

# Reliability Requirements of Advanced Packaging in the Era of Electrified, Automated and Connected Driving

Przemyslaw Gromala  
Robert Bosch GmbH  
Automotive Electronics



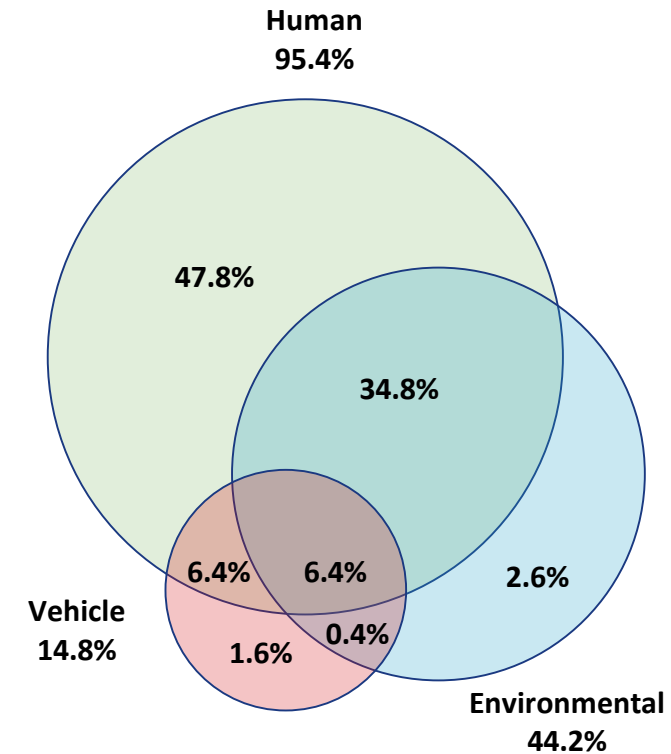
Bundesministerium  
für Wirtschaft  
und Energie

PLUTO S, FKZ: 16IPCEI626

- Motivation
- Role of advanced packaging in automotive
- Challenges
  - Warpage
  - Reliability
  - Prognostics and health management
- Conclusions

- Connectivity
- Automation
- Sharing
- Electrification

Study of traffic accidents



Source: TechSearch International

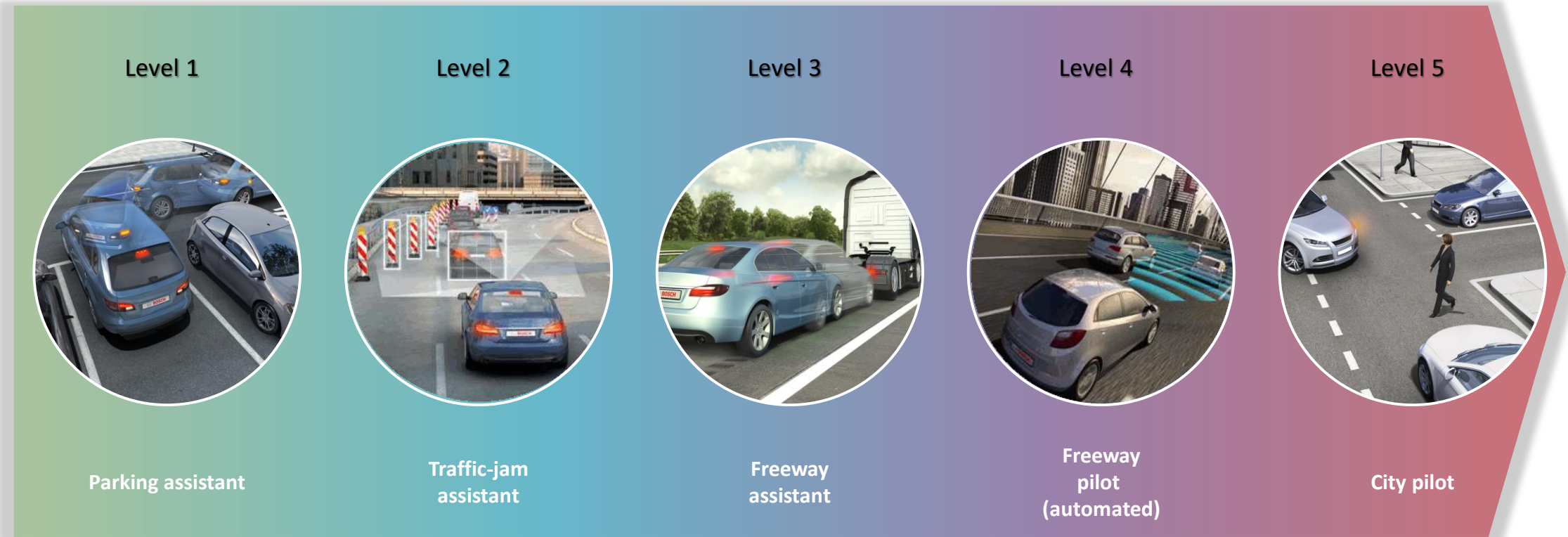
New components (e.g. SiP, GPUs)

New use case conditions

New services

New materials

# Advanced packaging... ...pave the way to highly automated driving



Lidar

Radar

Camera

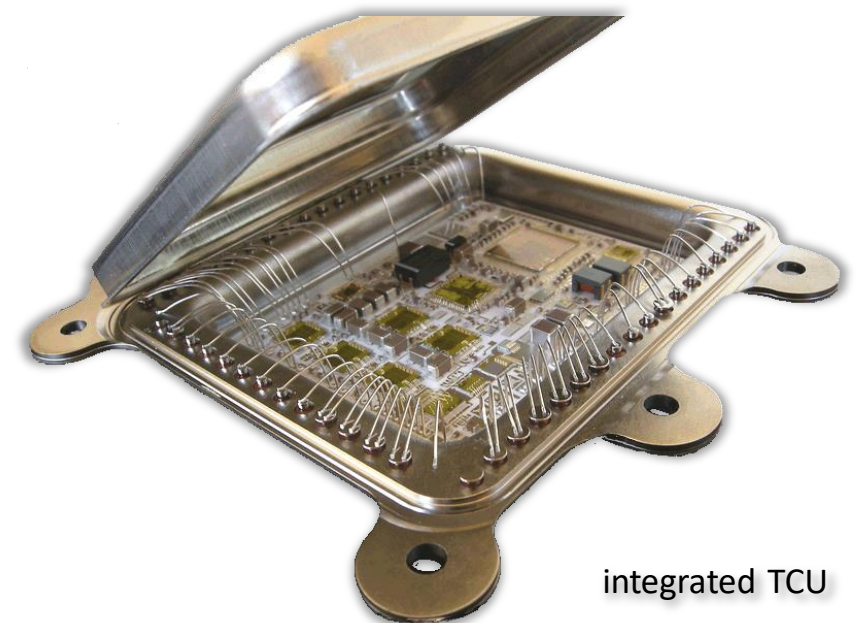
High performance computers

# Advanced packaging... ...examples



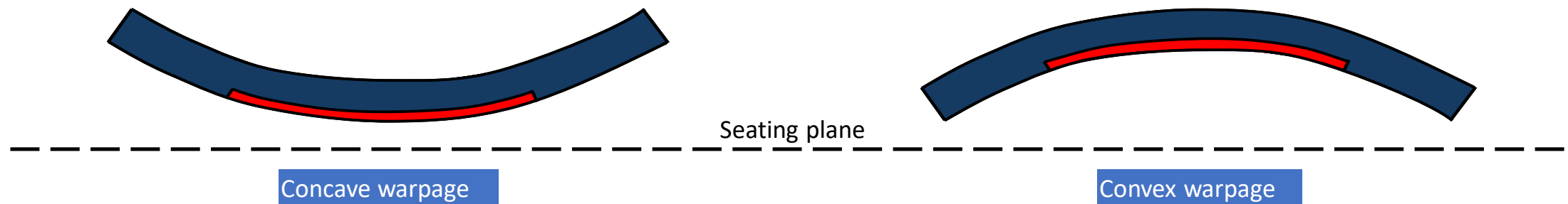
# Advanced packaging... ... what does it mean harsh environment

- Extremely harsh and demanding environment (TCU)
  - Extreme ambient temperatures (-40 °C to +60°C ...+140°C under normal operating conditions)
  - Abrupt temperature changes
  - Exposure to fluids (oil, fuel, water, salt water)
  - Effects of moisture
  - Mechanical stresses (e.g. engine or transmission vibration)
- Other ECUs
  - Exposure to sunlight (UV)
  - High currents (self-heating)

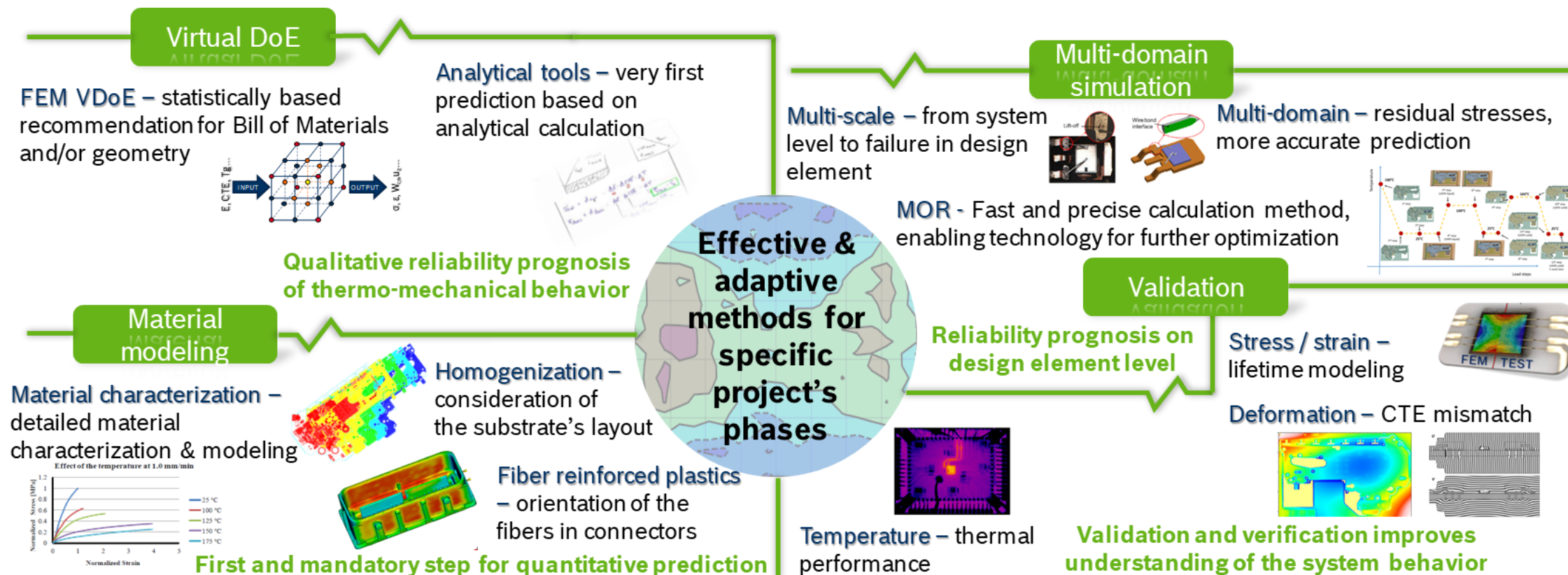


# Warpage... ...still is a challenge

- Packages subjected to the thermal load results in deviation from planar flatness.
- Warpage is caused by
  - Different coefficient of thermal expansion
  - Temperature and time dependency
  - Process conditions
  - Aging of materials



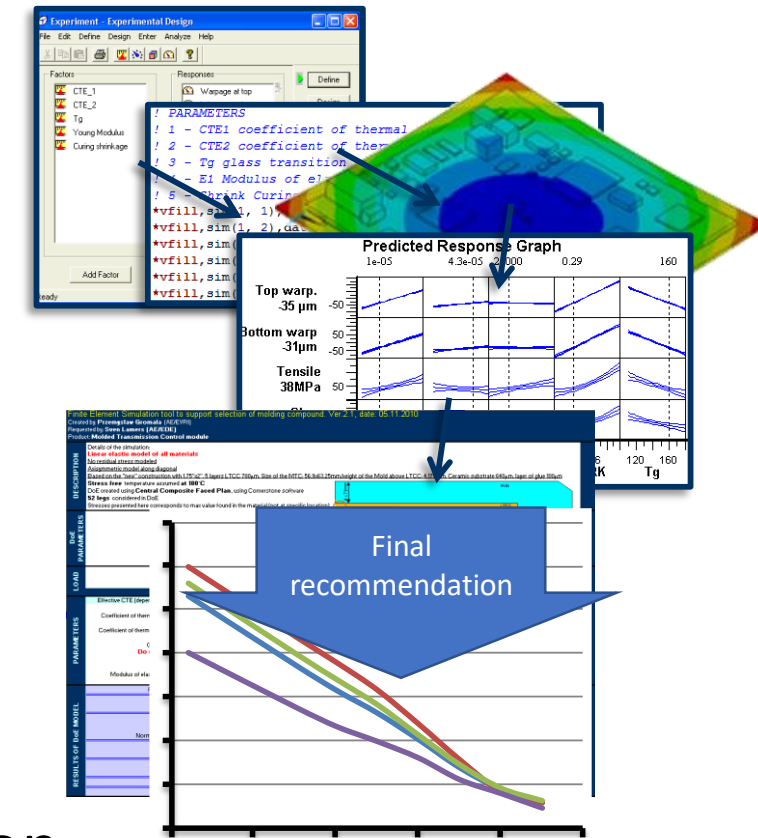
# Robust design of advanced packaging... Simulation driven design



Virtual pre-qualification as a design method

### Understand the effect of the molding compound properties on the stress in molded control unit

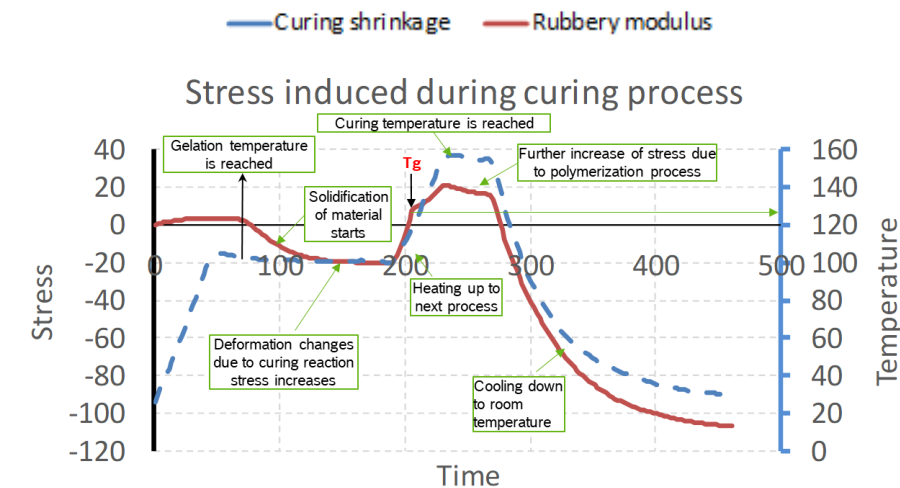
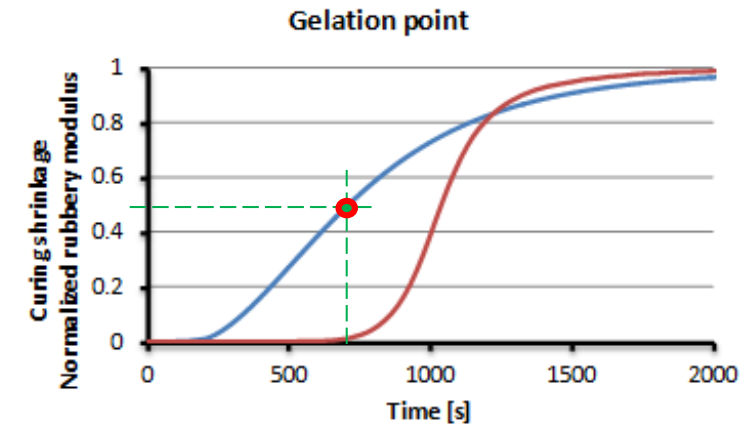
- Input parameters:
  - Coefficient of thermal expansion below and above glass transition temperature
  - Glass transition temperature
  - Chemical shrinkage
  - Modulus of elasticity
- Design of experiment
- Regression analysis
- Proposal for material properties for specific application



Qualitative reliability prognosis of the thermo-mechanical behavior

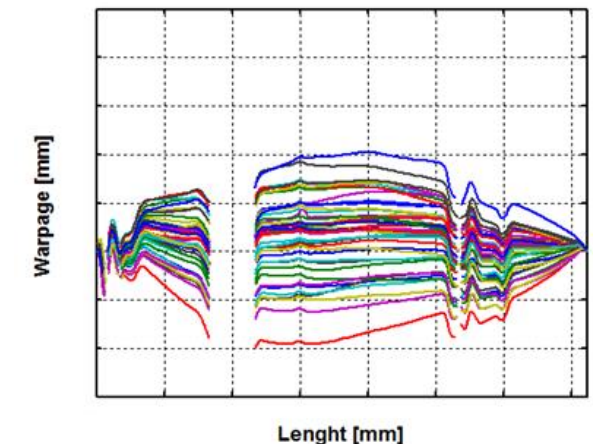
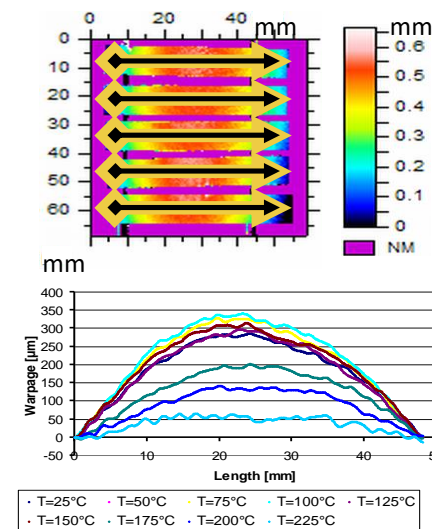
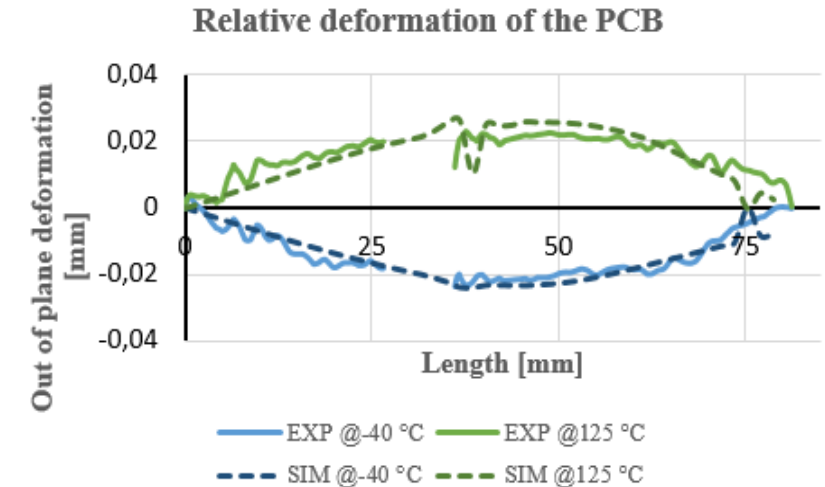
# How to quantitative predict warpage ... material characterization and modeling

- Detailed characterization is a must
  - DMA – describes elastic properties
  - TMA – describes thermal expansion
- For quantitative prediction is still one parameter required:
  - Curing shrinkage
- Curing shrinkage happens during polymerization process of epoxy based thermosets
- Curing shrinkage causes:
  - volumetric shrinkage → change of deformation
  - Modulus of elasticity increases with time → stresses



**W. Beveridge:** *“no one believes an hypothesis except its originator but everyone believes an experiment except the experimenter”*

- Numerical methods accelerate development cycle of the semiconductor products
- The accuracy depends on inputs
- Numerical models must be validated experimentally



- Multi Level Interactions

- Thermal mechanical Chip to Package Interaction (CPI)
  - ELK and bump failures
- Electrical CPI (e-CPI)
  - FinFET performance shift induced circuit performance drift
- Board level stress interaction with package and chip
  - Build-up substrate failure
  - Bump and Chip level failures
- System level
  - Influence of housing
  - Influence of mounting position

# Chip package interaction

## ... how we can detect degradation of the IC package

### Indirect detectors (“non-invasive”)

- Mission profile tracking
- Stand alone aging monitors

### Direct failure detectors (“invasive”)

- Verify current consumption
- Monitor output signals of the structure/block

### Event logging detectors

- ESD-Event loggers
- Max temperature/voltage/current-detectors
- Load dump counter (e.g.  $200\text{ms} > V_{\text{MAX}}$ )

### Technology failure detectors

- Seal ring integrity, Pad/IMD-crack detectors
- Corrosion detectors, delamination detectors

# Chip package interaction

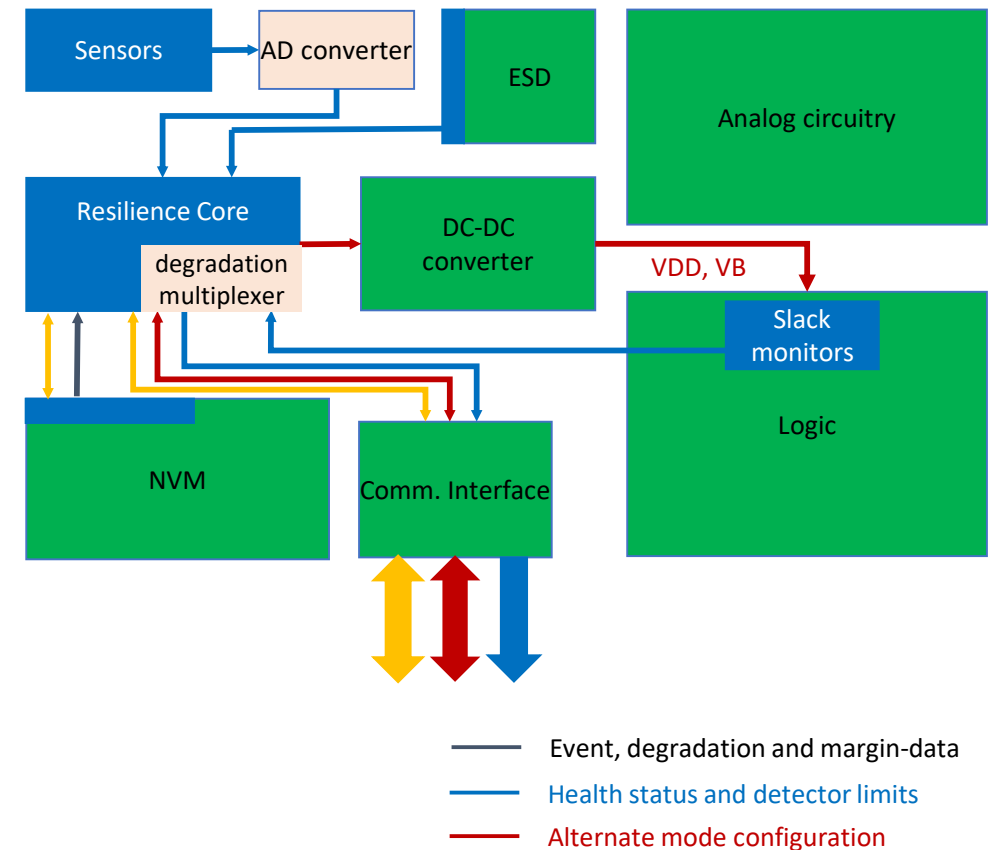
## What is needed to implement resilient system

### 1. Sensors and detectors

- Standardized IP (+ AD?)
- Application-specific sensors

### 2. Resilience core and communication interface

### 3. Optional: integrated alternate operation modes

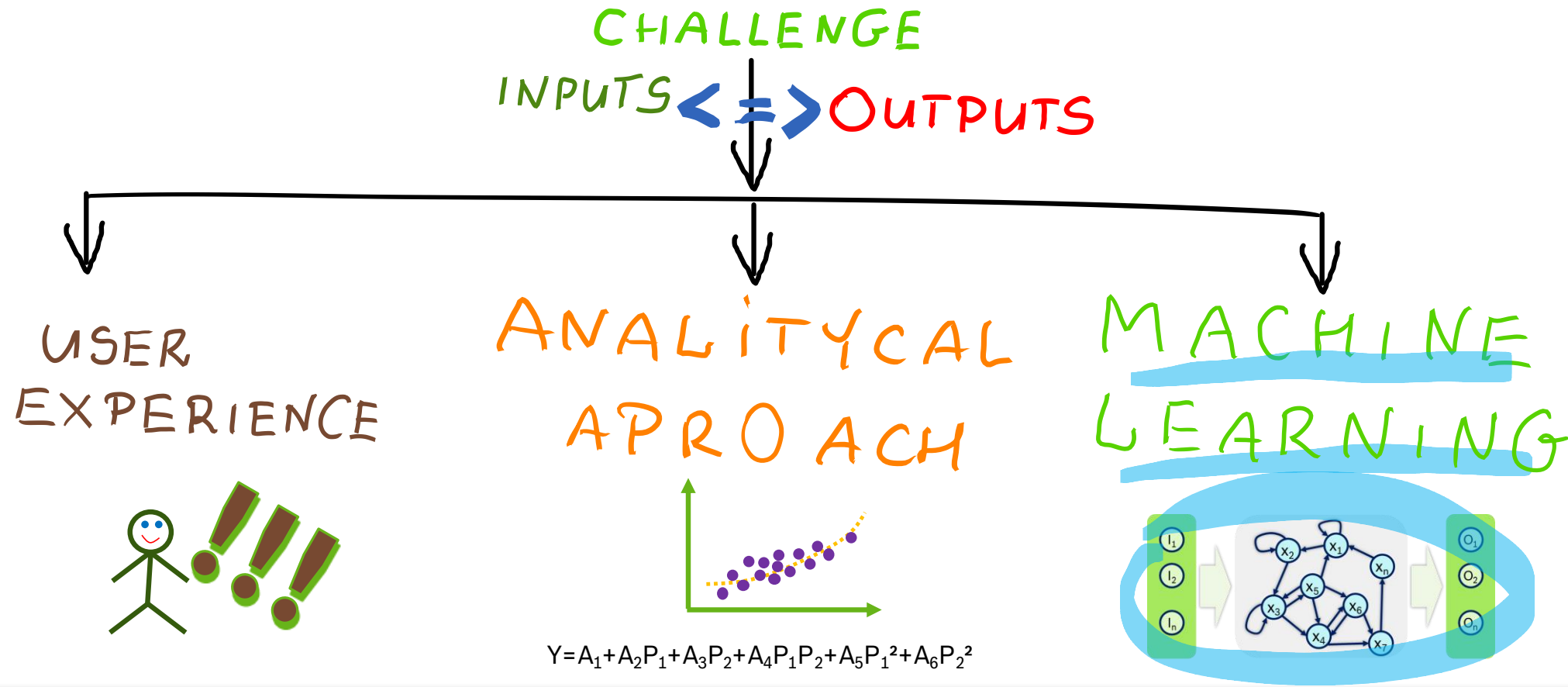


Source: F. Dietz

# Next generation of reliability... ... hybrid PHM



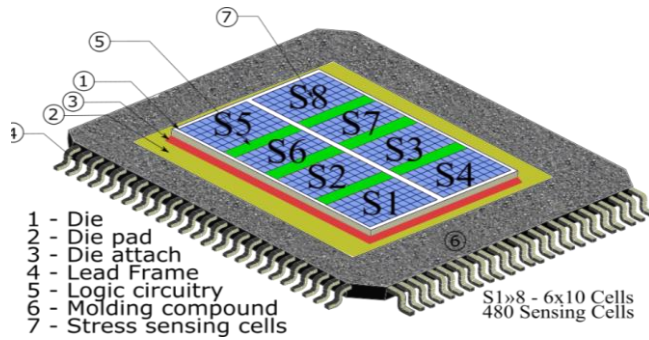
# Next generation of reliability... ... how we can solve complex relationships



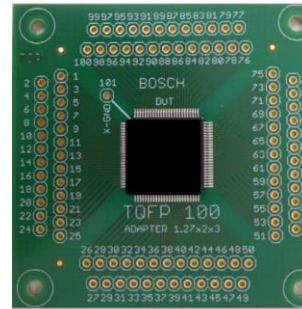
ML used to understand relation between inputs and outputs

# Next generation of reliability... ... how we used ML based to predict delamination

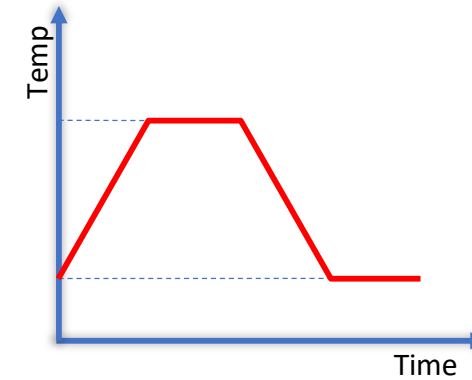
Stress sensor



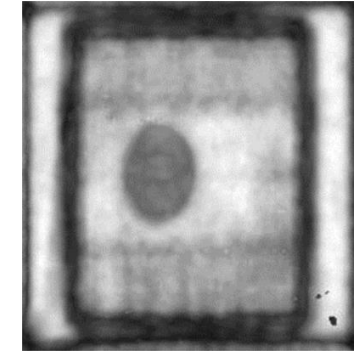
TQFP on board



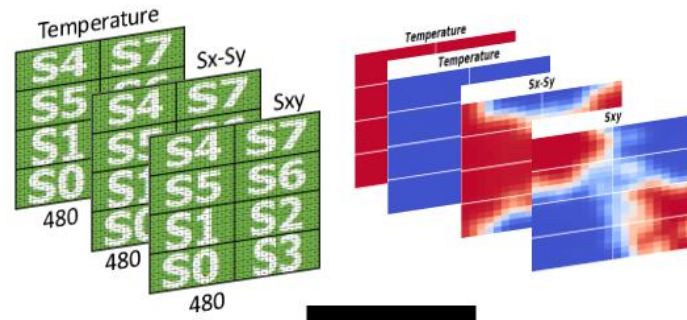
Accelerated tests



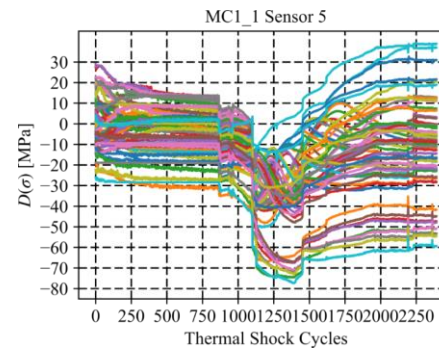
Investigated failure mode



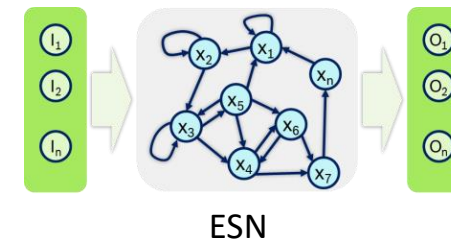
Preprocessing of the data



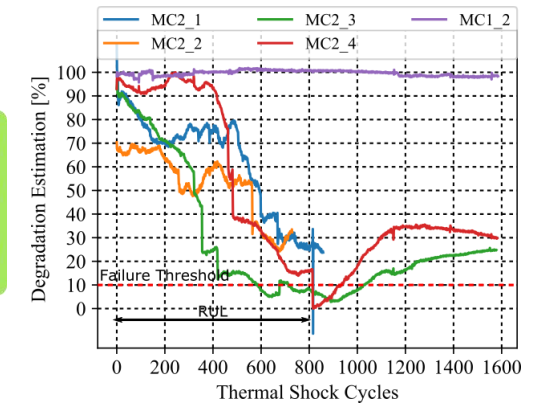
Stress results



Application of ML



In-situ lifetime prediction



A. Prisacaru et al, EuroSimE 2019

- Advanced packaging is one of the technology driver of automotive electronics
- Simulation driven design is the tool to accelerate development process
- Components / board / system level reliability is crucial during design and qualification phase
- Next generation of reliability will require implementation of prognostics and health management on component (IC packaging) and system (ECU) level