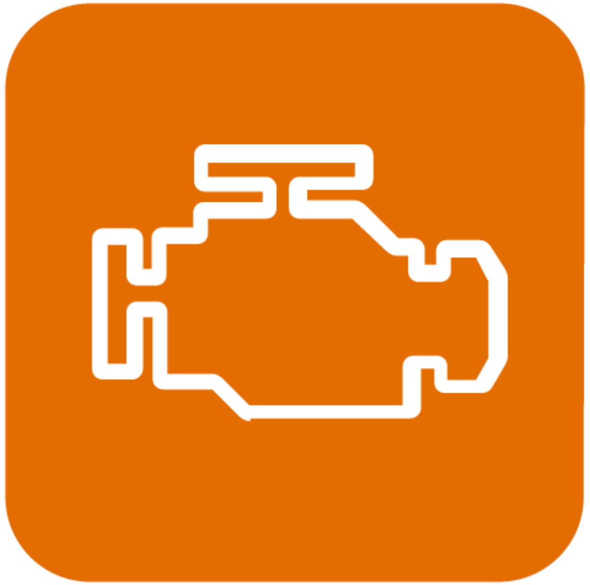
ENGINE DYNAMICS LIBRARY

Overview

Modelon

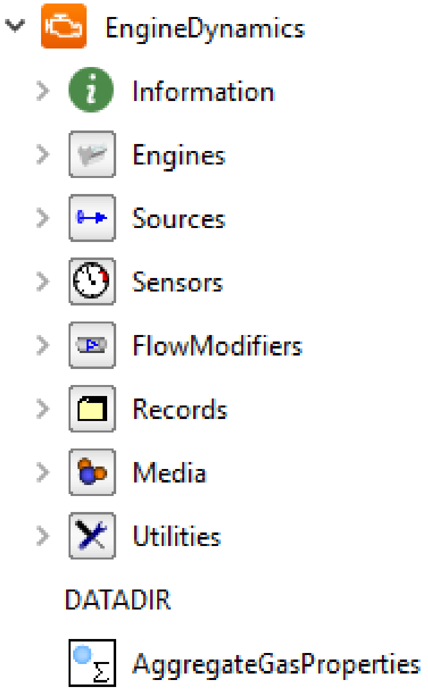
AGENDA

- ❑ About Engine dynamics library
- ❑ Key Features
- ❑ Key Capabilities
- ❑ Key Applications
- ❑ Library Contents
- ❑ Modelon Compatibility
- ❑ Latest Release



ABOUT ENGINE DYNAMICS LIBRARY

- Modelica library for simulation of combustion engine systems, including air path management and gas exchange with focus on the gas dynamics.
- Transient dynamics and steady state performance of engine systems
- Mean-value combustion models for both SI and CI engines
- Fast simulation performance
- Capture trends of emission generation

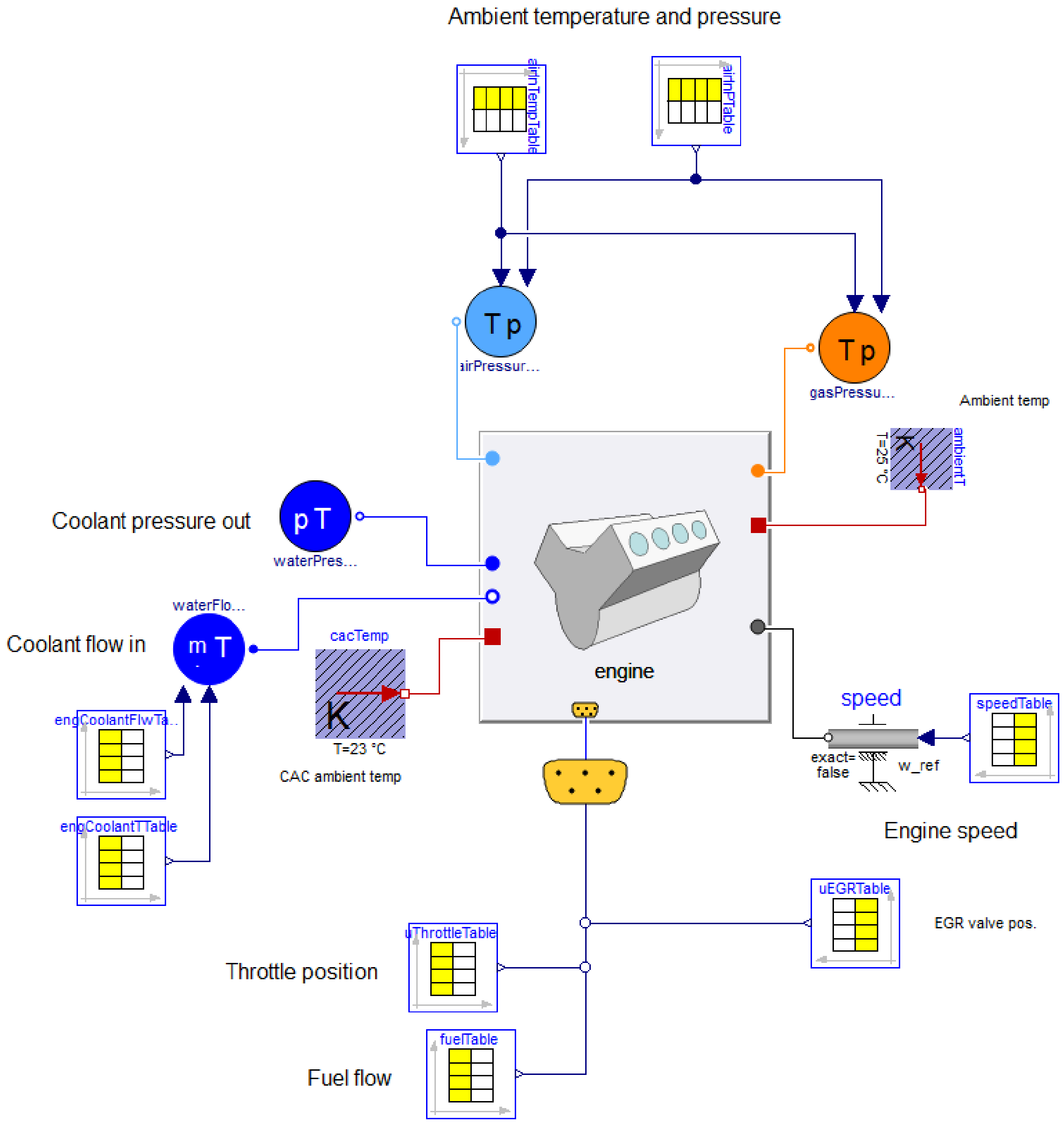


KEY BENEFITS

- Physical gas exchange modeling
- Mean value combustion model
- Flexible model options for torque, heat generation, emissions
- Capture dynamics and steady state performance of engine systems
- Wide range of engine and fluid component models
- Engine system templates and examples for rapid model realization
- Compatible with other Modelica libraries for full vehicle thermal management, drivability, fuel economy, etc.
- SIL simulation with engine control system

KEY CAPABILITIES

- Diesel and spark-ignited engines
- Capture essential system behavior such as non-minimum phase and sign reversal effects
- Transient exhaust condition modeling and emissions
- Virtual prototyping on system level
- Drivability analysis
- SiL simulation with engine control system
- HiL simulation
- Capture trends of Nox and soot

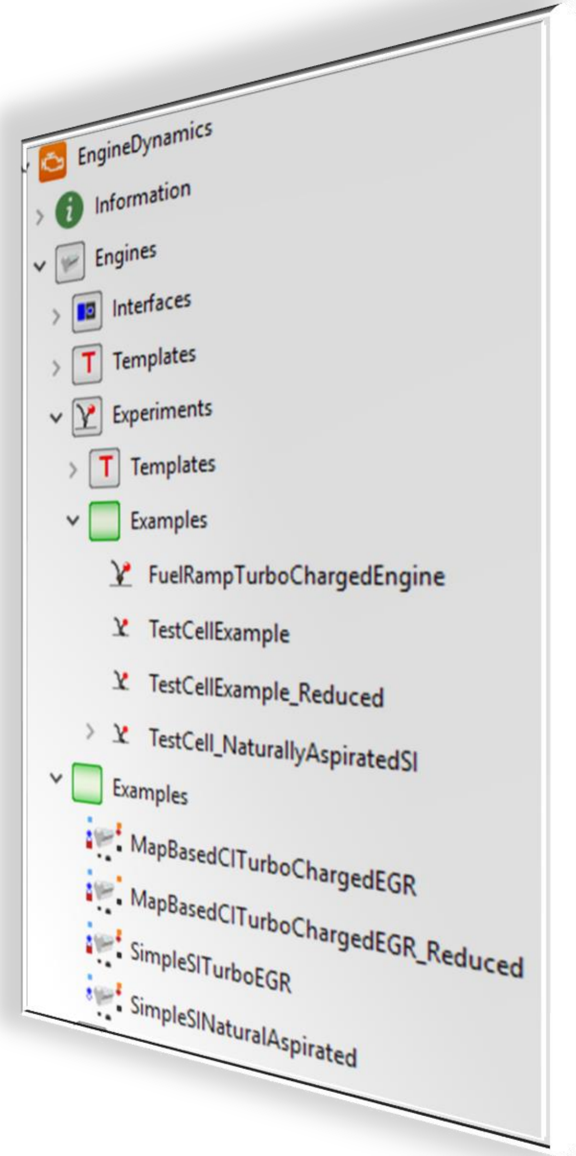


Modelon

KEY APPLICATIONS

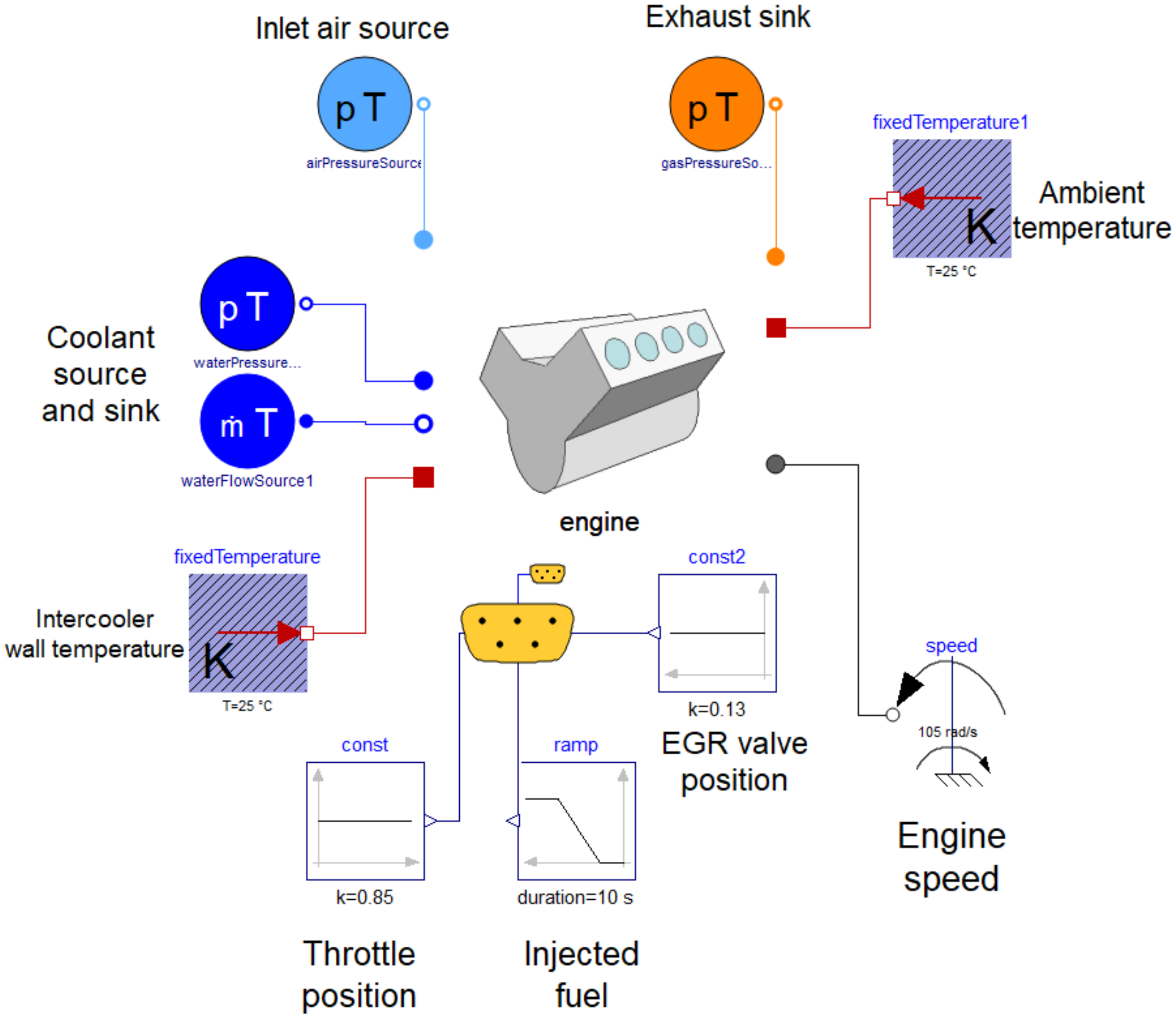
KEY APPLICATIONS

- Model of an engine in a test cell with fixed speed & ramped fuel injection.
- Spark ignited engine
- Boost pressure
- Vehicle Thermal Management (VTM)



EXAMPLE: FUEL RAMP TURBO CHARGED ENGINE

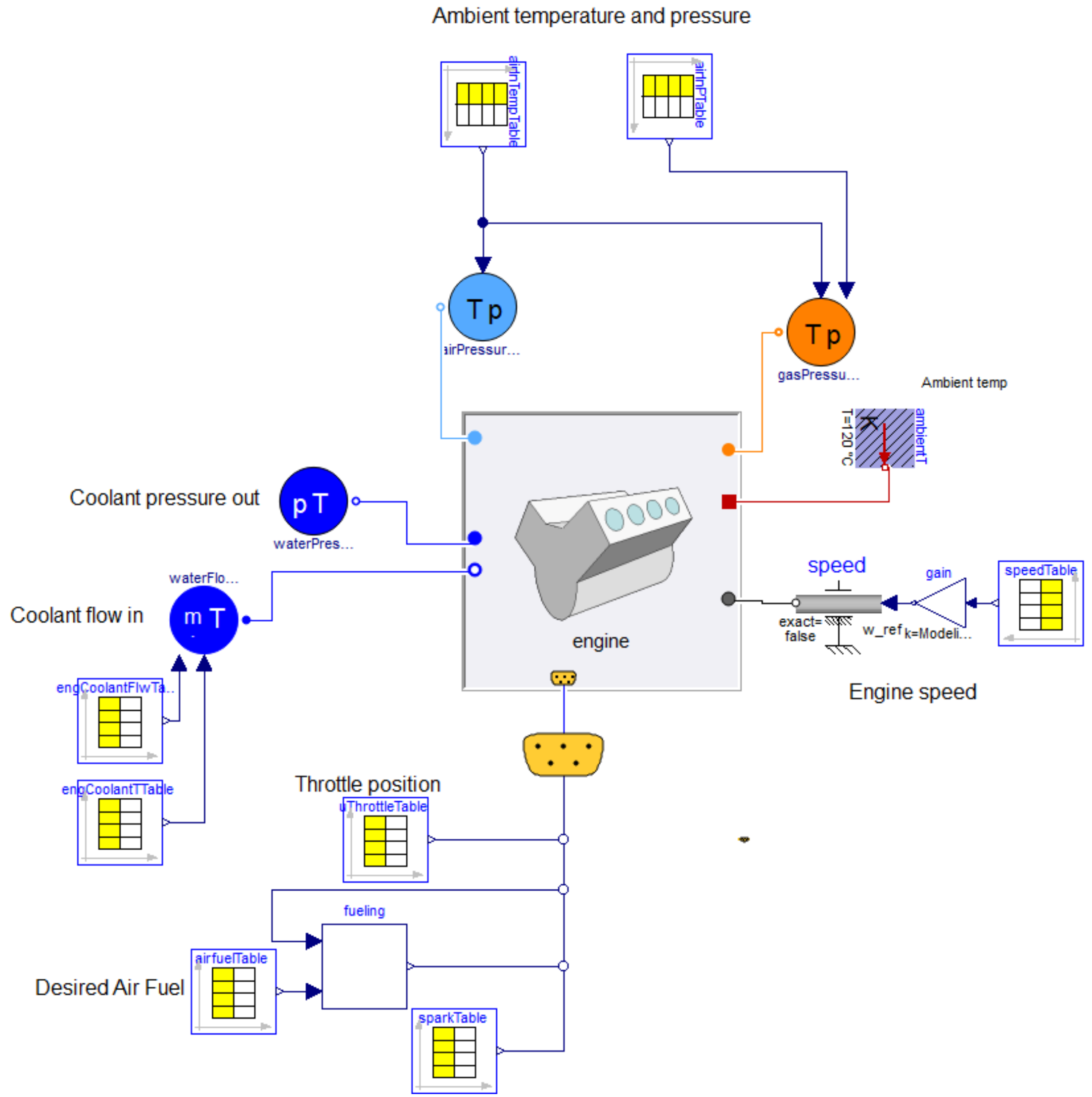
This is an example simulation model illustrating how engine test cell simulations can be performed. The engine is assumed to be mounted to an electrical dynamometer that directly controls the engine speed.



Modelon

EXAMPLE: SPARK IGNITED ENGINE

Test model for the entire engine system with dynamic measured signal as input. To create an experiment, extend from this model and redeclare the engine with a configured one. Then chose parameters and initial values in the drop-down menus in the engine parameter dialog. These are best created by using the supplied MATLAB functions.

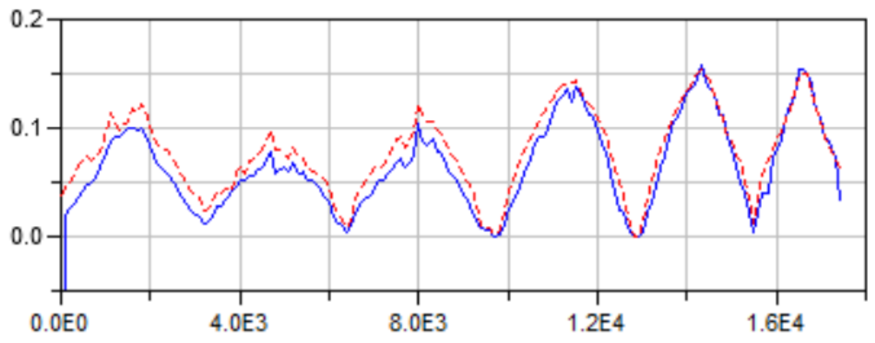


CASE STUDY

Boost pressure step response to EGR valve actuation

Objective

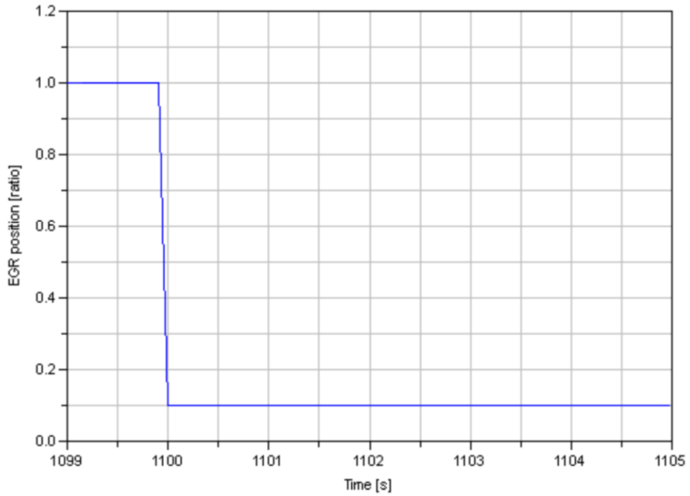
The EGR valve model is validated with part load map data. Upstream and downstream pressures are prescribed and the simulated EGR flow rate is compared to measurements

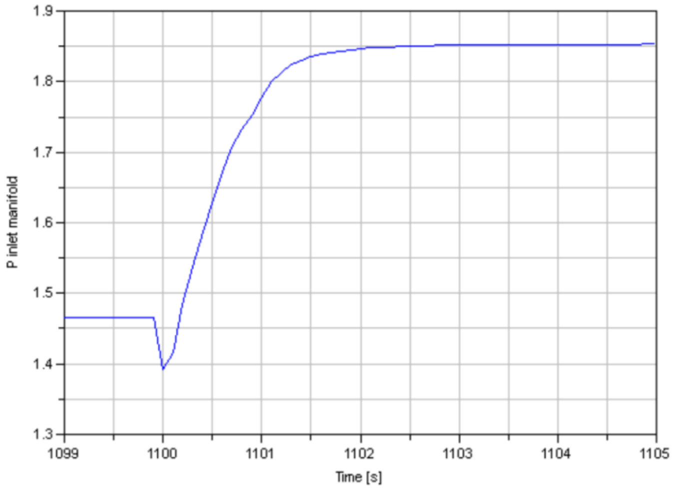


EGR flow model validation. EGR flow [kg/s], simulated (solid) and measured (dashed)

Results

EGR valve has some essential system properties such as nonminimum phase behavior in the intake manifold pressure and a non-minimum phase behavior and a sign reversal in the compressor flow. It captures the non-minimum phase behavior between the EGR valve position, change and inlet manifold pressure.





Modelon

CASE STUDY

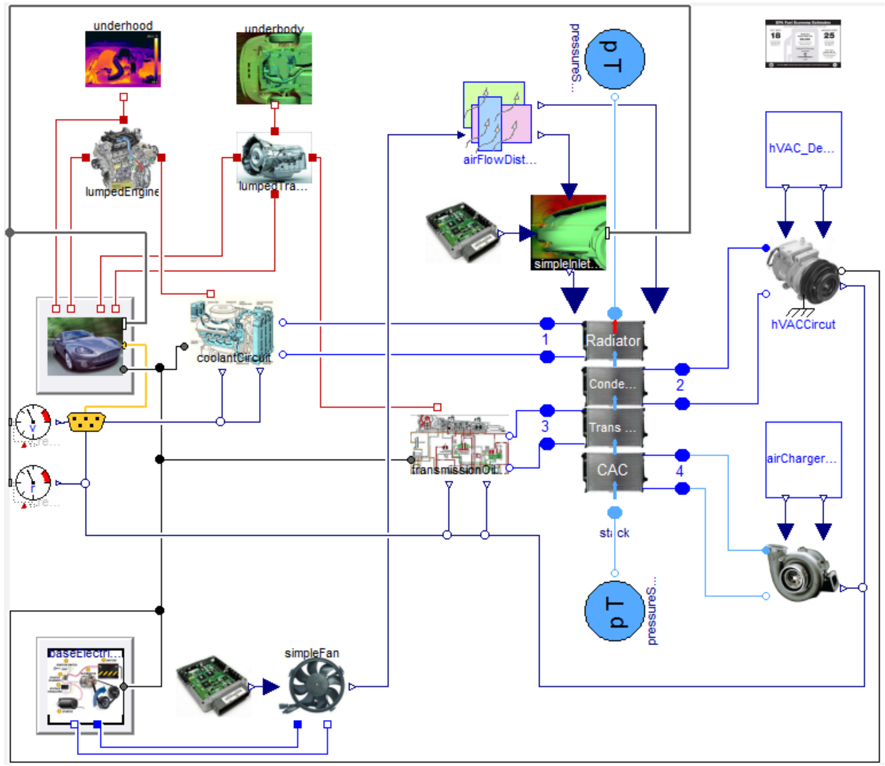
Vehicle Thermal Management (VTM)

Objective

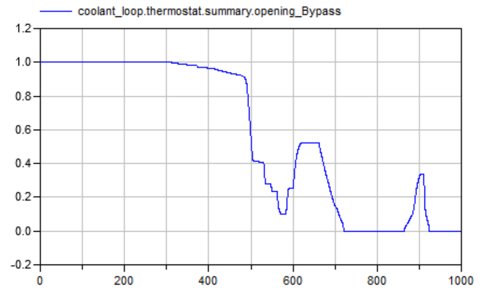
Balancing system level requirements for cooling and energy usage

Results

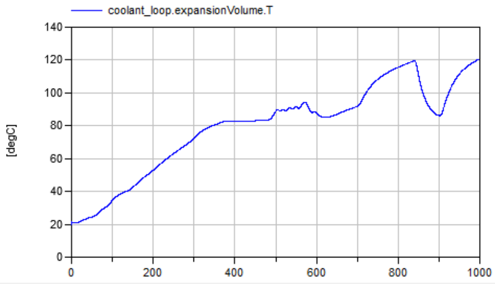
- Multi-domain physical modeling approach for energy conservation across domains (mechanical, thermal, electrical, thermofluid) and vehicle thermal management
- Flexibility in integration of physical and controls models



- Thermal
- Mechanical
- Electrical
- Coolant
- Air
- Controls



Controlled temperature

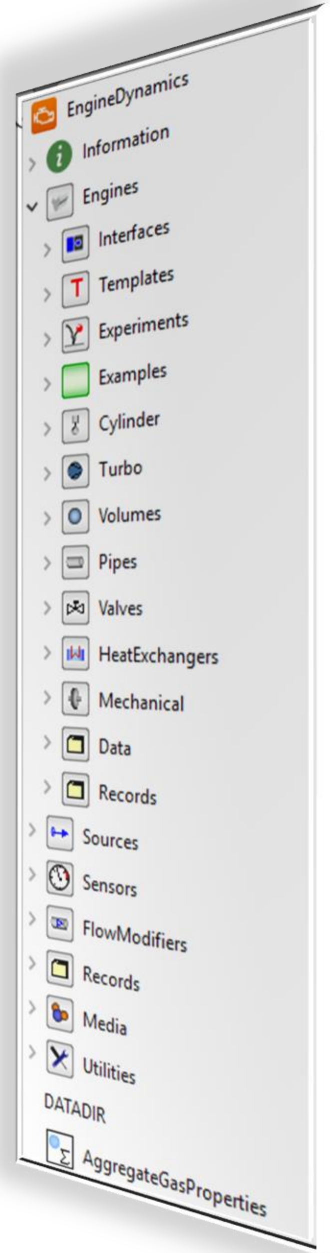


Actuator - thermostat

LIBRARY CONTENTS

LIBRARY CONTENTS

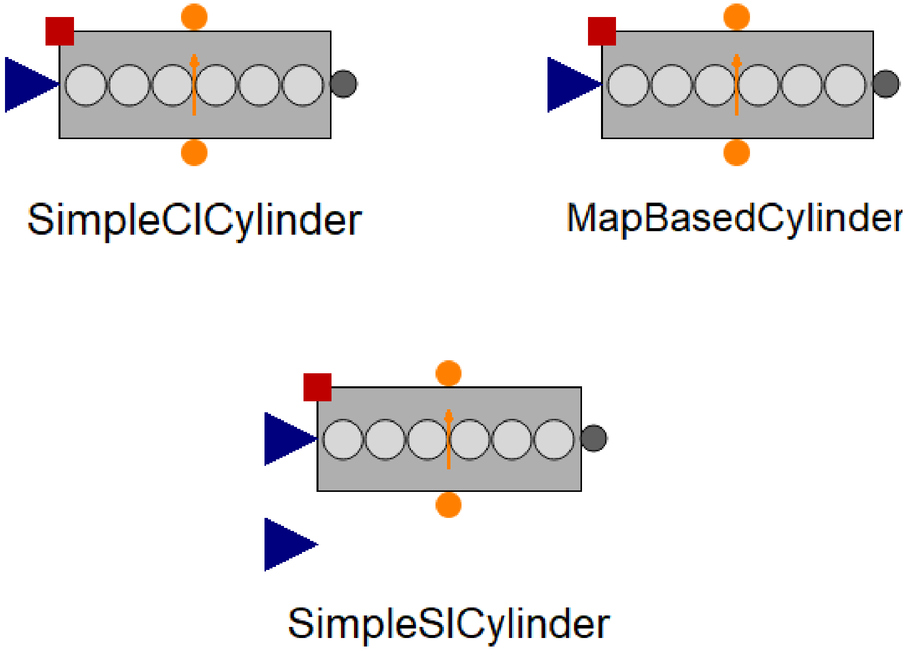
- Engines
  - Cylinder component
  - Turbo components
  - Heat exchangers
  - Volumes
  - Pipes
  - Valves
- Media models
- Sources
- Sensors
- FlowModifiers

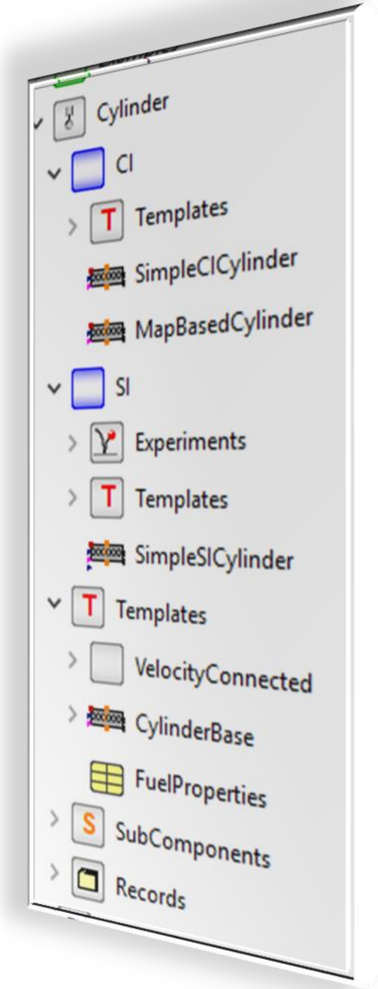


LIBRARY CONTENTS

Cylinder

- CI (Compression ignition)
    - SimpleCICylinder
    - MapBAsedCylinder
- SI (Spark ignited)
    - SimpleSICylinder
- Templates
    - CylinderBase (This template defines a minimal interface of connectors and parameters as well as basic physical equations for a MVM)

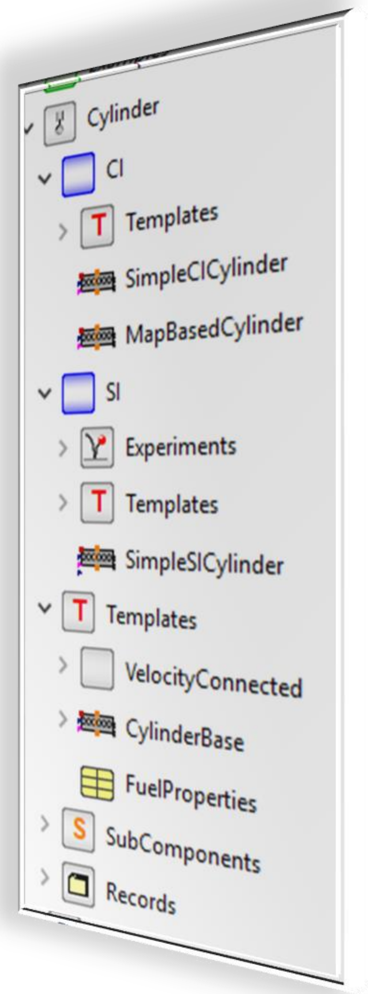




LIBRARY CONTENTS

Cylinder Correlations

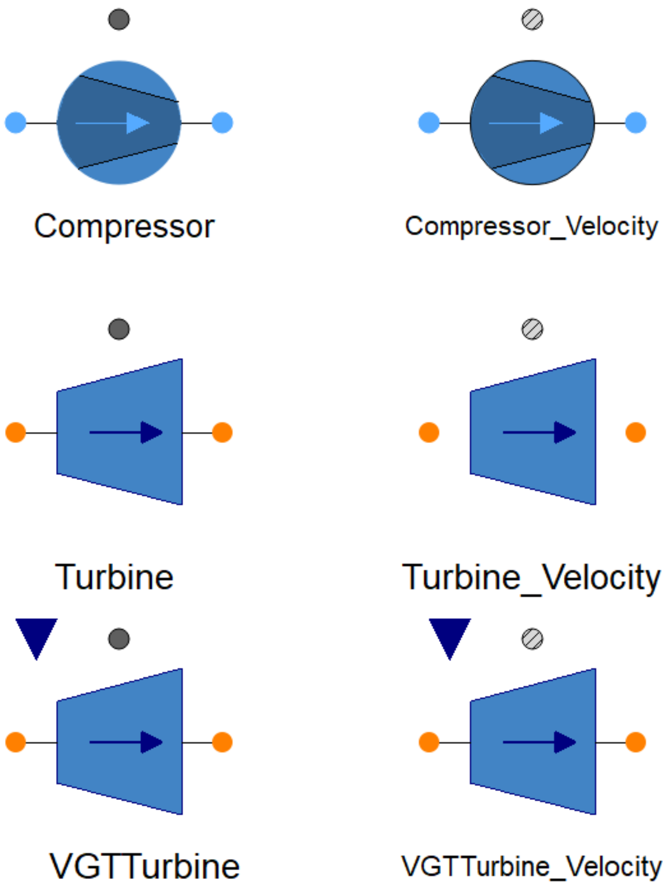
- The properties that must be assigned are:
- Volumetric efficiency
- Energy conversion efficiency, η = Indicated MEP / Fuel MEP
- Mechanical friction torque
- Exhaust gas temperature
- Emission concentrations, as defined by medium model
- Torque during engine brake
- Exhaust gas temperature during engine brake

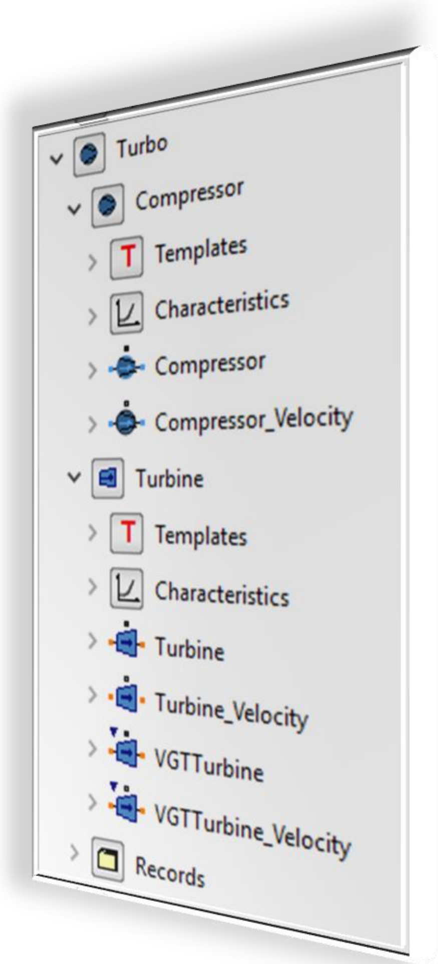


LIBRARY CONTENTS

Turbo

- Compressor
  - Compressor & Compressor_velocity
- Turbine
  - Turbine & Turbine_velocity
  - VGTTurbine & VGTTurbine_Velocity
- All are parameterized by maps of:
  - Corrected mass flow
  - Isentropic efficiency
  - Corrected speed
  - Pressure ratio



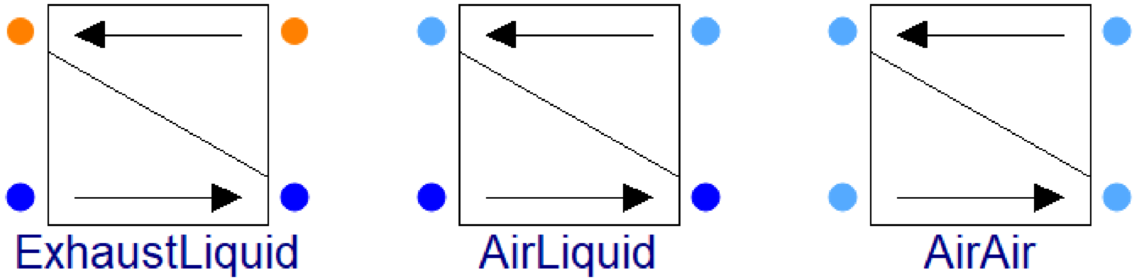


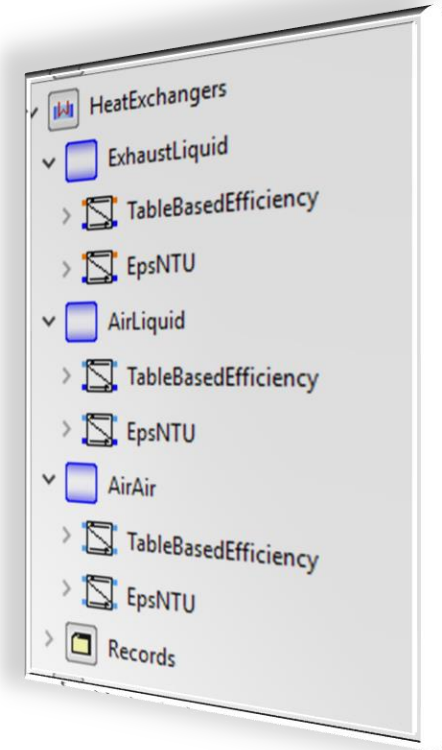
Note: Turbo components are *flow models* – use them between volume models or pressure sources for good numerics.

LIBRARY CONTENTS

HeatExchangers

- ExhaustLiquid
  - TableBasedEfficiency
  - EpsNTU
- AirLiquid
  - TableBasedEfficiency
  - EpsNTU
- AirAir
  - TableBasedEfficiency
  - EpsNTU





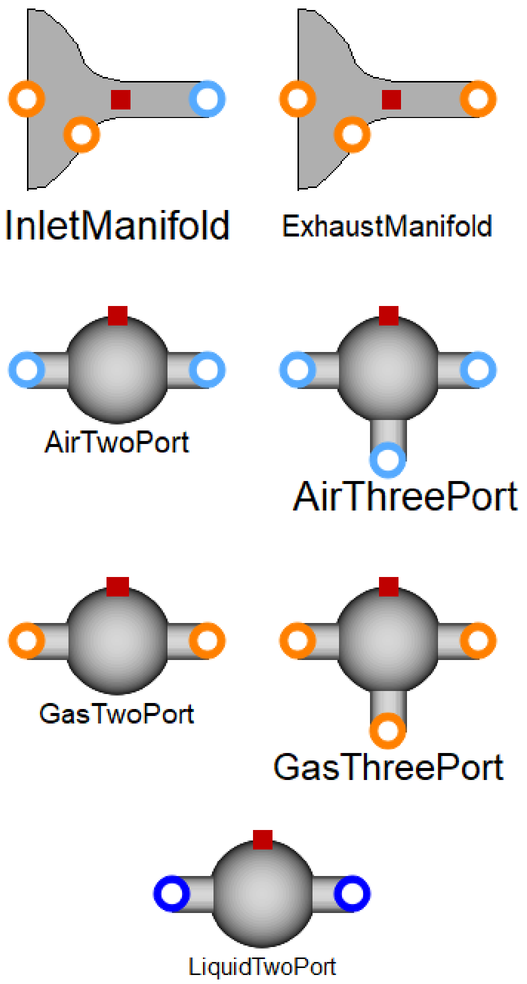
Note: The heat exchangers are *flow models* – use them between volume models or pressure sources for good numeric. The friction model is replaceable.

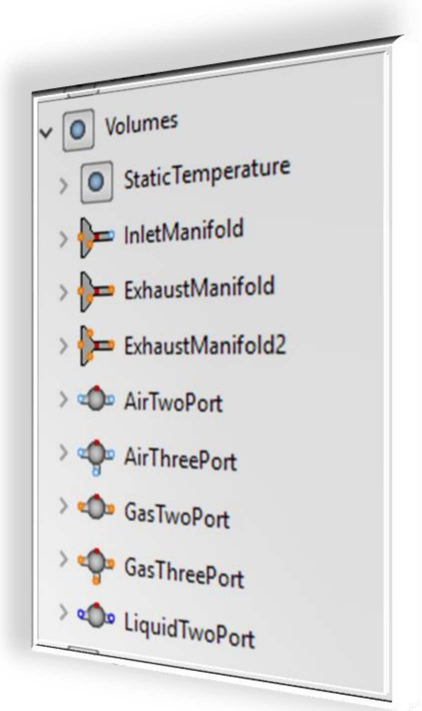
LIBRARY CONTENTS

Volumes

Several volume components are available

- Storage of mass and energy, assumes ideal mixture
- Introduce state variables for
  - Pressure, Temperature, and Mass fractions and trace from medium model
- Via parameters it is possible to include
  - Wall heat capacity & Heat trasfer between gas and wall
- Difference between components
  - Port configuration, Default medium choice &
  - Connector color

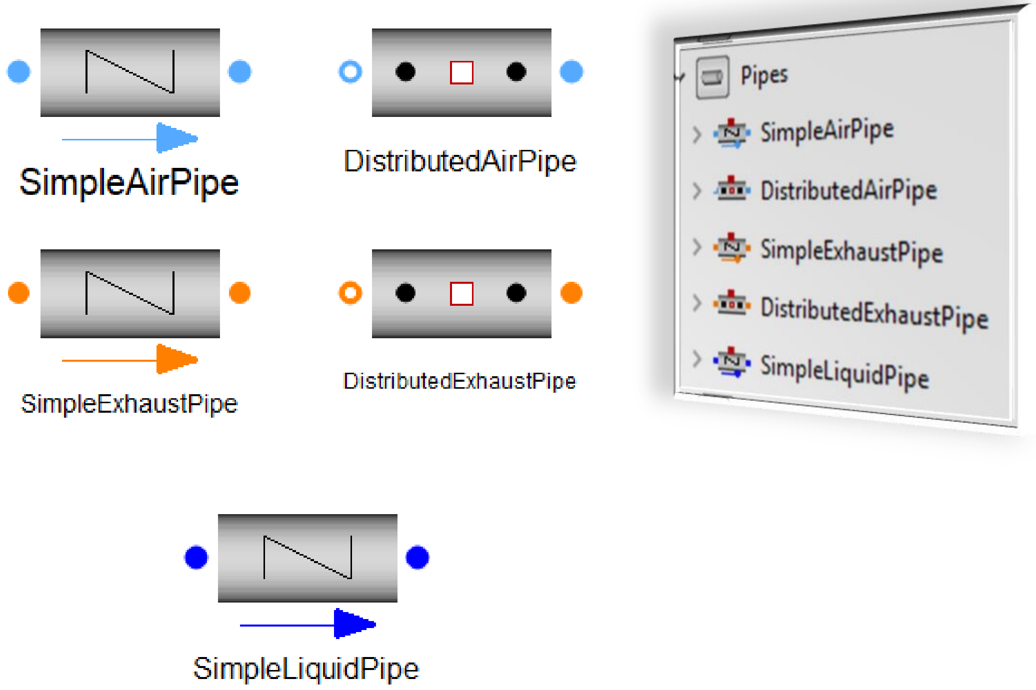




LIBRARY CONTENTS

Pipes

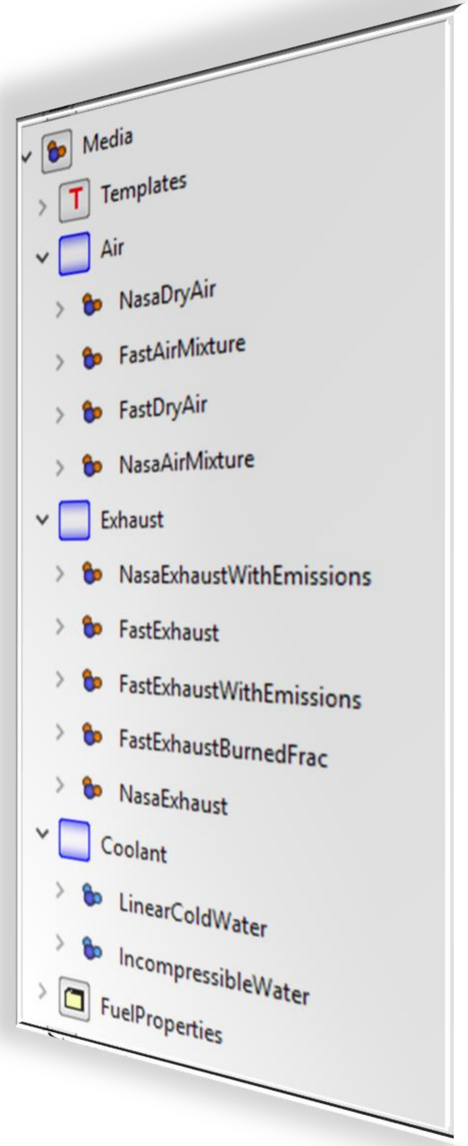
- Pipe components for air, exhaust gas and coolant are available.
  - The pipe component can model any component where friction and heat transfer are the dominant effects, including coolers.
  - Friction and heat transfer correlations are selectable using the parameter dialog
  - Use pipe models between volumes or pressure sources for good numerics



LIBRARY CONTENTS

Media Models

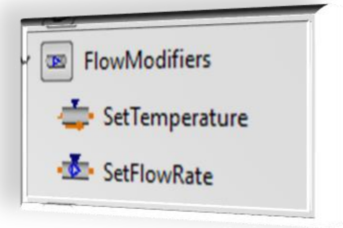
- Air
  - 4-component mixture (H_2O, O_2, N_2, Ar) – Full NASA
  - 4-component mixture (H_2O, O_2, N_2, Ar) – Linear Cp
  - 1-component (Dry air) – Linear Cp
- Exhaust gas
  - 5-component mixture (CO_2, H_2O, O_2, N_2, Ar) – Full NASA, with trace components (NOx, Soot, Hydrocarbons, CO)
  - 5-component mixture (CO_2, H_2O, O_2, N_2, Ar) – Linear Cp, with trace components (NOx, Soot, Hydrocarbons, CO)
  - 5-component mixture (CO_2, H_2O, O_2, N_2, Ar) – Linear Cp
  - 2-component mixture (Air, Burned gas) – Linear Cp

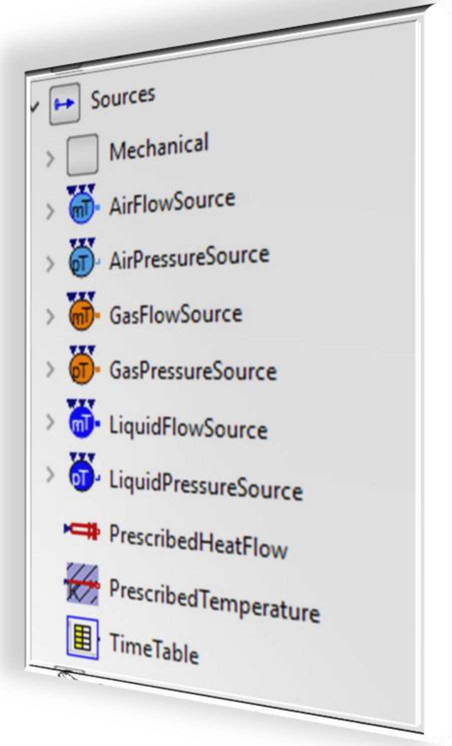


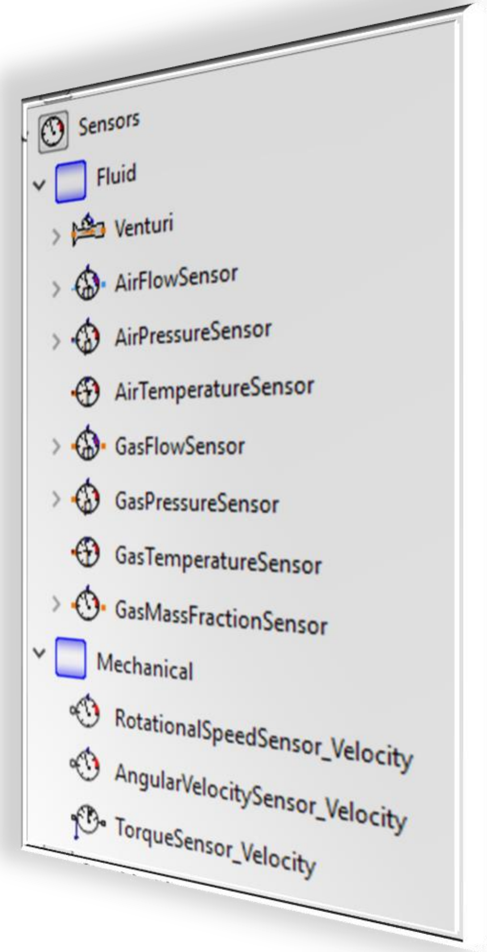
LIBRARY CONTENTS

Basic Components

- FlowModifiers
- Sources
- Sensors





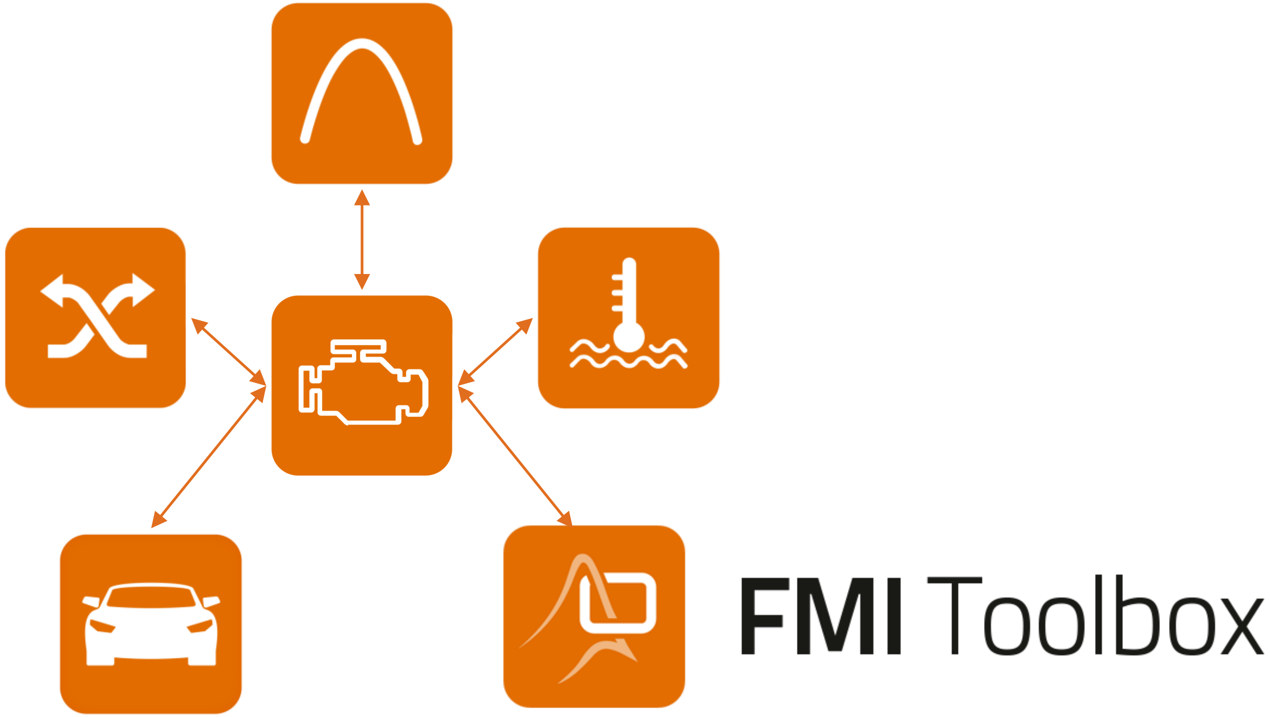


Modelon

MODELON COMPATIBILITY

RECOMMENDED MODELON LIBRARY COMPATIBILITY

- Engine Dynamics Library components are seamless compatible with HeatExchanger Library, VaporCycle Library, Liquid Cooling Library and Vehicle Dynamics Library.
- Engine Dynamics Library compatible with Modelon product FMI Toolbox



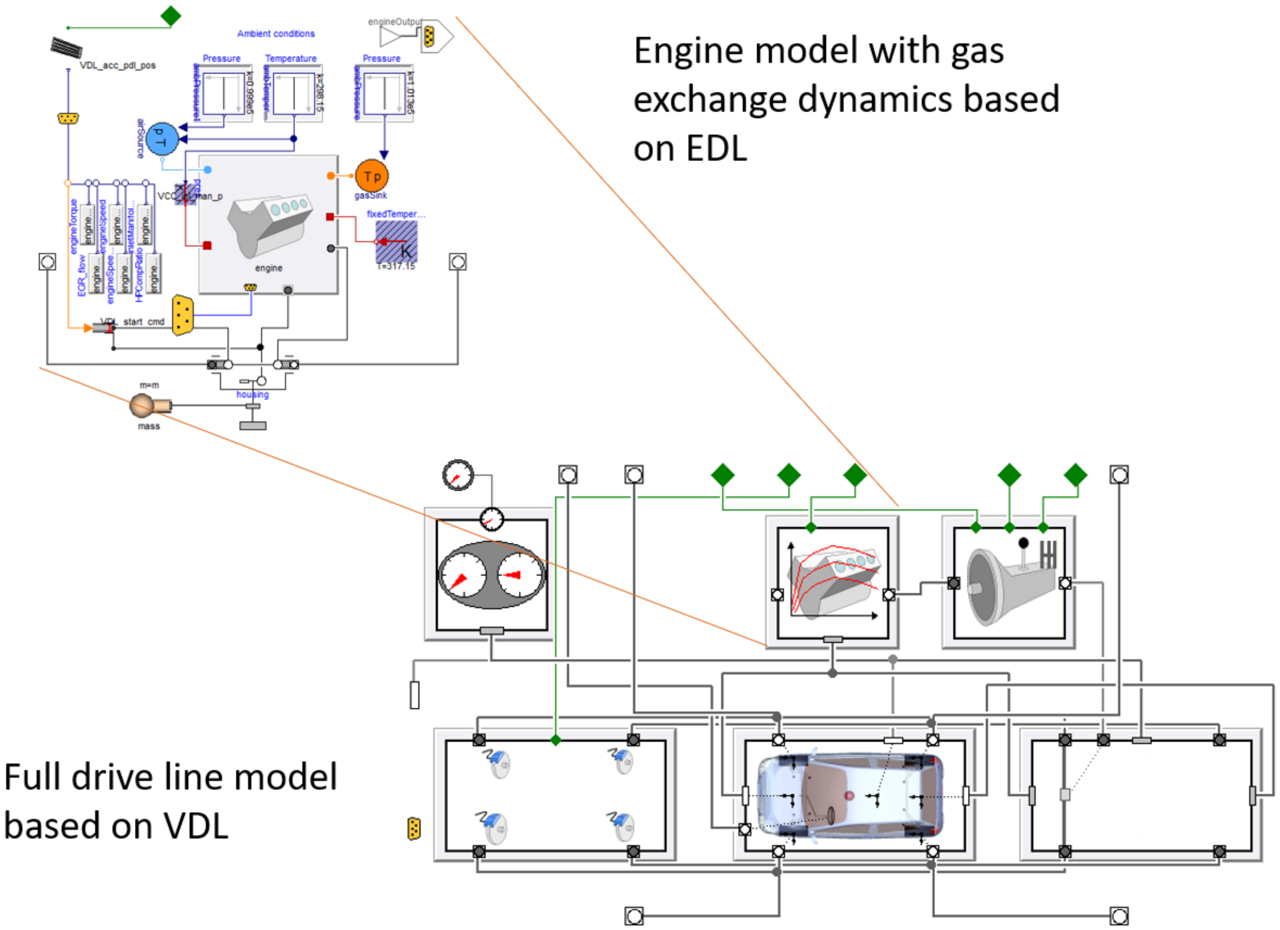
EXAMPLE : DRIVABILITY

Problem: Engine and drive line control balancing energy consumption and drivability.

Solution: Model-based system design/optimization and control design

Tools: Dymola + Engine Dynamics Library + Vehicle Dynamics Library

Partner: OEM

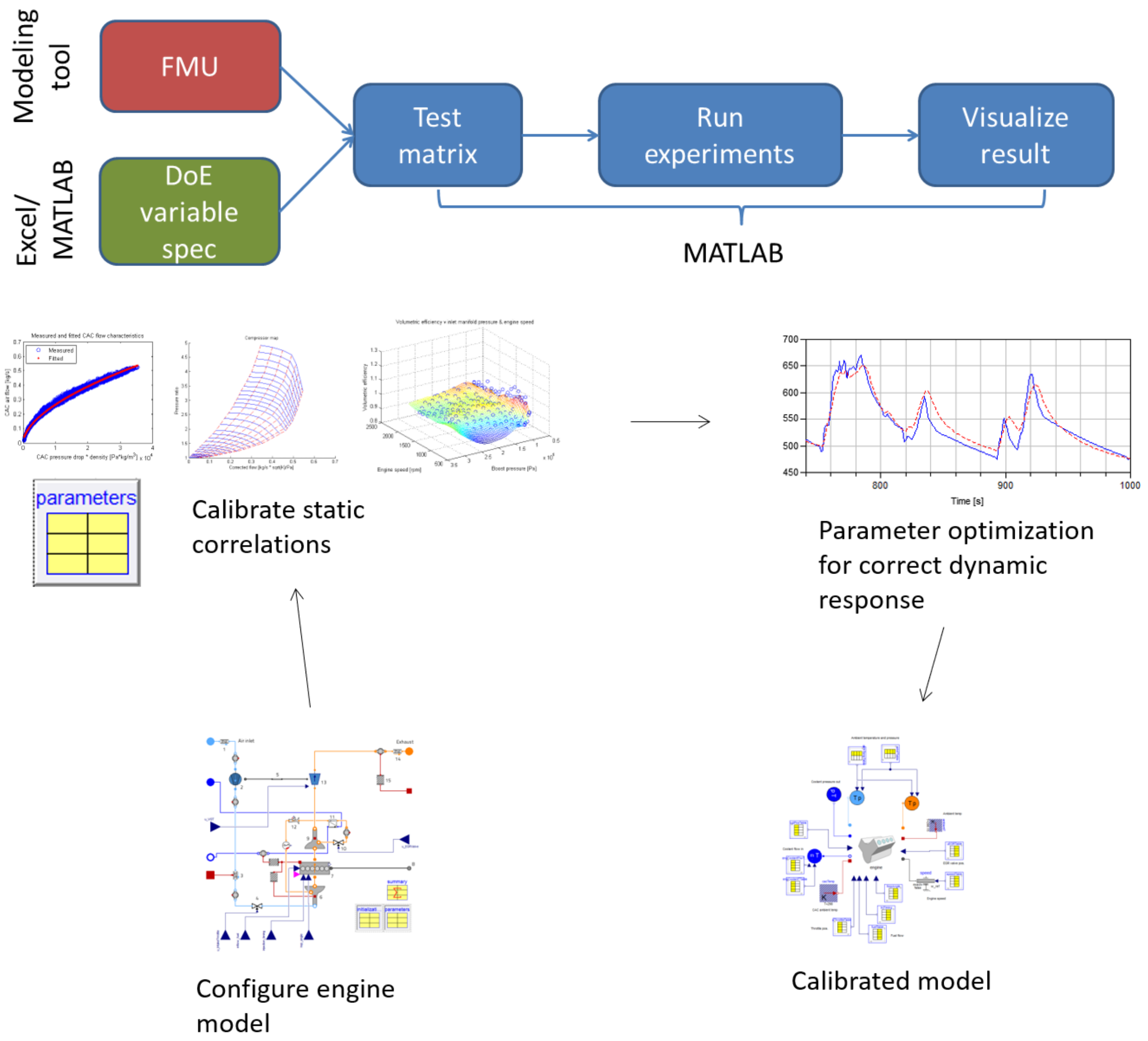


Modelon

EXAMPLE : A WORKFLOW EXAMPLE

Using the Functional Mock-up Interface, state-of-the-art physical models becomes accessible in each state-of-art tool.

Workflow of analyze a Modelica model in MATLAB using Modelon's Functional Mock-up Interface for MATLAB



LATEST RELEASE

RELEASE: 2021.2

Enhancements

- Version 2.7 is updated for use with Modelon Base Library 3.7