ADVANCING EVTOL BATTERY DEVELOPMENT THROUGH SYNERGETIC INTEGRATION OF ADVANCED SIMULATION AND TESTING TECHNOLOGIES

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AVL Test System Inc.

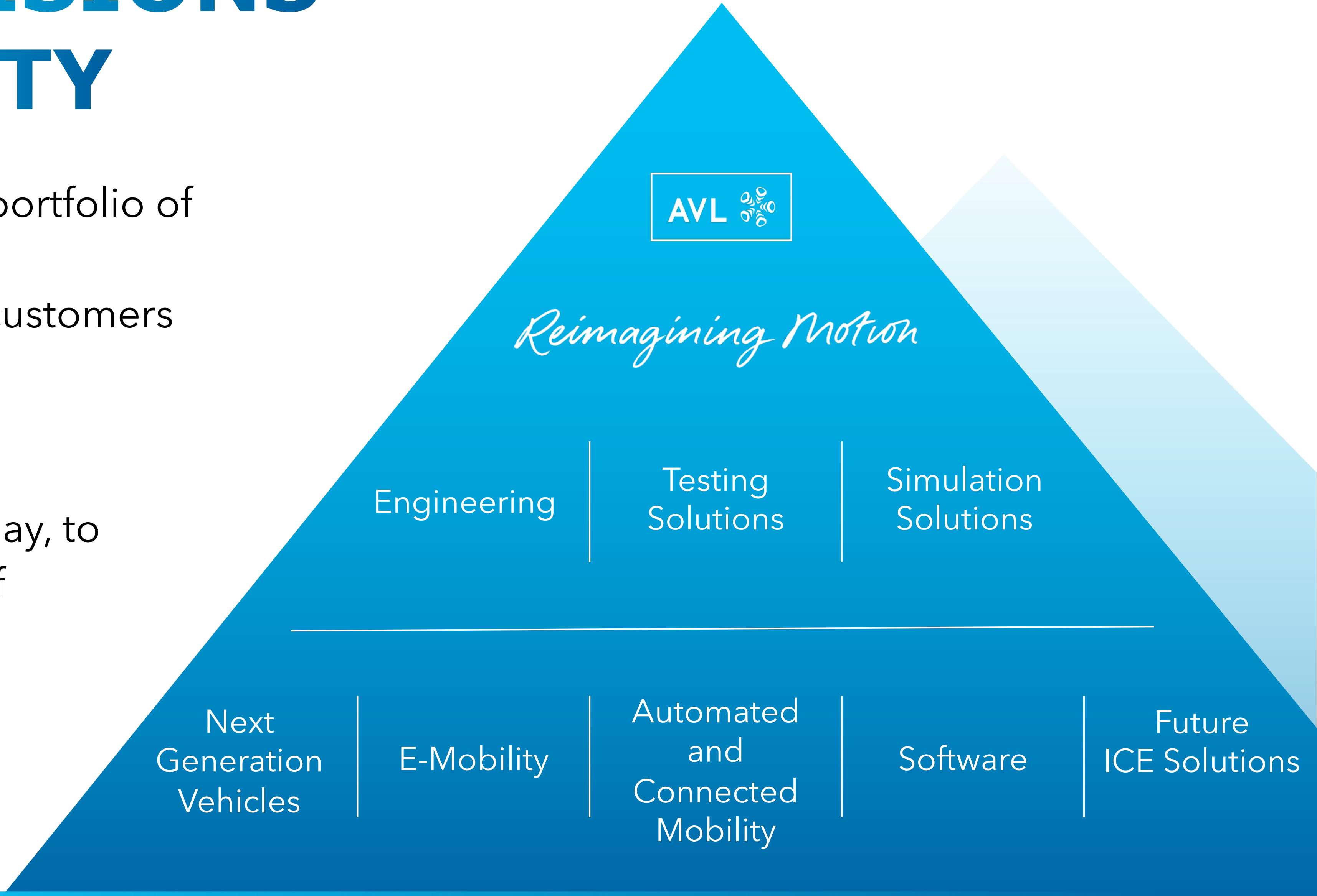
ABOUT US

At AVL, we are one of the world’s leading mobility technology companies for development, simulation and testing in the automotive industry, and in other sectors. Drawing on our pioneering spirit, we provide concepts, solutions and methodologies for a greener, safer and better world of mobility.

TURNING VISIONS INTO REALITY

We constantly transform our portfolio of high-end methodologies and technologies to support our customers in achieving their ambitions.

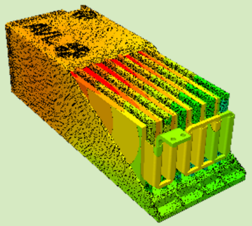
We are driving innovation today, to build the mobility concepts of tomorrow.



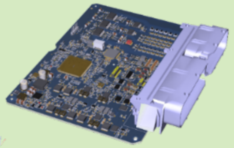
DEVELOPMENT

- Benchmarking & Concept Development

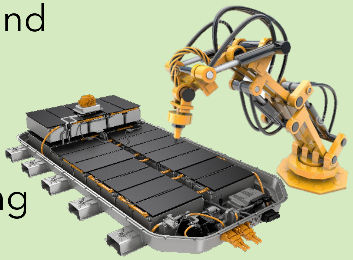
- Connected Simulation



- Systems Engineering & Controls Development



- Prototype build, Test and Validation



- Production Engineering

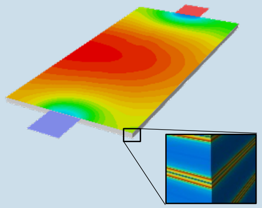
DEVELOPMENT PLATFORMS

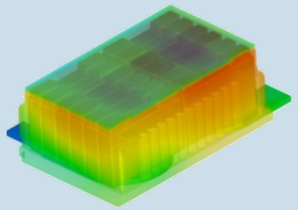
- Cell Testing
- Module Testing
- Pack Testing

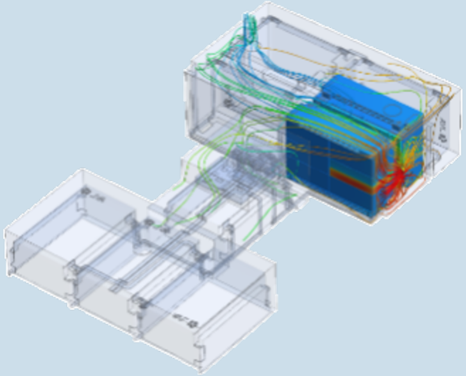
Testing Solutions

Simulation Solutions

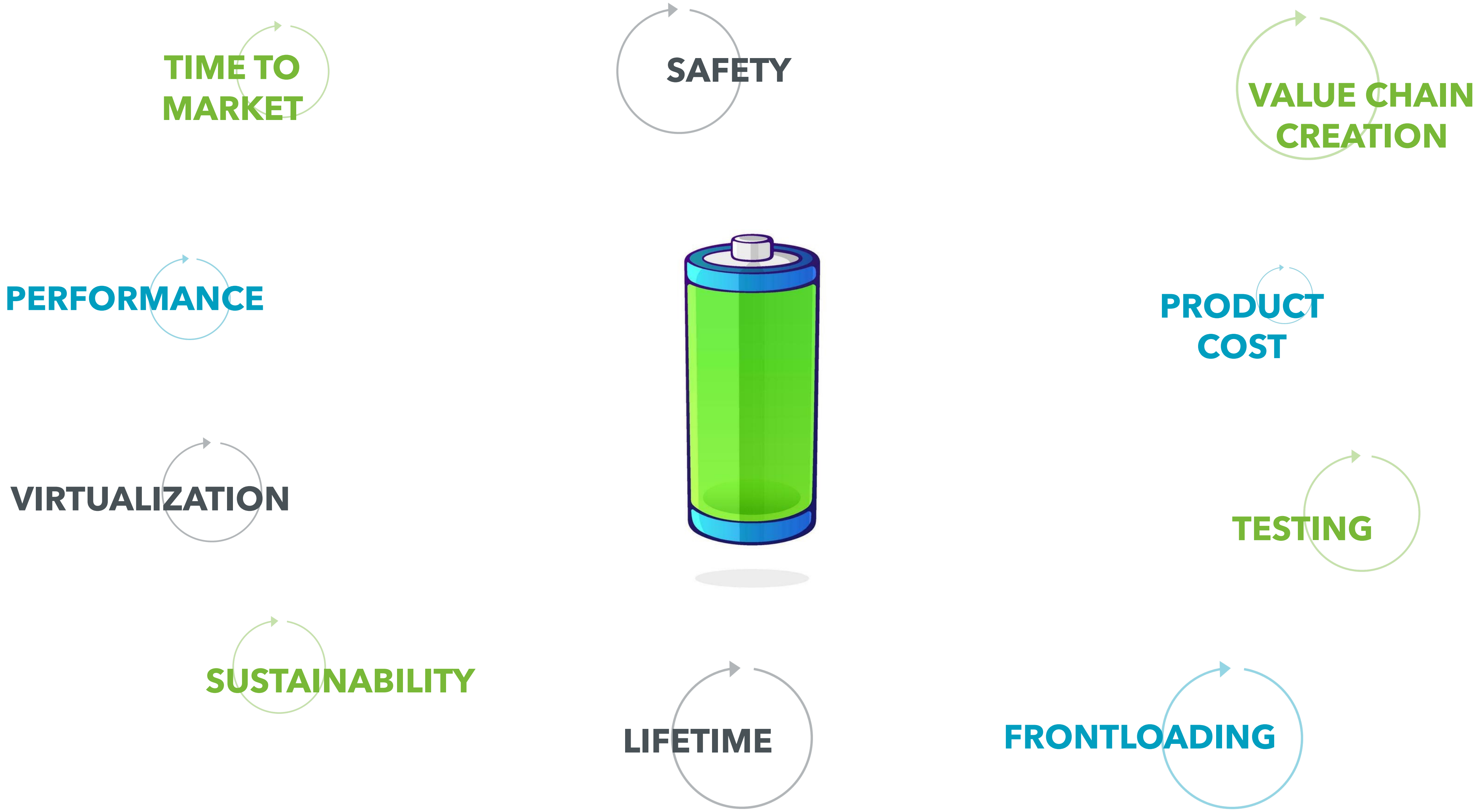
Support product development process by means of applying "**Virtual Development**"



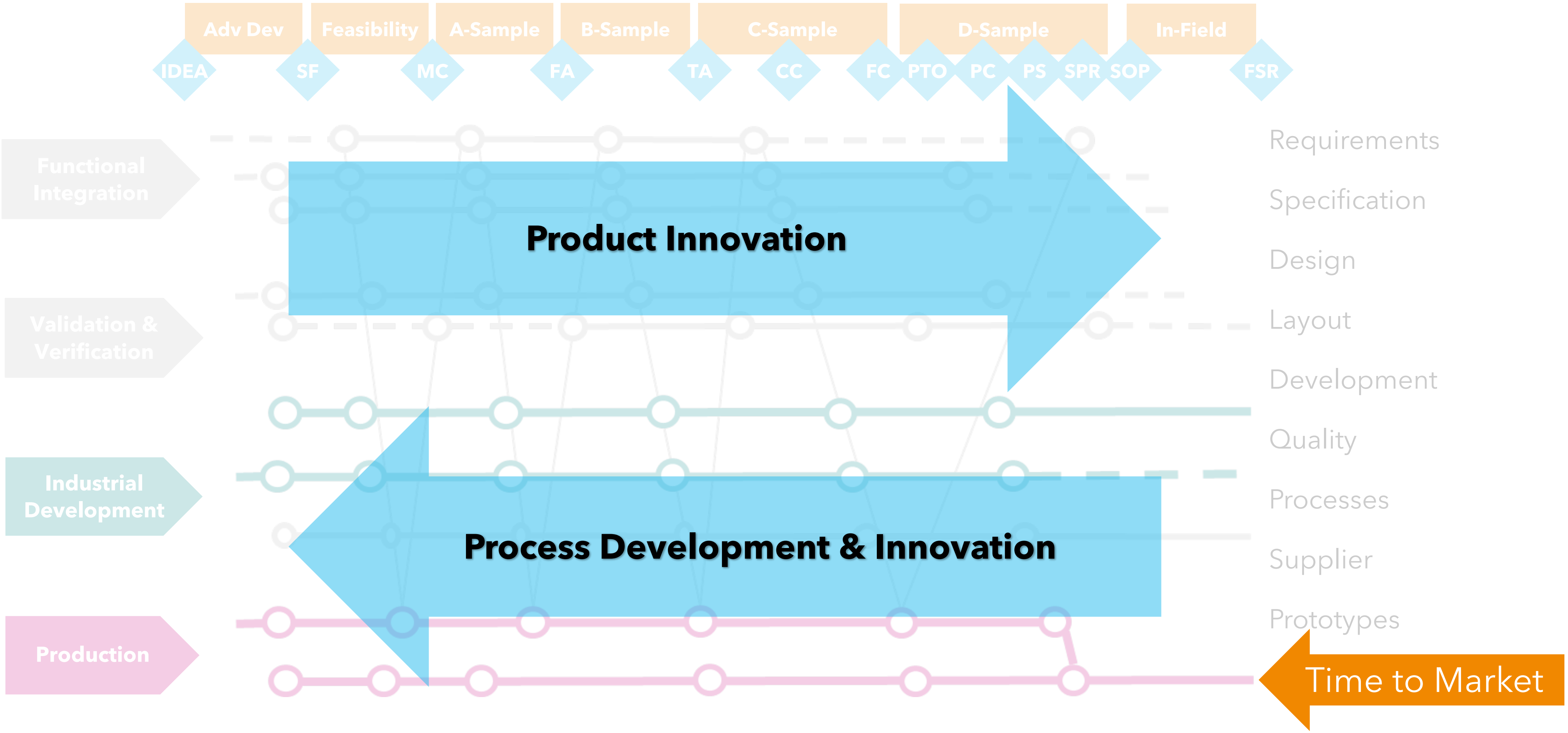





H2 HYDROGEN
H2 HYDROGEN


TIME TO MARKET
SAFETY
VALUE CHAIN CREATION
PERFORMANCE
PRODUCT COST
VIRTUALIZATION
TESTING
SUSTAINABILITY
LIFETIME
FRONTLOADING

ACCELERATING TIME TO MARKET

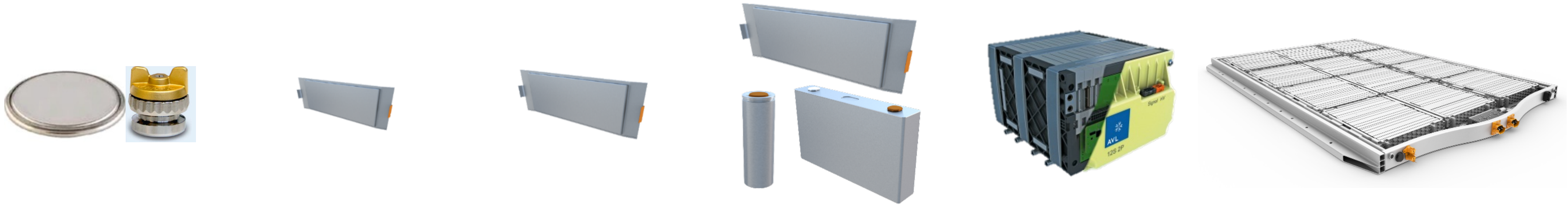


THE MAIN CHALLENGE

Cell development

Cell integration & Pack development

Chemistry R&D → Single Layer → Multi-Layer → Final Cell → Module → Pack



Shorten time to market without neglecting performance and quality

THE AVL SOLUTION

Typical simulation tasks for battery development

Single Cell

- ✓ Electro-chemical analysis
- ✓ Cell calibration for:
  - Performance characteristics
  - Short circuit investigation
  - Venting

Battery Module

- ✓ Transient electrical and thermal behavior
- ✓ Cooling assessment
- ✓ Short circuit investigation
- ✓ Thermal Runaway
- ✓ Venting and melting

Battery Pack

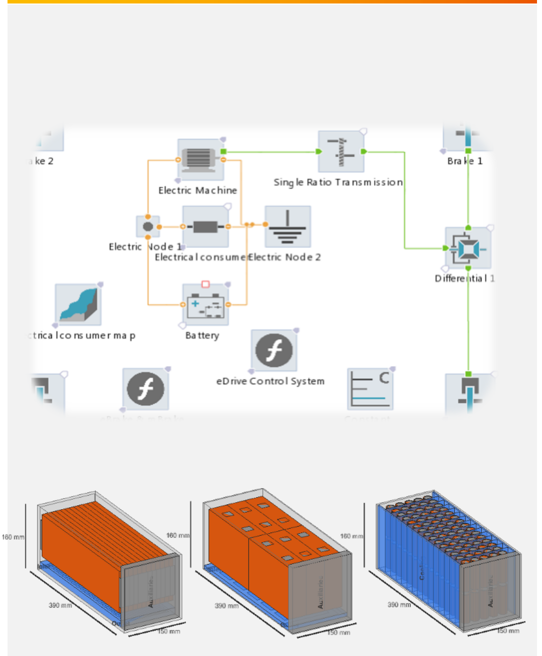
- ✓ Transient electrical and thermal behavior
- ✓ Cooling assessment
- ✓ Short circuit investigation
- ✓ Thermal Runaway
- ✓ Venting and melting

Vehicle

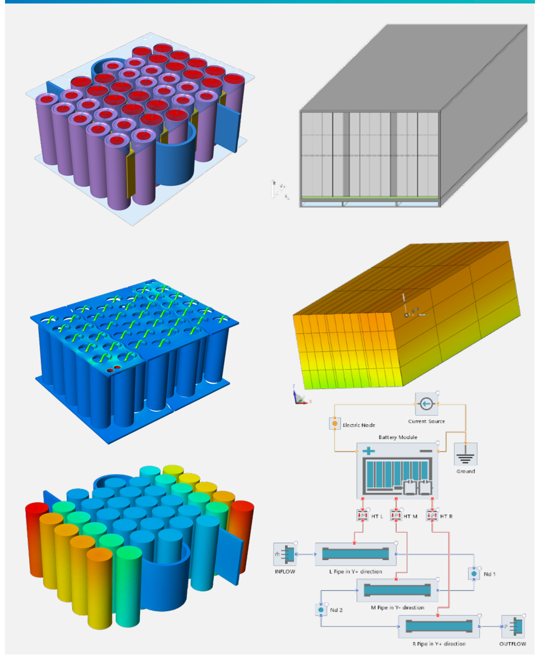
- ✓ Vehicle integration
- ✓ Control function development
- ✓ TMS and EMS optimization
- ✓ Climatic robustness
- ✓ Lifetime prediction

AREA OF APLICATION

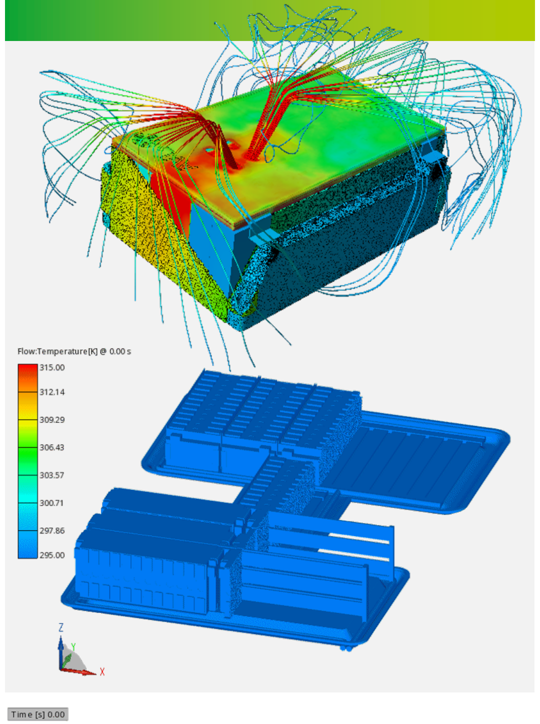
Concept and Layout



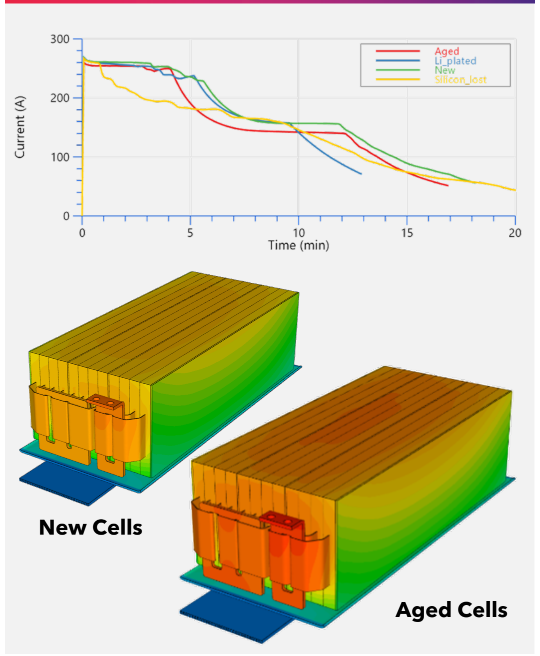
Active Safety



Passive Safety



Battery Life

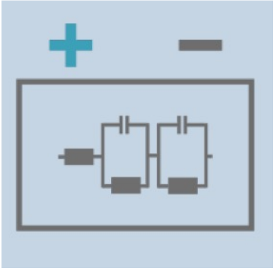


TESTING WITH ACCURACY

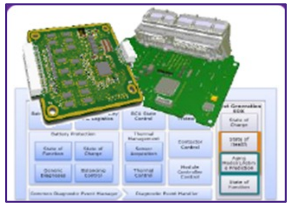
Use case example: Mapping SOC and OCV

Needs

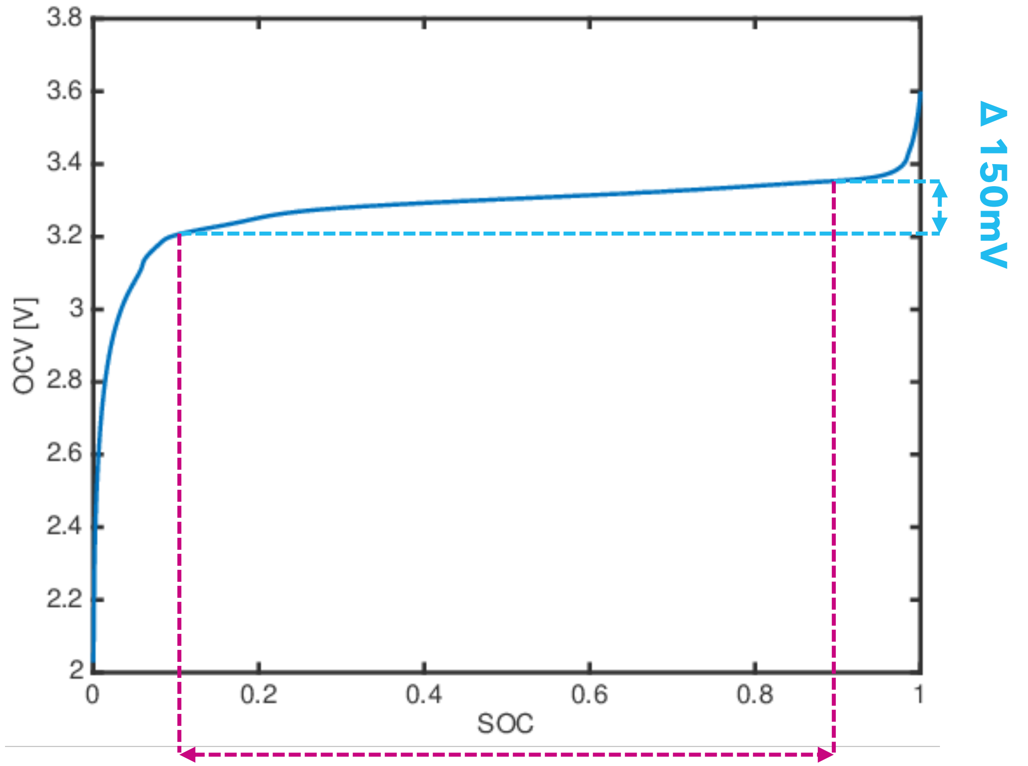
Feed RLC model



Feed BMS Design



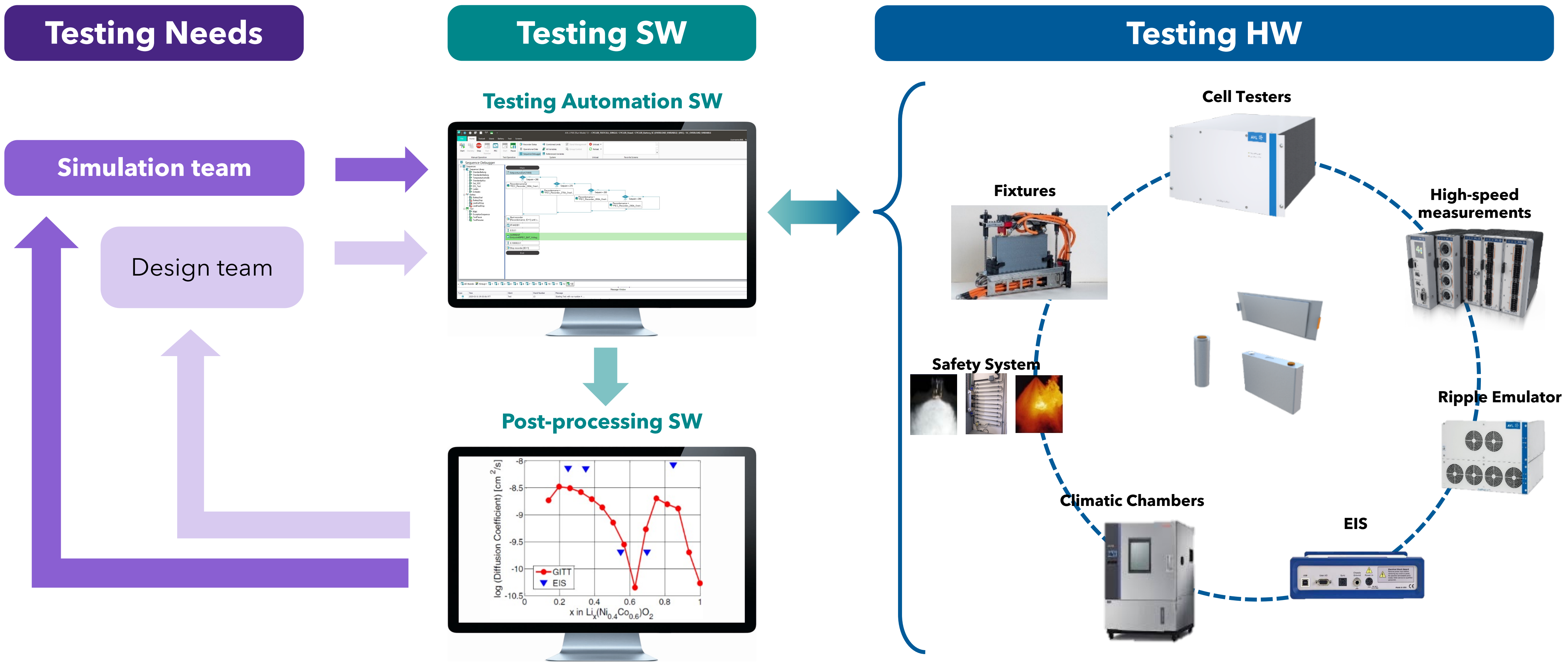
Typical LFP OCV/SOC curve



Required accuracy

Target SoC Accuracy	Voltage Accuracy (abs.)	Voltage Accuracy (% of FS)
1.0%	1.667mV	0.033%
0.5%	0.833mV	0.017%
0.1%	0.167mV	0.003%

TESTING WORKFLOW

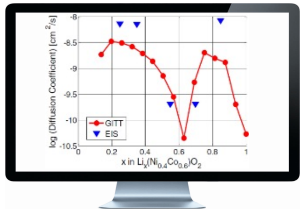


SCALABE CONCEPT

Testing need

Simulation team

Design team



Post processing

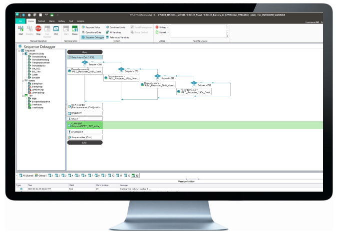
- Standardized post-processing algorithm
- Unified variable name

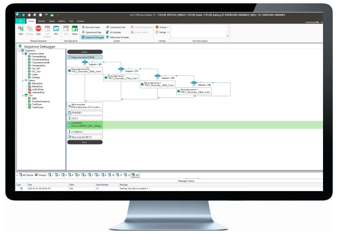
Lab mgmt. SW

- Automatic scheduling
- Standardized sequences
- Centralized request processing
- Unified variable name

Testing SW

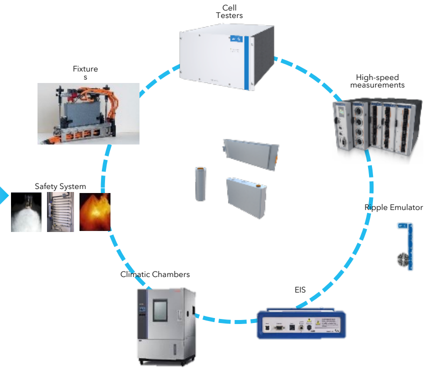
- Central point of control
- Single results file
- Automatic sequence
- Easily programmable

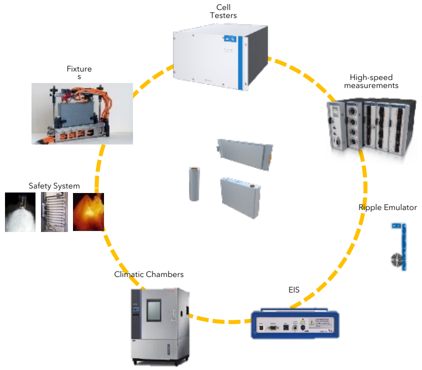




Testing HW

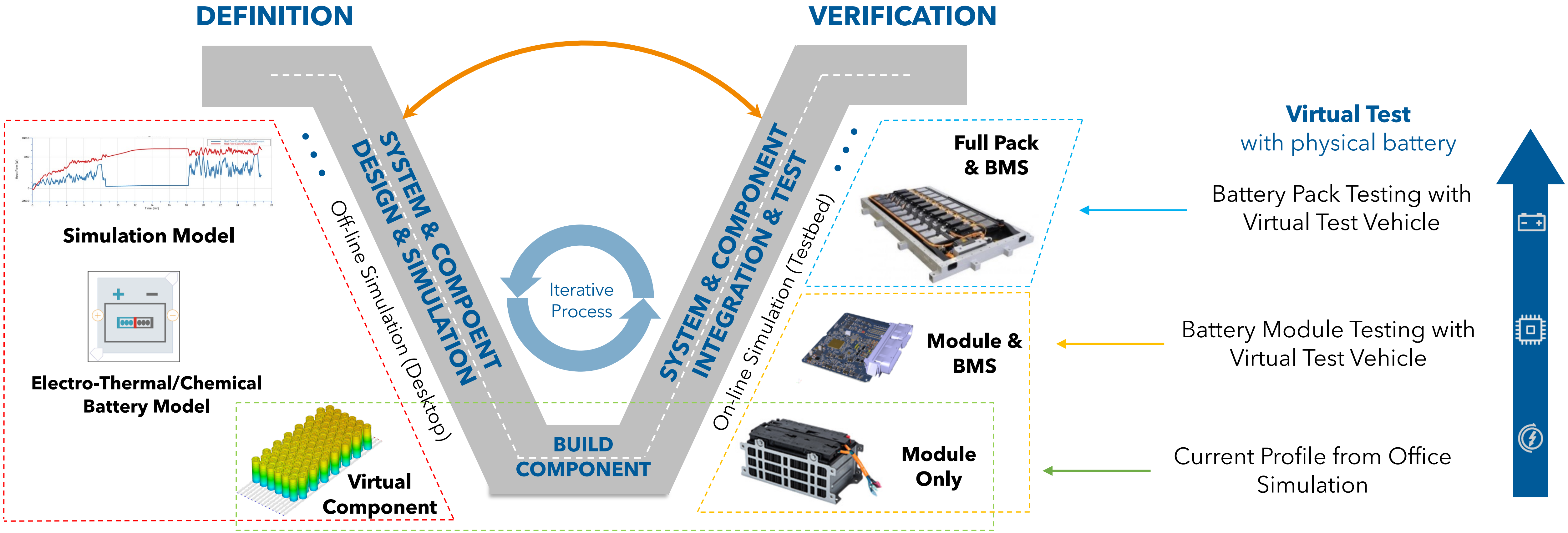
- Adaptable
- High performance



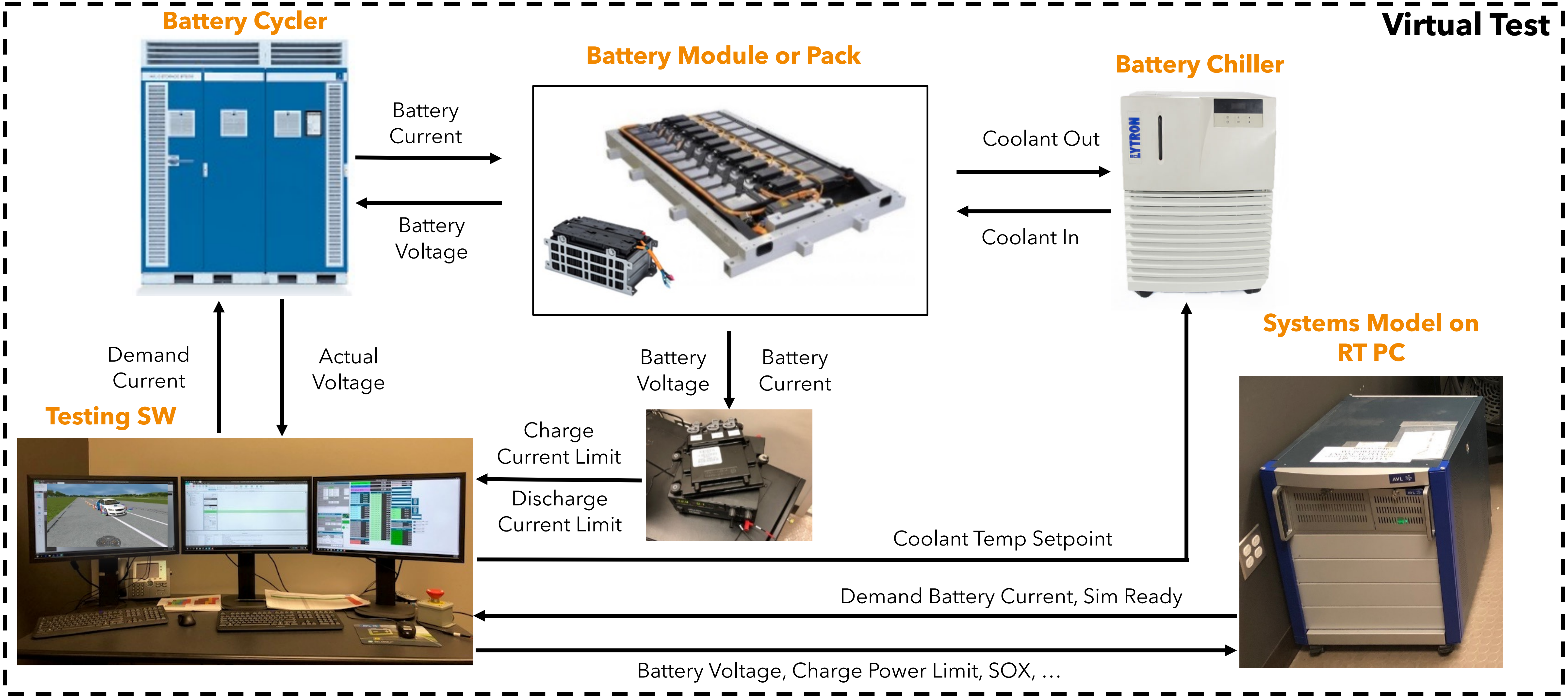


SIMULATION AND TESTING
DEVELOPMENT'S HEARTBEAT

- Combining simulation with hardware testing and calibration enables system level requirements to be evaluated throughout entire development process
- All battery testing could be performed either on virtual or real environments, depending on the levels of battery HW & SW maturity



VIRTUAL TEST WITH PHYSICAL BATTERY



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USE CASE

VIRTUAL BATTERY DEVELOPMENT for eVTOL

TACKLING CHALLENGES JOINTLY

Inlet Manifold Analysis

Cooling Perfo

Busbars

Subpack

VERTICAL

AVL

Flow Uniformity

Abuse An

Modules

Cooling Plate

E/E

TACKLING CHALLENGES JOINTLY

VERTICAL

AVL

Phase 1
Support Test Planning

Phase 2
Engineering Decisions

PHASE 1 – HIGHLIGHTS

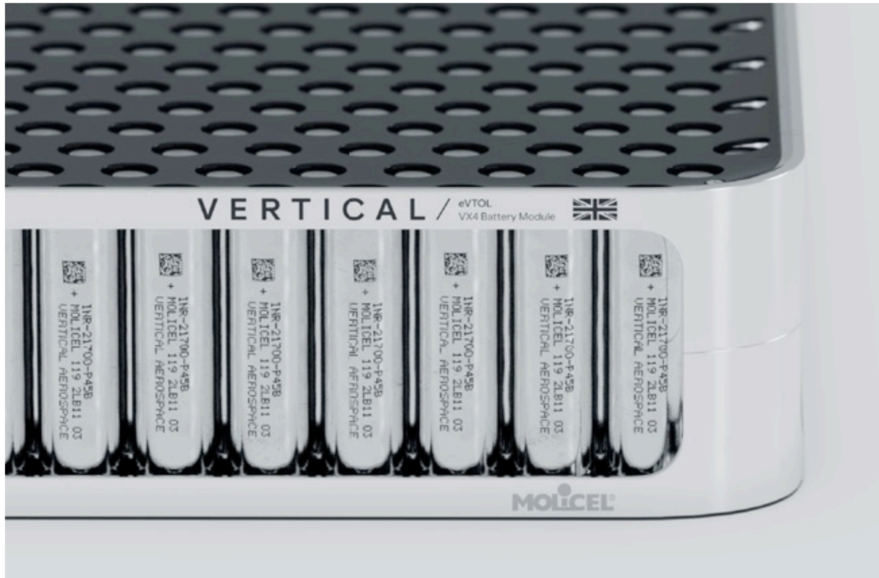
- Prototyping and "*Brainstorming*" Phase
- Modelling of smaller prototypes
- Quickly sweep through different design options
- Focus on liquid cooling

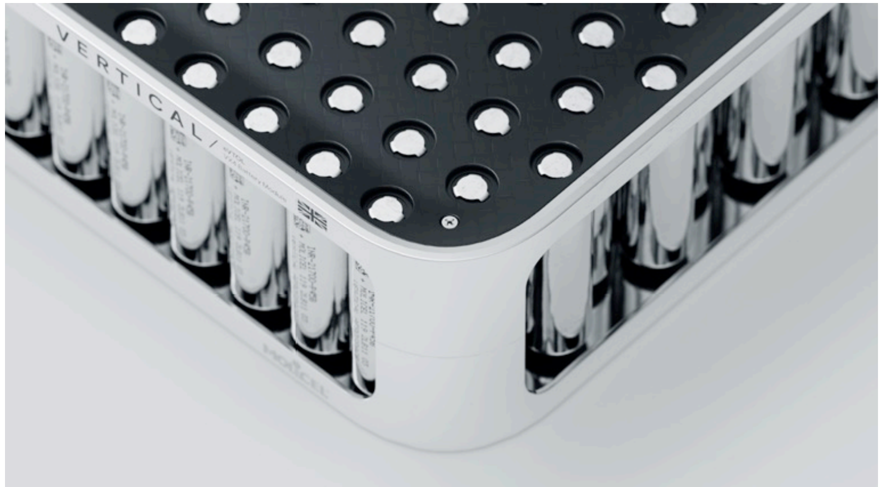
Which coolant to use?

Which cooling concept?

Which thermal propagation solution?

SIMULATION IMPACTS TESTING





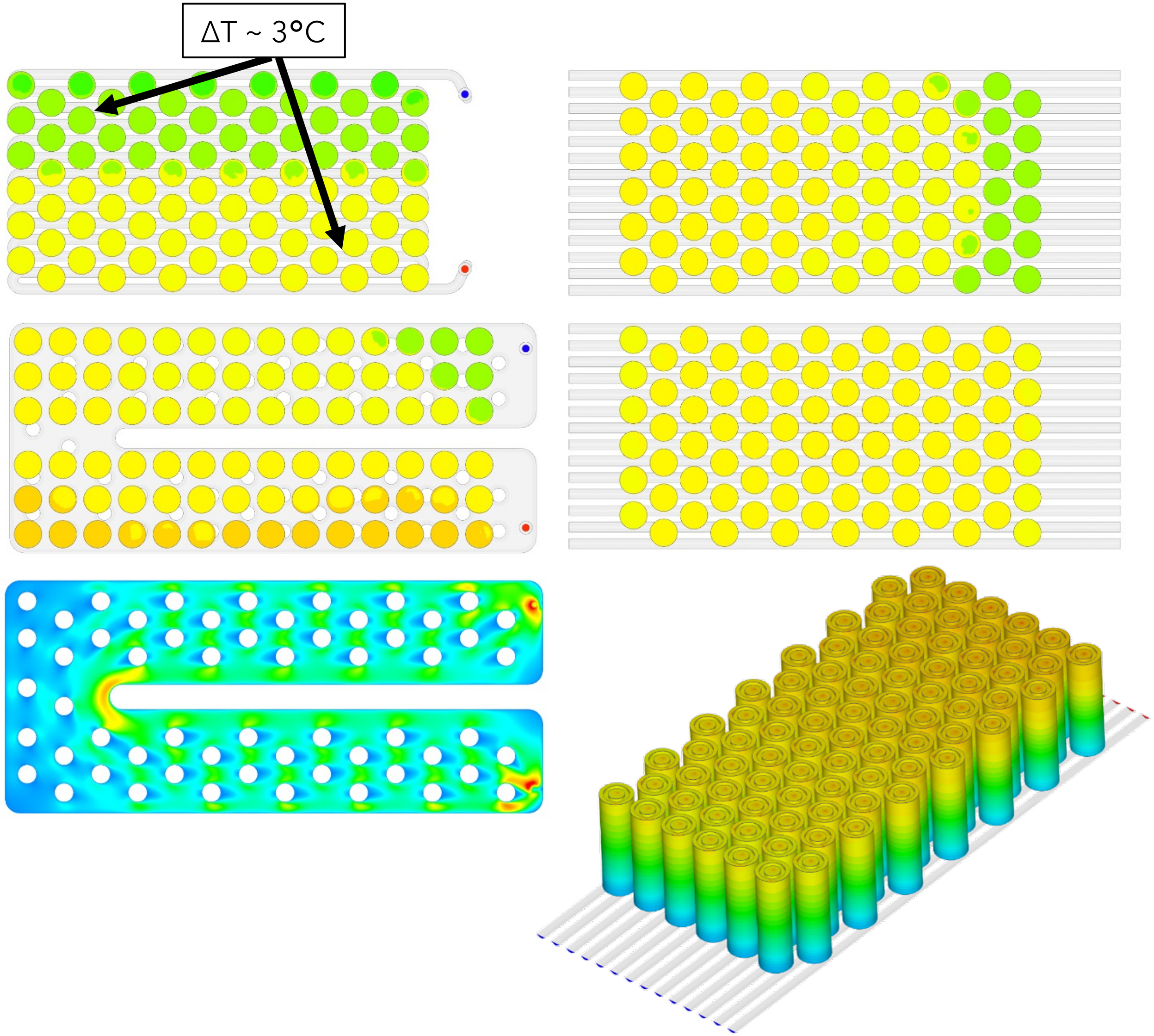
Vertical Aerospace VX4 (Source: Vertical Aerospace)

PHASE 1 – COOLING PERFORMANCE ANALYSIS

- Which cooling concept?
- Which coolant to use?
- Strengths/weaknesses of a design

- **Vary cooling plate designs**
- Vary different coolants

- Local temperatures & HTCs
- Cell temperature & thermal path histograms
- Identification of weak spots

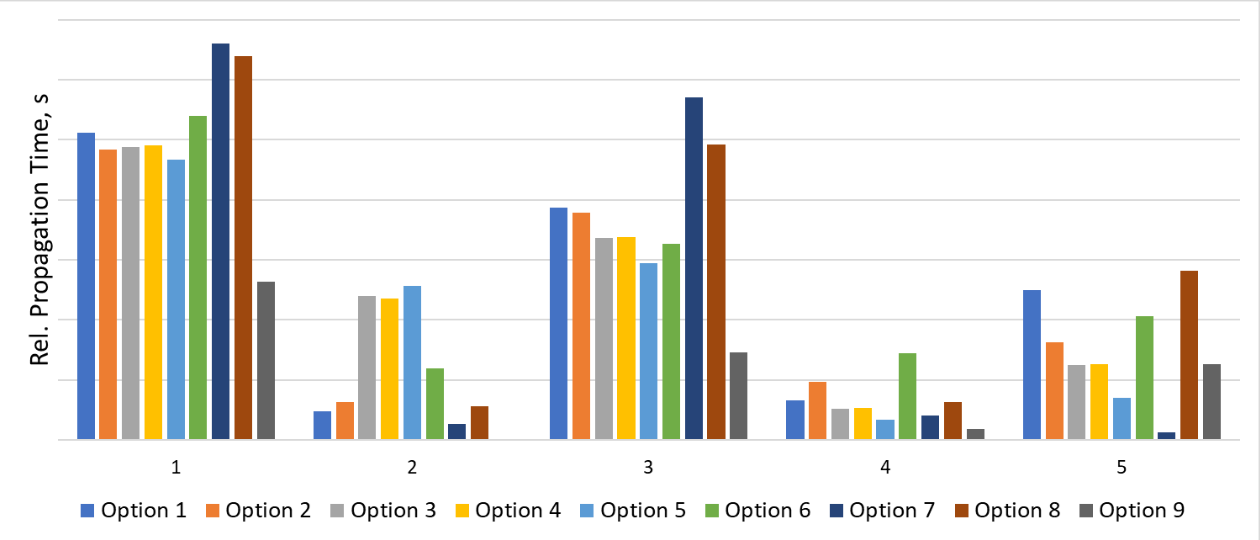


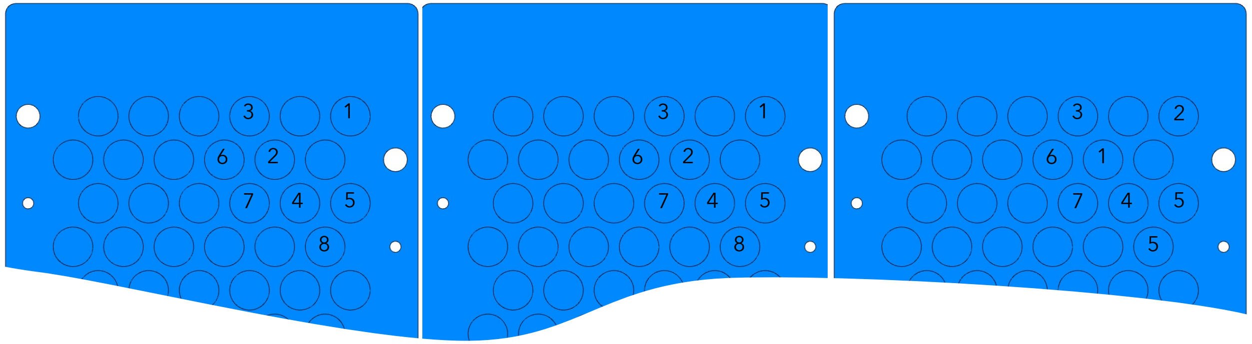
PHASE 1 – THERMAL PROPAGATION ANALYSIS

- Is the design safe?
- Which thermal propagation solution approach can delay or stop thermal propagation?
- Objective: Guide small scale module prototype testing

- Vary thermal propagation solution

- Relative propagation times
- Heat transfer analysis





Option A Option B Option C

PHASE 2 – HIGHLIGHTS

- Upscaling to system level
- More sophisticated modelling
- Focus on air cooling
- Connecting to the FEA team

What about the flow uniformity?

Are E/E components operated within specs?

Are all cells cooled uniformly?

SIMULATION IMPACTS DESIGN

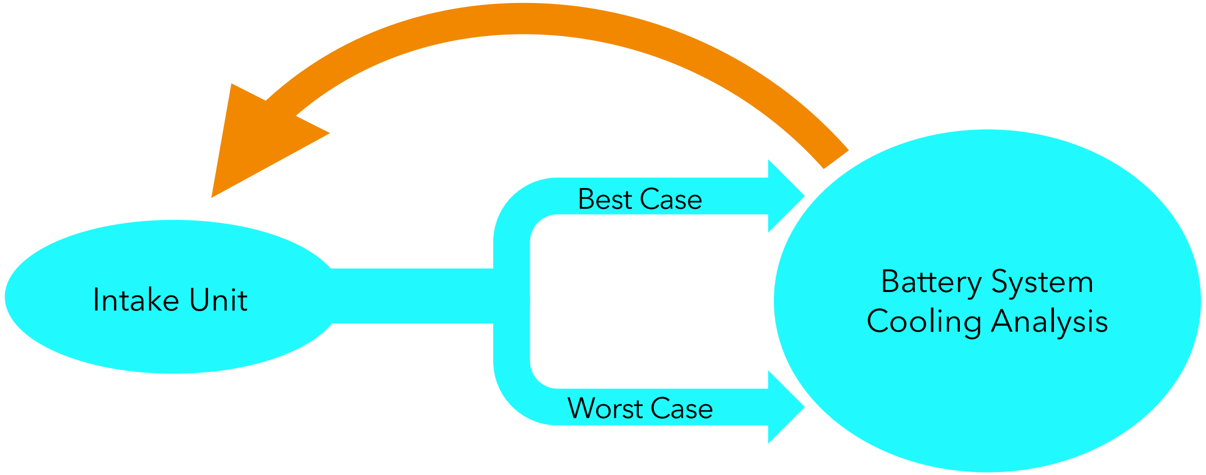
Vertical Aerospace VX4 (Source: Vertical Aerospace)

PHASE 2 – COOLING PERFORMANCE ANALYSIS

- Is the flow equally distributed?
- What is the optimal amount of cooling flow?
- Are the cells heating up uniformly?

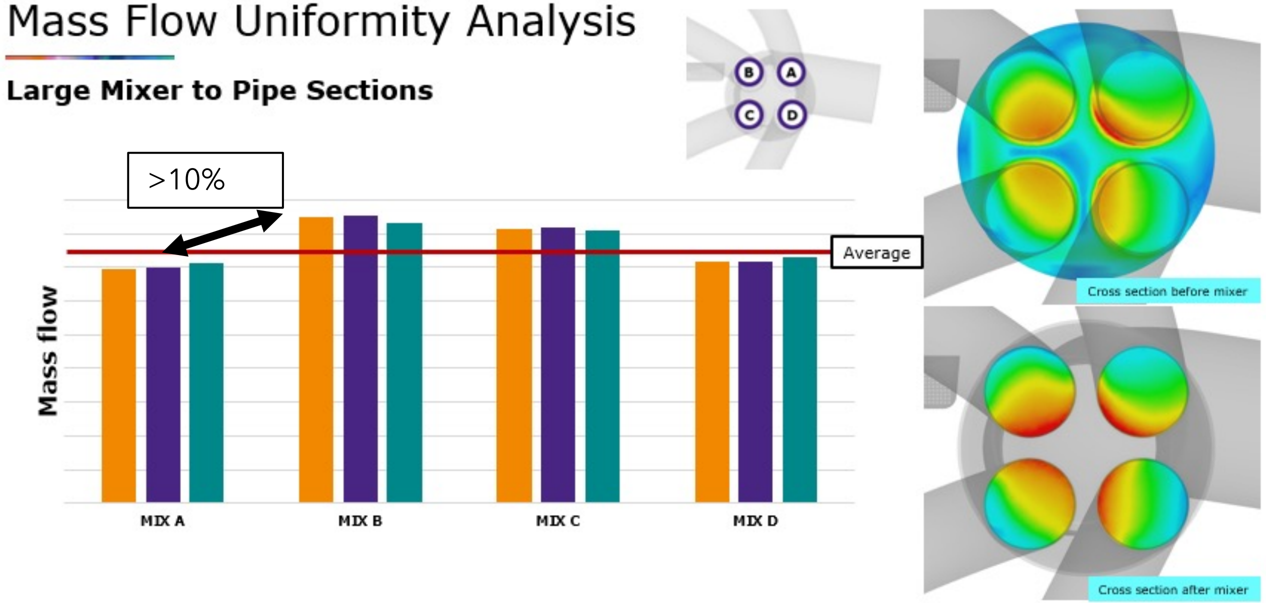
- Analyze flow uniformity in inlet manifold
- Identify best and worst-case scenarios
- Fully coupled electrothermal simulations

- Mass flow & pressure drop in intake system
- Heat dissipation per cell in system
- Temperature uniformity in system



Mass Flow Uniformity Analysis

Large Mixer to Pipe Sections



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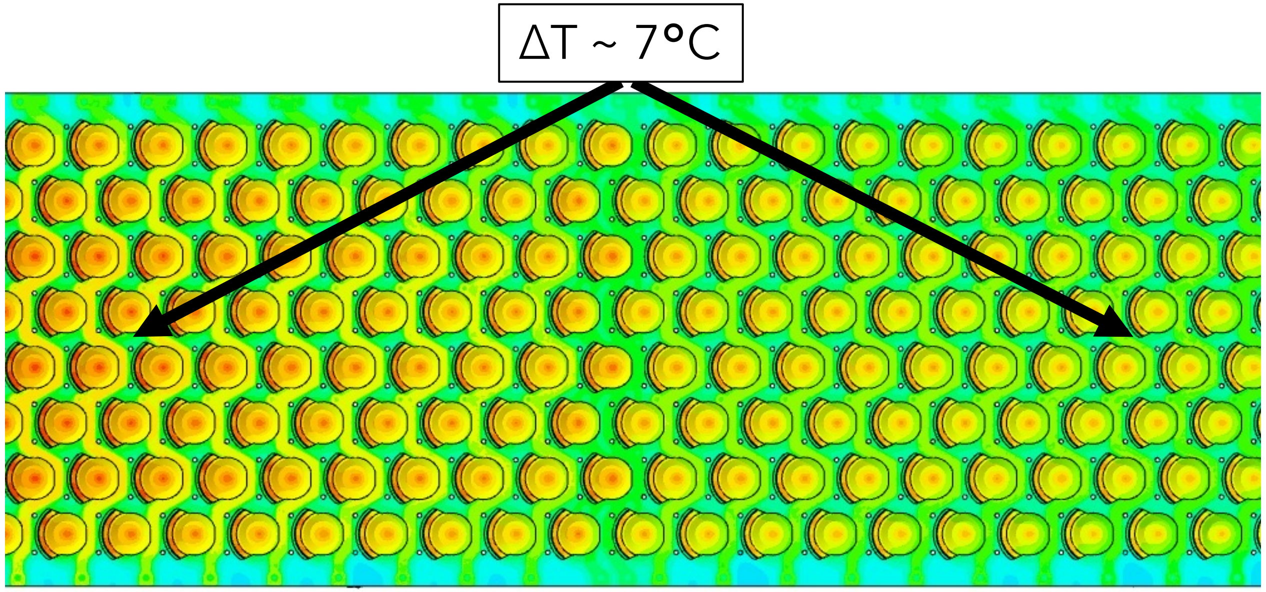
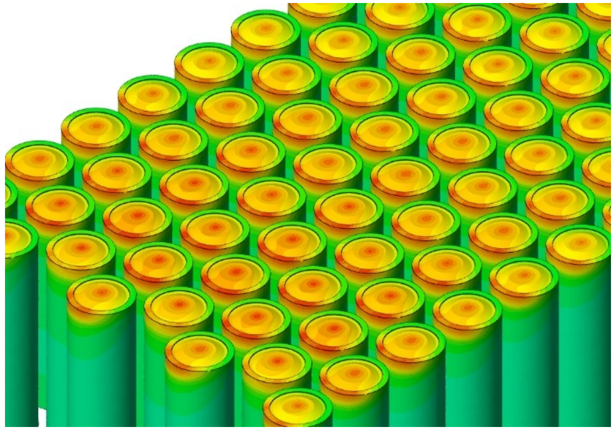
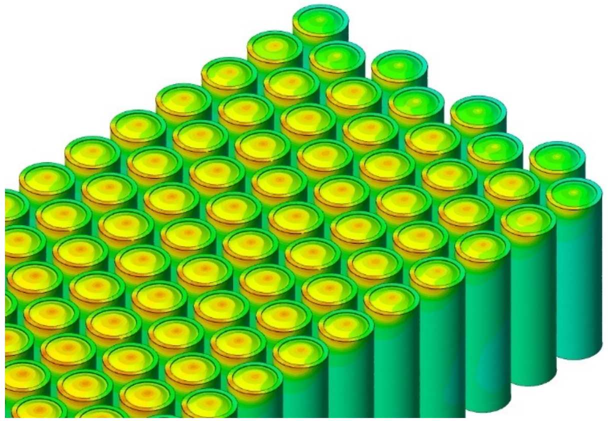




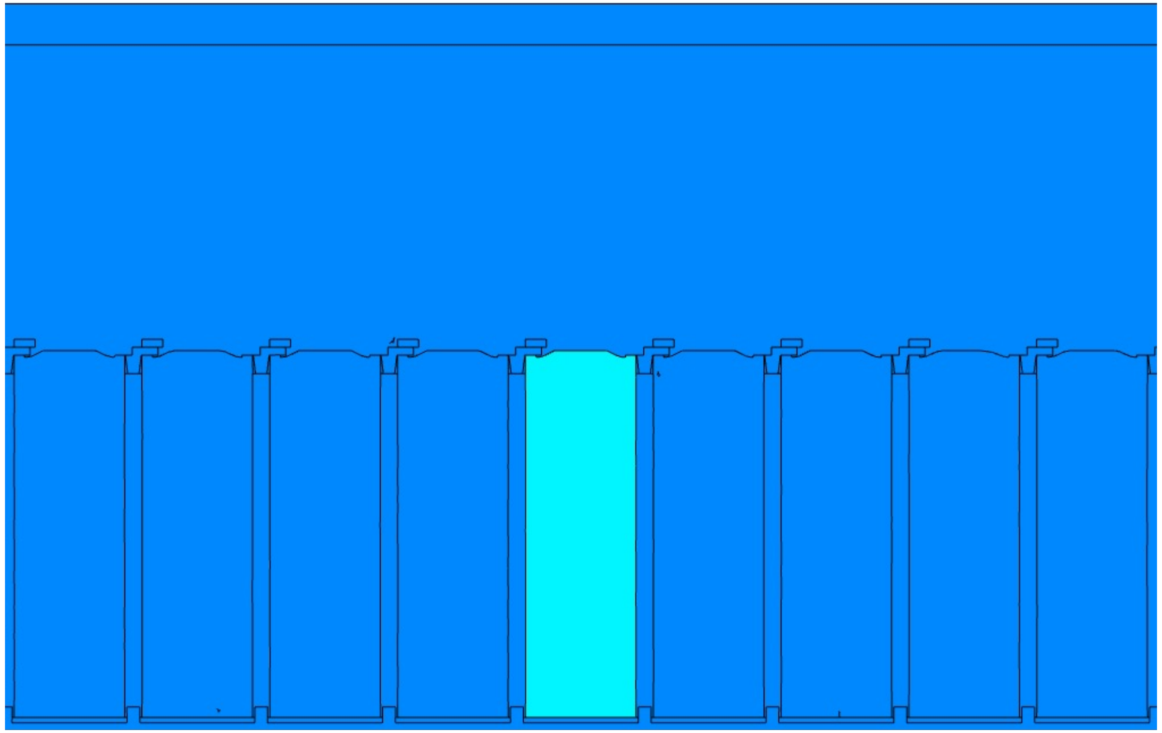


PHASE 2 – THERMAL RUNAWAY ANALYSIS

- How does venting affect the enclosure?
- What are the main thermal paths in case of a thermal runaway event?
- Is the system safe?

- Analyze thermal propagation on module level
- Analyze venting on system level

- Heat transfer to adjacent parts
- Assessment of enclosure temperatures
- Assessment of outlet temperatures



THANK YOU

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