IDAJ
integrated digital advanced solution

IDAJ公司

电池准三维热管理分析

IDAJ中国

GT小组

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电池开发遇到的问题

- 不断增加的纯电续航里程
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- 不断缩短的充电时间
  - 电池发热量
- 电池热管理难度增加
  - 散热量/加热量
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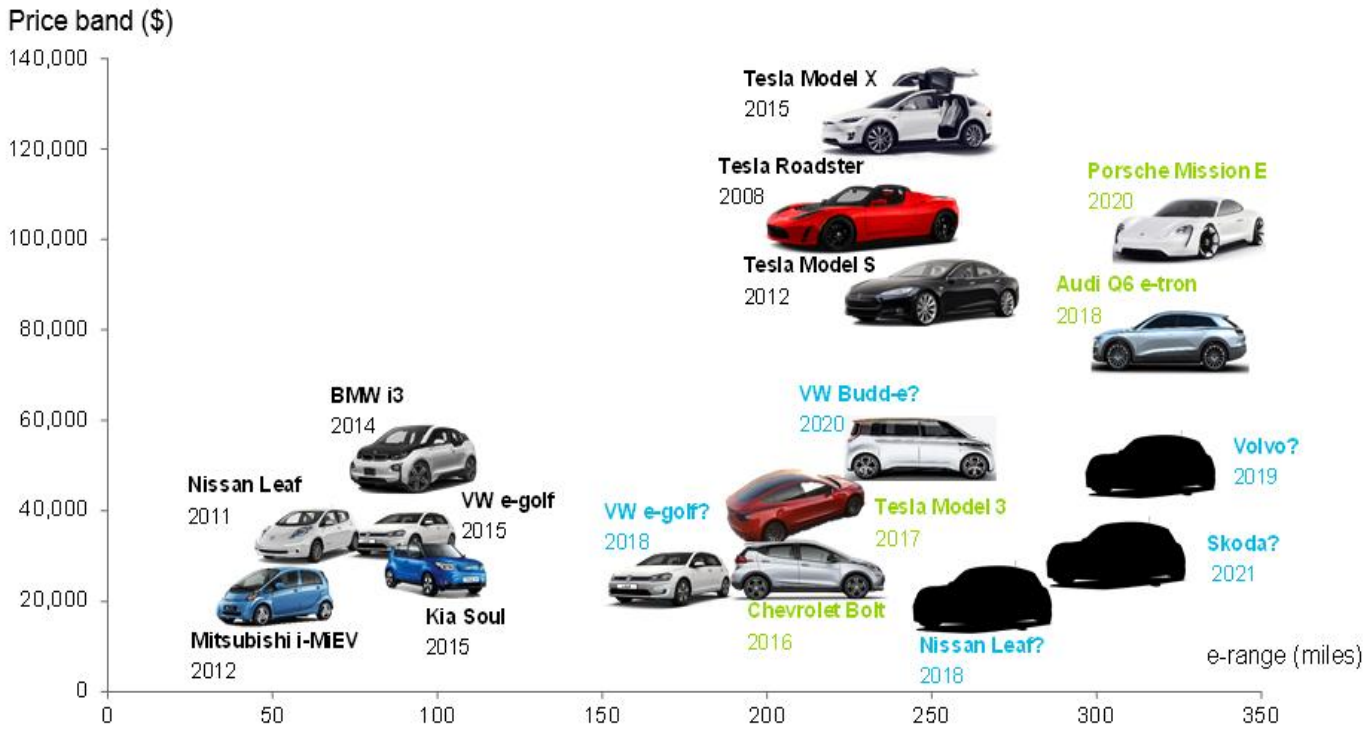
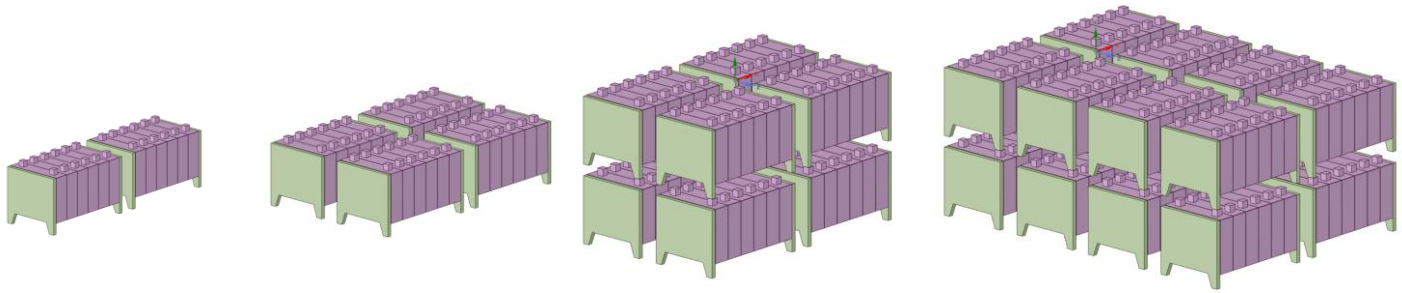
- 不断压缩的产品设计周期
  - 长周期试验、CFD
- 电池如何设计
  - 成组方案
  - 热管理系统设计

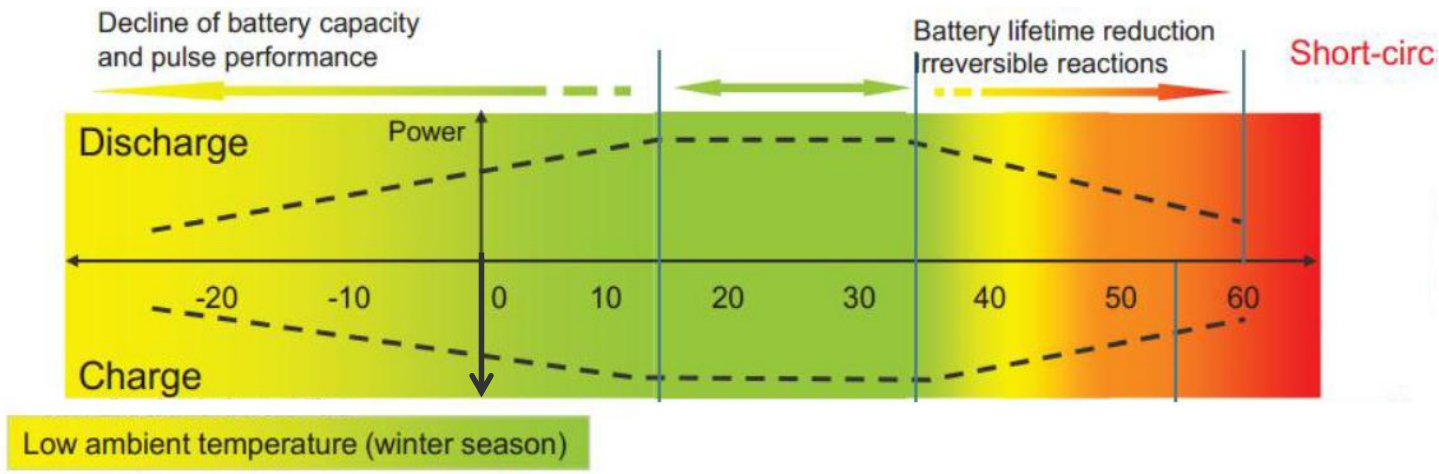


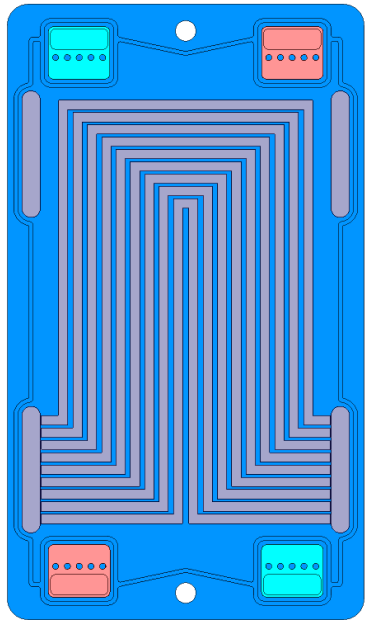
Source: Bloomberg New Energy Finance

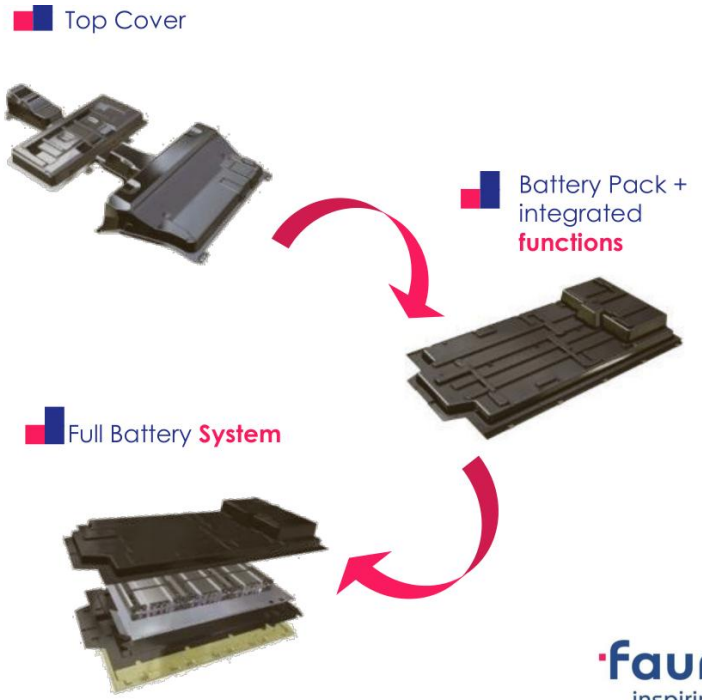


电池热管理开发的设计要求

- 电芯温度
  - 快速暖机
  - 快速冷却
- 电芯温差
  - 3~5℃
  - 模组布置
  - 水冷板布置
    - 流量分布
    - 流阻
- 外围系统要求
  - 冷却液温度
  - 冷却液流量
  - 系统功耗

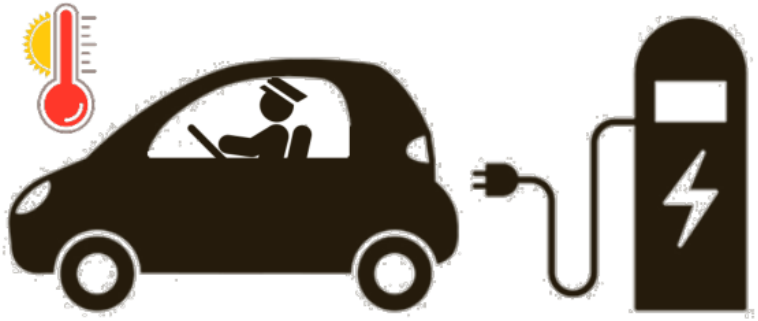


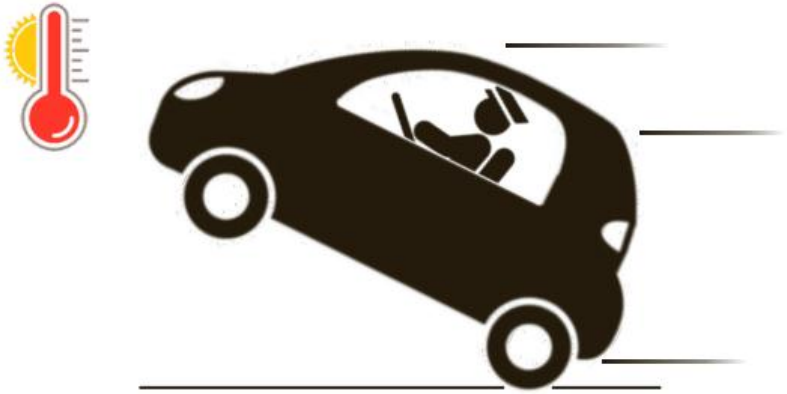




电池热管理系统开发的难点

- 长周期的物理过程
  - 1C快充>1h
  - NEDC循环>10h
  - 交变工况
- 多维度的设计方案
  - 水冷板布置
  - 冷却液温度
  - 冷却液流量
  - 控制策略





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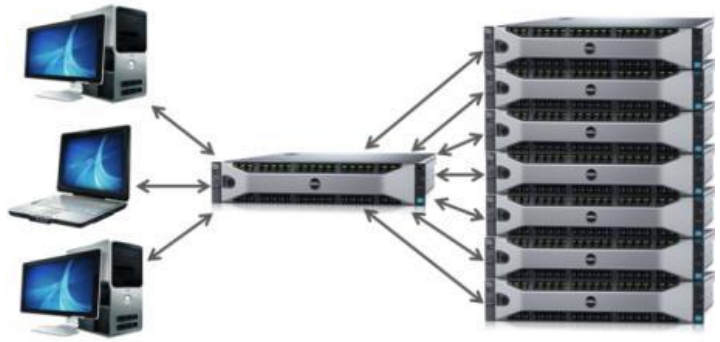
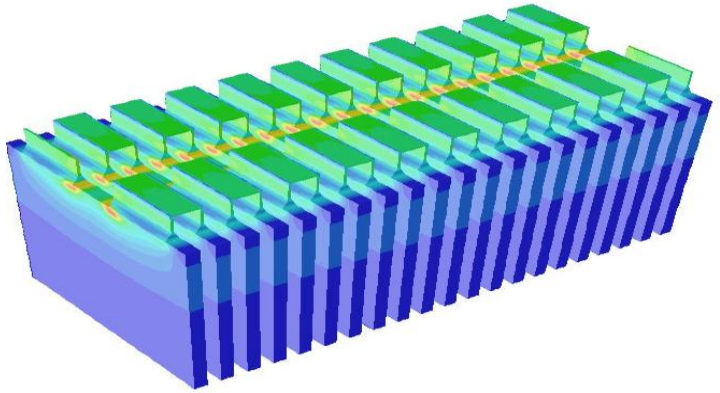


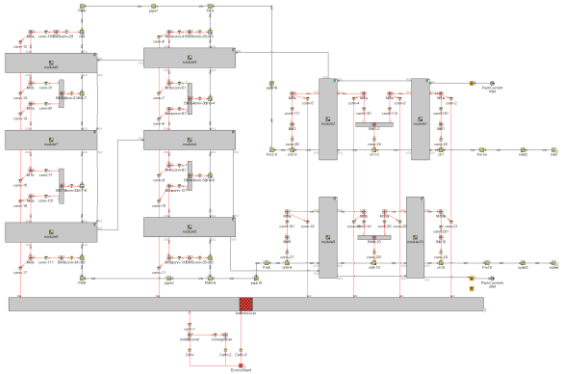
电池热管理仿真的主要方法

预测性

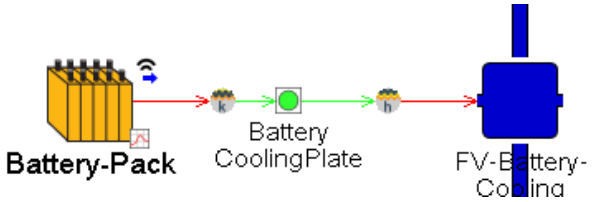
3D有限元模型



准3D模型



集总参数模型

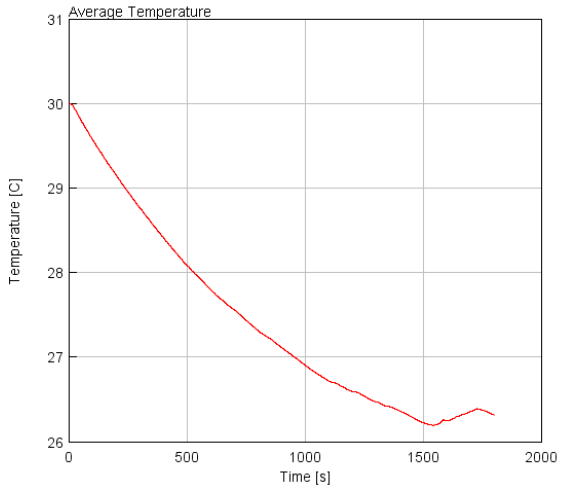


计算时间

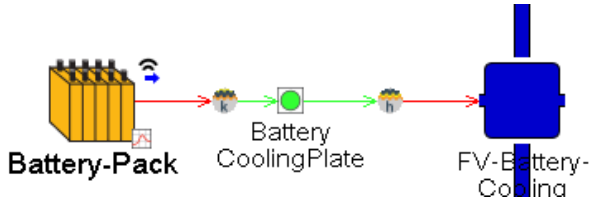
电池热管理仿真的主要方法

预测性

电池平均温度



集总参数模型



技术方案	将电池视为一个整体，不考虑具体结构及参数，通过2~3个简单系数标定电池与冷却液及环境的换热系数
输入数据	电池发热量、水冷板流阻、水套换热系数、电池导热系数
温度场预测能力	无，只能输出平均温度
水冷板流阻预测能力	无，需要输入
外部环境影响	只能粗略考虑
网格数量	<5
计算速度	非常快
适用场景	概念设计阶段、系统回路仿真、整车能量管理系统集成

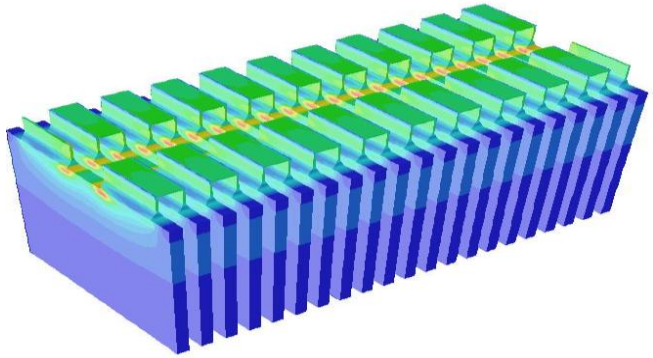
计算时间

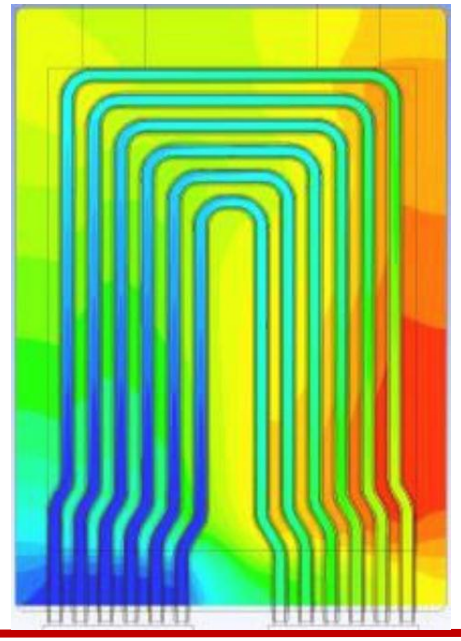
电池热管理仿真的主要方法

预测性

技术方案	基于详细几何数模划分网格、输入全部物性参数计算电池包内温度场
输入数据	电芯发热量、几何数模、全部零件材料属性
温度场预测能力	强
水冷板流阻预测能力	强
外部环境影响	可考虑
网格数量	10^6~10^7
计算速度	慢，需要并行计算
适用场景	详细设计阶段、单一工况模拟，设计方案确认

3D有限元模型



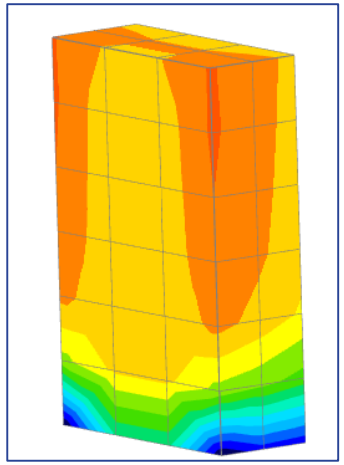


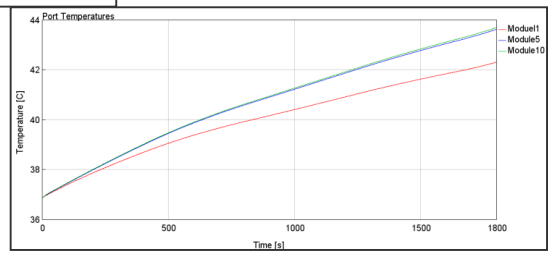
计算时间

电池热管理仿真的主要方法

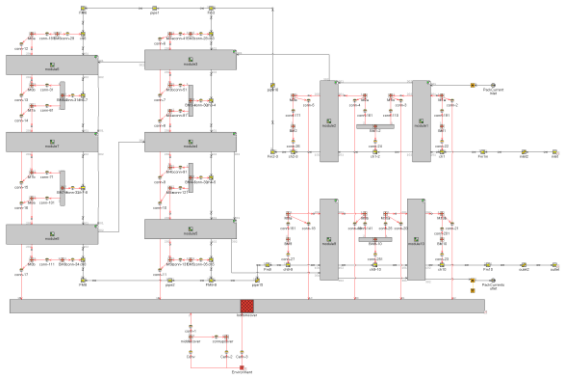
预测性

温度分布及变化

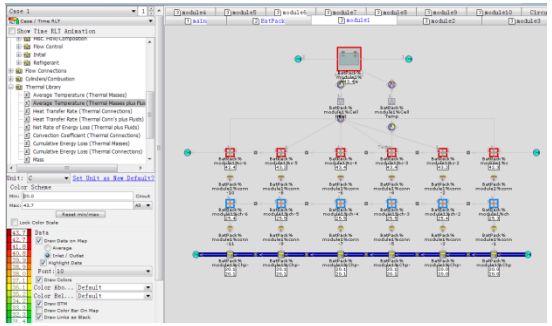




准3D模型



换热量分布

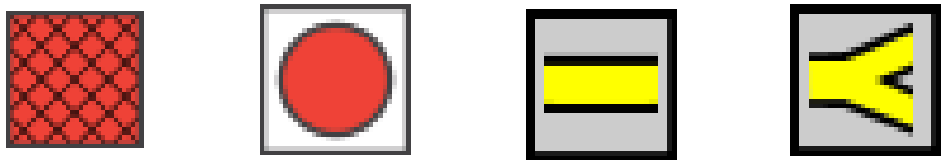


技术方案	根据几何数模将电池包内结构离散为1D传热计算单元，结合材料属性计算传热计算单元温度分布
输入数据	电芯发热量、几何数模、全部零件材料属性
温度场预测能力	有，可预测局部温度
水冷板流阻预测能力	有
外部环境影响	可考虑
网格数量	10^2~10^3
计算速度	快，满足实时仿真需求
适用场景	电池包布置方案优化、系统方案验证、控制系统开发、长周期瞬态模拟

计算时间

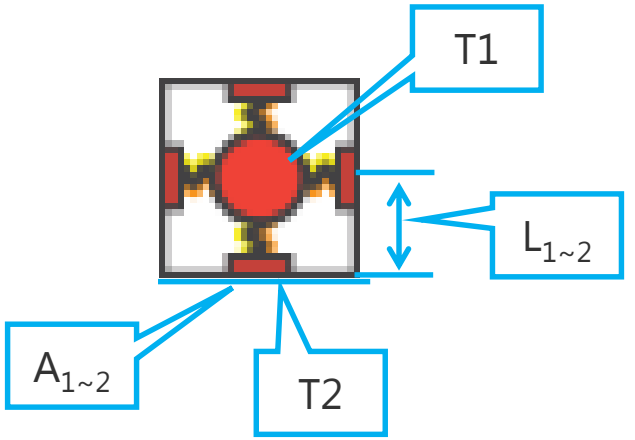
准3D电池仿真方法的基本理论

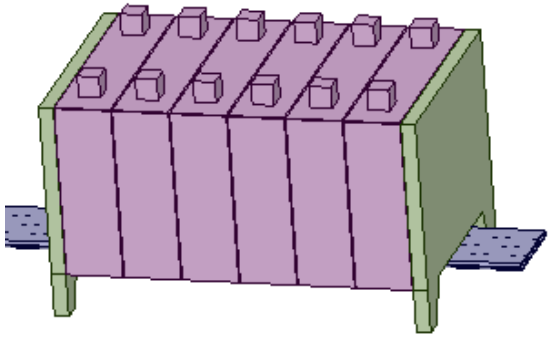
- 使用基本传热单元和流动单元来描述电池包内传热网络
  - 基本传热单元：
    - 模组、电芯、电芯某一部分
    - Thermal mass、ThermalFiniteElement、ThermalNode
  - 流动单元：
    - 管路、腔体
    - Pipe、FlowSplit
  - 包内传热网络：
    - 冷却液对流换热、固体之间导热、环境辐射
    - CovectionConn、ConductanceConn、ResistanceConn、RadiationConn

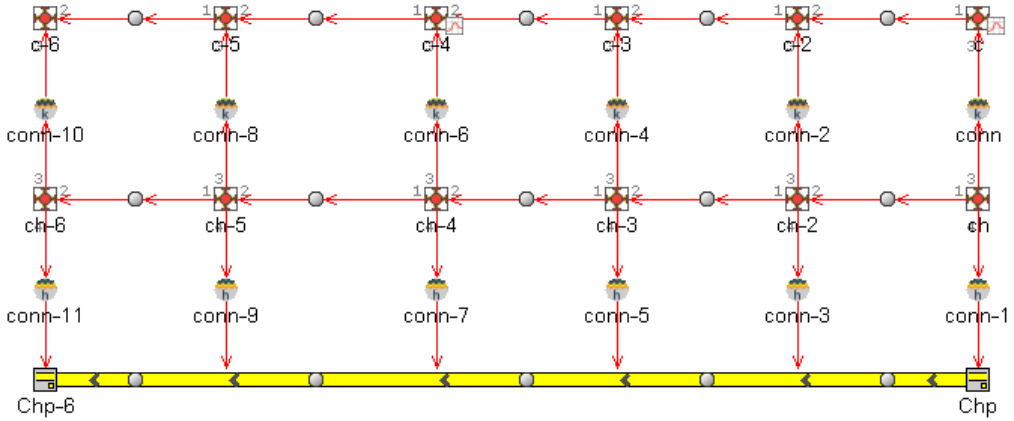


$$Q=\frac{T_1-T_2}{R}$$

$$R=\frac{L}{kA}$$

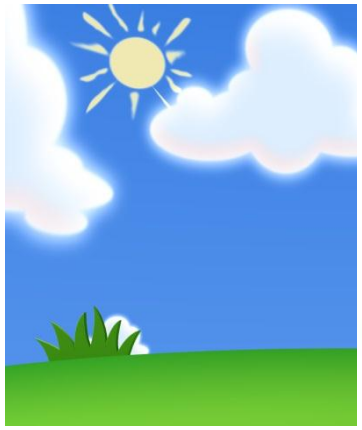






准3D电池仿真解决方案

- 准3D建模面临的问题
  - 复杂的几何形状如何建模
  - 复杂的传热结构如何体现
  - 复杂的换热边界如何给出



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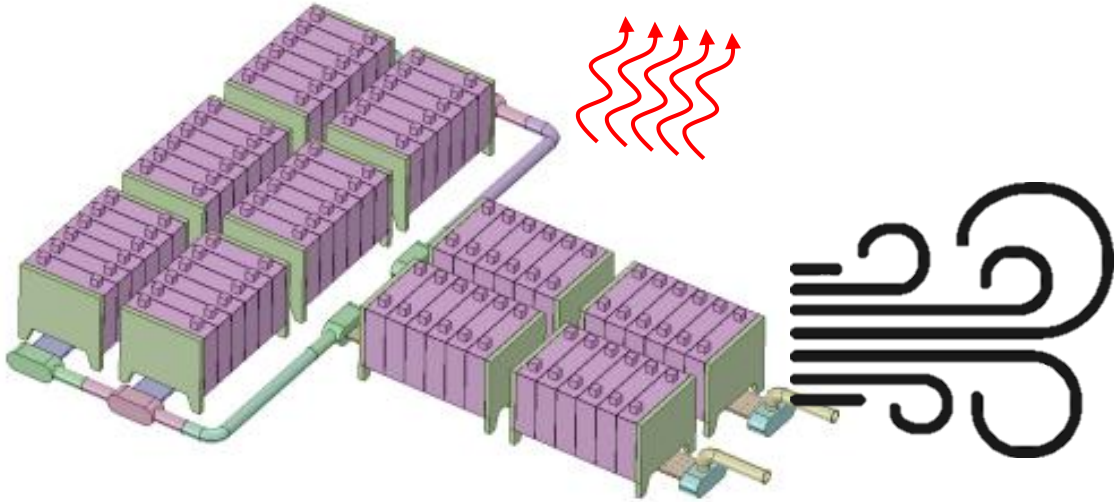

- GT-SUITE解决方案
  - GT-SPACECLAIM数模前处理：数模修整、水套抽取
  - GEM3D数模转换：将复杂几何形状自动转换为1D模型，包括固体、流体、自动识别换热边界、预留换热边界
  - GTISE整包模型：子模型调用实现复杂架构建模、交变工况模拟

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GT-SpaceClaim

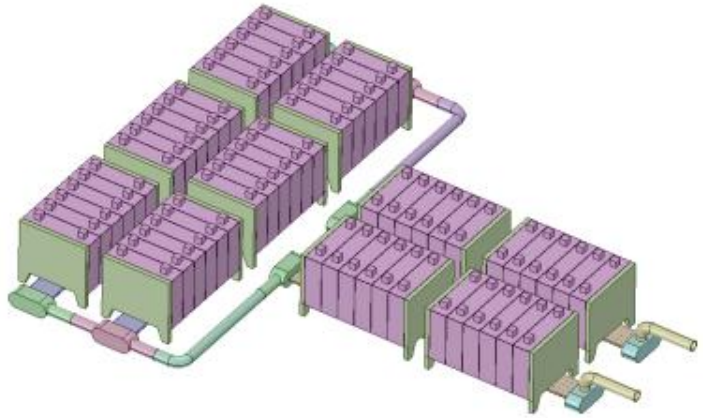
GT-SUITE GEM3D

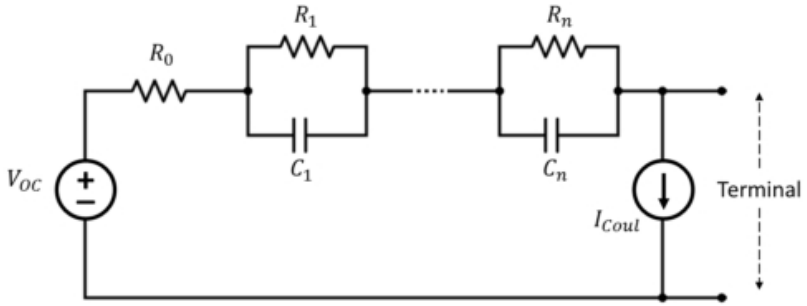
GT-SUITE GT-ISE

准3D电池仿真方法

数据准备

- 几何数模
- 材料属性：密度、比热容、导热系数
  - 电芯、水冷板、支架、外壳
- 电芯发热量
  - 发热量
  - 等效电路参数+电路边界
  - 电化学参数



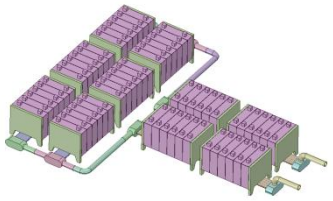


工作流程

1. 数模整理：SpaceClaim
2. 数模转换：GEM3D
3. 模组模型：GTISE
4. 整包封装：GTISE

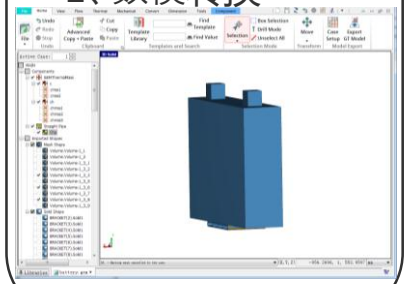
GT SpaceClaim

1、数模整理



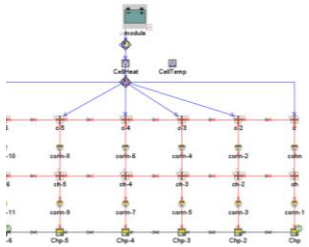
GT-SUITE GEM3D

2、数模转换



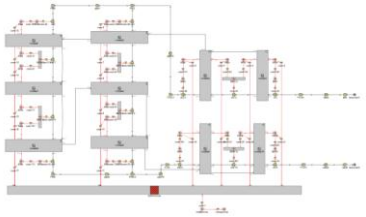
GT-SUITE GT-ISE

3、模组封装

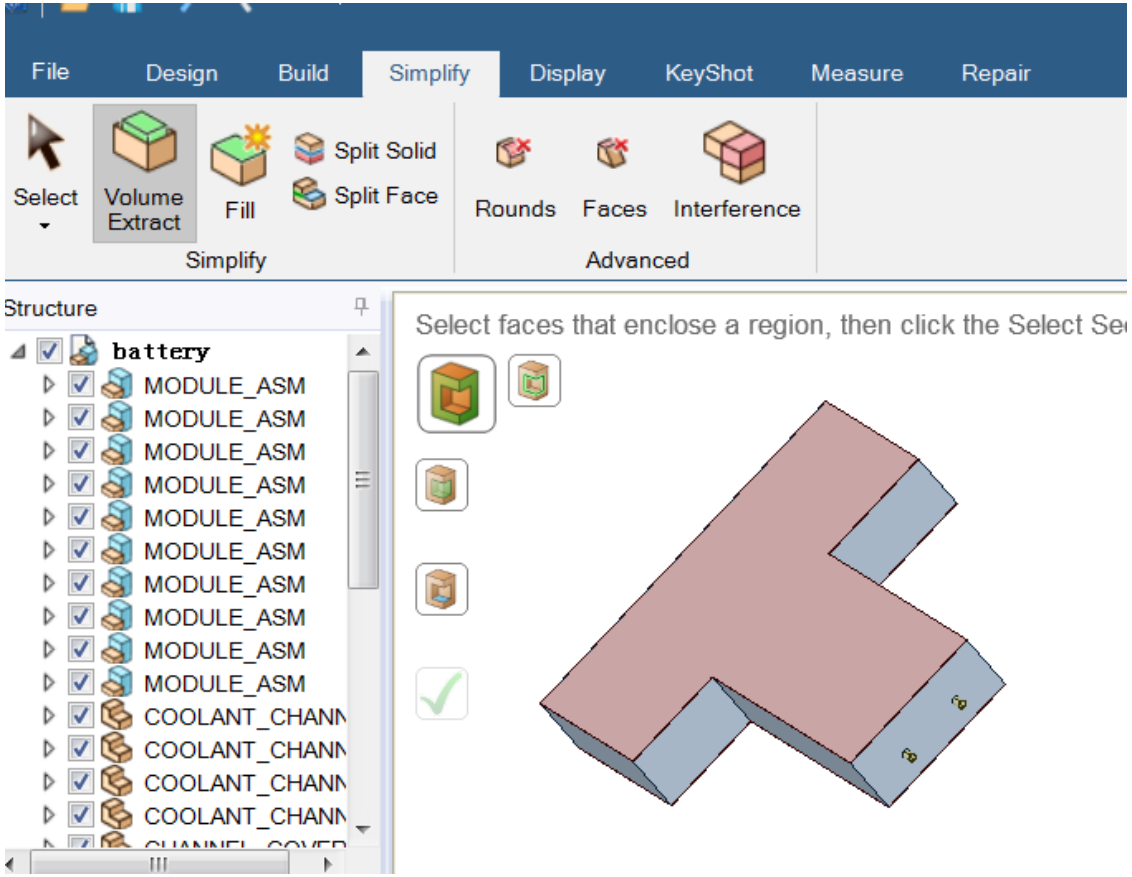


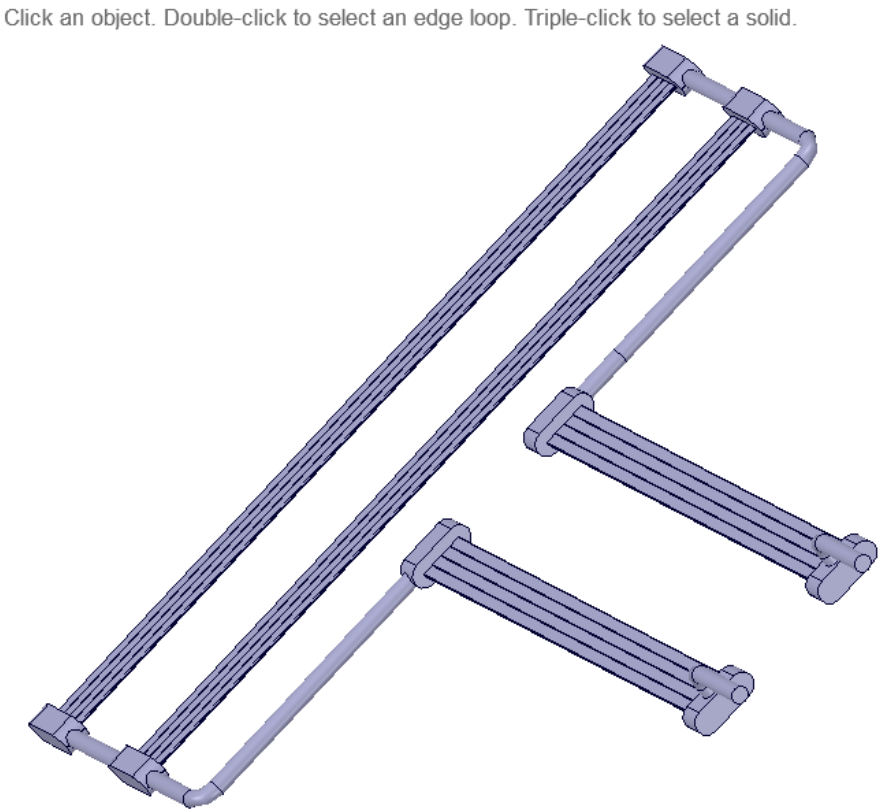
GT-SUITE GT-ISE

4、整包封装



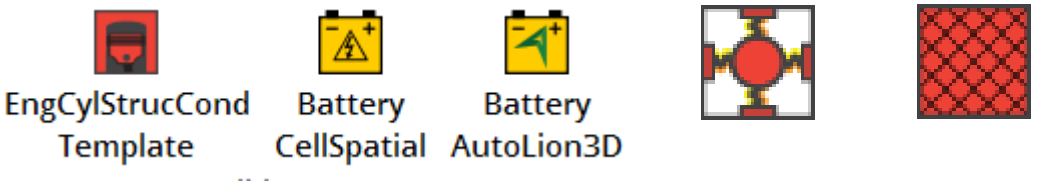
- 目的：水套抽取
  - 支持绝大部分CAD数模格式



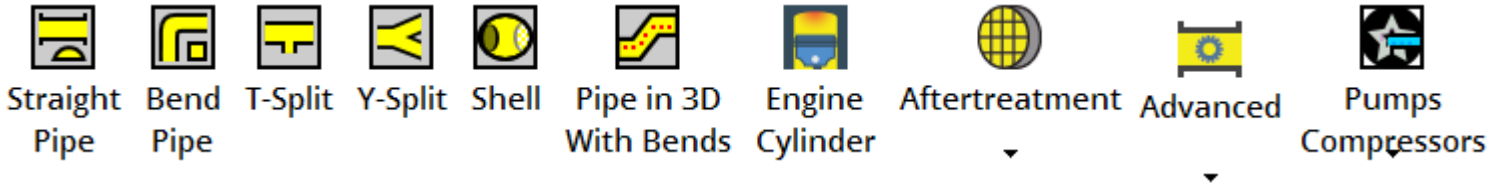


GEM3D功能

- 固体域：



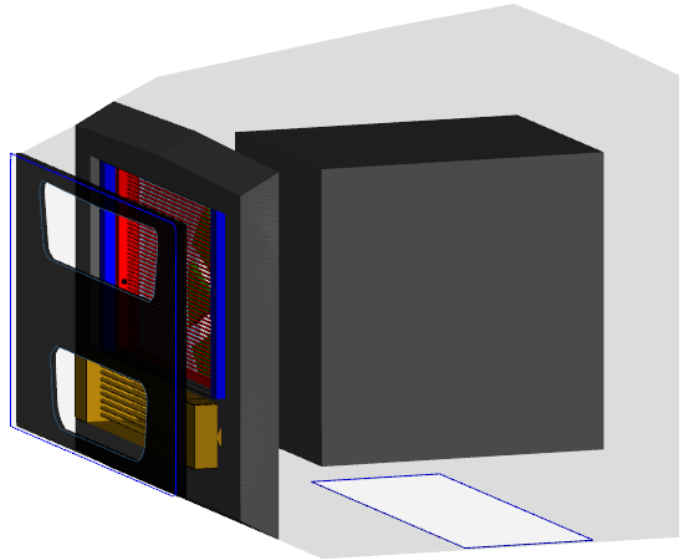
- 流体域：



- 机械域

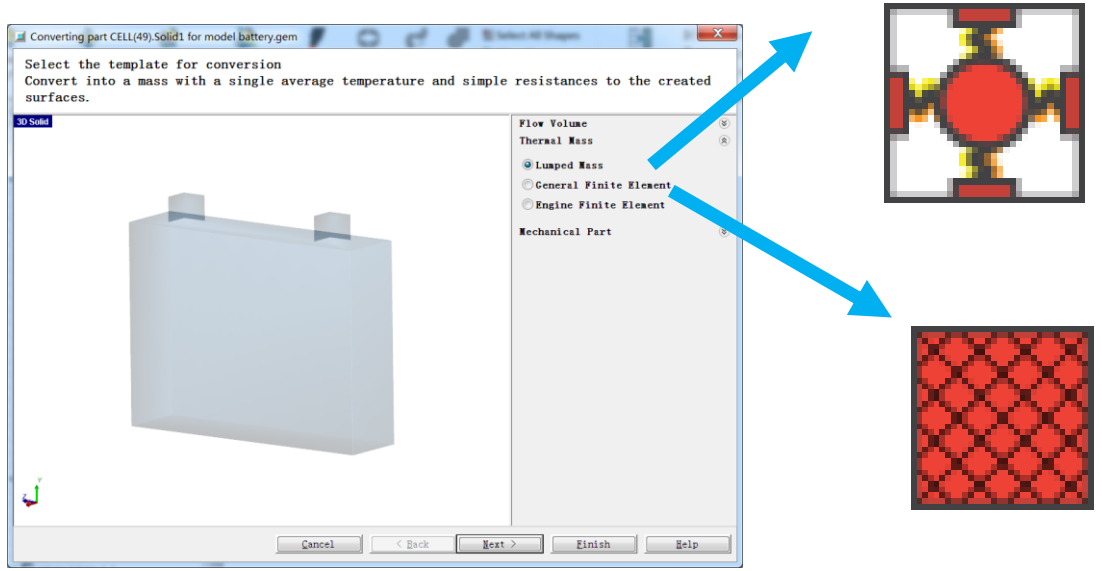
- 乘员舱

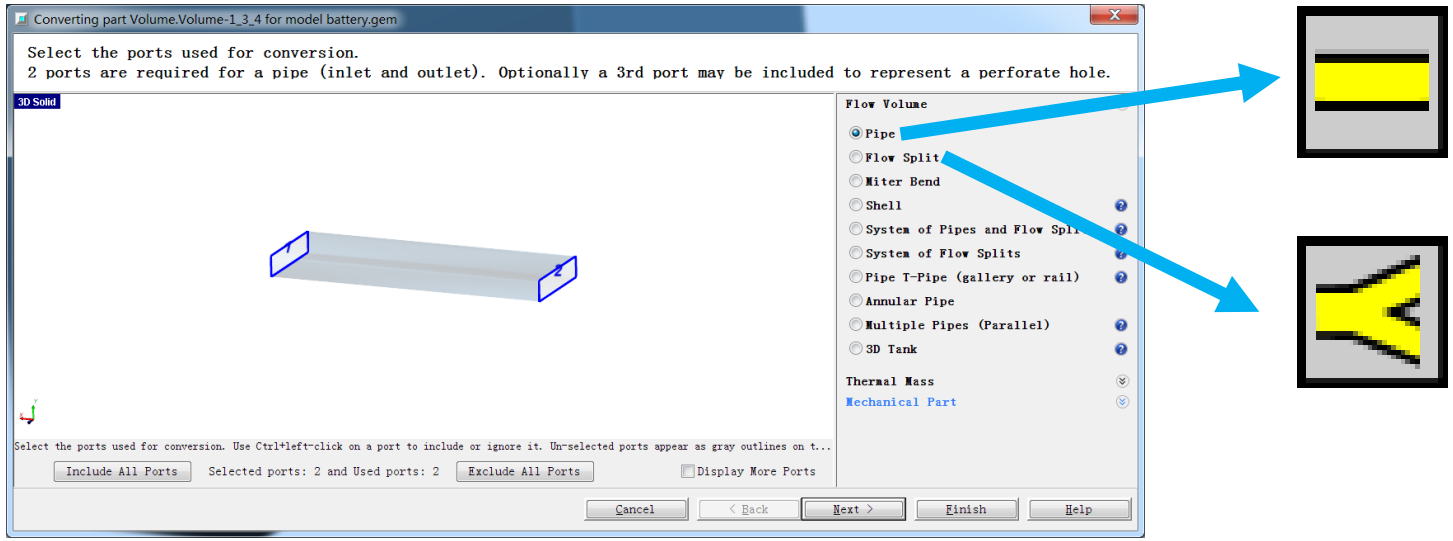
- 动力舱



GEM3D数模转换

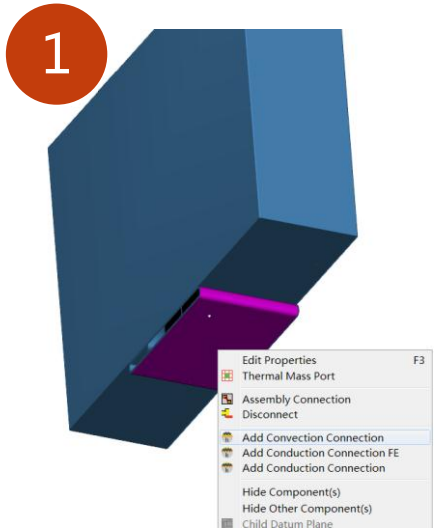
- 固体域：
  - Lump Mass：适用于形状规则、不考虑温度分布的零件，如电芯
  - General Finite Element：适用于形状不规则、考虑温度分布、难以手动切割的零件，如外壳
- 流体域：
  - Pipe：管路
    - 口琴管
  - Flow Split：腔体

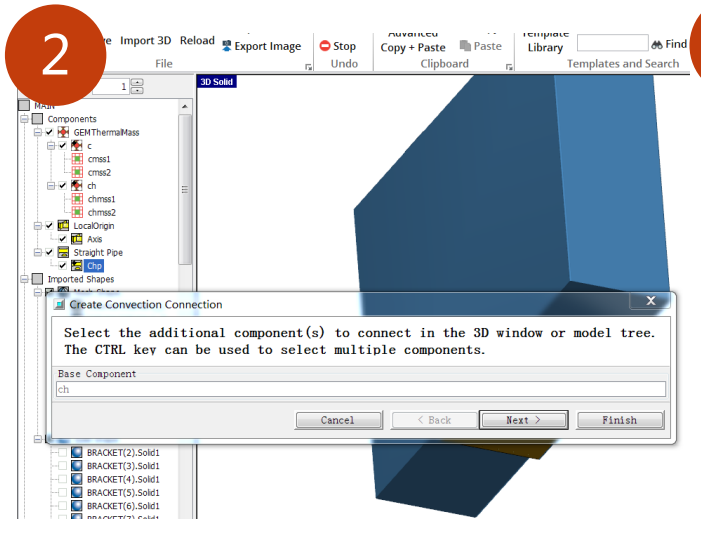


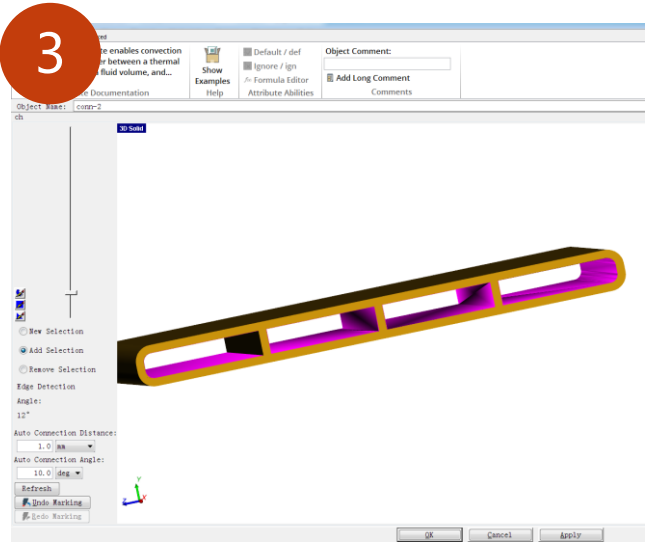


GEM3D数模转换

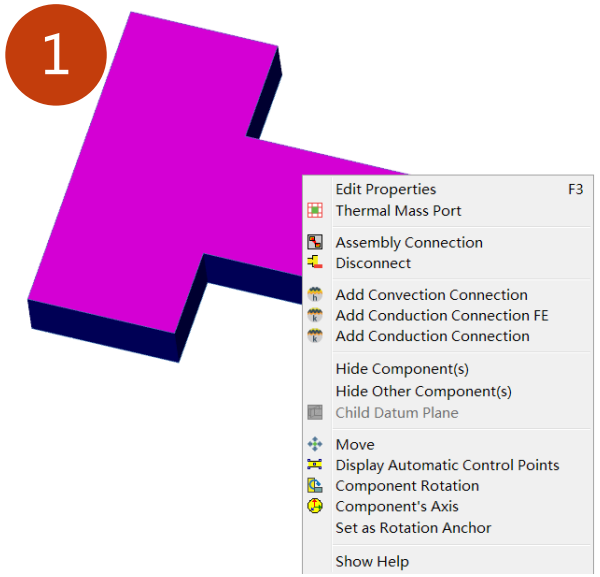
- 零部件之间换热
  1. 添加换热端口
  2. 选择换热部件
  3. 确认换热面

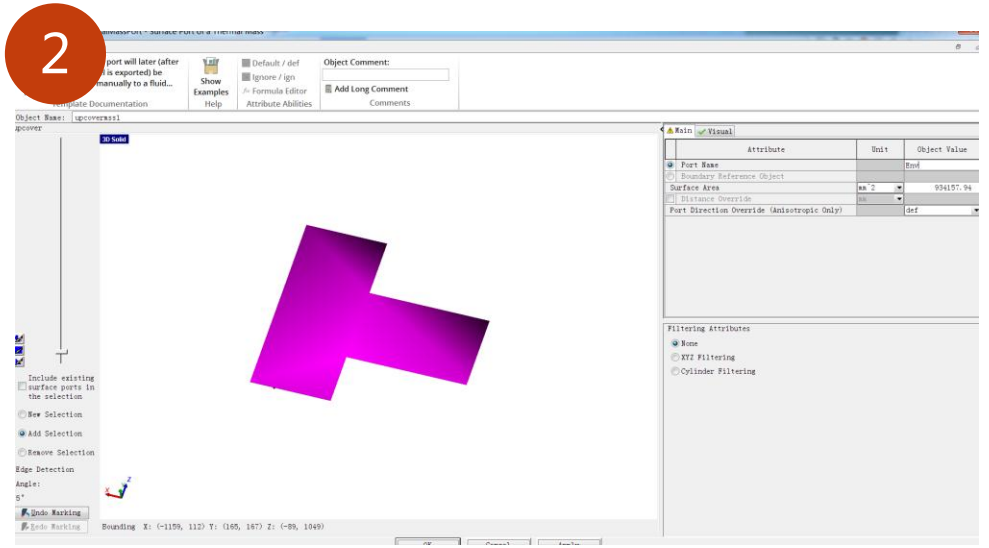






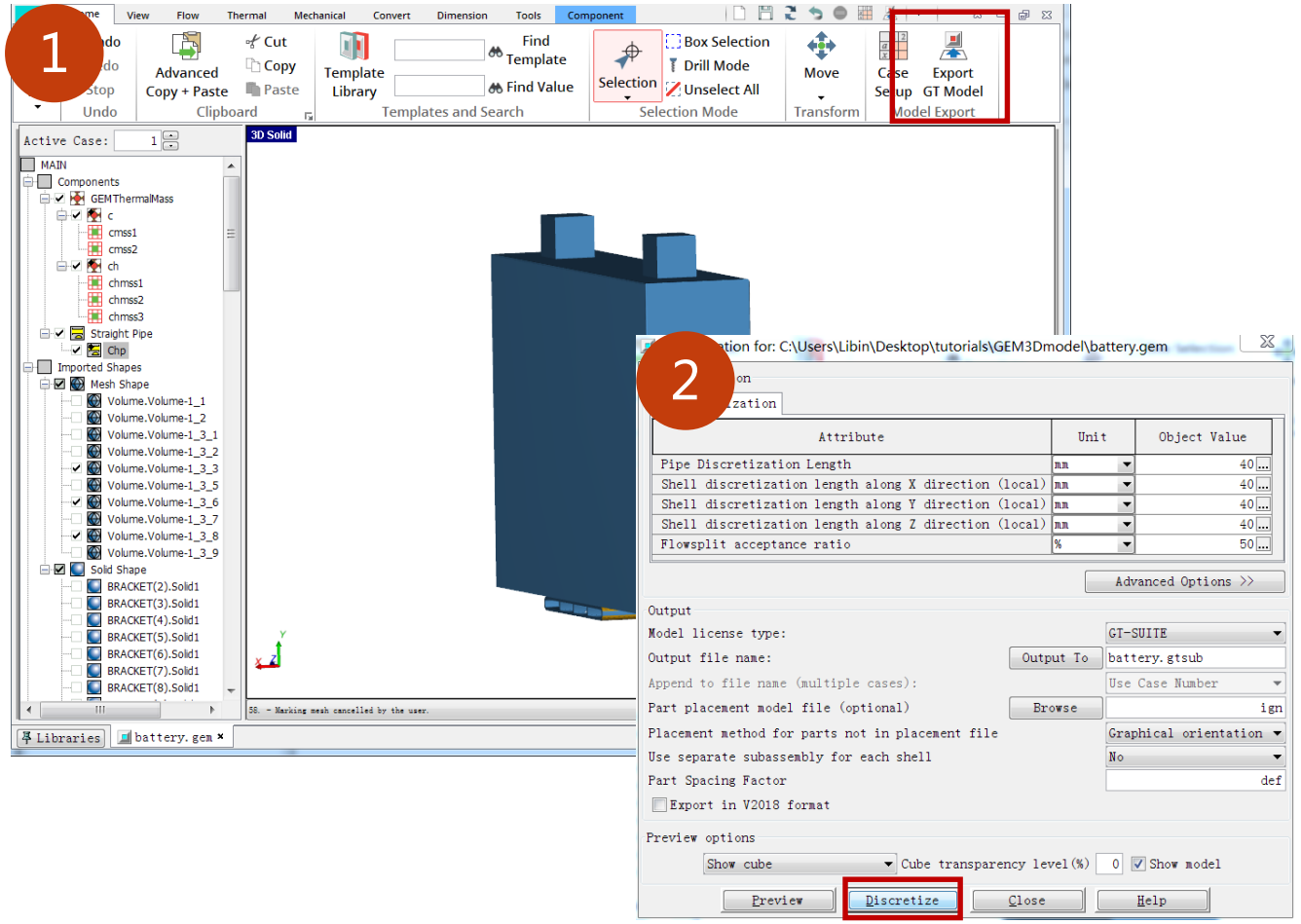
- 预留换热面
  1. 选择零件
  2. 换热面选择

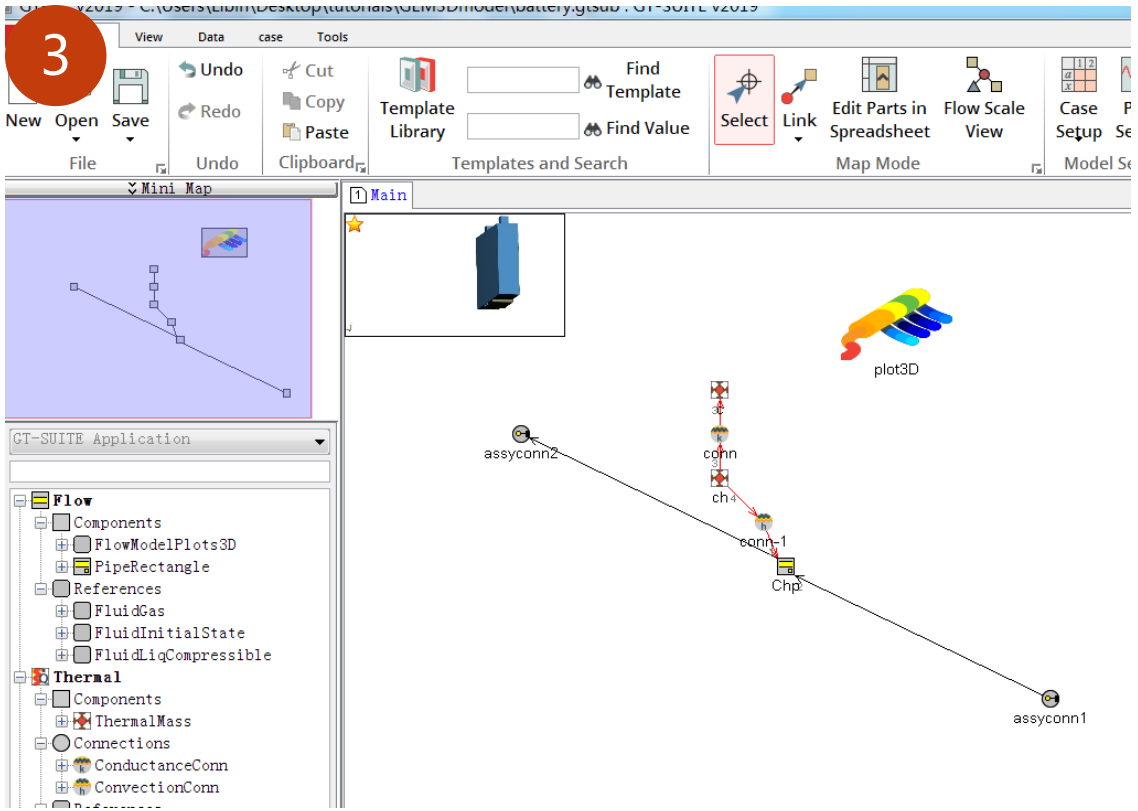




GEM3D数模转换

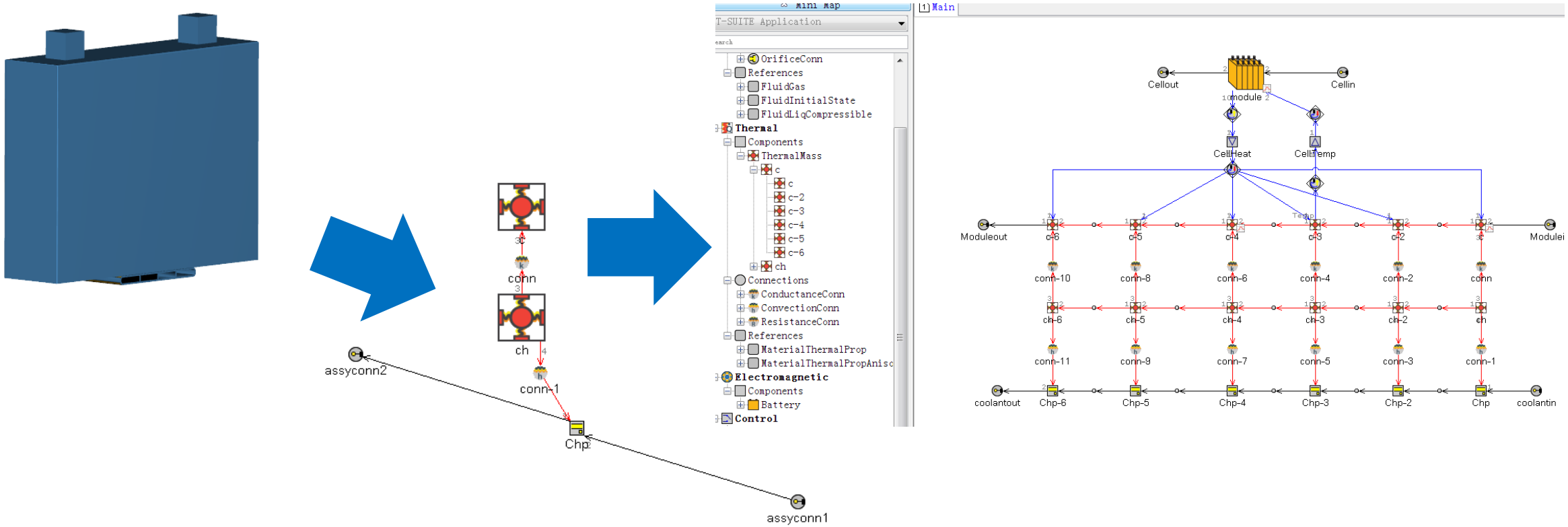
- GTISE模型导出





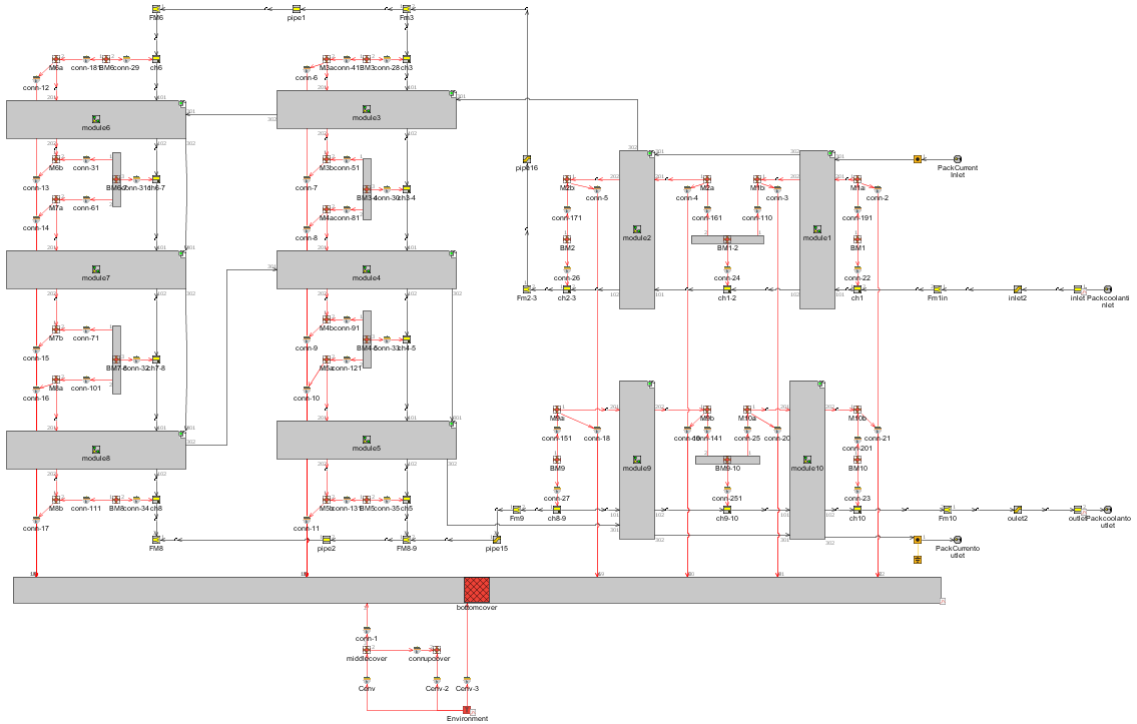
GTISE模组封装

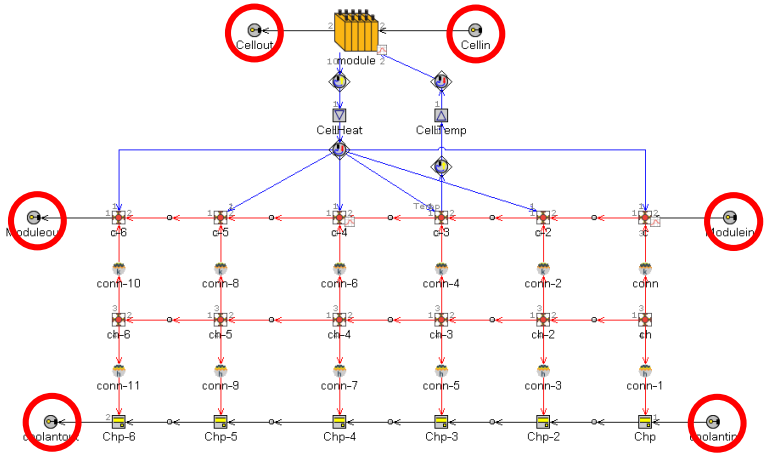
- 问题：电芯数量>100，每个单独转换不现实
- 解决方案：按照电池包组装顺序逐级建模
  - 电芯（GEM3D）->电芯（GTM）->模组（GTM）->整包（GTM）



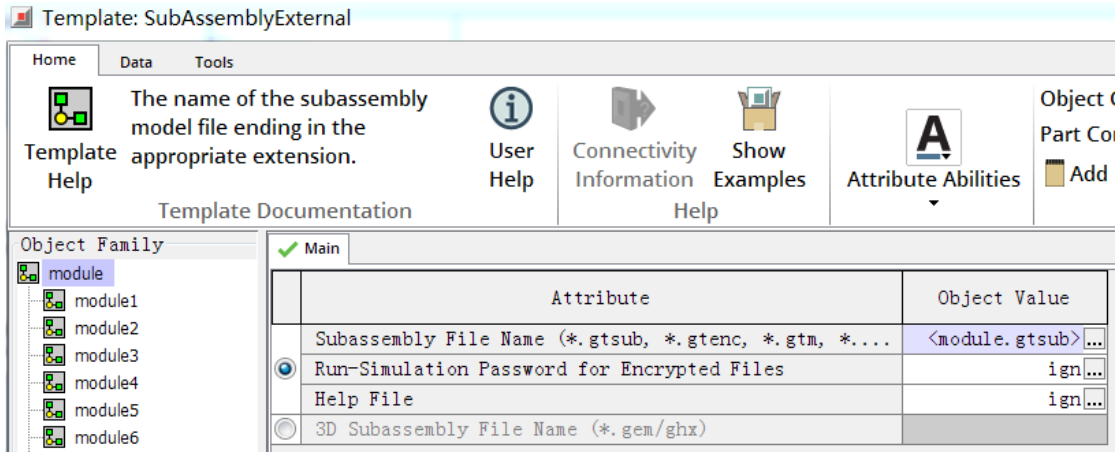
GTISE电池包封装

- 问题：电池整包界面过于杂乱，界面如何调整
- 解决方案：使用子模型调用
  - 逻辑清晰
  - 修改方便





○ 主模型连接点



发热源

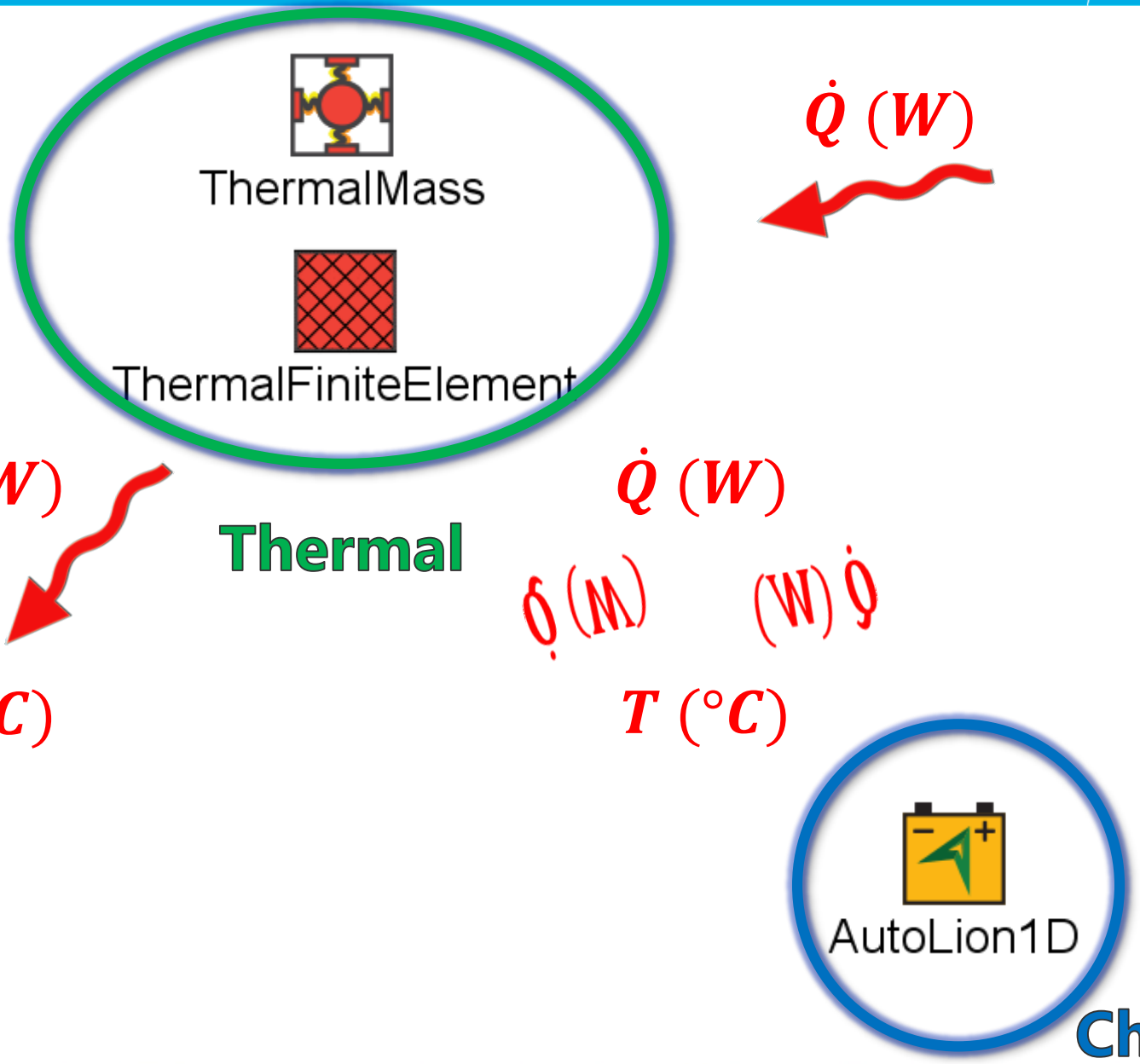
① 热量

② 等效电路模型

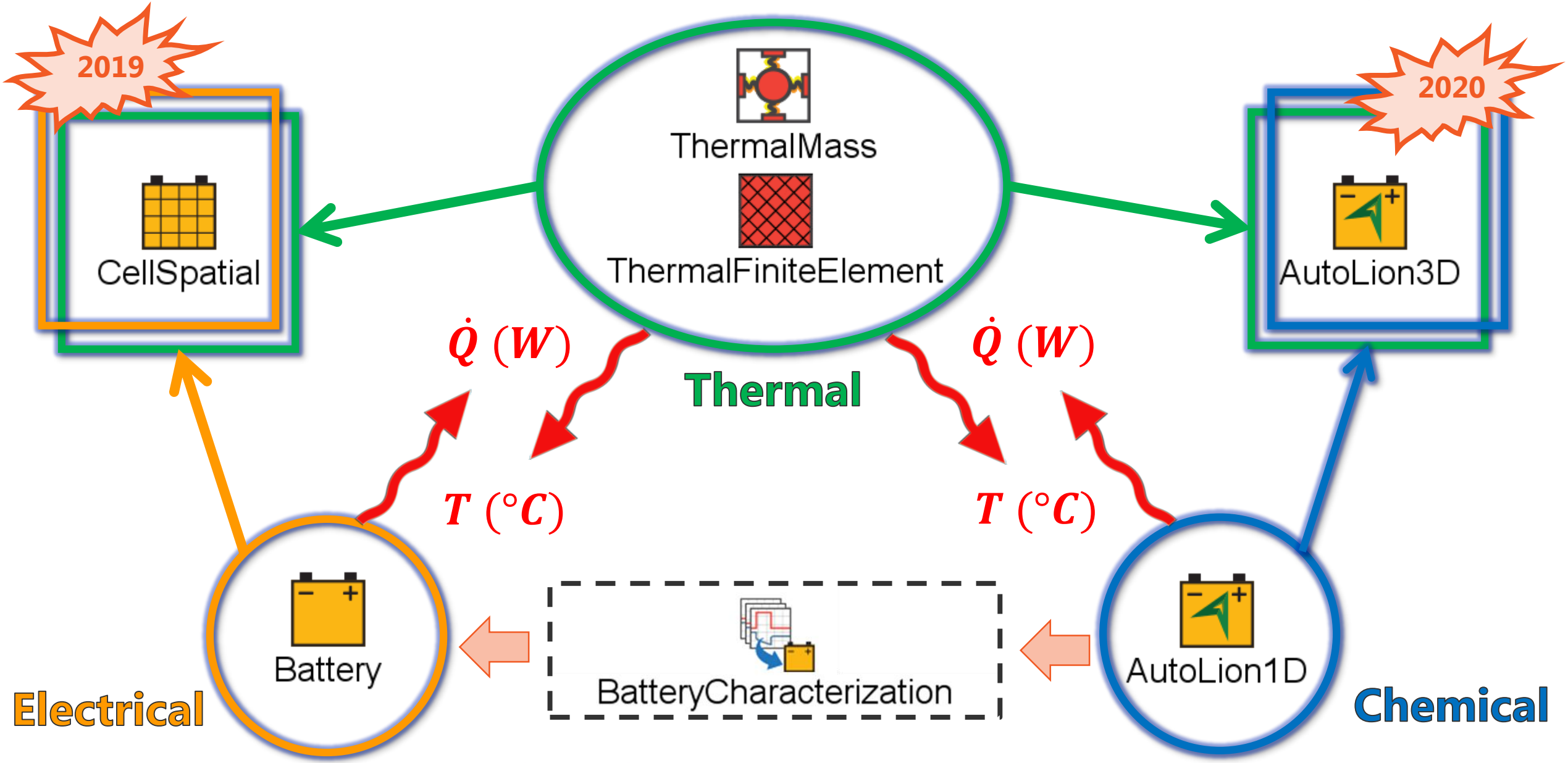
- 热-电耦合

③ 电化学模型

- 热-化耦合

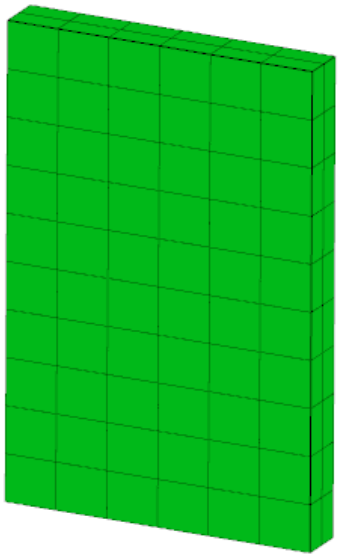


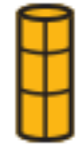
热-电耦合与热-化耦合

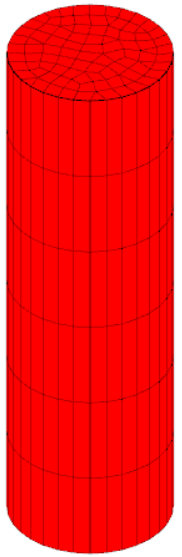


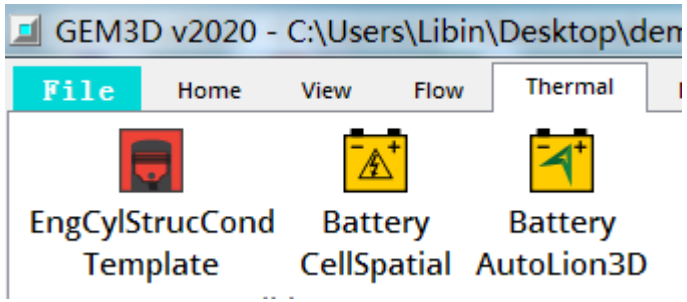
热-电耦合模块

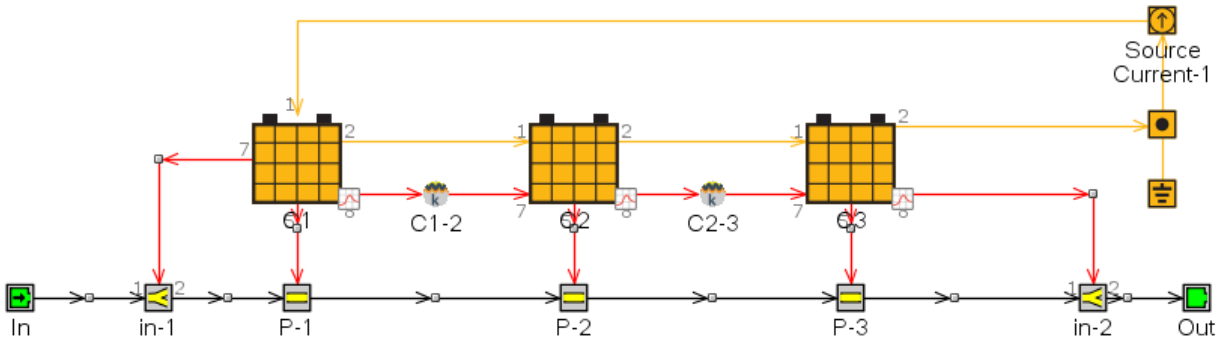
- 热电耦合
  - 自动划分热路网格、电路网格
  - 模拟电极电阻
  - 支持GEM3D界面建模

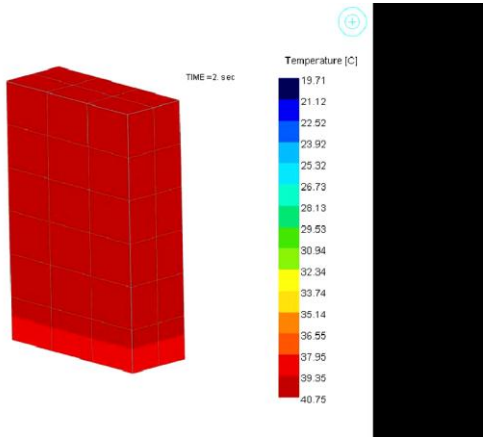




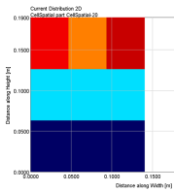


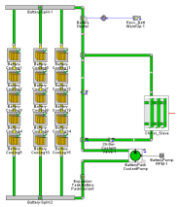


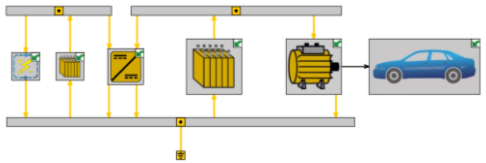




不同层级模型应用场合







Modeling Level

Battery AutoLion1D

ThermalMass

1D

Battery AutoLion1D

ThermalFiniteElement

1D/3D

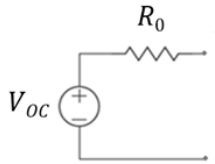
CellSpatial

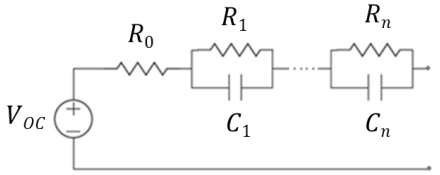
3D

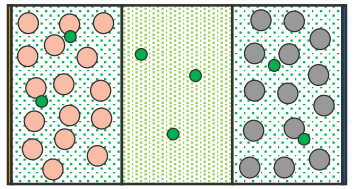
AutoLion3D

3D

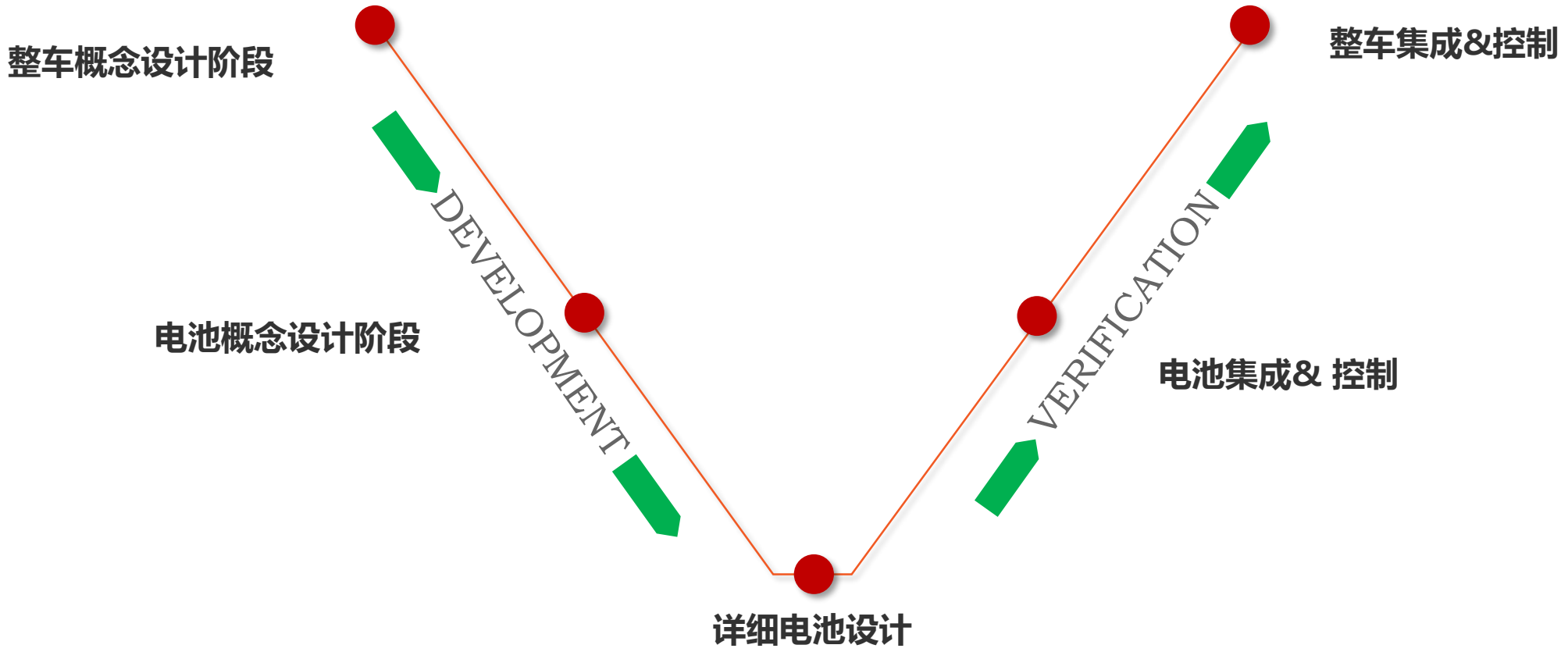
Simulation Run Time







整车开发流程



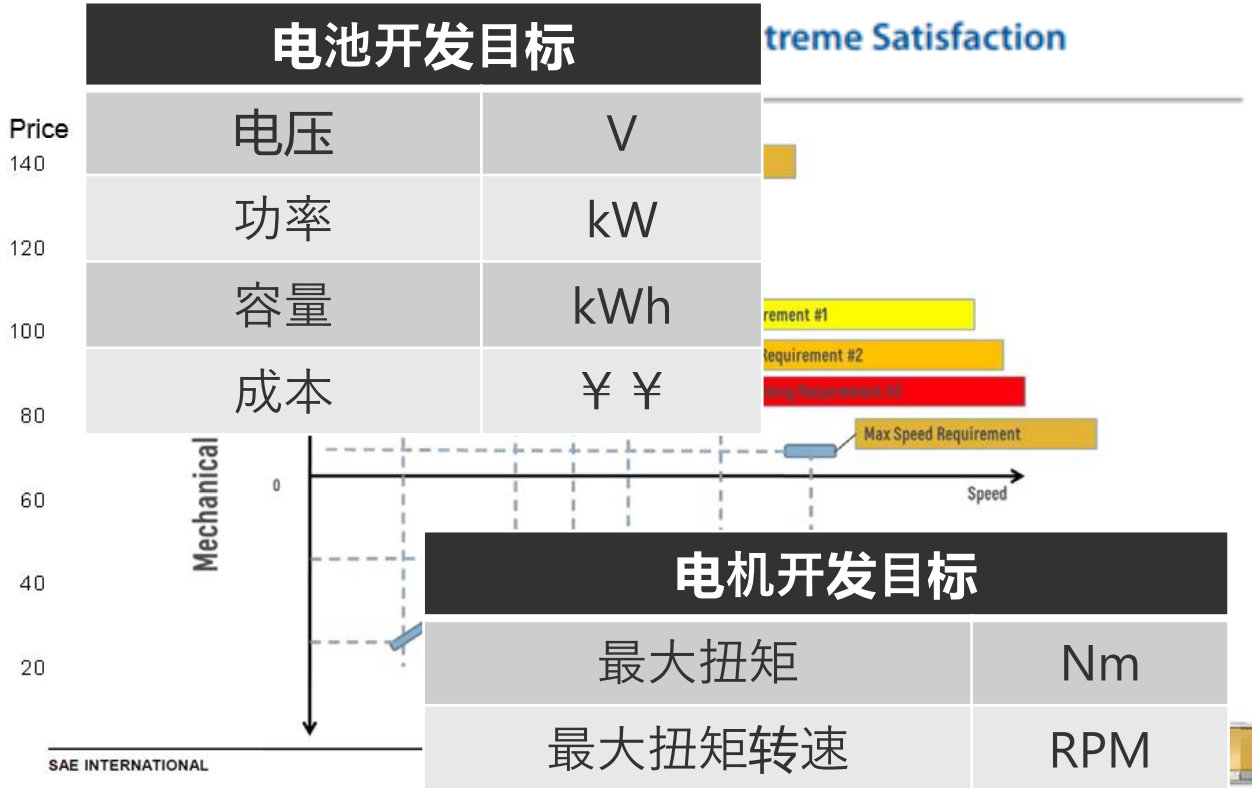
整车概念设计阶段

输入

整车开发目标:

- 续航里程
- 动力性
- 开发成本

电池开发目标	
电压	V
功率	kW
容量	kWh
成本	￥￥



电机开发目标	
最大扭矩	Nm
最大扭矩转速	RPM
最大功率	kW
最大功率转速	RPM
成本	￥￥

参考文献: Ga
SAE HEV
Survey Result

输出

整车设计方案
电池开发目标
电机开发目标

GT-SUITE在整车概念设计阶段的应用

GT-ISE v2018 - C:\Users\gtilap\Desktop\Joe\HEV Marketing\Electric_Vehicle.gtm : GT-SUITE v2018 *

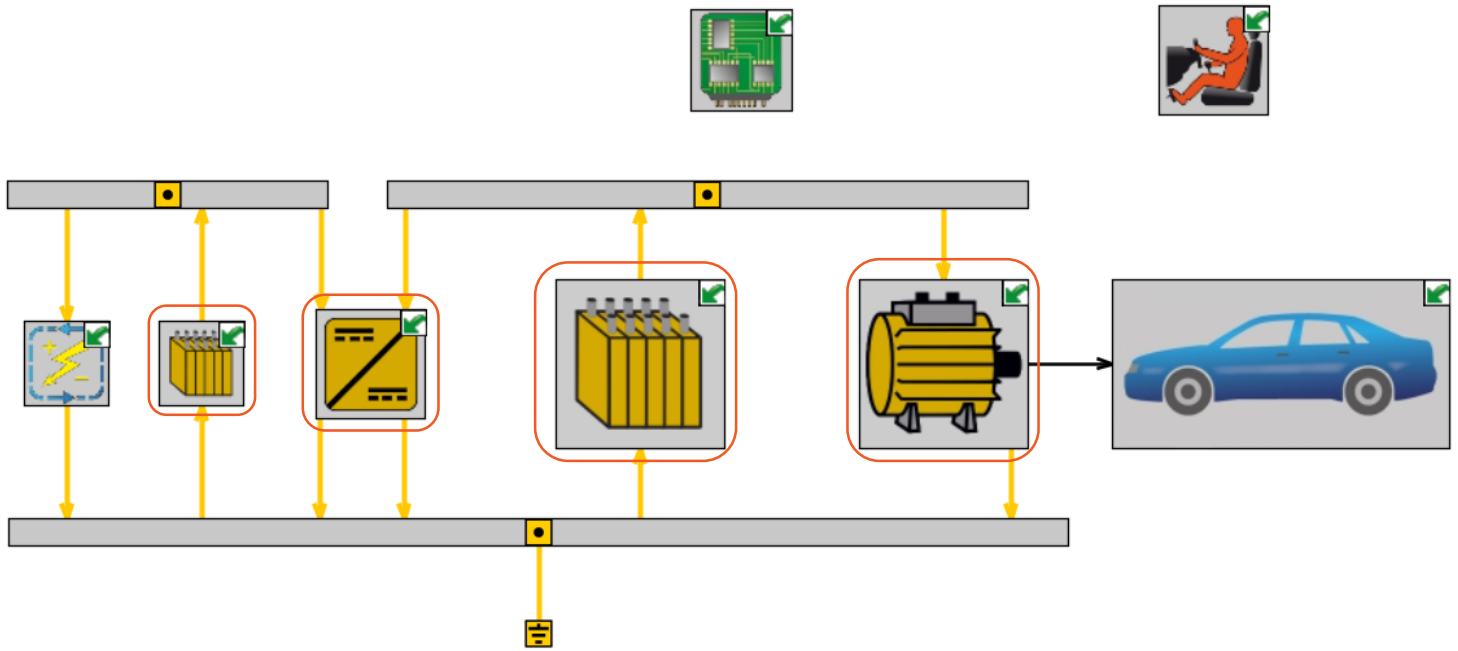
File | Home | View | Data | Tools | INHOUSE

New | Open | Save | Undo | Redo | Cut | Copy | Paste | Template Library | Find Template | Find Value | Select | Link | Edit Parts in Spreadsheet | Flow Scale View | Case Setup | Run Setup | Plot Setup | Output Setup | Advanced Setup | Optimization | Run | View Results | Preprocess | Stop | Distributed Queue

File | Undo | Clipboard | Templates and Search | Map Mode | Model Setup | Run

Main | Battery | Inverter_Motor | Vehicle | DC-DC | 12VBattery | Aux | DRIVER | Supervisory_Controller

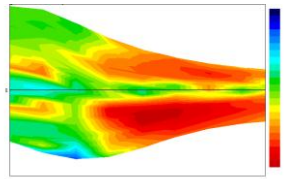
Electric Vehicle



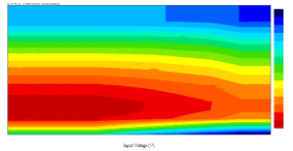
整包等效电路参数

基于MAP 电机&控制器

电机 & 电机转换器
效率Map



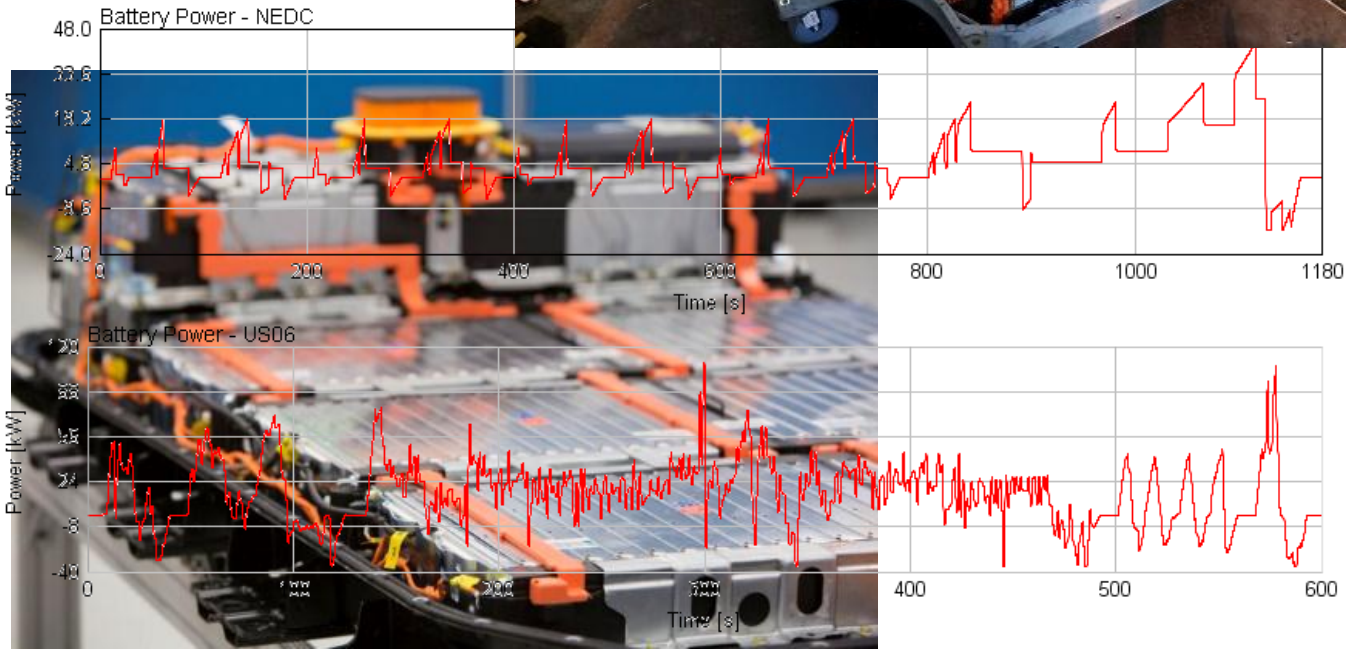
DC-DC转换器:
效率Map



Libraries | Mild_Hybrid.gtm | P2_Hybrid.gtm | Series_Hybrid.gtm | TTR_Hybrid.gtm | Electric_Vehicle.gtm

电池概念设计

- 电压
- 功率
- 容量



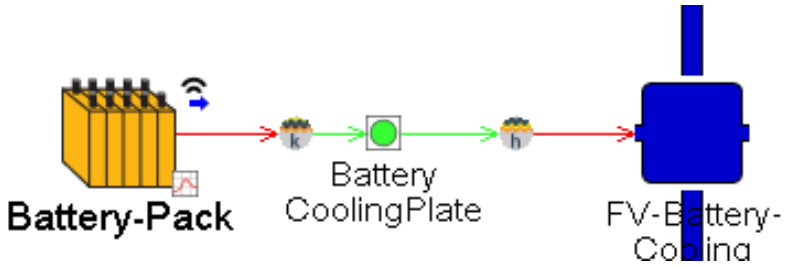
输入

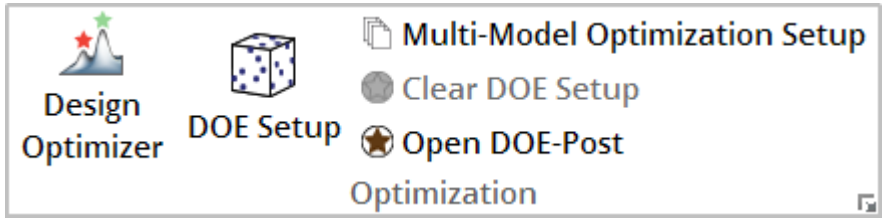
电池设计要求
功率需求
寿命需求
充电要求
温度要求

输出

电极材料
电芯设计
模组设计
电池包布置方案
冷却需求

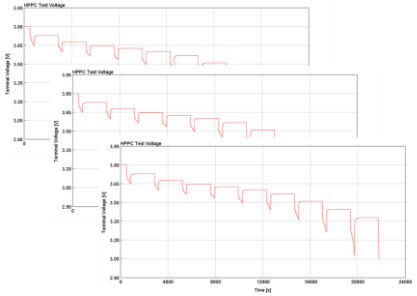
GT-SUITE在电池概念设计阶段的应用

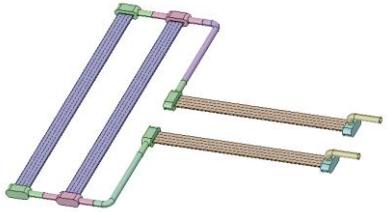




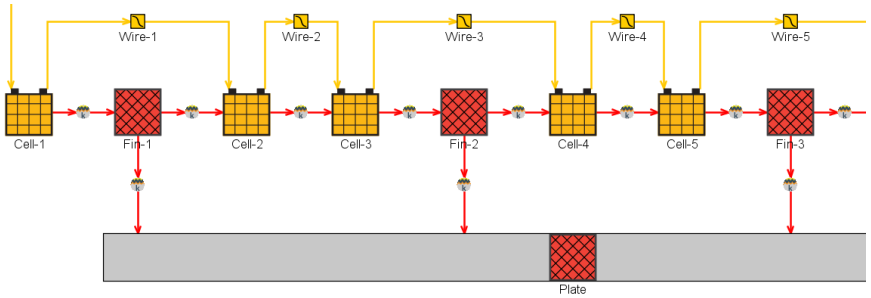
水泵规格

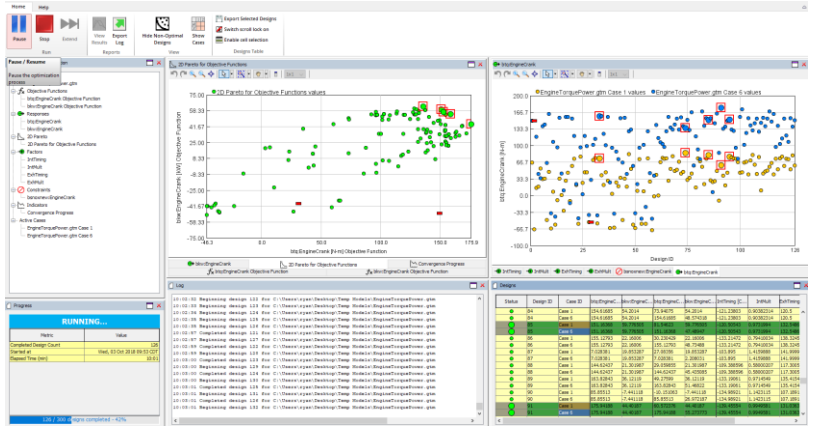
AutoLion
Lithium-ion Battery Simulation

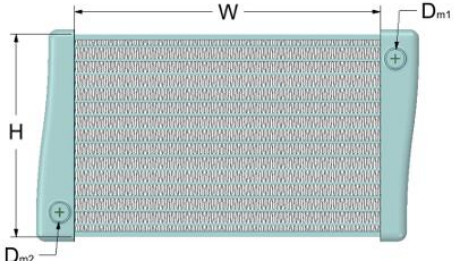




冷板布置

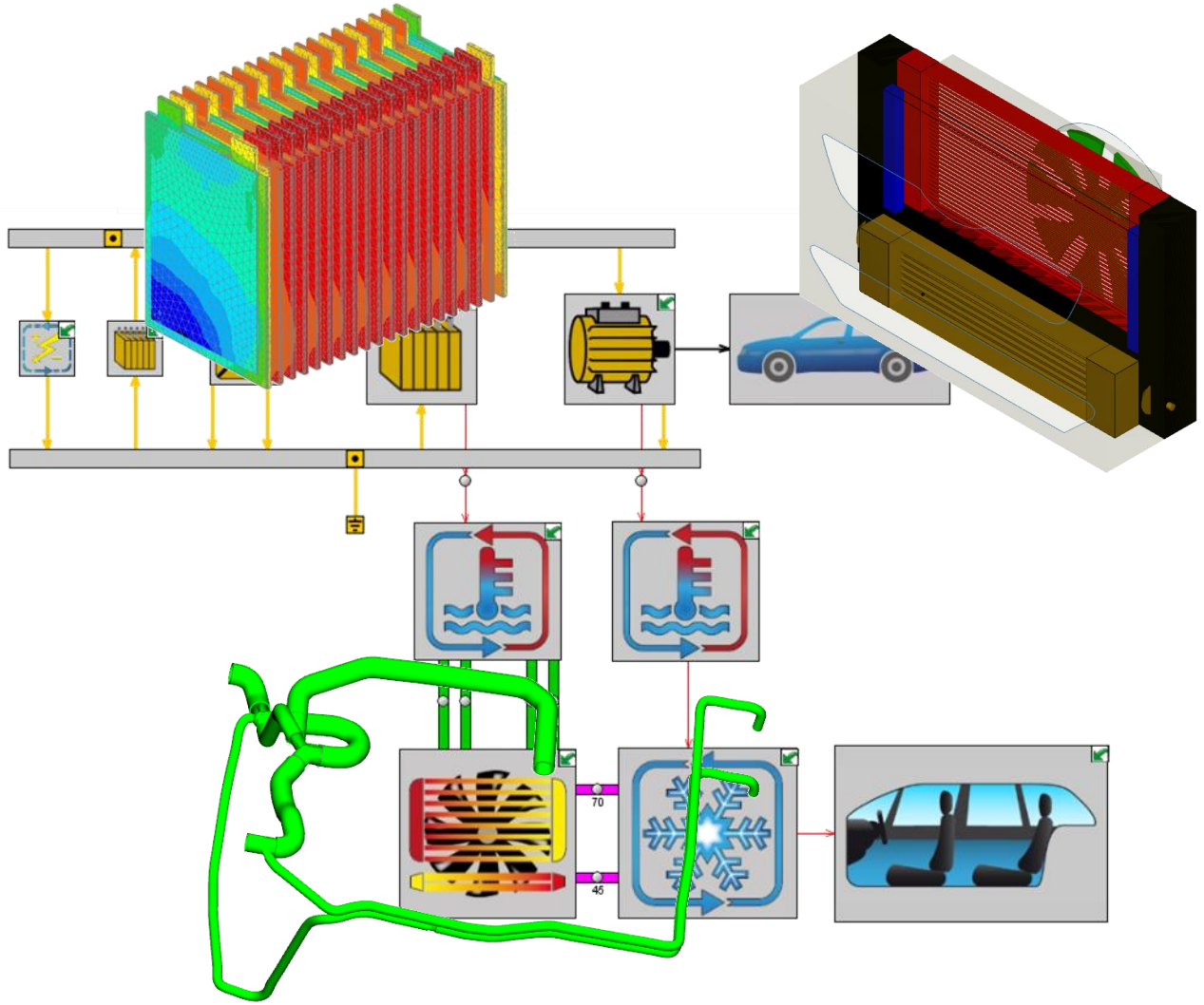






散热量

整车系统集成&控制



输入

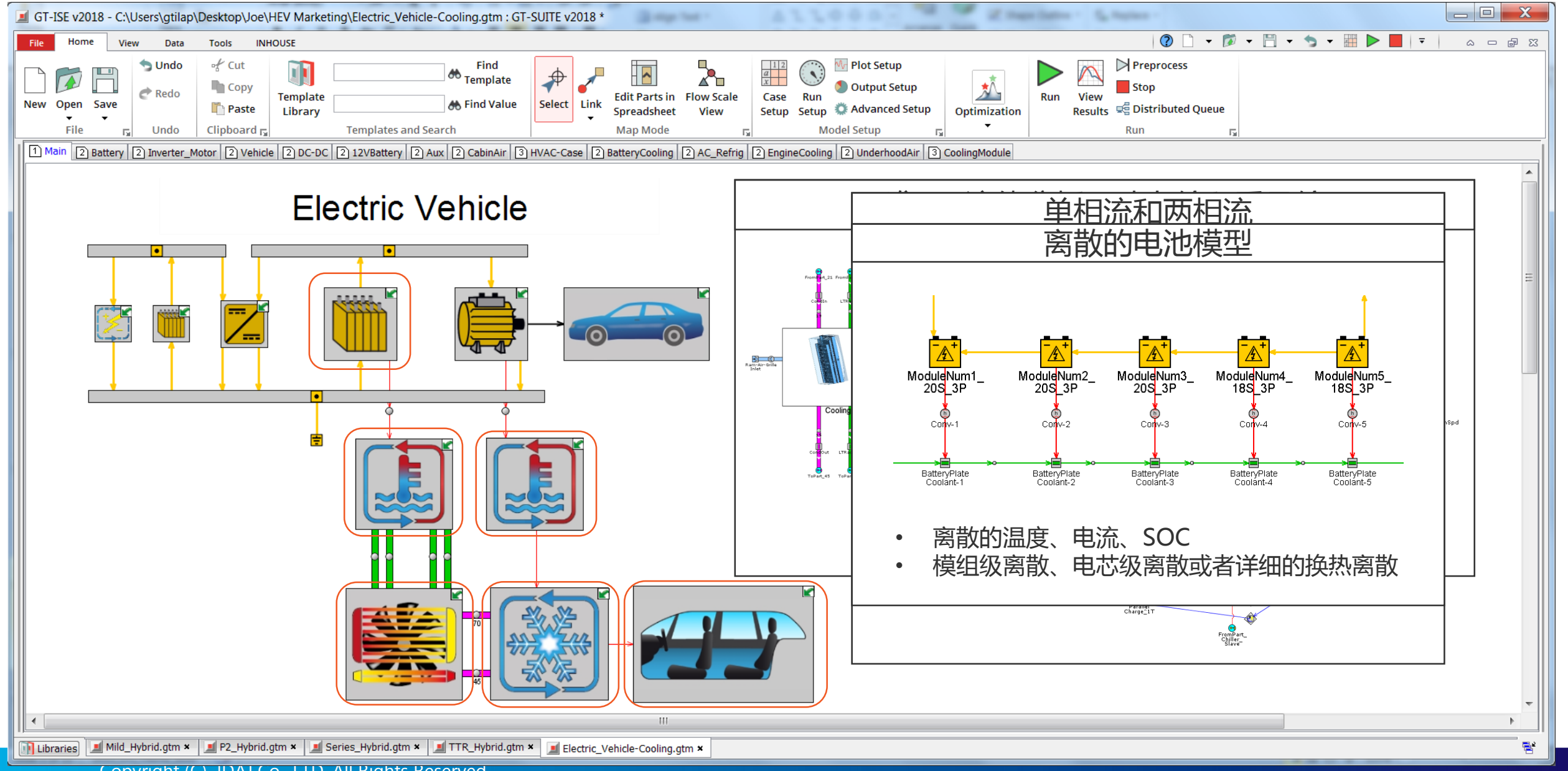
快速计算3D/1D 模型

- 电池
- 电机
- 动力总成 & 整车
- 换热器
- 系统管路

输出

续航里程
电池温度
控制策略优化
驾驶员舒适性

GT-SUITE整车能量管理



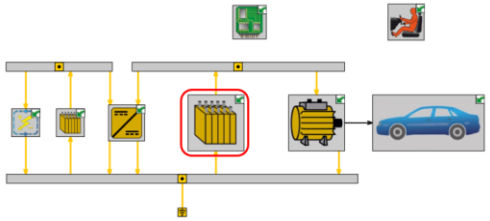
整车开发平台

Model Based Design

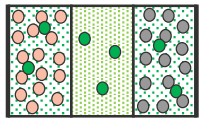
DEVELOPMENT

VERIFICATION

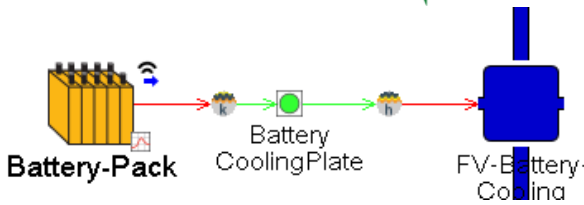
整车概念设计阶段



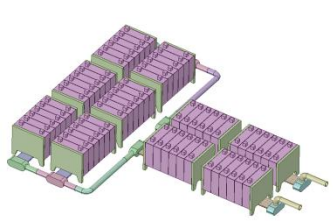
电池概念设计阶段

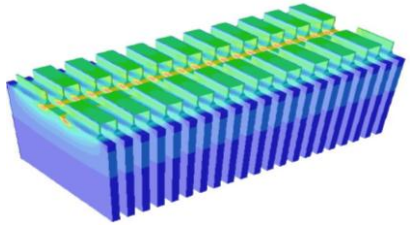


AutoLion
Lithium-ion Battery Simulation

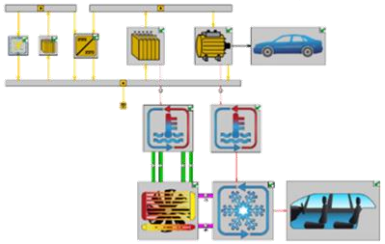


详细电池设计

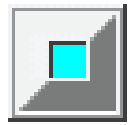


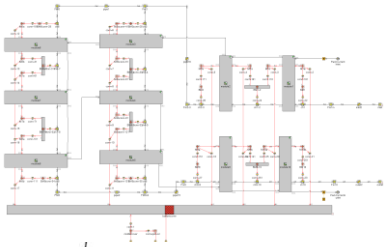


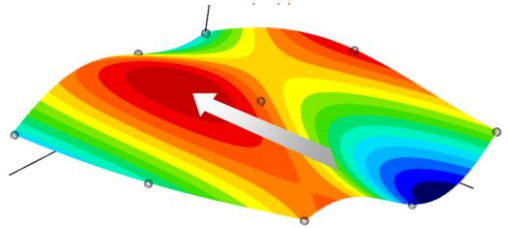
整车集成&控制



电池集成& 控制







要点总结

- 电池热管理系统在新能源汽车开发过程中尤为重要
- 针对不同的分析目的，需要使用不同层级的模型
- 准3D电池热管理模型可有效应用于电池热管理系统开发
- GT-SUITE是电池-整车系统开发的理想工具
  - 具有完备的部件库
  - 快捷的前处理工具
  - 完整的整车能量管理平台
  - 优化和DOE

超过600+的客户

Tesla
Tesla Energy
Lucid Motors
Karma Automotive
Nikola Motor Co
SF Motors
Zoox
Hyliion
Exagon Motors

Chrysler
General Motors
Ford
Porsche
PSA
Renault
Daimler/AMG
Volkswagen Group
Volvo Cars
Harley Davidson

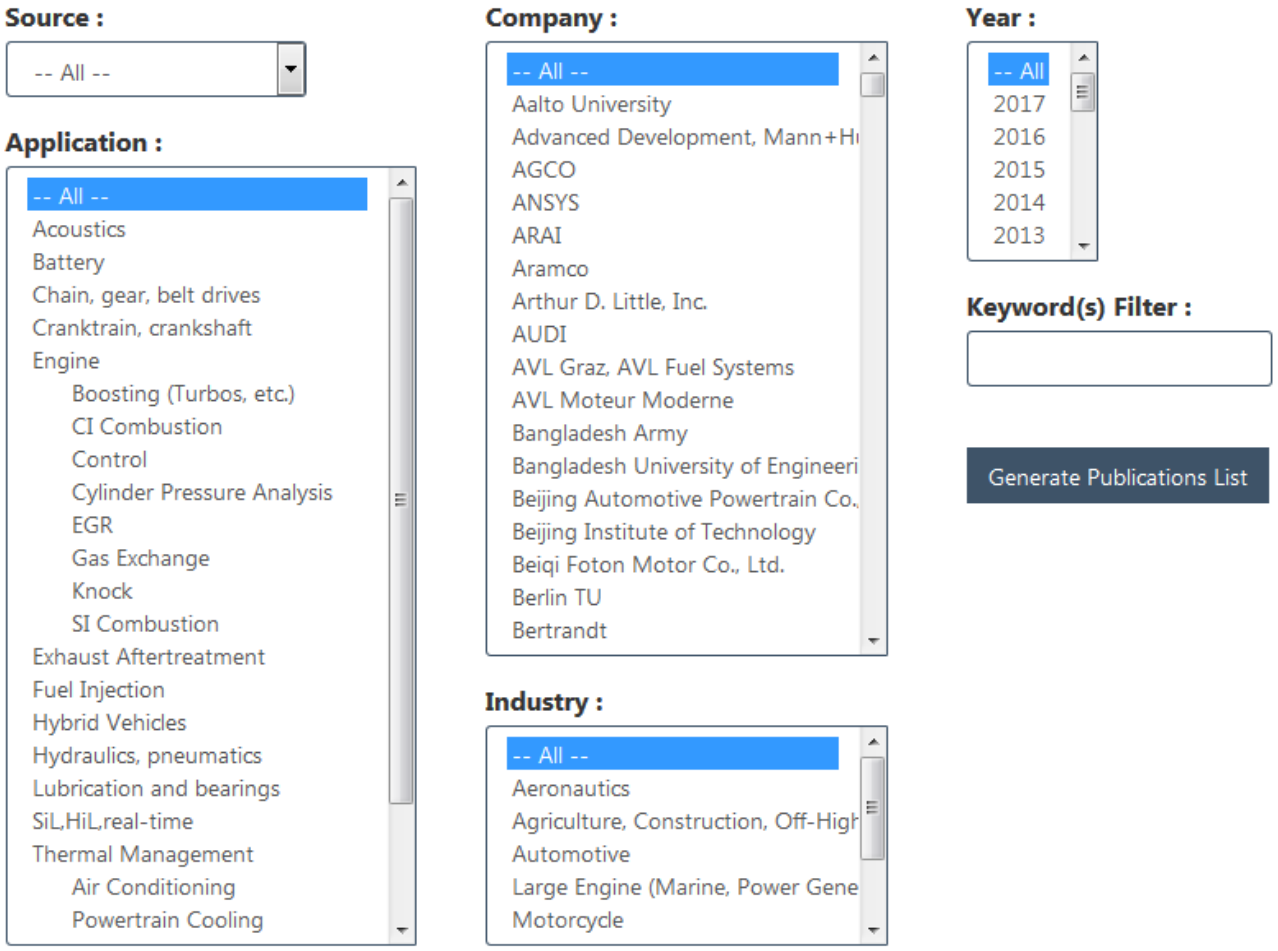
Honda
Toyota
Nissan
Hyundai
Daewoo
Isuzu
Ssangyong
Mazda
Subaru
Suzuki
Yamaha
Dalian Diesel

Audi/Lamborghini
Bentley
BMW
BOSCH
FCA/Ferrari
JLR
Delphi

GT-SUITE新能源客户

GT-SUITE使用情况

- 超过 800 篇文章收录:
- 网址：
  https://www.gtisoft.com/gt-suite/publications/



感谢倾听
期待与您的进一步合作 ☺

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