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KULI drive

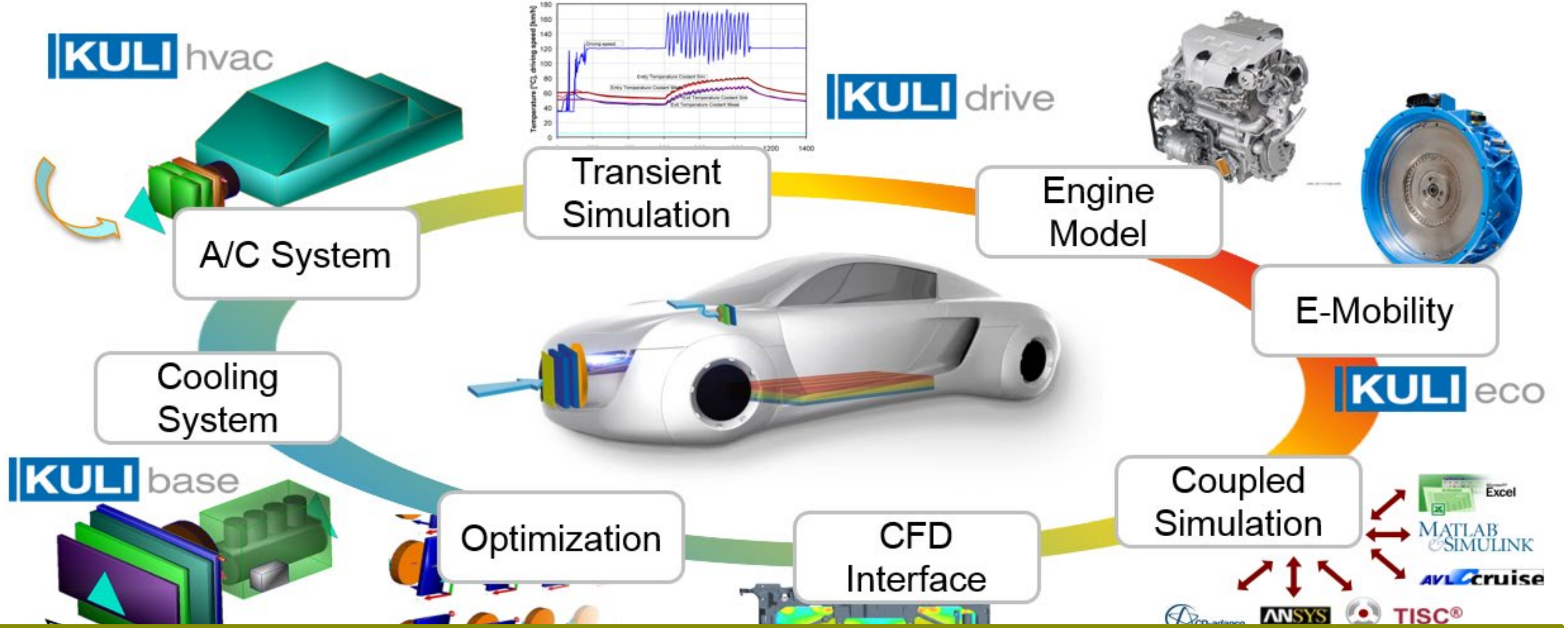
ENERGY MANAGEMENT OPTIMIZATION

Add-on Feature for Transient Thermal Management Simulation

瞬态热管理仿真

What is KULI drive?
什么是KULI drive？

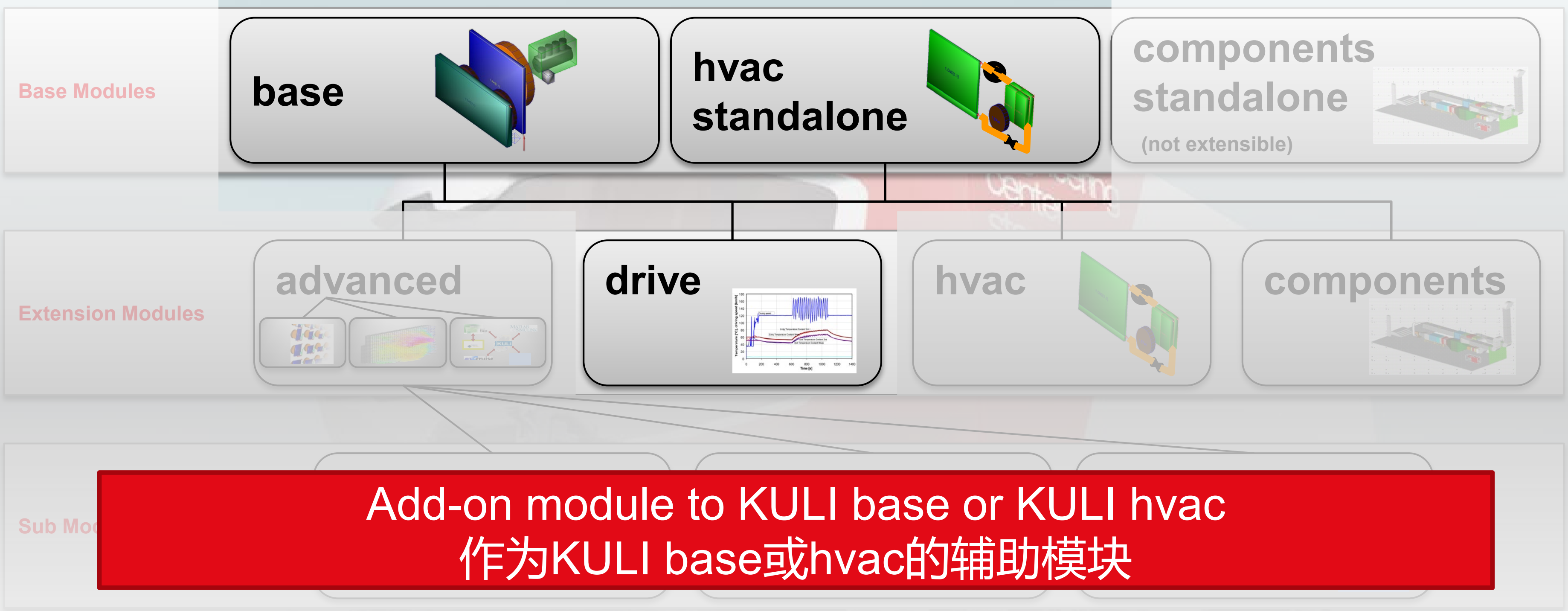
Energy Management Software 能量管理软件



…After calibration of your steady state simulation model the next step in your project can be done…

在您稳态仿真模型标定后的下一步开始启动

KULI – Modular Structure 模块结构



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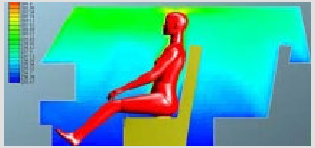
KULI drive – Motivation 目的

Transient Elements in a Vehicle 车辆中的瞬态元素

Engine 发动机

Fluids in the circuits
回路中的流体

Tubes and pipes
管路



Passenger cabin 乘员舱

Any additional thermal capacities 其它任意热容

Heat exchange 热交换

- Tran
- Con
- Con

Only transient simulation allows using the full potential of CAE regarding component sizing & packaging and implementation of warm-up and cool-down strategies
仅瞬态仿真可以充分利用CAE的全部潜能对零部件尺寸定义和封装并执行升温和降温策略

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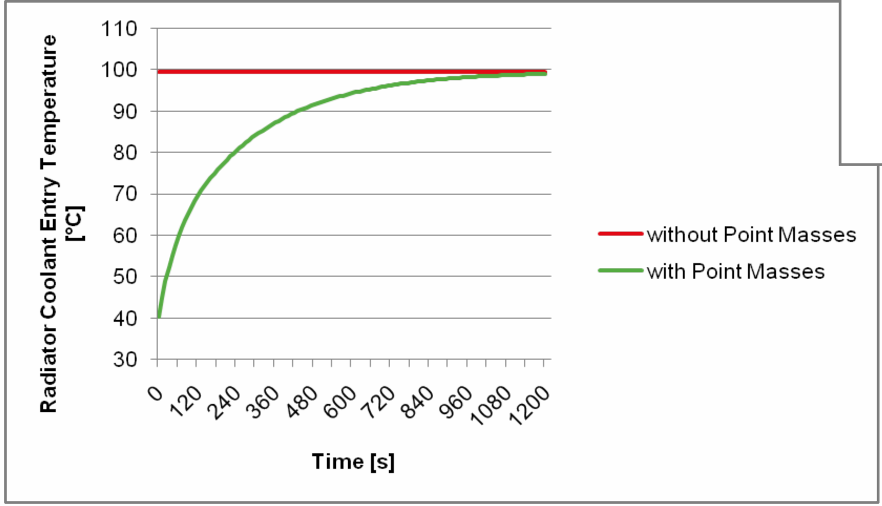
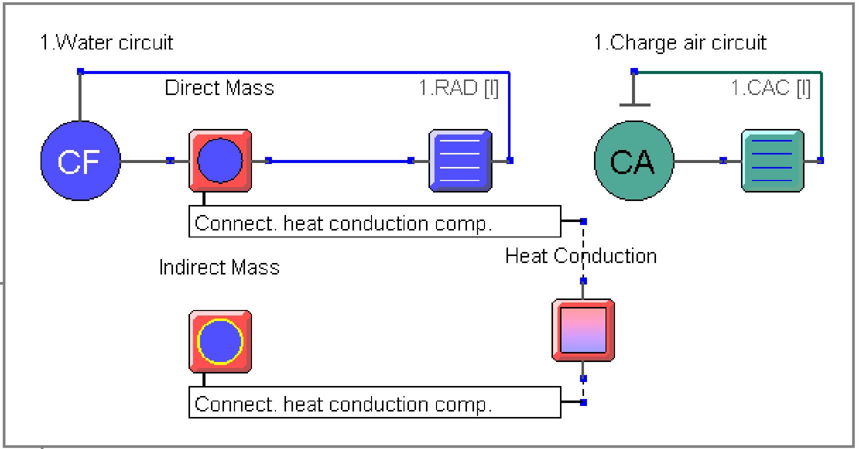
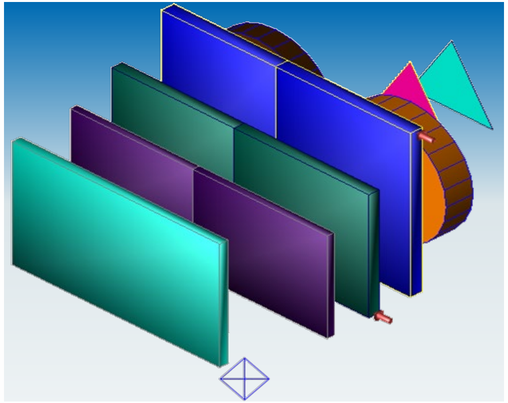
Typical Applications 典型应用

Typical Application – Heat-up of Cooling System
典型应用 – 冷却系统加热

- **Consider the heat up effects on the cooling system after engine is started 考虑发动机启动后的冷却系统加热**







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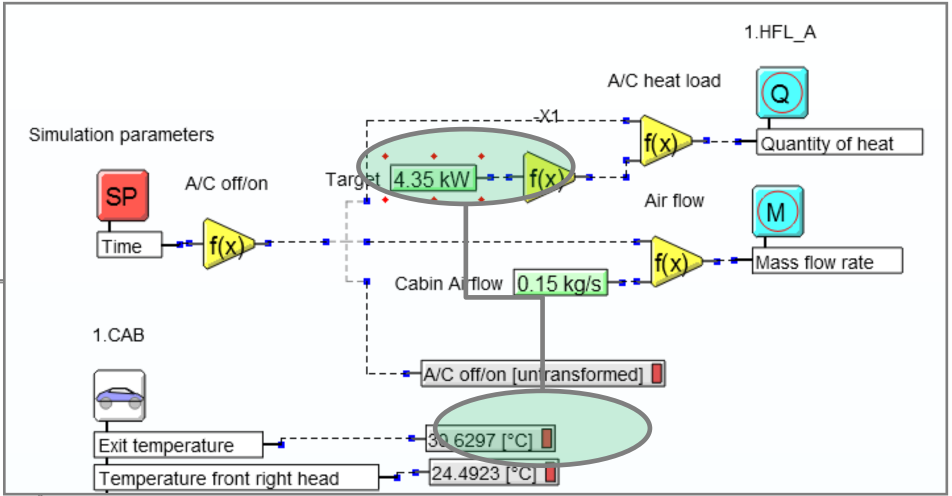
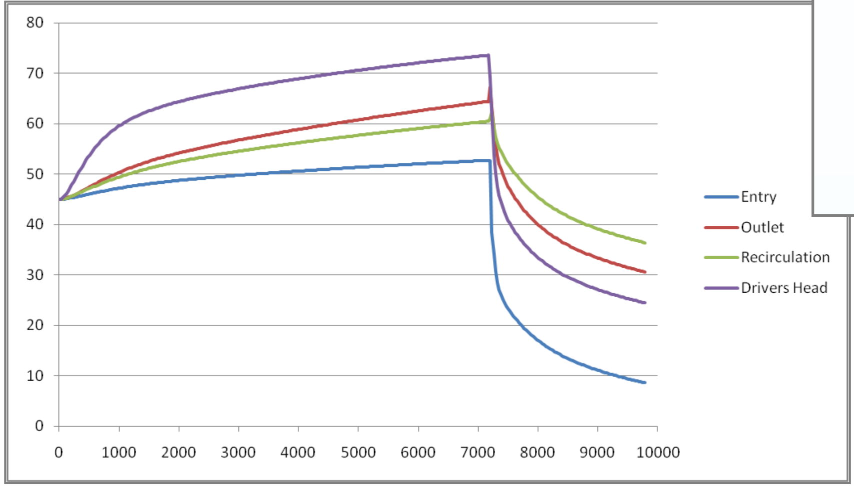
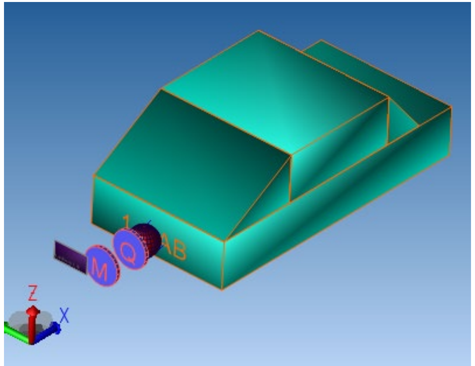
Typical Application – Cool Down Simulation
典型应用 – 降温模拟

- **Find evaporator heat load such that passenger cabin cool down requirements are met within a certain period 寻找蒸发器热负荷以满足一定时间内的乘员舱降温需求**







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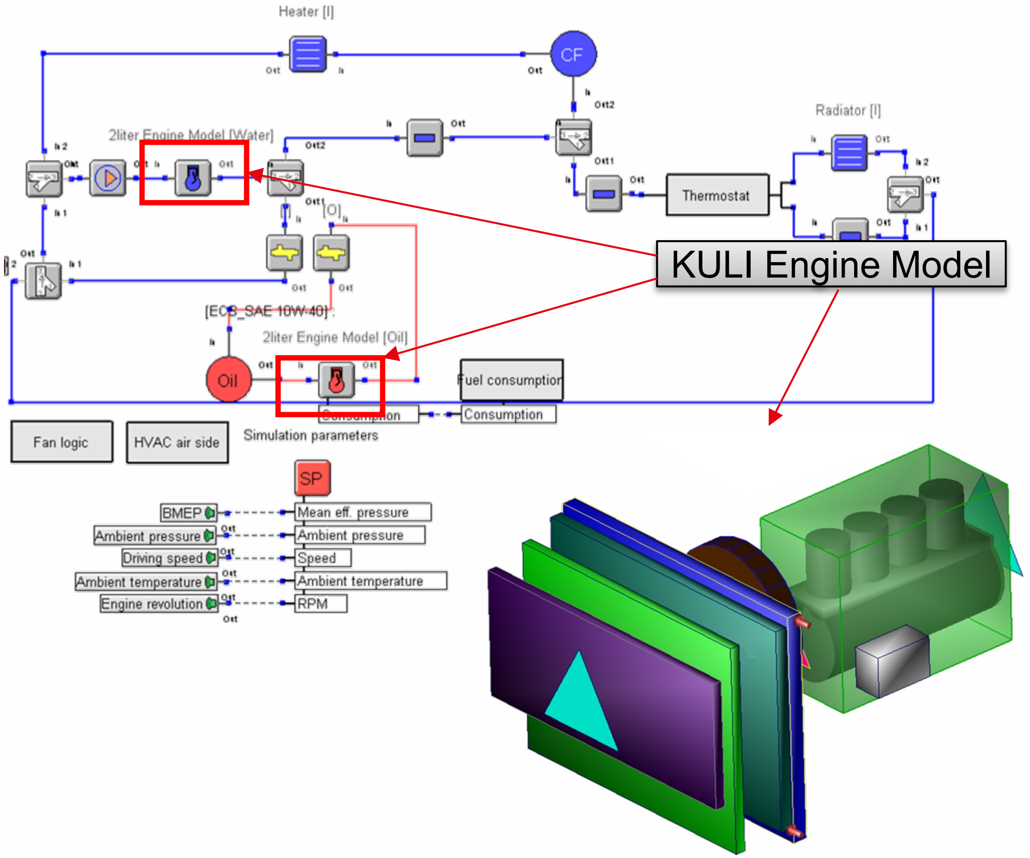
Typical Application – Simulation with Engine Model
典型应用 – 发动机模型

- Consider **friction losses** as well as **fuel consumption**
  考虑摩擦损失和油耗
- Reduce fuel consumption due to **faster engine warm-up**
  加速发动机温升以降低油耗
- Consideration of **auxiliaries and drivetrain cooling**
  考虑附件及传动系统冷却
- Optional consideration of **HVAC system** and cabin warm-up
  可以考虑空调系统以及乘员舱温升
- Possibility for fast **concept studies** regarding comfort and fuel economy
  可以对舒适性和燃油经济性进行快速分析



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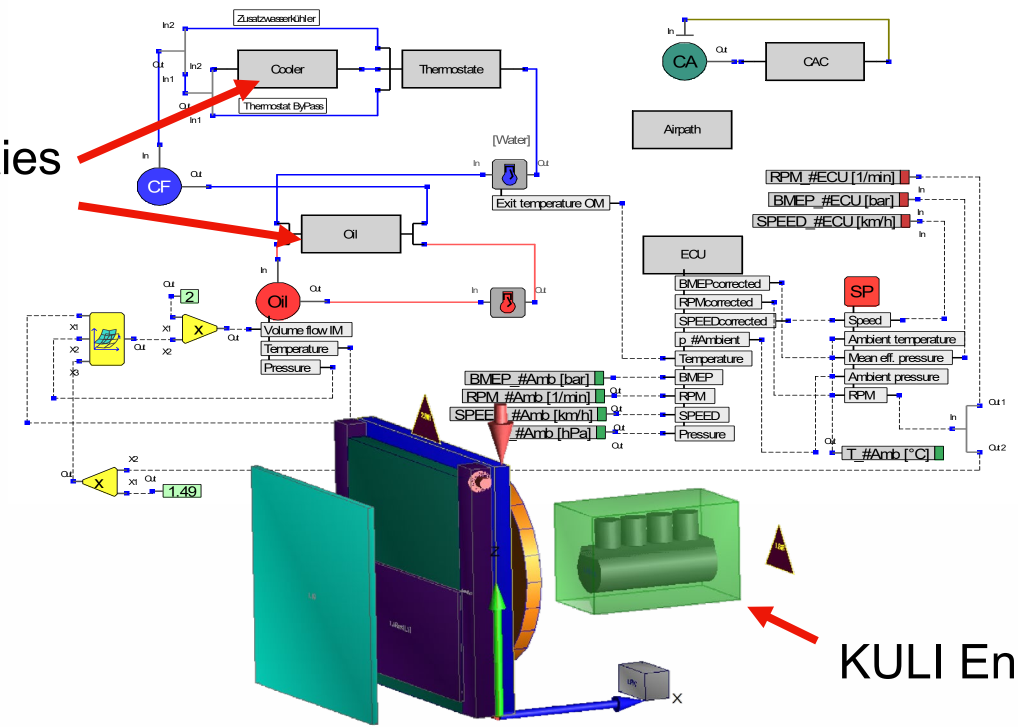
Typical Application – Transient Simulation
典型应用 – 瞬态仿真

- Avoid **oversizing** of components due to steady state operating points
  避免稳态工况点的零部件过设计

Thermal capacities considered
考虑热容量



KULI Engine Model

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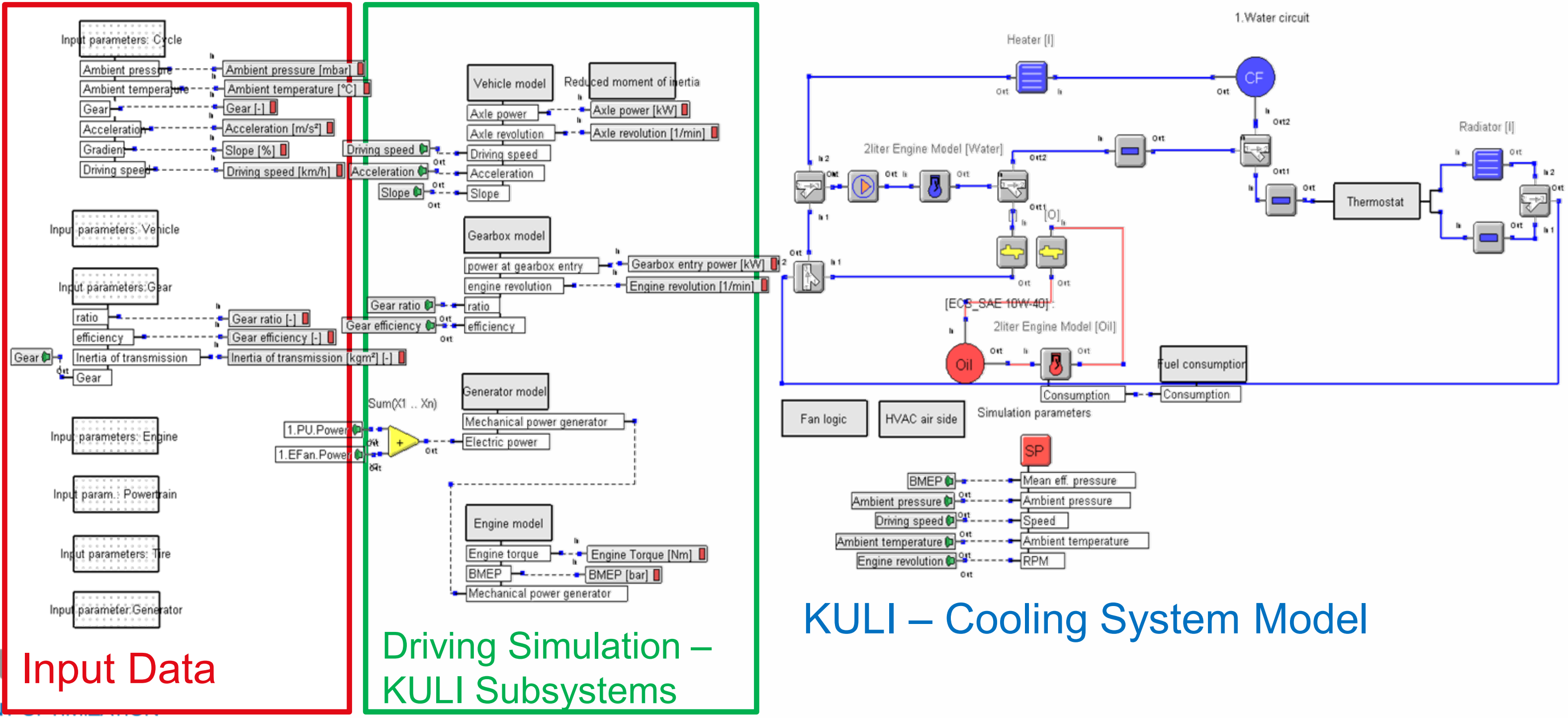
Typical Application – Driving Simulation
典型应用 – 驾驶仿真

- **Thermal behavior on a defined route (velocity vs. time), e.g. NEDC, FTP75 根据定义的路谱 （车速vs时间）得到热表现，如：NEDC，FTP75**



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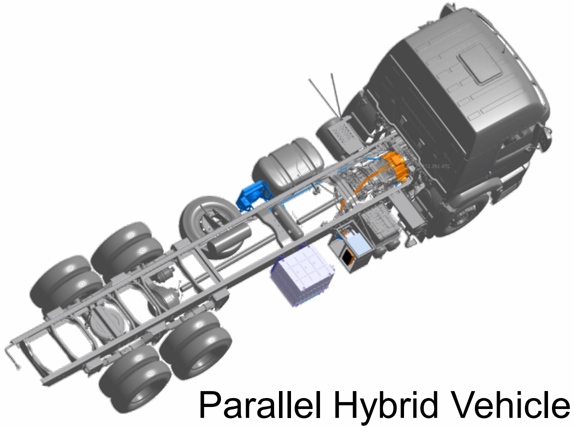
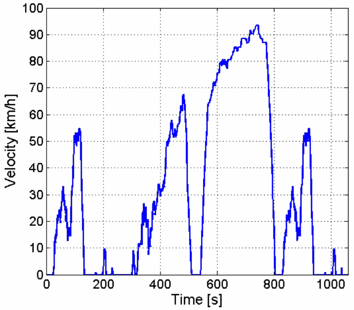
Typical Application – Energy Management
典型应用 – 能量管理

- **Design optimized control strategy to minimize energy consumption**
  优化控制逻辑用以最小化能耗

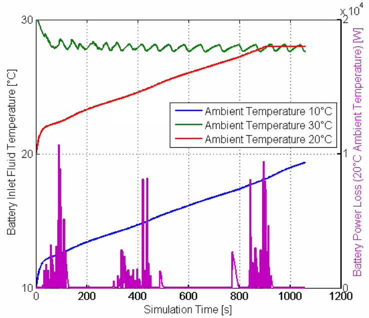
e.g. Energy Management Simulation for a Hybrid Truck
例如：混合动力卡车的能量管理仿真



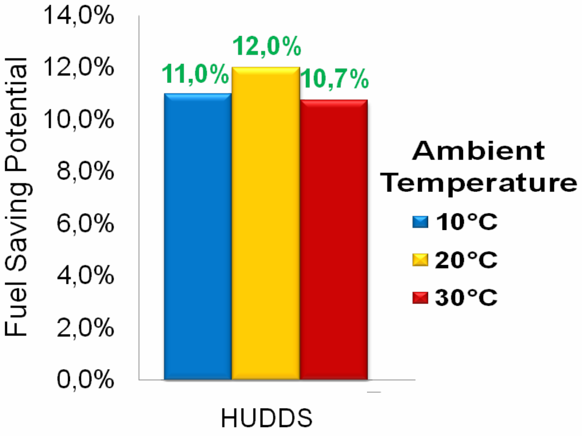
Parallel Hybrid Vehicle
并行式混合动力



Driving Cycle (HUDDS)
Heavy-Duty Urban Dynamometer Driving Schedule



Battery, Coolant Temperature
电池、冷却液温度



Fuel Saving Potentials
节油潜力

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Components & Features
零部件&特性

KULI drive – Transient Calculation 瞬态计算

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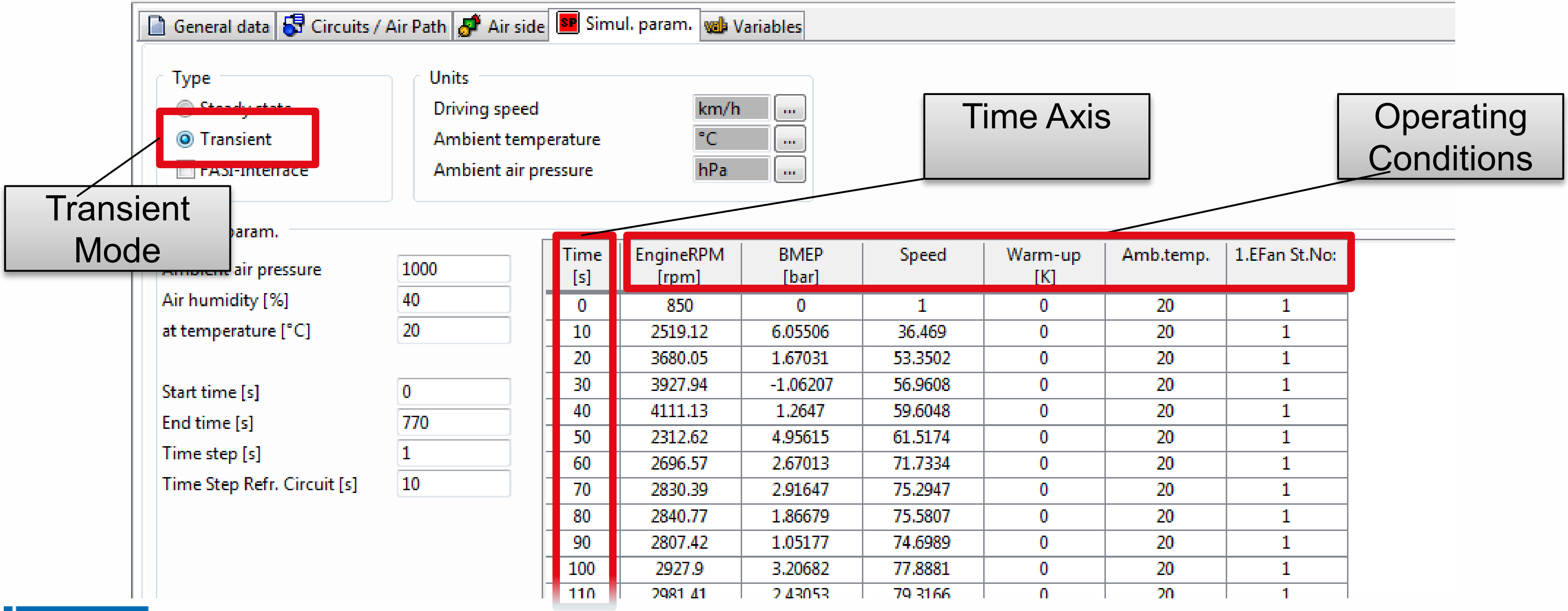
- **Transient calculation by definition of operating conditions at different time steps 根据不同的工况及时间步长进行瞬态计算**



Time [s]	EngineRPM [rpm]	BMEP [bar]	Speed	Warm-up [K]	Amb.temp.	1.EFan St.No:
0	850	0	1	0	20	1
10	2519.12	6.05506	36.469	0	20	1
20	3680.05	1.67031	53.3502	0	20	1
30	3927.94	-1.06207	56.9608	0	20	1
40	4111.13	1.2647	59.6048	0	20	1
50	2312.62	4.95615	61.5174	0	20	1
60	2696.57	2.67013	71.7334	0	20	1
70	2830.39	2.91647	75.2947	0	20	1
80	2840.77	1.86679	75.5807	0	20	1
90	2807.42	1.05177	74.6989	0	20	1
100	2927.9	3.20682	77.8881	0	20	1
110	2981.41	2.43053	79.3166	0	20	1

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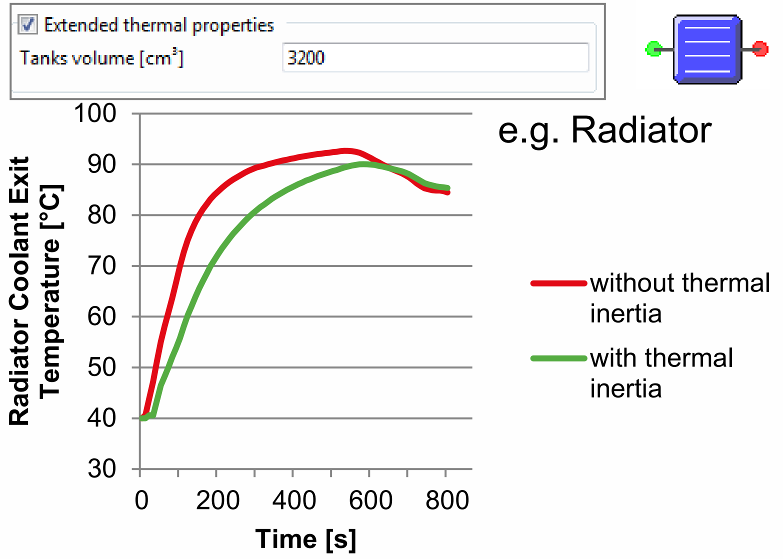
KULI drive – Thermal Capacities 热容量

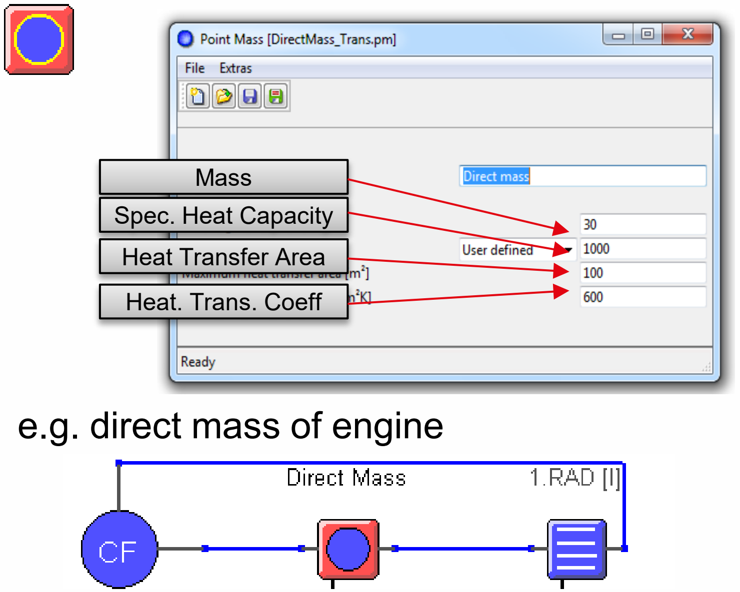
- **Consideration of the warming up and cool down of various components (thermal capacities of components) 考虑各种零部件的升温和降温（零部件热容量)**

Thermal inertia of Components 零部件热惯量



"Abstract" Point Masses 抽象质点

for flexible transient modeling



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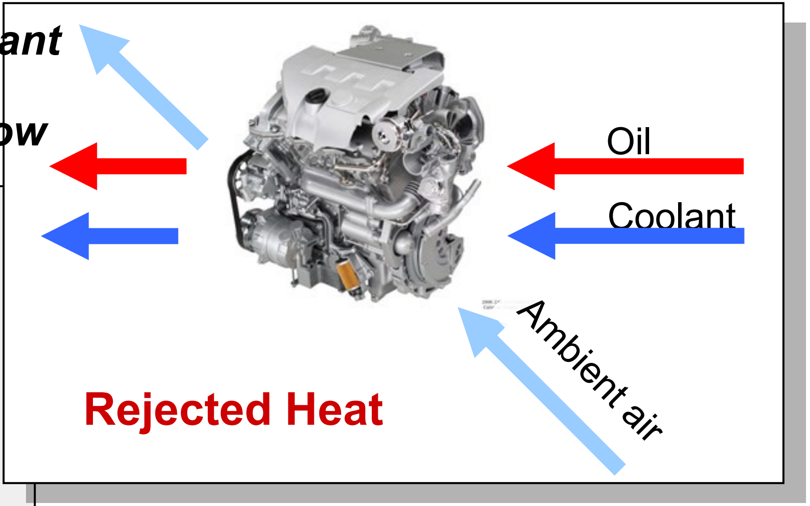
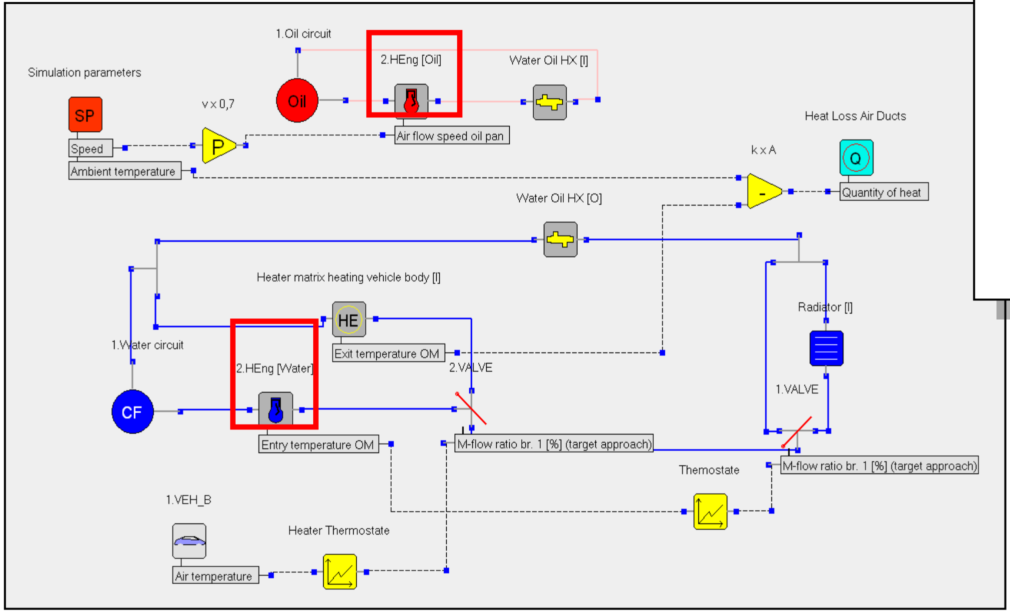
KULI drive – Engine Model 发动机模型

- 4-/5-mass engine model for the consideration of friction losses at different temperatures
  4-或5-发动机质量模型用以考虑不同温度下的摩擦损失

Influences…
- ***Coolant***
- ***Oil***
- ***Airflow***





Heat from… 热量来自
- ***Combustion 燃烧***
- ***Friction 摩擦***

KULI drive – Thermal Network 热管网

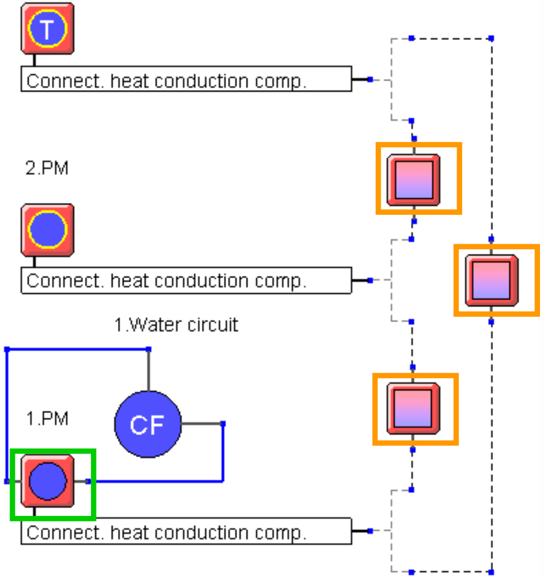
- **Thermal network to model complex thermal correlations**
  使用热管网用以建立复杂热关联

A thermal network is described by a **system of differential equations**:
热管网表达为微分方程组

$$\frac{dT_1}{dt} = \frac{1}{(m \cdot c_p)_1} \cdot \left[k \cdot A \cdot (T_K - T_1) + \left(\frac{\lambda \cdot A}{l}\right)_{12} \cdot (T_2 - T_1) + \left(\frac{\lambda \cdot A}{l}\right)_{13} \cdot (T_3 - T_1) \right]$$

$$\frac{dT_2}{dt} = \frac{1}{(m \cdot c_p)_2} \cdot \left[\left(\frac{\lambda \cdot A}{l}\right)_{12} \cdot (T_1 - T_2) + \left(\frac{\lambda \cdot A}{l}\right)_{23} \cdot (T_3 - T_2) \right]$$

$$\frac{dT_3}{dt} = 0$$



Mass 1: *convection* and *conduction*

Mass 2: *conduction*

Mass 3: *constant*

This is ***solved numerically!***
采用自动求解!

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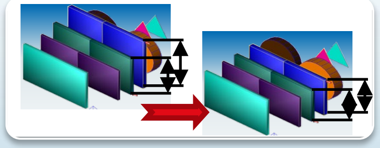
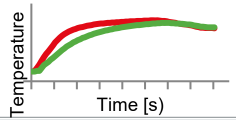
Benefits 优势

KULI drive – Benefits 优势

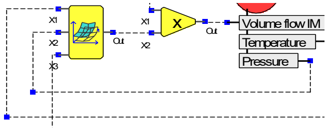


No over sizing of components due to steady state operating points
避免因稳态工况条件而导致的零部件过设计

Reduced fuel consumption due to faster engine warm-up
因加速发动机暖机而降低的油耗



More realistic temperature profiles due to consideration of thermal capacities (e.g. engine model, thermal network)
因考虑热容量而产生的更真实温度分布（如：发动机模型、热管网）



Optimization of control strategies due to consideration of auxiliaries in drivetrain cooling
因考虑驱动系统附件冷却而优化的控制策略

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DRIVING **EXCELLENCE.**
INSPIRING **INNOVATION.**