

VIRTUAL ASSESSMENT & OPTIMIZATION OF IMMERSION COOLED BEV COMPONENTS

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AGENDA

- 1 Introduction and First 1D Simulation**
- 2 Simulation with MAGMASOFT: our Philosophy**
- 3 Initial MAGMASOFT 3D Results**
- 4 Updated 1D Simulation and Summary**

INTRODUCTION

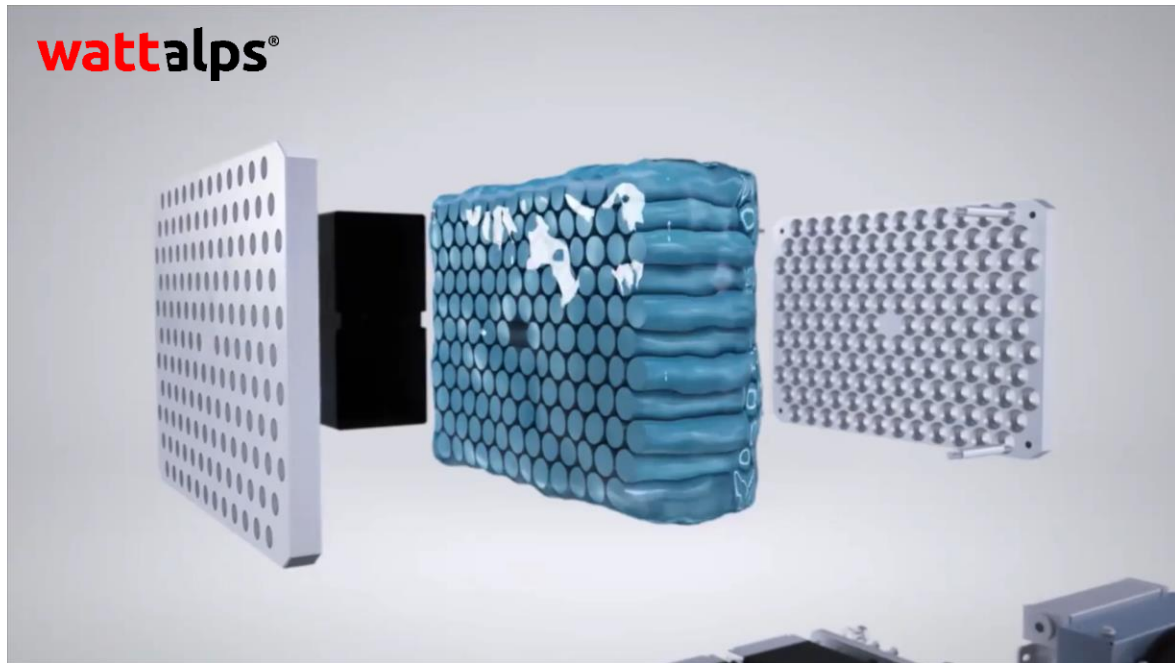
Immersion Cooled Batteries by Wattalps

One of the bottlenecks in battery cooling is always the contact between cells and cooling media.

Immersion cooling allows very good heat transfer from cells into cooling fluid.

This allows huge benefits, especially in high performance applications:

- Sports Cars
- Off-Highway
- ...



INTRODUCTION

Our Project Mission

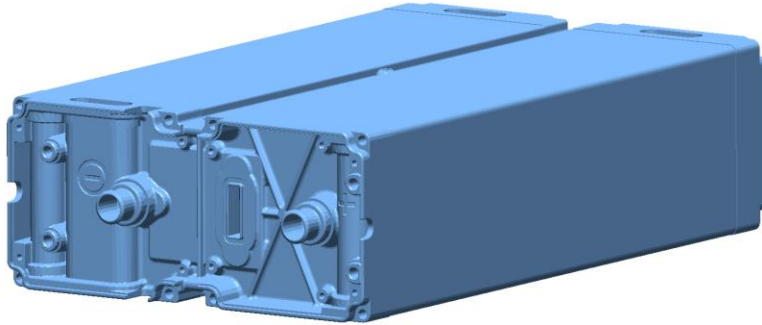
We want to define an
optimized cooling system design workflow
for
immersion-cooled battery packs

“We“ are and we contribute to this project:

- Wattalps: Supplies data for their innovative high performance battery packs to the project
- Magma: Does 3D flow simulation of the battery modules with MAGMASOFT
- Magna: Supplies 1D thermal system simulation with KULI

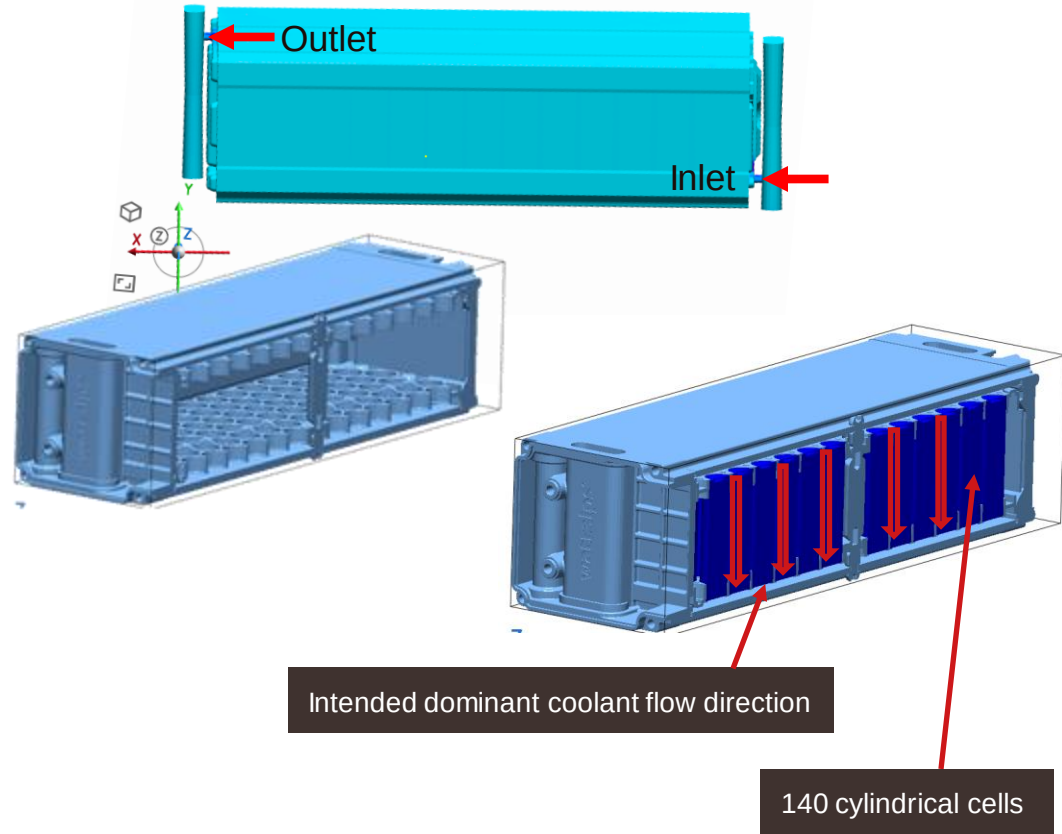
INITIAL DATA FROM WATTALPS

Design and parameters



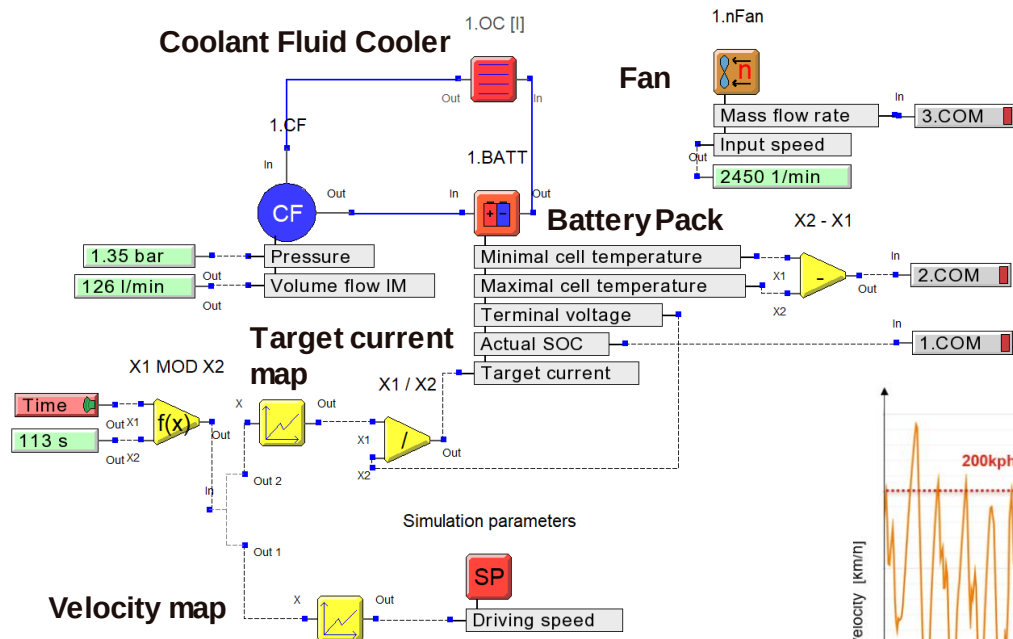
Project parameter

- ✓ Battery pack with 42 modules
- ✓ Each module 140 battery cells
- ✓ Simulation of 1 module with thermal output:
 - ✓ Max.: 2 KW
 - ✓ Avg. 0,5 KW
- ✓ xx l/min. flow rate of coolant
- ✓ about 1,8 times exchange of coolant/min.
- ✓ 25°C starting temperature: inlet, cells, housing
- ✓ 20°C ambient temperature



SIMPLIFIED INITIAL KULI SIMULATION MODEL

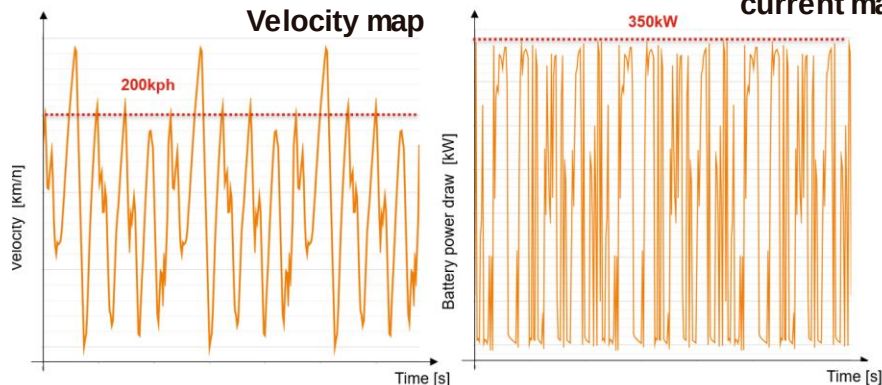
Assumption: Homogeneous Flow as Intended



Targets

- ✓ Predict cell temperatures for a given volume flow
- ✓ Find suitable heat exchanger/fan combination
- ✓ Evaluate feasibility of challenging high-power drive cycle

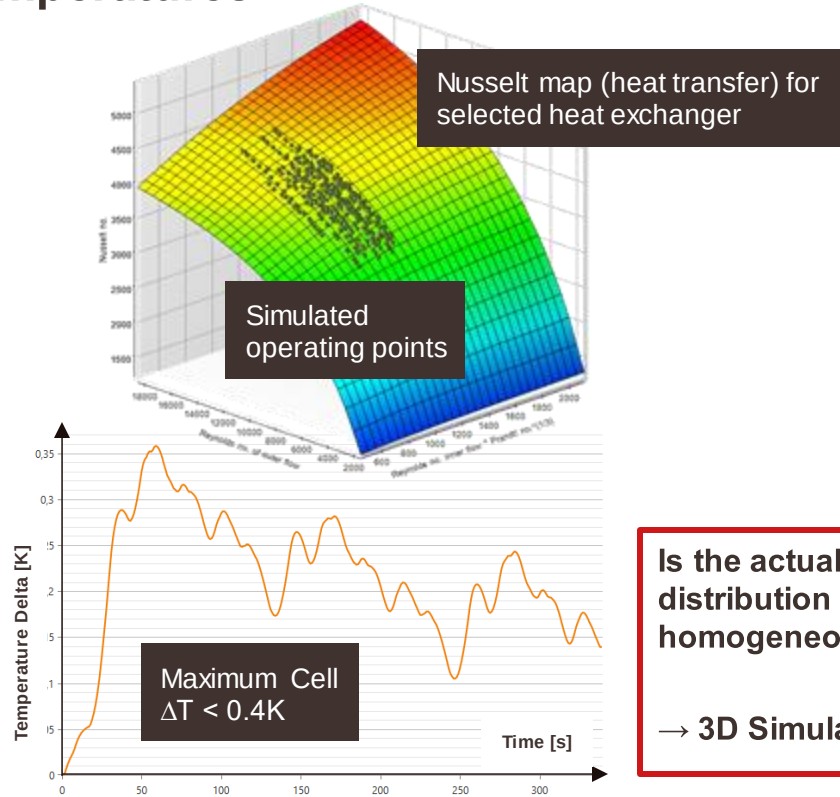
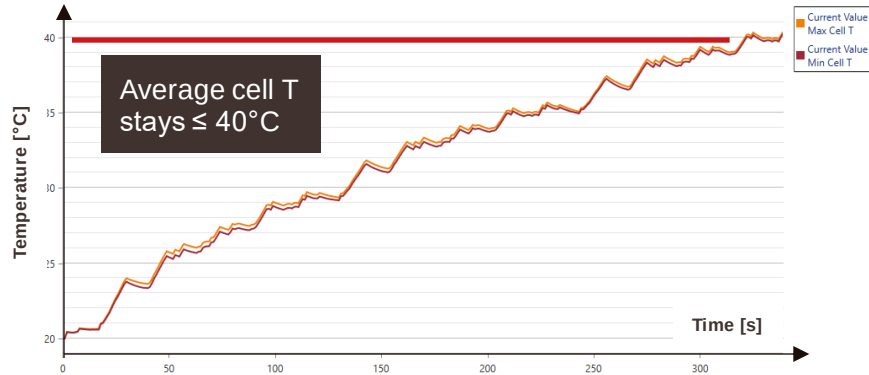
Target current map



COOLING SYSTEM COMPONENT SELECTION

And Simulated Impact on Cell Temperatures

- ✓ The used cooling fluid has a much higher **viscosity** than a standard water/Glycol mixture
- ✓ the internal structure of the heat exchanger needs to be different from a normal radiator to achieve good **turbulence (Reynolds number)** and **heat transfer**
- ✓ An **oil cooler** was chosen and scaled to size
- ✓ The **fan** is only relevant in low-velocity parts of the cycle



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MAGMA IN A NUTSHELL



- ✓ Founded 1988 in Aachen, HQ
- ✓ 320 people globally, 8 locations
- ✓ 3 units: MAGMA, SIGMA, Flow Science
- ✓ Aachen: >50 engineers for software programming
- ✓ Midsize company, private ownership (foundation)
- ✓ Short DMP
- ✓ > 2.000 customers globally from SME to global OEMs: so everybody who is producing or using castings



More than just numerical multi-physics simulation:

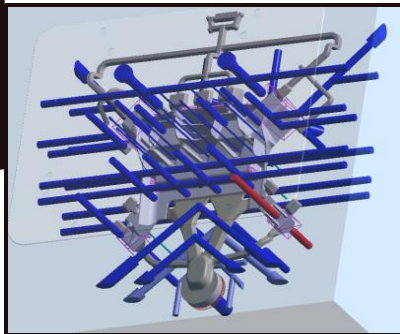
- ✓ Software
- ✓ Autonomous Engineering
- ✓ Implementation (e.g. INTERACT)

"You can give away as much software as you want, but if you don't provide training and support, it will sit there and not be used", Paul Lethbridge, ANSYS.

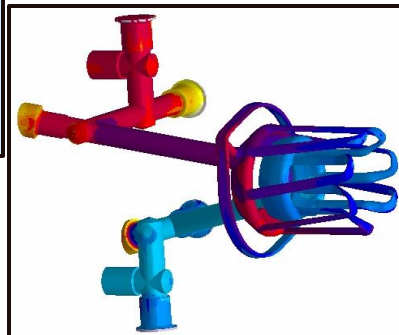
1 HEAT & TRANSFER: OUR PASSION



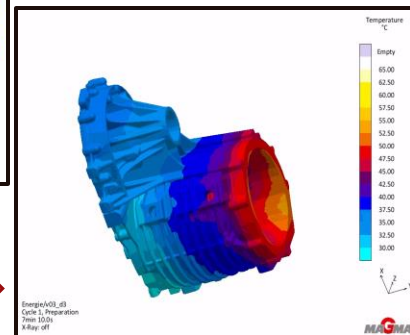
Filling &
solidification



Heating & cooling
of cavities/tools



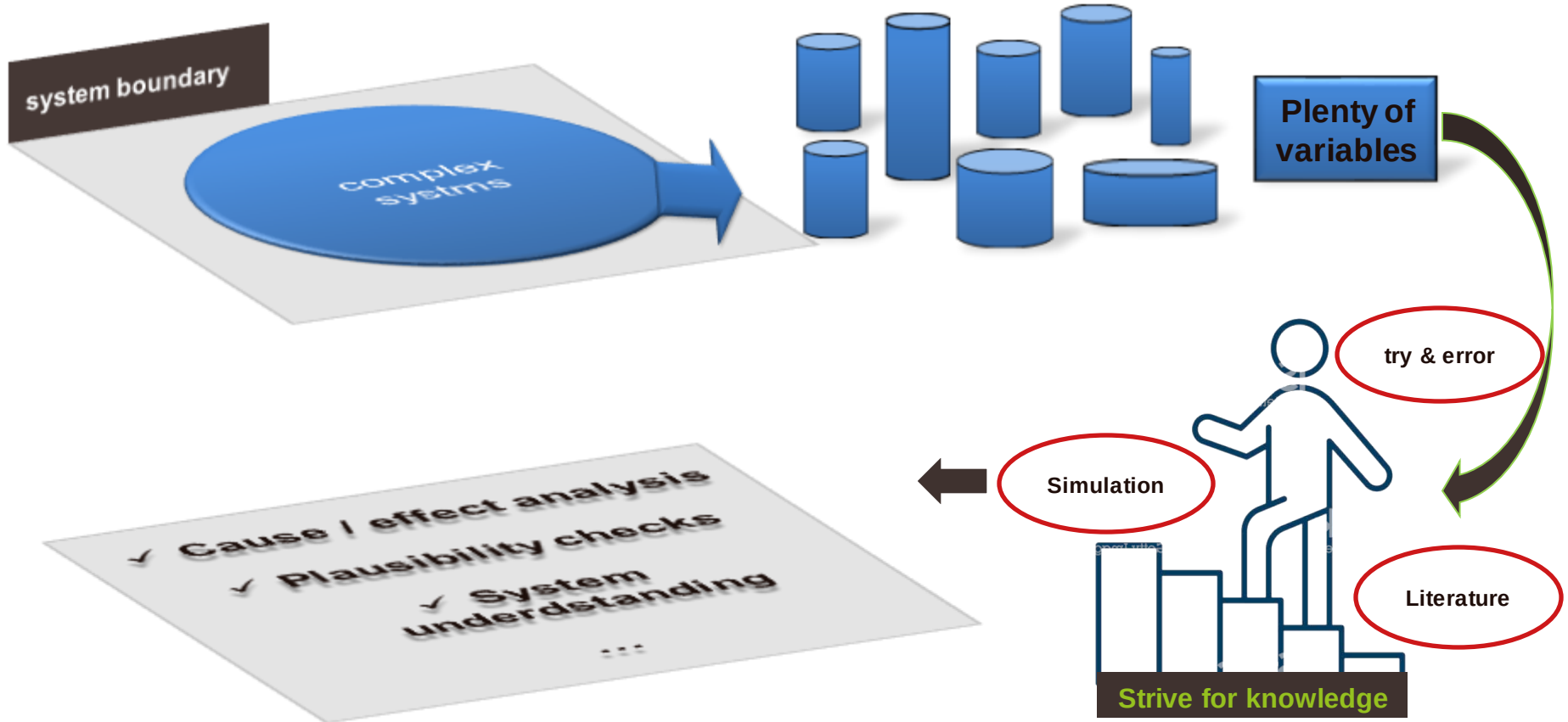
(Heating) & cooling
of E-motors



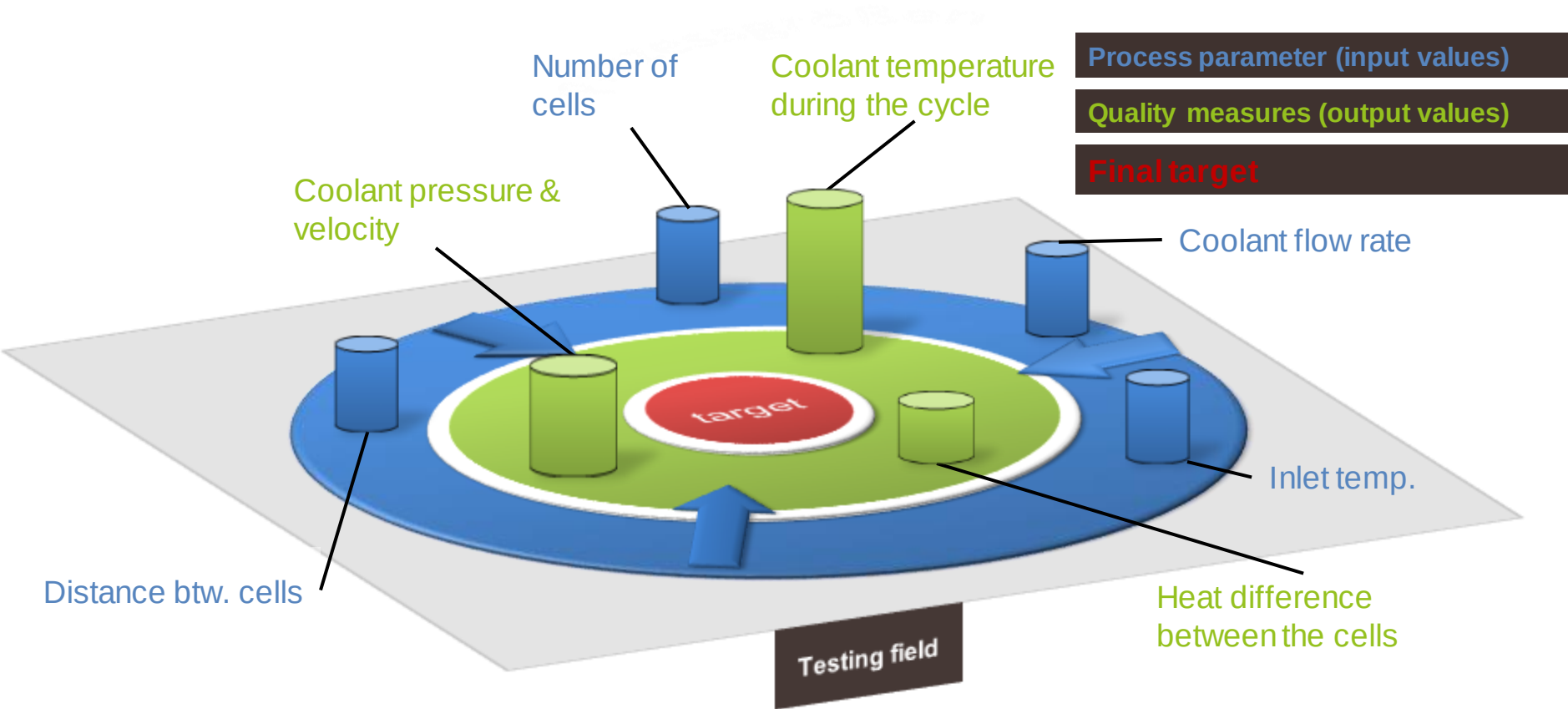
Heating & cooling of
traction batteries

It's all about:
Heat & transfer

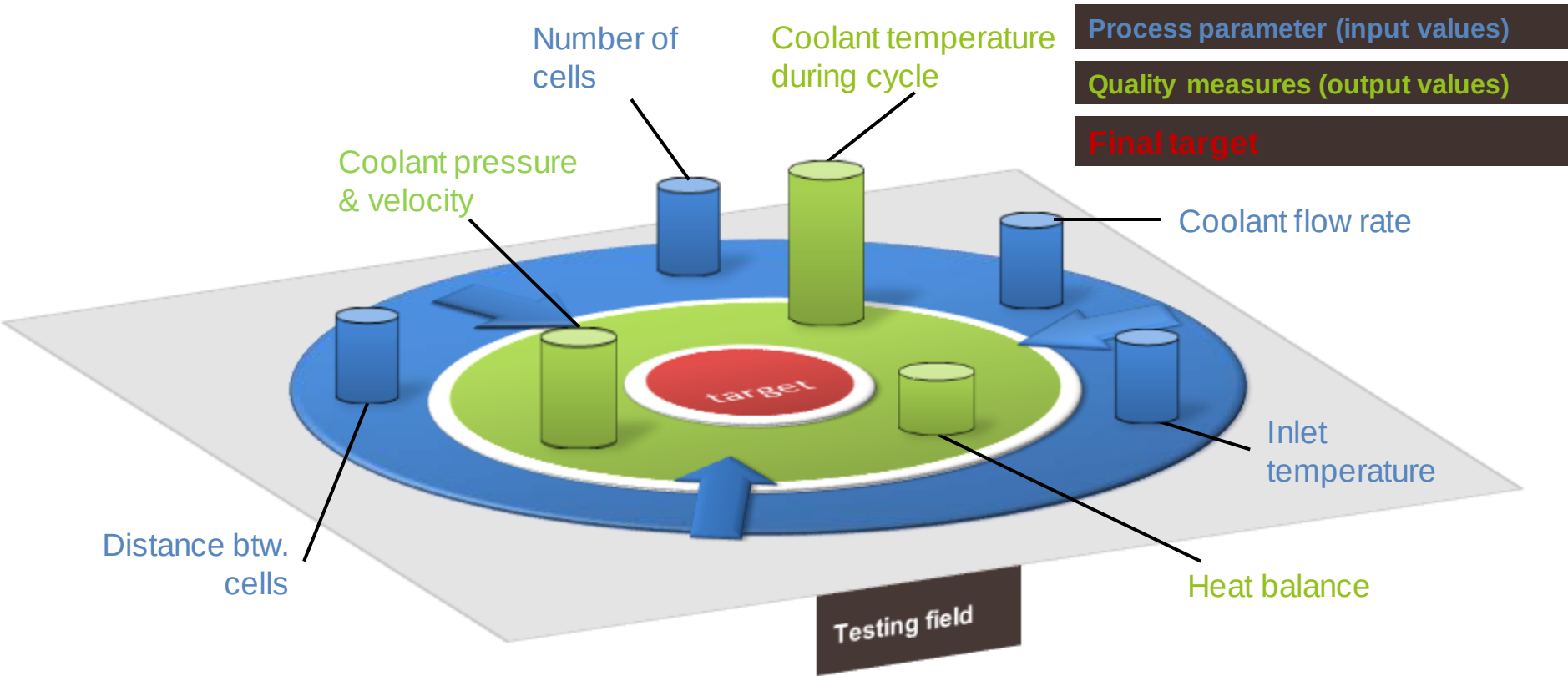
MAGMA'S PHILOSOPHY



AUTONOMOUS ENGINEERING



AUTONOMOUS ENGINEERING

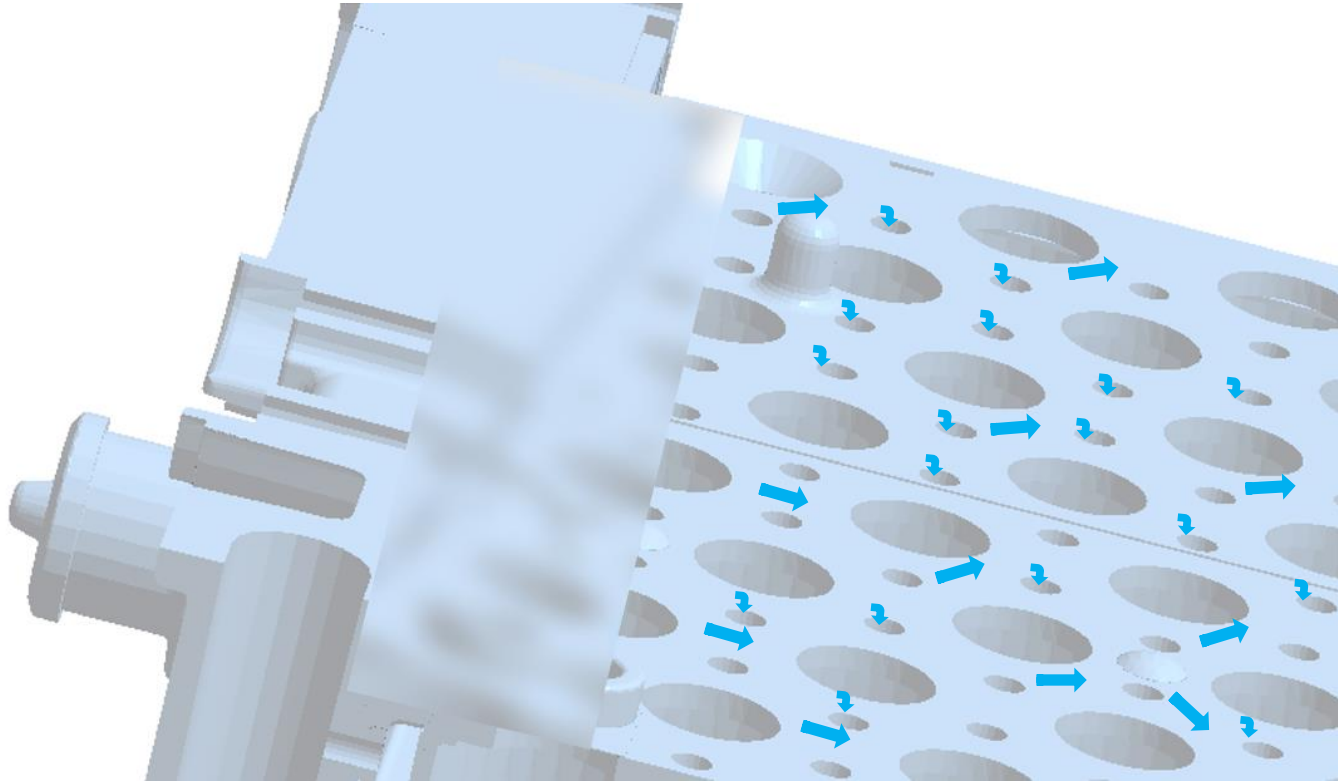


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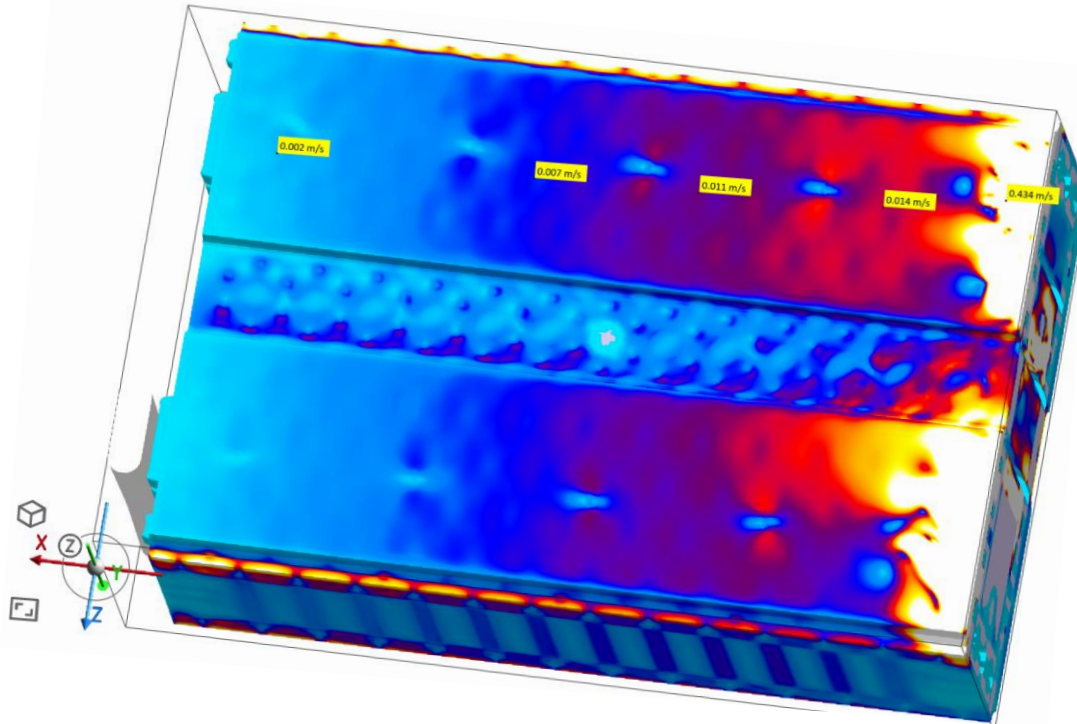
3D SIMULATION

Intended Flow Direction

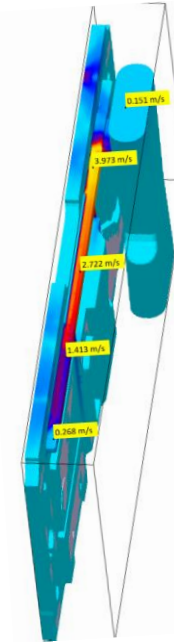


FLOW RATES

Velocity of coolant – constant flow conditions



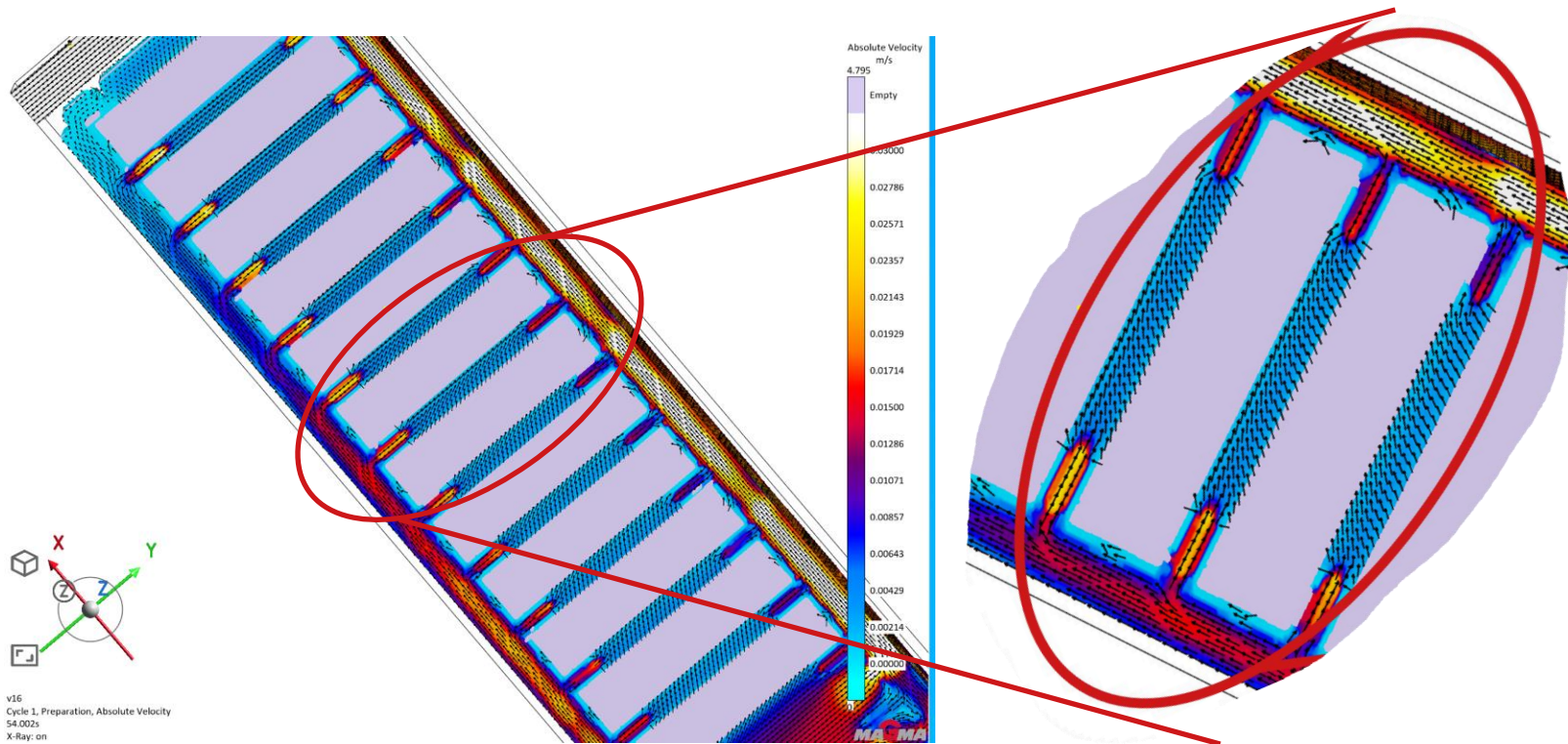
Inlet “plate”



Inlet channel

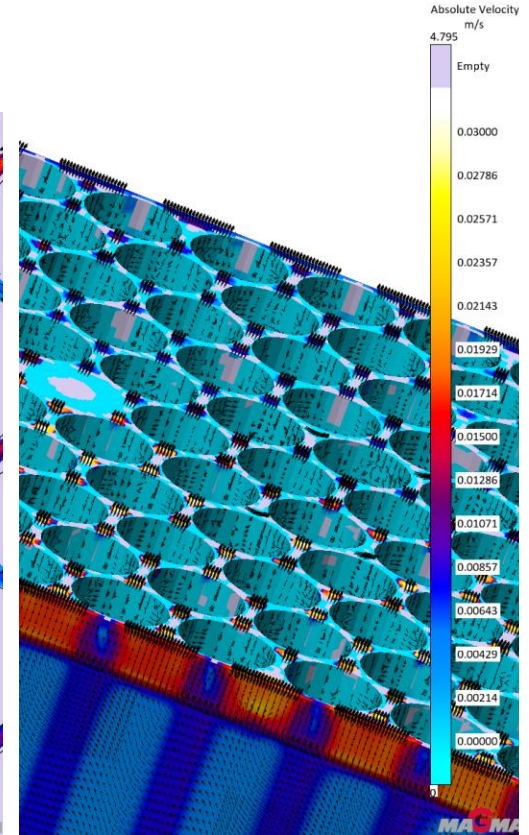
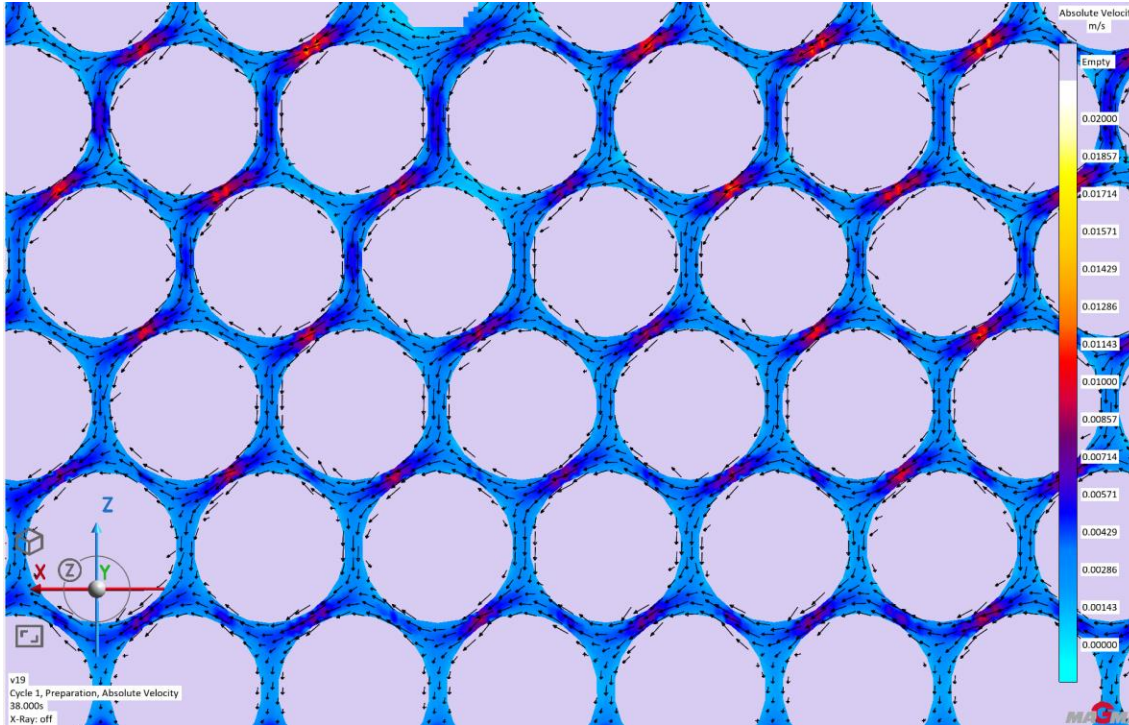
FLOW RATES

Initial filling of cavity with coolant



FLOW RATES

Vectors show directions of flow



COOLANT TEMPERATURE



v16
Cycle 1, Preparation, Temperature
3min 20.0s
X-Ray: on

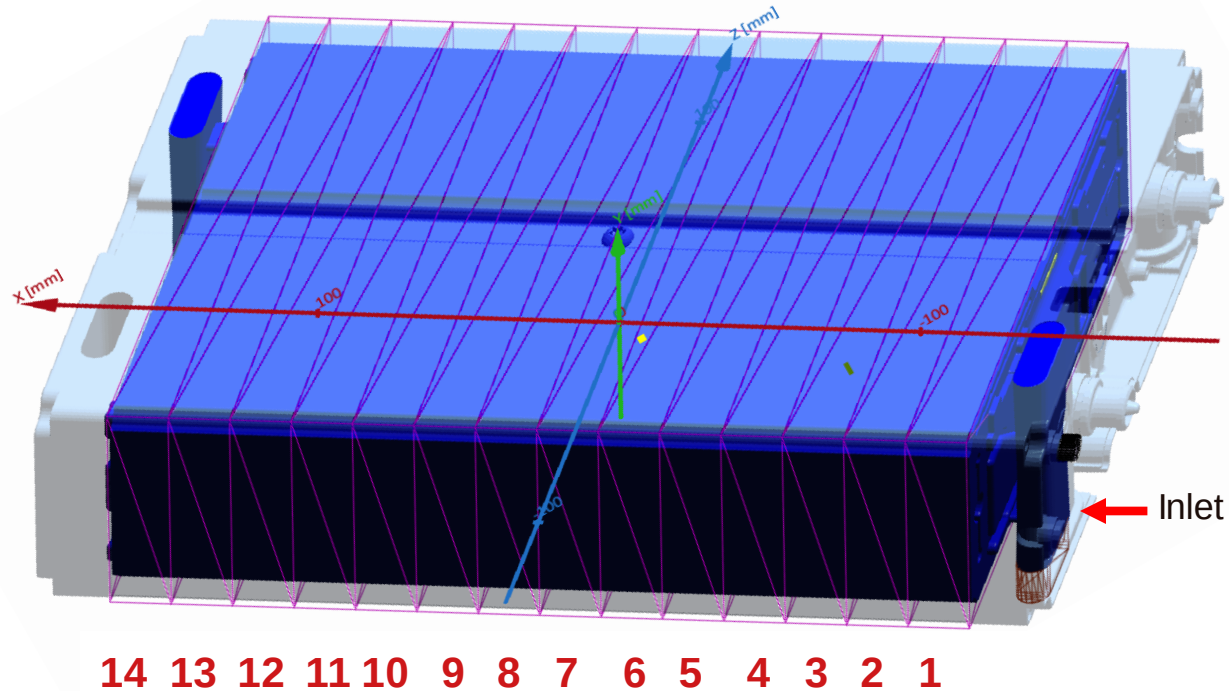


MAGMA

MAGMA

FLOW RATES

Based on KULI's defined 14 sections



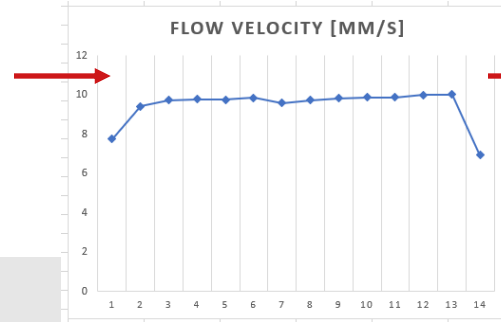
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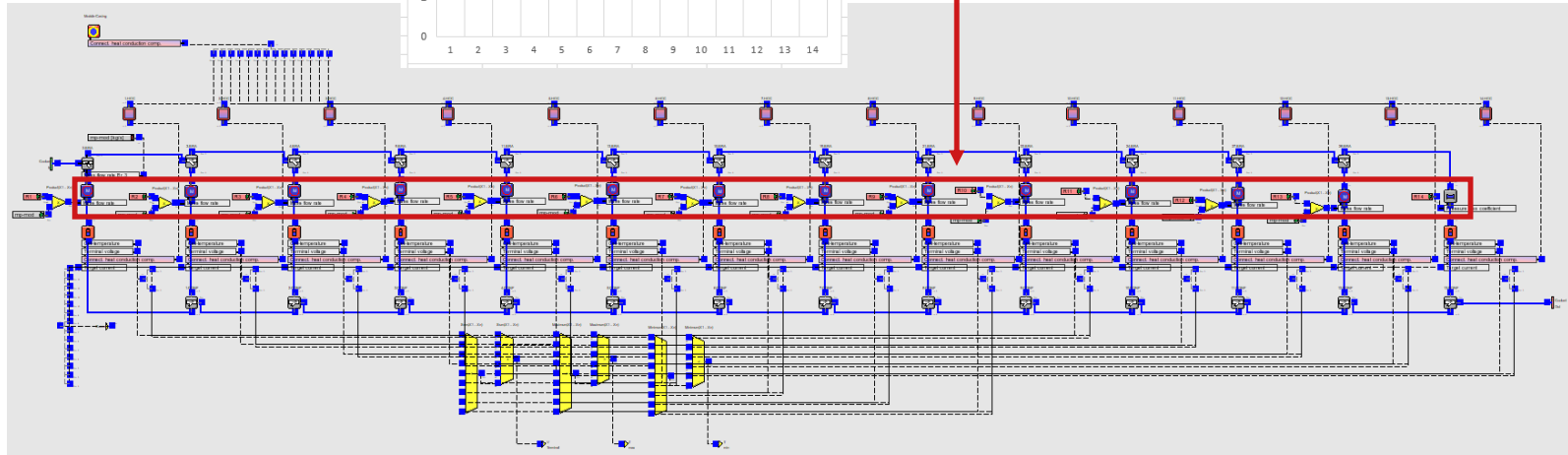
TEMPERATURES

14 Sections: Flow Distribution in the Battery Module

Simulation result from
MAGMASOFT



Map this flow distribution to
an updated KULI 1D model



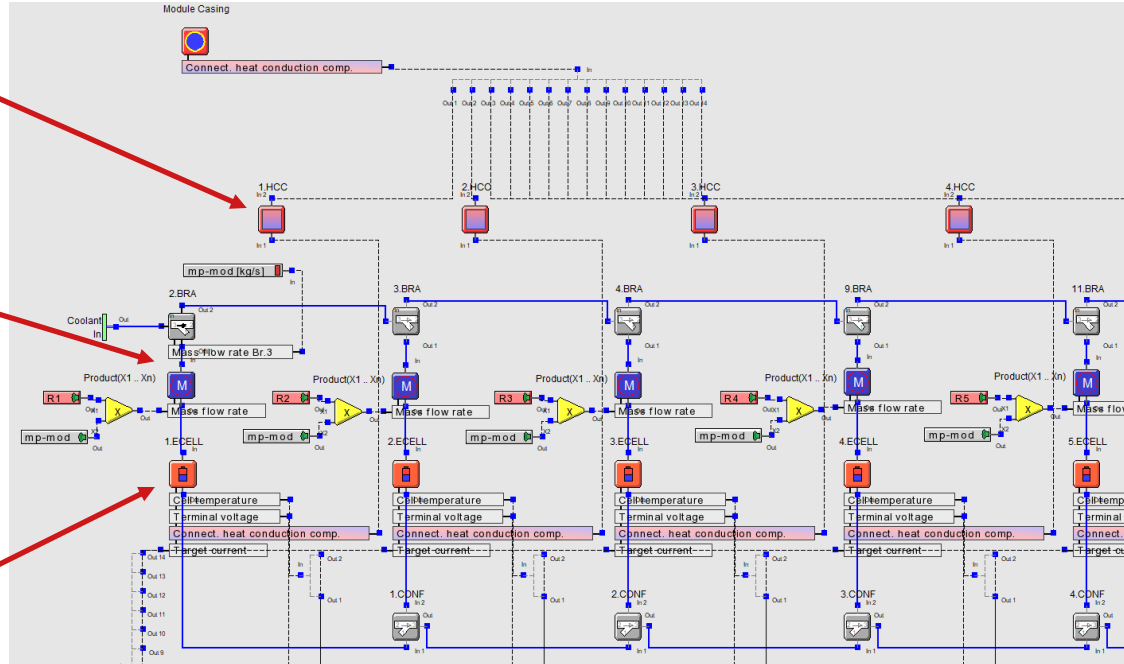
SIMULATION MODEL DETAILS

A Closer Look at one Module

Heat transfer to module casing

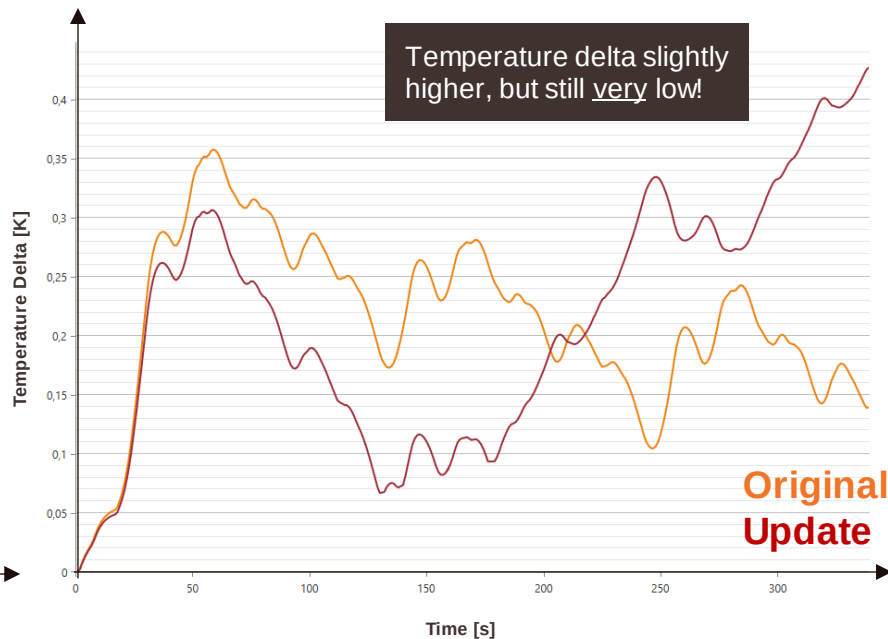
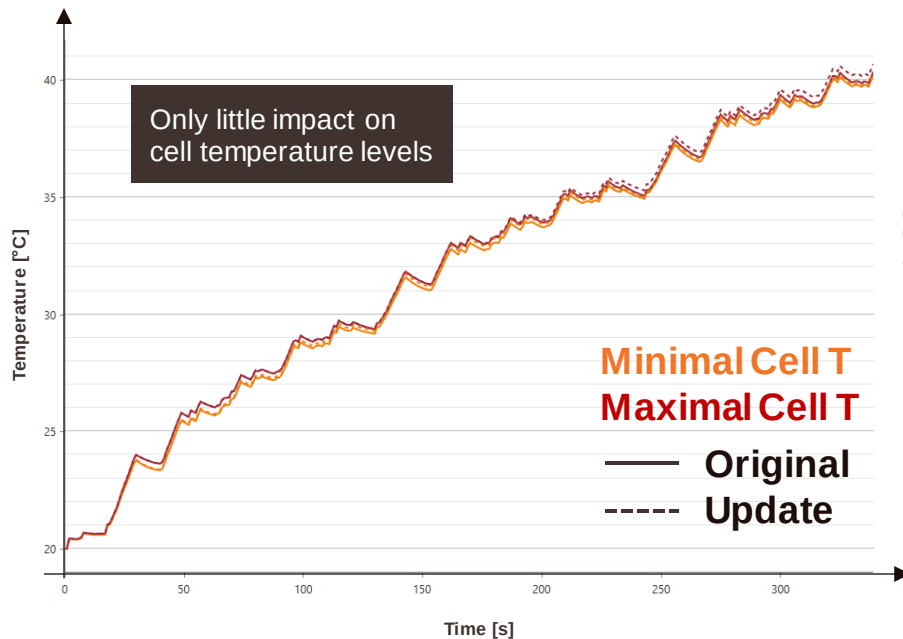
Mass-flow distribution

Individual cell-groups (x14)



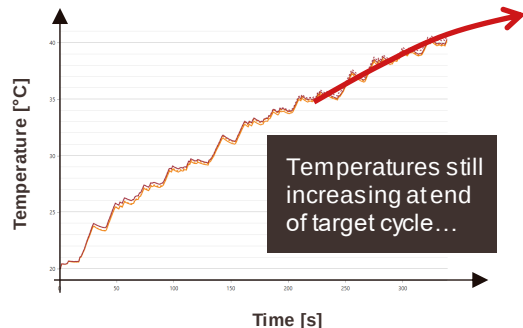
UPDATED 1D SIMULATION RESULTS

KULI



SIMULATION OUTLOOK

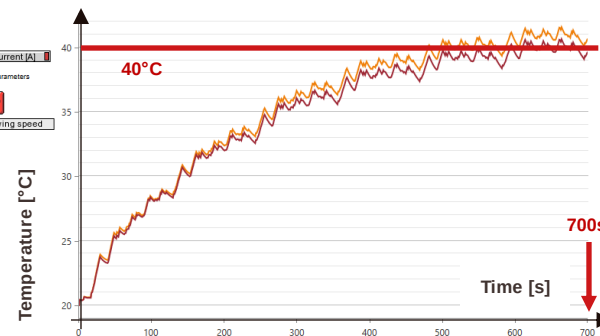
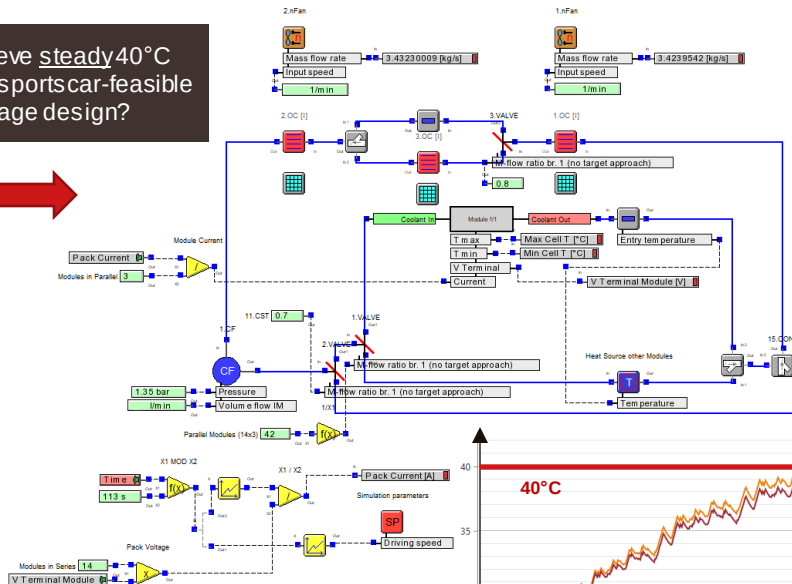
Improved Cooling System Performance and Packaging



Can we achieve steady 40°C AND have a sportscar-feasible cooling package design?

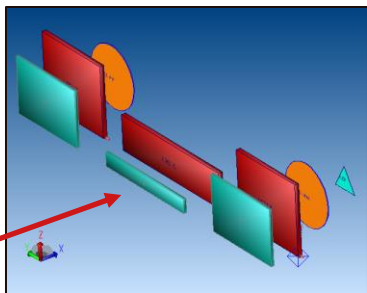
Yes, we can!

$T_{avg} \leq 40^\circ\text{C}$
 $\Delta T \leq 1\text{K}$
 $P_{max} \sim 30\text{kW}$



Side cooler with fan

Front cooler (ram air only)



SUGGESTED WORKFLOW

1. Initial Design Layout

(no CAD Data available, only parallel/serial for flow & electric current)

2. Initial System Studies in KULI

(simplifications and assumptions to allow comparison of overall design variants and component selection)

3. 3D Simulation by MagmaSoft

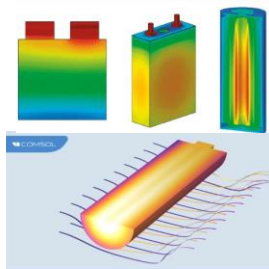
(yields details on flow distribution and heat transfer coefficients based on 3D design)

4. Refinement of KULI simulation model

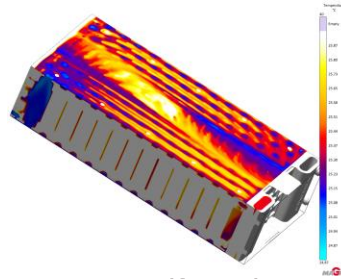
(to simulate complete operation cycles)

Summary & outlook

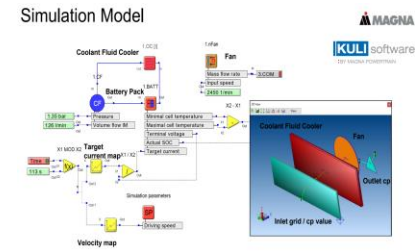
- For optimal thermo management a deeper understanding of the components and their impact on the entire system is needed
- 3D simulations of transient behaviors of such systems can offer valuable input to the 1D system simulations
- In the future a simulation chain from the single cell to the battery module and hence the entire thermo system should be established



Batterie Cell



Module/Stack/Battery



Vehicle