

Introduction: VTM Benefit Studies

C. Rathberger, Magna

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What are the potential benefits of a new VTM technology?

- **Can it improve vehicle performance, range or durability?**
 - Can it reduce VTM system energy consumption?
 - Can it reduce vehicle weight?
 - Can it reduce battery aging?
- **Can it improve passenger comfort?**
 - Faster warm-up in winter?
 - Faster cool-down in summer?
- **Can it reduce vehicle costs?**
 - By saving component costs?
 - By simplifying system and manufacturing?

**To sell a new idea to customers
we must prove its benefits!**



**Simulation helps to identify
and quantify potentials!**

Typical Questions to Answer...

How much can we increase the range, if we install a thermal storage component?
Or does the additional weight even decrease the range?

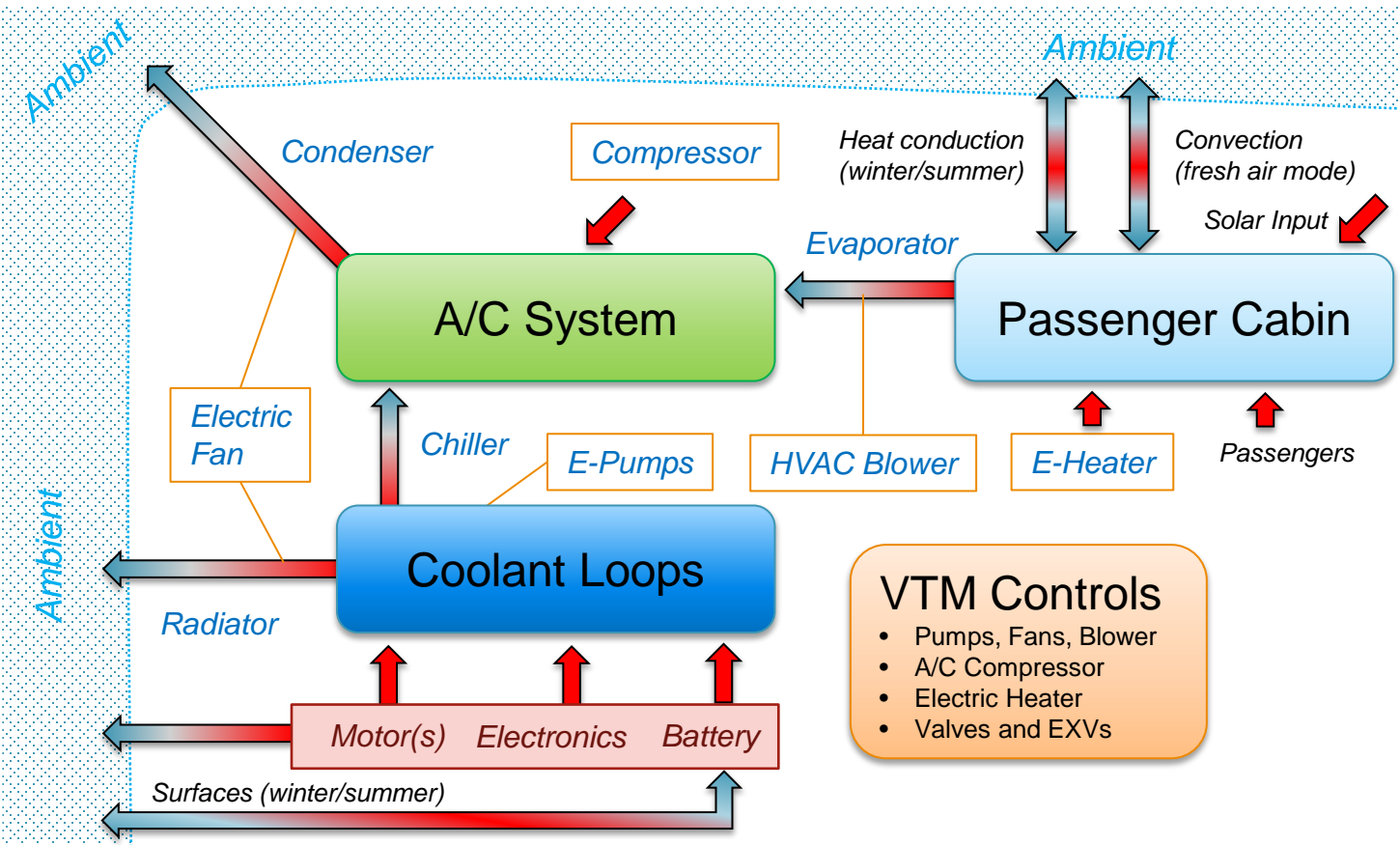
Will installing additional cabin insulation
increase the warm-up speed?

How does the vehicle range get
affected by cabin air recirculation?

Is additional battery thermal insulation
necessary? Is it maybe even a problem in summer?



Benefit Studies Step 1: Understand heat flows and energy consumption by auxiliaries



Explanation:

- Heat conduction or conduction
- Heat sources

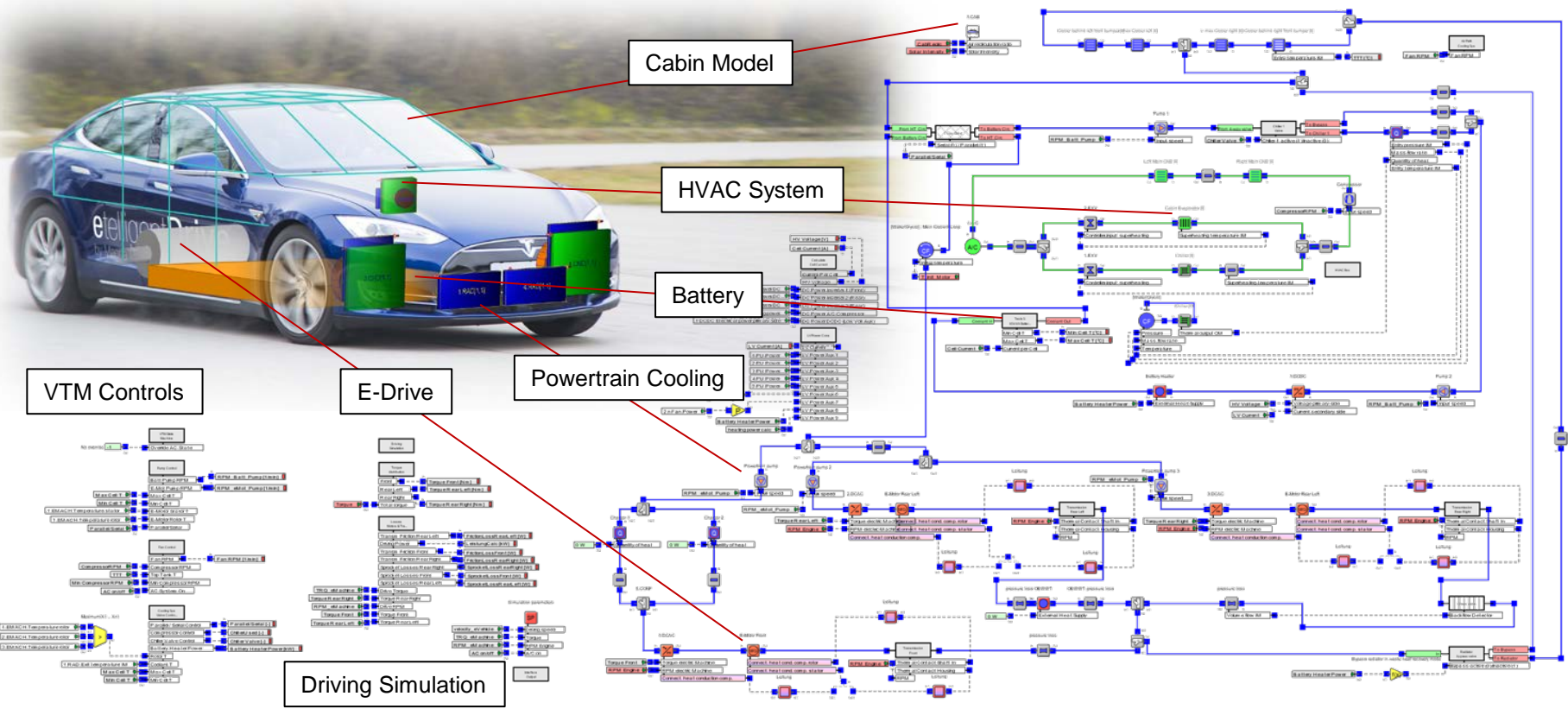
VTM Components

Electric Auxiliaries

Other VTM Influences

- VTM Controls**
- Pumps, Fans, Blower
 - A/C Compressor
 - Electric Heater
 - Valves and EXVs

Benefit Studies Step 2: The complete vehicle VTM simulation model



Cabin Model

HVAC System

Battery

VTM Controls

E-Drive

Powertrain Cooling

Driving Simulation

How to get a complete vehicle simulation model? (as a “non-OEM”)

- Several complete VTM models are openly available for use in KULI:

- Mitsubishi i-MiEV
(small EV for city use, lower segment)



- Tesla S / Magna E1
(sportive sedan EV, luxury segment)



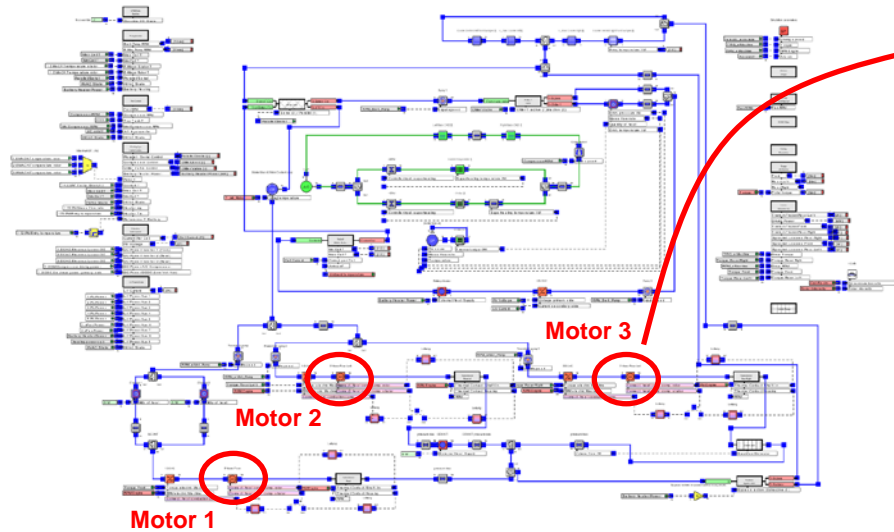
- Jaguar i-Pace
(sportive sedan EV, luxury segment)
(KULI model under development, expected Q3/Q4 2021)



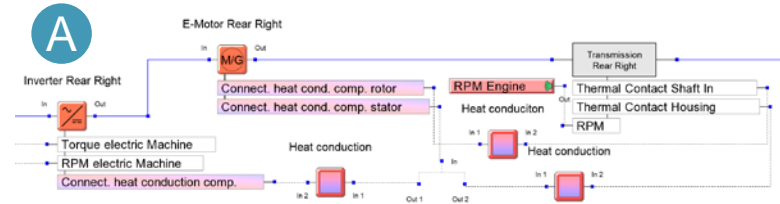
- These models can be obtained from us free of charge and used with your standard KULI license (if you own the necessary module licenses)
- In case you do not have simulation capabilities or capacities inhouse, it is also possible to ***do a simulation project together with us...***

Benefit Studies Step 3: Virtual prototype system performance investigation

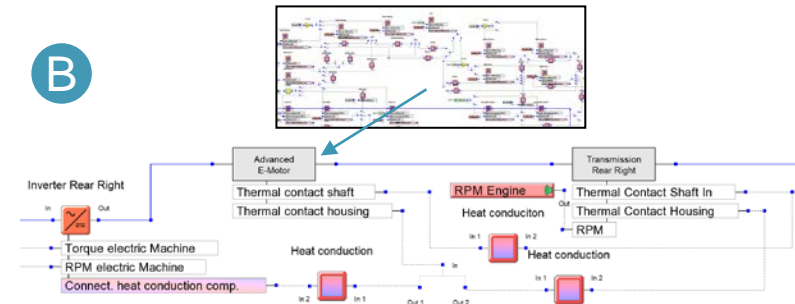
Example: Benefit investigation for an improved e-motor (KULI model for Magna E1)



Base Model: Conventional oil-filled e-motor with cooling jacket

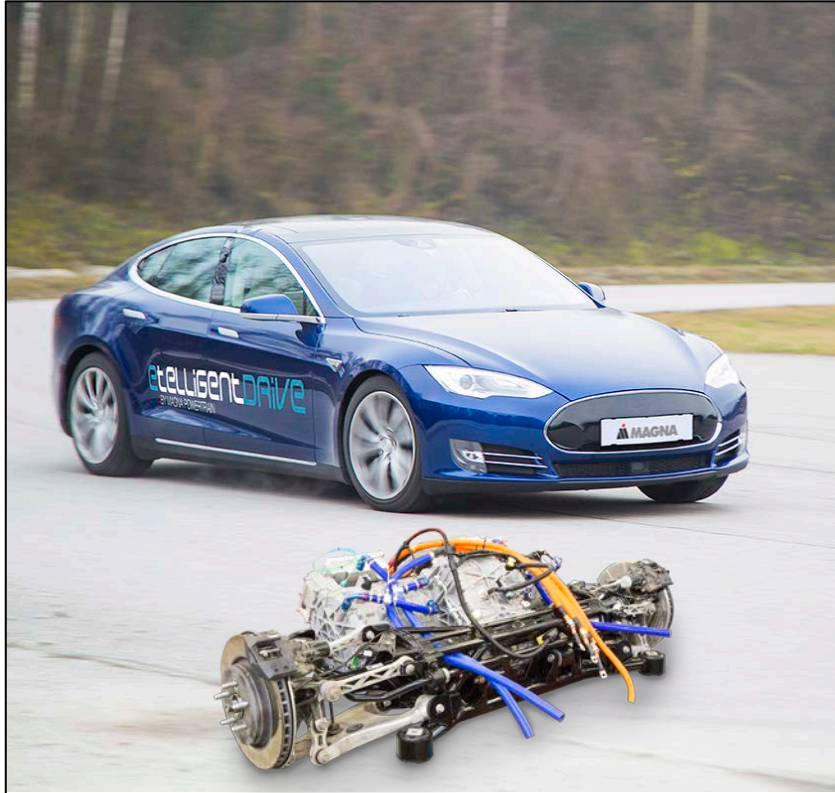


Virtual PT: Advanced shaft-cooling of e-motor



- Run e.g. WLTC for both variants A and B
- Compare transient temperature levels, energy consumption, range...

Vehicle & VTM System Overview



Objectives:

- Demonstrate eDrive product capabilities
- Proof system and vehicle Integration capabilities
- Vehicle controls: improved stability and handling
- Electronic Torque Vectoring (eTV)

Technical Data:

Front Axle: Highly Integrated eDrive System, with ASM

Peak power	140kW (for 60s)
Peak Torque	3300Nm (10s)
Inverter (integrated)	500A _{rms}

Rear Axle: Highly Integrated eDrive System, 2 x ASM with summation gearbox, with axle lock clutch (eTV)

Peak power	280kW (for 20s)
Peak Torque	6600Nm (10s)
Inverter (integrated)	2x 500A _{rms}

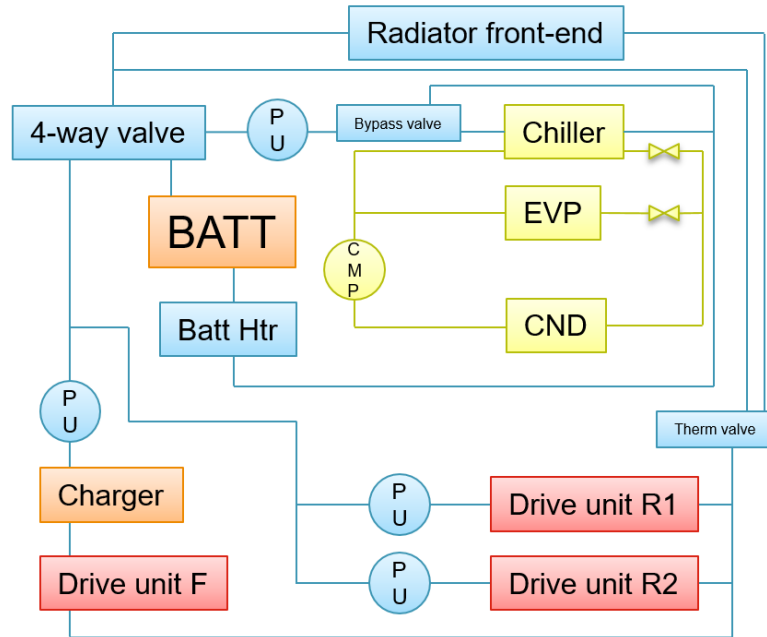
Both drives: Liquid cooled Inverter, e-Motor stator and rotor
Enhanced thermal management
Rare Earth free

The Magna E1 Cooling System

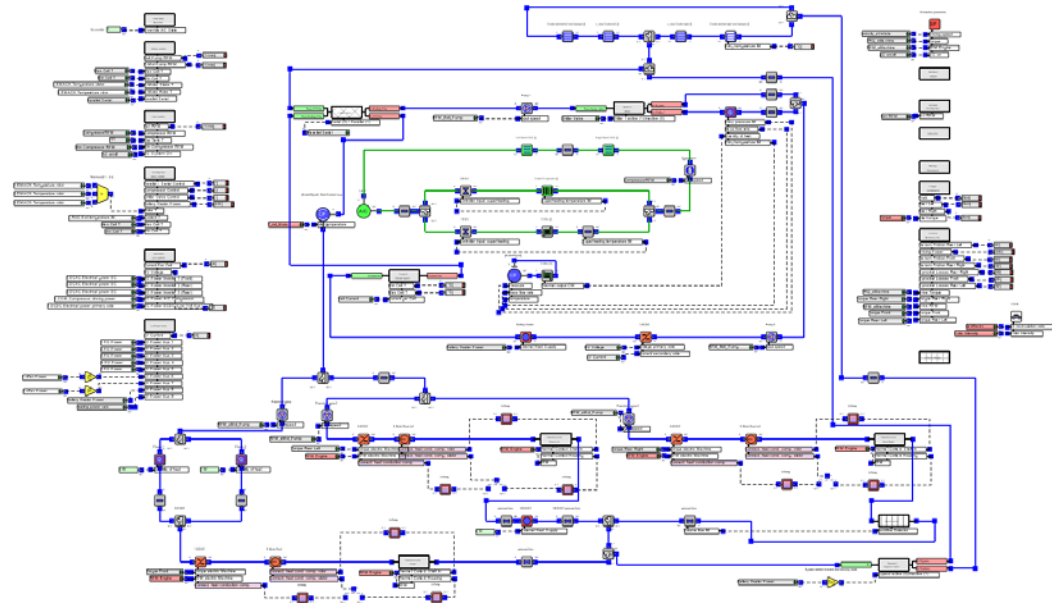


Block Chart Schematics:

E-Drive Cooling, Battery Cooling, A/C System



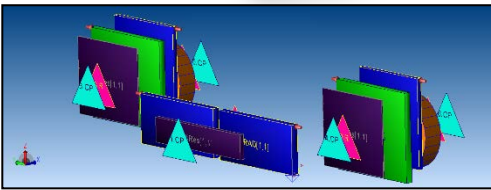
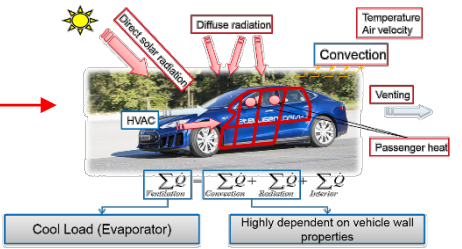
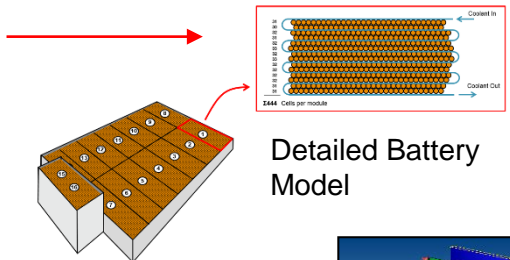
KULI Simulation Model



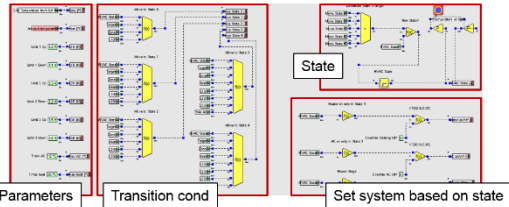
Focus Topics of the Simulation Model



- Detailed powertrain sub-models
(all main heat sources including battery, motors power electronics and transmission systems)
- Detailed underhood air path
(for modelling the performance of the cooling pack)
- Multi zone cabin model
(for comfort investigations)
- HVAC control unit
(for investigating and optimizing operating strategies)
- Driving simulation... etc...



HVAC Control State Machine



In the following block we will highlight 3 supplier benefit-studies we did together with our project partners in 2020...

- Benefits from thermal insulation of batteries
Evonik
- Benefits from passenger cabin insulation
Honeywell
- Benefits from anti-fogging window coating
GXC Coatings



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