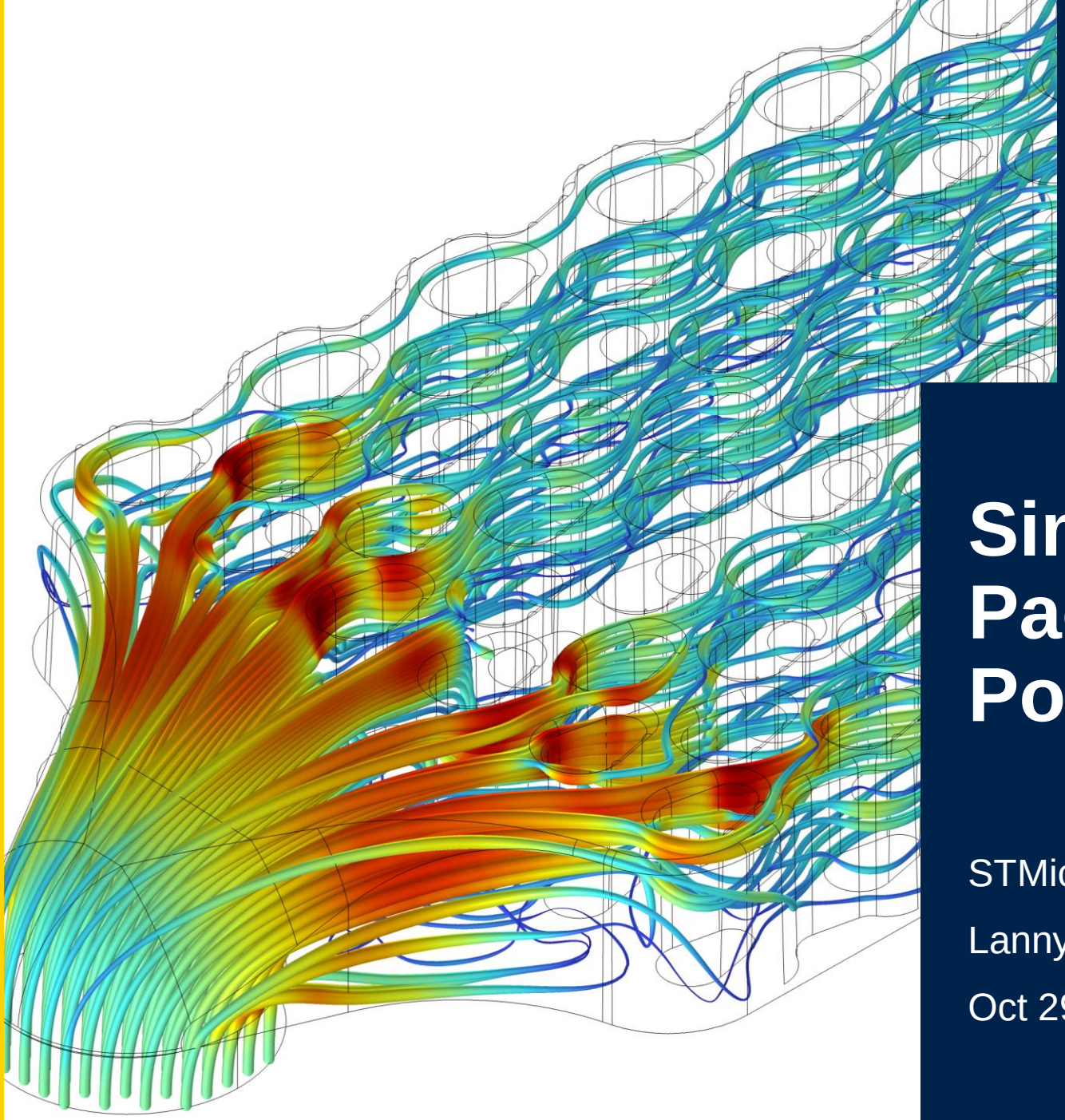


INDUSTRIAL SUMMIT 2024
POWERING YOUR SUSTAINABLE INNOVATION

Simulation Augmented Package R&D For SiC Power Electronics

STMicroelectronics | Advanced Power Packaging Lab

Lanny LIANG, Qingming FENG

Oct 29, 2024

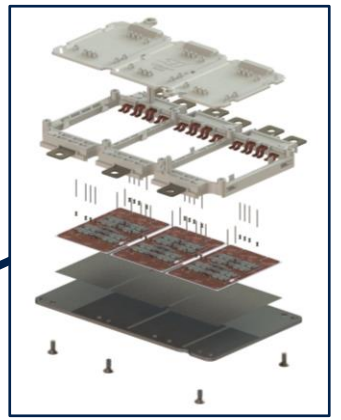
Agenda

1. Power Package Design
2. Simulation Method
3. Design Verification

Power Package Design

- Design for X
- Design considerations
- Design flow

Power Package Design



Testing

Manufacture

Sustainability

Design for X

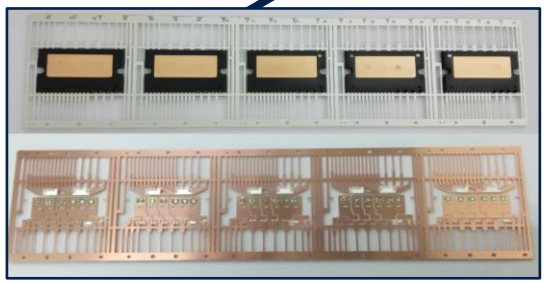
Assembly

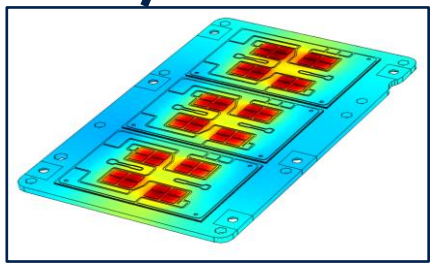
Cost

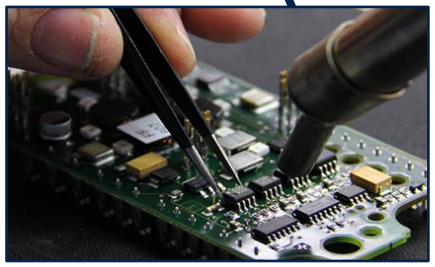
Reliability

Performance

Quality







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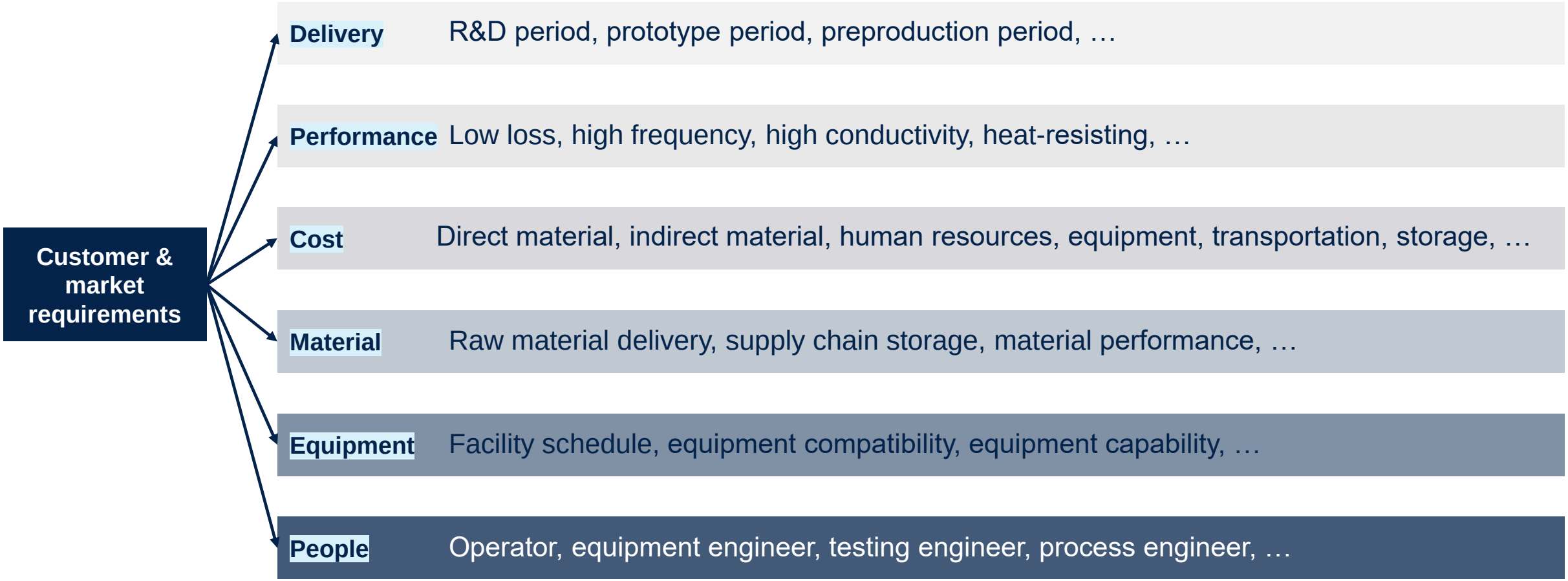
Power Package Design Considerations



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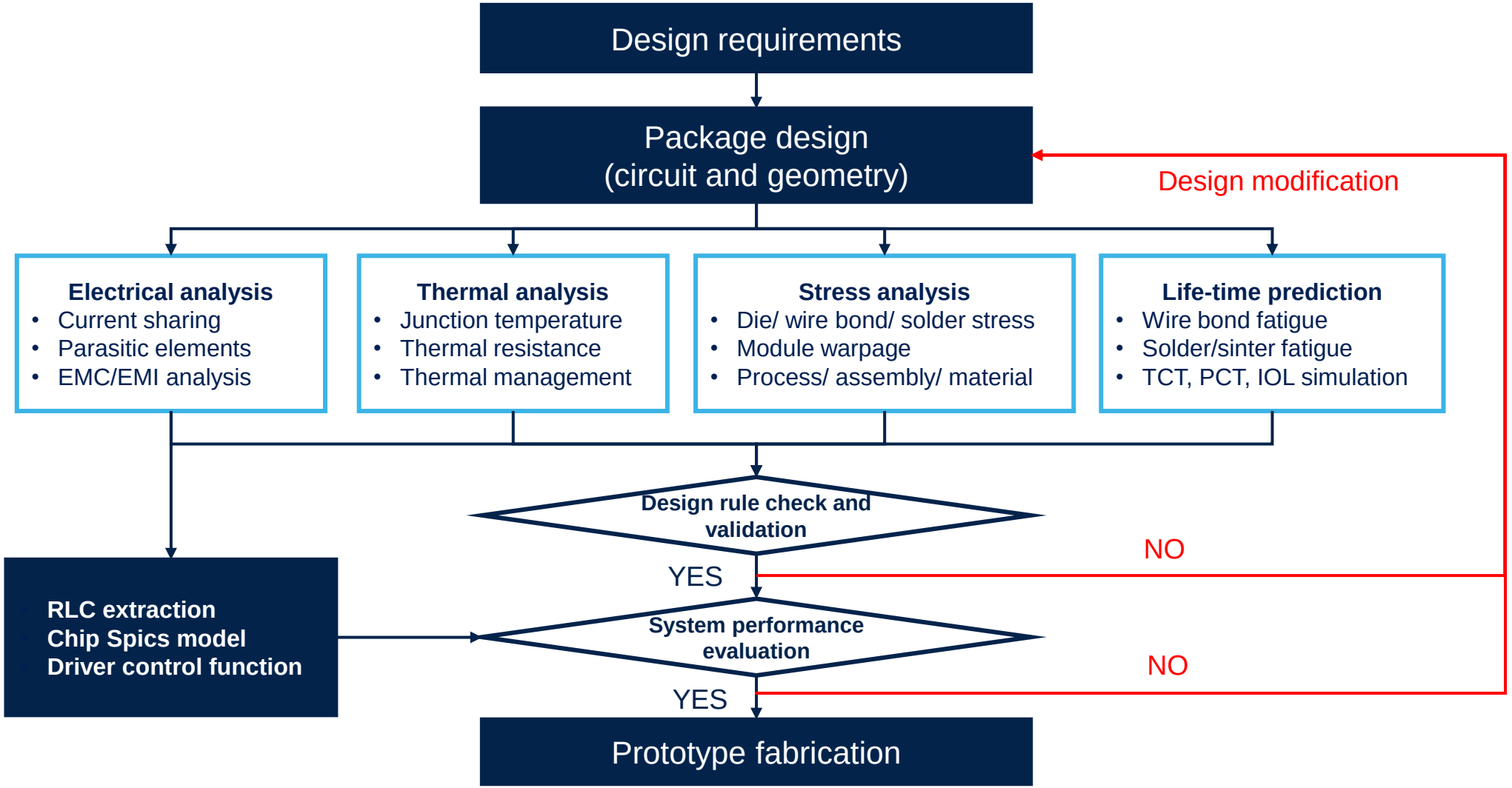
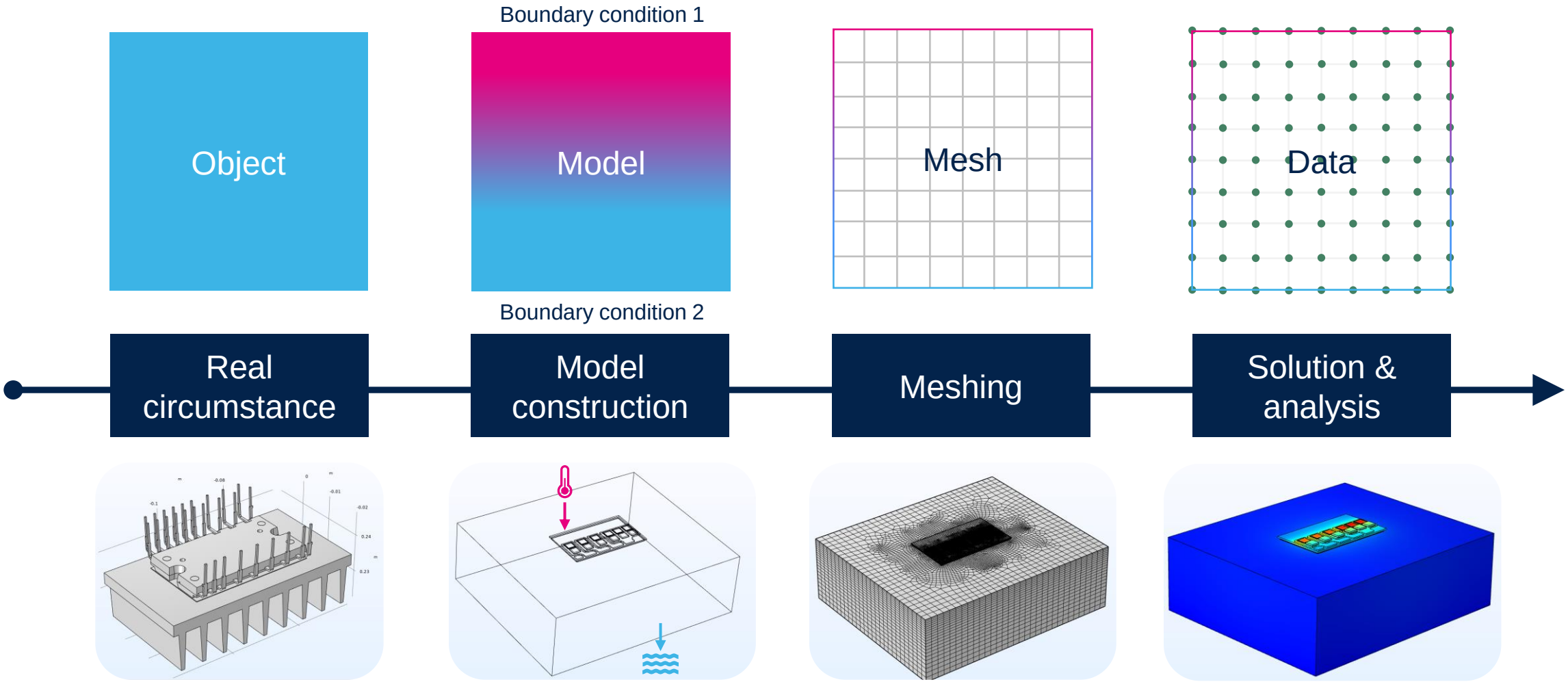
Power Package Design Flow



Simulation Method

- How it works?
- Why we use?
- Where to use?

Simulation Method



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How We Use Simulation

- Problem definition
- Model construction
- Mesh generation

Preprocessing

Processing

- Material description
- Boundary conditions
- Solver setting

- Simulation results
- Data analysis
- Model optimization

Postprocessing

Software

Ansys

Engineering simulation software

Simulation platform recognized by customers, widely used in industry with sufficient references.

COMSOL

Software for multiphysics simulation

FE analyses including mechanical, electrical, thermal, simulations, and multiphysics coupling.

SIMetrix TECHNOLOGIES

Circuit design & simulation

SPICE simulation tool for evaluating electrical performance under specified condition.

MathWorks

Makers of MATLAB & Simulink

Programming tool for data analysis and algorithm development.

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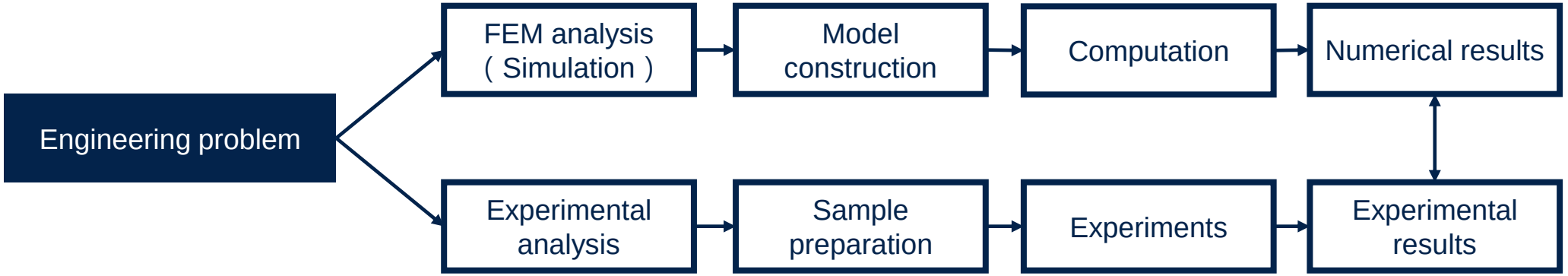
Why We Use Simulation



Result comparison	FEM analysis (Simulation)	Experimental analysis
Time	Shorter time • Number & quality of mesh • Complexity of the constitutive model (multiphysics & nonlinearity) • Material & geometrical nonlinearity	Longer time • Specimen preparation • Repeated experiments • Design of experiments
Accuracy	Accuracy depending on: • Mesh quality • Convergence accuracy of the solver • Accuracy of material & geometry	Accuracy depending on: • Number of repeat experiments (statistic fitting) • Equipment accuracy • Consistency of experiments

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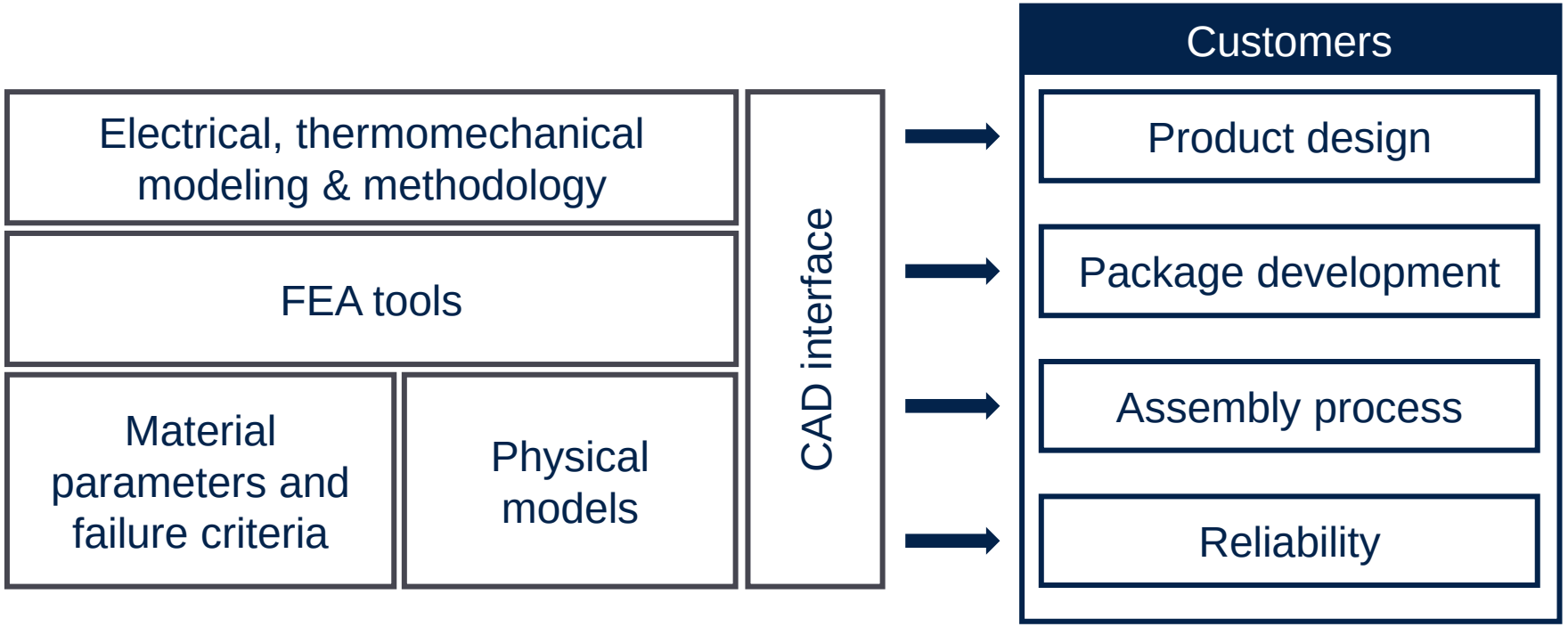
Where We Use Simulation



The basic mapping of the modeling and simulation in power module industry

Modeling overall goal	• Support technology development and optimization • Reduce development time and costs

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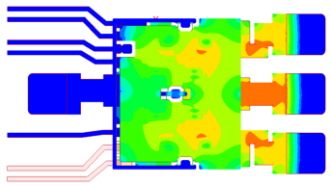
Design Verification

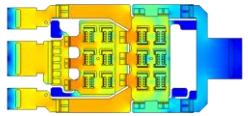
- Overview
- Electrical simulation
- Thermal simulation
- Thermal CFD simulation

Design Verification



Electrical simulation

- Stray inductance
- Current map
- Glitch & oscillation check
- Unbalanced dice/EMC/EMI

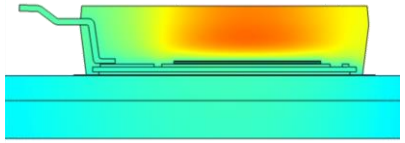


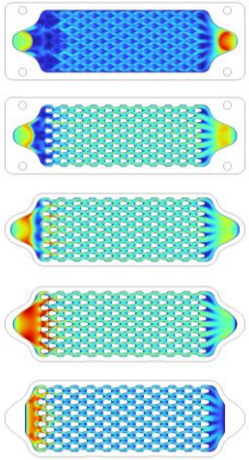
Electro-thermal

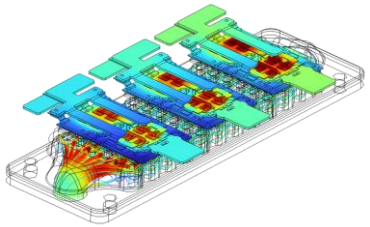
- Busbar ampacity
- Power loss
- Joule heating

Thermal simulation

- Thermal resistance
- Junction temperature
- Thermal map
- Transient thermal





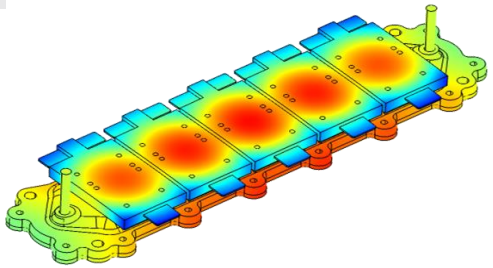


Thermal CFD

- HTC map
- Flow temperature
- Transient T_j

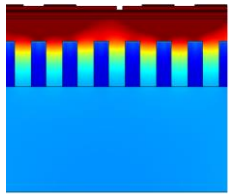
Thermomechanical

- Warpage
- Residual stress
- Lifetime estimation



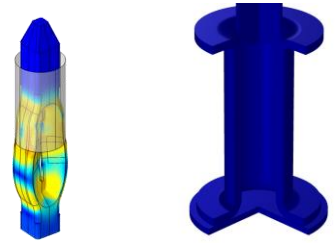
CFD simulation

- Pressure drop
- Flow velocity
- Moldflow
- Void defect



Mechanical simulation

- Structural deformation
- Stress status
- Fatigue
- Crack & delamination



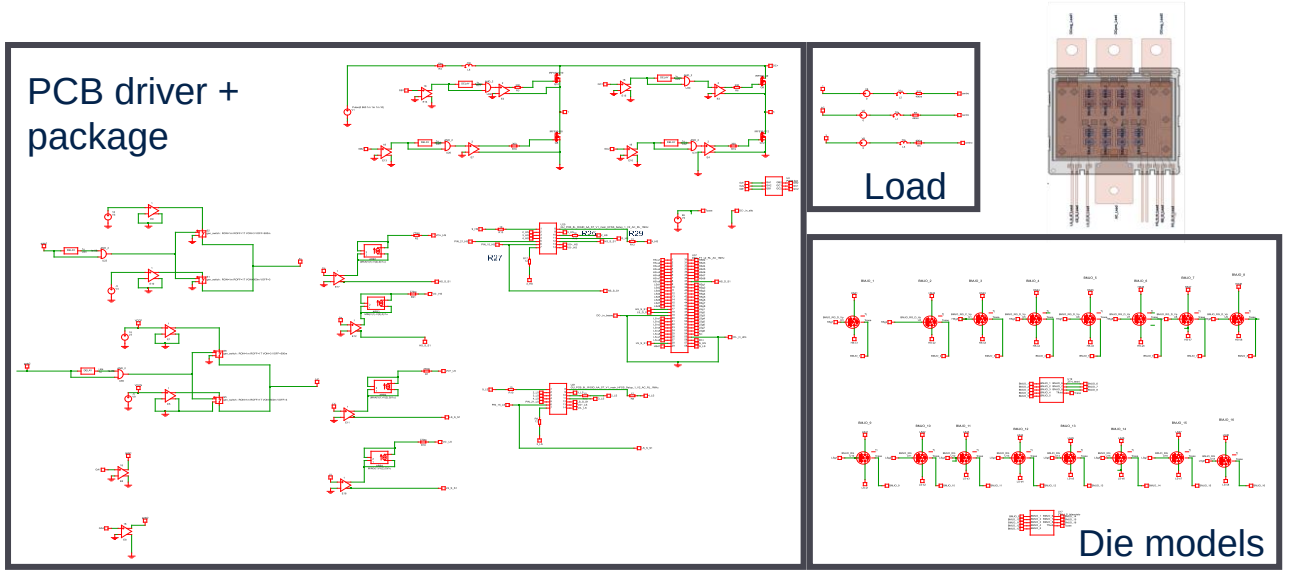
Design Verification - Electrical Simulation

For sole package:

- Double-pulse test is mainly used for package-level examination
- Main focuses are on the first turning-off and the second turning-on

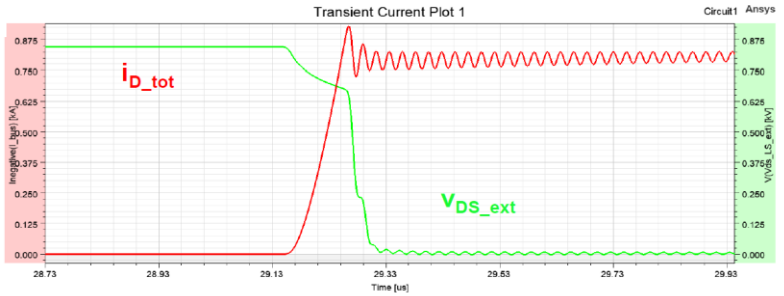
For integrated system:

- Both harmonic and dynamic loads can be examined
- Both system-level EMI and detailed power losses can be evaluated

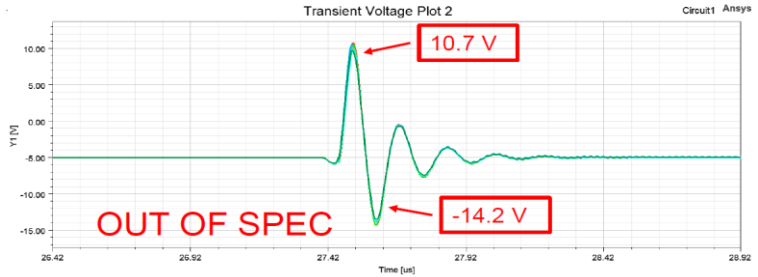


SPICE model structure of system level package electrical assessment

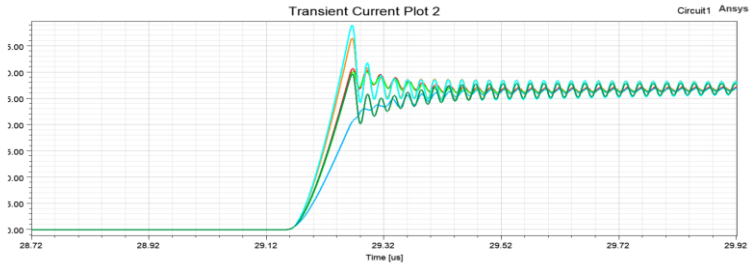
Results



I_D and V_{ds} during switching



V_{gs} of passive dice



Distributed current through individual die

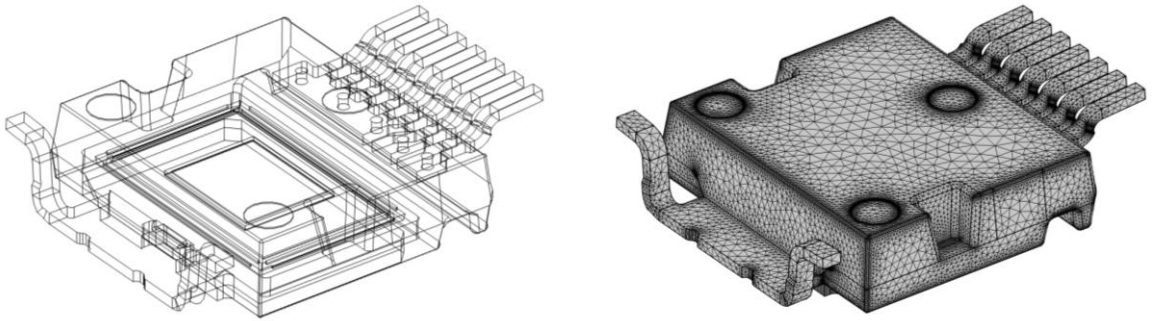
Design Verification - Thermal Simulation

Objective

- To identify potential high temperature in the structure
- To assess the heat exchange performance of the package
- To evaluate thermal resistance and thermal map
- To refine the package stack and layout

Link to reality

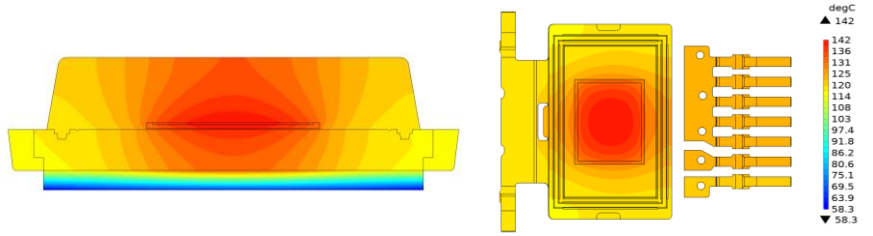
- Temperature-dependent material properties
- Dynamic thermal behavior
- Introduction of potential defect
- Standard-based model setup



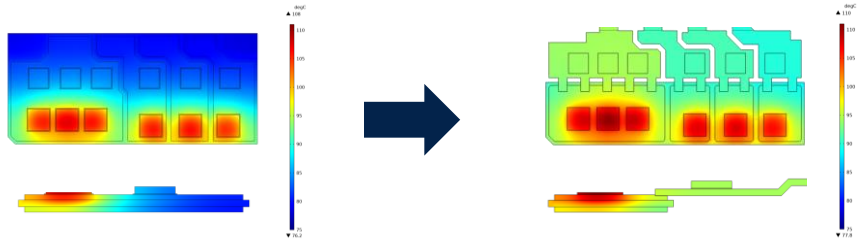
Example of package geometry and corresponding mesh

Results

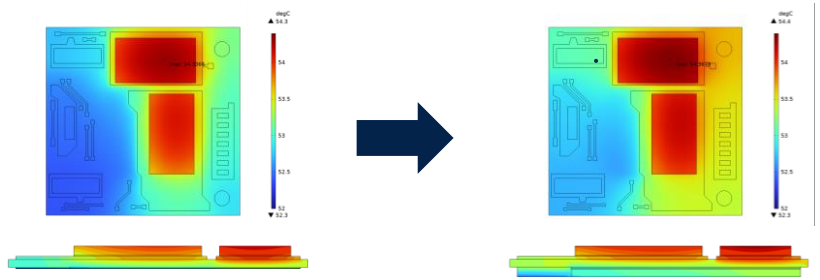
Thermal performance check



Design comparison



Material benchmark



Examples of thermal simulation results

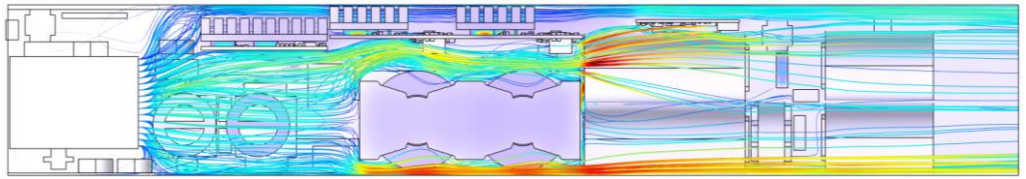
Design Verification - Thermal CFD Simulation

Why with CFD?

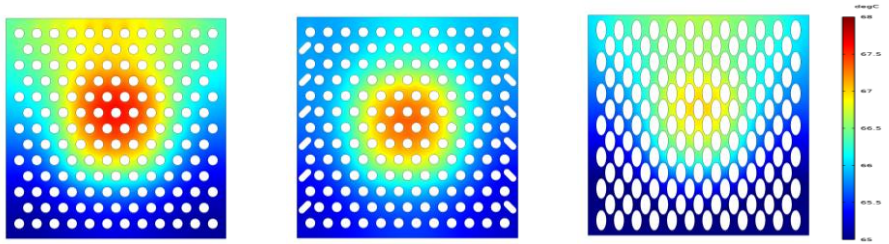
- To better simulate the convective heat exchange behavior
- To evaluate fluid-related properties
- To optimize the heat source arrangement
- To improve the flow channel design

Application

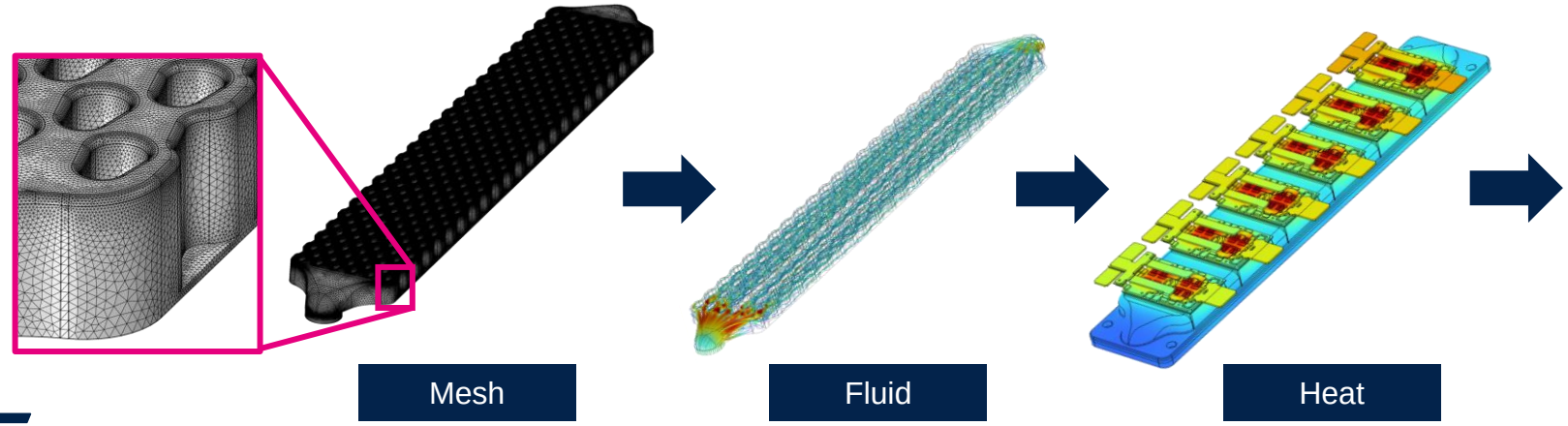
- System-level thermal performance assessment
- Benchmarking of cooling system designs



Example of system-level air cooling simulation



Thermal performance of different cooling plate layouts



Schematic plot of thermal CFD simulation process

Takeaways

Power package development in ST goes through a rigorous and detailed design and qualification procedure, including full life cycle requirements and manufacturing realities.

Simulation is a proven method to streamline workflows and is a powerful tool that enhances accuracy and accelerates the entire R&D effort.

Simulation is embedded throughout the design iteration and optimization processes for rapid evaluation in terms of electrical, thermal, and multiphysics analysis.

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