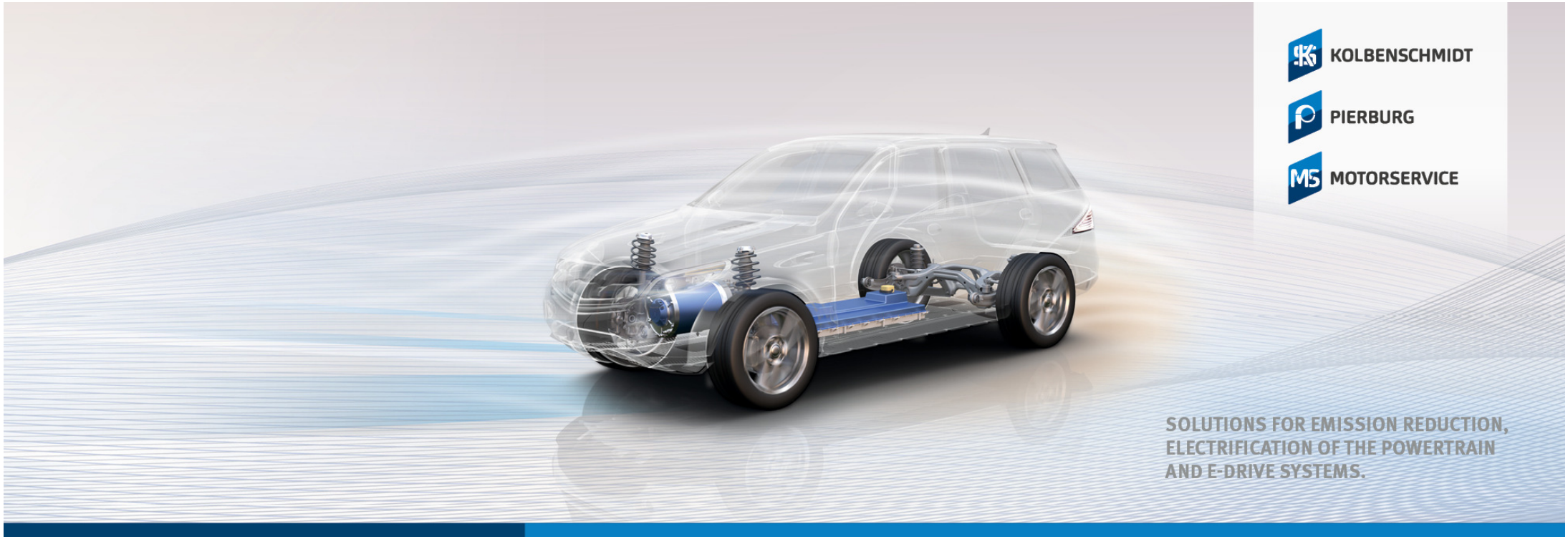


Evaluation of the Thermal Behavior of a 48V EV Battery with Passive Cooling

GT

European GT Conference

M.Sc. Dennis Schier / Dr.-Ing. Frank Seifert

Frankfurt, October 2019

OUR **HEART** BEATS FOR YOUR ENGINE.

RHEINMETALL AUTOMOTIVE

Agenda

Introduction

- **Rheinmetall Automotive** is traditionally strong in the market of conventional drive trains
- Expansion of the traditional product portfolio with products for electric and hybrid drive trains
  - become a competent partner for electric drives, battery packs and power electronics

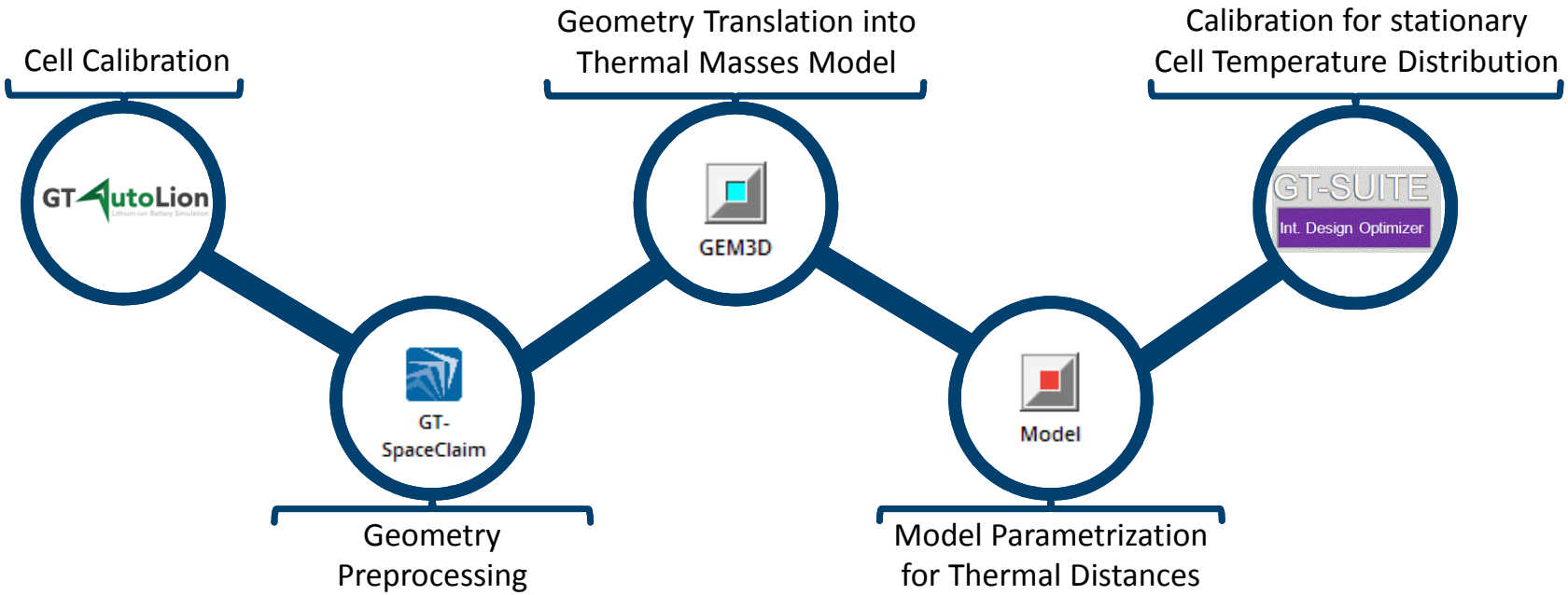
Motivation:

- Development of a simple tool for the evaluation of (scalable) battery pack concepts
- Fast reaction for customer inquiries

Requirements:

- Low calibration effort based on 3D CFD
- Cell Temperature error should not exceed 1K on average
- Gradient of the individual cell temperatures across the battery pack must be consistent

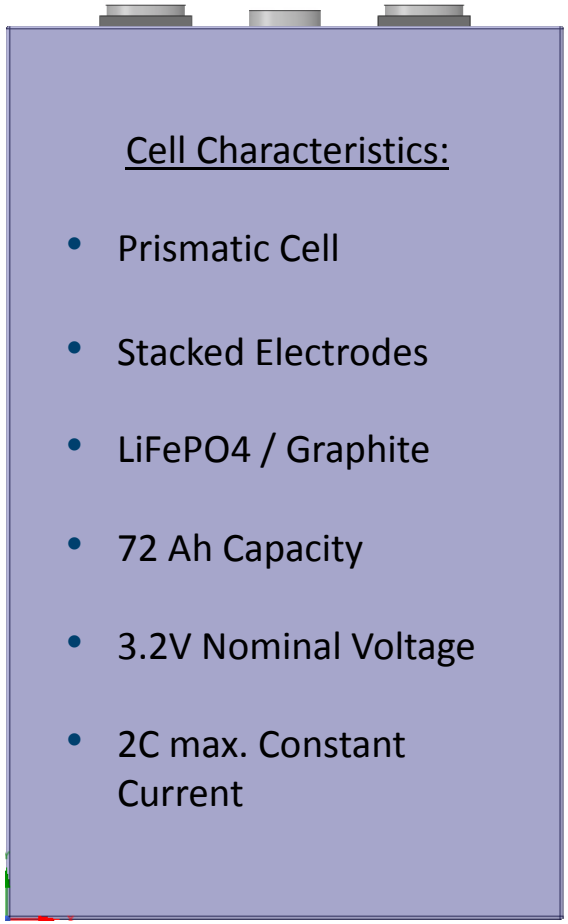
Simulation Workflow



- ✓ Comparison of stationary and transient results with 3D CFD
- ✓ Comparison of cell model with test results
- ✓ Validation with test results
- ✓ Calculation of temperature distribution for real drive cycles

Agenda

GT-AutoLion | Cell Description



Cell Characteristics:

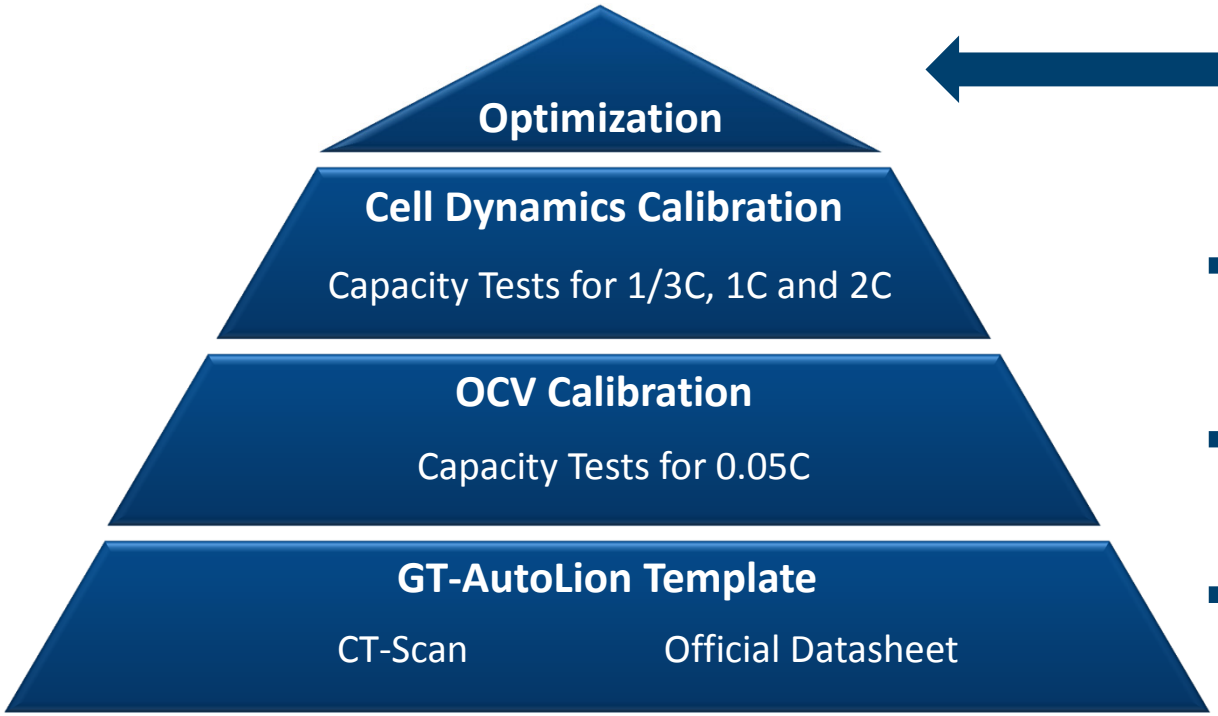
- Prismatic Cell
- Stacked Electrodes
- LiFePO4 / Graphite
- 72 Ah Capacity
- 3.2V Nominal Voltage
- 2C max. Constant Current

Create AutoLion model to simulate cell behaviour:

Available Data for model creation and calibration:

- CT-Scan
- Official Datasheet
- Capacity Test for 0.05C (Discharge)
- Capacity Test for 1/3C, 1C and 2C (Discharge)

GT-AutoLion | Calibration Workflow



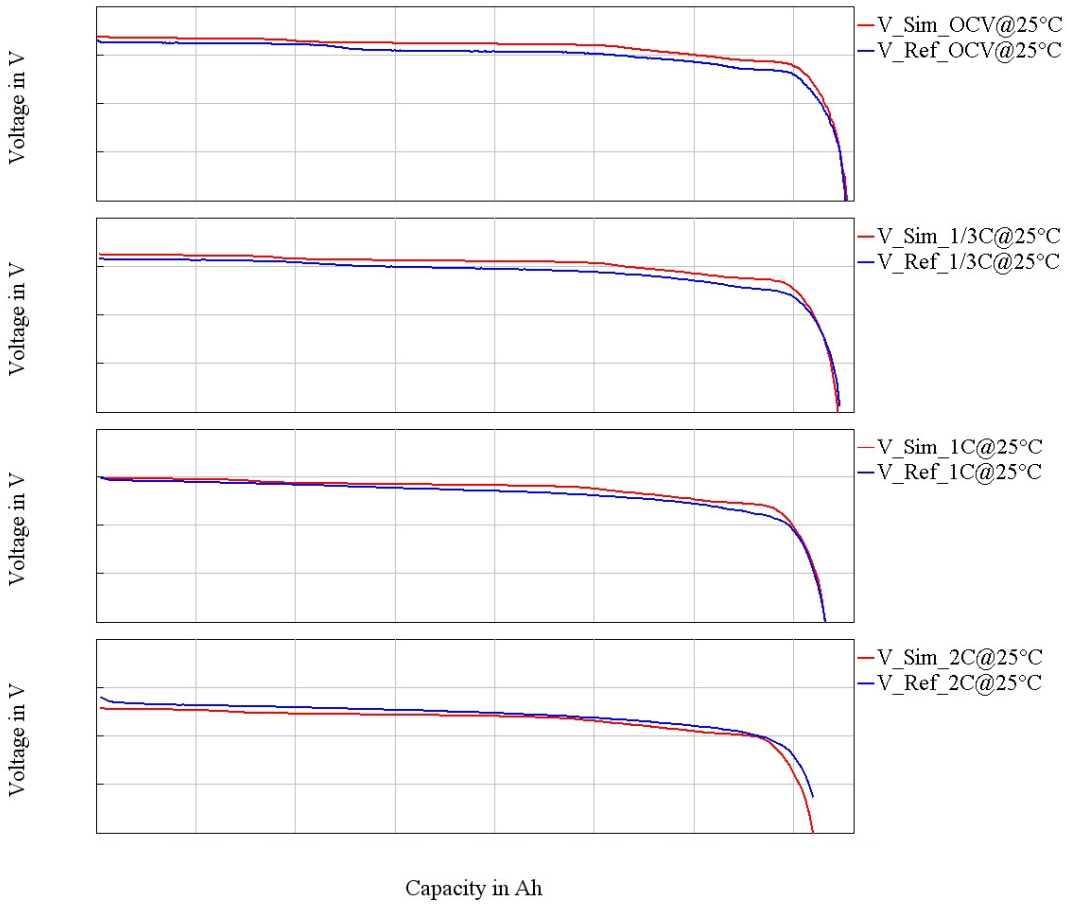
- Contact Resistance
- Diffusivity Multiplier
- Heat Transfer Coefficient

- Capacity Loading | N/P Ratio
- First Charge/Discharge Capacity
- OCV@100% SOC

- Geometry Parameters

GT-AutoLion Template Parameters

GT-AutoLion | Calibration Results



- Calibration results for capacity discharge tests OCV|1/3C|1C|2C
- Maximum error about 1% for voltage values
- Capacity fit for all cases (except 2C)
- No calibration of charging tests so far

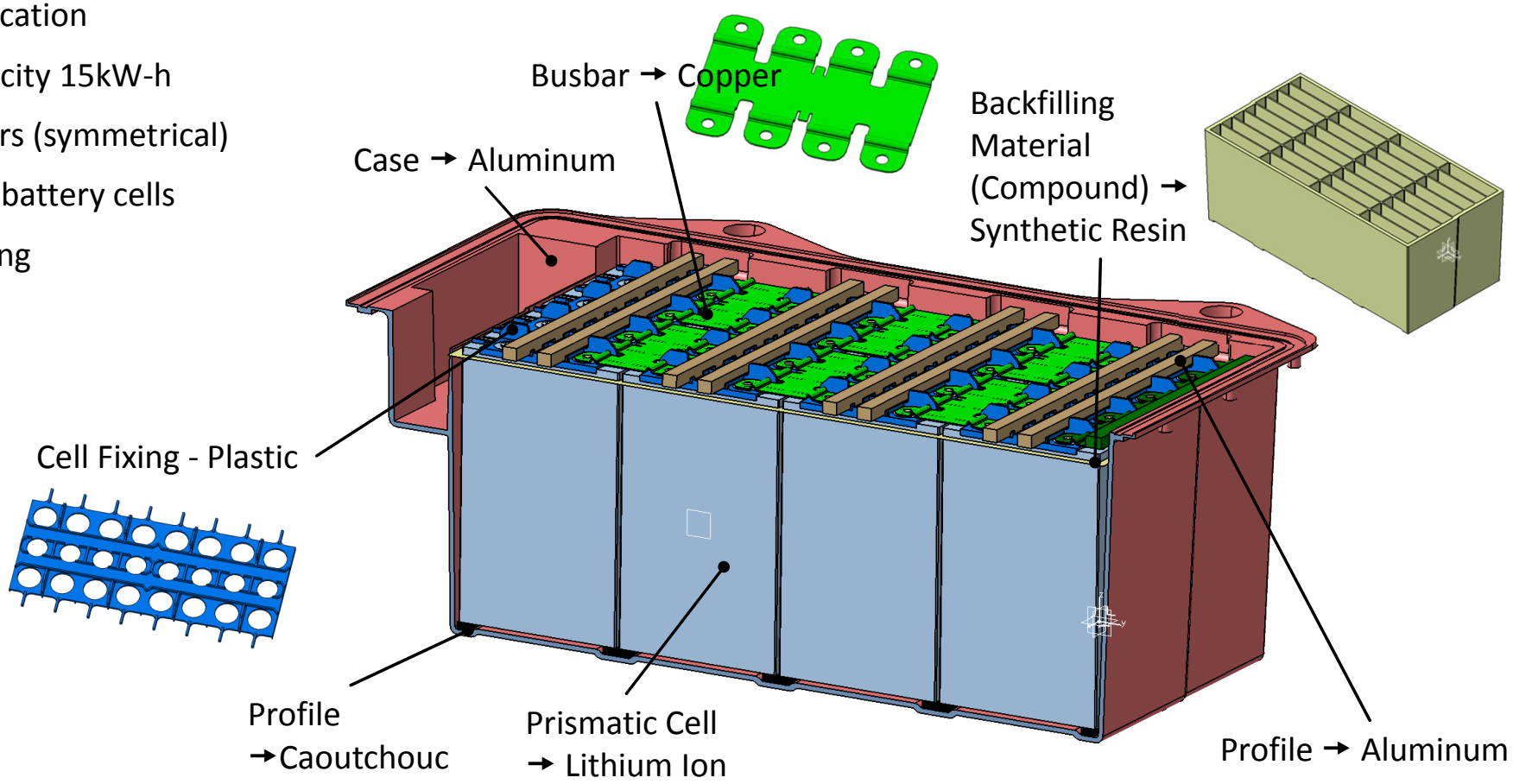
✓ Template can be integrated into complete Battery System Model

✓ Heat flow from cells can be extracted and fed into Thermal Model

Agenda

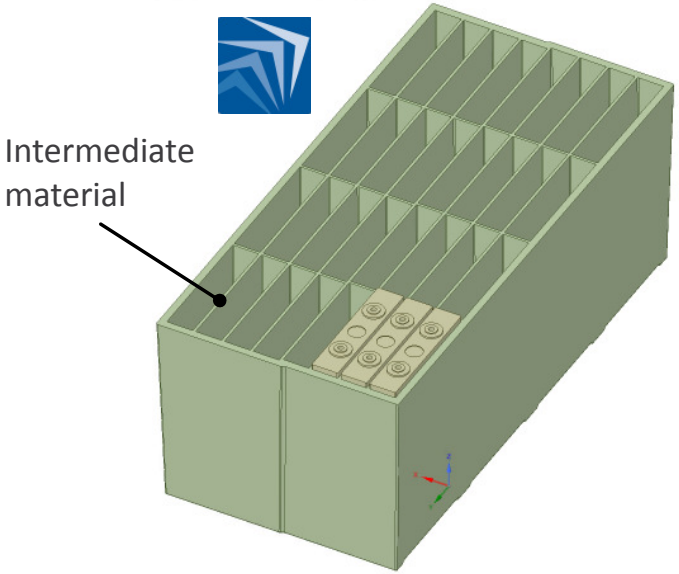
Thermal Model (TM) | Battery Setup

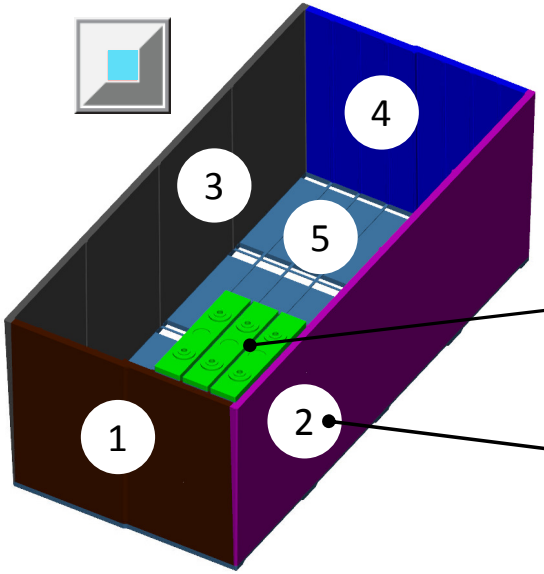
- 48 Volt Application
- Battery Capacity 15kW-h
- Two chambers (symmetrical)
- 64 prismatic battery cells
- Passive cooling



TM| Geometry Preparation and Modelling

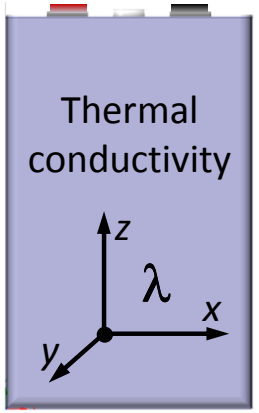
- Preparation of the CAD geometry in SpaceClaim
- Simplification of the CAD model
- Definition of a thermal resistance between the cells instead of a thermal mass for the casting compound
- Consideration of the anisotropy of the battery cell
- Control of the heat flows in the battery pack





Thermal resistance between all cells

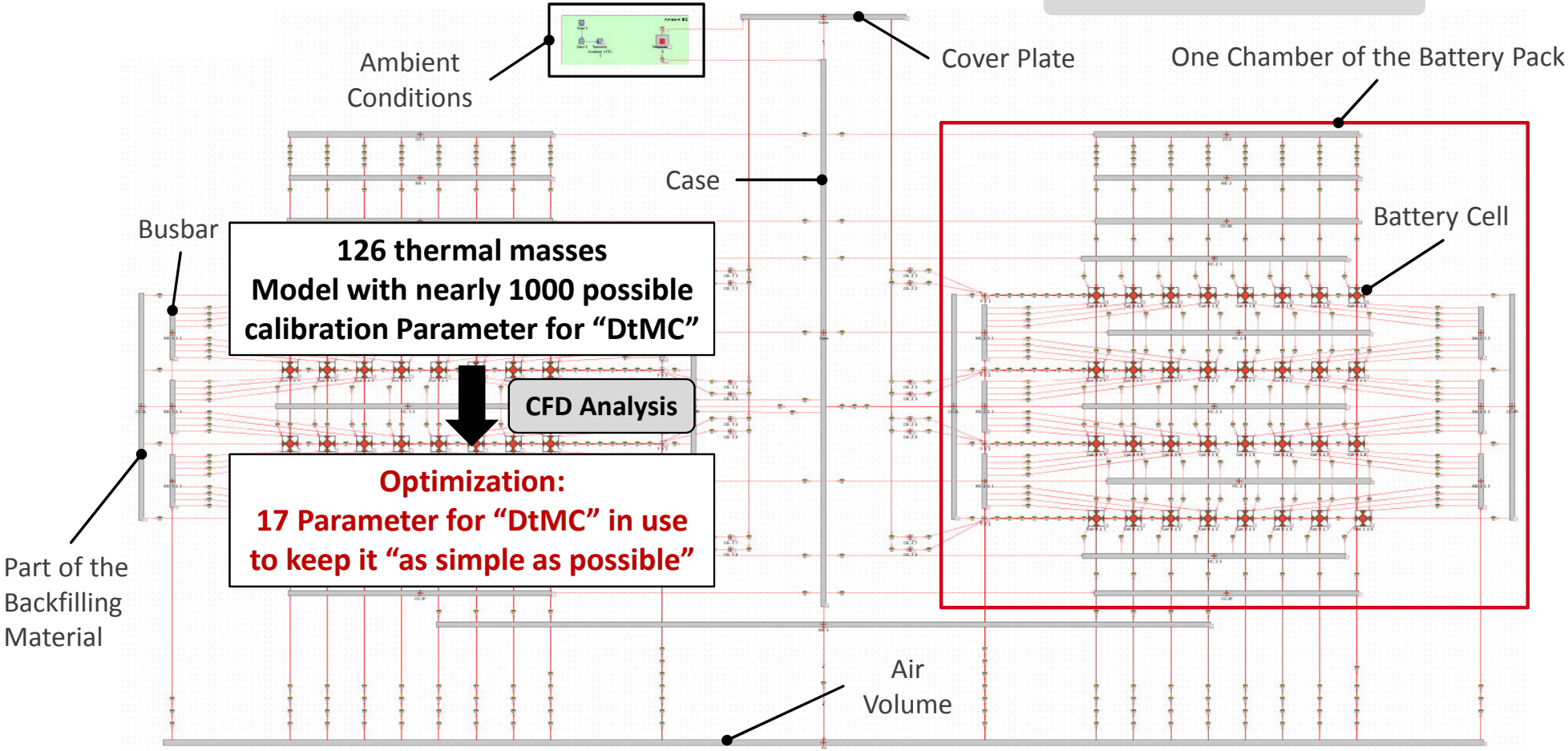
Sectioning of the casting compound into 5 thermal masses



- Anisotropic material properties
- Coordinate direction

TM| Battery Pack with Thermal Masses

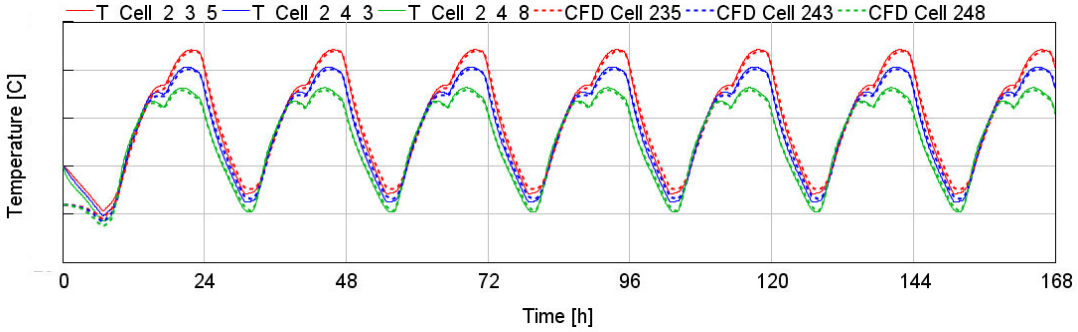
"DtMC": Distance to Mass Center

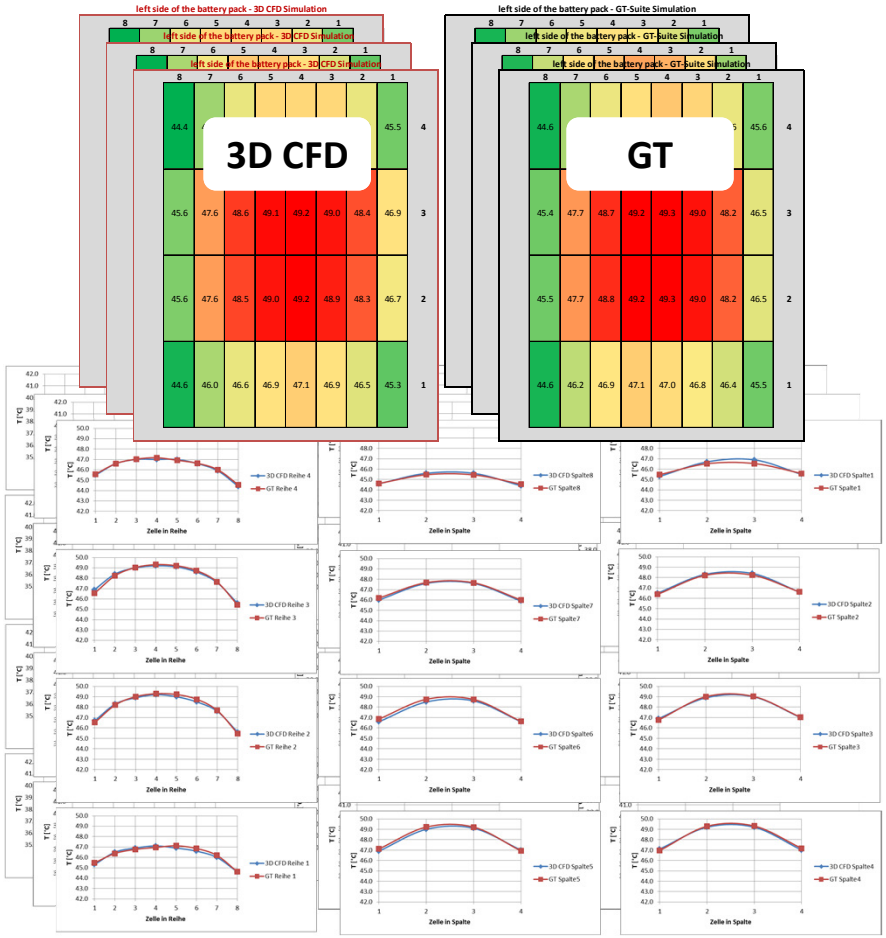


TM | Model Calibration

- Calibration of stationary load points with results from 3D CFD for different cases
  - Variation of stationary cell heat source
  - Variation of stationary ambient conditions
  - **Optimization** for “Case Sweep and Cross-Case Studies”
  - **Goal**: average cell temperature calibration error ≤ 1K
  - **Result**: max. ave. error about 0.25K / symmetry between chambers

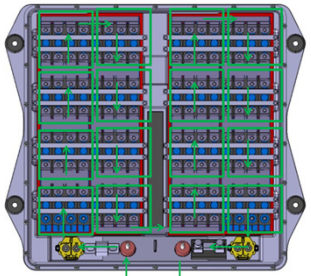
- Transient results for a 7-Day-Cycle with calibrated model
  - Changing BC´s for HTC, temperature and heat source

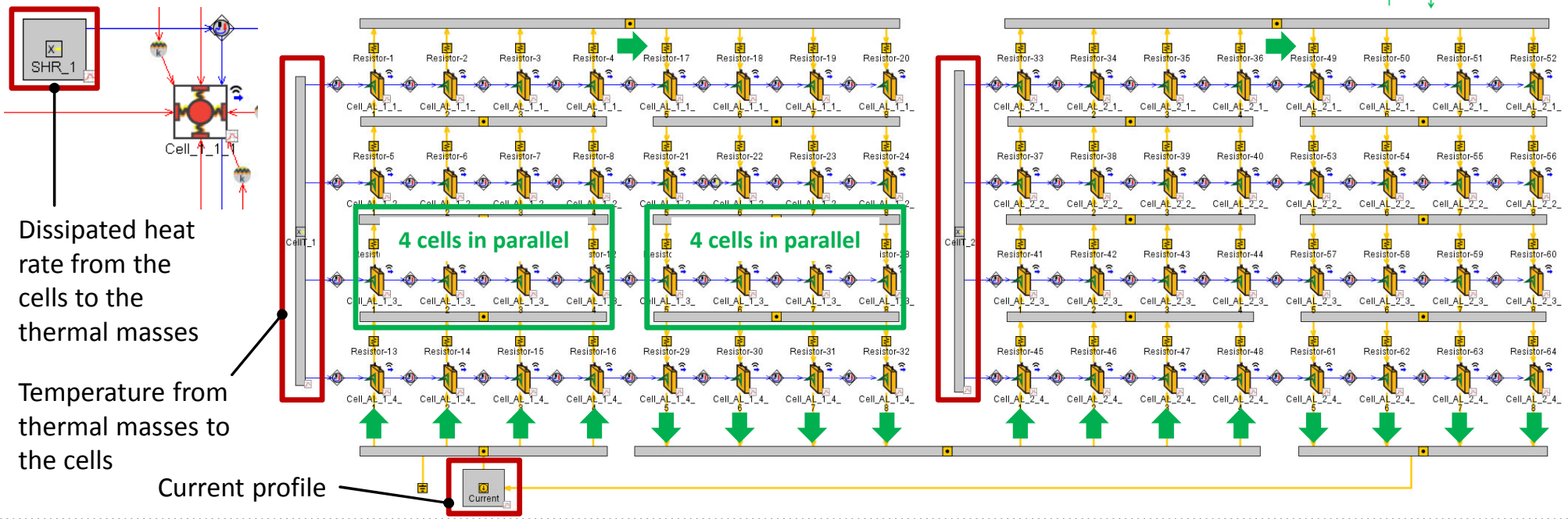




TM | Battery Pack with Thermal Masses and GT-AutoLion

- Electrochemical integration with GT-AutoLion → validated model
- Build up of the battery cell arrangement and electrical flow
- 4 cells in parallel and 16 cells in series (4p16s)
- Transfer of dissipated heat from battery cell and ave. temperature from thermal mass





Agenda

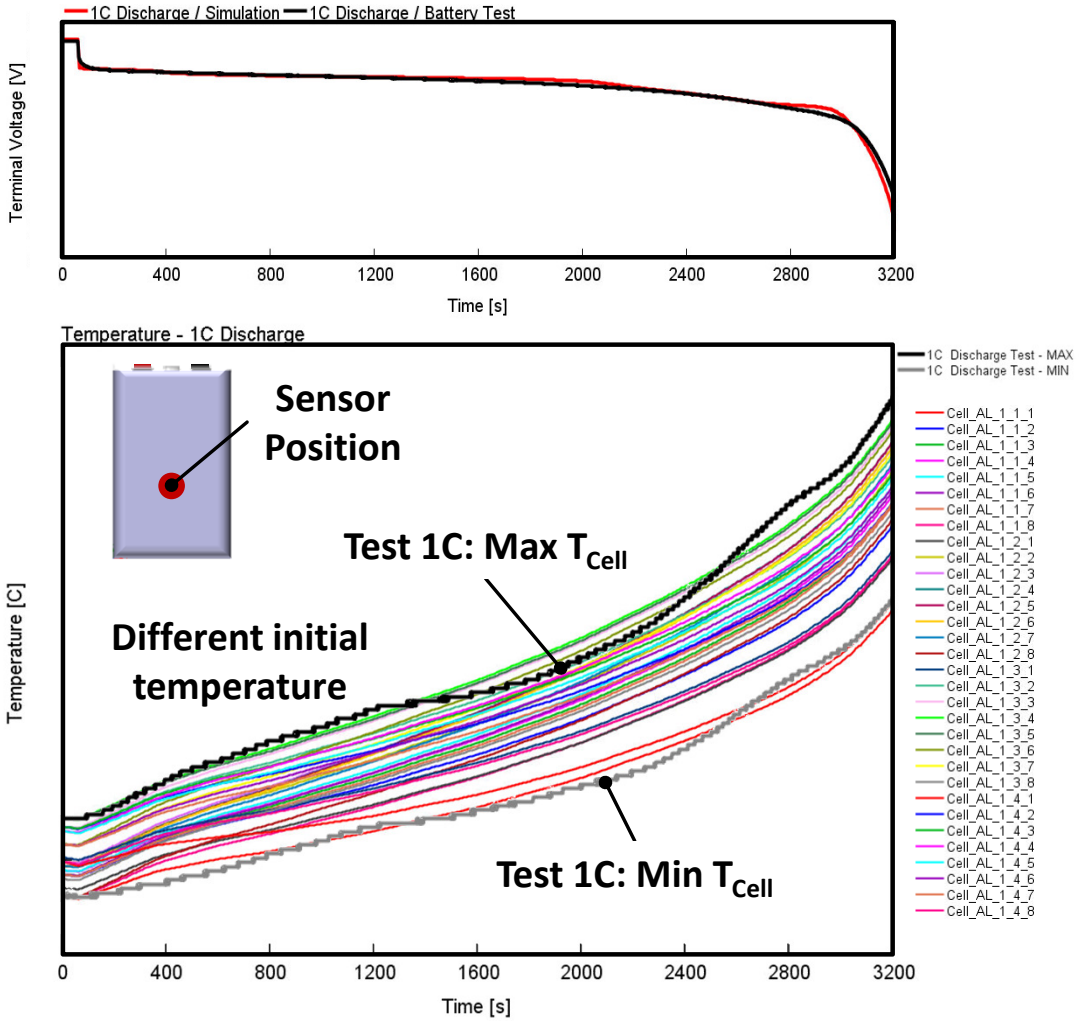
Results | 1C Discharge Battery Pack

Boundary Conditions

- Measurement for 1C Discharge
- Battery cell initial temperature 31-33°C
- Ambient temperature 25°C
- Start-SOC = 0.85

Results

- The gradient of the temperature characteristic is similar
  - Note: model calibration only with 3D CFD!
- Simulation results for the 1C discharge match the test results very well
- For the case of battery charging, there are currently deviations between simulation and measurement



Agenda

Conclusion

- GT-AutoLion Cell Calibration successful according to recommended workflow by GT
  - Small Error for discharging curves after calibration
- GT suitable for thermal management modeling
  - Easy build-up of a battery model with passive cooling
- First verification with battery pack measurements shows good matches
- The model fulfills the defined requirements
- Further investigations are necessary

Thanks to

Peter Stopp / Vehicle & Electrification

Dr. Dig Vijay / Thermal Management

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