Battery System Design with Oasys LS-DYNA Environment

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Agenda

- Overview of EV battery modelling
- Modelling battery cells using the Battery Setup Tool in Oasys PRIMER
- Application of the Oasys LS-DYNA Environment in the Design of EV Battery Systems

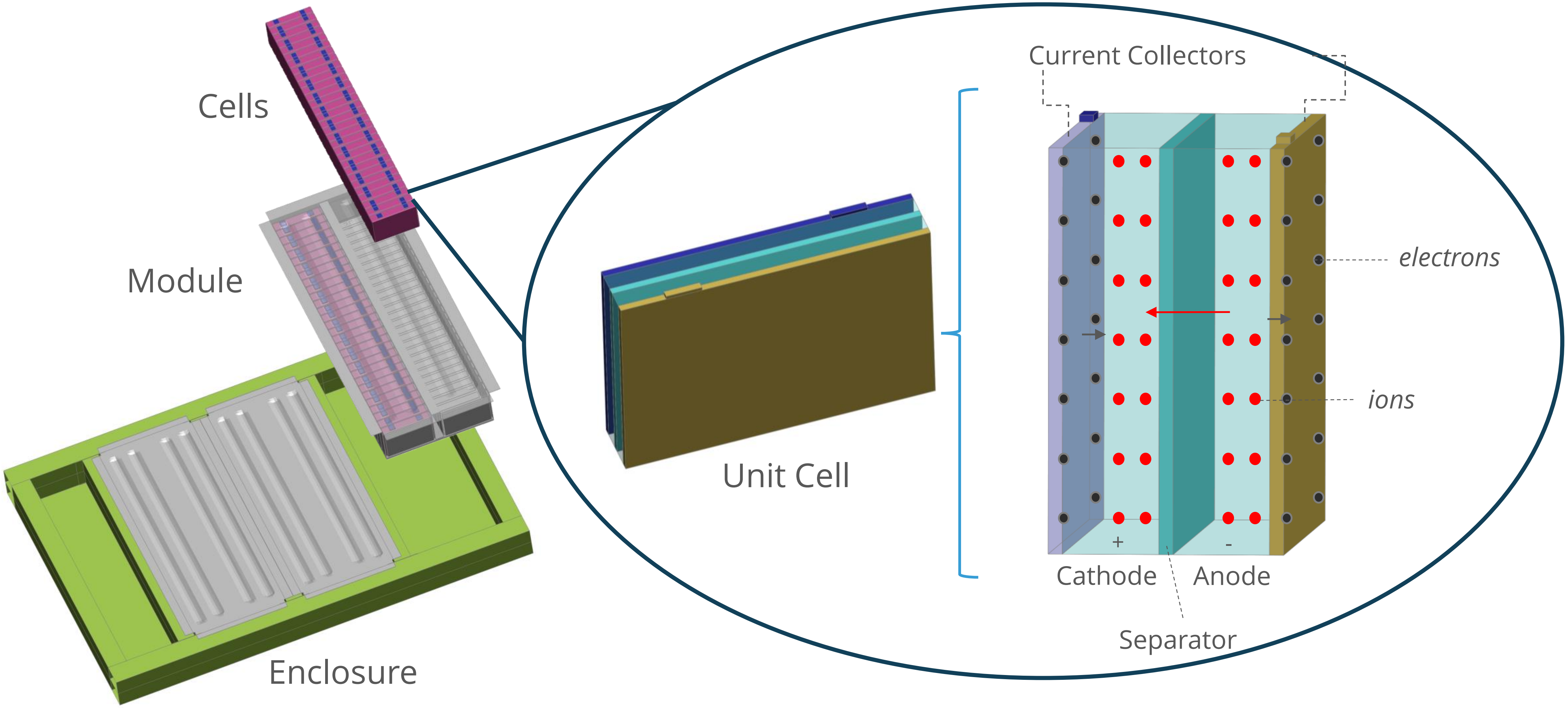
EV Battery Modelling

Efficient vehicle integration

Dedicated design and development

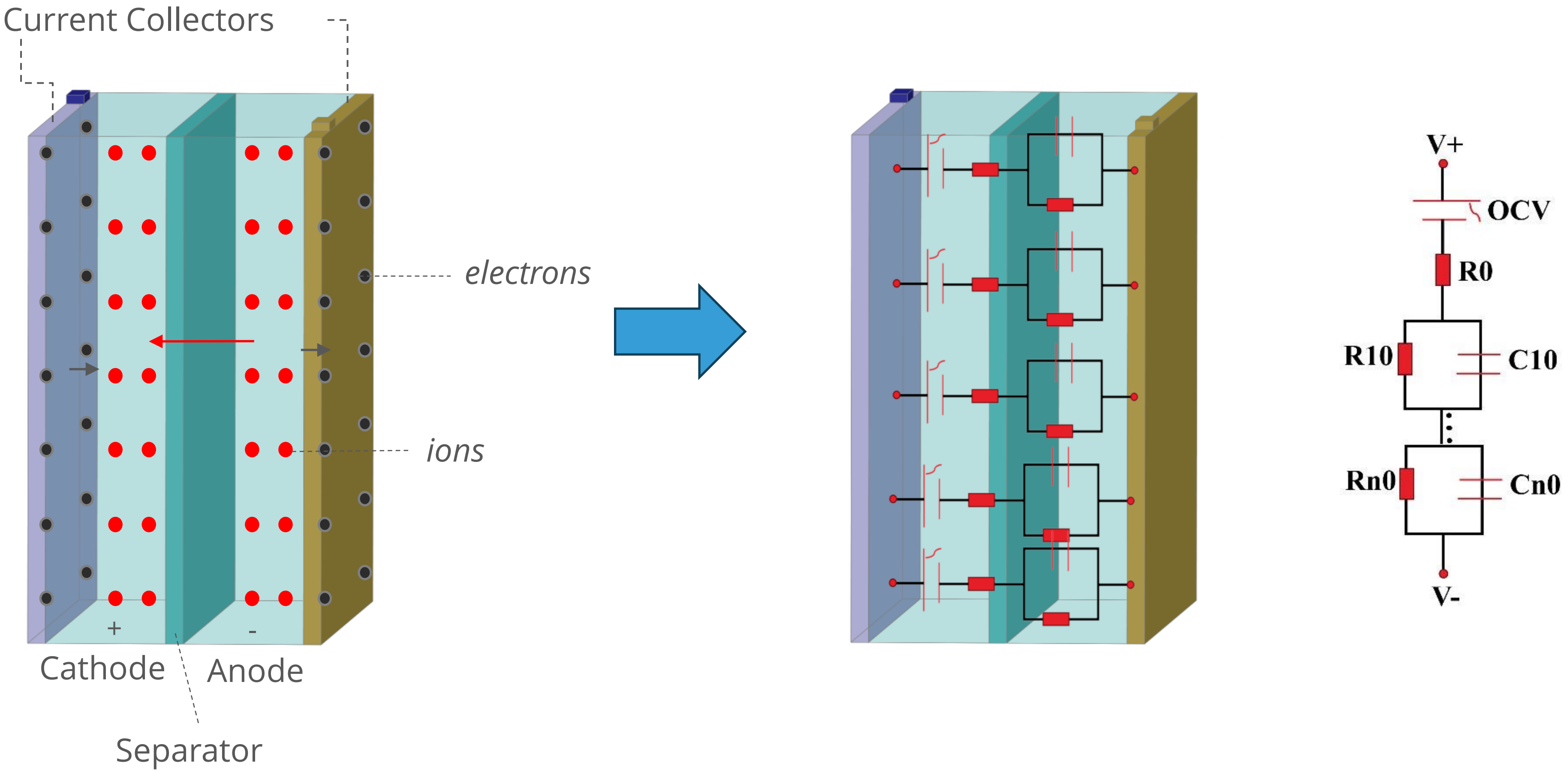
Safety regulations

EV Battery Pack Anatomy



Randles Capabilities – Cell Level Analysis

- The LS-DYNA EM solver offers the option to simulate the internal electrochemical reactions of a battery cell via equivalent distributed electrical circuit models called Randles circuit.



Randles Capabilities

- LS-DYNA offers 4 different solutions to model Randles circuits within a battery cell on different scales and level of detail.

Highest level of detail
&
Simulation time

Micro scale –
***EM_RANDLES_SOLID**

Meso scale –
***EM_RANDLES_TSHELL**

Macro scale -
***EM_RANDLES_BATMAC**

Physical cell structure required

Lowest level of detail
&
Simulation time

Meshless scale -
***EM_RANDLES_MESHLESS**

Physical cell structure not required

Battery Cell Modelling Challenges

- Comprehensive understanding of the different LS-DYNA Randles circuit modelling options and requirements
- Multi-step process
- Demands careful attention and effort
  - Meshing the layers cell structure
  - Meshing the tabs structure
  - Connecting the tabs to the layers cell structurally and electrically
  - Defining the electromagnetic properties of the different components
  - Defining the Randles parameters
  - Selecting and defining Analysis keywords

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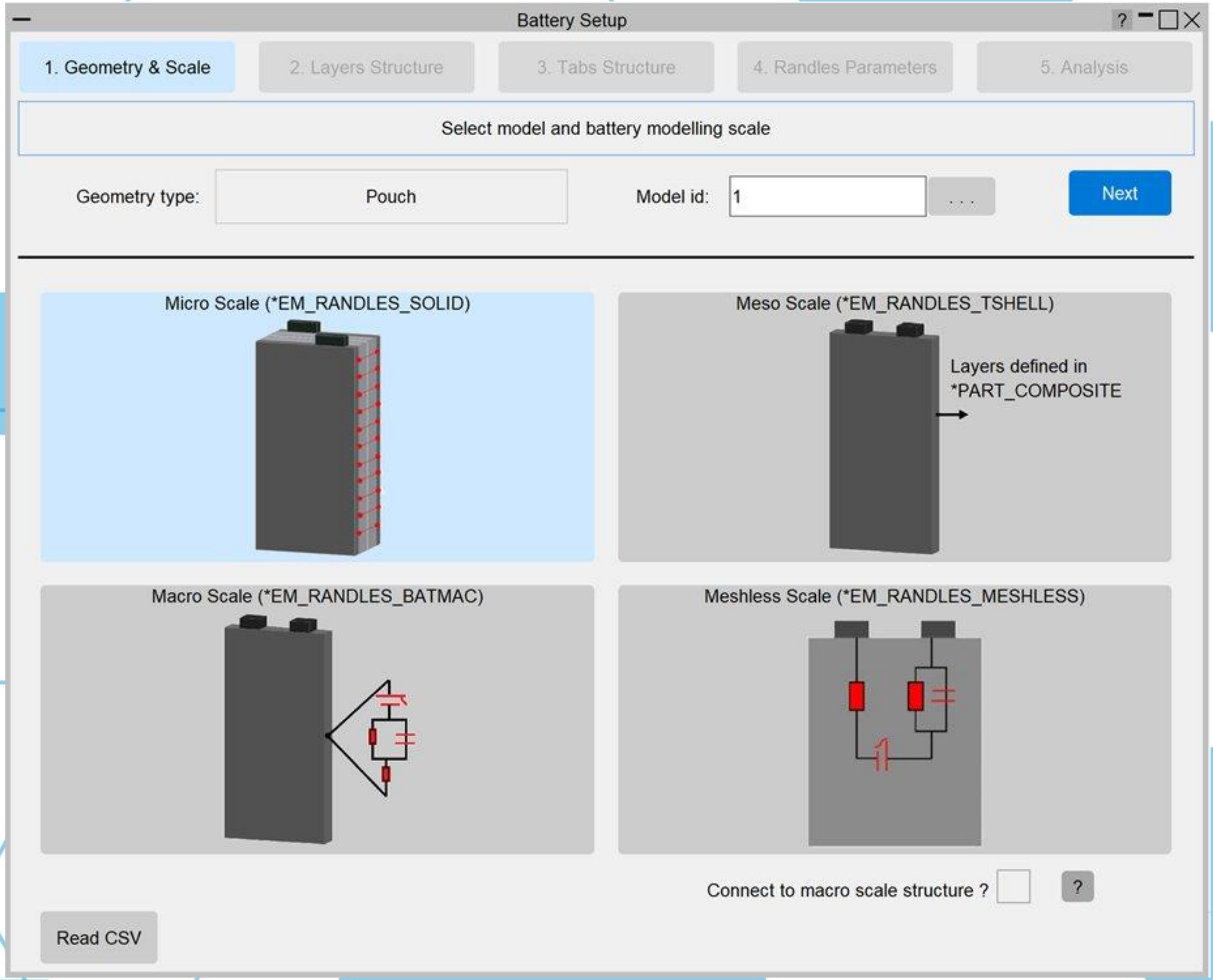
Battery Setup Tool in Oasys PRIMER



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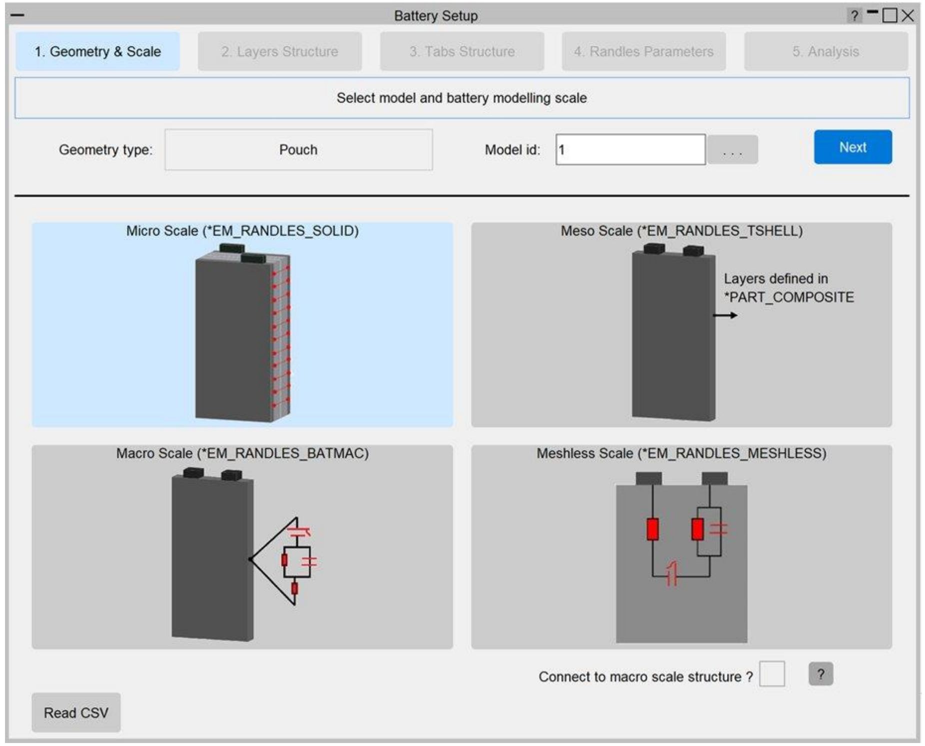
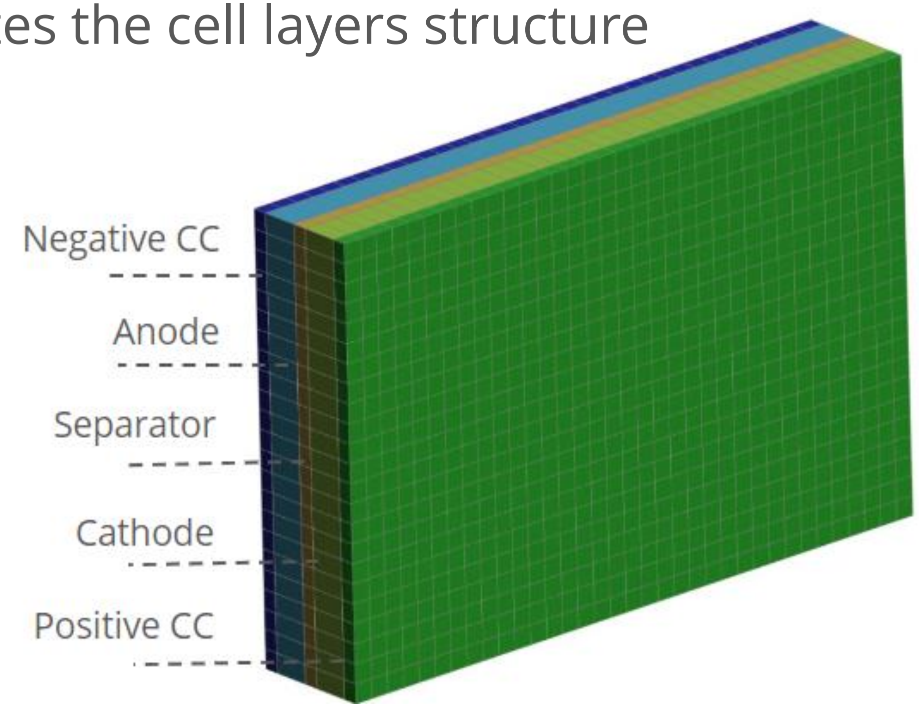
Battery Setup Tool in Oasys PRIMER

- Expedites the creation of battery cell models of pouch geometry
- Provides guidance through the different stages of model creation
- Automates creation of electrical and structural connections
- Supports all 4 LS-DYNA Randles modelling scales

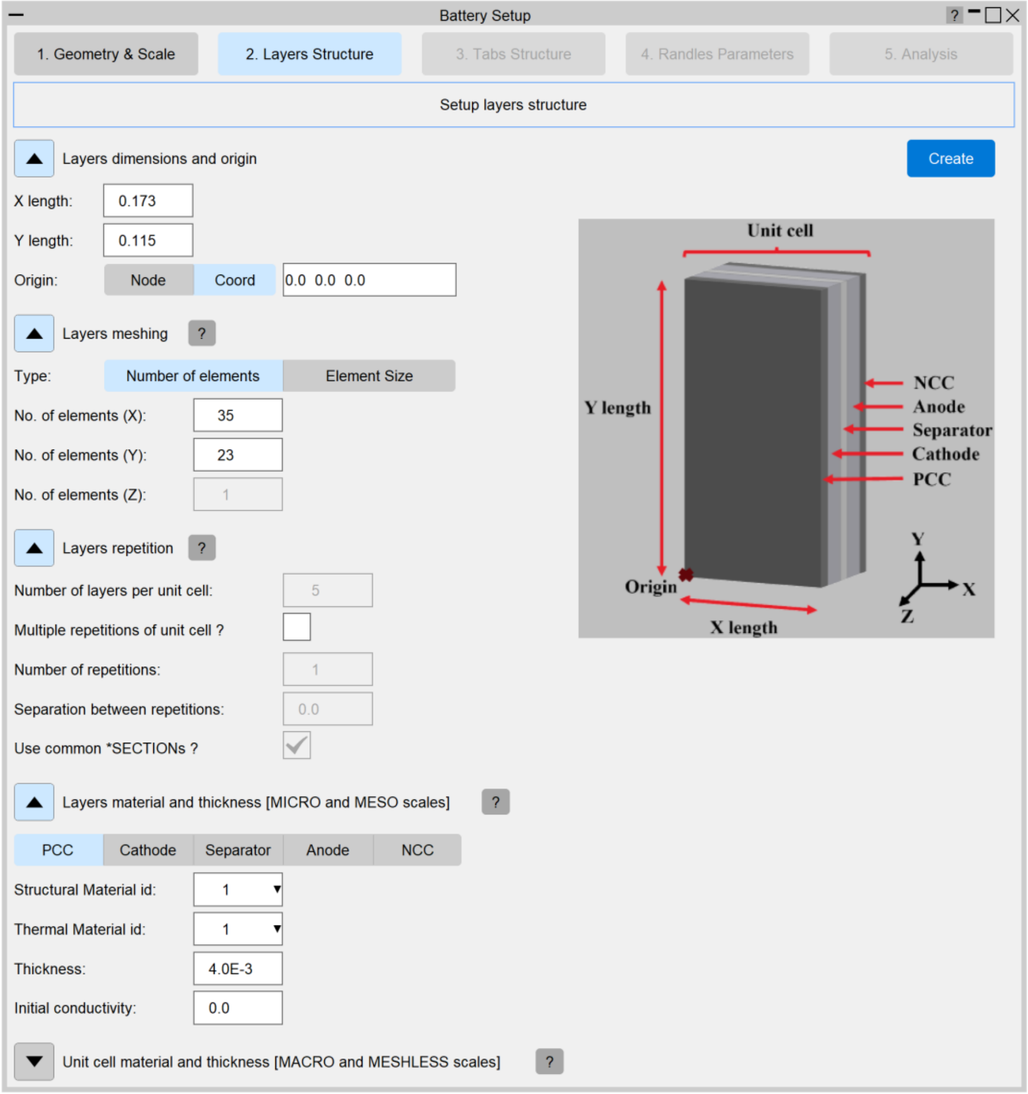


Battery Setup Tool in Oasys PRIMER

- Creates the cell layers structure

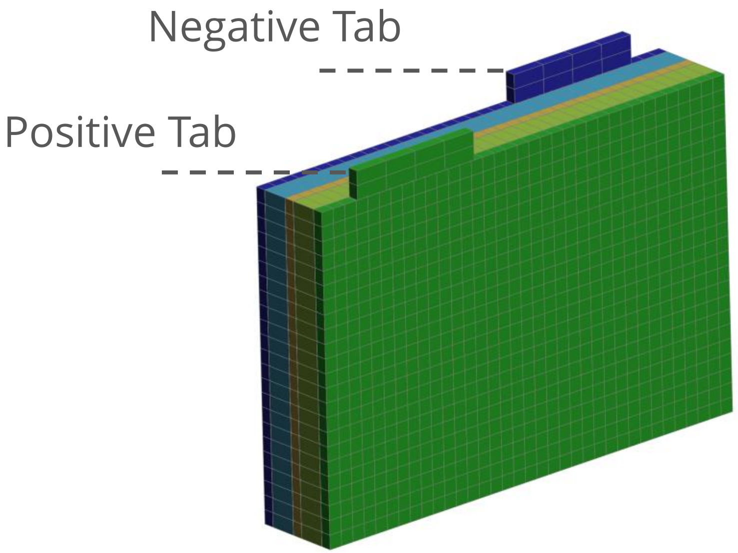


Structural material - *MAT
Thermal material - *MAT_THERMAL
Set by user
Material ID
Electromagnetic properties - *EM_MAT
Automatically created by the tool

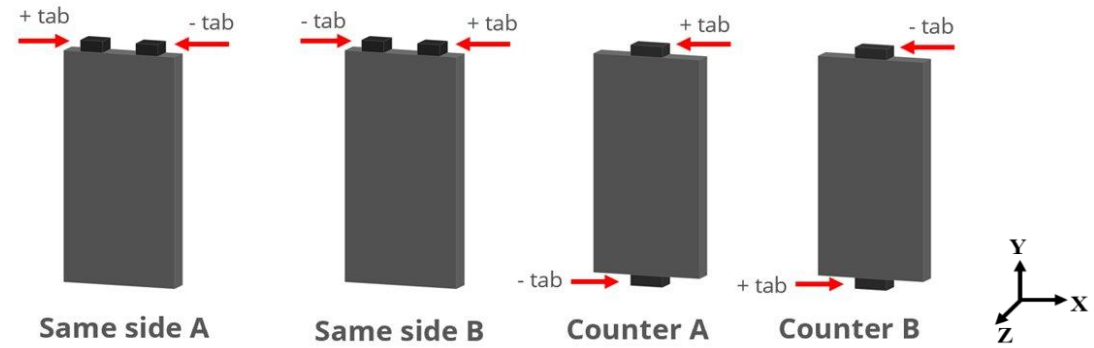


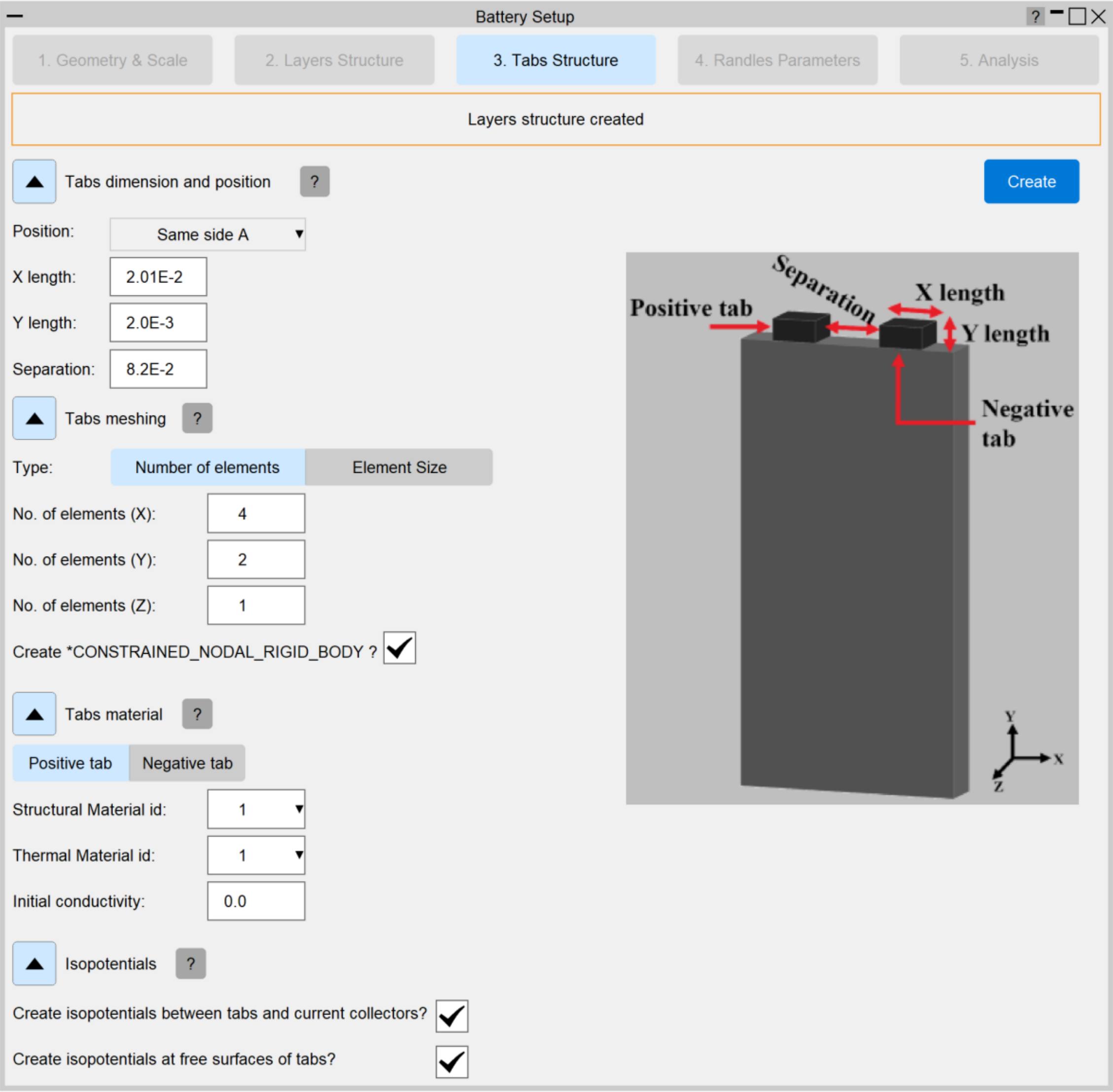
Battery Setup Tool in Oasys PRIMER

- Creates the tabs structure



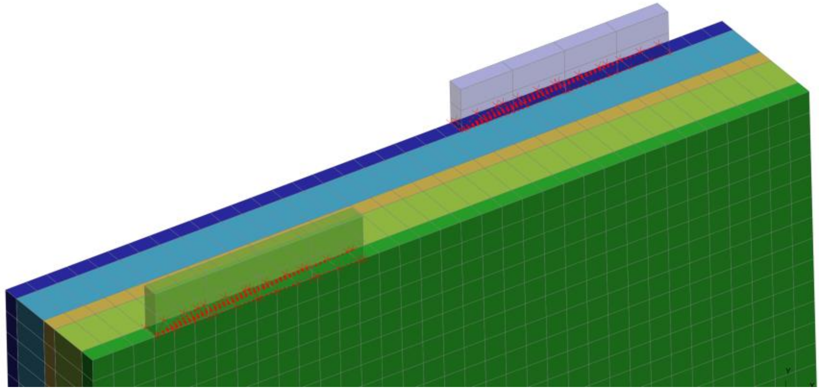
Different configurations of tab positioning are available to select from

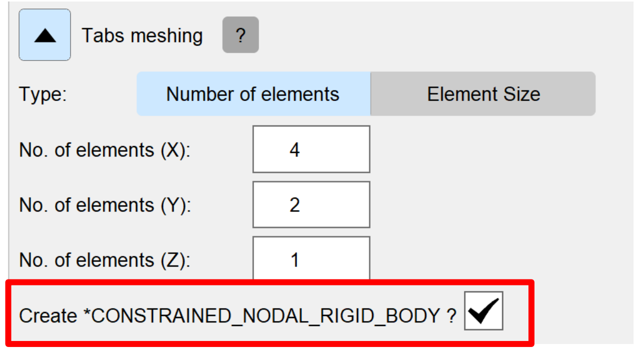




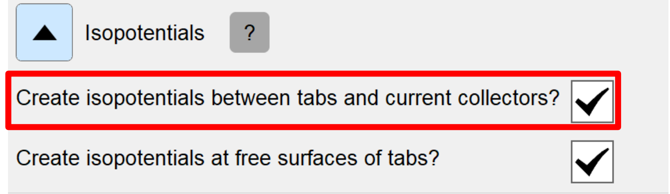
Battery Setup Tool in Oasys PRIMER

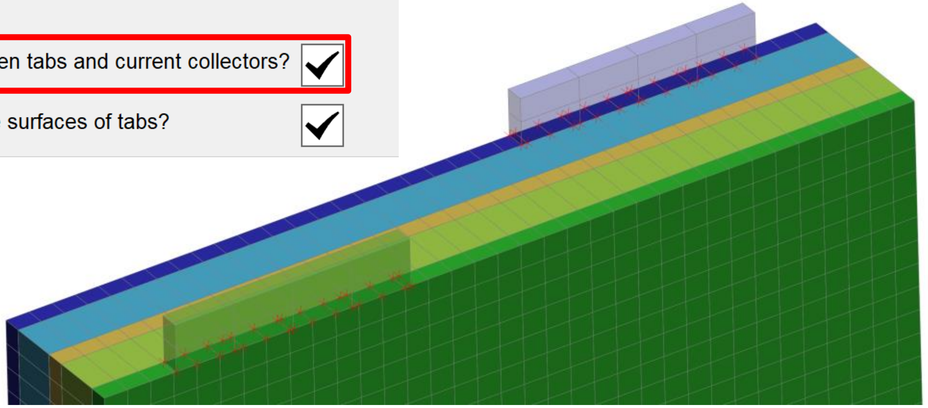
- Structural connections via ***CONSTRAINED_NODAL_RIGID_BODY**





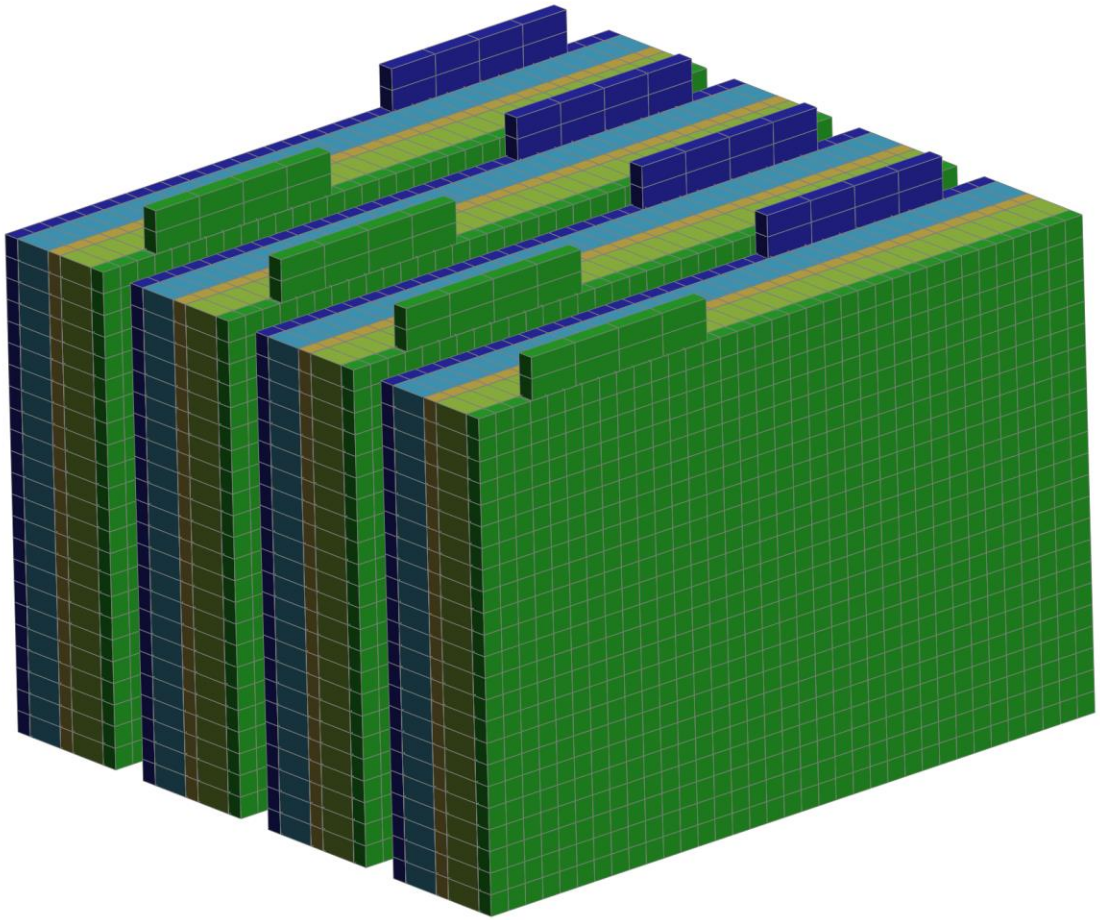
- Electrical connections via ***EM_ISOPOTENTIAL** and ***EM_ISOPOTENTIAL_CONNECT**

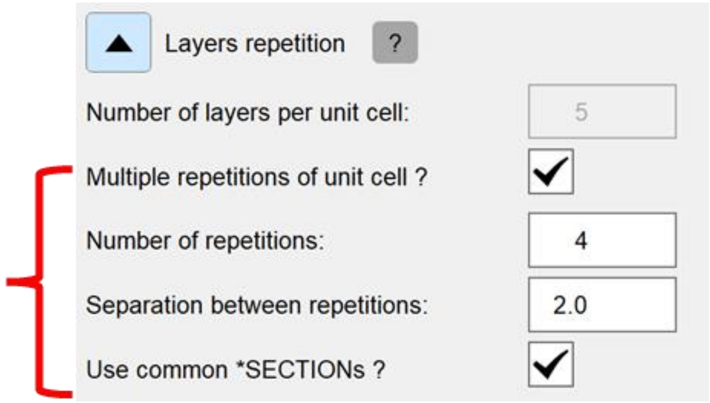




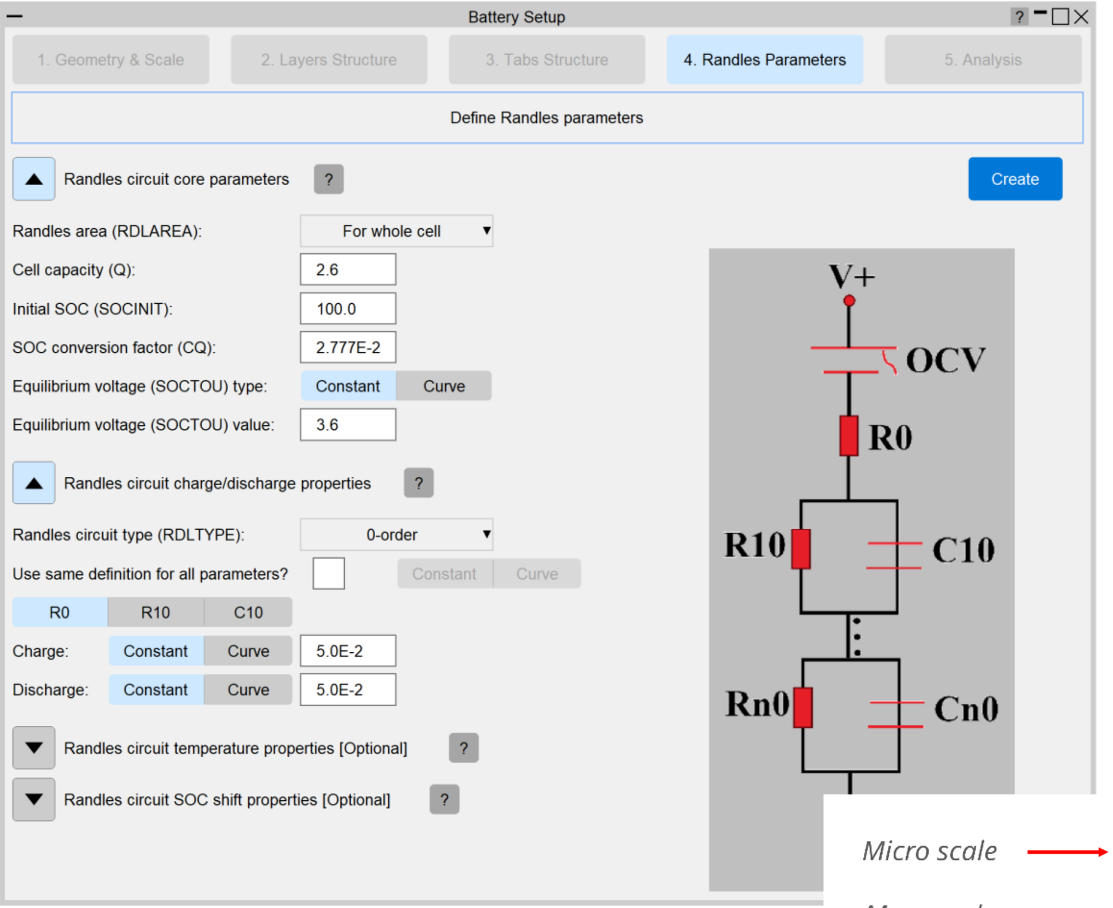
Battery Setup Tool in Oasys PRIMER

- Multiple repetitions of the unit cell can easily be created for any scale.





Battery Setup Tool in Oasys PRIMER



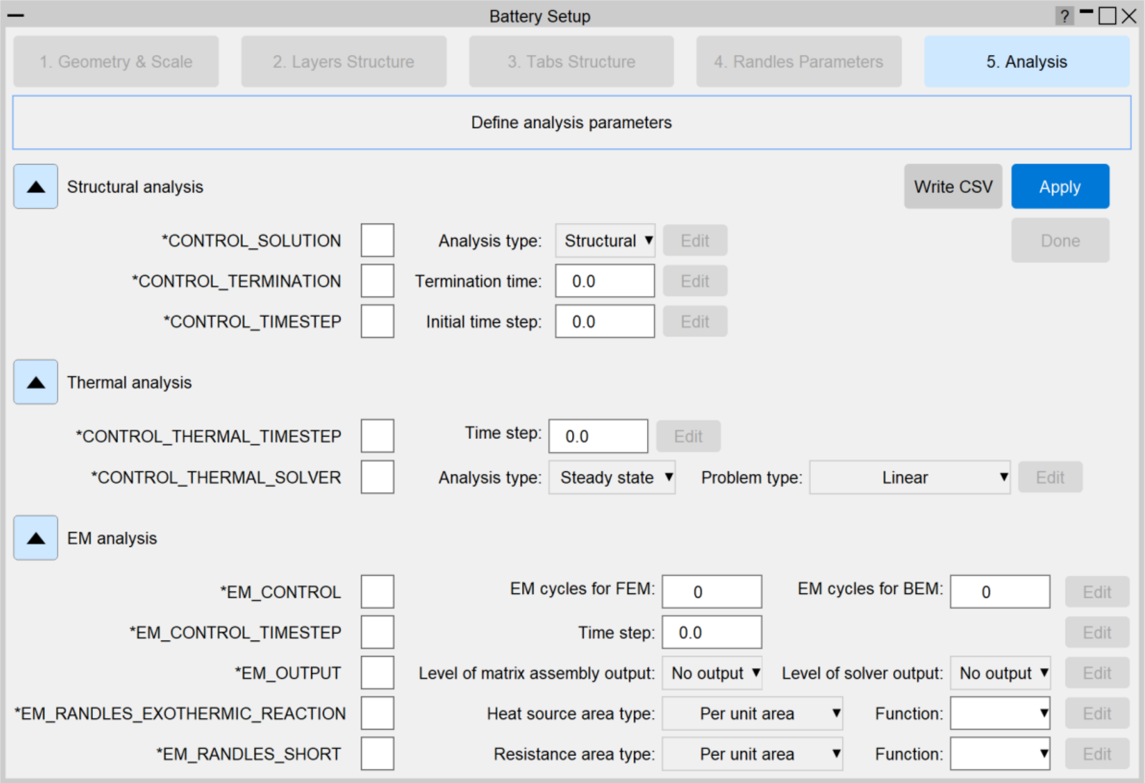
Randles Parameters

Micro scale → ***EM_RANDLES_SOLID**

Meso scale → ***EM_RANDLES_TSHELL**

Macro scale → ***EM_RANDLES_BATMAC**

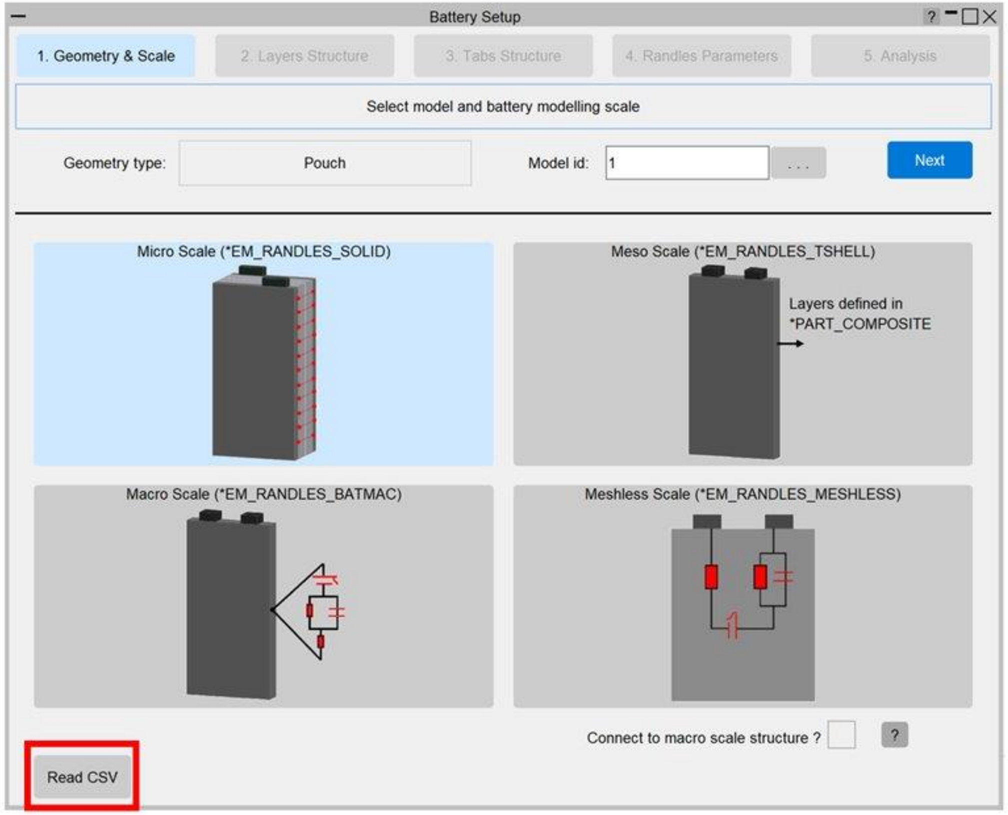
Meshless scale → ***EM_RANDLES_MESHLESS**

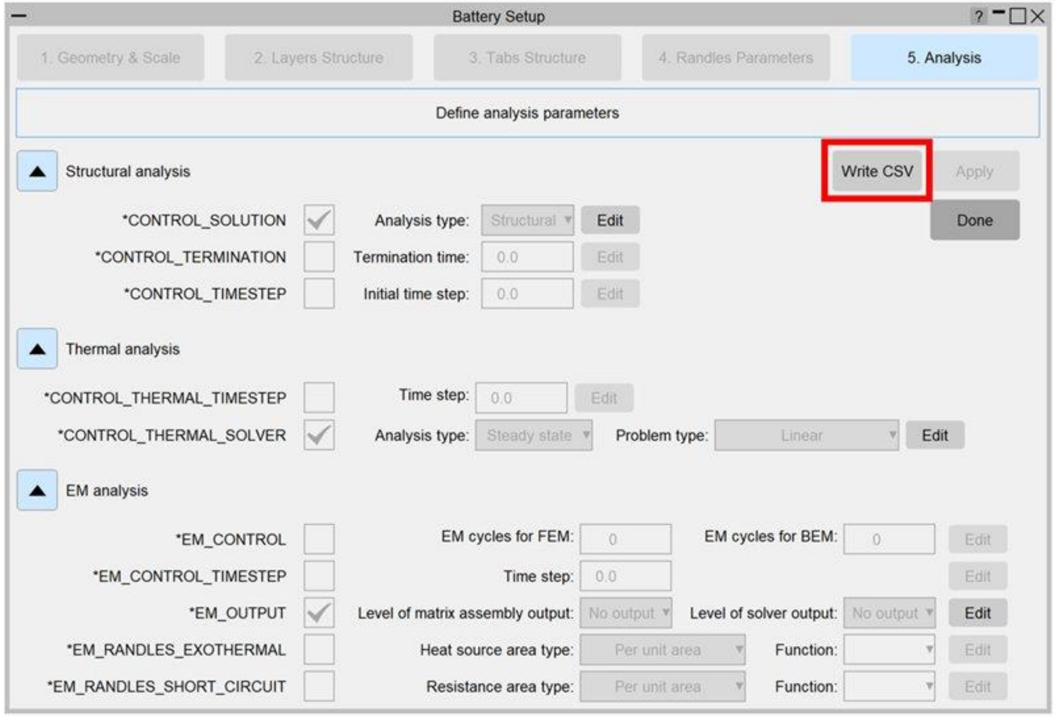


Analysis Keywords

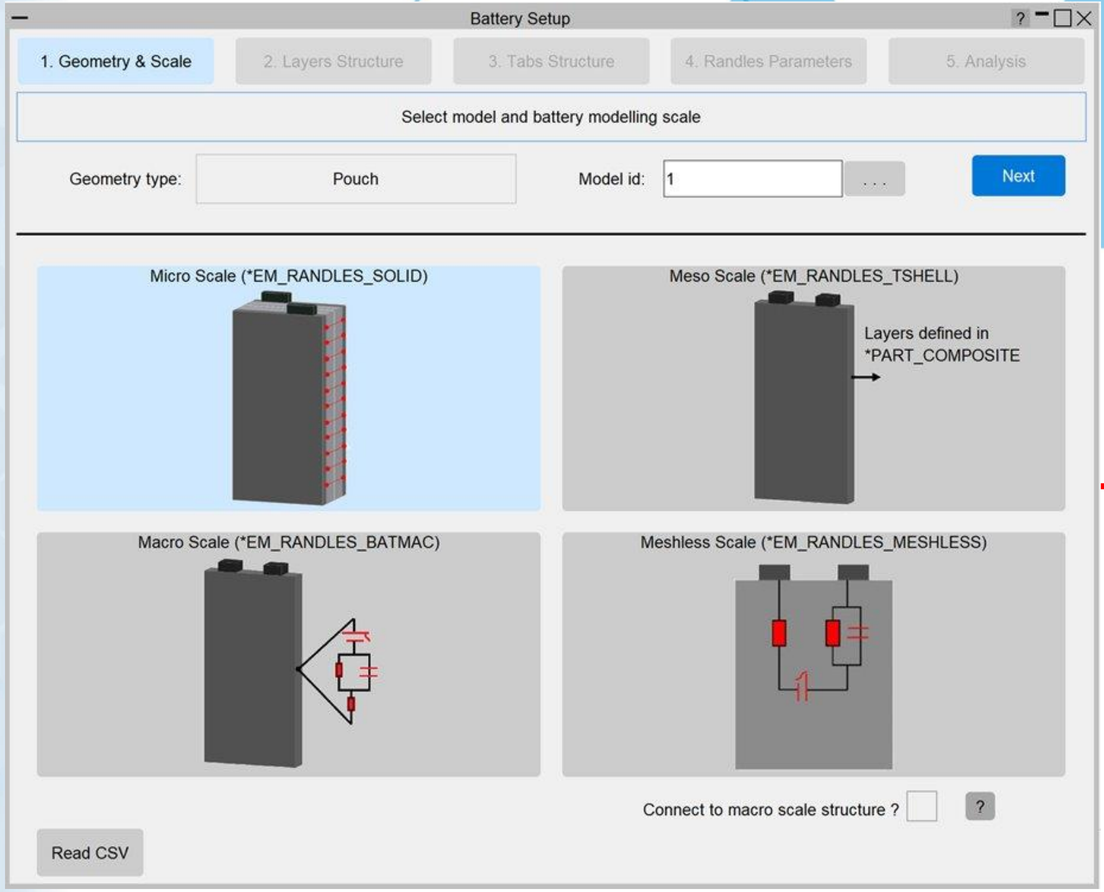
Battery Setup Tool in Oasys PRIMER

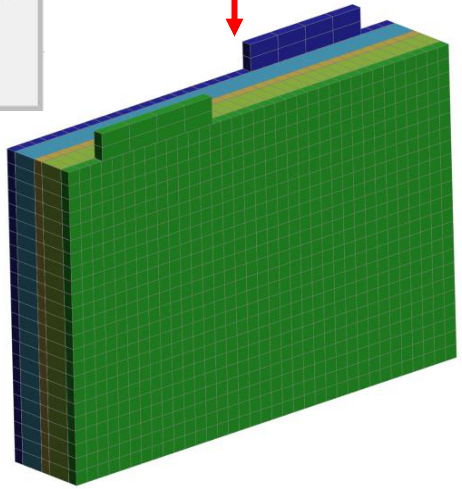
- Saving data

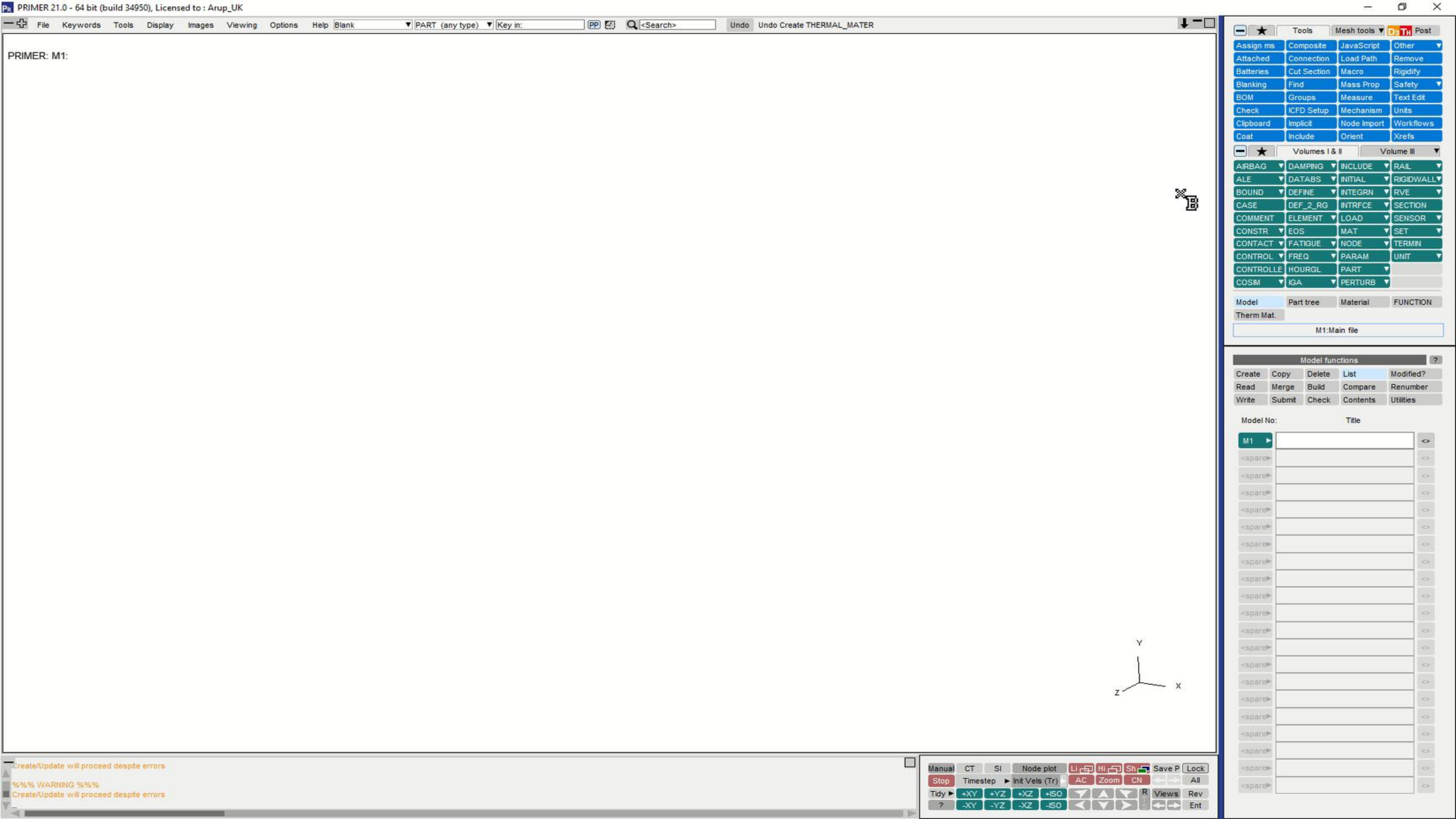




Battery Setup Tool Demo






PRIMER 21.0 - 64 bit (build 34950), Licensed to : Arup_UK
File Keywords Tools Display Images Viewing Options Help Blank PART (any type) Key in: PP <Search> Undo Undo Create THERMAL_MATER
PRIMER: M1:
Tools Mesh tools Post
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Attached Connection Load Path Remove
Batteries Cut Section Macro Rigidify
Blanking Find Mass Prop Safety
BOM Groups Measure Text Edit
Check ICFD Setup Mechanism Units
Clipboard Implicit Node Import Workflows
Coat Include Orient Xrefs
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AIRBAG DAMPING INCLUDE RAIL
ALE DATABS INITIAL RIGIDWALL
BOUND DEFINE INTEGRN RVE
CASE DEF_2_RG INTRFCE SECTION
COMMENT ELEMENT LOAD SENSOR
CONSTR EOS MAT SET
CONTACT FATIGUE NODE TERMIN
CONTROL FREQ PARAM UNIT
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Model Part tree Material FUNCTION
Therm Mat.
M1:Main file
Model functions
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Read Merge Build Compare Renumber
Write Submit Check Contents Utilities
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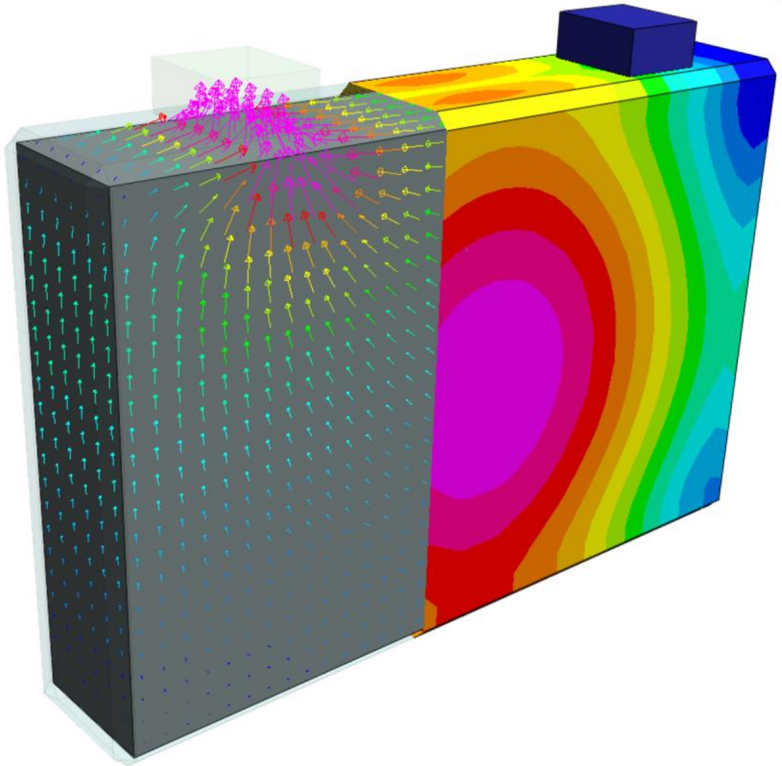
Application of the Oasys LS-DYNA Environment in the Design of EV Battery Systems

Simon Hart

Technical Services, Arup



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Analysis with LS-DYNA to Support Battery System Design

Battery systems for EV applications must comply with global regulations:

UN ECE R100 (Europe)	GB 38031-2020 (China)	FMVSS 305 (USA)

Many of these requirements can be analysed using LS-DYNA:

Mechanical Shock	Mechanical Integrity	Thermal Shock
Random Vibration	Fixed Frequency Vibration	

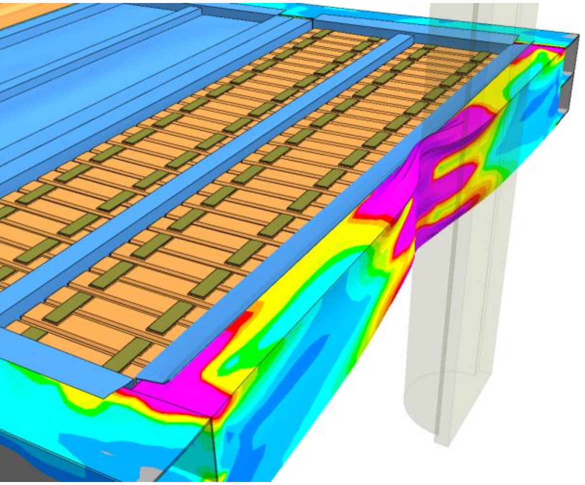
LS-DYNA can also be used to study other attributes of the battery system:

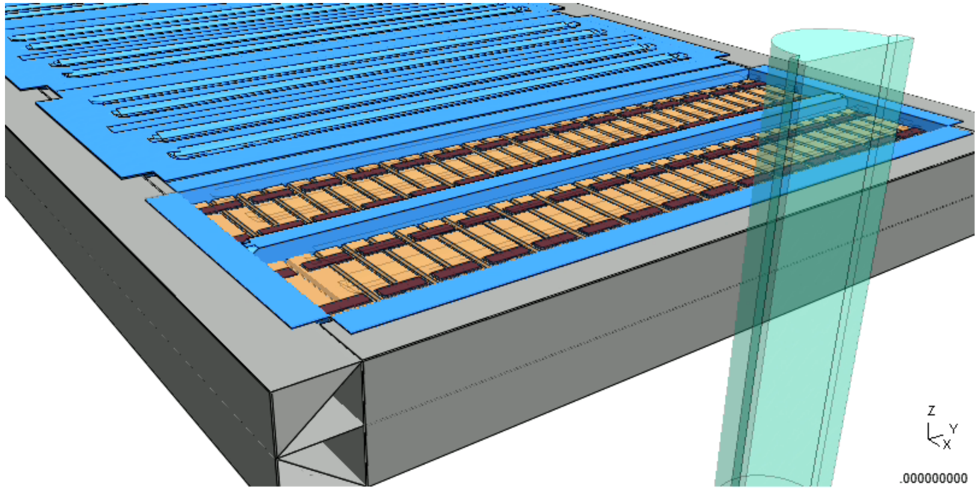
Internal Gas Pressure	Cell Swelling Loads	Thermal Management
Handling Loads	Drop / Impact	Internal Short Circuits

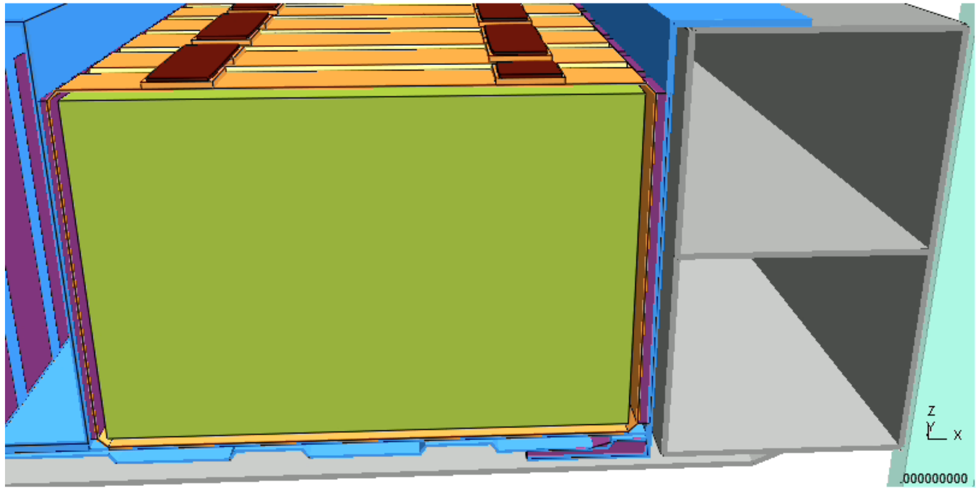
Crushing / Mechanical Integrity E.g. GB 38031-2020

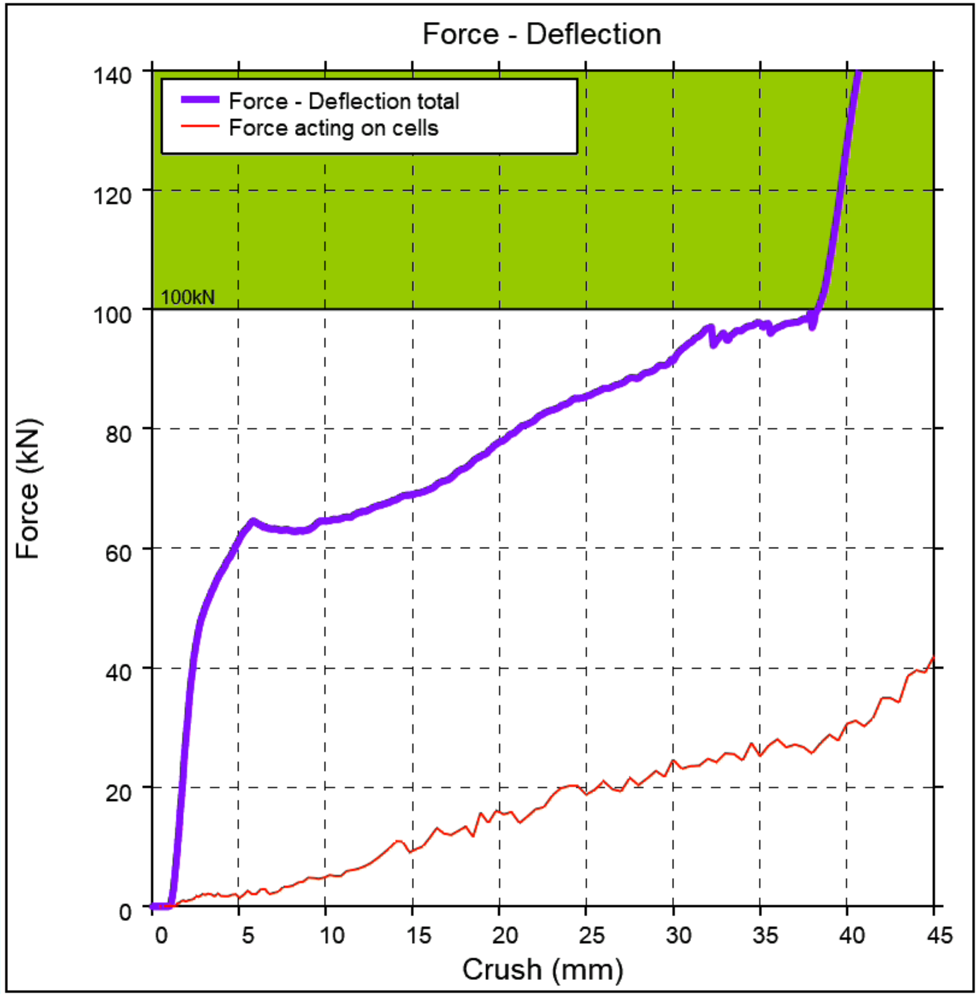
Quasi-static compression test to 100kN or deflection limit

Explicit Solver





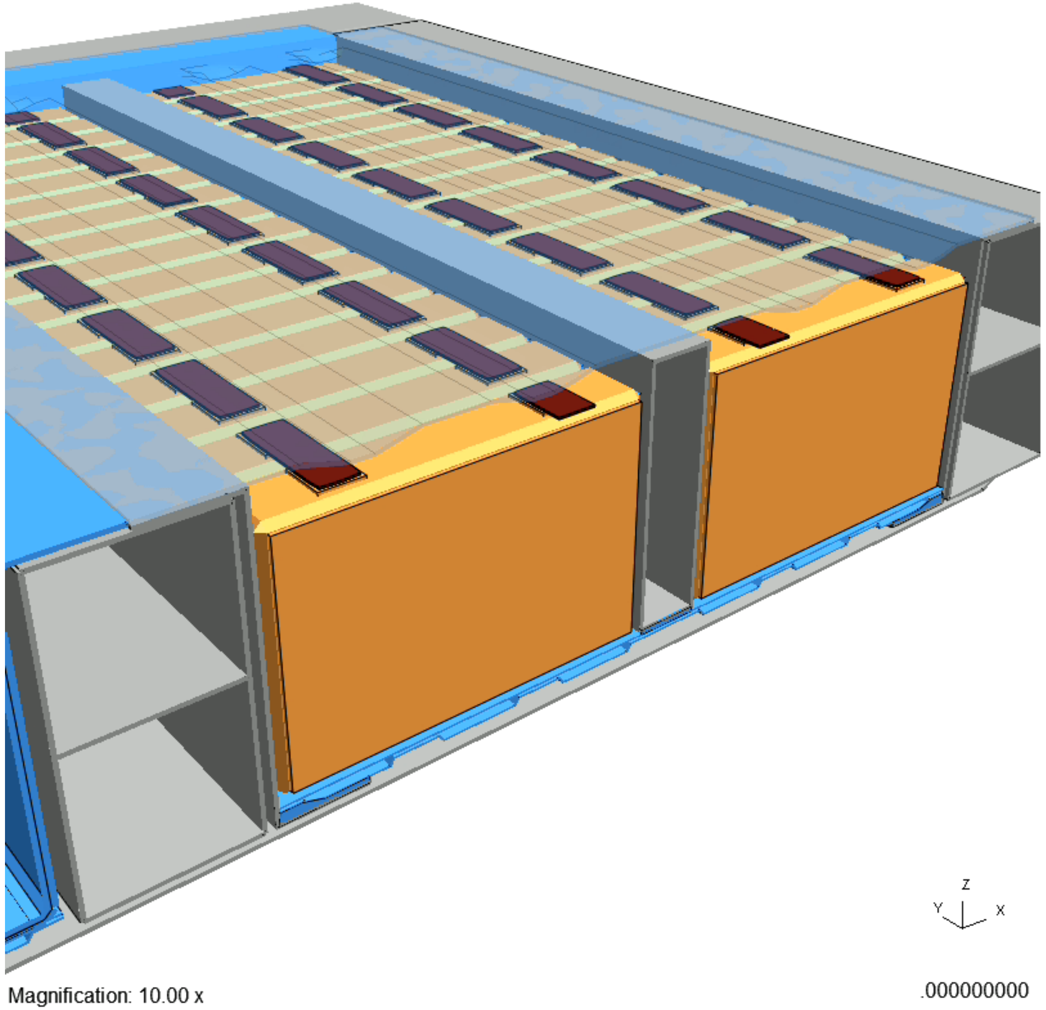


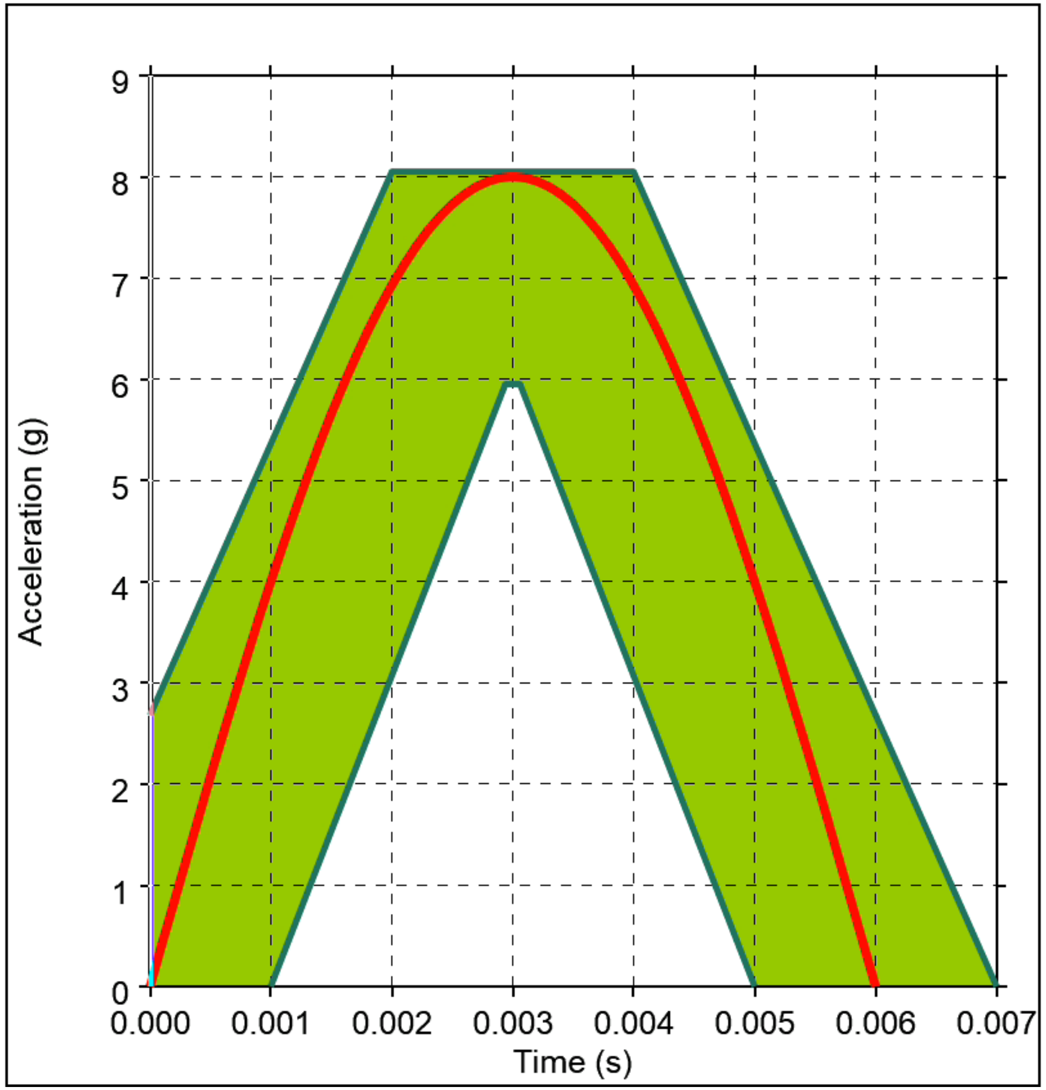


Mechanical Shock / Impact   E.g. GB 38031-2020

Acceleration applied at module mounting points in vertical direction

Explicit Solver



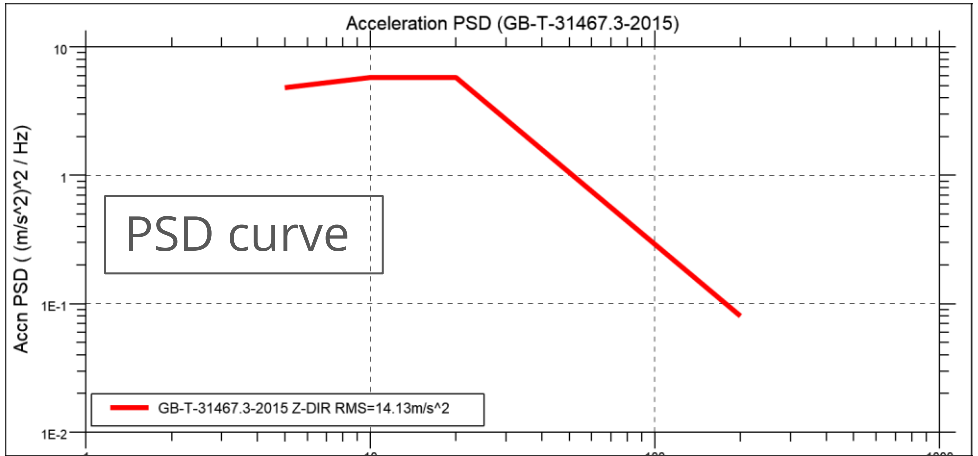


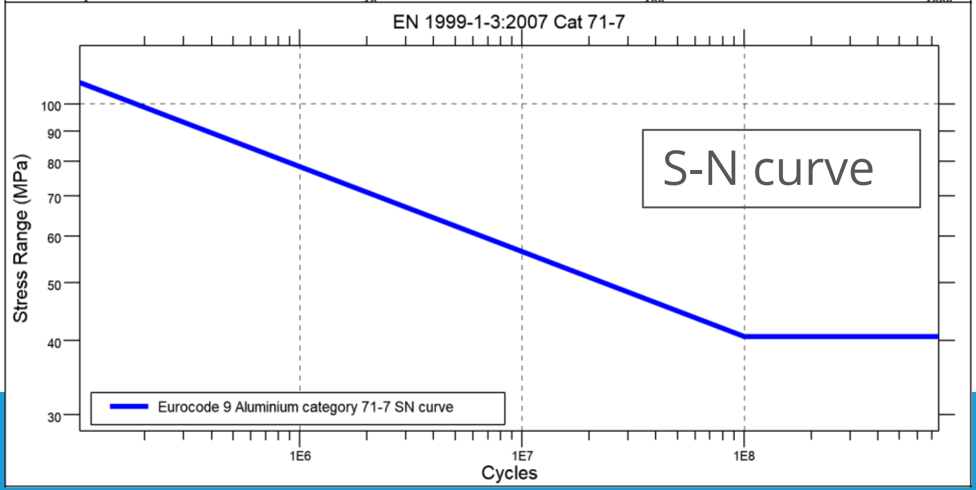
Random vibration fatigue E.g. GB 38031-2020

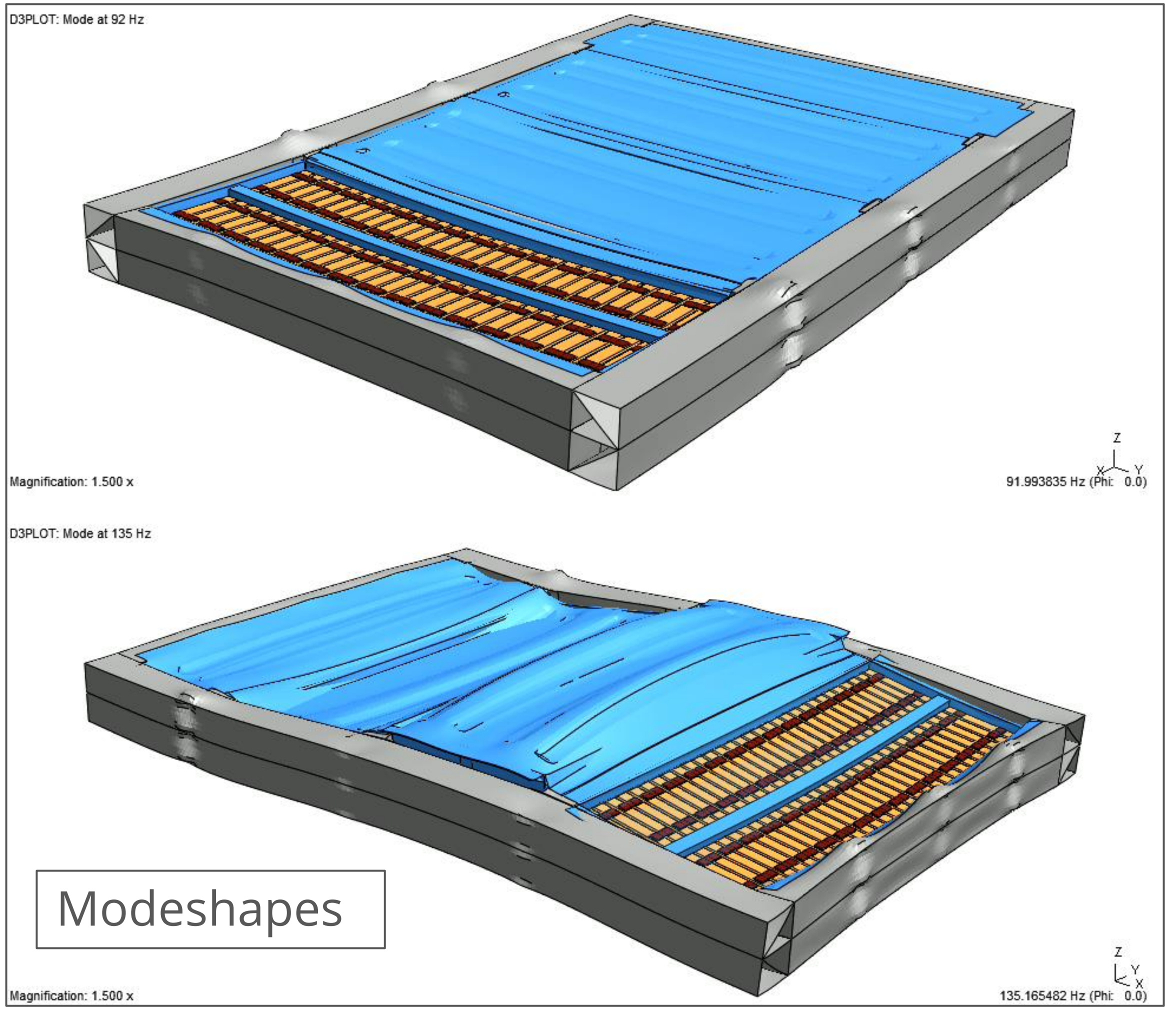
***FREQUENCY_DOMAIN_RANDOM_VIBRATION_FATIGUE**

Implicit Solver

- Frequency response (stresses) by modal superposition
- Amplitude at each frequency defined via PSD
- Fatigue computed from S-N curve

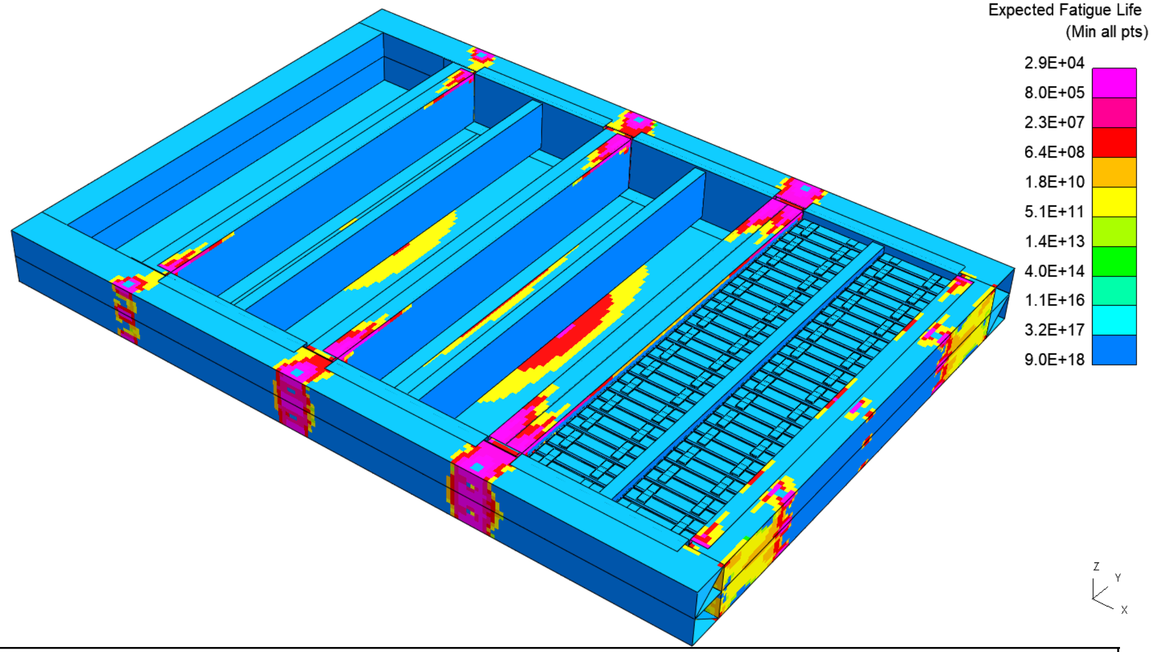






Random vibration fatigue

*FREQUENCY_DOMAIN_RANDOM_VIBRATION_FATIGUE

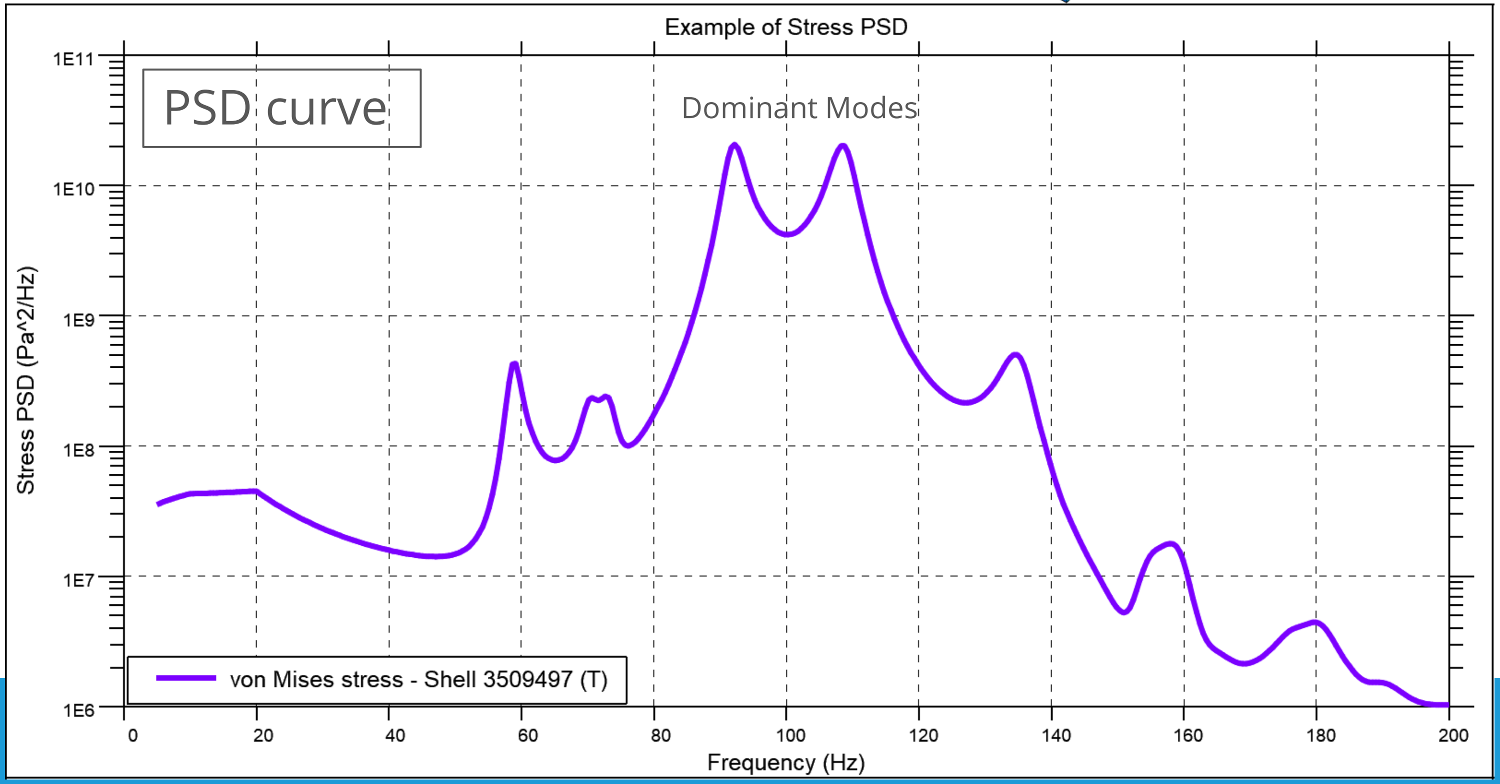


The stress response at any point in the structure is a combination of the input PSD and the structural frequency response.

Options for fatigue prediction include:

- Steinberg's 3-band method
- Narrow Band method
- Dirlik - used here
- Several others

All are based on the statistical characteristics of the stress PSDs.

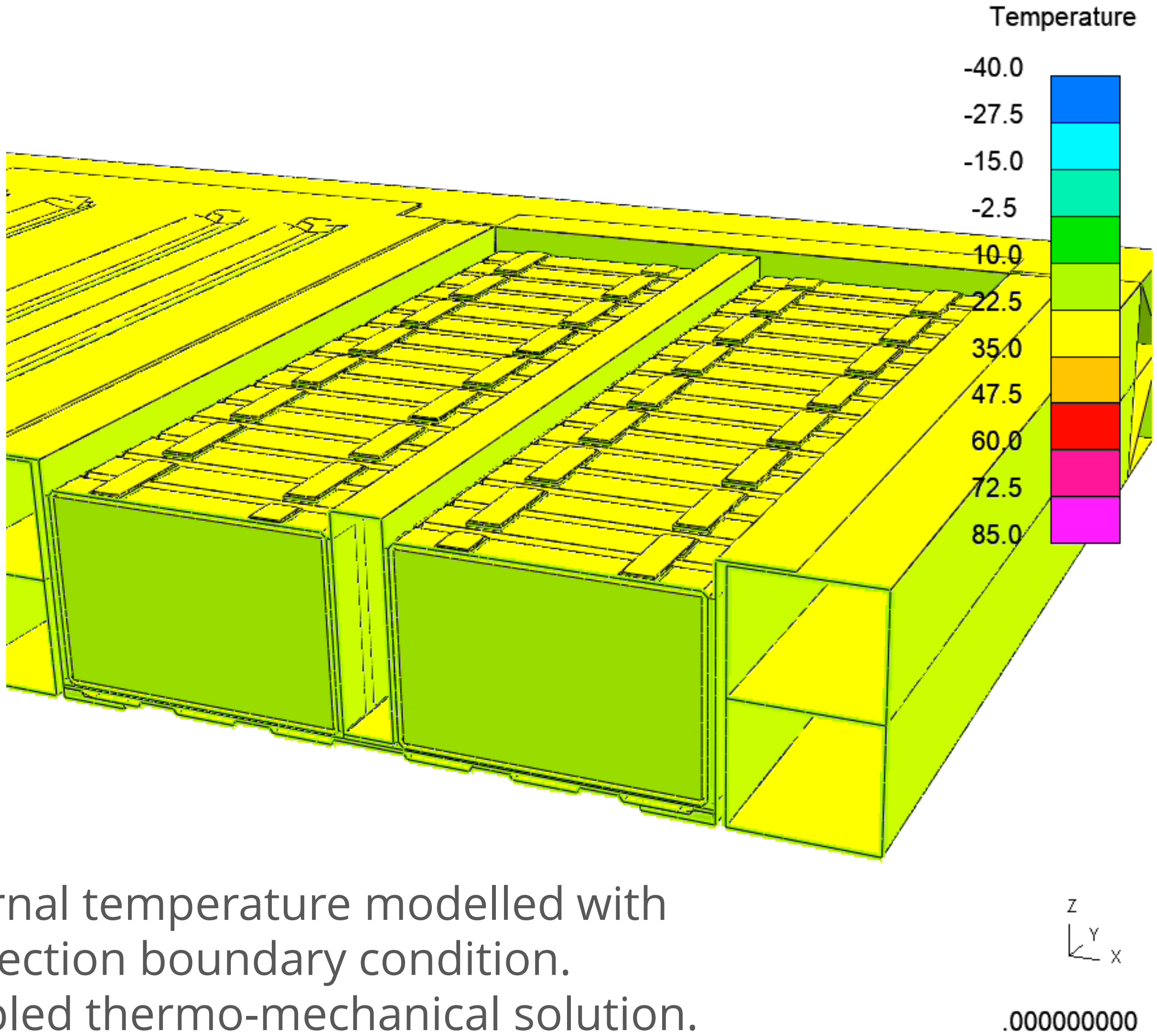


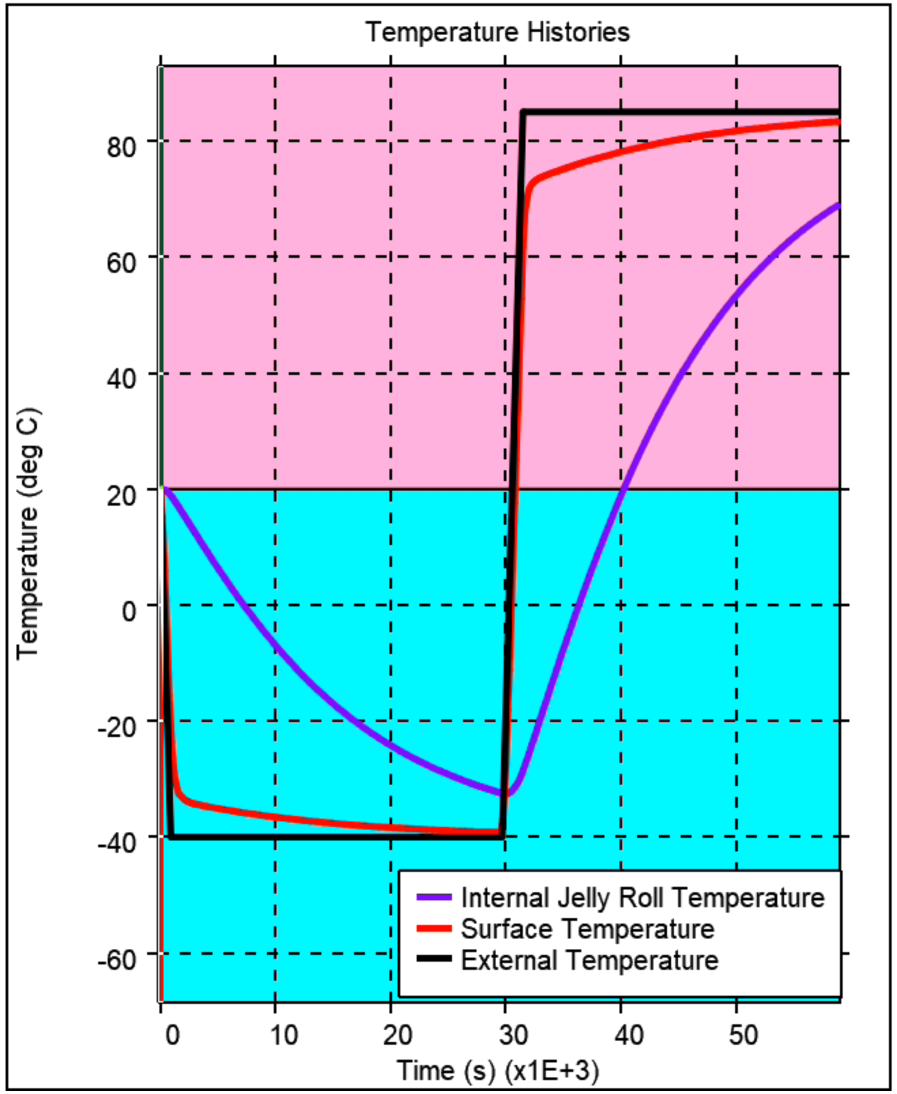
Implicit Solver

Thermal Shock E.g. UN ECE R100

Battery is externally heated and cooled for five cycles

Implicit Solver



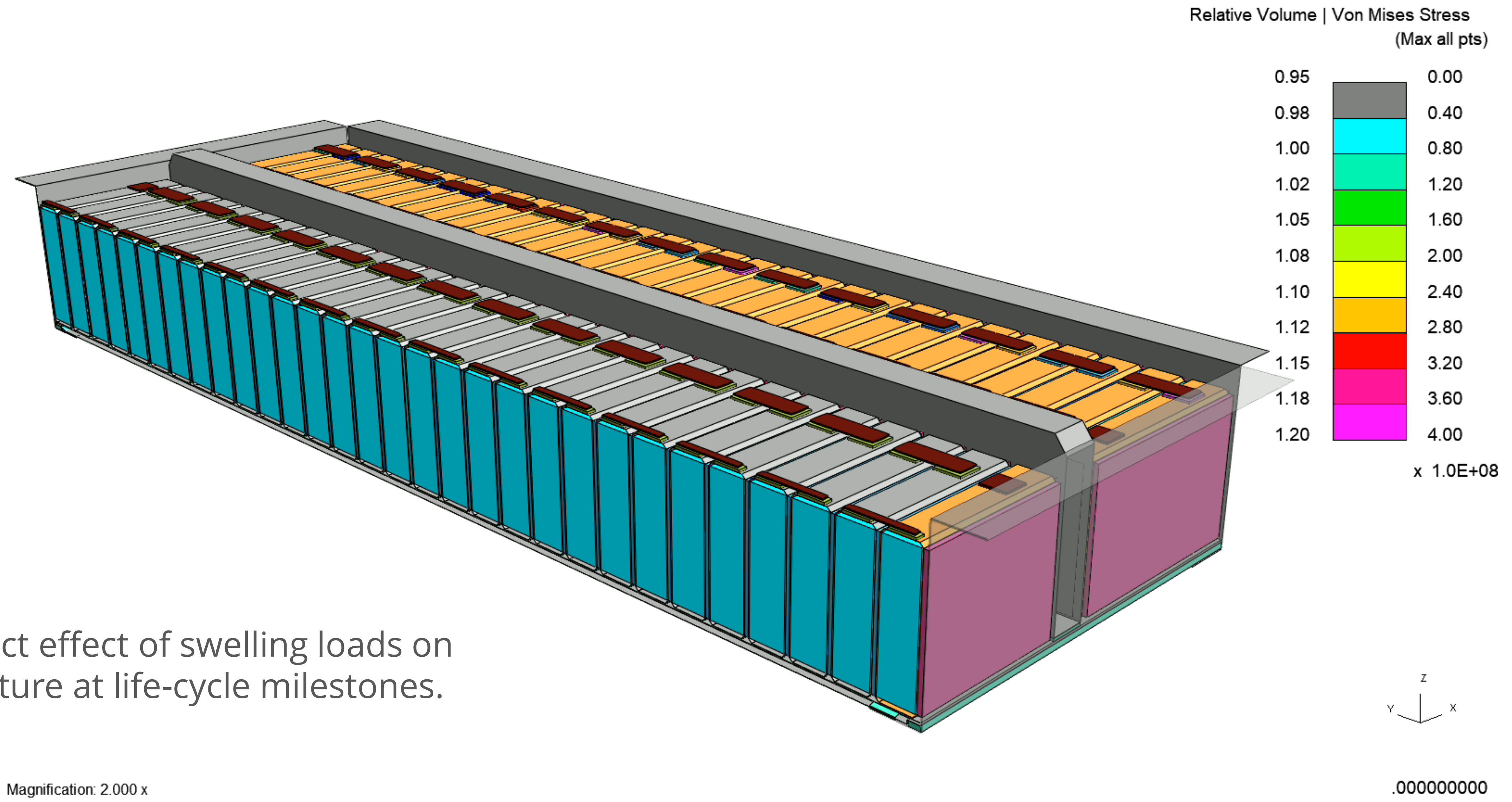


External temperature modelled with convection boundary condition.
Coupled thermo-mechanical solution.

Swelling

Prediction of mechanical response to jelly roll swelling due to ageing effects.

Explicit Solver

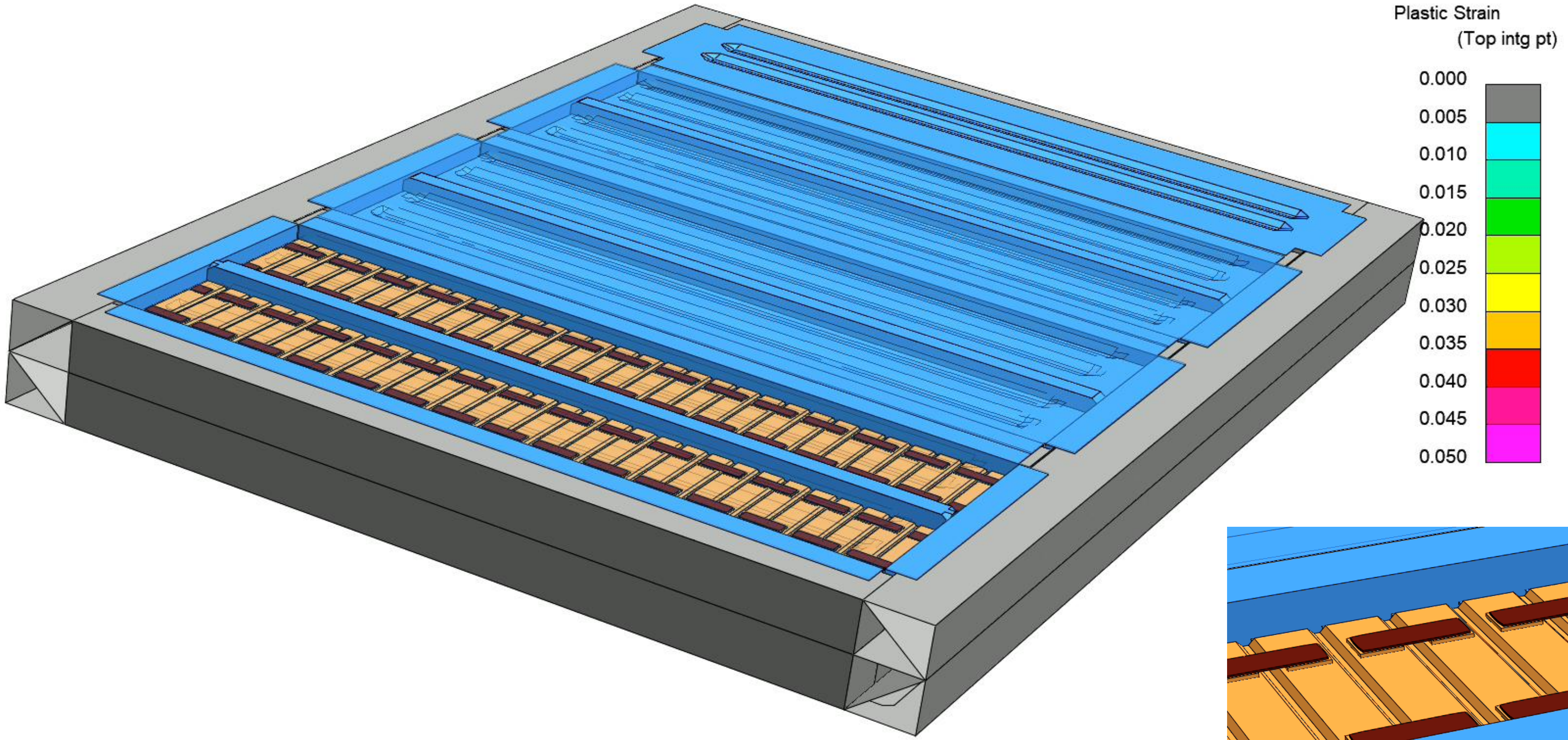


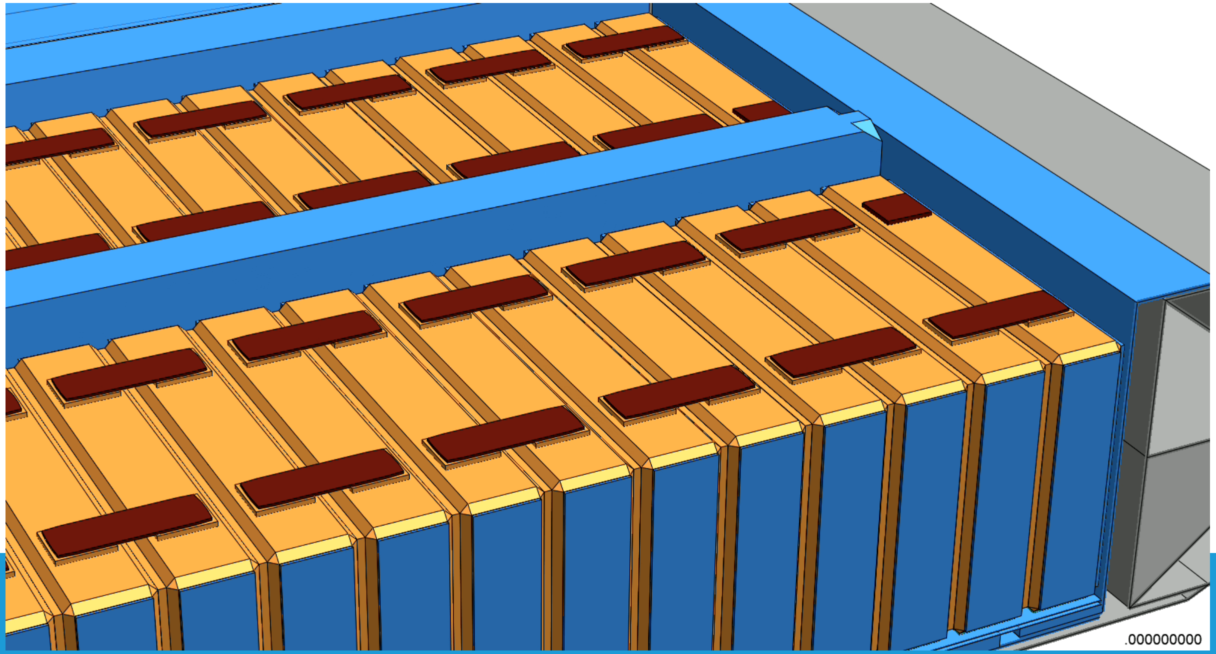
Predict effect of swelling loads on structure at life-cycle milestones.

Drop / Impact

Edge-down drop from 1m. E.g. accidental drop

Explicit Solver



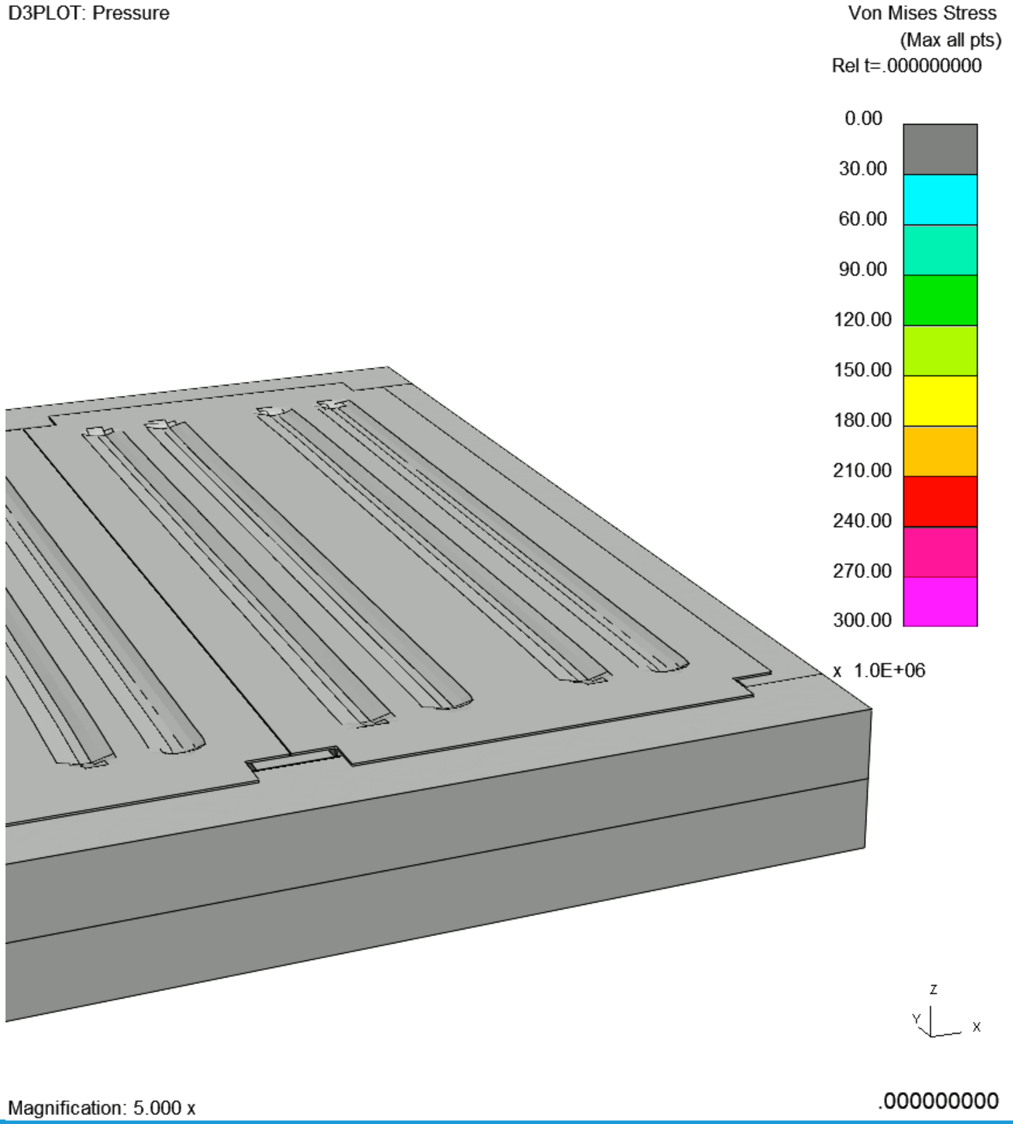


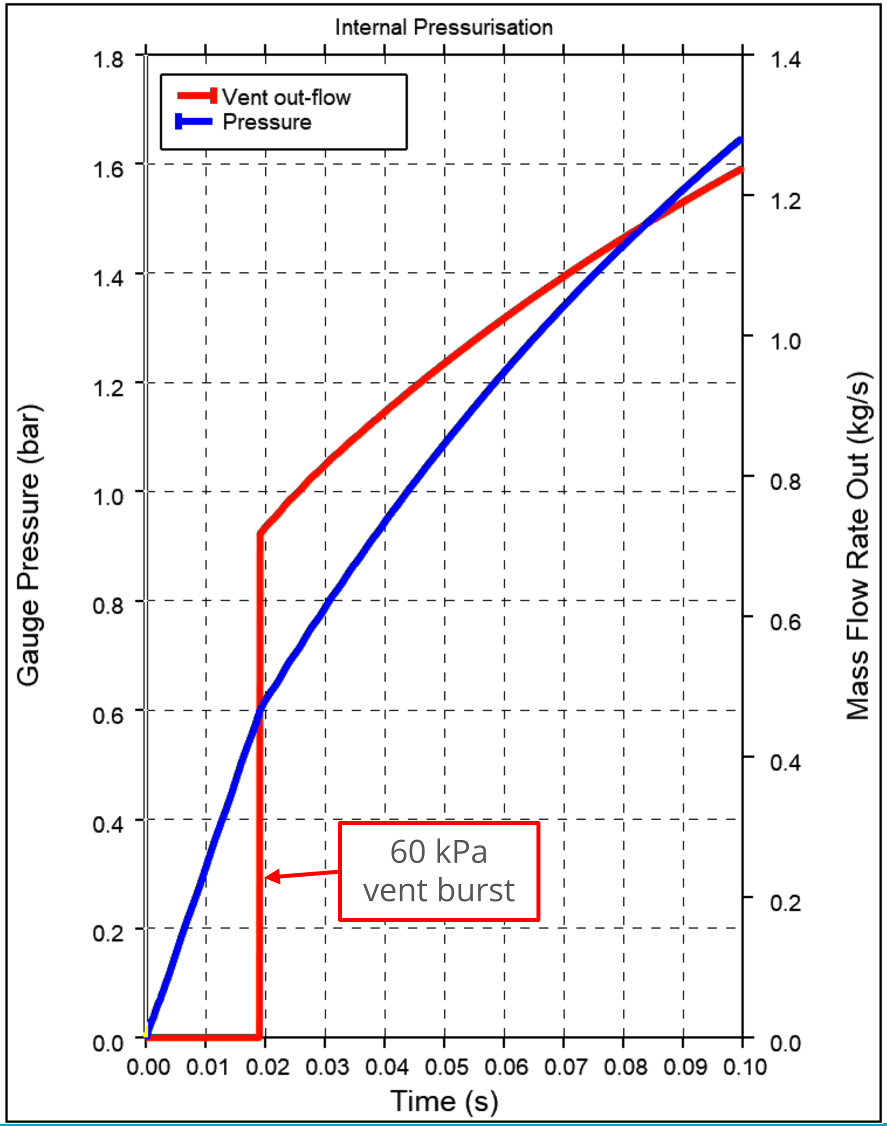
Check for damage to structure, electrical connections, adhesives, etc.

Internal Gas Pressure

Internal pressure due to gas generation, with simple venting model

Explicit Solver





Ref: Thermal runaway of lithium-ion batteries and hazards of abnormal thermal environments
John C. Hewson, Stefan P. Domino

Thermal Management

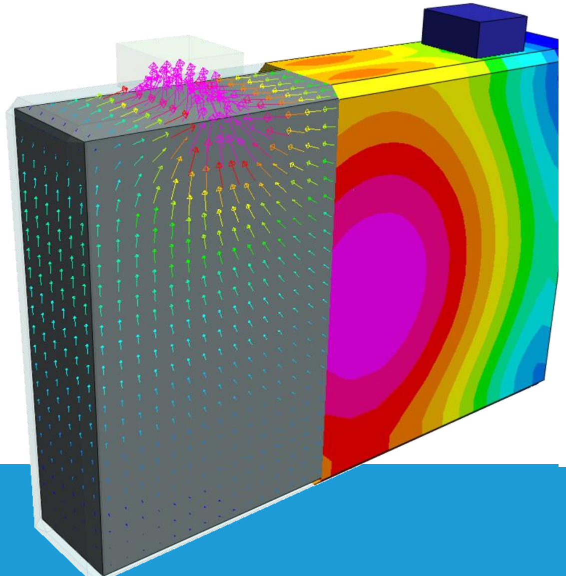
Coupled electromagnetic / thermal analysis

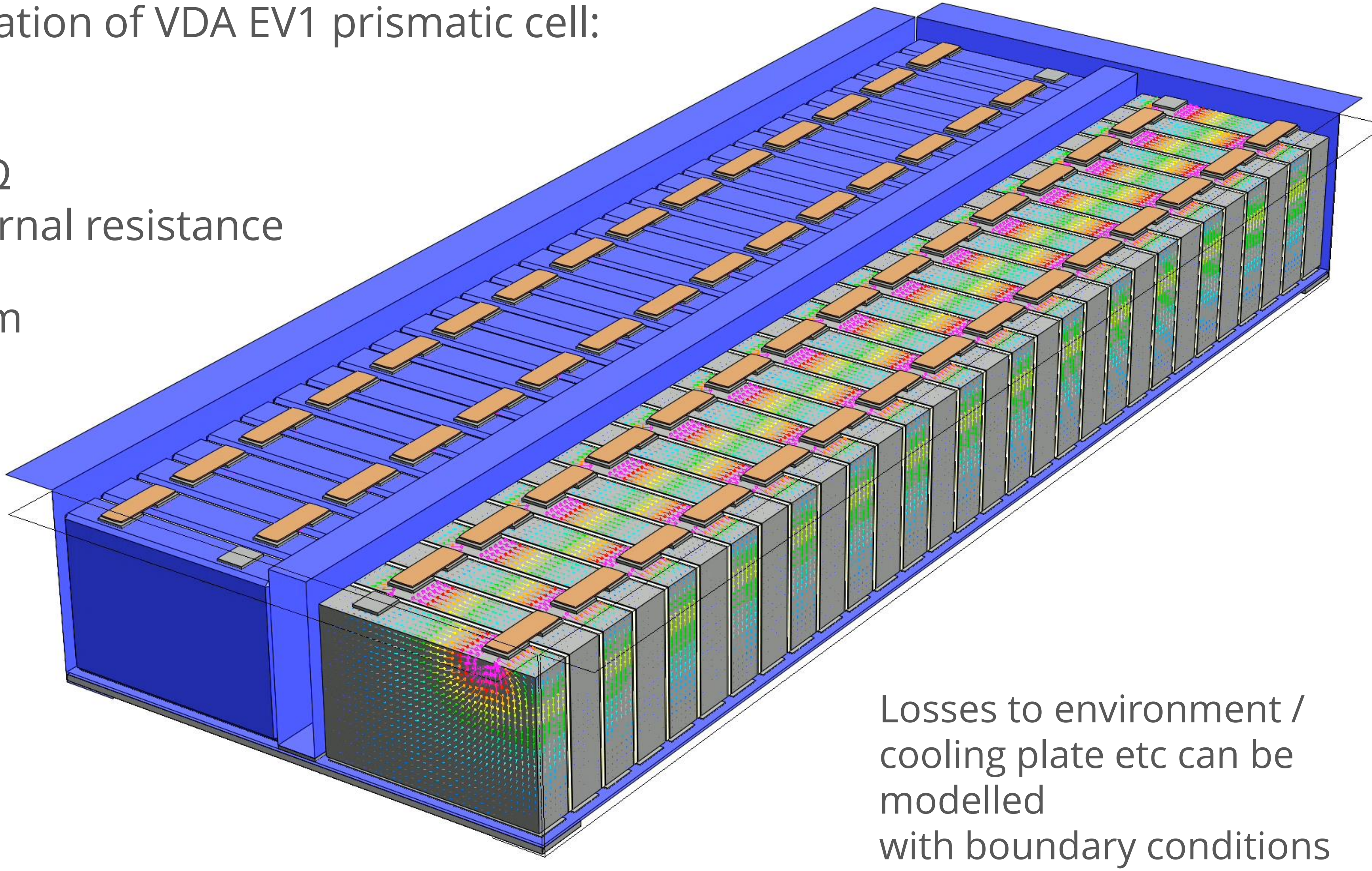
Implicit Solver

Simple BATMAC representation of VDA EV1 prismatic cell:

3.6V | 40Ah cells
Internal resistance 200 mΩ
5C discharge through external resistance

Model of heat transfer from the cells into the structure during high current discharge.





Losses to environment / cooling plate etc can be modelled
with boundary conditions

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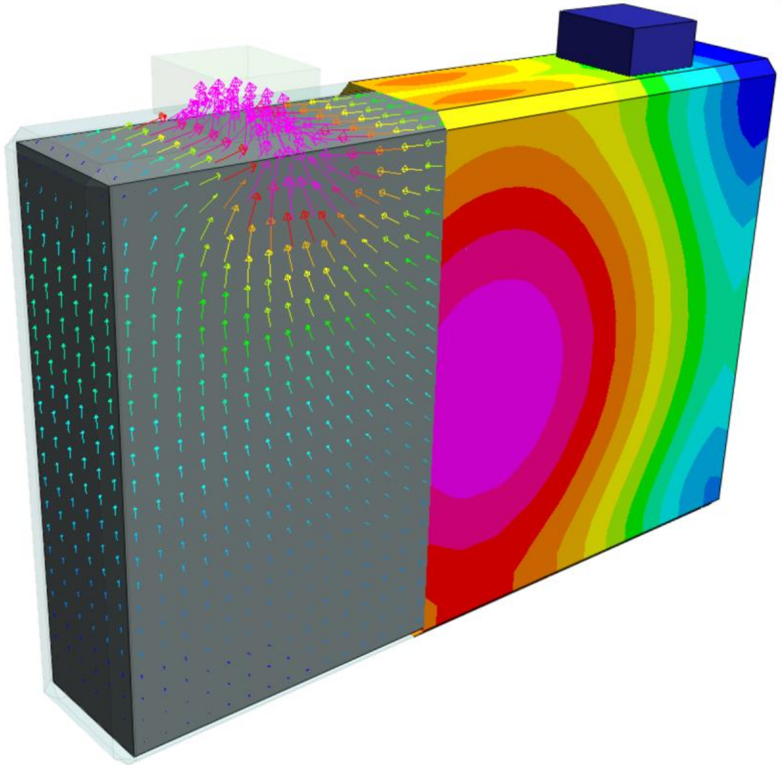

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