Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

15. Weimarer Optimierungs- und Stochastiktage

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Dynardo GmbH:

Dr. S. Klonk, Dr. D. Schneider, Dr. S. Wolff

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- **Results**
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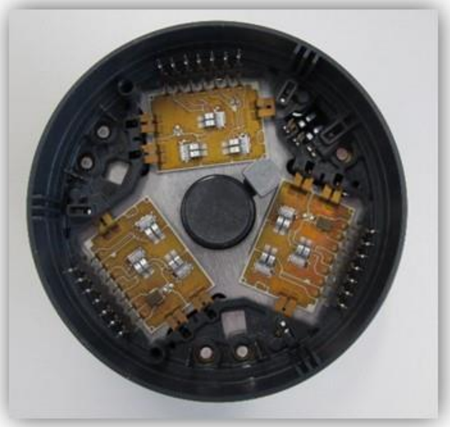
  - Conclusion / Outlook

Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

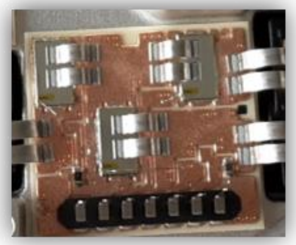
Electronic power steering

Electronic power steering



Electronic control unit (ECU)

Power pack



DBC

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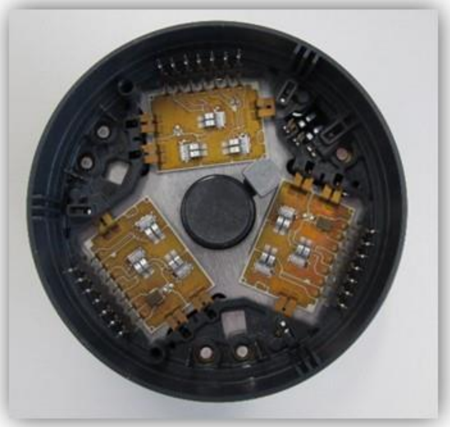
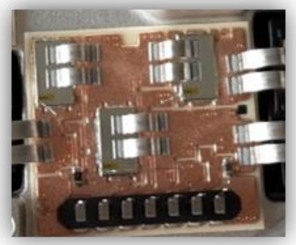
Electronic power steering

Environmental influences:

Electronic power steering



Electronic control unit (ECU)

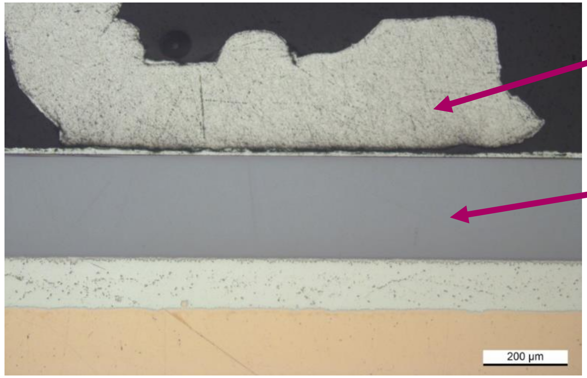


DBC

Power pack

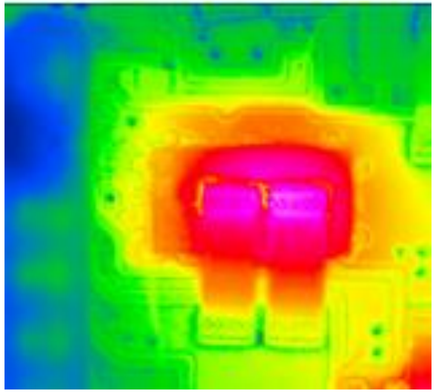
Motivation

- Different environmental influences lead to fatigue during lifetime
- Typical fatigue failure mechanism on DBCs are bond cracks due to thermal mismatch between aluminum bonds and silicon dies



Al-bond: 23ppm/K

Si die: 3ppm/K

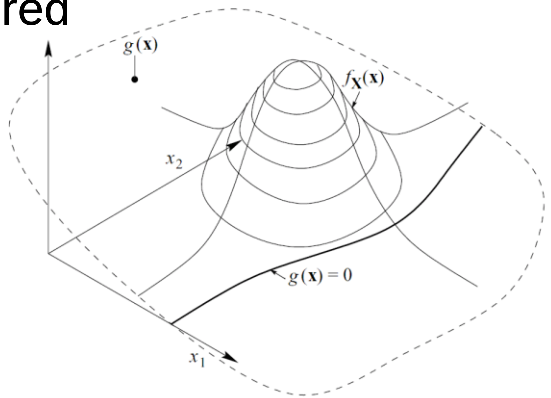


- Engineering goal: No fatigue failures during lifetime

Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

Motivation

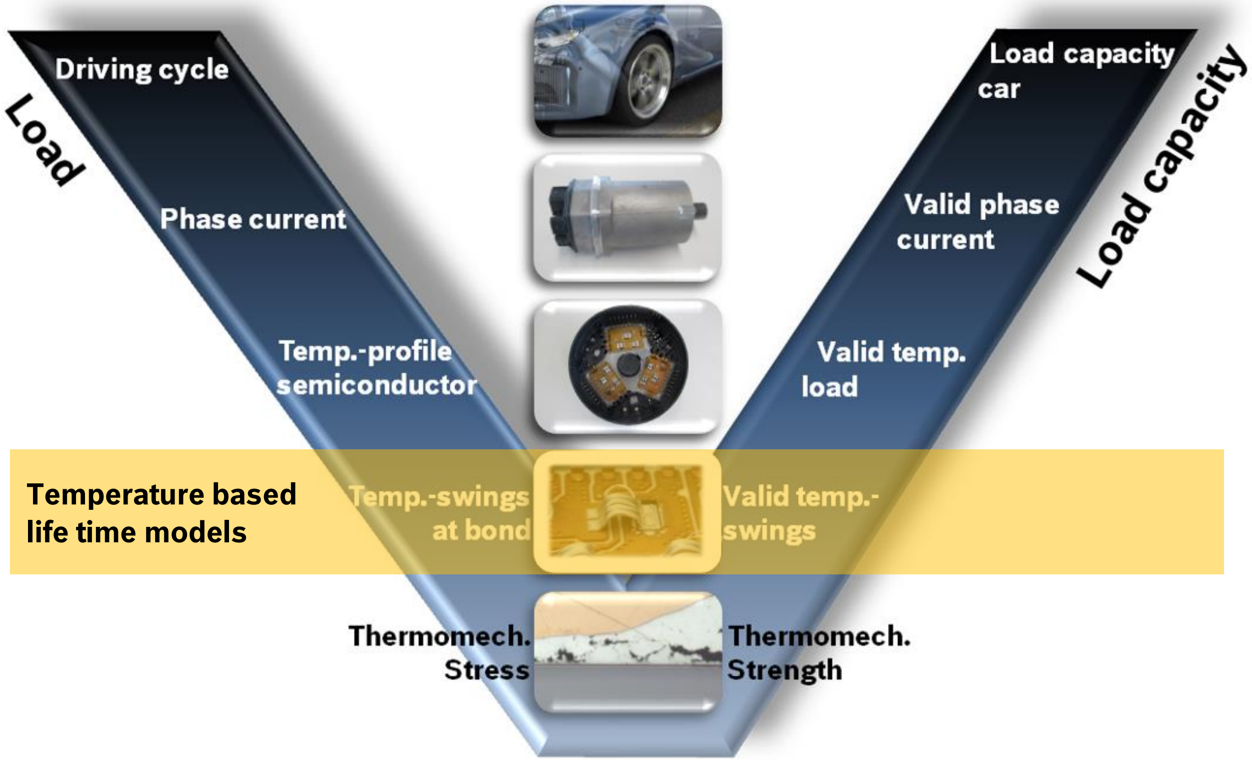
- Load and load capacity need to be compared



- State of the art reliability dimensioning and proofs are based on thermal based life time models, e.g.

$$N_f = A \cdot \left(\Delta T_{Global} + \boldsymbol{k} \cdot \rho \cdot J^2\right)^{-\alpha} \cdot \exp\left(\frac{\boldsymbol{Q}}{RT_m}\right)^{(*)}$$

(*)CIPS Presentation: Dürr, Faust-Ellsässer, Pröpper, Riester, 2016

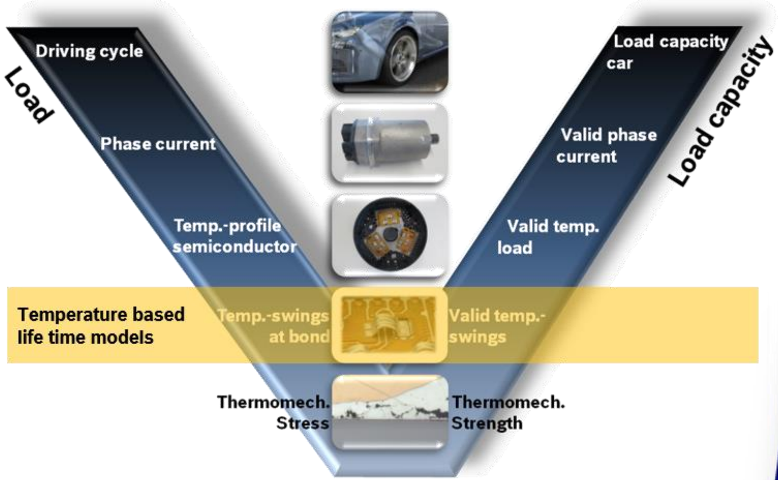


Advantage: Easy accessible parameter

Disadvantage: Geometry dependent parameter

Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

Motivation



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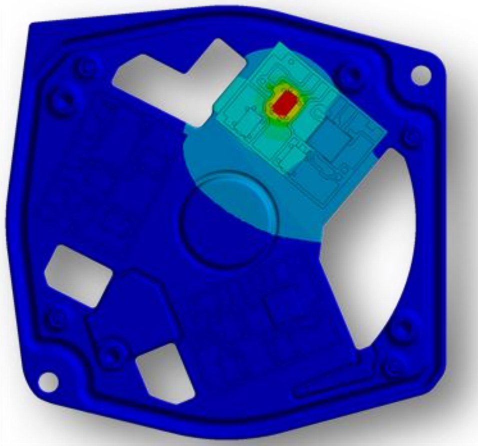
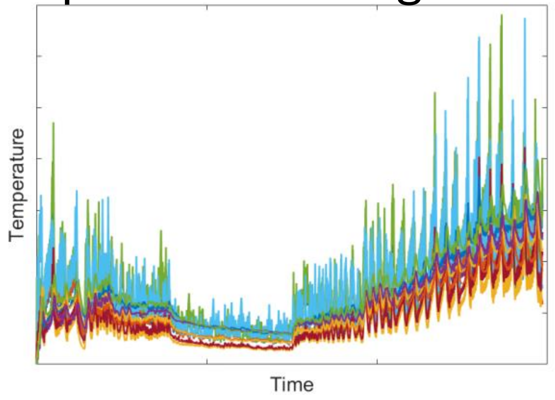
Easy accessible parameter:

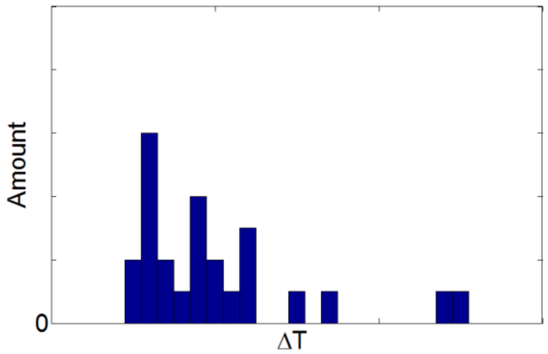


FEM Simulation

Temperature at design element



Rainflow counting



Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

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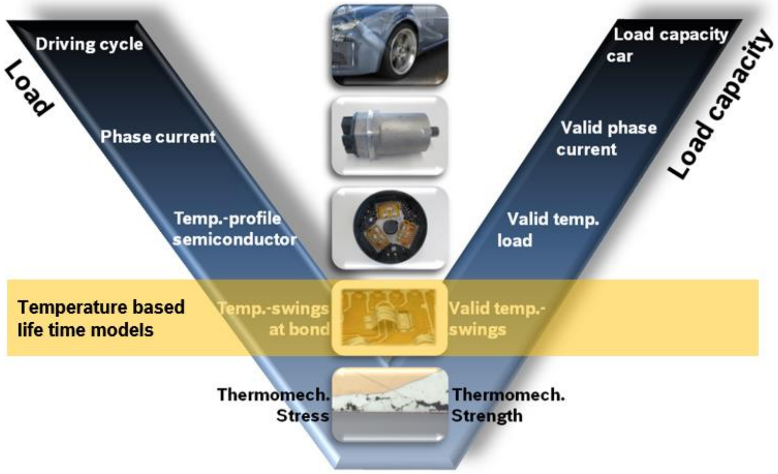

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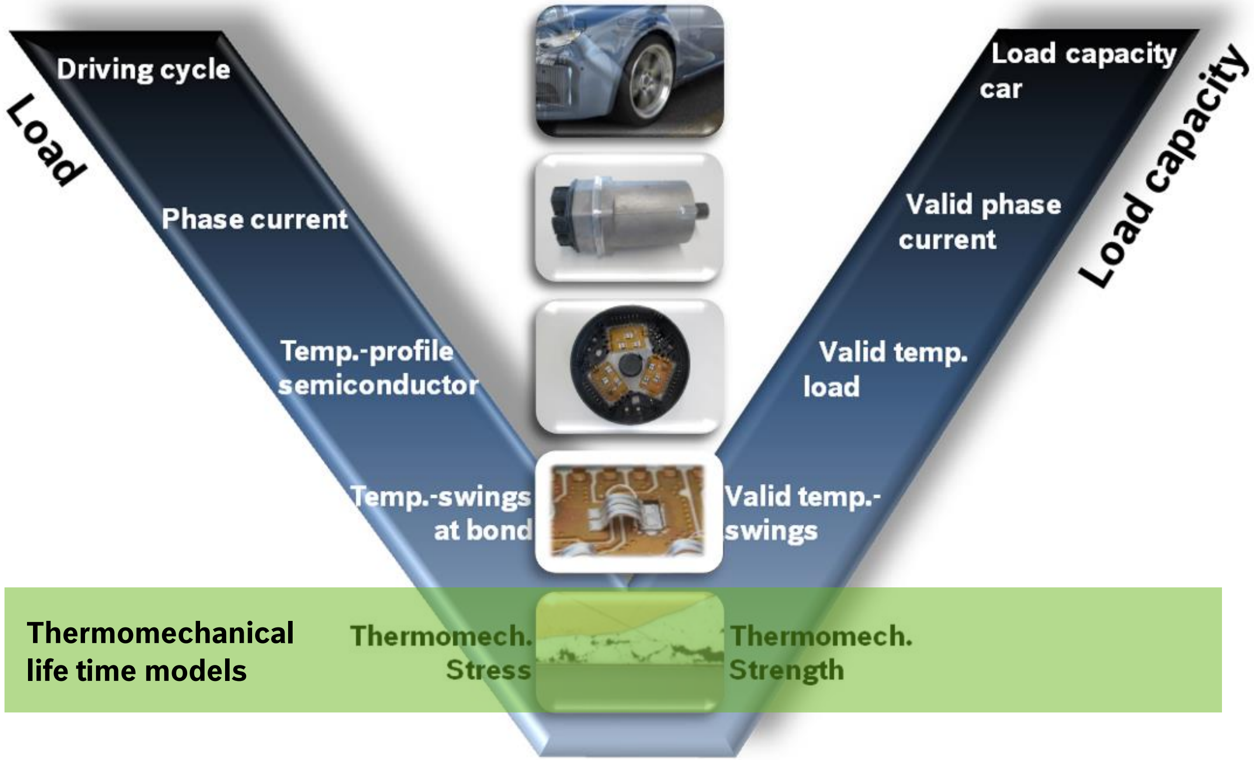
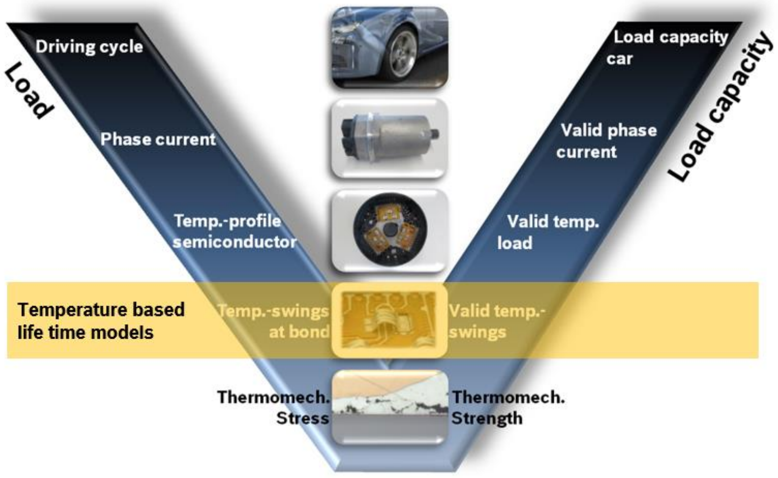


Advantage: Geometry independent parameter
Disadvantage: Elaborate accessible parameter

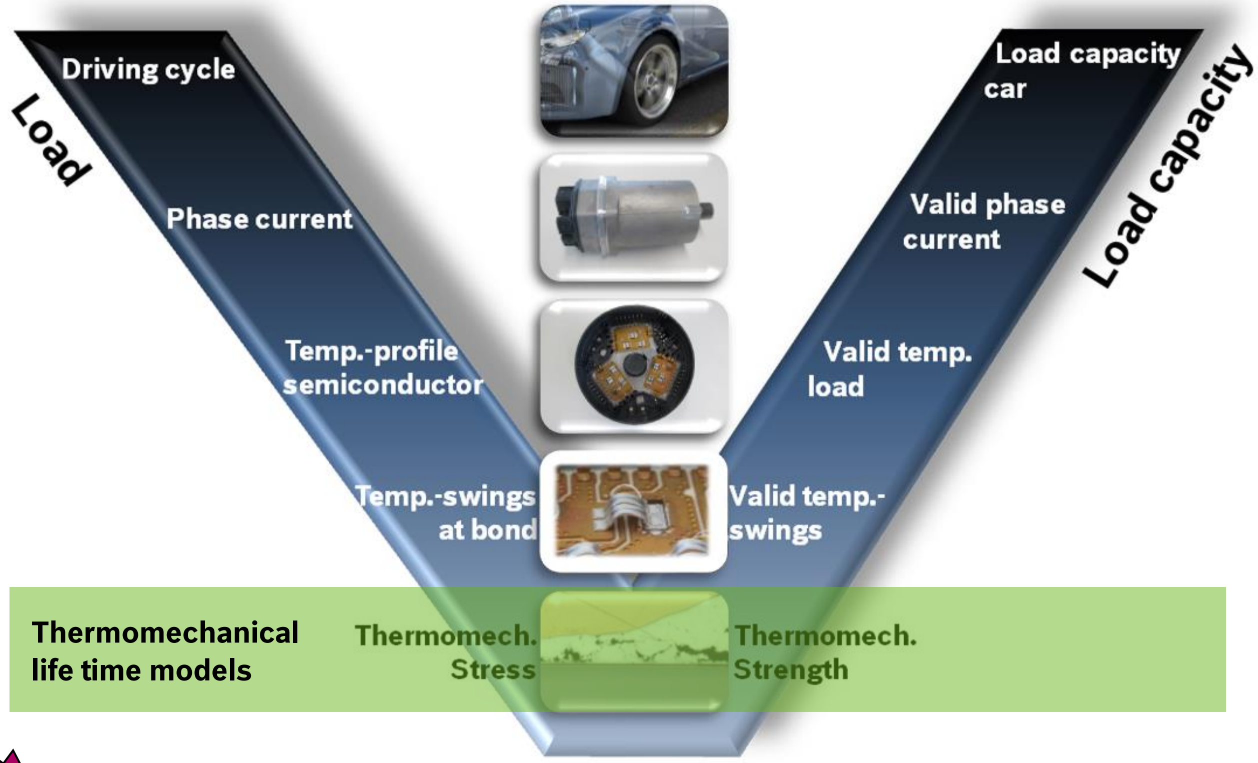
Motivation



Advantage: Easy accessible parameter

Disadvantage: Geometry dependent parameter

Allows earlier prognosis in development process on design element level



Advantage: Geometry independent parameter

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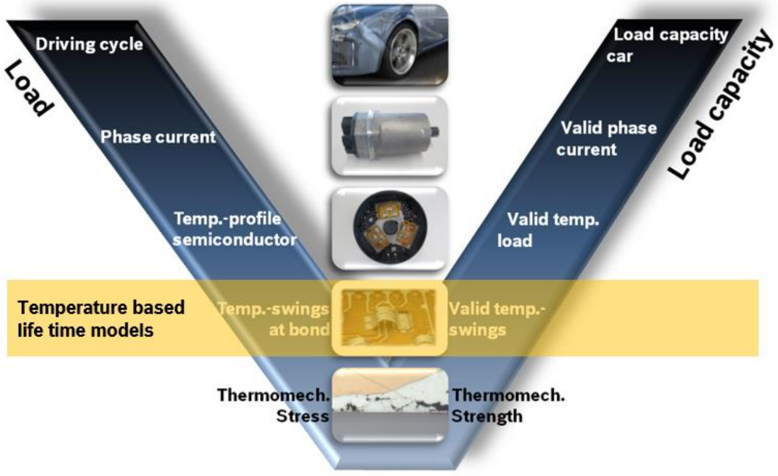

Advantage: Easy accessible parameter

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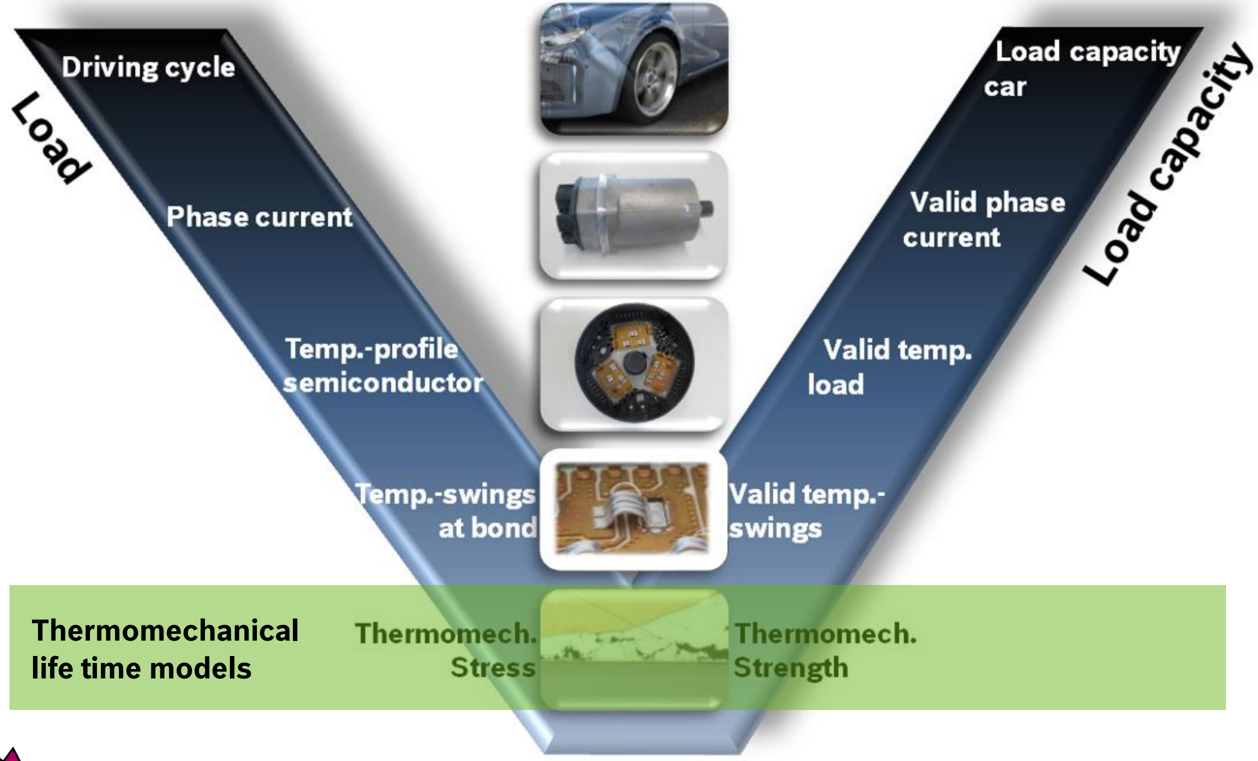

Advantage: Geometry independent parameter

Disadvantage: Elaborate accessible parameter?

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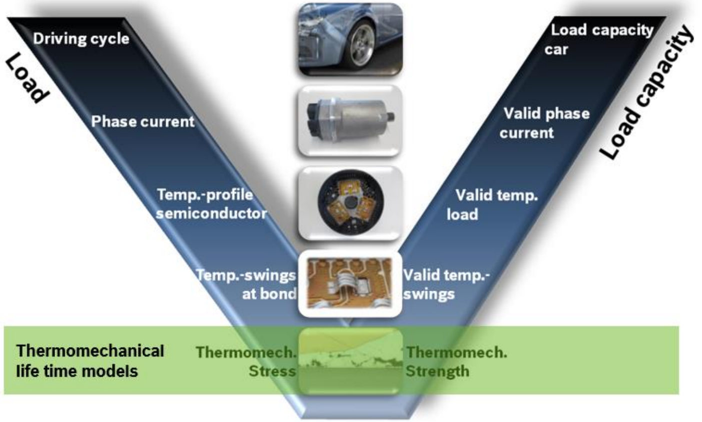
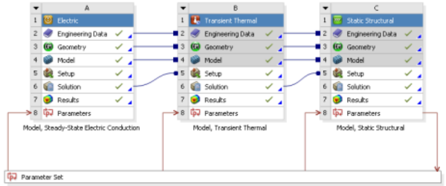
Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

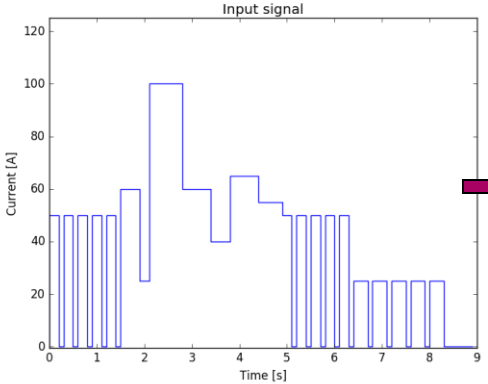
Motivation

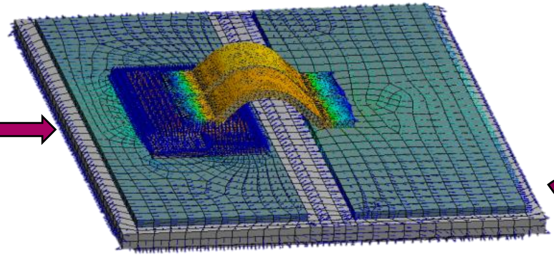


Elaborate accessible parameter?

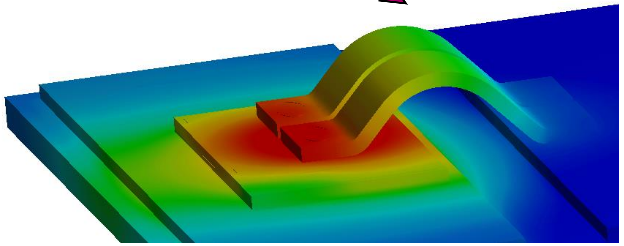


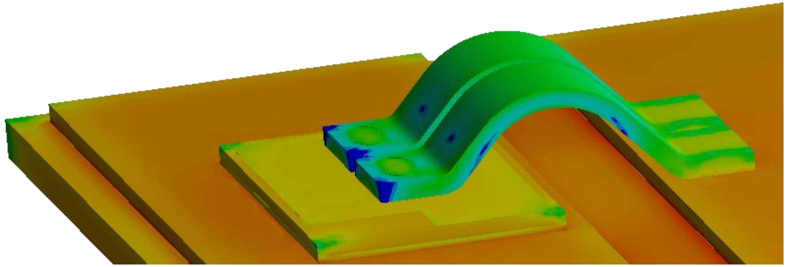
Electrical Analysis





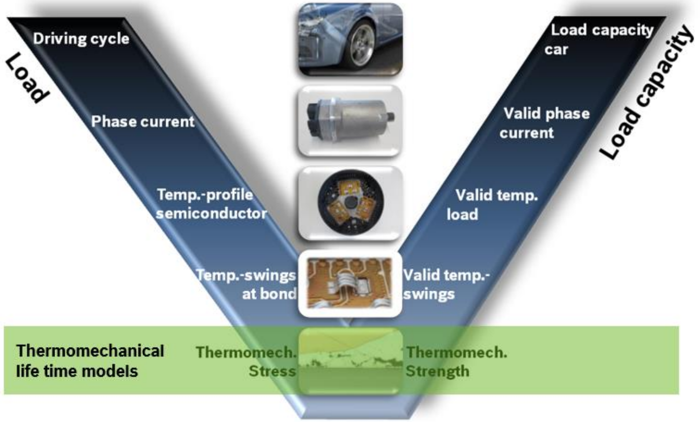
Thermal Analysis





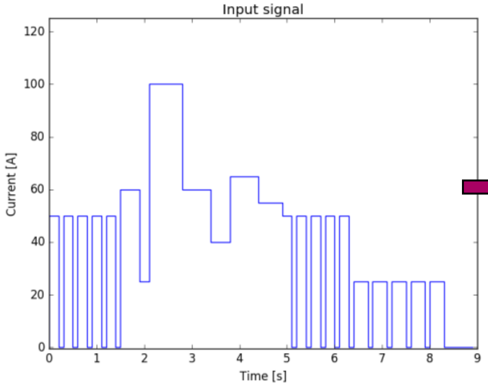
Mechanical Analysis

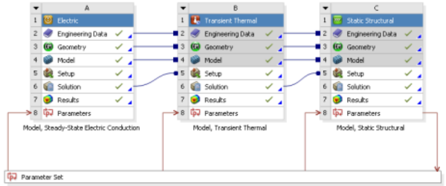
Motivation

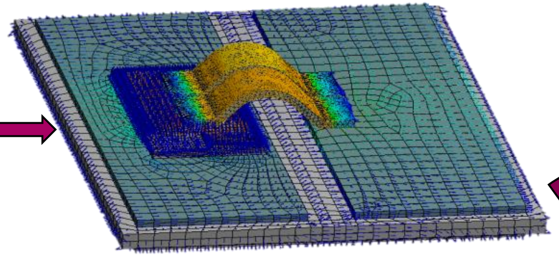


Elaborate accessible parameter?

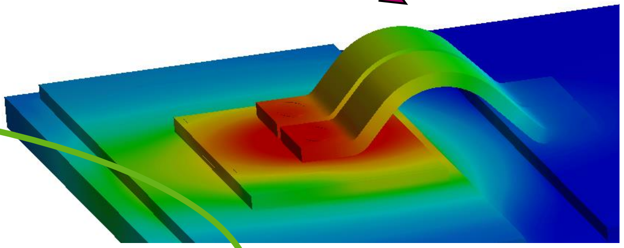
Electrical Analysis

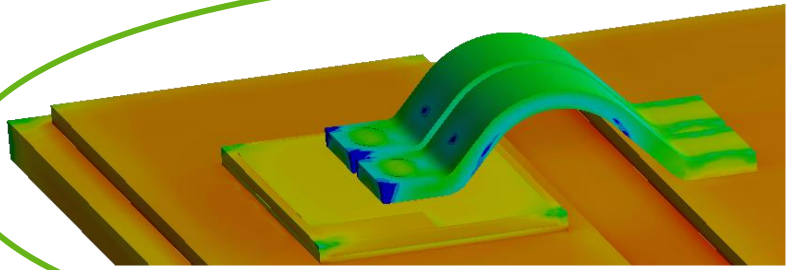






Thermal Analysis



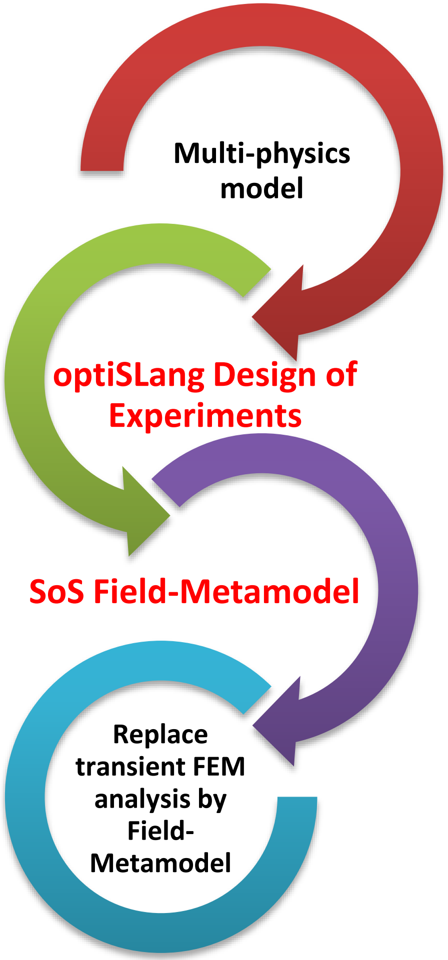


Mechanical Analysis

Nonlinear mechanical FEM simulation for transient load profile of whole ECU is not purposeful at the moment

Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

Goal of the project

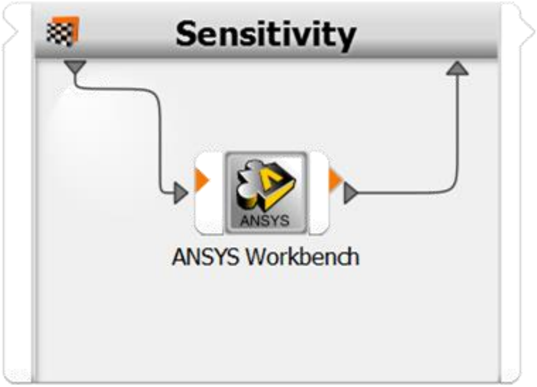


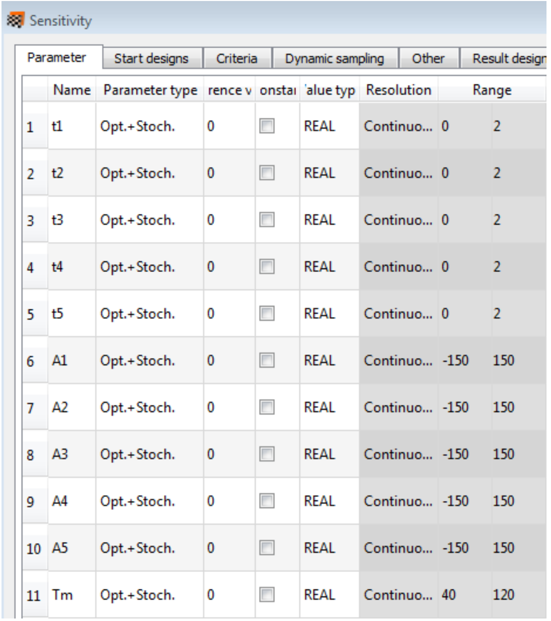
- The goal of the project is to produce an optiSLang SoS Field-Metamodel.
  - It can be used as a replacement for the coupled multi-physics simulation model.
- The Field-Metamodel is a surrogate model that can be used to **very rapidly assess new designs**.

Creation of a field meta model on the basis of electro-thermal-mechanical FEM simulations

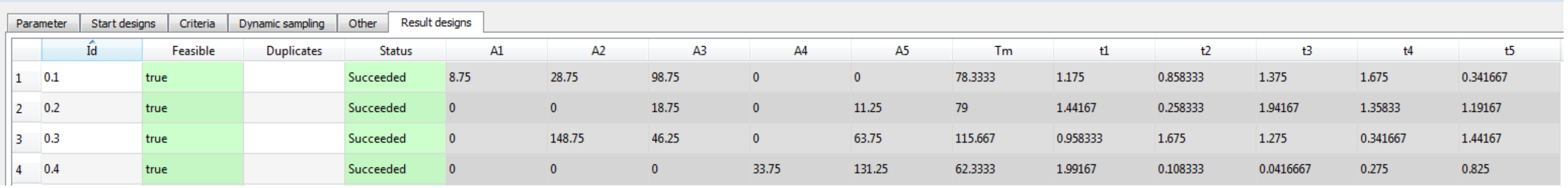
optiSLang sensitvity analysis

- An optiSLang sensitivity analysis is used to generate a sampling data base.
- optiSLang SoS is then used to generate Field-Metamodels (F-MOPs) for solution field quantities like temperature and stresses.





	Name	Parameter type	rence v	onstai	'alue typ	Resolution	Range	
1	t1	Opt.+Stoch.	0	☐	REAL	Continuo...	0	2
2	t2	Opt.+Stoch.	0	☐	REAL	Continuo...	0	2
3	t3	Opt.+Stoch.	0	☐	REAL	Continuo...	0	2
4	t4	Opt.+Stoch.	0	☐	REAL	Continuo...	0	2
5	t5	Opt.+Stoch.	0	☐	REAL	Continuo...	0	2
6	A1	Opt.+Stoch.	0	☐	REAL	Continuo...	-150	150
7	A2	Opt.+Stoch.	0	☐	REAL	Continuo...	-150	150
8	A3	Opt.+Stoch.	0	☐	REAL	Continuo...	-150	150
9	A4	Opt.+Stoch.	0	☐	REAL	Continuo...	-150	150
10	A5	Opt.+Stoch.	0	☐	REAL	Continuo...	-150	150
11	Tm	Opt.+Stoch.	0	☐	REAL	Continuo...	40	120



	Id	Feasible	Duplicates	Status	A1	A2	A3	A4	A5	Tm	t1	t2	t3	t4	t5
1	0.1	true		Succeeded	8.75	28.75	98.75	0	0	78.3333	1.175	0.858333	1.375	1.675	0.341667
2	0.2	true		Succeeded	0	0	18.75	0	11.25	79	1.44167	0.258333	1.94167	1.35833	1.19167
3	0.3	true		Succeeded	0	148.75	46.25	0	63.75	115.667	0.958333	1.675	1.275	0.341667	1.44167
4	0.4	true		Succeeded	0	0	0	33.75	131.25	62.3333	1.99167	0.108333	0.0416667	0.275	0.825

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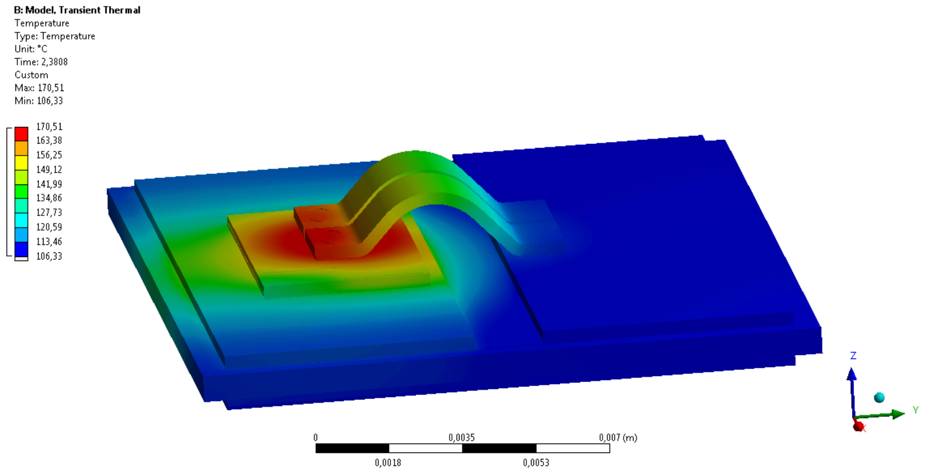
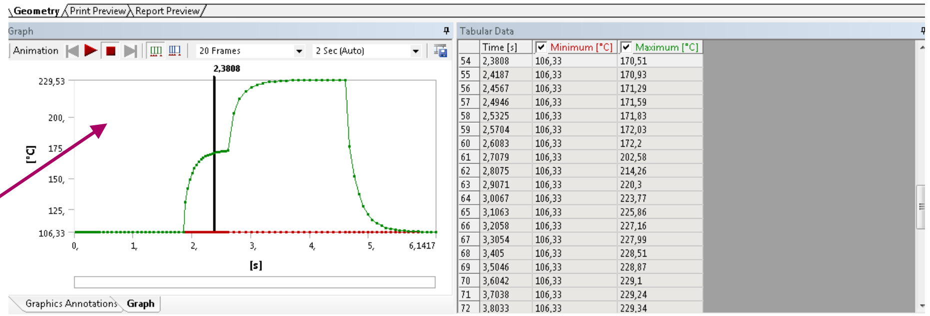
Transient simulation

- Transient electrical loading leads to an increase in the temperature of the domain and, subsequently, to thermally induced stresses.



- Dynardo consulting services:
- Workflow based on Ansys APDL.



Parameter | Start designs | Criteria | Dynamic sampling | Other | Result designs

	Id	Feasible	Duplicates	Status	A1	A2	A3	A4	A5	Tm	t1	t2	t3	t4	t5
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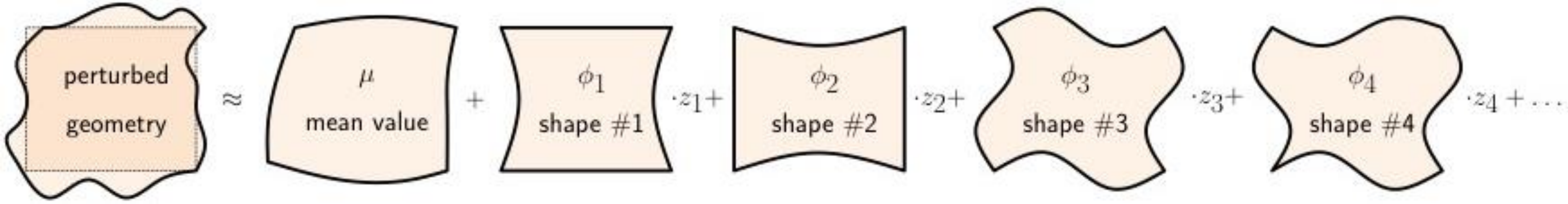
SoS F-MOP

- The Field-Metamodel is based on the non-linear combination of a random shape decompositioning of the solution fields.
- F-MOP is an enhancement of the classical optiSLang metamodelling technique



- New input-parameter combinations can be … e the full output field.

Inputs:
- Current amplitude signal
- Ambient temperature
- Transient temperature field

Outputs:
- TEMP,
- SX,
- SEQV,
- …

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F-MOP Approximation quality

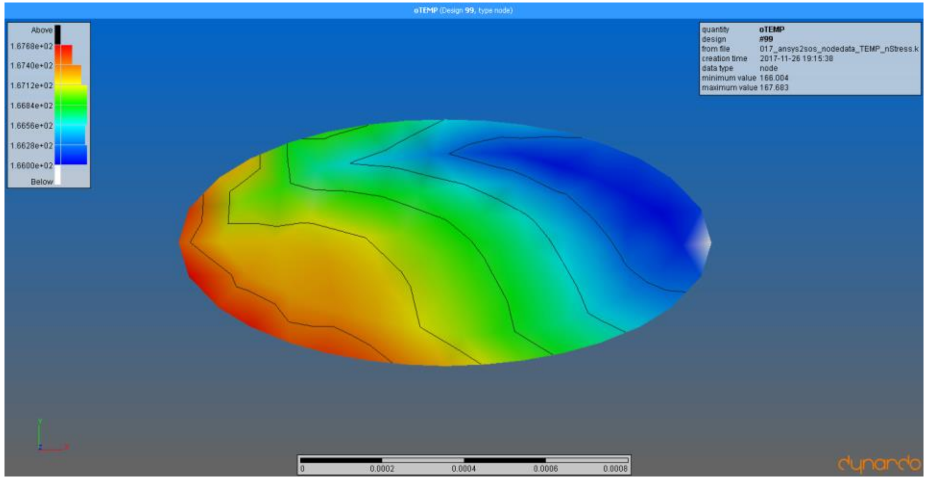
- Like for a classical optiSLang Metamodel, COP values can be used to assess, whether the metamodel has a high approximation quality.

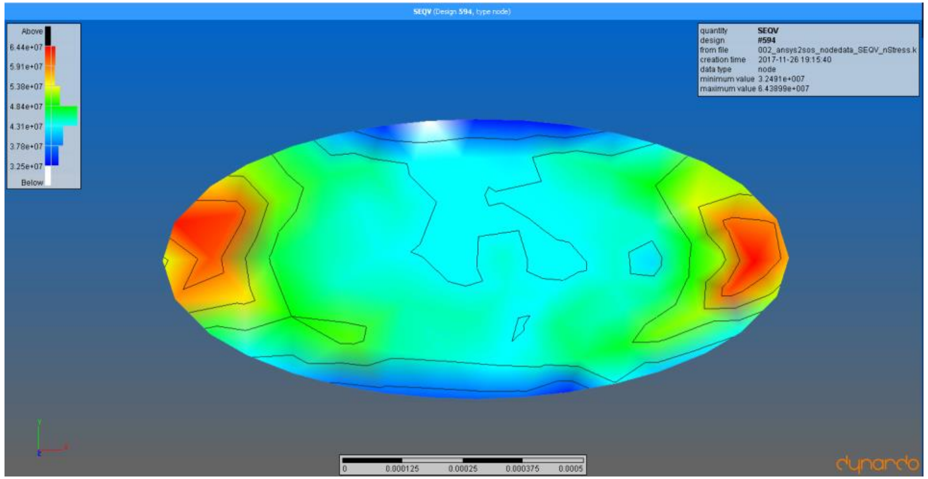
- For the generated Field-Metamodel the F-CoP (Total) values are very high.

- **The field metamodel has a very good approximation quality for all results.**

	S1	S2	S3	SEQV	SX	SXY	SXZ	SY	SYZ	SZ	iTEMP	oTEMP
F-CoP[A]	41.36 %	43.46 %	43.56 %	44.47 %	165.12 %	170.47 %	99.03 %	105.99 %	41.88 %	33.37 %		92.21 %
F-CoP[Total]	92.33 %	93.71 %	94.31 %	93.58 %	94.21 %	93.59 %	93.57 %	94.00 %	93.53 %	94.78 %		98.26 %
F-CoP[Tu]	32.70 %	30.53 %	32.50 %	31.20 %	95.69 %	113.92 %	80.89 %	74.69 %	51.36 %	19.75 %		4.97 %
F-CoP[amp[iTEMP][node]_shape[1]]	10.20 %	10.10 %	10.01 %	10.90 %	33.01 %	38.82 %	25.13 %	24.81 %	16.40 %	4.60 %		
F-CoP[ts]	8.07 %	9.62 %	8.25 %	7.02 %	16.74 %	27.32 %	19.58 %	25.31 %	31.71 %	37.07 %		1.07 %

Solution postprocessing in optiSLang SoS





Visualized are solution fields for the temperature and the equivalent stress for the contact surface.

All field quantities are available for statistical postprocessing in SoS.

A Field-Metamodel (F-MOP) can be produced for these result quantities.

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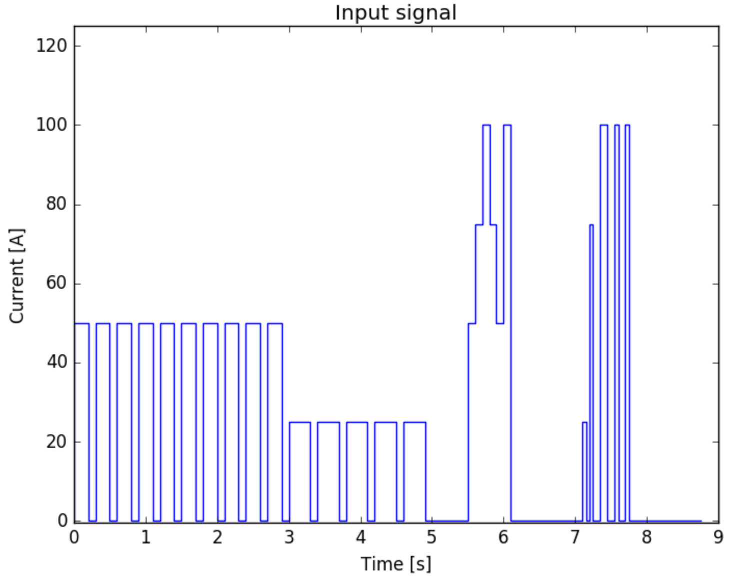
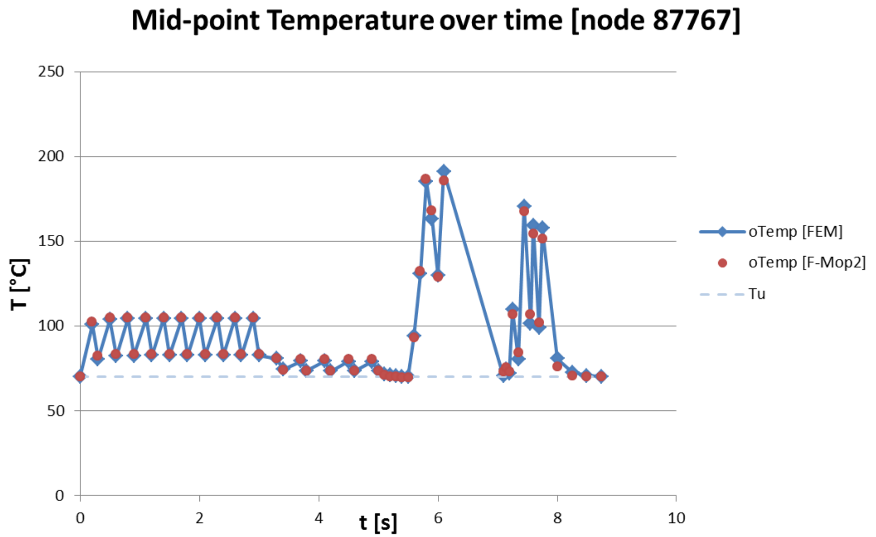
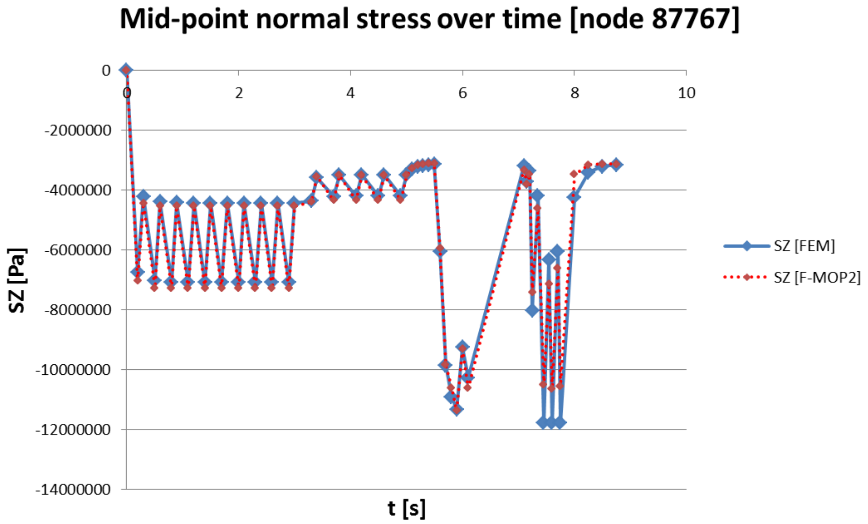
F-MOP result validation







Output at point of the contact:

- **Excellent approximation result for transient temperature and contact stresses.**

Automotive Electronics | Riester, Faust-Ellsässer, Rupp | Dynardo: Klonk, Schneider, Wolff | 2018-03-23

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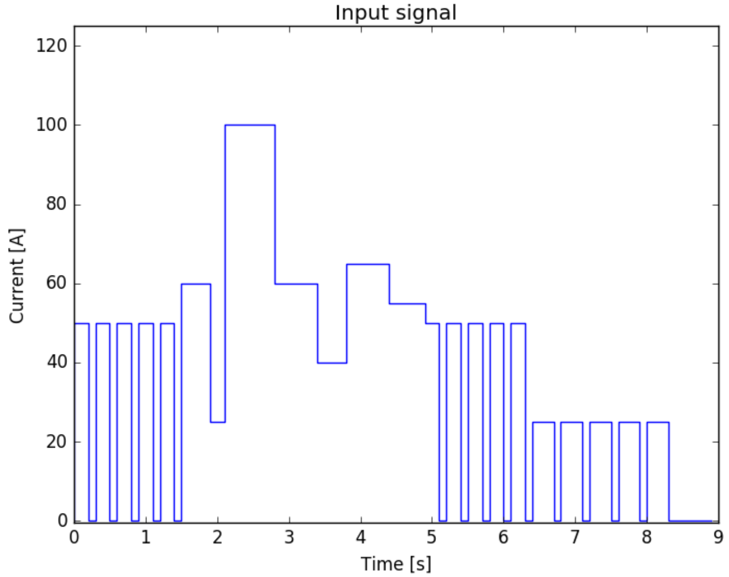
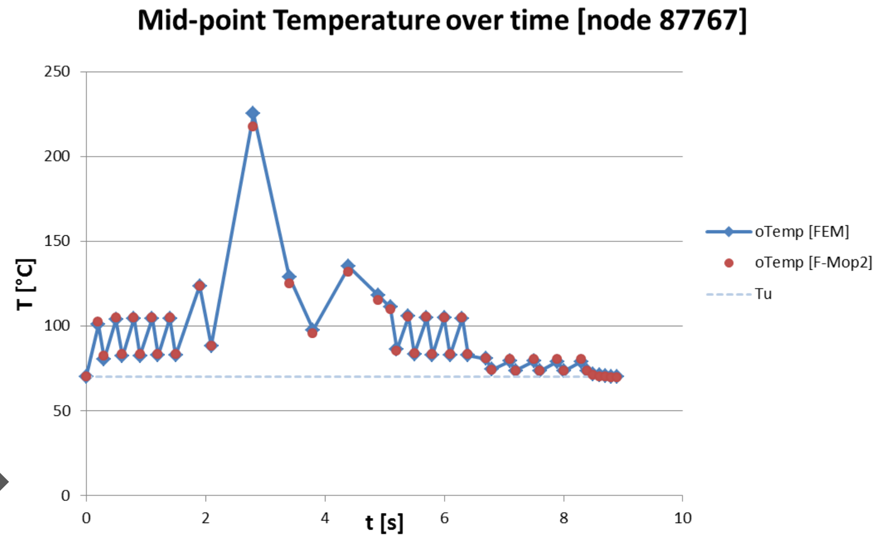
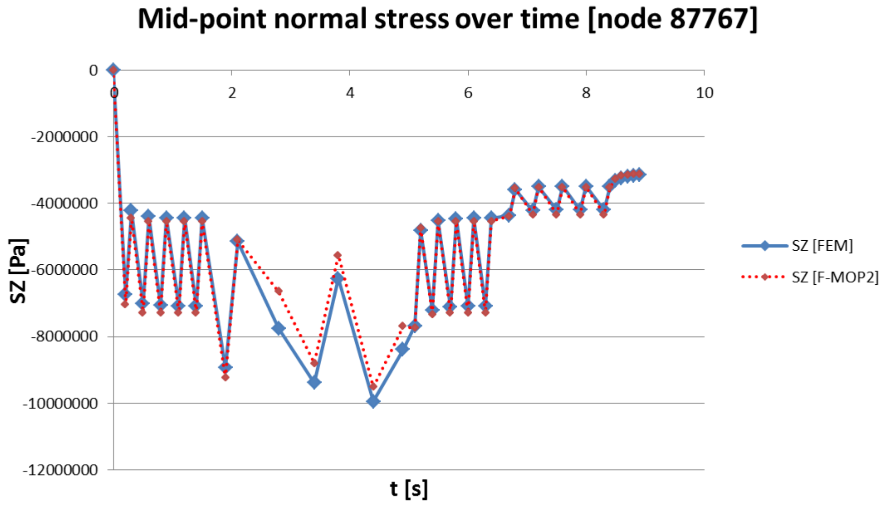
F-MOP result validation



Field-MOP





Output at point of the contact:

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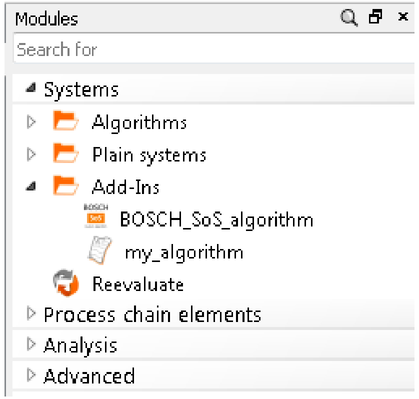
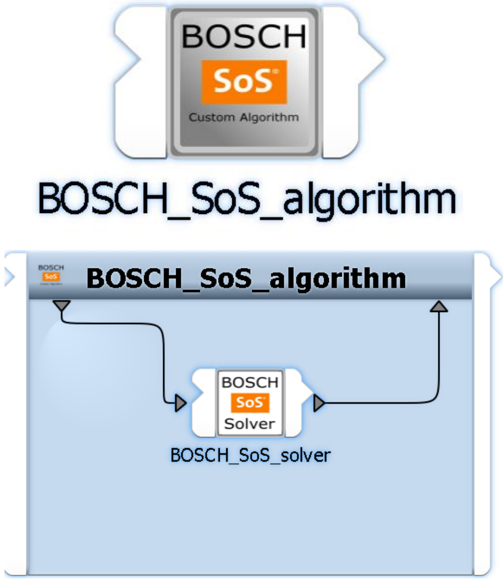
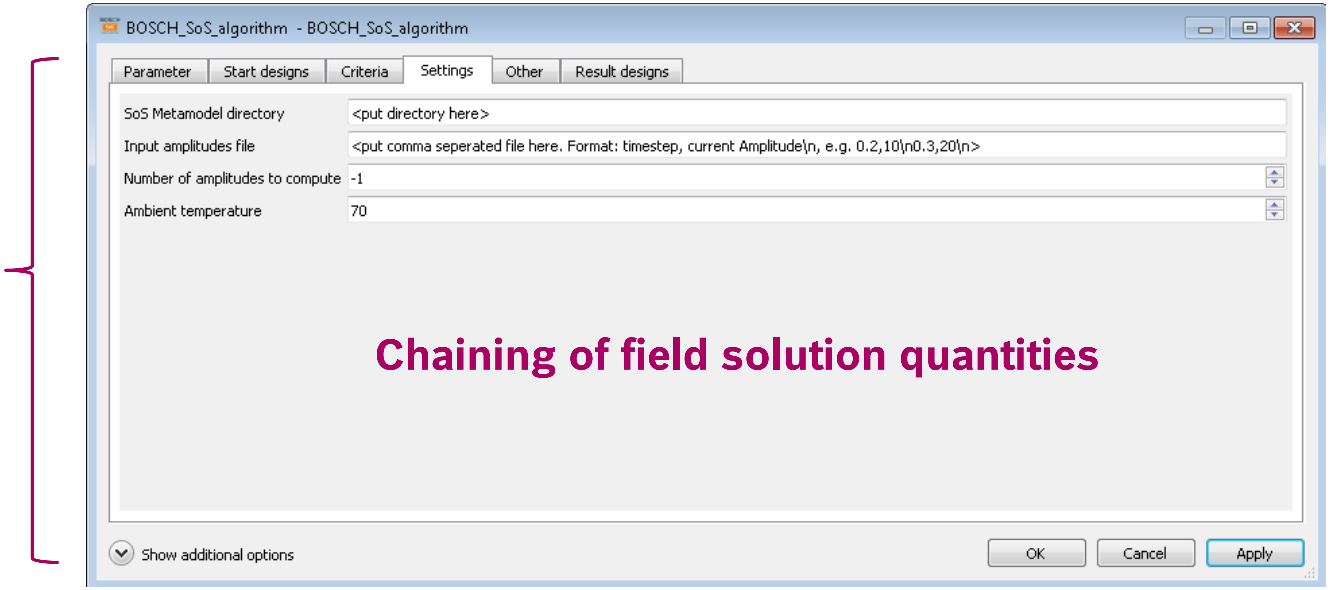
Field input/output - transient solver

- Based on the optiSLang Custom Algorithm interface, a custom user interface has been generated to **solve for transient field inputs/outputs**.
- Realized as custom node in optiSlang.







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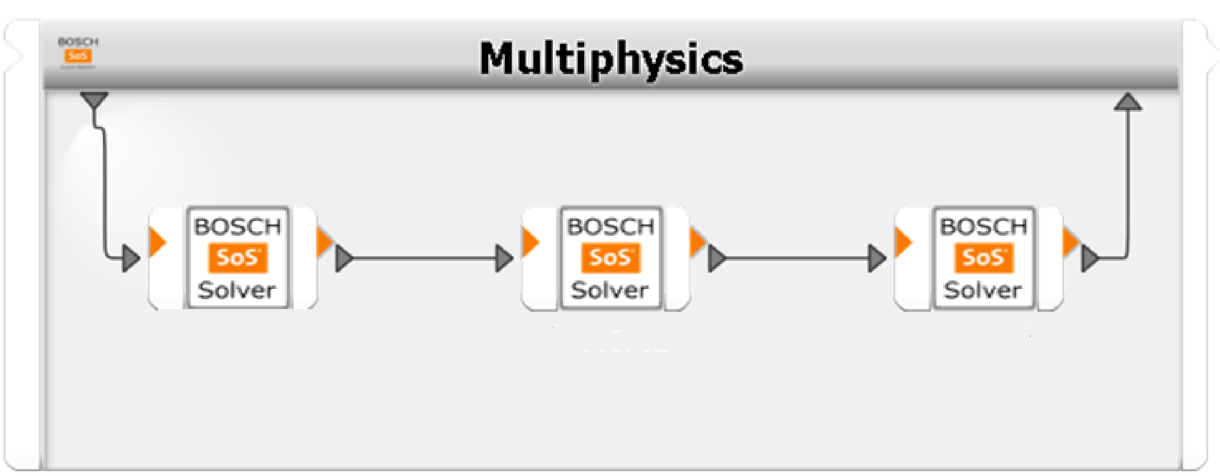
Résumé



Selective access:
- CAE expert
- Design engineer
- Project manager

- **The generation of the SoS F-MOP was successful.**
- F-MOP allows the rapid evaluation of field quantities without the need to run a full simulation model.
- The field metamodel can be saved in a database (QM).
- Team based access can be organized on a high-level using optiSLang technology.

CPU-time for validation 1

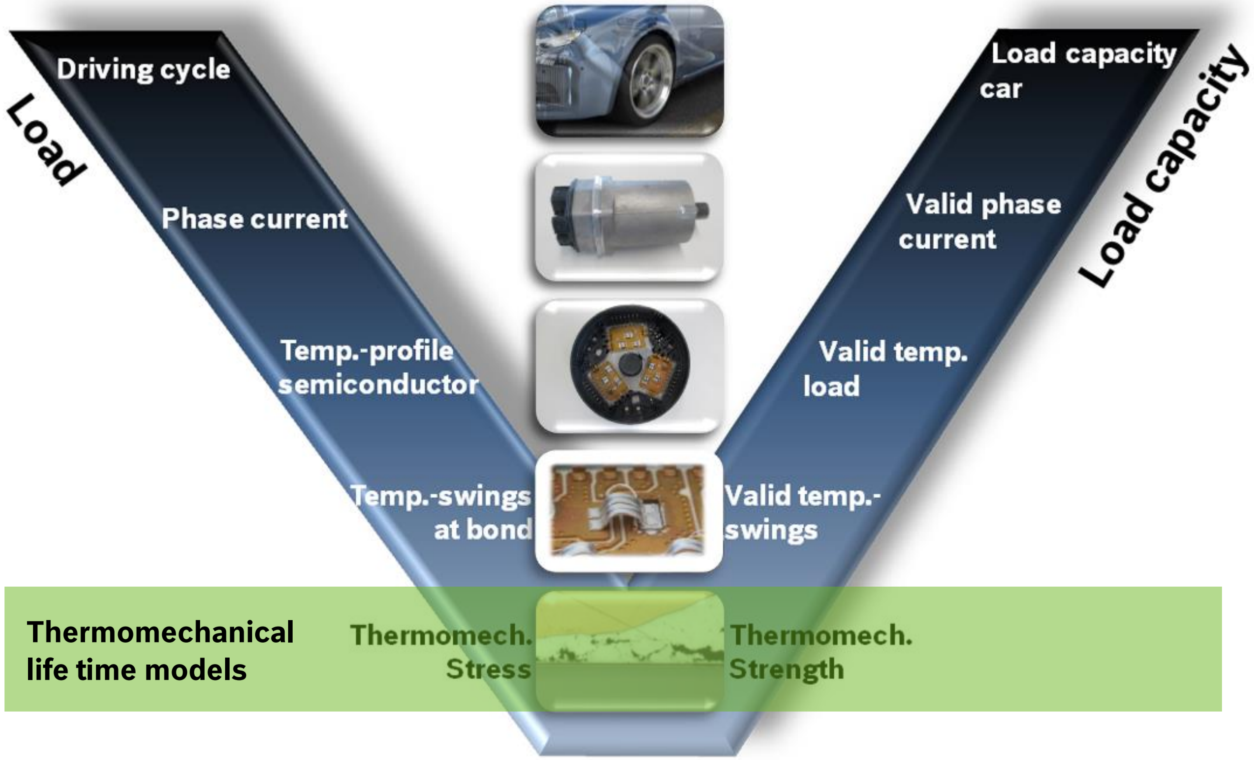
FEM: 24.85 h

SoS Field-MOP: 130 s

Conclusion / Outlook

- SoS F-MOP enables to go one step deeper on the load side of the V model and reach a geometry independent parameter for comparing load and load capacity

- Outlook:
  - F-MOP validation for different design elements is ongoing
  - F-MOP could enable real time simulation to identify remaining life time of the ECU
  - Web access & Digital Twin application



THANK YOU

FOR YOUR ATTENTION