VIRTUAL WOST 2021

COMPAS

Metamodels generated from thermo-mechanical simulation for the design of a test setup for microelectronics packages

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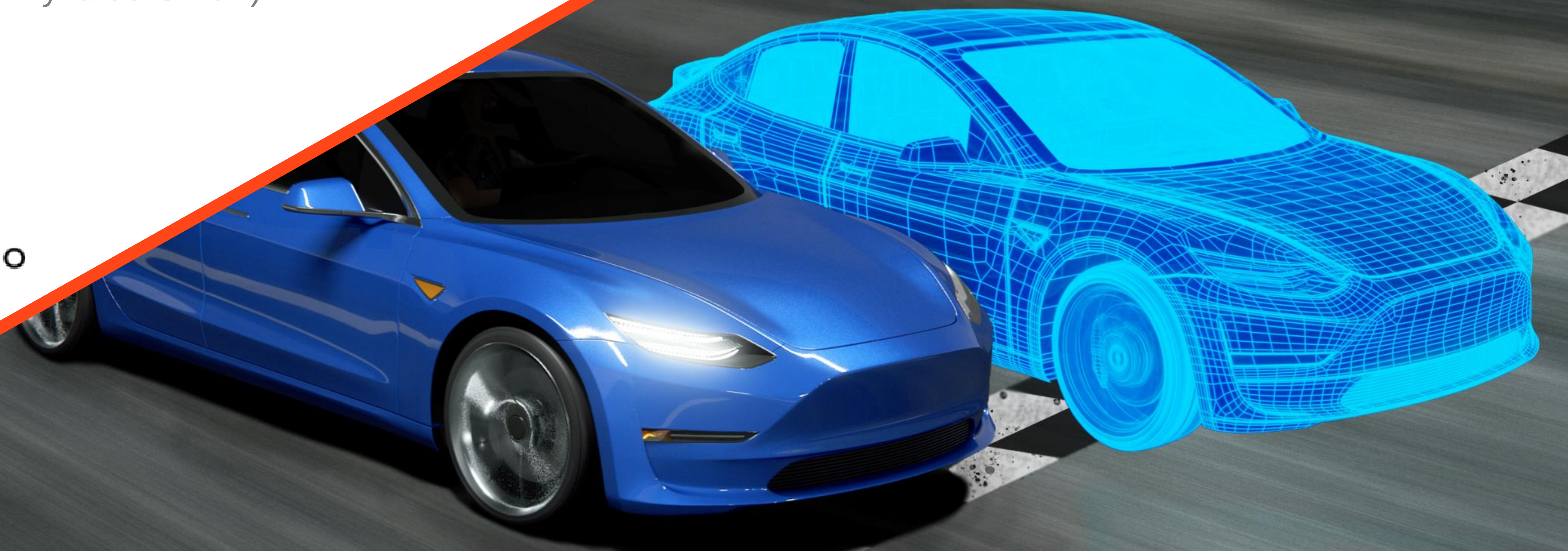


June 17th 2021

Funding Acknowledgement

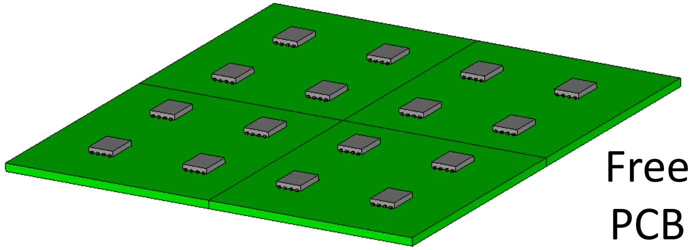
COMPAS

Compact modelling of high-tech systems for health management and optimization along the supply chain

This work is funded via the ITEA3 EU-level project COMPAS by the national public authority Bundesministerium für Bildung und Forschung (BMBF).

Tested for at Tier2

Solder fatigue due to CTE mismatch of components vs. PCB

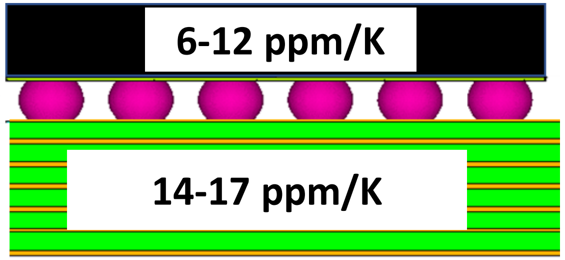


Free PCB

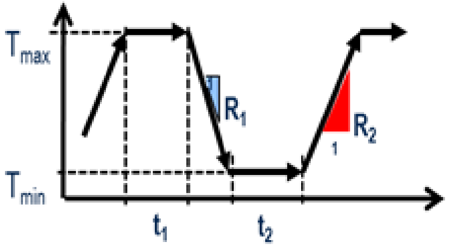
Microelectronics package

Solder balls

PCB

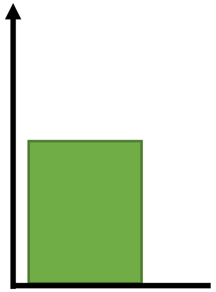


Temperature cycling (accelerated test)

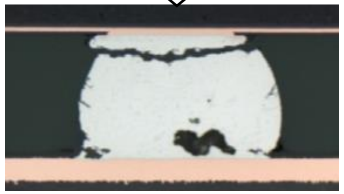


+125°C

-40°C



Tier2 stress test



Source: [2]

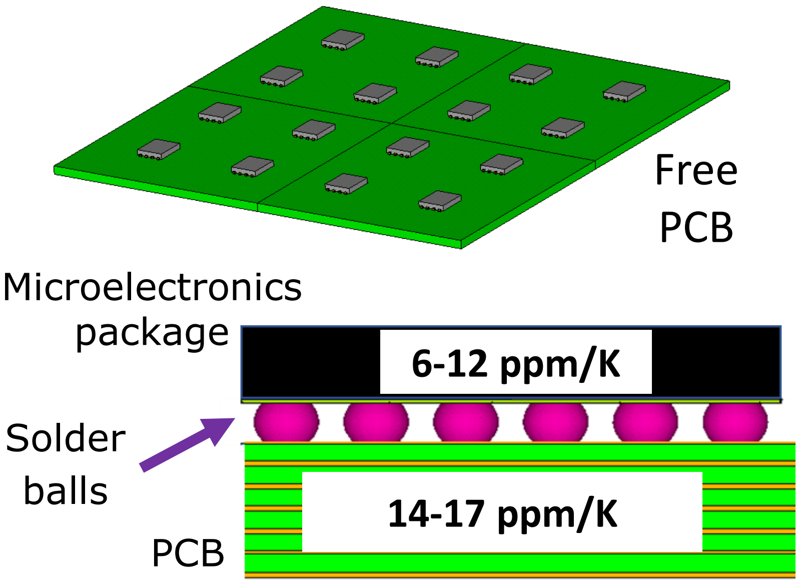
[1] R. Dudek *et al.* , Results TRACE/CATRENE,EuWoRel 2018.
[2] G. Haubner *et al.*, "77 GHz automotive RADAR", Microelectronics Reliably , 2016.
[3] M. van Soestbergen *et al.* , COMPAS, EuWoRel 2020.

- Solder fatigue is one of the major failure modes in automotive hardware

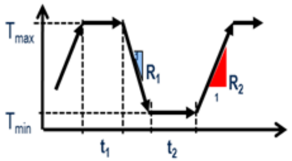
Motivation | Step #1: Homogenization

Tested for at Tier2

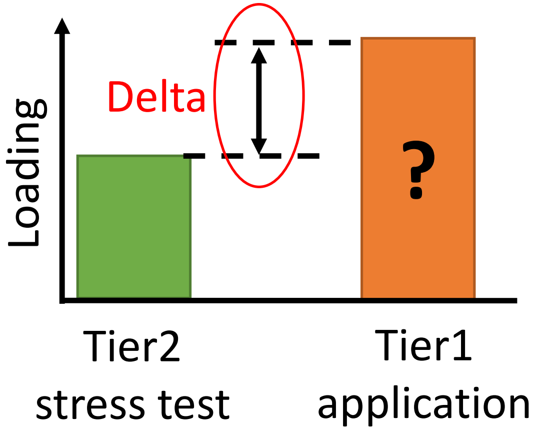
Solder fatigue due to CTE mismatch of components vs. PCB

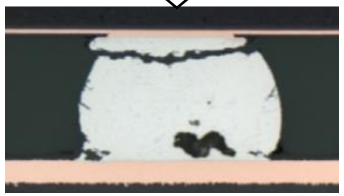


Temperature cycling



Consequence:
Unknown delta

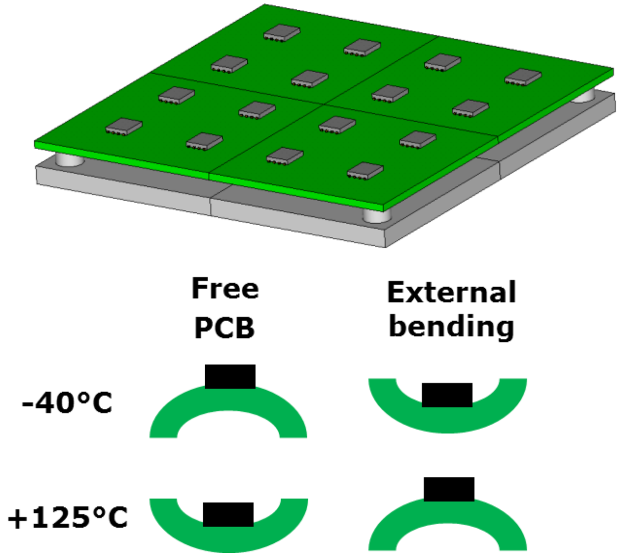




Source: [2]

Not tested for at Tier2

Solder fatigue due to external PCB bending from Tier1 ECU housing



[1] R. Dudek *et al.* , Results TRACE/CATRENE,EuWoRel 2018.
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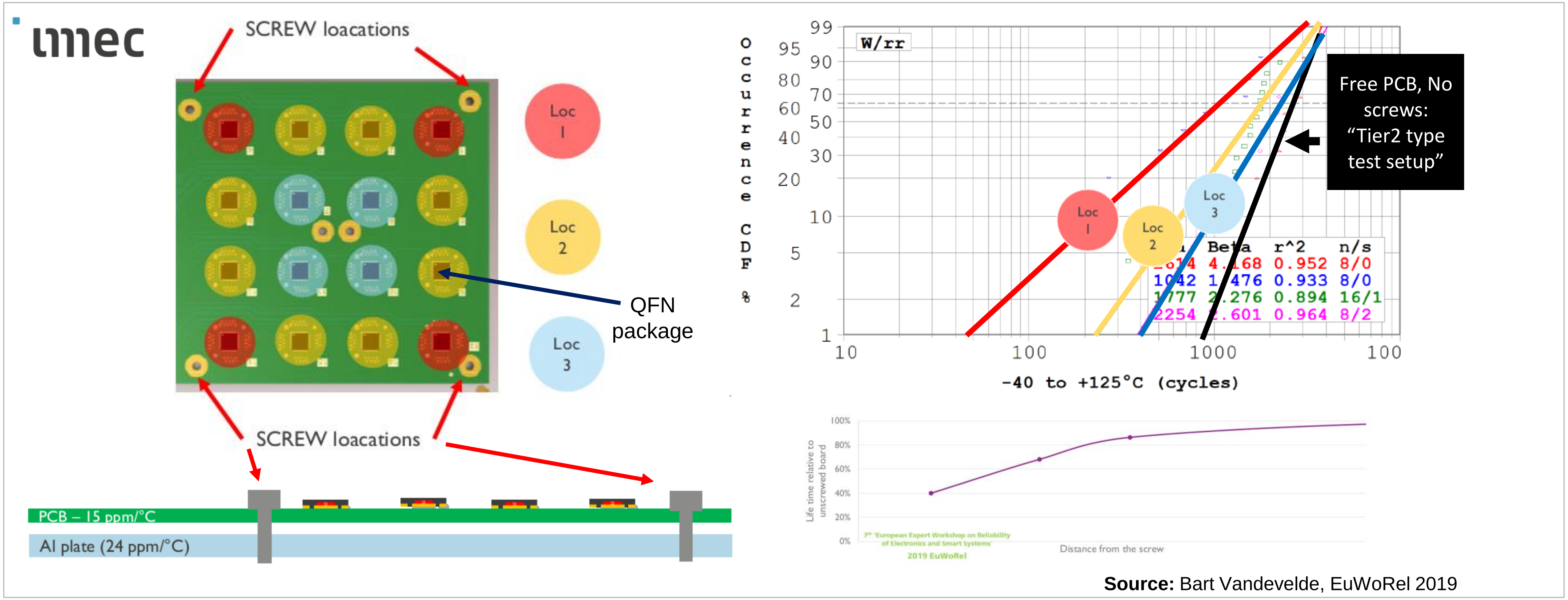
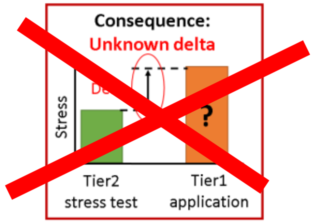
- Solder fatigue is one of the major failure modes in automotive hardware
- Tier2 tests do not cover all possible loading conditions at Tier1

Motivation | Step #1: Homogenization



- Bart Vandevelde (IMEC) demonstrated the impact of PCB mounting on solder joint reliability using a simplified test setup

COMPAS.idea:




[1]


[1]

Material supplier → Tier2 → Tier1 → OEM

COMPAS.focus

[1] M. van Soestbergen *et al.* , COMPAS, EuWoRel 2020.

Pass along thermo-mechanical compact models →

← **Feedback data about loading conditions**

COMPAS.paradigm

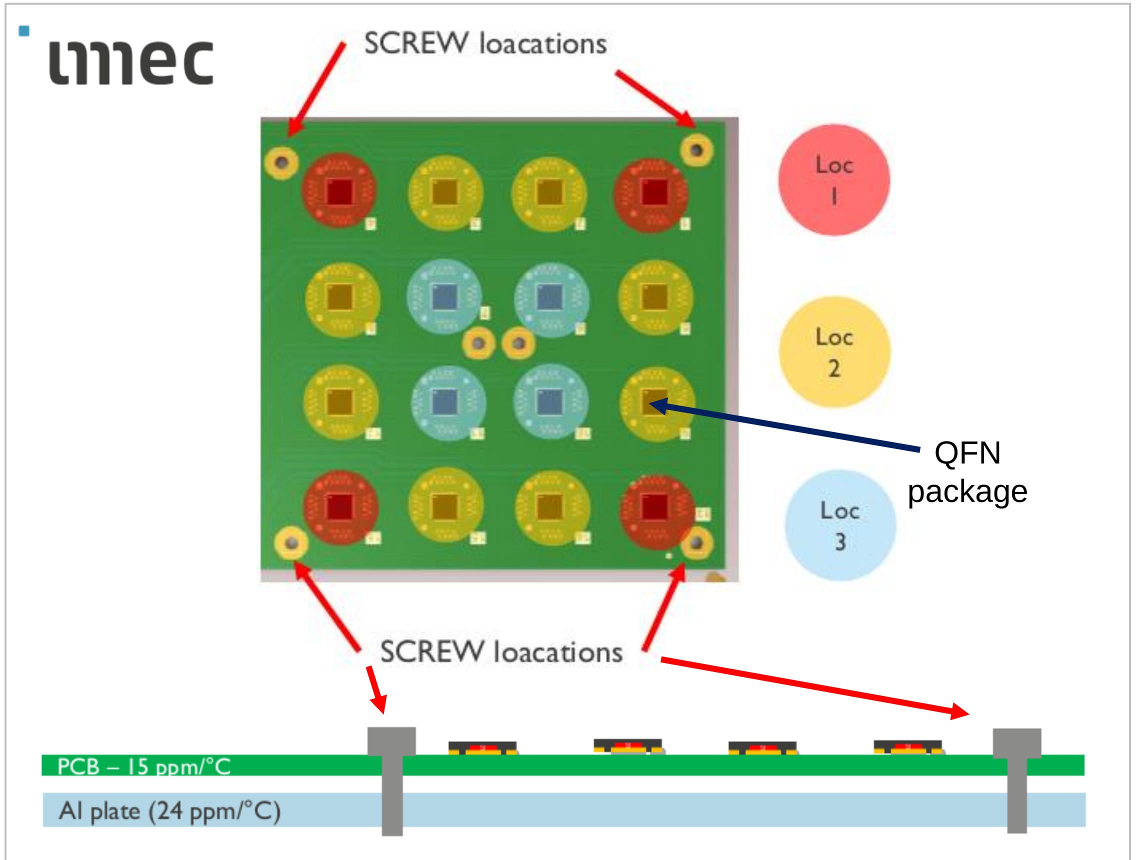
- Thermal compact models are already standardized and passed along value chain

COMPAS.challenge

- Thermo-mechanics is more complex
- No suitable automatic compact modeling frameworks or standardized exchange formats yet
- Reduction of computational effort
- IP-safe compact models

- COMPAS funding project aims at developing thermo-mechanical compact models

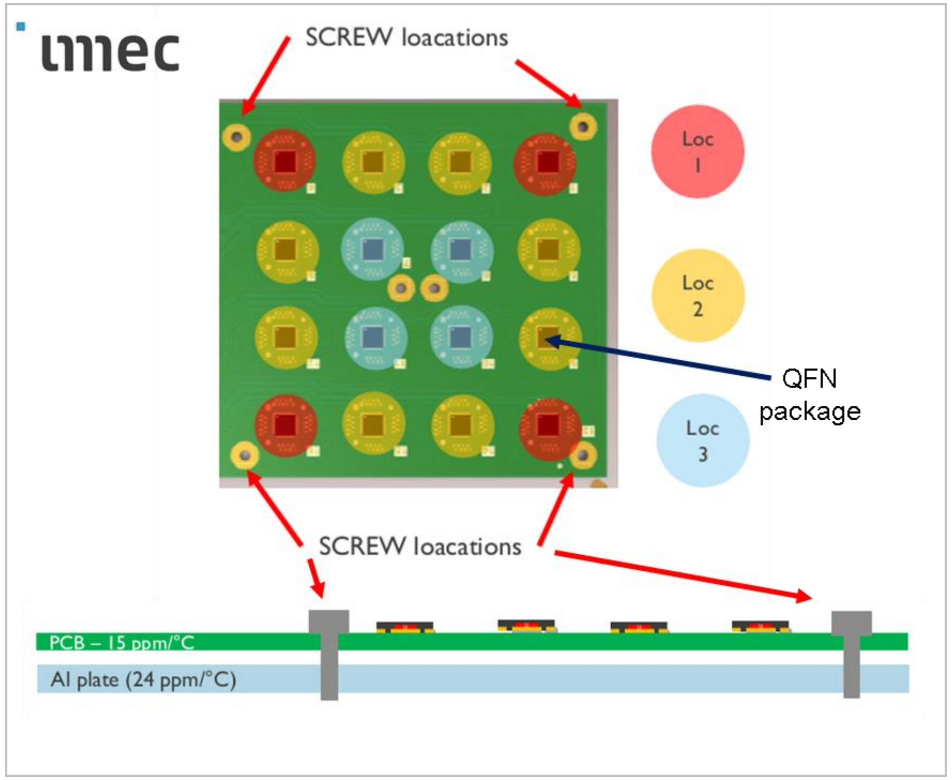
COMPAS.validation



Source: Bart Vandevelde, EuWoRel 2019

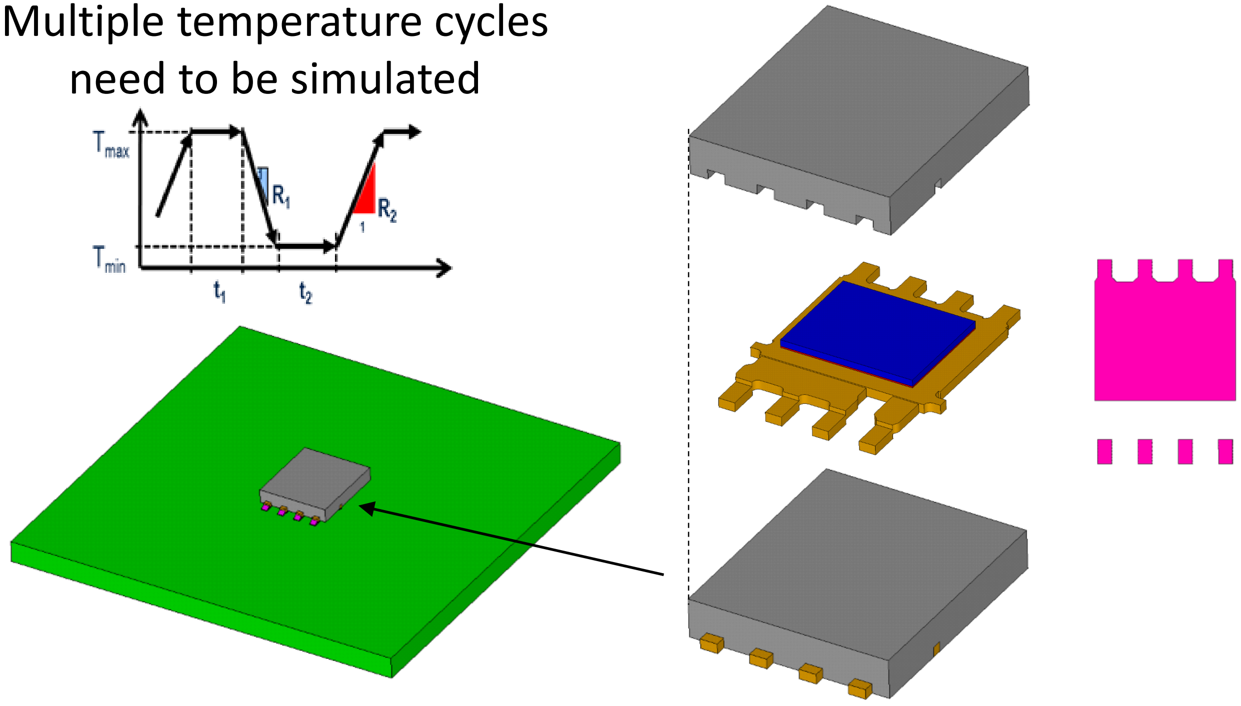
- Rebuild the setup used by IMEC for experimental validation of thermo-mechanical compact models
- Adapt the design used by IMEC to the type of packages investigated in COMPAS
- Understand sensitivities of this setup and generate MOP for discussion with layout/test

- For the validation of the compact models developed in COMPAS, a tailored test setup shall be developed based on the concept used by Bart Vandevelde



Source: Bart Vandevelde, EuWoRel 2019

Multiple temperature cycles need to be simulated

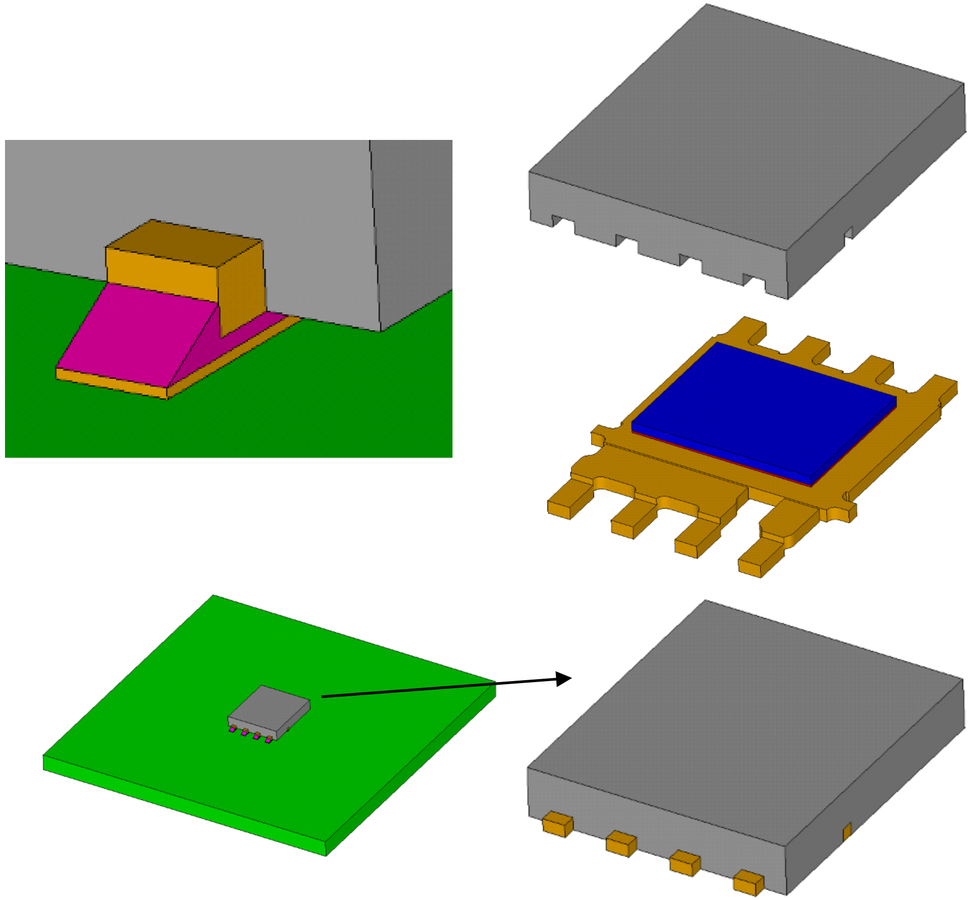


Effort for a solder joint analysis run for one (detailed) package on one PCB:

x*hours @ 40 cores

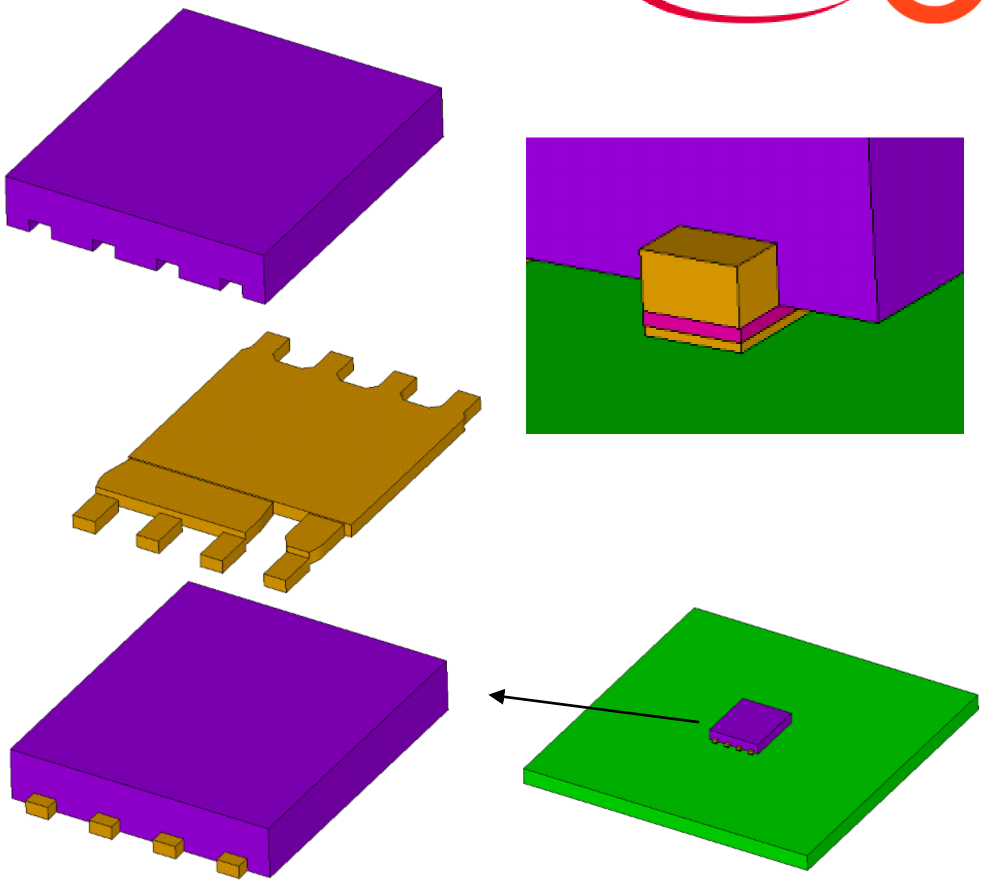
- In order to perform thermo-mechanical simulation of such a setup with multiple packages, the computational effort of the package model needs to be reduced

Step #1: Homogenization | Step #2: AMOPs



De-feature manually & Homogenize by AMOP

Note:
Non-productive BoM is chosen in order to reduce duration of test

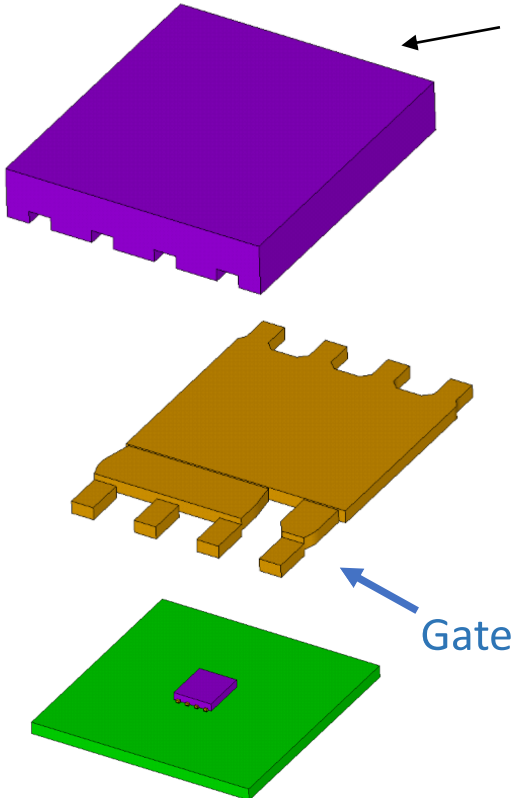


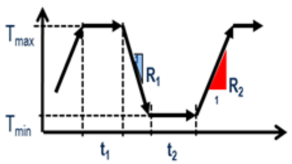
x*hours @ 40 cores

x*minutes @ 40 cores

- Since COMPAS approach is still being developed, a mixture of manual de-featuring and homogenization using optiSLang AMOP is used

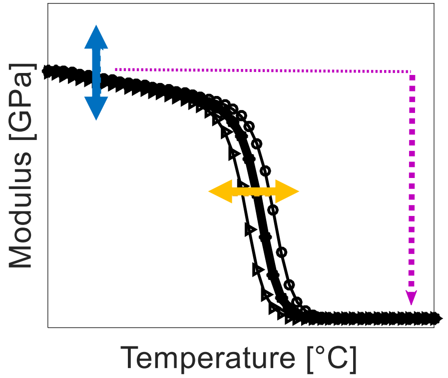
Step #1: Homogenization | Step #2: AMOPs

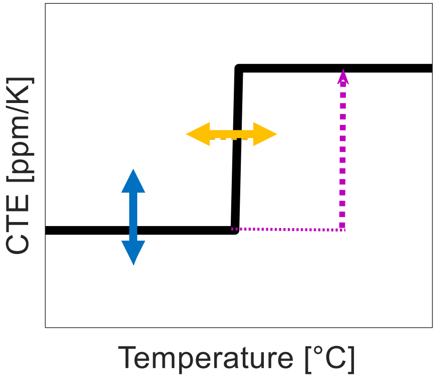




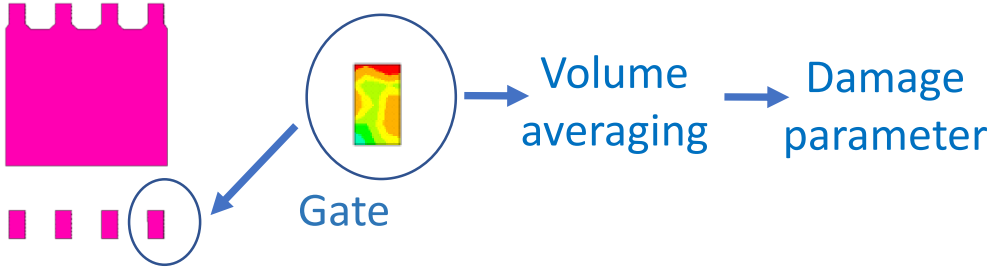
Cyclic loading

WHAT: Effective linear-visco-elastic material model shall be used for homogenized block



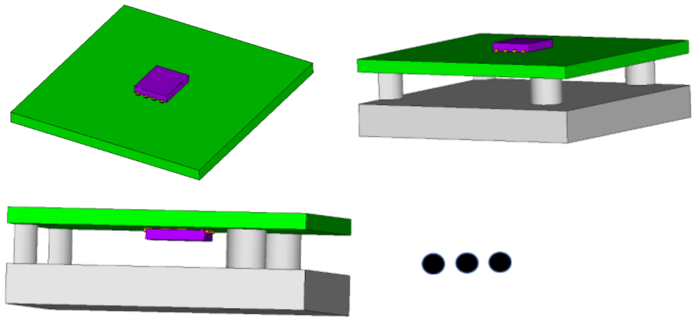


CRITERION: Loading of gate solder joint is evaluated as criterion for homogenization



Merged objective:

- High weighting on capturing relative change in loading of different configurations

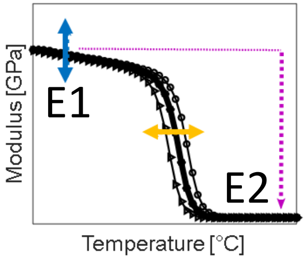


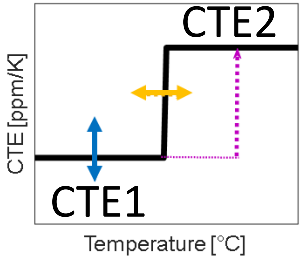
- Reduced weighting on quantitative accuracy (solder joint geometry changed)

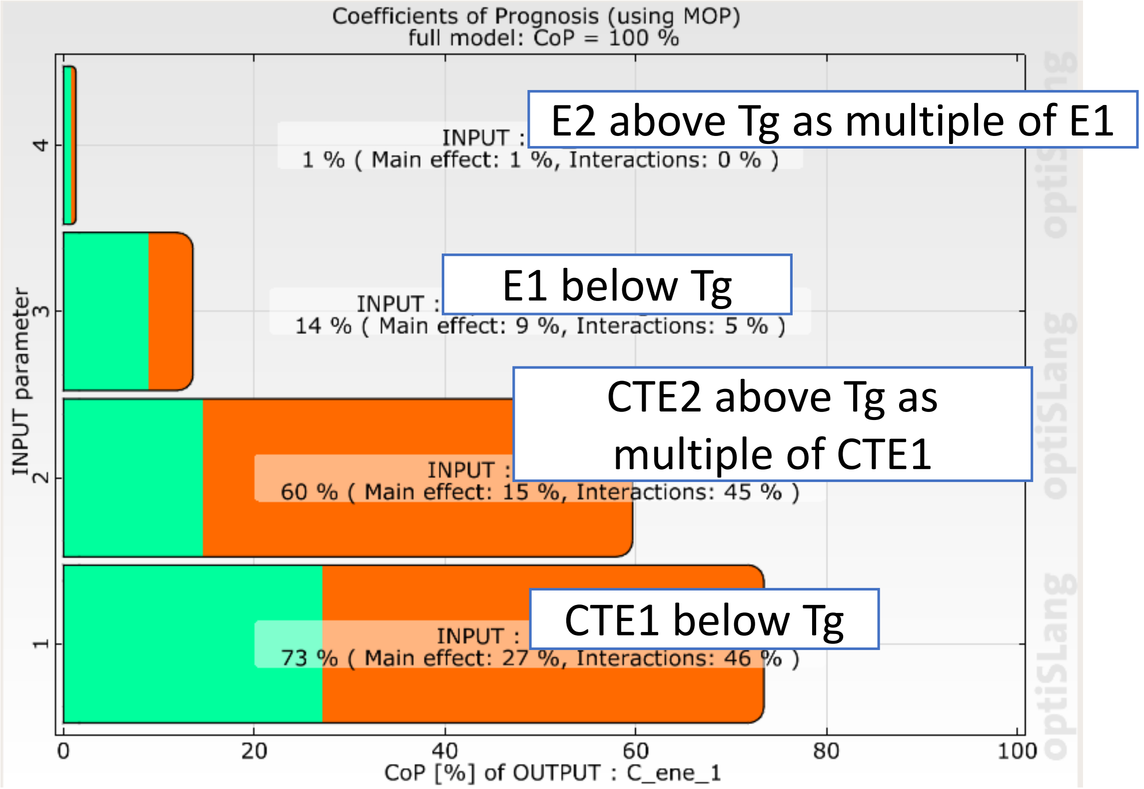
- Effective linear-visco-elastic material model is calibrated using the loading of the gate solder joint (→ damage parameter) as a criterion

Step #1: Homogenization | Step #2: AMOPs

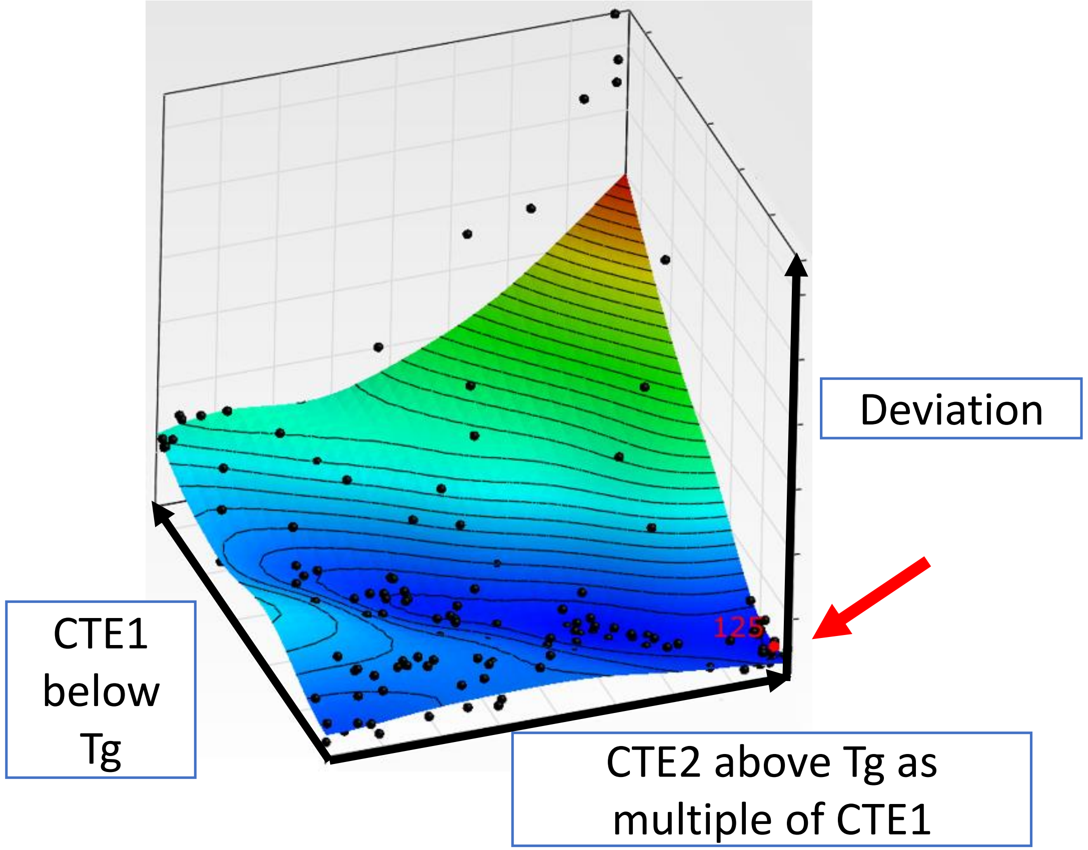
As per design:
Strong interactions





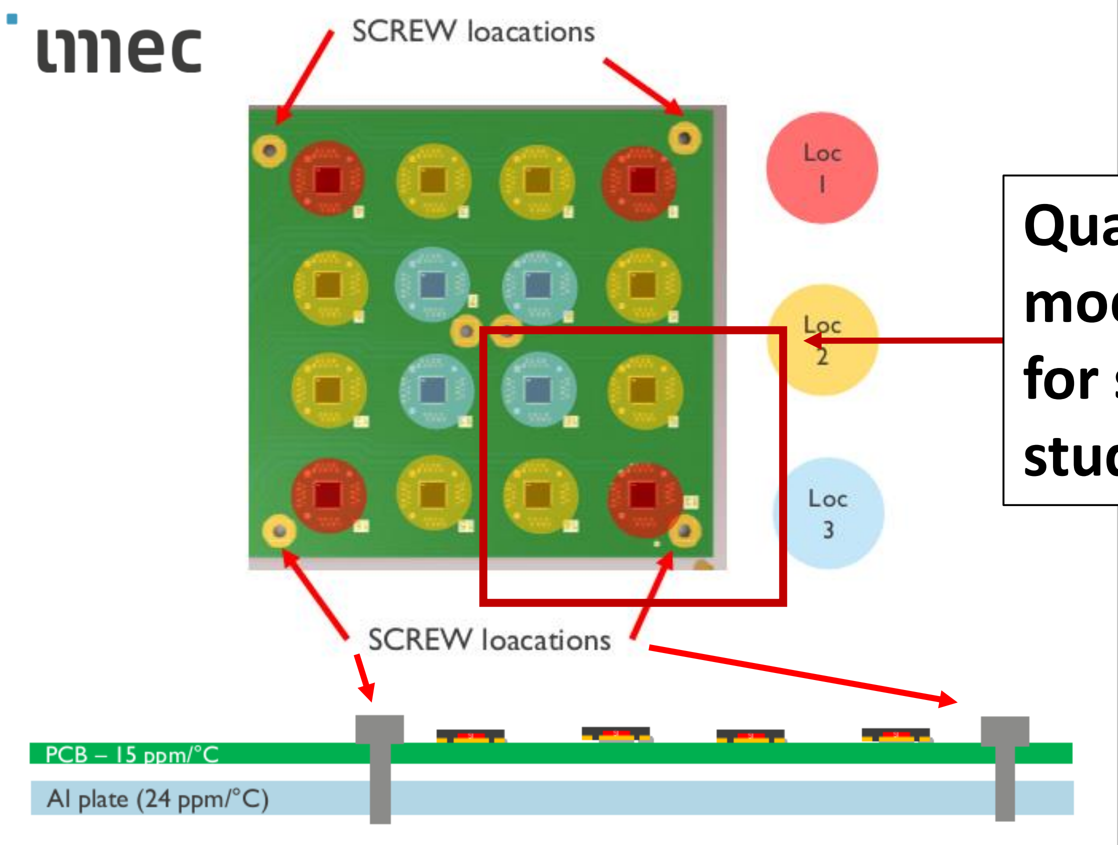


Response surface from AMOP shows important trends helping to select parameters



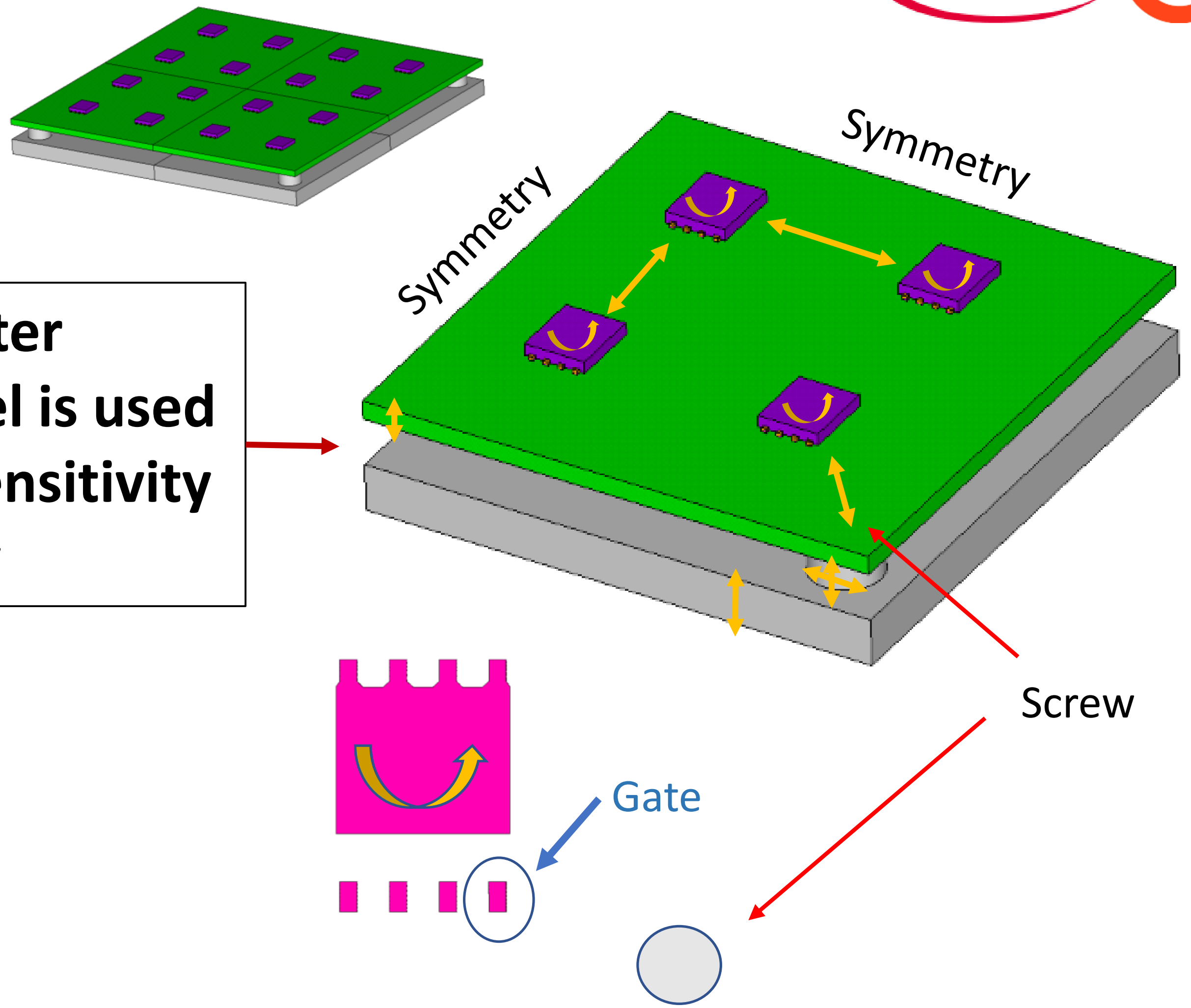
- Best design/parameters selected and confirmed using additional considerations
- Reduced model has only 10% of DOFs and 5% of compute time of full model

1. Motivation
2. Step #1: Homogenization for reducing computational effort
3. Step #2: AMOP analysis of test setups
4. Outlook: “Fragility surface plots”
5. Summary

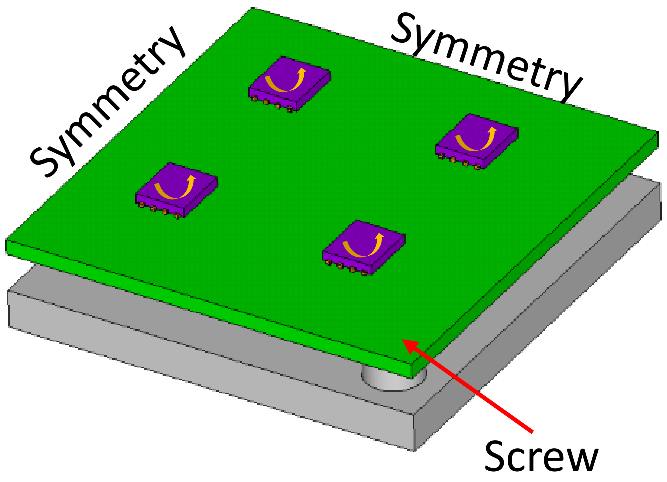


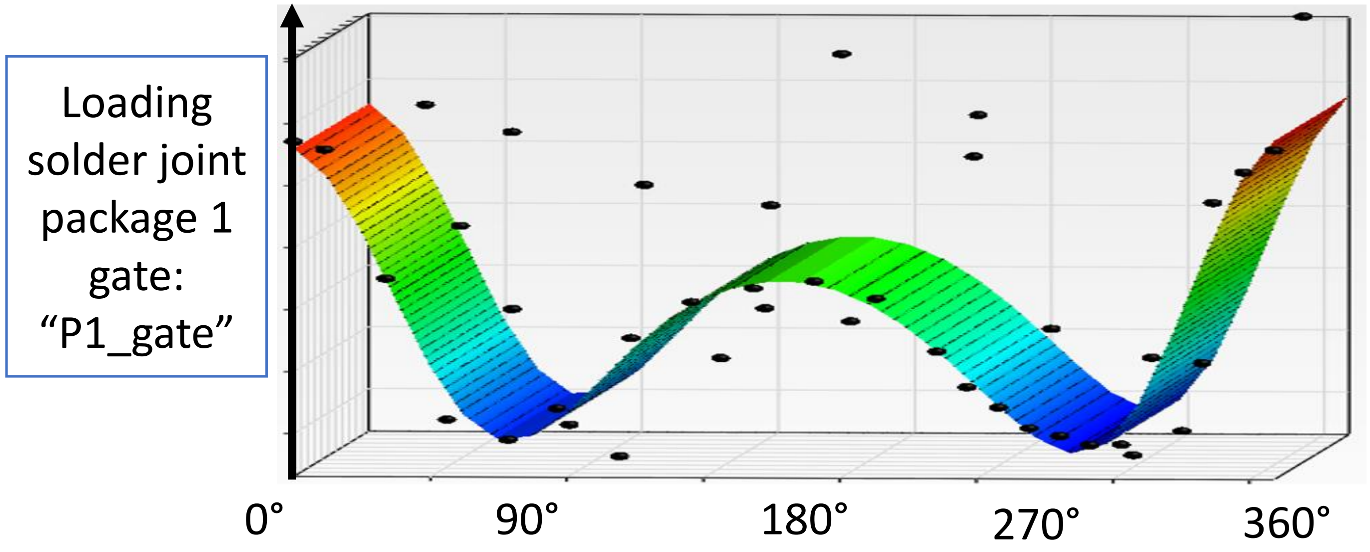
Source: Bart Vandevelde, EuWoRel 2019

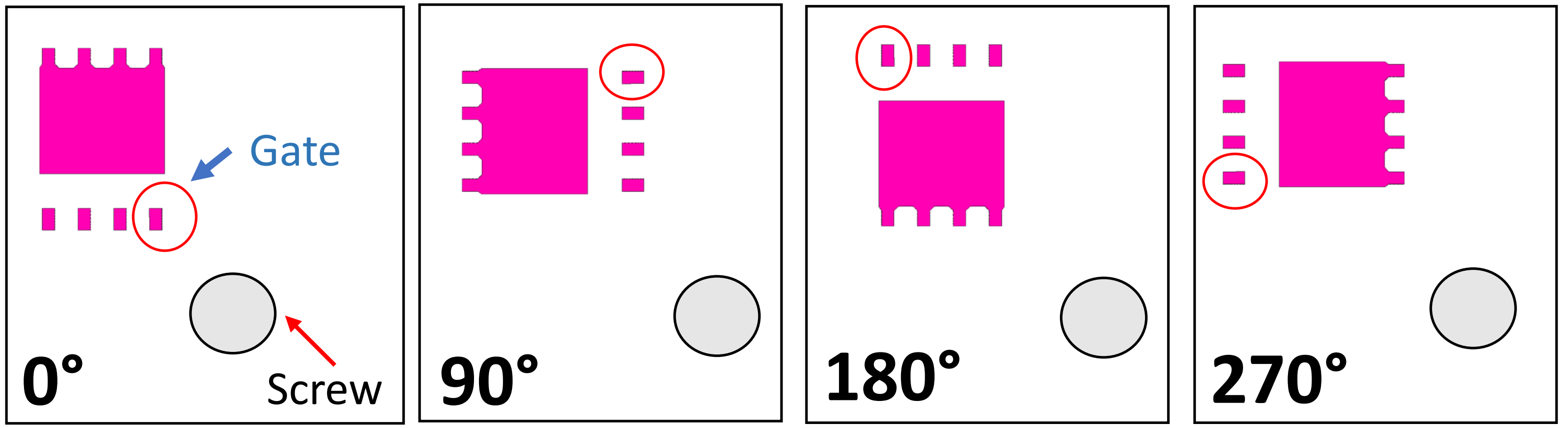
Quarter model is used for sensitivity study

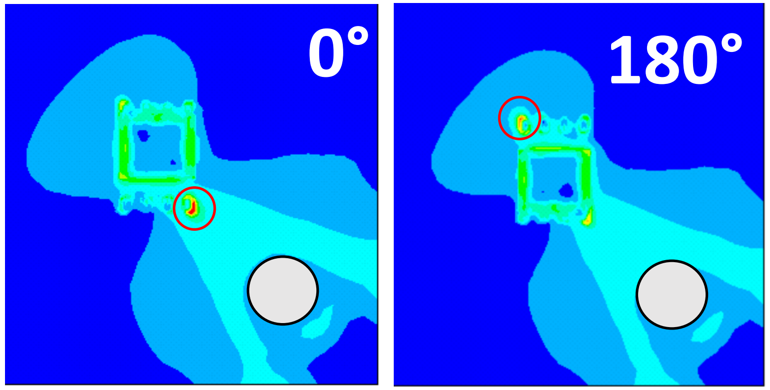


- Quarter model is used for performing a sensitivity study (AMOP) ➔ MOP
- Focus is to design a setup which leads to high loading ➔ short testing times

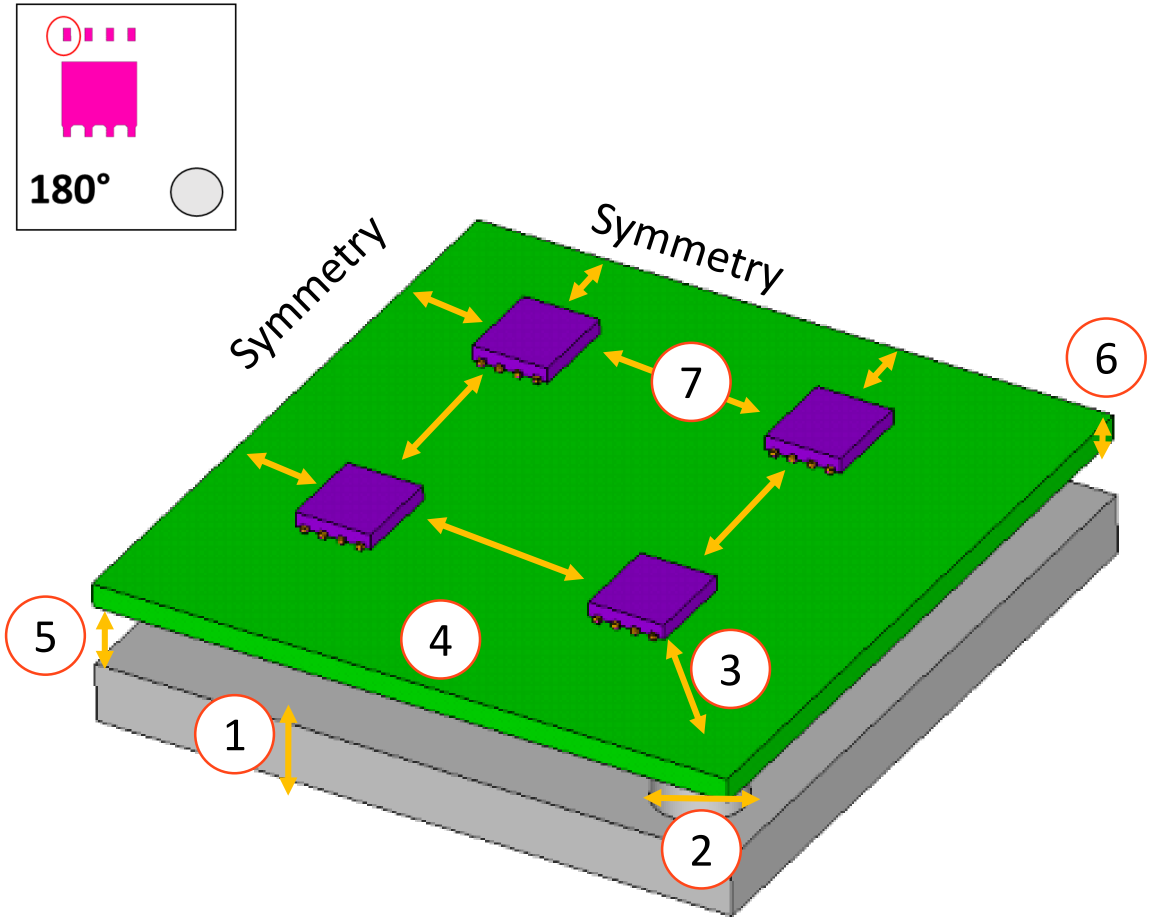


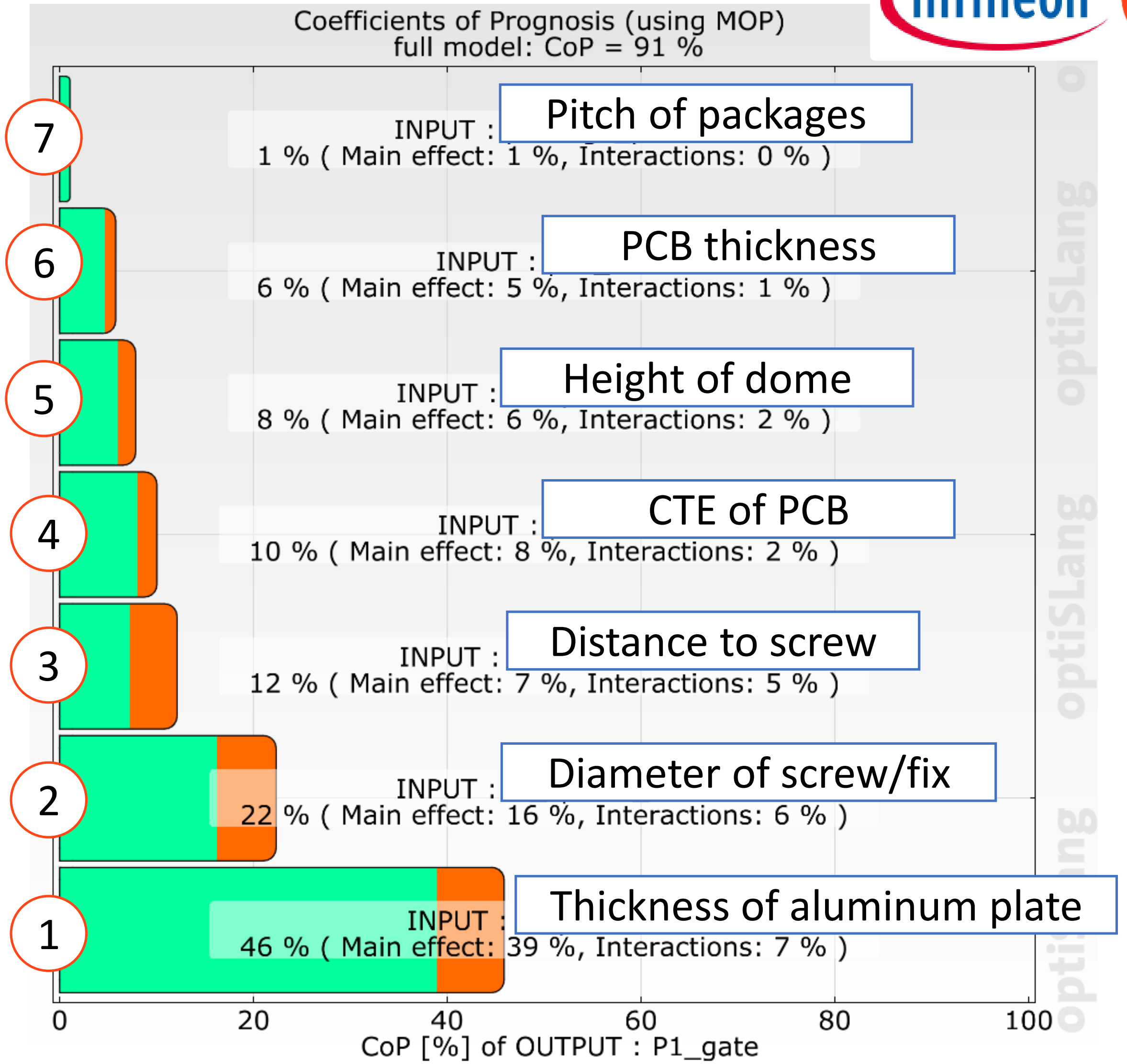




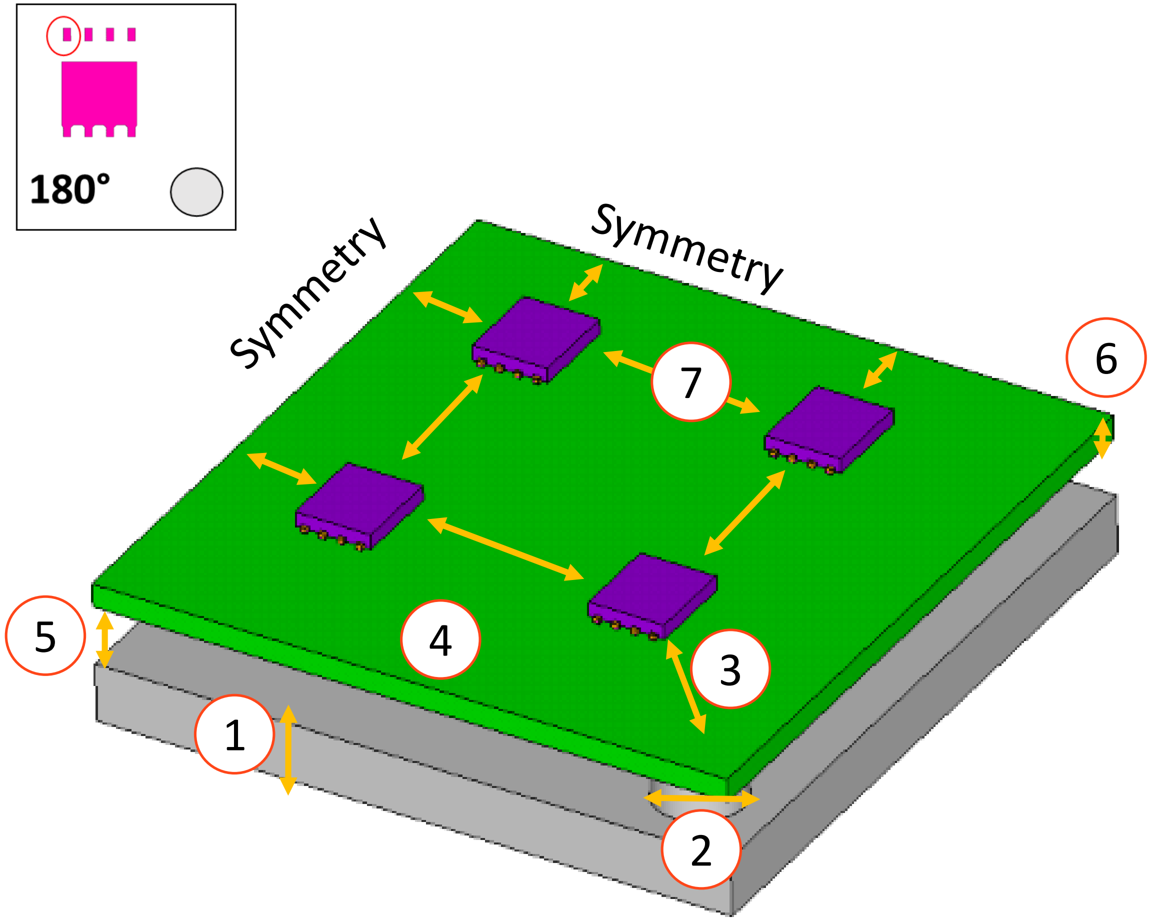


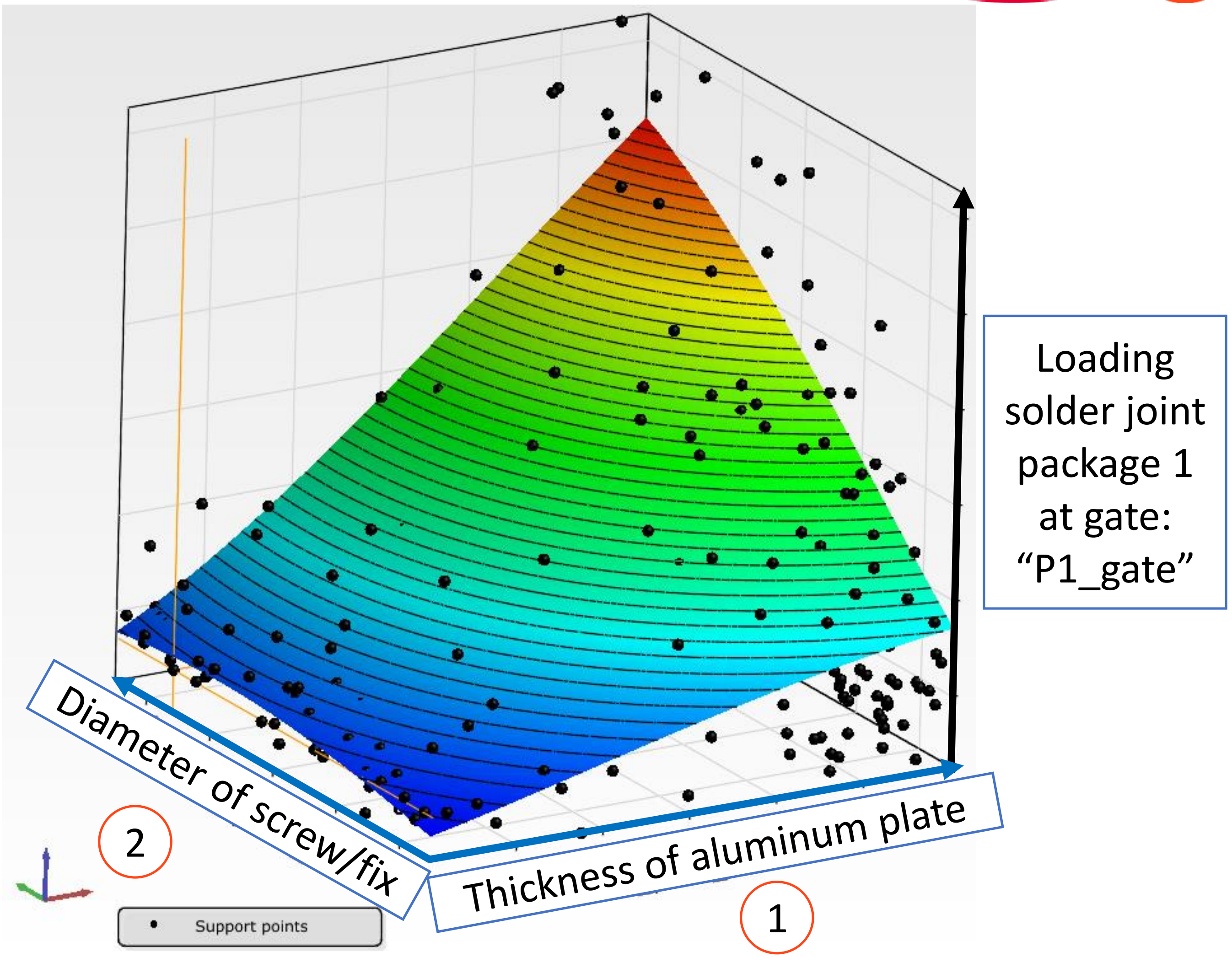
- Rotation of asymmetric footprint w.r.t. screw has high impact
- Rotation of 180° is chosen





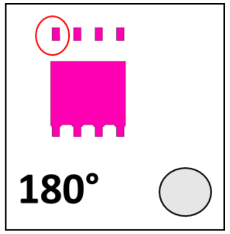
- Highest impact not from distance to screw, but from thickness of aluminum plate and diameter of screw/fix

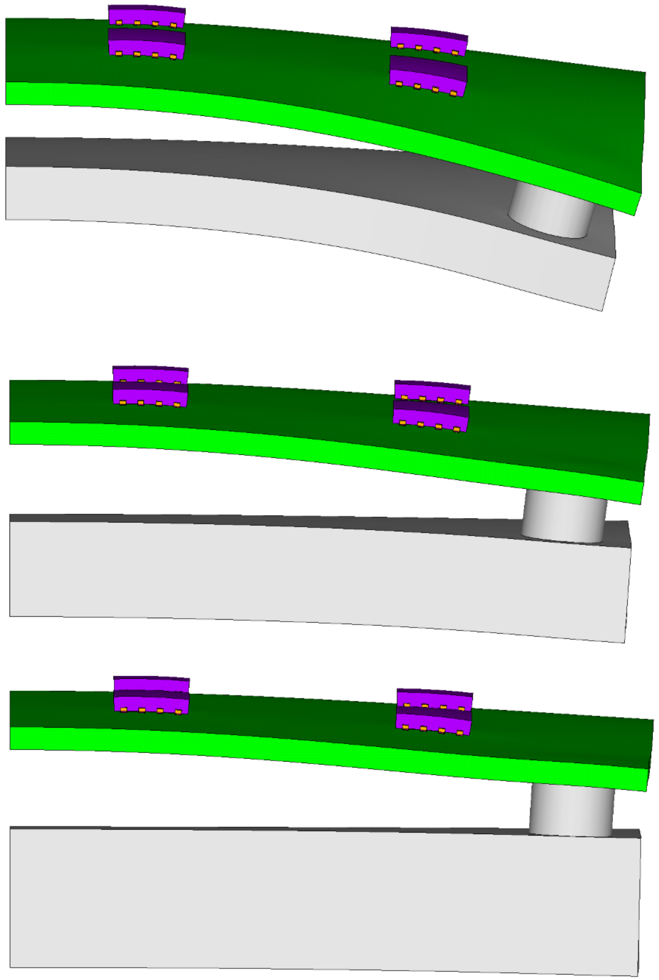




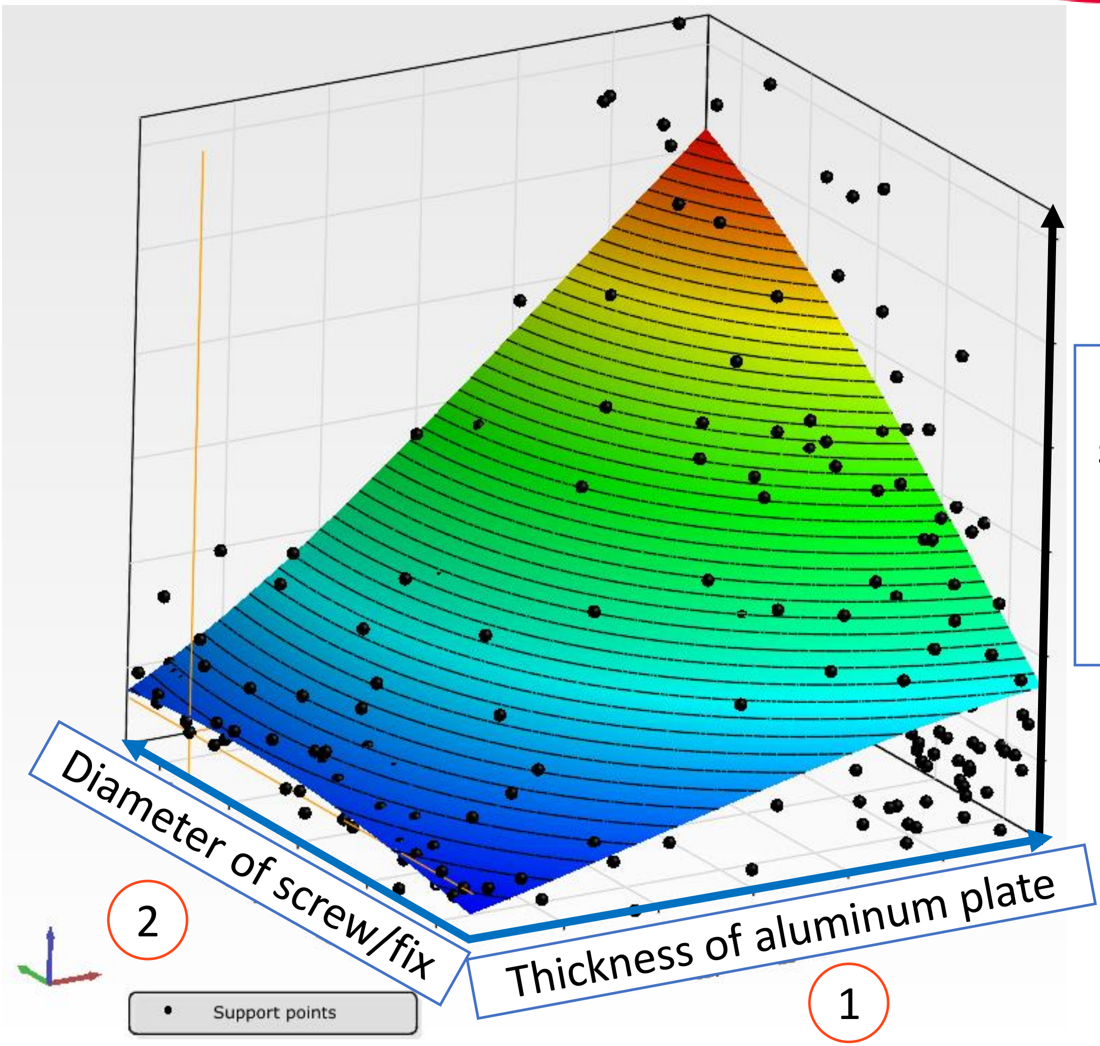
- Highest impact not from distance to screw, but from thickness of aluminum plate and diameter of screw/fix

Step #2: AMOPs Test Setups | Outlook



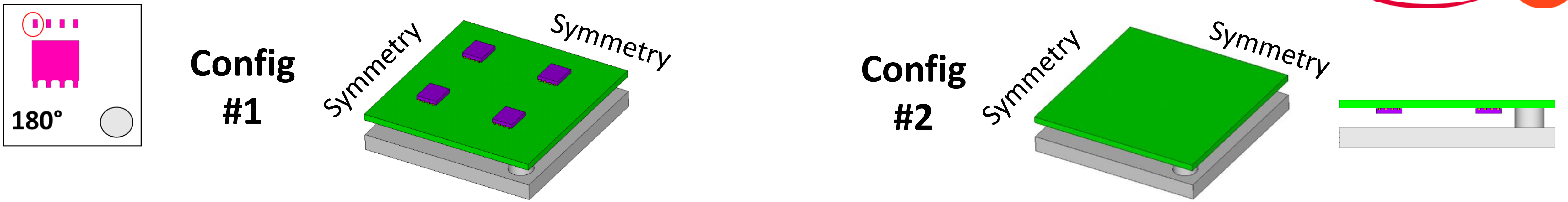


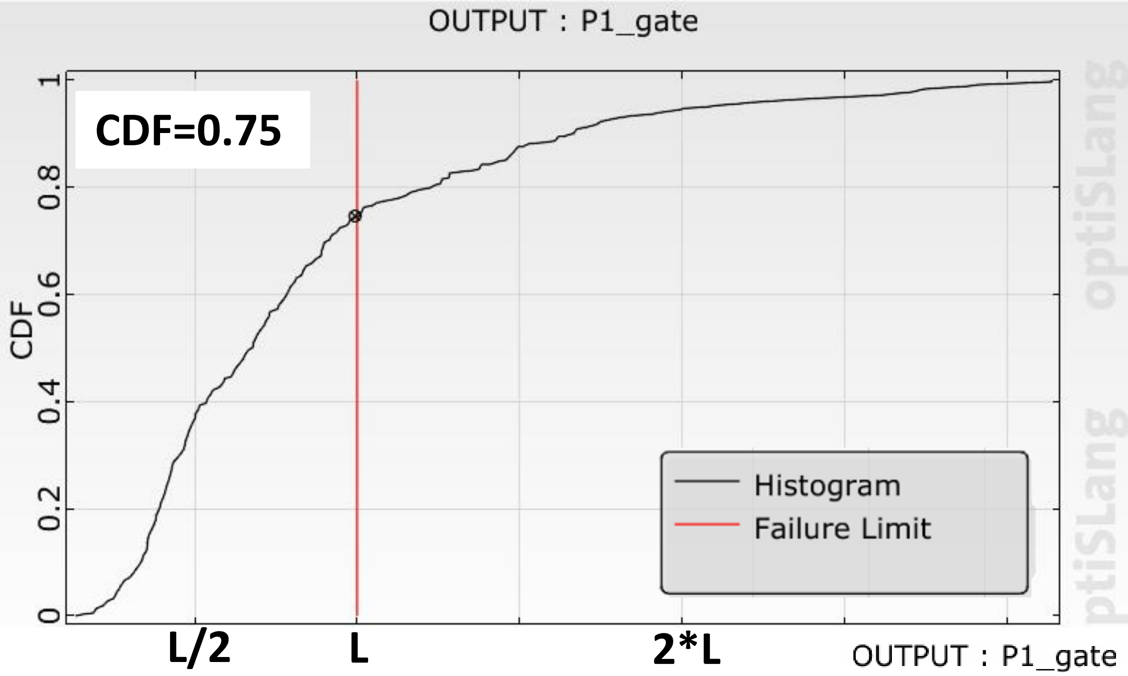
Deformation plots at -40°C Factor 100x over-scaled

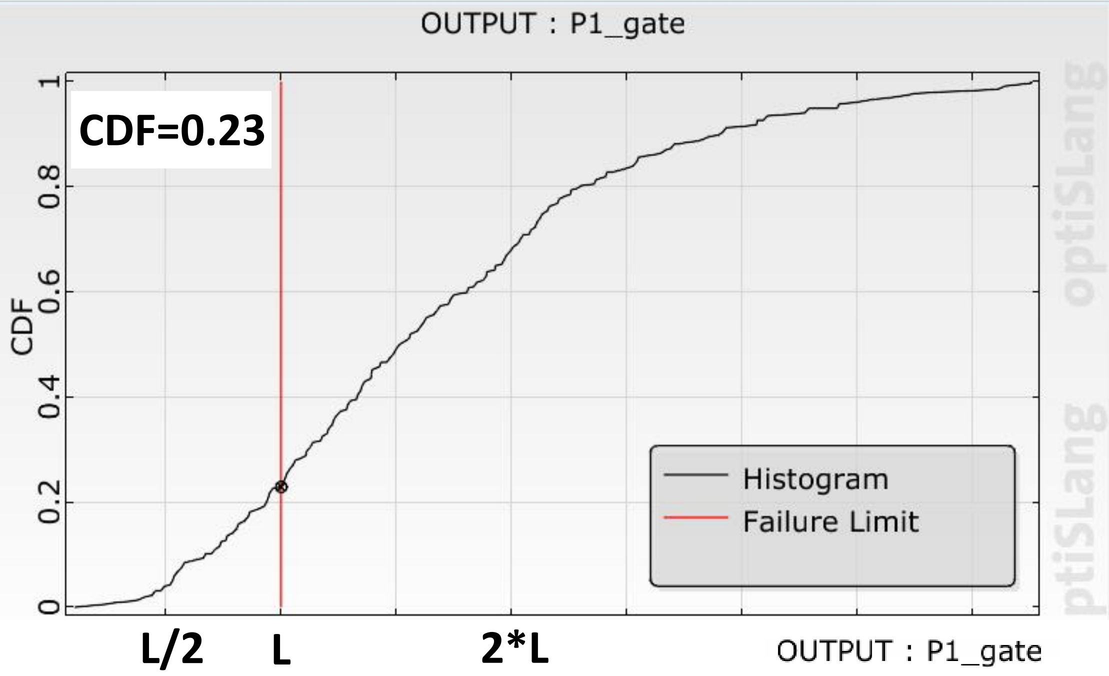


Loading solder joint package 1 gate: “P1_gate”

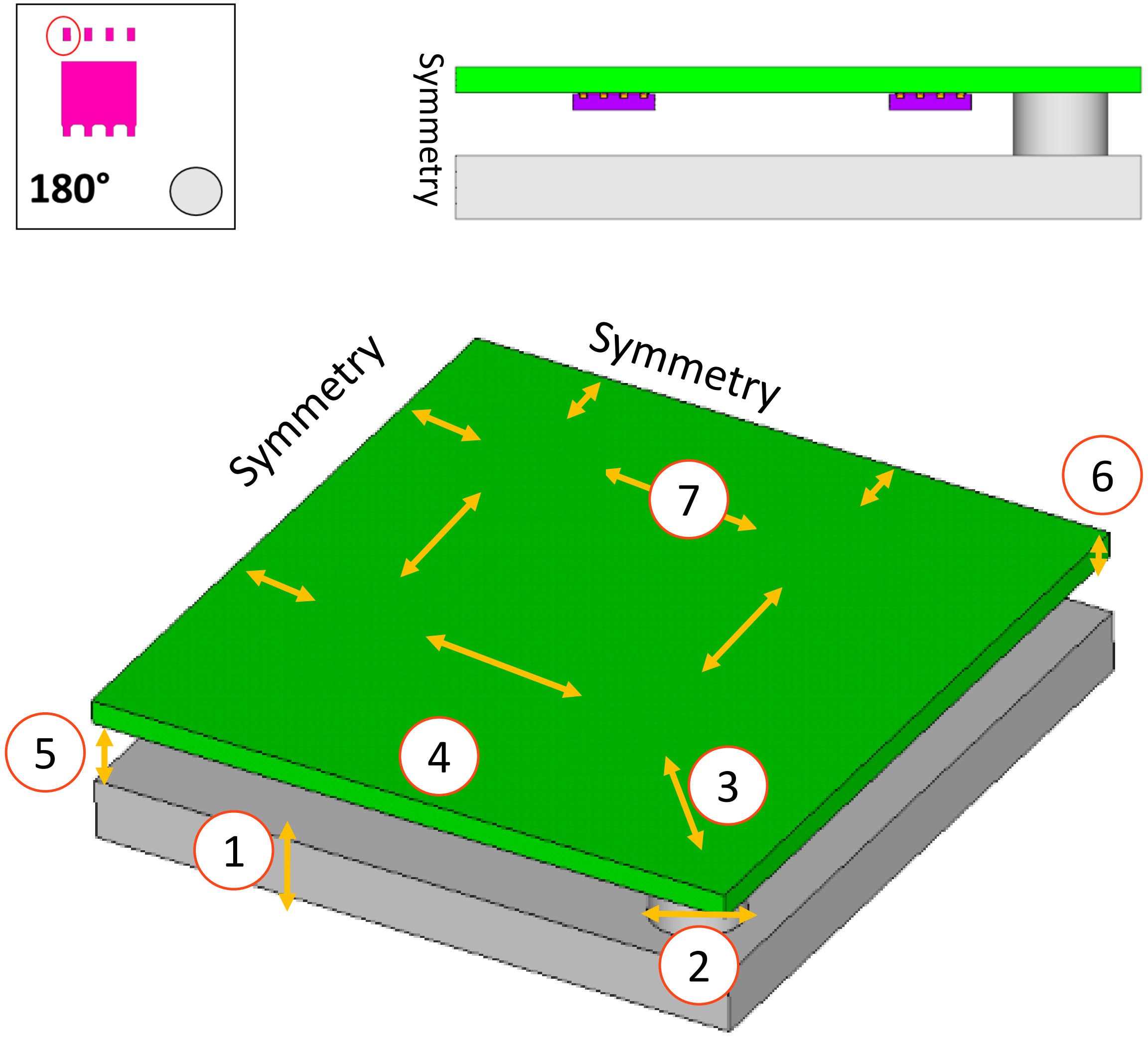
- Thicker aluminum plate will result into stiffer step, no longer bend and, consequently, induce more stress into PCB

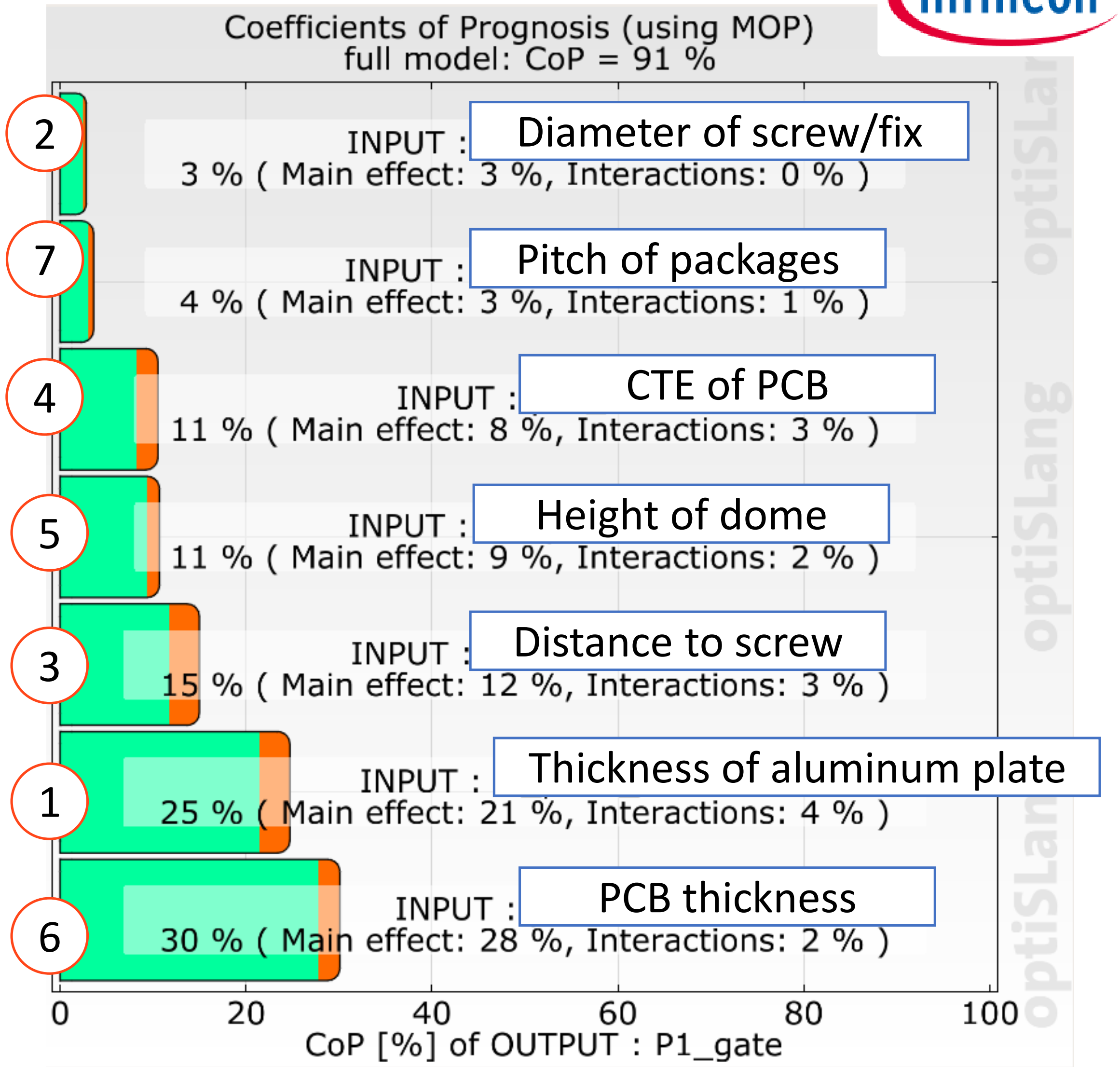






- Flipped PCB leads to overall increased loading
- CDF: For arbitrarily selected limit *L*, config #1 has 3x designs below limit than #2

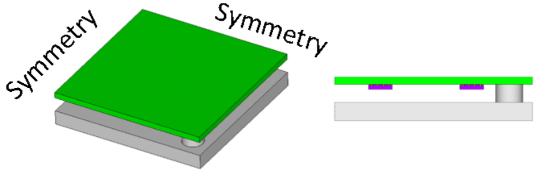




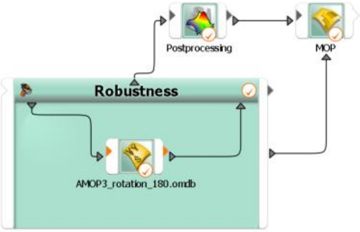
- CoP ranking of parameters changes significantly

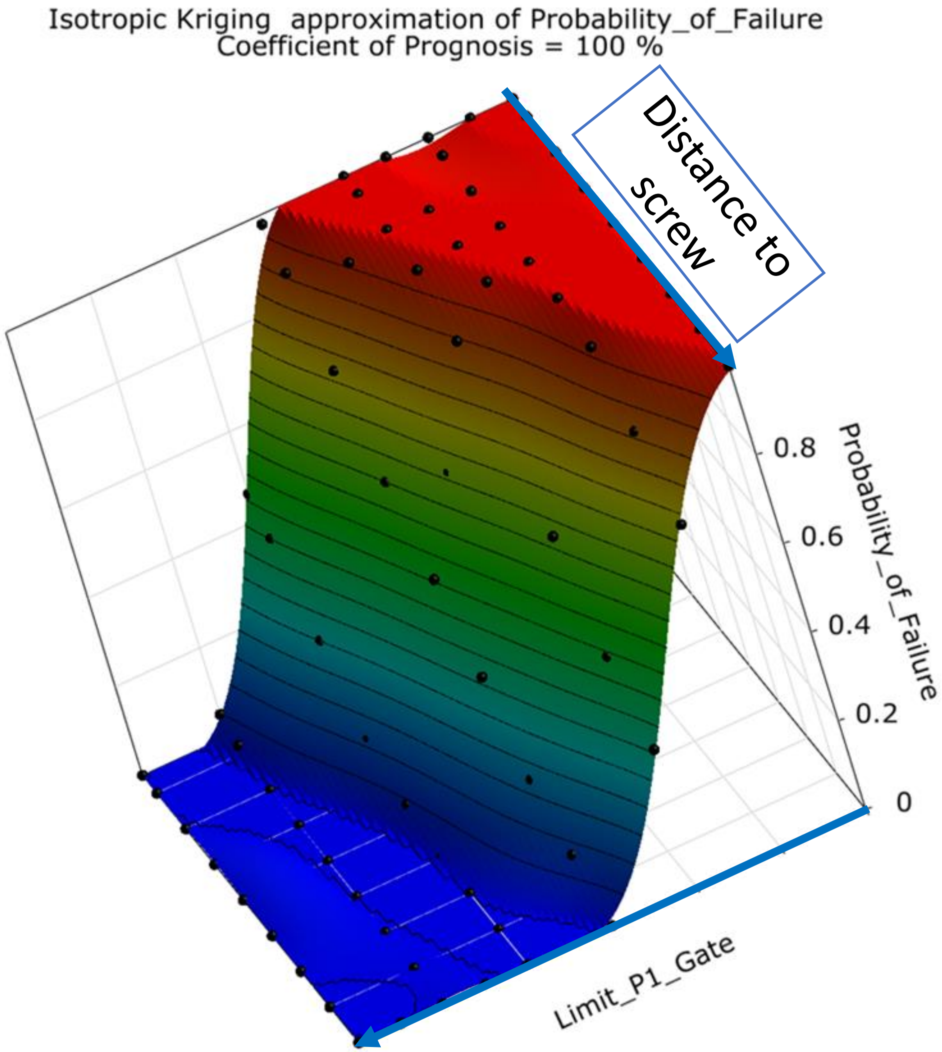
Question:
Which loading is achieved with which distance to screw when the PCB varies?

Config: **Config #2**



Fixed:	Thickness of aluminum plate			
	Pitch of packages			
	Height of dome			
	Diameter of screw/fix			
Vary:	PCB thickness	Opt.+Stoch.	UN...	+/- 5%
	CTE of PCB	Opt.+Stoch.	UN...	+/- 7%
	E-modulus of PCB	Opt.+Stoch.	UN...	+/- 7%
→	Distance to screw			





- “Fragility” surface plots allows for thorough analysis of this impact

1. Motivation
2. Step #1: Homogenization for reducing computational effort
3. Step #2: AMOP analysis of test setups
4. Outlook: “Fragility surface plots”
5. Summary

- optiSLang AMOP functionality was successfully used to calibrate a homogenized simulation model which allowed to significantly reduce the computational effort

- optiSLang AMOP functionality was successfully employed to study the sensitivities of two test setup configurations w.r.t. solder joint loading:
  - Strong difference in overall loading level as well as sensitivity to the individual parameters was identified

- “Fragility surface plots” are investigated in order to assess the impact of PCB variation w.r.t. solder joint loading of the test setups

- Next step: Use MOPs for discussion with layout and test teams in order to develop the test setup

COMPAS

Thank you for your attention!