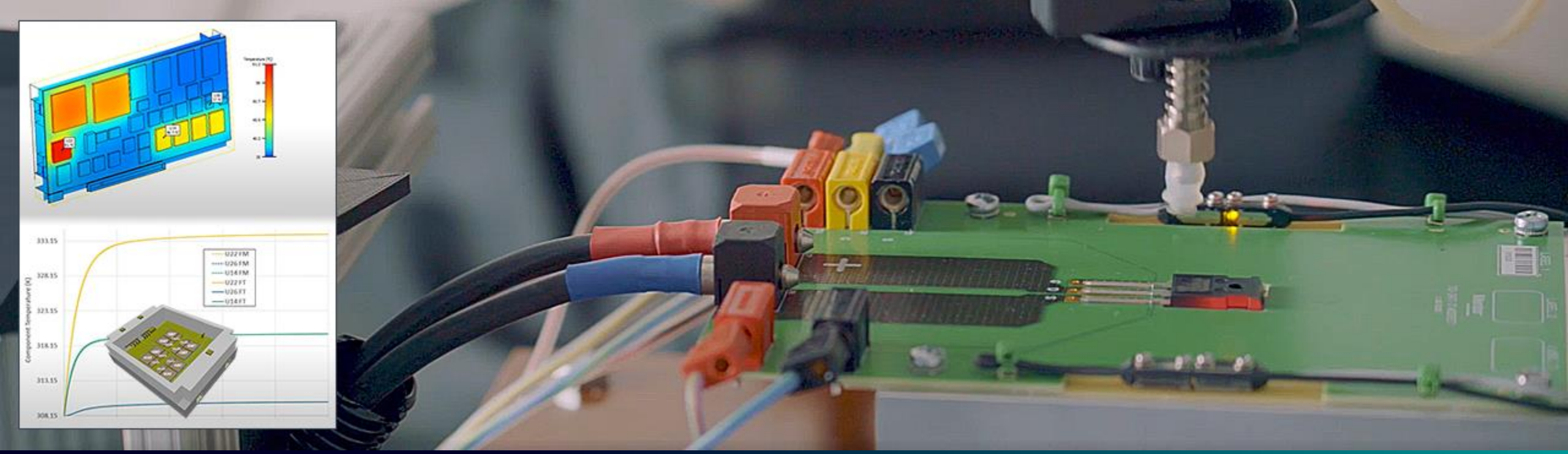

Characterization of power semiconductor devices

Antonio Caruso

Business Development Manager E&S – Power Electronics

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Power Electronics Trends

Brief Overview of:

- Electrothermal Simulation
- Thermomechanical Simulation
  - Application Example: FADEC
- Quality Testing and Reliability

Summary

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Power Electronics Trends

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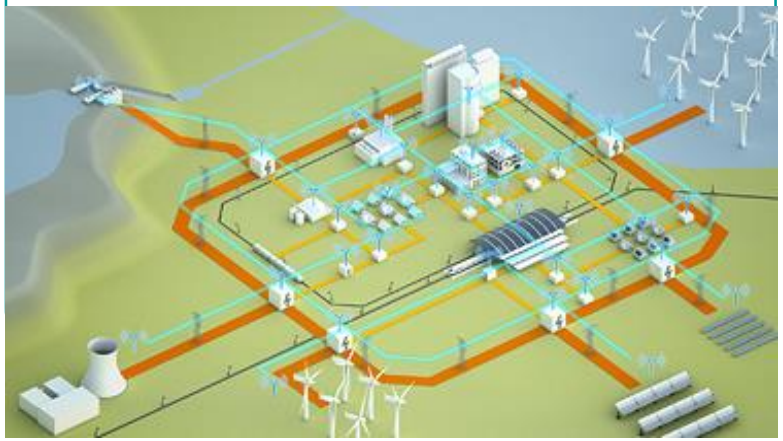
Power Electronics Trends

Smart Grid & Renewables



Challenges

HIGH-LEVEL SYSTEM INTEGRATION

SWaPC

STRINGENT RELIABILITY STANDARDS

Transportation

1900 Mercury arc rect.
Vacuum-tube rect.
Ignitron

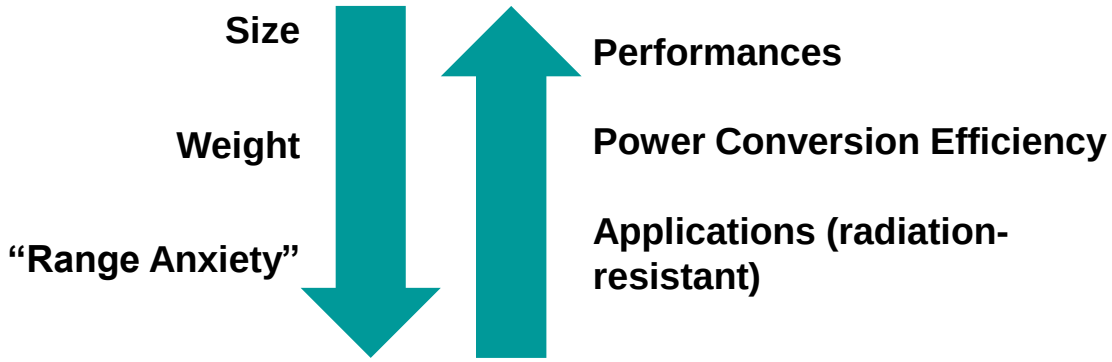
1960 Diode
Thyristor

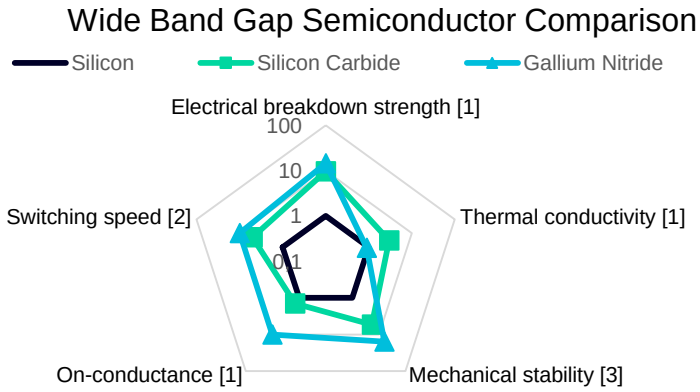
1970 GTR
Power MOSFET
…

1980 IGBT
….

2000 WBGs
….

Wide Band Gap Semiconductors





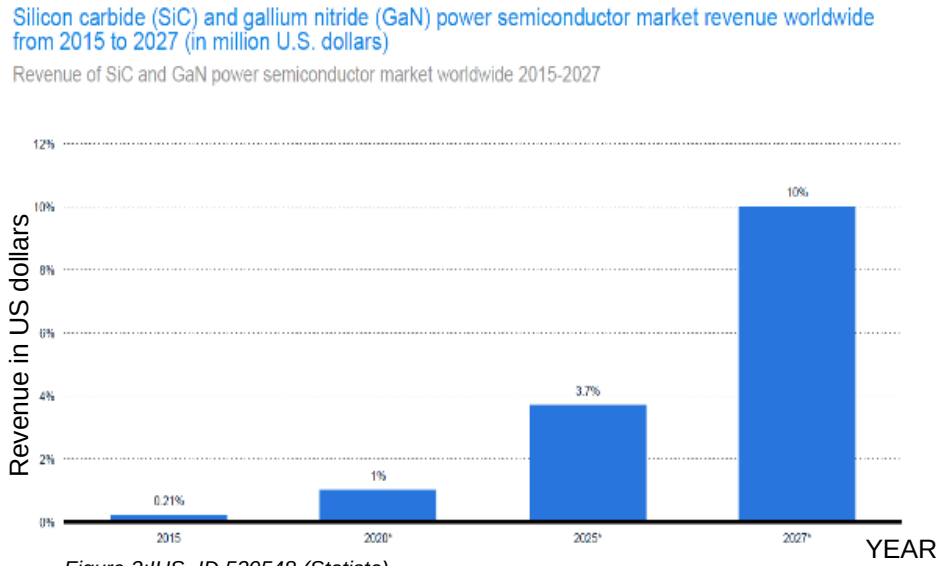
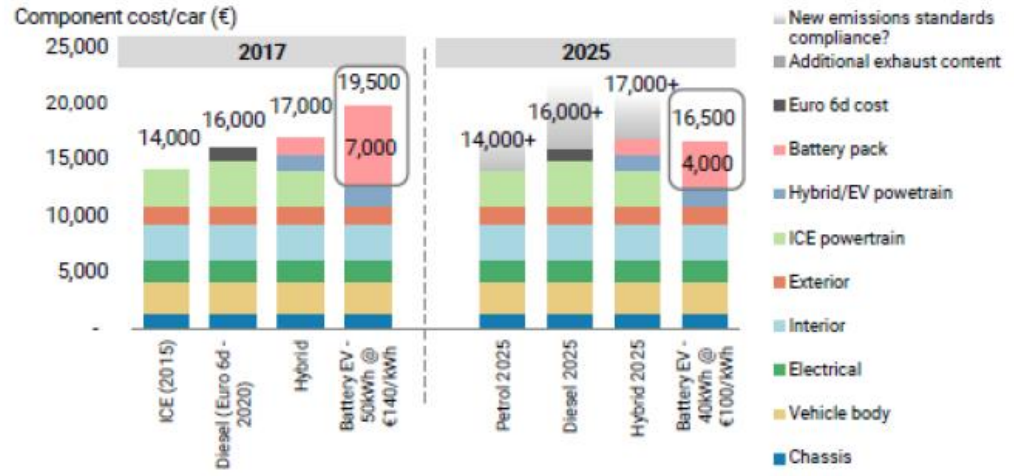


Figure 3:IHS- ID 530548 (Statista)



Source: Company data, Morgan Stanley Research estimates

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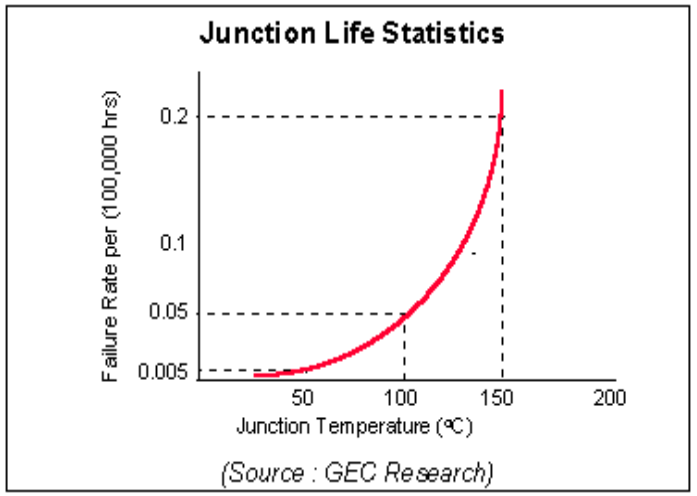
Reliability



Failure Modes

Wear-Out

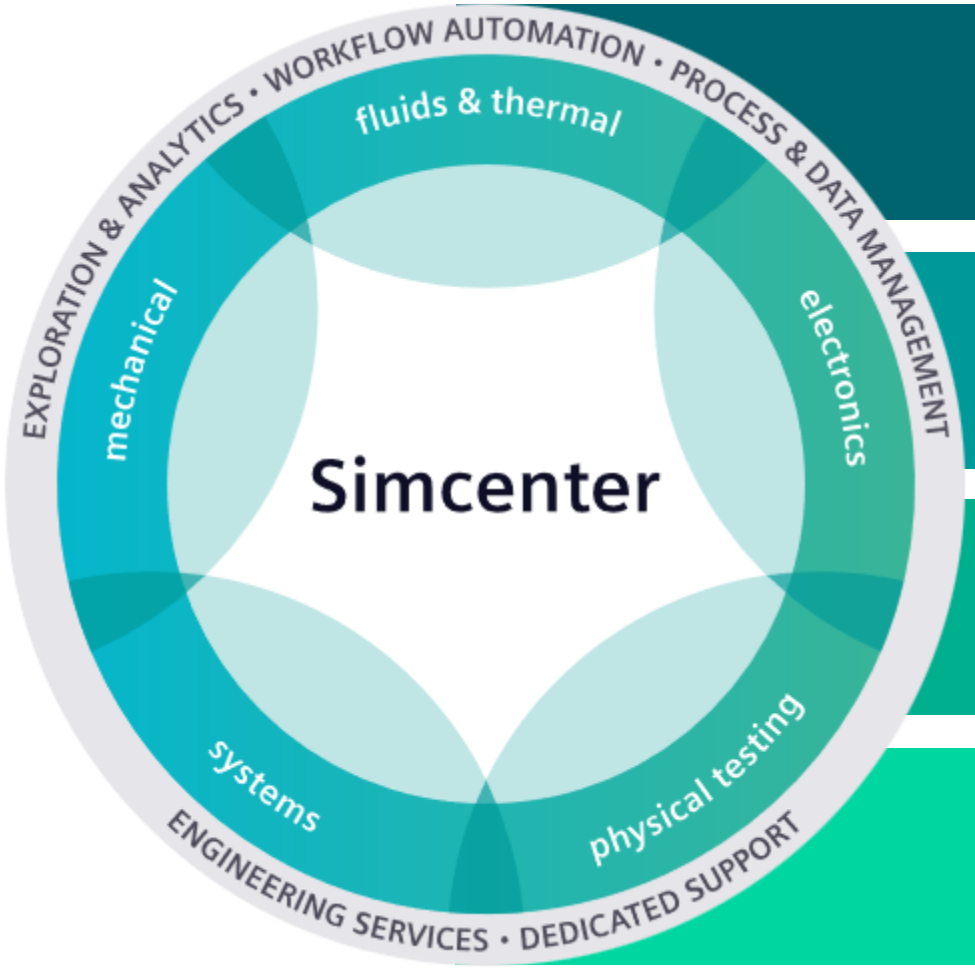
Solder-Joint Failure
Bond-Wire Lift Off
Gate-Oxide Degradation
….

Catastrophic

High-Voltage Breakdown
Electrostatic Discharges
….

Electrical Thermal Mechanical stress

Simcenter Portfolio
Engineer Innovation for Electronics System Design



Thermal Performance

Structural Integrity

Acoustics

Electromagnetic Performance

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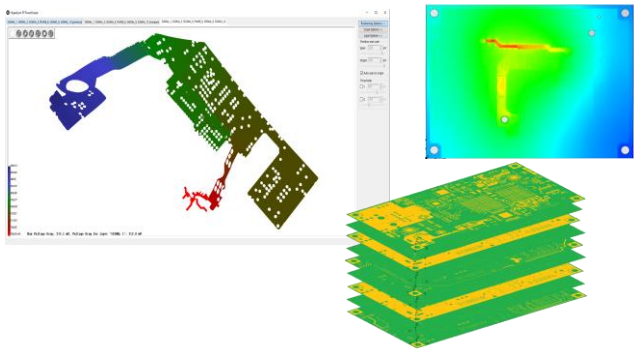


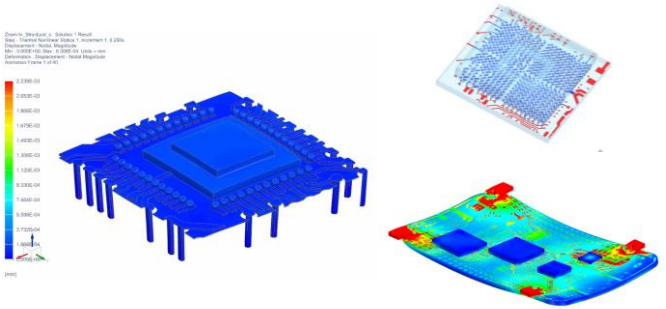
Electrothermal Simulation

DC drop analysis at board level to perform **joule heating**

ECAD <> MCAD synchronization

Power-Map for CFD thermal investigation

Temperature-Map for correct electrical resistivity calculation

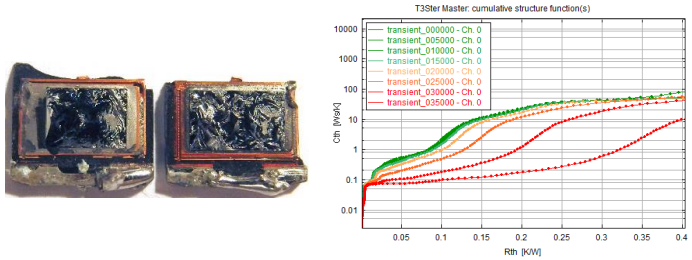


Thermomechanical Simulation

Fluid flow with conjugate heat transfer and structural analysis

Combine **linear** and **non-linear** analysis

Heat-loads to encounter **thermal expansion** and enforced **deformation**



Quality Testing and Reliability Analysis

Thermal quality testing for product validation and lifetime analysis

Model calibration to drastically reduce simulation uncertainty

Structure function to extract thermal metrics and lifetime estimation based on non - destructive tests

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Power Electronics Trends

Brief Overview of:

- **Electrothermal Simulation**
- Thermomechanical Simulation
  - Application Example: FADEC
- Quality Testing and Reliability

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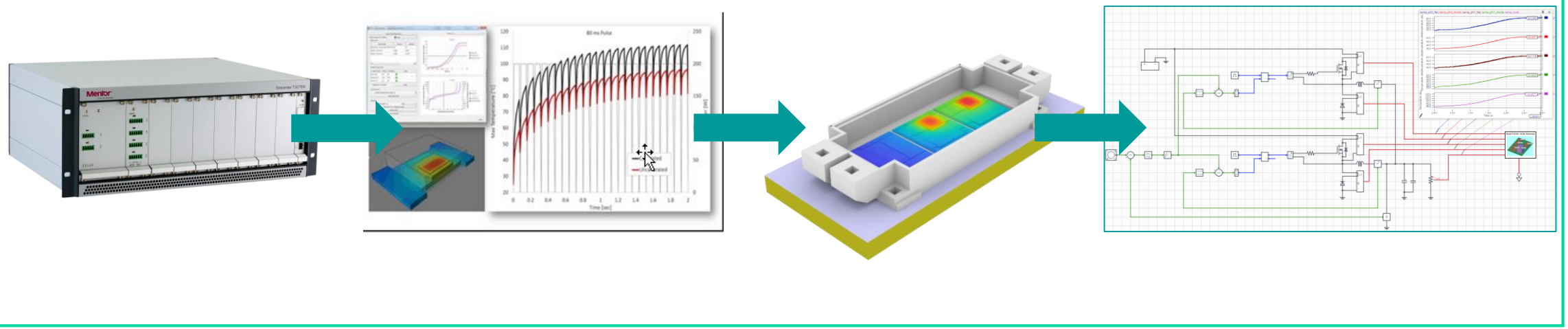
Electrothermal simulation

Bringing together thermal and electrical engineering world

- Compact thermal model from thermal transient testing
- BCI-ROM from thermal model in the electrical simulation tool
- Temperature and Power solved simultaneously



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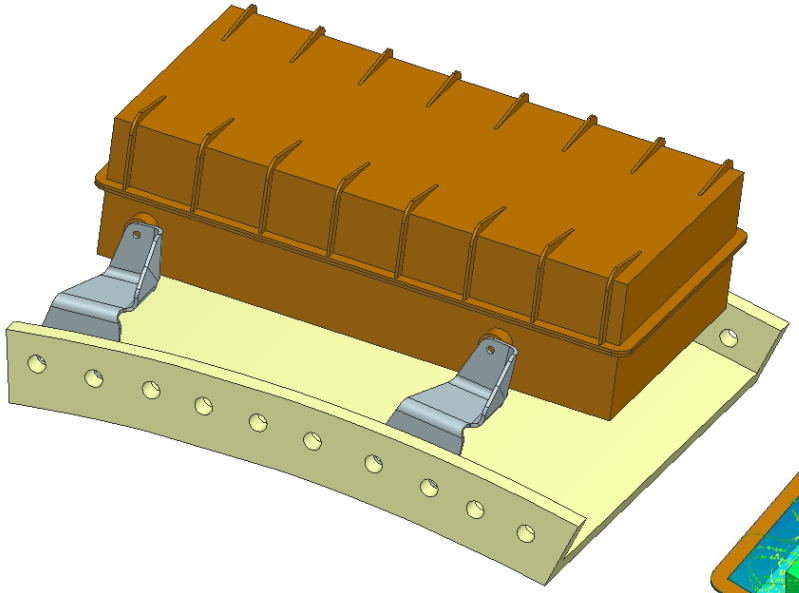
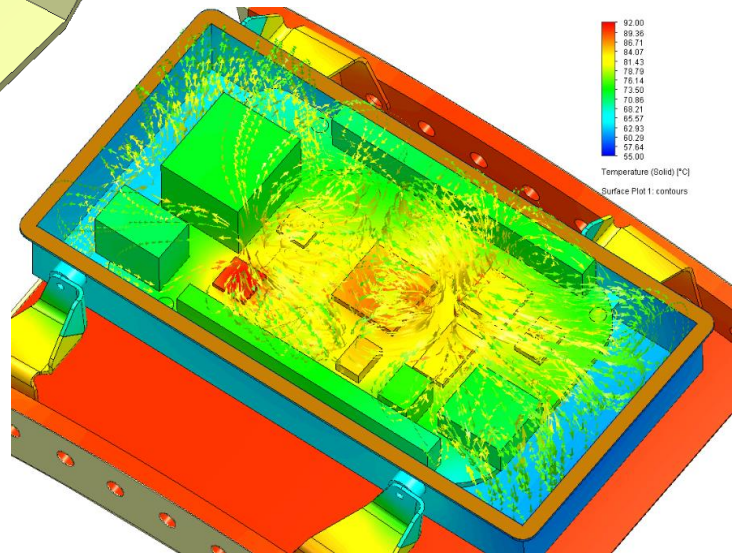
Power Electronics Trends

Brief Overview of:

- Electrothermal Simulation
- **Thermomechanical Simulation**
  - **Application Example: FADEC**
- Quality Testing and Reliability

Application: FADEC





Simulation of a Full Authority Digital Engine Control

Multiphysics Simulation:

- **Thermo-Fluid**
- **Vibration**
- **Thermo-mechanical**

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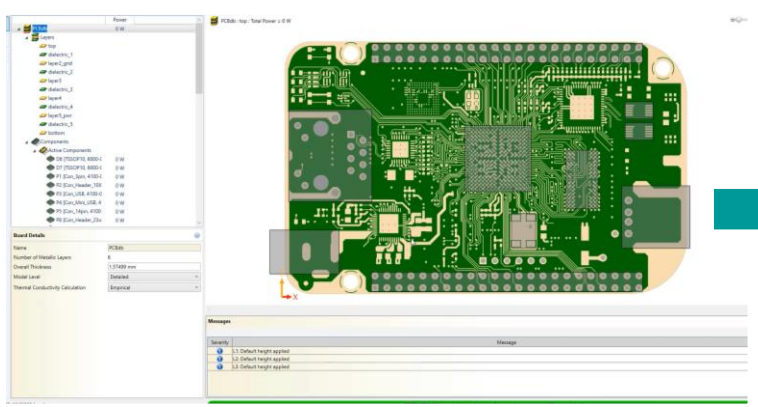
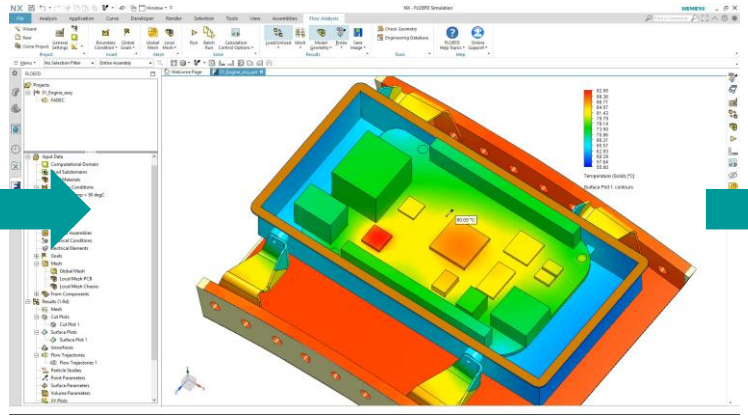
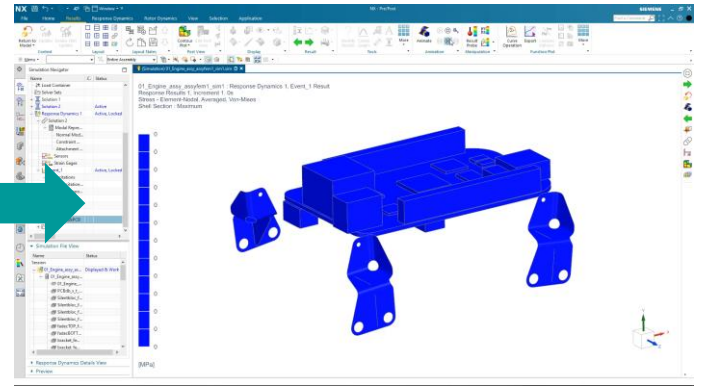
Extend CFD capabilities to optimize product performance and reliability

- Bridge Electrical Layout into the CFD environment
- Perform thermal simulation to identify critical heat spots
- FEA analysis to model transient stress simulation

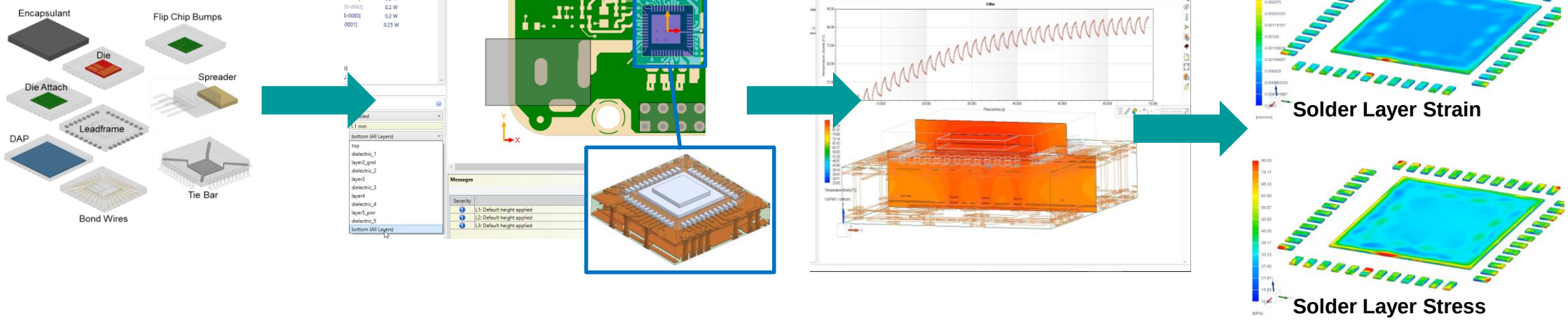






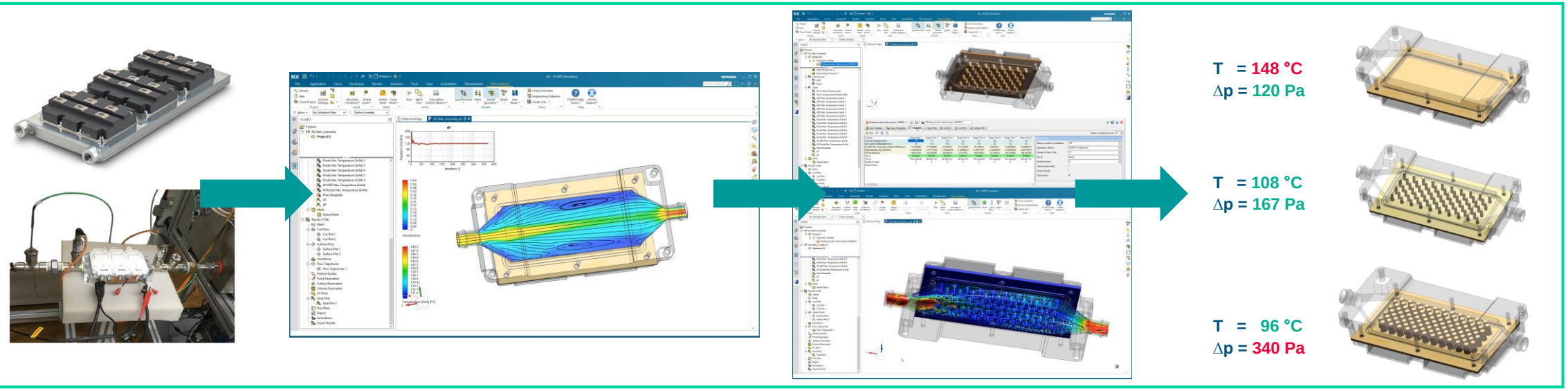
Non-Linear Multi-Physics Simulation

- Detailed component-level thermal simulation
- Power Cycling simulation to determine 3D temperature fields
- Stress, strain and deformation predicted and inspected



Topology optimization

- Find best design out of many scenarios
- Optimize design preventing efficient surface temperatures before final prototyping
- Automatic design space exploration



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Power Electronics Trends

Brief Overview of:

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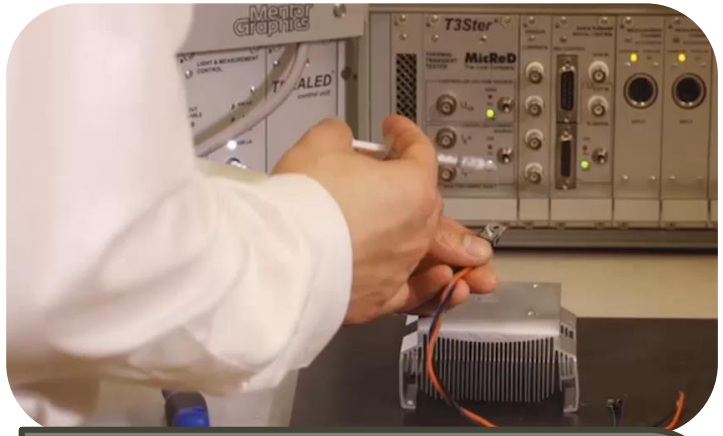
- Thermomechanical Simulation
  - Application Example: FADEC
- **Quality Testing and Reliability**

Summary

Thermal Testing Workflow

Non-destructive transient thermal testing for thermal characterization of packaged semiconductor devices

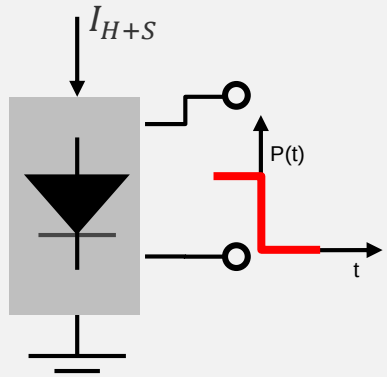


Measurement Setting

TSP calibrated against temperature change

Pins connection with testing cables

Input parameter from control SW

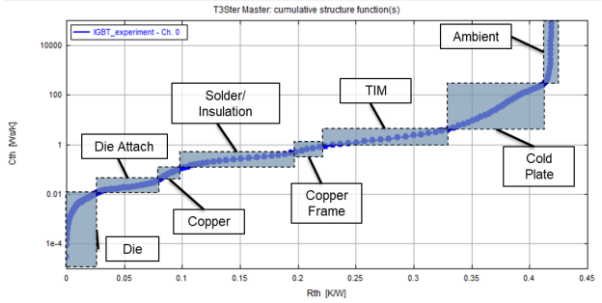


Testing

Measurement based on device (Saturation mode, BD sensing…)

TDIM JEDEC JESD51-14 setup

Fast switching to mitigate electrical transients



Post-Processing

Thermal metrics (Z_{th}, Pulsed thermal resistance)

Structure Function

Thermal compact model

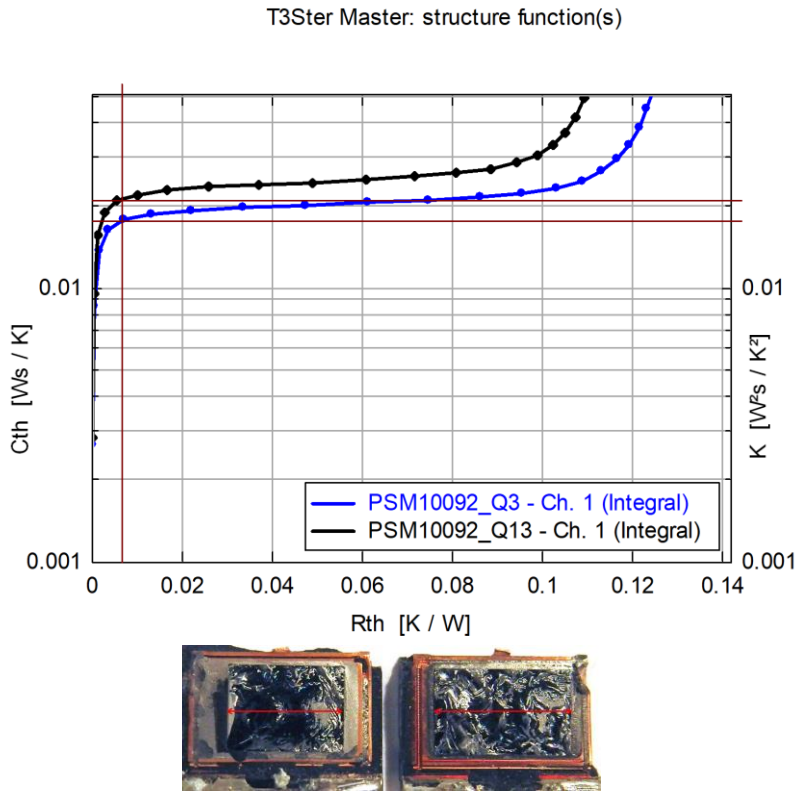
Thermal Quality Testing

Semi - Automatized thermal quality analysis of multiple power devices

Real-time inspection

Component to component tolerances

Reduced TTM benefiting of automated testing methodology



Two components supposedly the same, however, with SF a difference was measured.

Thermal performance consistency

Increased data-set

State of the art production

Devices binning/sorting

Sudden failure type reduction

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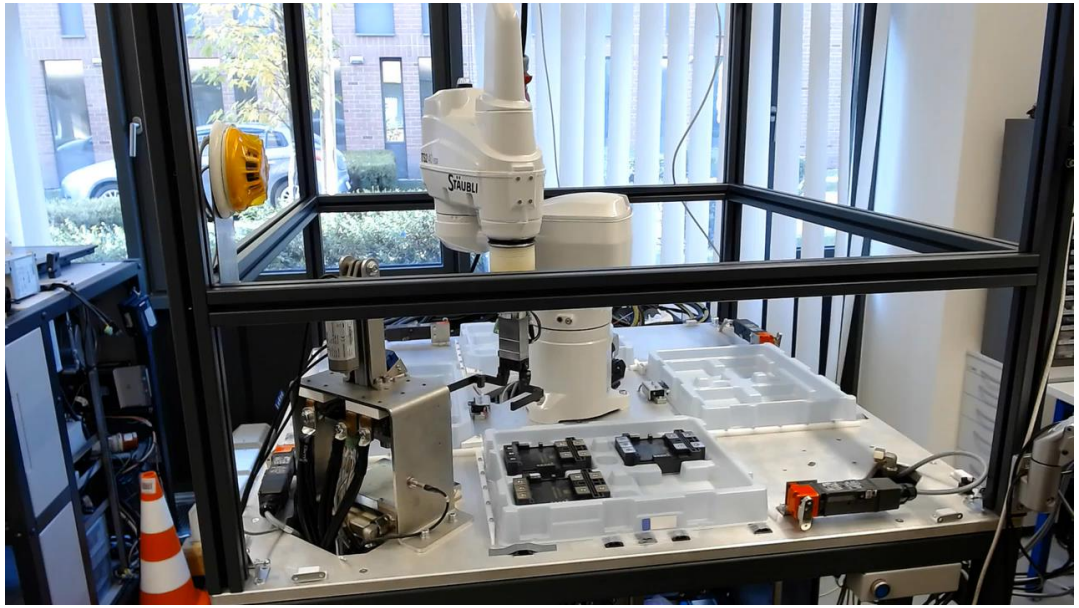
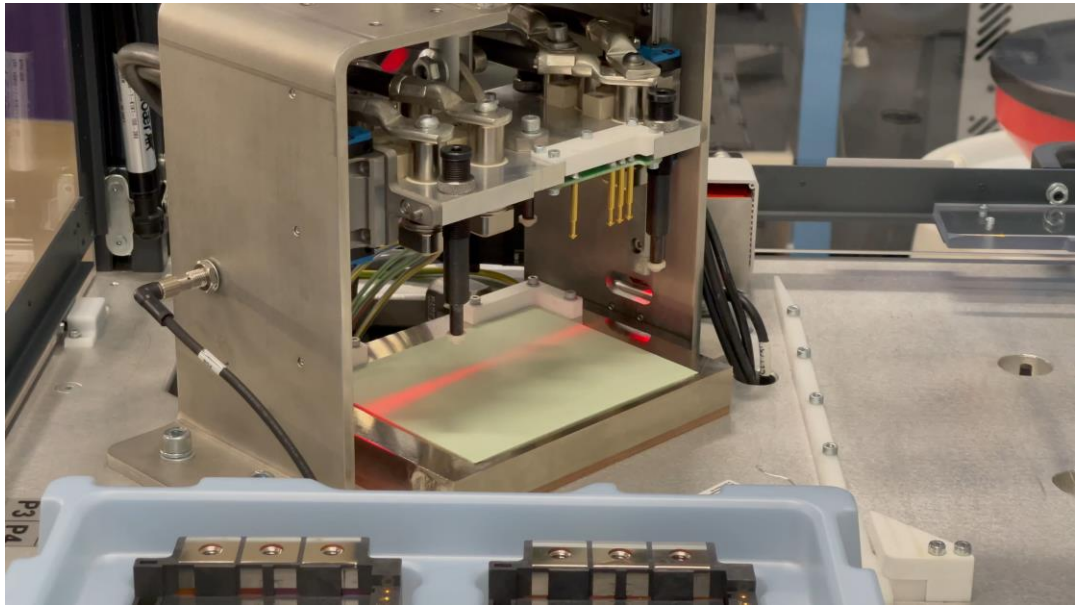
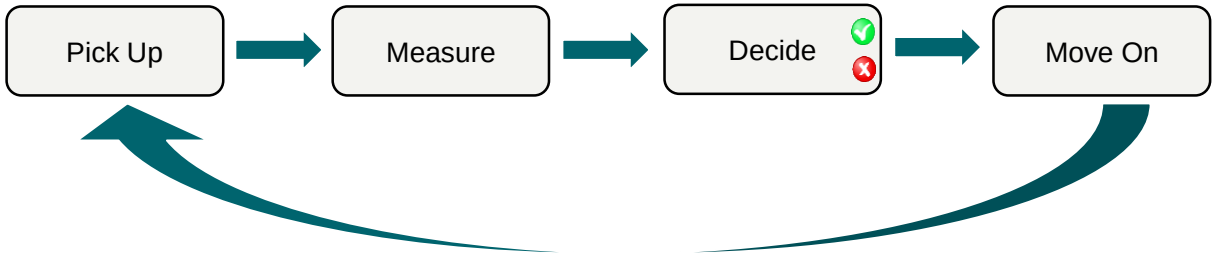
Thermal Quality Testing







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Summary

Power Electronics Devices footprint strongly increases in transportation and smart grids

Wide Band Gap design is critical

Accuracy in space and time is paramount from detailed to compact model simulation

Thermal testing is a differentiator at all levels

Reliability strongly dependent from electrothermal and thermomechanical effects

Quality Testing closes the gap from design to products

Thank You

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Contact

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Italy

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E-mail Antonio.Caruso@siemens.com

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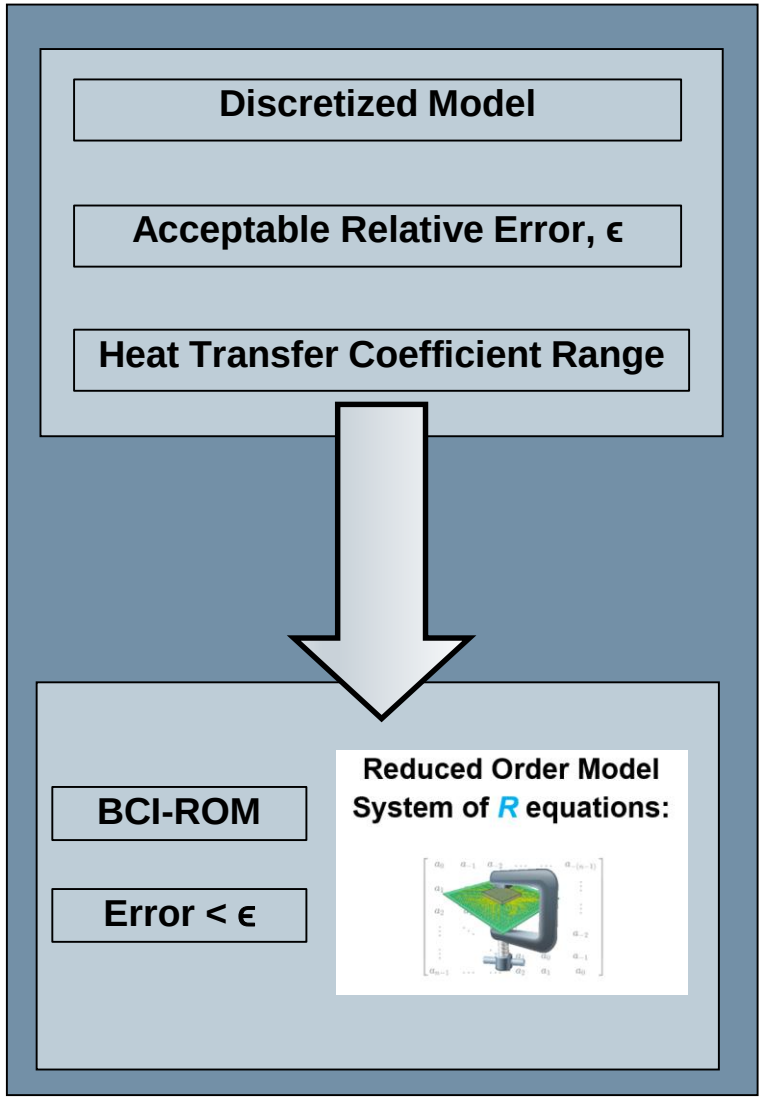
Backup

FANTASTIC Method for Reduced Order Models

L. Codecasa, V. d'Alessandro, A. Magnani, N. Rinaldi and P. J. Zampardi,
"**Fa**st **N**ovel **T**hermal **A**nalysis **S**imulation **T**ool for **I**ntegrated **C**ircuits (FANTASTIC)," *20th International Workshop on Thermal Investigations of ICs and Systems*, London, 2014

Ideal Compact Thermal Model:

- Boundary Condition Independent ✓
- High Accuracy – Known Accuracy ✓
- Supports Multiple Heat Sources ✓
- Transient Support ✓
- Internal Geometry cannot be reverse engineered ✓
- Solves orders of magnitude faster than detailed model ✓
- Can be created quickly and reliably ✓



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