

## LMS Imagine.Lab AMESim Vehicle Thermal Management



# LMS Imagine.Lab Vehicle Thermal Management

LMS Imagine.Lab Vehicle Thermal Management solutions provide dedicated tools to build and analyze complete vehicle thermal management models in a single environment. The solutions let users model, size and analyze components, subsystems, subsystem interaction, run steady-state and real transient multi-domain simulations and handle strategic heat management scenarios and their impact on fuel consumption and pollutant emissions as well as passenger comfort and engine performance. Vehicle thermal management solutions give engineers the possibility to work on detailed models of vehicle thermal management subsystems like cooling, lubrication, thermal engines, air-conditioning and in-cabin systems.





- Vehicle Thermal Management
- Engine Thermal Management
- Engine Cooling System
- Refrigerant Loop
- Passenger Comfort
- Lubrication

## References

**Toyota** - Heat management simulation for diesel engines

**Ford** - Modeling of engine lubrication systems

**Renault** - Vehicle thermal management - AC and cabin thermal load simulation

**Valeo** - Additional heating strategies on vehicle fuel consumption and pollutant emissions

**Calsonic** - CO2 AC system performances evaluation and vehicle thermal management



# LMS Imagine.Lab Vehicle Thermal Management

LMS Imagine.Lab Vehicle Thermal Management provides a dedicated set of tools and libraries to study the energy flows under the hood and within the cabin, which are directly or indirectly contributing to pollutant emissions, fuel consumption, engine performance and passenger comfort. It helps engineers to focus on the interactions between different subsystems (lubrication, cooling, exhaust line, combustion chamber, engine thermal masses, air conditioning, electric auxiliaries, cabin and vehicle) to find the best compromises for energy flow management (thermal, thermal-fluids, electrical and mechanical).

LMS Imagine.Lab Vehicle Thermal Management, based on multi-physical component libraries, offers a decisive approach to control the energy flows.

Furthermore, LMS Imagine.Lab Vehicle Thermal Management helps analyze the influence of new generation subsystems (heat pump systems, energy storage systems, heat recovery system) or components (electric pumps, controlled valves, immersion heaters) on the overall system behavior and especially on fuel consumption, pollutant emissions and passenger comfort.

LMS Imagine.Lab Vehicle Thermal Management provides a cost effective alternative to prototypes so that virtual vehicle subsystems integration can be easily and rapidly studied. It is fully integrated into the LMS Imagine.Lab AMESim platform, and therefore takes advantage of its flexibility and its multi-domain modeling capabilities.

## Features

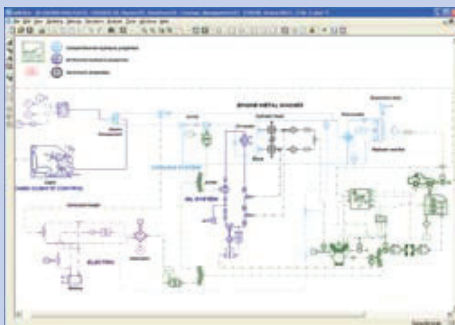
- Basic element approach for each subsystem (higher flexibility, higher degree of freedom in the modeling)
- Advanced application components
- Model design including subsystems connection and interaction
- Off-the-shelf pre-existing models for vehicle thermal management subsystems: vehicle model, air-conditioning, exhaust, cabin environment, and electric consumers

## Benefits

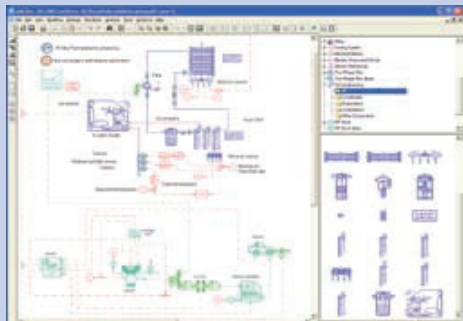
- Efficient and low cost alternative to prototyping or test rigging
- Easy to study subsystem integration
- Modeling of energy flows under the hood and in the cabin into a single environment
- Fast validation of existing vehicle architectures
- Anticipate architecture changes on potential gains in passenger comfort, fuel consumption and pollutant emissions



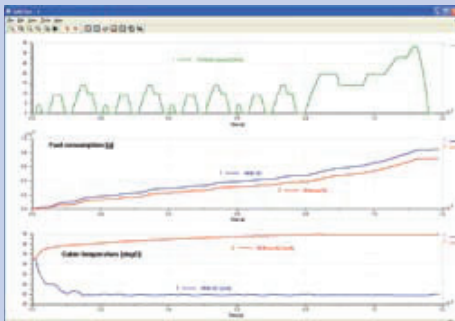
LMS Imagine.Lab Vehicle Thermal Management helps study energy flows under the hood and within the cabin.



LMS Imagine.Lab Vehicle Thermal Management tests the impact of cabin heating strategies on fuel consumption.



LMS Imagine.Lab Vehicle Thermal Management defines fuel consumption increase due to air-conditioning loop activation.



This graph shows the temperature in the cabin with and without air conditioning, and the impact on fuel consumption.

# LMS Imagine.Lab

## Engine Thermal Management

LMS Imagine.Lab Engine Thermal Management helps model the overall energy balance of an engine in a single platform by considering thermal interactions between the lubrication and cooling systems, the thermal engine, the combustion chamber and the intake and exhaust pipes.

System integration is one of the current challenges faced by car manufacturers and suppliers, especially in the field of engine thermal management. To ensure engine performance and design low consumption and low emission engines, while providing the best possible comfort to passengers, engineers have to be able to optimize the engine warm-up. With LMS Imagine.Lab AMESim tools, users can model engine warm-up and associated key-criteria (consumption, cabin heating) in a specific normalized cycle and rapidly study the influence of topological modifications of each subsystem (split cooling, energy storage tank, engine material changes, electric pump).

LMS Imagine.Lab Engine Thermal Management comes as a set of physics-based libraries such as Thermal, Thermal-Fluid and application libraries like Cooling Systems, IFP-Engine (combustion chamber thermal losses). Each product assists the user in building individual subsystems, analyzing their independent behavior, and defining interaction ports with the other subsystems. Finally, all the modules are connected together to create the engine thermal management model in a single environment.

This model is able to:

- Perform sensitivity analyses and optimization of the systems
- Test new heat management strategies (split cooling, electric pump and thermostat, water passage size, energy storage tank, additional heaters)
- Test new engine architectures (double cylinder block water jacket, new engine materials, thermal screen integration)
- Create fuel consumption simulators

### Features

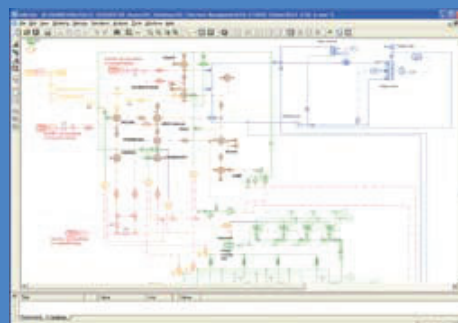
- Complete engine thermal model in a single environment
- State-of-the-art components
- Boundary conditions in combustion chamber from combustion analysis models (IFP-Engine library)
- Real transient models
- Ready-to-apply methodologies for design of complete engine thermal management models

### Benefits

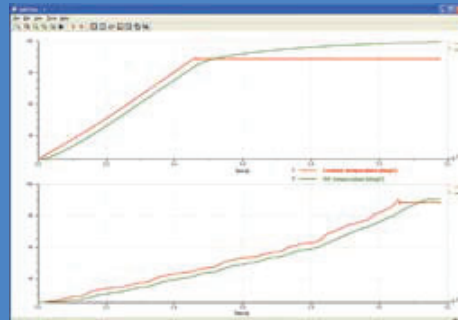
- Rapidly study influence of new heat management strategies and engine architectures on warm-up, fuel consumption and pollutant emissions
- Reduce development time by reusing models
- Adapt models to new engines
- Study influence of solids and fluids temperatures on friction and work on specific solutions to reduce/optimize engine friction
- Focus on system analysis instead of working on codes
- Easily integrate specific user libraries (heat exchangers, new technological components)



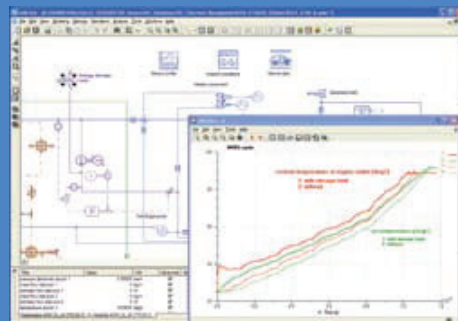
LMS Imagine.Lab Engine Thermal Management helps to study the engine temperature influence on friction.



A complete engine thermal management model, including the metal masses, the lubrication circuit, the cooling circuit and a first modeling level of the combustion chamber and the friction heat sources.



Typical results from engine thermal analysis are the oil and coolant temperature, both on a single operating point or on a driving cycle.



The flexibility of LMS Imagine.Lab Engine Thermal Management helps simulate the impact of structural modifications, such as the addition of a storage tank in the coolant circuit, or the warm-up of the engine.

# LMS Imagine.Lab Engine Cooling System

With LMS Imagine.Lab Engine Cooling System, engineers can model the complete cooling system of a vehicle, including all the components (pump, thermostat, radiator) with the associated heat exchanges and interactions with other under the hood subsystems. It comes with a set of physics based elements, advanced component libraries and a specific heat exchanger stacking tool (vehicle front end) for thorough system analysis (isothermal or thermal) in steady-state and or transient configuration. Innovation in the engine cooling system field is clearly influenced by restrictive emissions requirements for reduced fuel consumption.

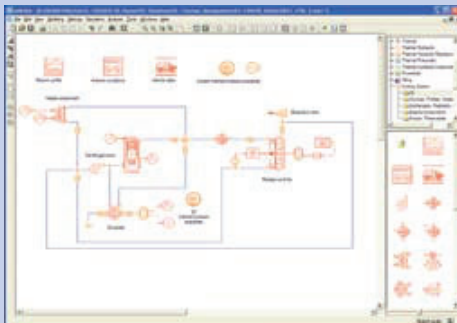
With LMS Imagine.Lab Engine Cooling System, engineers can calculate the coolant flow rate distribution as well as predict pressure and temperature levels throughout the circuit to study individual component and global system performances and behavior. Moreover, components thermal interactions and system architecture modifications (front end heat exchanger stacks) can be studied to perform drive cycle analysis and test new control strategies (fans, blowers, pumps).

## Features

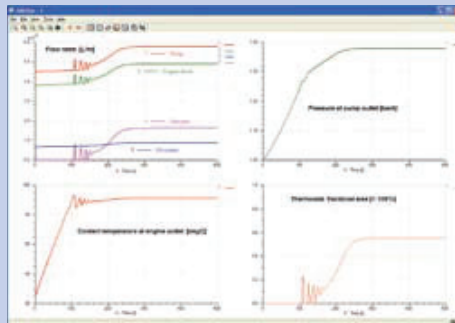
- Steady-state and/or transient analysis
- Isothermal or thermal analysis
- Prediction of coolant flow rates and pressure levels
- Prediction of coolant temperature levels
- Drive cycle analysis

## Benefits

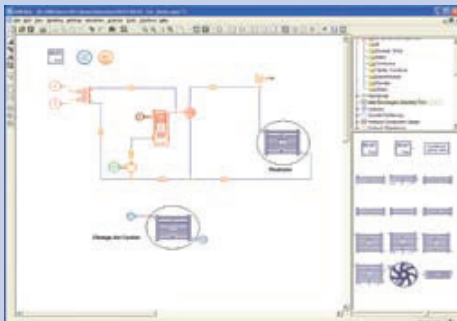
- Ensure a sufficient flow to maintain critical engine parts at a required optimal temperature
- Size pump and other components (radiator, thermostat)
- Evaluate modifications of existing architecture
- Evaluate new architecture in a pre-design stage
- Check thermal behavior with different operating conditions through a defined cycle (transient)



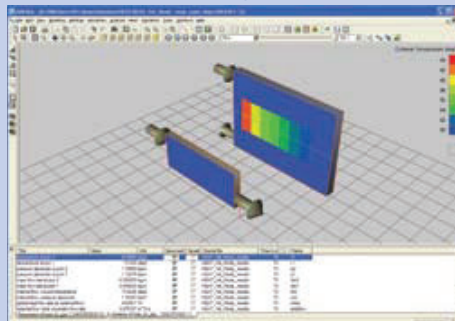
A typical engine cooling circuit, including a centrifugal pump, a thermostat, a radiator, an expansion tank, a heater component and an oil cooler.



The engine cooling system helps to calculate the coolant flow rate distribution as well as predict pressure and temperature levels throughout the circuit.



The solution allows also to show the impact of heat exchangers stacks on the cooling system performance, for example, influence of a charge air cooler located just in front of the radiator.



A 3D environment instantaneously shows the impact of heat exchangers on the others.

## LMS Imagine.Lab Refrigerant Loop

With LMS Imagine.Lab Refrigerant Loop the design of AC loops can be studied and performed. The climate control system has become one of the most important features in automotive comfort, and the refrigerant loop significantly influences fuel consumption and pollutant emissions. LMS Imagine.Lab Refrigerant Loop comes with a dedicated set of tools and libraries for pressures, temperatures, flow rates, prediction, heat exchangers characterizations, component performance optimization, Coefficient of Performance calculation, and drive cycle analysis. A new step in the understanding of the transient behavior of refrigerant loops has been achieved, by making it possible to efficiently size components (heat exchangers, compressor, thermal expansion valve), test alternative fluids (e.g. CO<sub>2</sub>) and optimize/evaluate new architectures (several stage compressors, multi-evaporator systems, heat pump systems).

Moreover, engineers can further investigate more global thermal issues associated with refrigerant loop behavior, such as developing and testing control strategies and studying the impact of the system on the engine thermal management.

LMS Imagine.Lab Refrigerant Loop gives engineers the ability to ascertain that the system performs to the highest standards for optimal passenger comfort regardless of operating conditions.

### Features

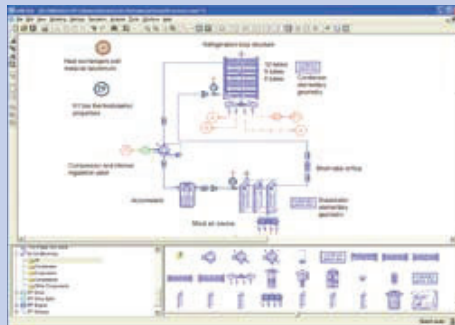
- Transient and steady-state analysis
- Prediction of pressures, temperatures and flow rates
- Geometrical heat exchanger characterization
- Prediction and optimization of component performance and coefficient of performance loop
- Drive cycle analysis

### Benefits

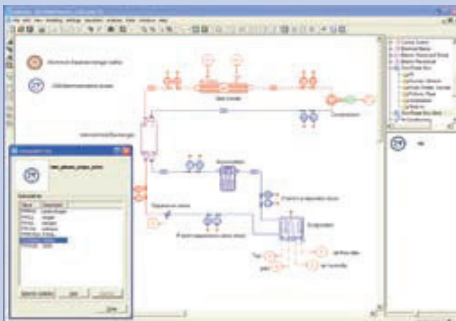
- Ensure sufficient loop performance to provide optimal passenger comfort regardless of operating conditions
- Size components (heat exchangers, compressor, thermal expansion valve)
- Optimize mass of refrigerant in the loop
- Evaluate new architectures (multi-evaporator, heat pumps)
- Evaluate loop performance using alternative fluids
- Suitable for studying HVAC as well as H<sub>2</sub> storage, household appliances refrigerant loops, cryogenic engine applications



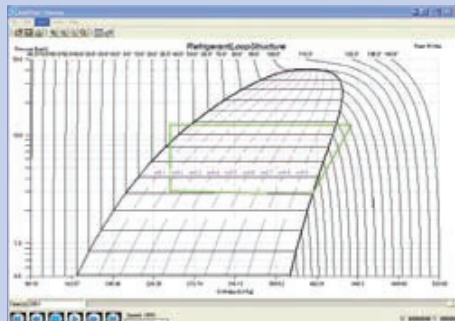
LMS Imagine.Lab Refrigerant Loop helps optimize passenger comfort regardless of operating conditions.



A classical automotive air conditioning circuit using R134a as a refrigerant loop.



The refrigerant loop database assists in simulating CO<sub>2</sub> air conditioning systems.



Advanced post treatment can be developed through Python scripts available in LMS Imagine.Lab AMESim.



# LMS Imagine.Lab Passenger Comfort

LMS Imagine.Lab Passenger Comfort helps to study thermal interactions between the air conditioning (AC) system, the cooling system and the cabin or vehicle interior. Engineers can evaluate and control the cabin cool down or heating processes (air temperature and humidity), as well as study the integration of additional heaters and their influence on passenger comfort, especially when using high efficiency engines with low thermal losses.

Engineers can study the impact of exterior conditions and technological choices on the air temperatures and humidity within the cabin.

The different analysis capabilities of the platform help the user thoroughly study the behavior of the entire system according to heating strategies and drive cycles under specific operating conditions. With LMS Imagine.Lab Passenger Comfort, it is possible to accurately size components (heater core, evaporators, ducts, fans/blowers), test control strategies (AC compressor displacement, recycling modes, automatic AC control, control of blowers and fan rotary speeds) and analyze innovative air-conditioning architecture.

## Features

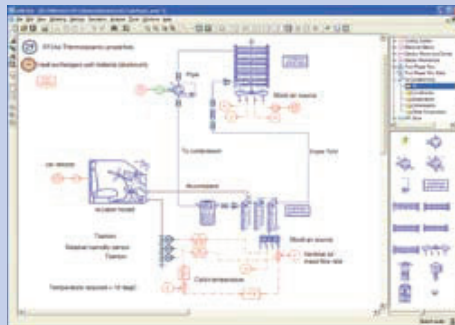
- Transient and steady-state analysis
- Prediction of air temperatures and humidity in the cabin (cool down or heating) through ducts, heat exchangers and fans
- Prediction of pressure and heat losses from outside to the cabin air extraction
- Additional heating strategies
- Drive cycle analysis

## Benefits

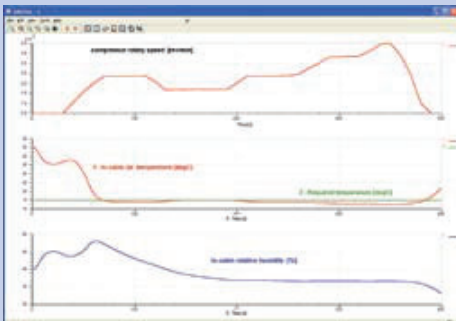
- Size components (heater core, evaporators, ducts, fans/blowers)
- Test control strategies (AC compressor displacement, recycling modes, automatic AC control, control of blowers and fans rotary speeds)
- Test innovative AC solutions to optimize passenger comfort under specific operating conditions



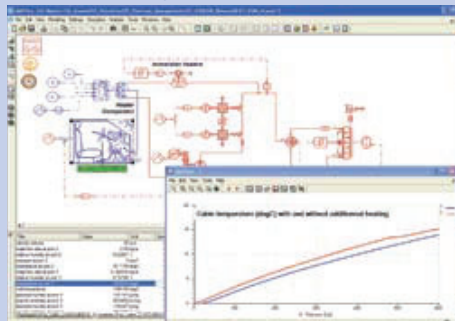
LMS Imagine.Lab Passenger Comfort helps study heating and cooling strategies to optimize passenger comfort.



The refrigerant loop can be connected to a cabin model to develop a temperature control strategy to achieve the desired passenger comfort.



The cabin model computes the internal temperature and the relative humidity, taking into account the passenger influence.



With LMS Imagine.Lab Passenger Comfort additional heating strategies can be rapidly tested.



## LMS Imagine.Lab Lubrication

LMS Imagine.Lab Lubrication offers the required tools to model and design the entire engine lubrication system with all the associated components (pump, valves, bearings) for performance validation, system optimization, failures investigation and evaluation of new architecture.

With LMS Imagine.Lab Lubrication, users can perform steady-state and transient analyses, as well as isothermal or thermal analyses.

The complete oil path through the engine model can be used to make sure that the required amount of oil is delivered to the different components. The aim is to optimize pump sizing, to develop intelligent systems (piloted pump) thereby reducing power absorbed by these components as well as systems using oil pressure (VVT, VVA and more). In this way, the integration of new components (oil cooler, VVT, VVA, piston cooling jets) can be evaluated. A total synchronization of components (pump) for different engines and platforms can thus be achieved as well as a detailed validation of production-driven architecture changes.

LMS Imagine.Lab Lubrication is able to run steady-state and transient analyses which take thermal effects into account. The user can integrate frictional heat sources in pumps, bearings and contacts between piston rings and cylinder liner to evaluate the oil temperature increase during warm-up. Moreover, it is possible to assess the thermal interactions between components and develop related heat management strategies for oil cooler and piston cooling jets, for example.

Dynamic analysis can also be performed by studying component and pressure dynamics. Especially for hydraulic components, line models and the hydraulic component design concept, the solution helps to assess pressure pulsations resulting from inertia effects in rotating parts (connecting rod supply) as well as the performance of fluid power systems using oil pressure from lubrication circuits (VVT, HLA, chain tensioner).

### Features

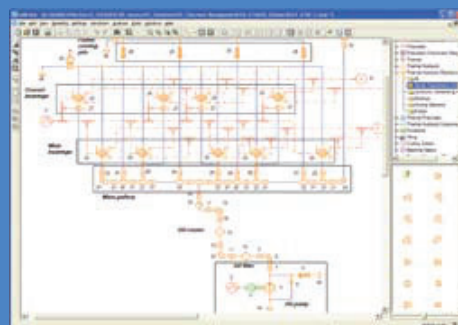
- Steady-state and/or transient analysis
- Isothermal or thermal analysis
- Prediction of oil flow rates and pressure levels
- Prediction of pressure oscillations linked to rotary velocities of reciprocating parts (Fluids Systems solutions for high frequency analysis)

### Benefits

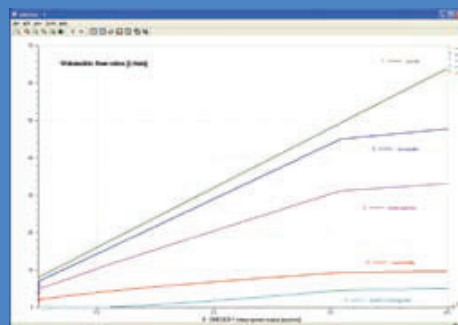
- Ensure sufficient supply of oil in any engine configuration
  - For the bearings and lubricated accessories (turbocharger)
  - For related actuators (VVA, VVT, HLA, chain tensioner)
- Size pump and pressure relief valve
- Evaluate modifications on existing architecture
- Evaluate new architecture at a pre-design stage
- Check thermal behavior in different operating conditions through a defined cycle (transient)



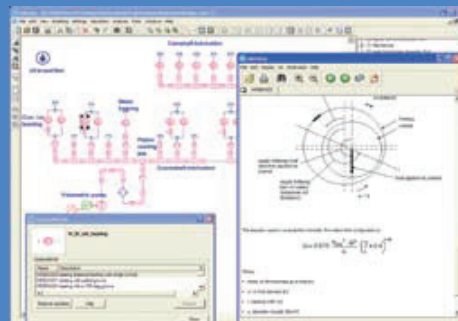
LMS Imagine.Lab Lubrication offers the required tools to ensure that sufficient oil is supplied in any engine configuration.



LMS Imagine.Lab Lubrication simulates the entire lubrication circuit with all the associated components: pump, valves, and bearings.



LMS Imagine.Lab Lubrication computes flow rates through each circuit, as a function of the pump rotary speed.



LMS Imagine.Lab Lubrication integrates a diversity of bearing models.



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