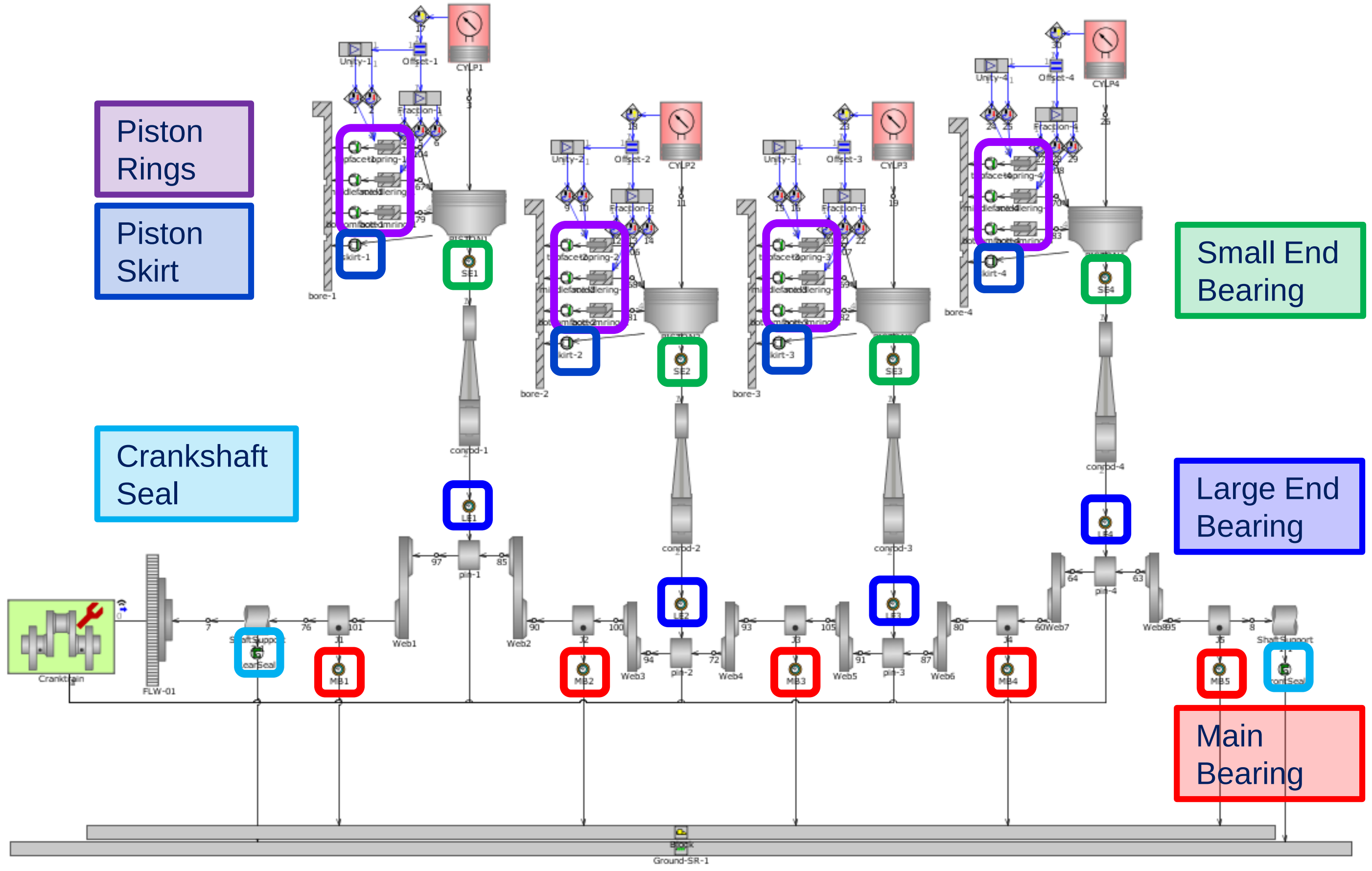
- In order to correlate the flow rate distribution among the different branches of the coolant system, pressure drops were tuned to match experimental measurements



2.4. Predictive Friction Model

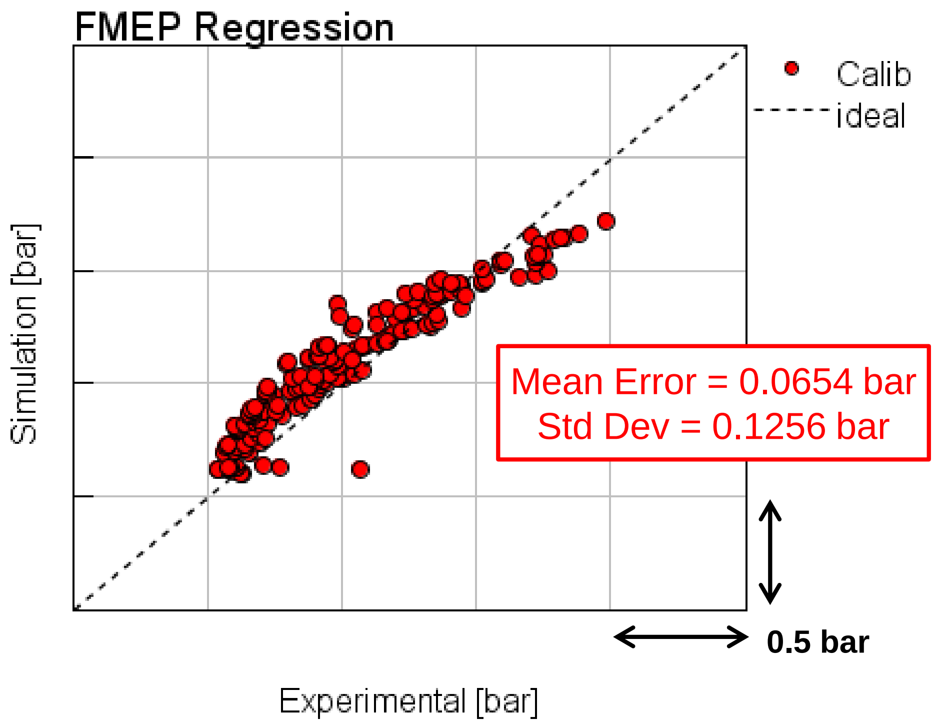
- GEM3D cranktrain converter tool used to build 1D model starting from 3D CAD
- Friction components added to the mechanical cranktrain model

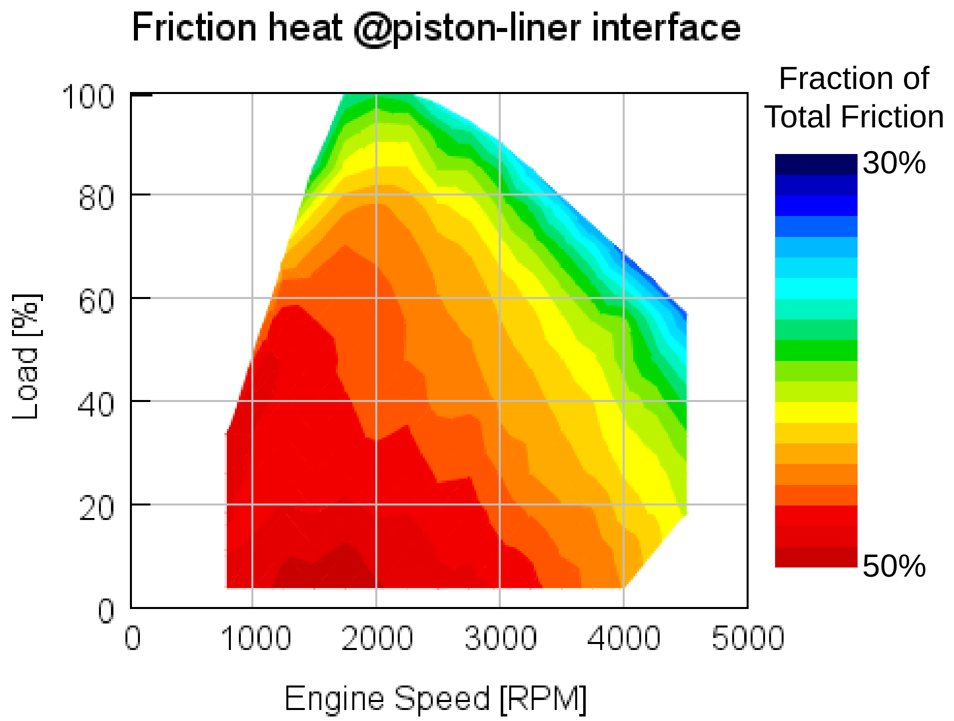




2.4. Predictive Friction Model

- Friction model calibrated against experimental data in both strip-down and firing conditions





→ Model outputs used to provide boundary conditions to the thermal model

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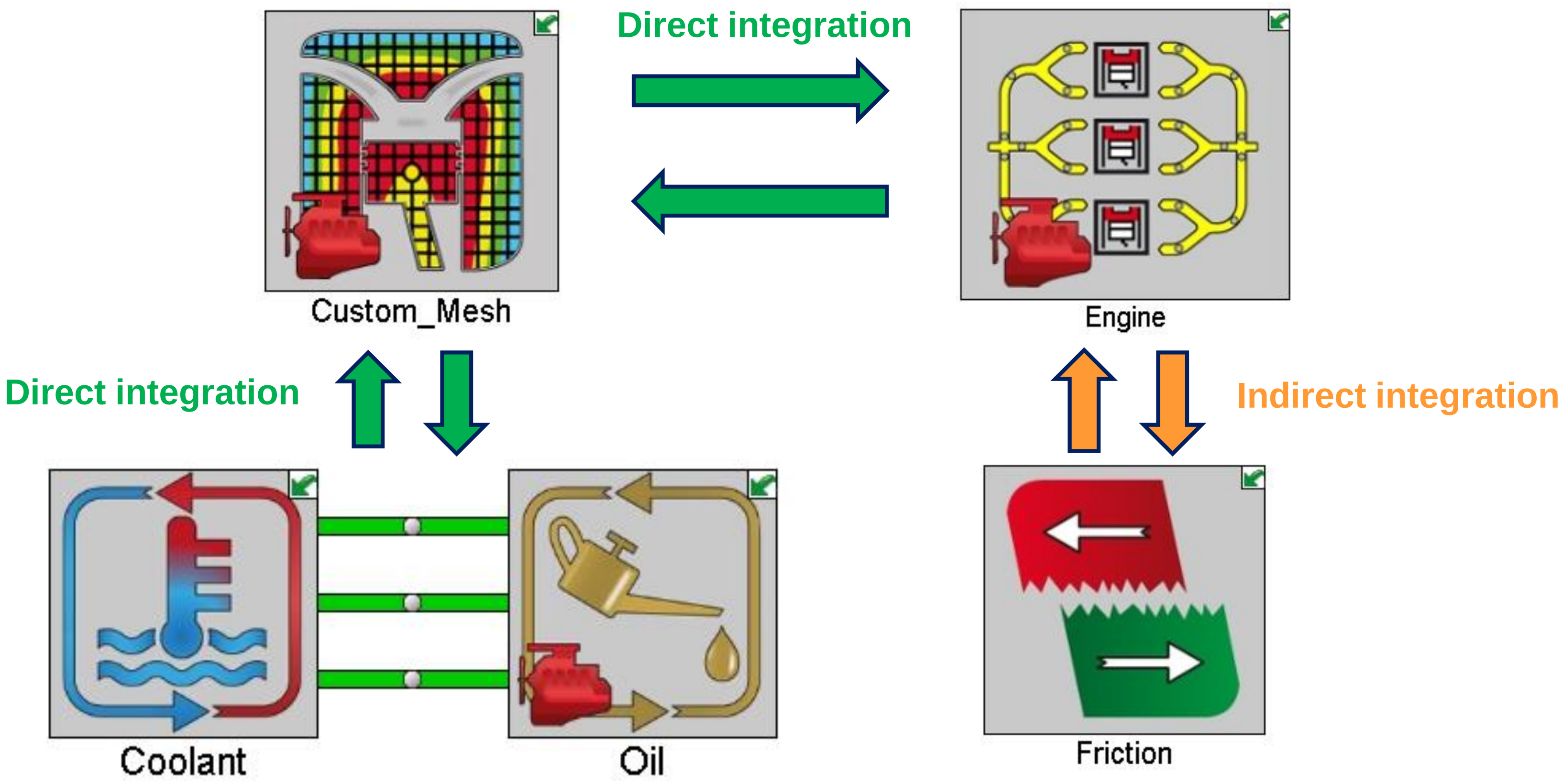
3. Integrated Model

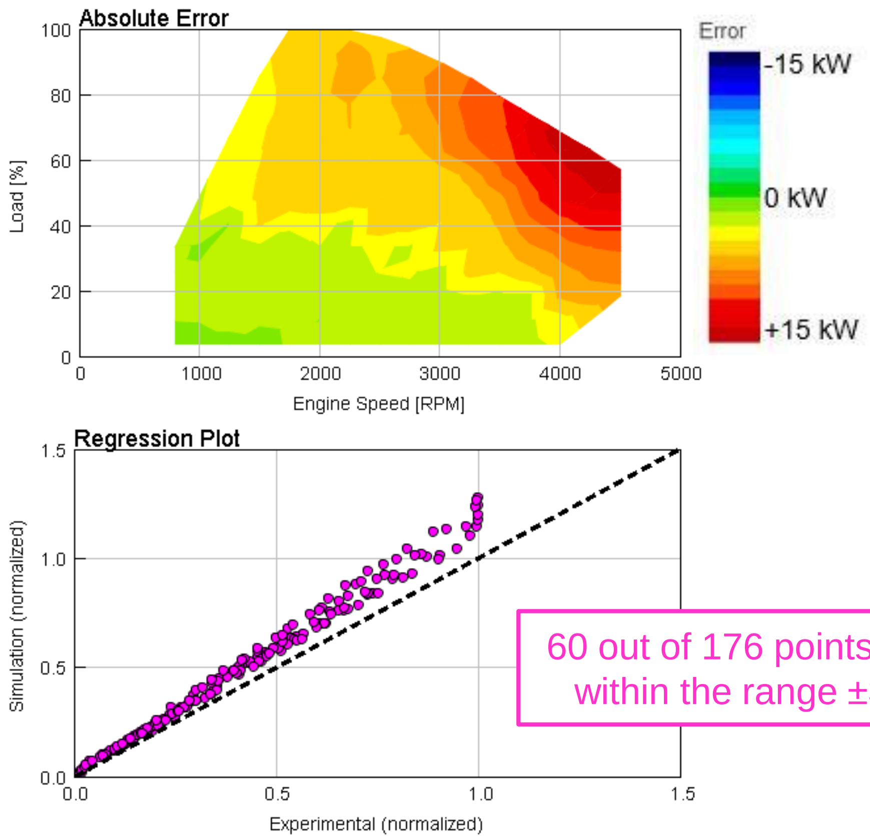
- All subsystems connect into a single integrated model
  - **Direct integration** between performance, thermal and hydraulic models
  - **Indirect integration** with predictive friction model



3. Integrated Model

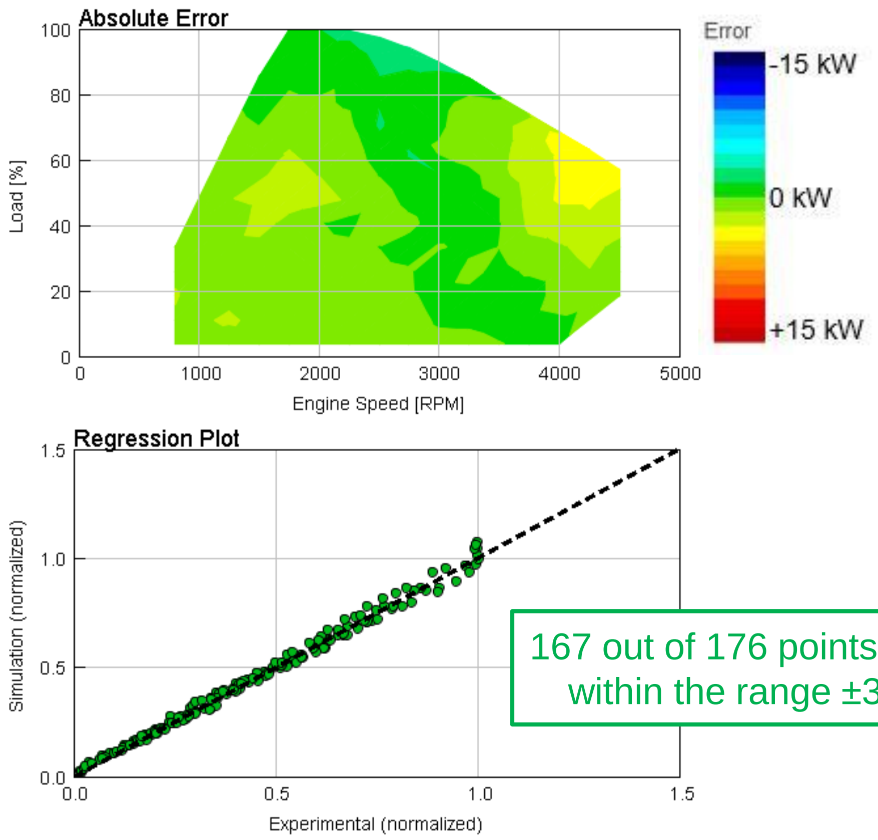
- Validation of the integrated model results
- Tuning of **<u>engine heat rejection</u>** prediction (mostly on the performance model)

Before tuning



60 out of 176 points **(34%)** within the range ±3 kW

After tuning



167 out of 176 points **(95%)** within the range ±3 kW

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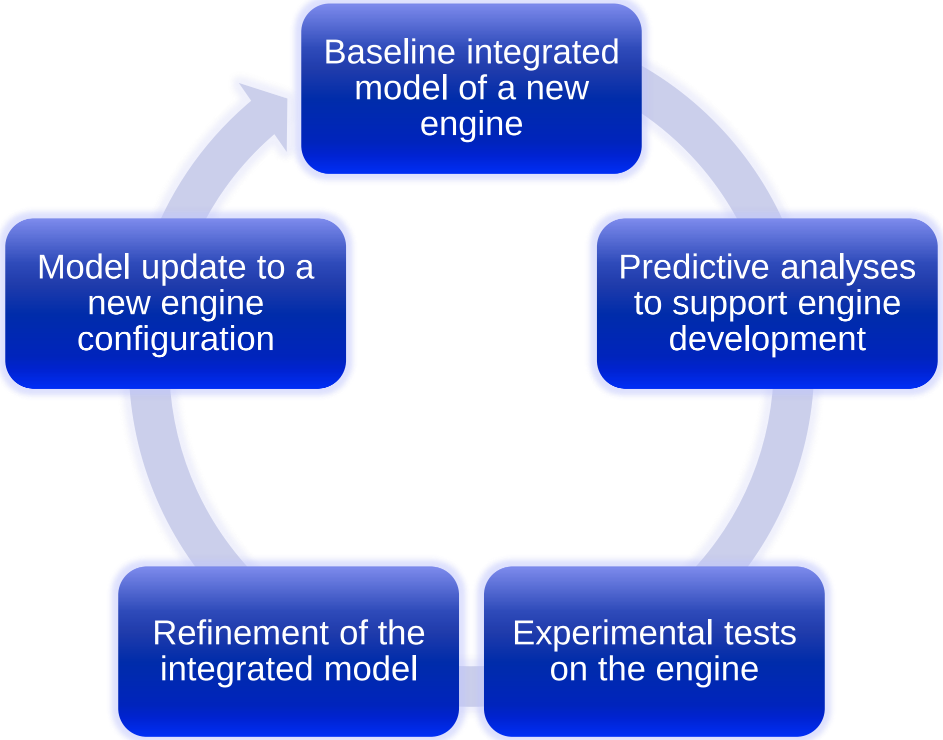
4. Conclusions

- 1D Simulation can support product development from the very beginning!
  - Predictive models can be inherited from previous programmes
  - They can be used from early stages to make informed decisions
  - As data become available, model can be updated/validated



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