

WELCOME TO

WOST

2019

Premium Sponsor

CADFEM[®]

Sponsor

BETA
SIMULATION SOLUTIONS

Exhibitors

CAESES

**MATH
2 MARKET**

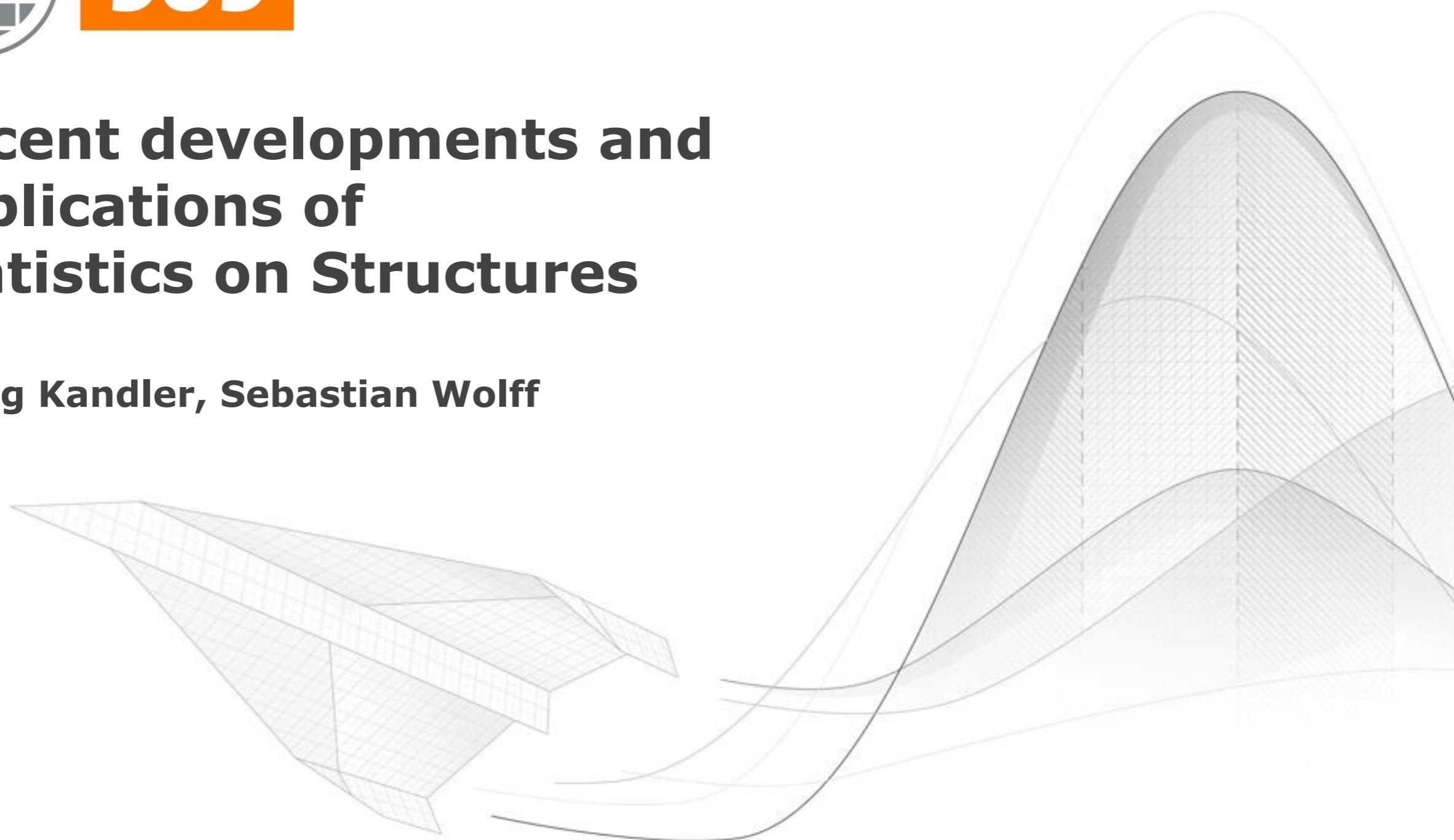
esi
get it right[®]



SoS

Recent developments and applications of Statistics on Structures

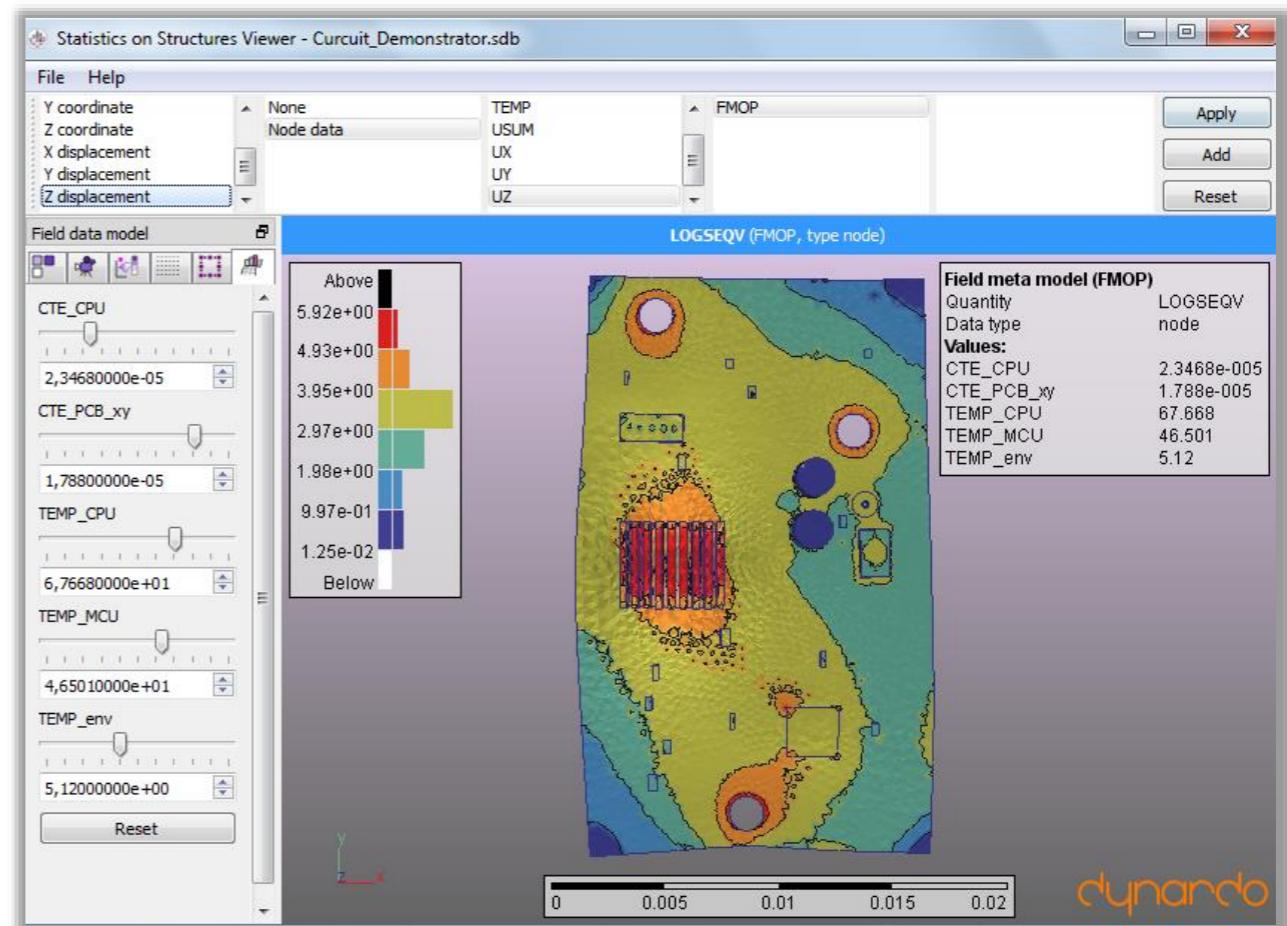
Georg Kandler, Sebastian Wolff



Statistics on Structures

Multidimensional data analysis

- Analysis of
 - 1D data (signals)
 - 2D data (performance maps)
 - 3D data (FEM, CFD)
- In terms of
 - Statistics
 - Random fields
 - Field meta models
- SoS Viewer and Web viewer interactive with sliders, export through DLL
- Supports various file formats
- ANSYS Mechanical plugin



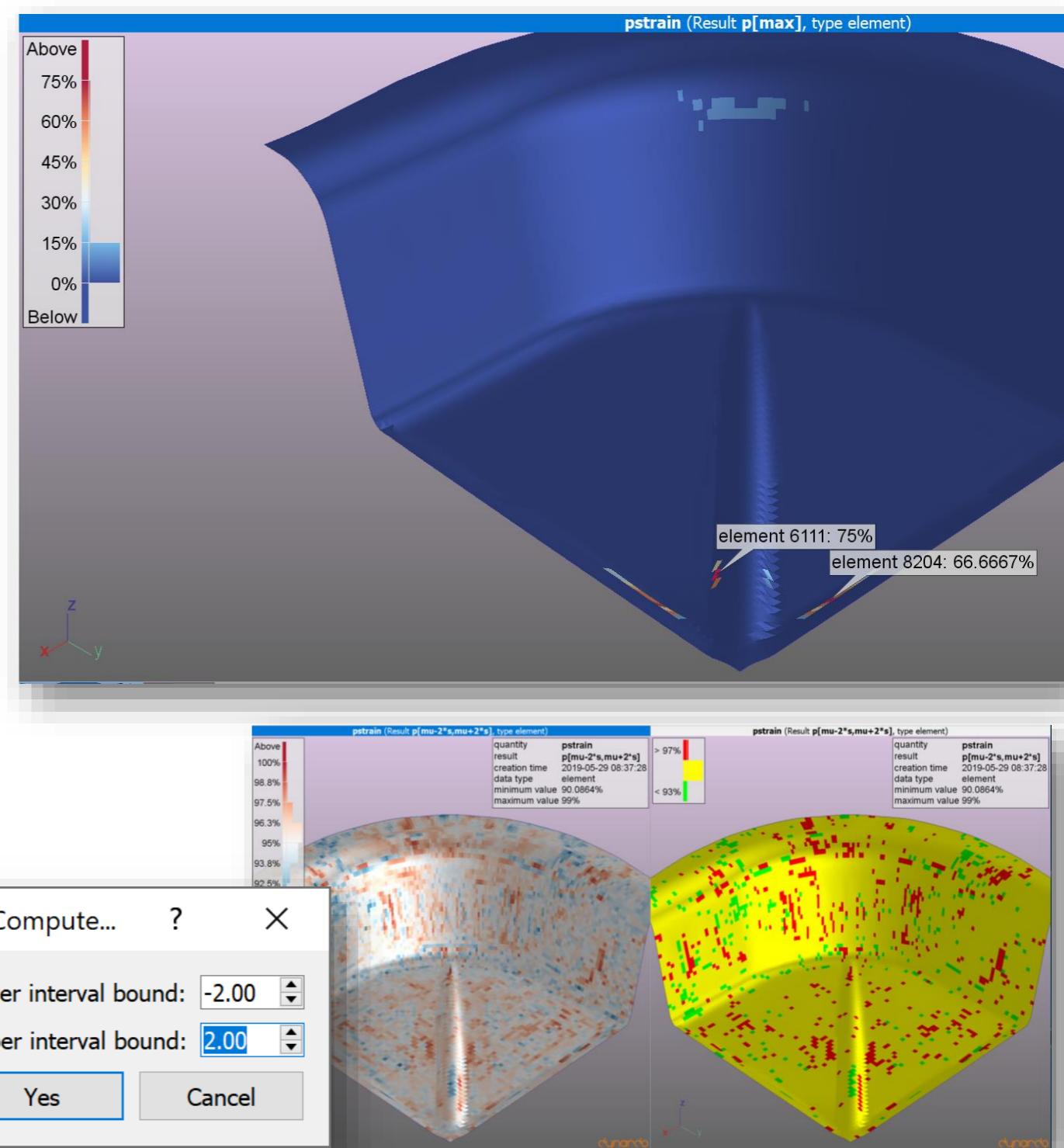
New features in SoS 7.1



Data analysis

Hot spot detection

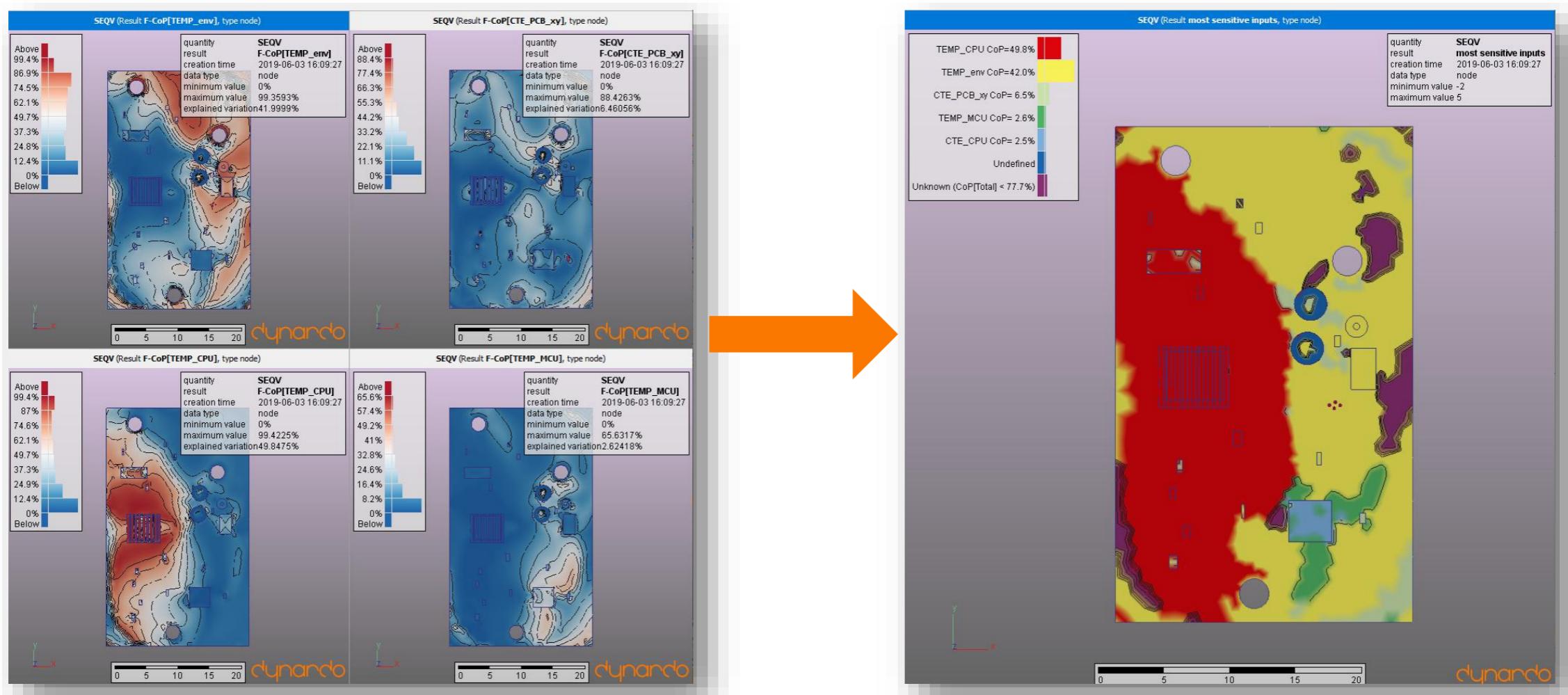
- Available: Several statistical functions (mean, stddev, quantiles, probabilities, standard errors, ranges, cp/cpk values and more)
- **New:**
 - Estimate probability of being minimum or maximum
 - 66-95-99.7 rule for outlier checks
 - Estimate interval probabilities



Field meta models

New: Most sensitive inputs

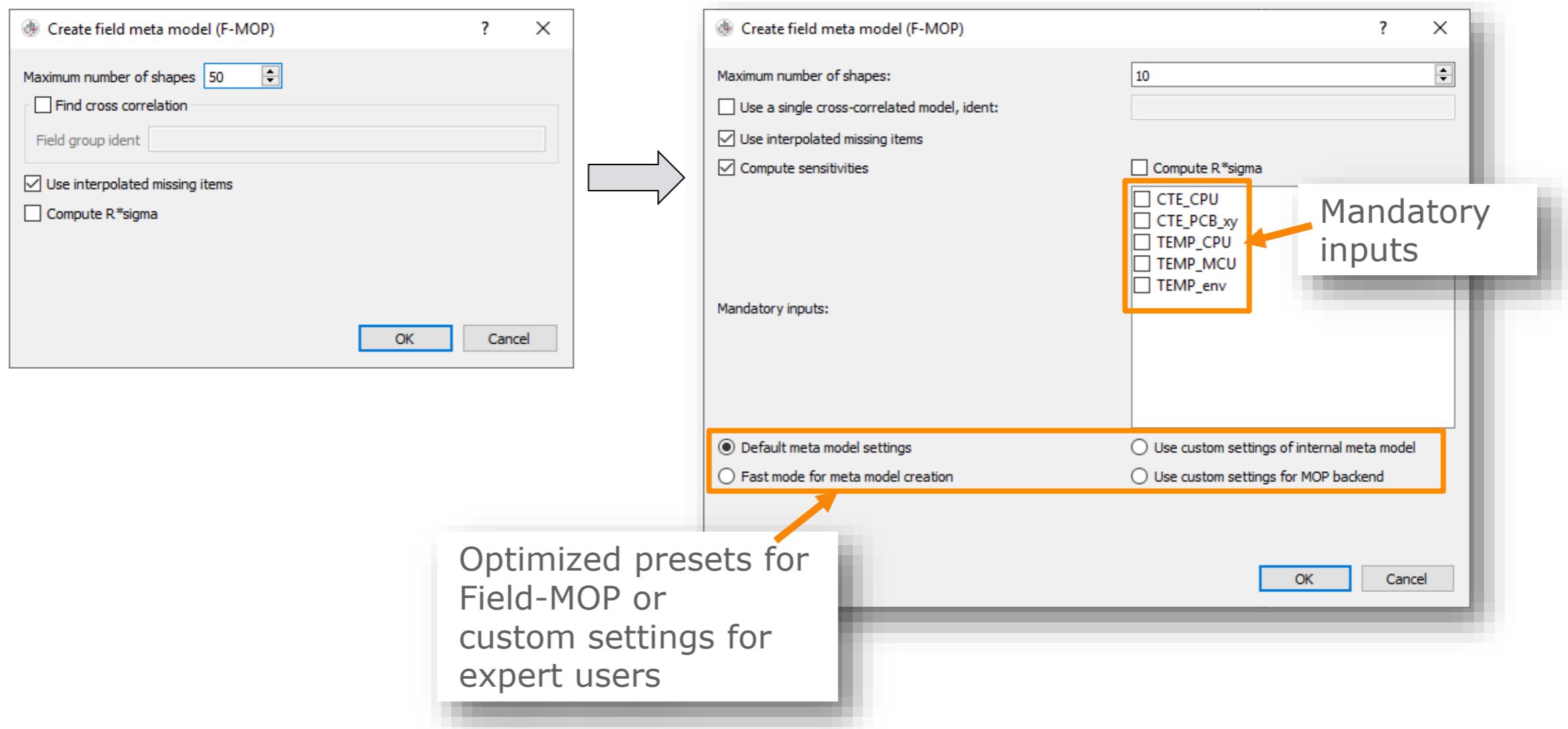
- Until now:
Inspection of individual F-CoP contour plots of sensitivities
- **New:** Most sensitive inputs plot: Spatial importance of inputs at a glance



Field meta models

Settings for Field-MOP and random fields

- Improved settings dialog for Field-MOP



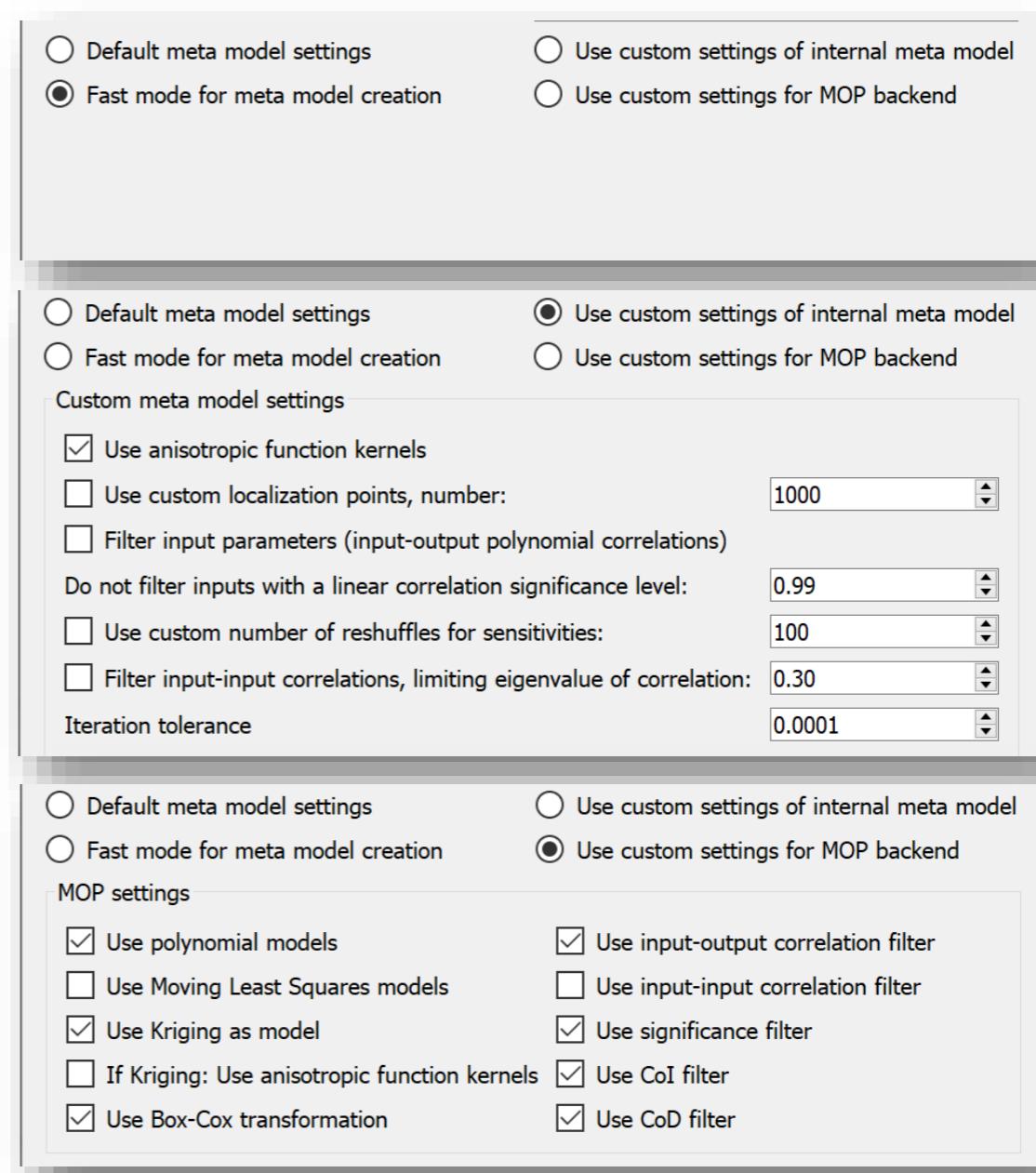
Field meta models

Settings for Field-MOP and random fields

1. **Fast mode** offers improved performance at the expense of accuracy. Use if the number of designs or inputs is large.

2. Select **custom settings** to have full control of the SoS Field MOP calculation. (e.g. filter input-input correlations)

3. Select **custom MOP settings** to use the optiSLang MOP backend to create the Field MOP.



The screenshot shows three vertically stacked panels of configuration options for Field meta models:

- Panel 1 (Top):** Options for selecting meta model creation methods. It includes radio buttons for "Default meta model settings" (unchecked), "Fast mode for meta model creation" (checked), "Use custom settings of internal meta model" (unchecked), and "Use custom settings for MOP backend" (unchecked).
- Panel 2 (Middle):** Options for custom meta model settings. It includes radio buttons for "Default meta model settings" (unchecked) and "Fast mode for meta model creation" (unchecked). Below these are sections for "Custom meta model settings" containing checkboxes for "Use anisotropic function kernels" (checked), "Use custom localization points, number:" (unchecked, with a dropdown set to 1000), "Filter input parameters (input-output polynomial correlations)" (unchecked), and "Do not filter inputs with a linear correlation significance level:" (unchecked, with a dropdown set to 0.99). There are also checkboxes for "Use custom number of reshuffles for sensitivities:" (unchecked, with a dropdown set to 100), "Filter input-input correlations, limiting eigenvalue of correlation:" (unchecked, with a dropdown set to 0.30), and "Iteration tolerance" (unchecked, with a dropdown set to 0.0001).
- Panel 3 (Bottom):** Options for MOP settings. It includes radio buttons for "Default meta model settings" (unchecked) and "Fast mode for meta model creation" (unchecked). Below these are sections for "MOP settings" containing checkboxes for "Use polynomial models" (checked), "Use Moving Least Squares models" (unchecked), "Use Kriging as model" (checked), "If Kriging: Use anisotropic function kernels" (unchecked), "Use Box-Cox transformation" (checked), "Use input-output correlation filter" (checked), "Use input-input correlation filter" (unchecked), "Use significance filter" (checked), "Use CoI filter" (checked), and "Use CoD filter" (checked).

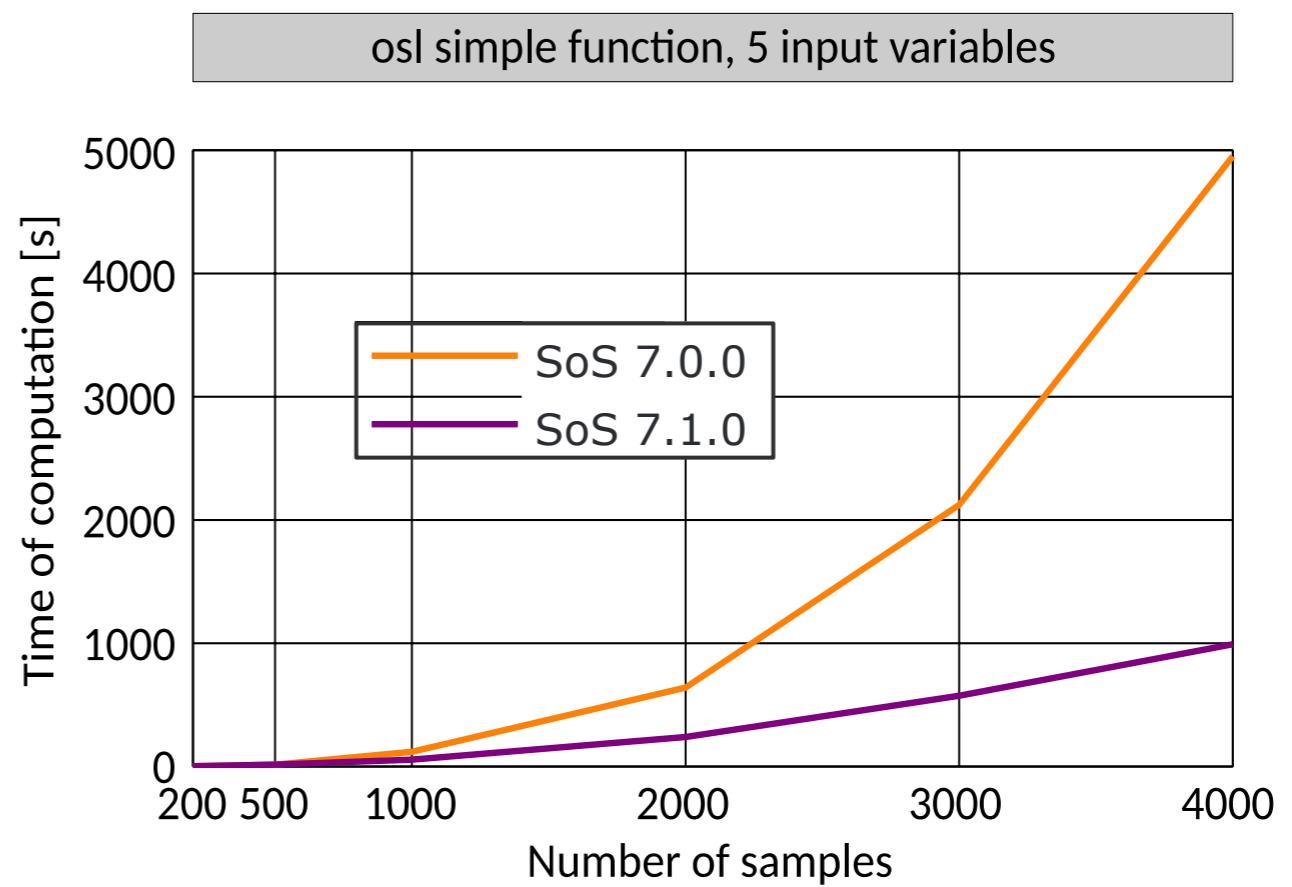
Field meta models

Performance improvements

- optiSLang simple function example
- 5 input variables
- Changing number of samples

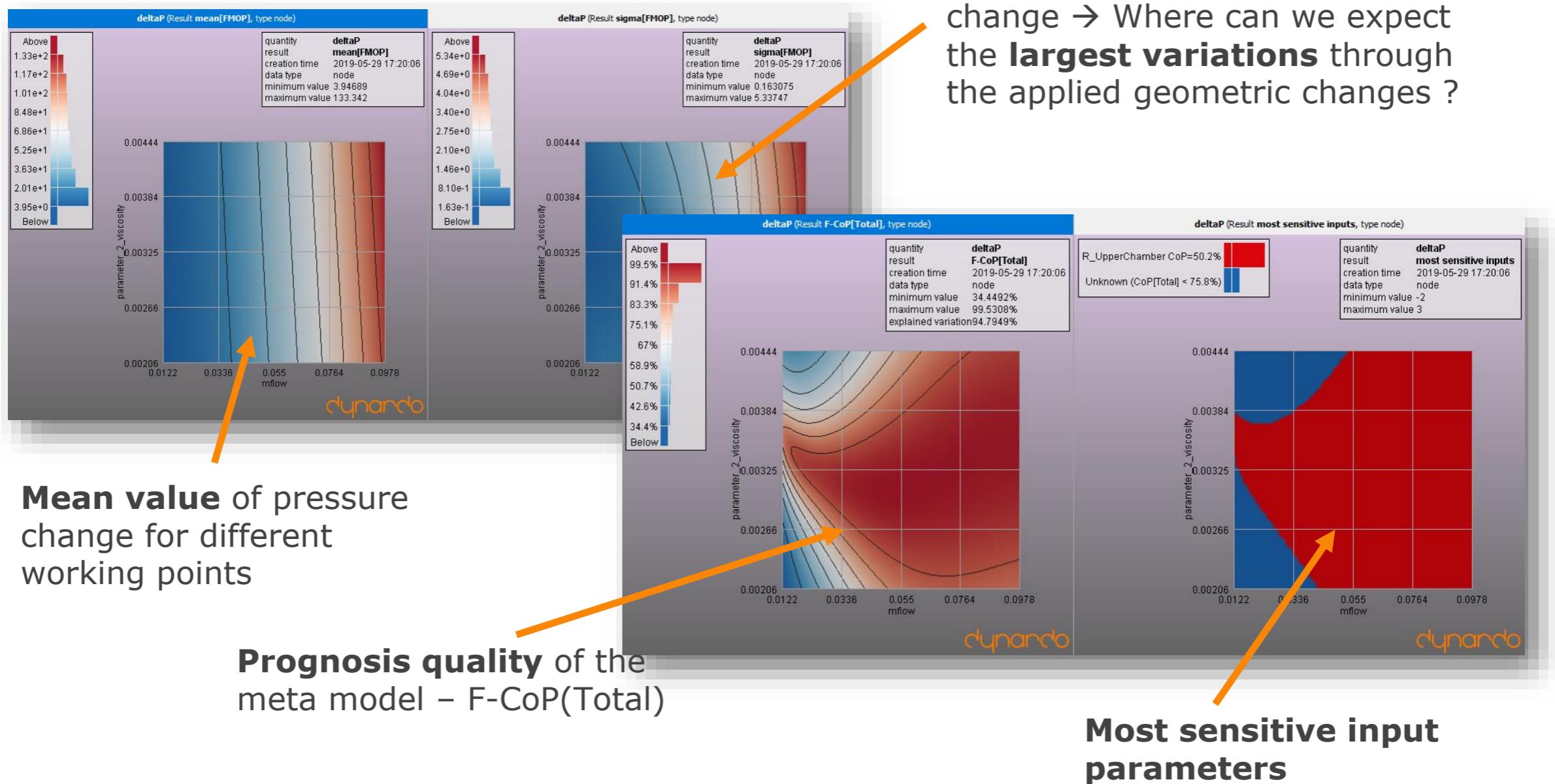
→ Computation time drastically improved for large sample sizes.

Up to 500% improvement



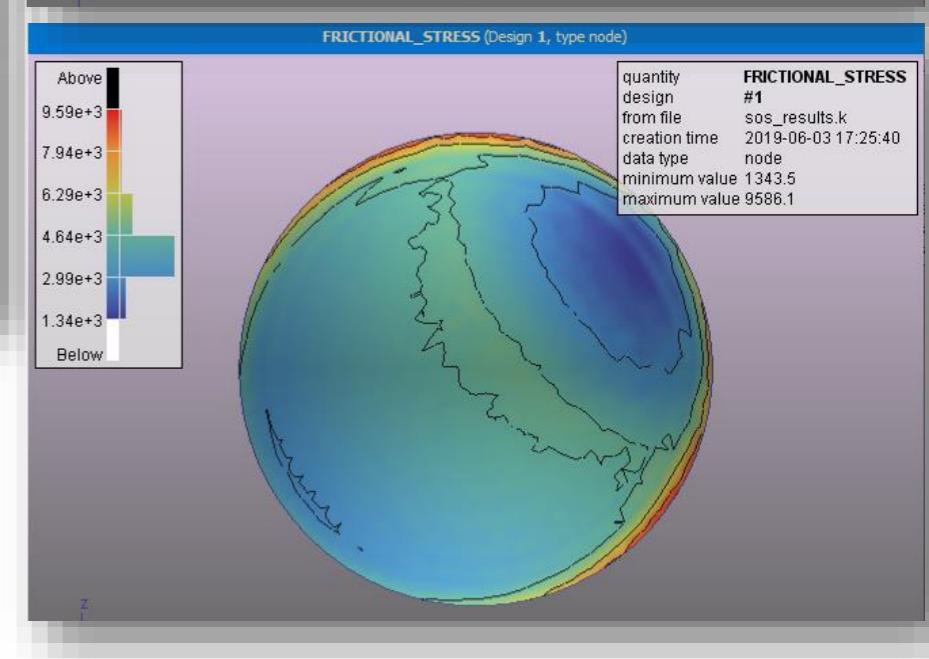
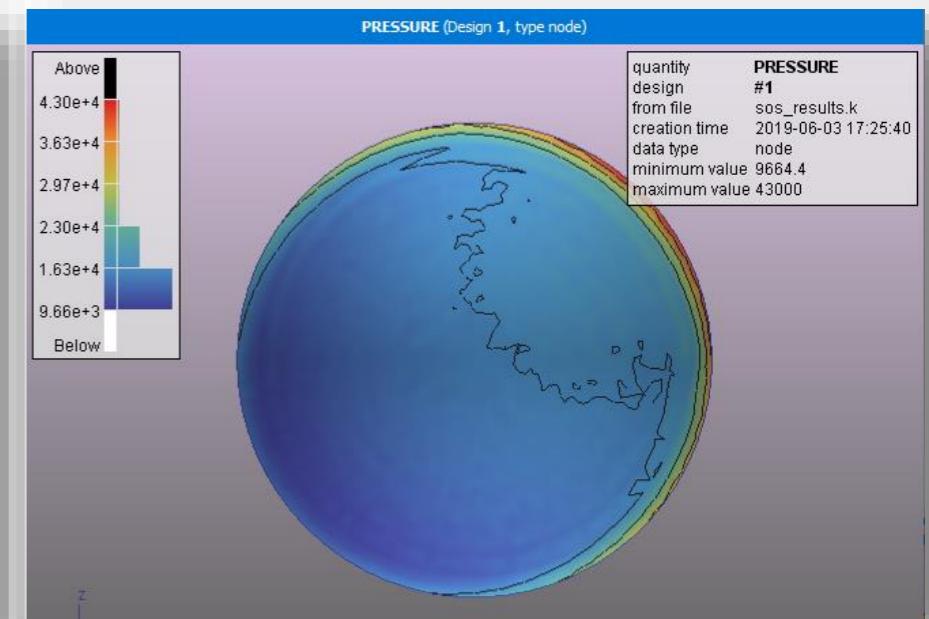
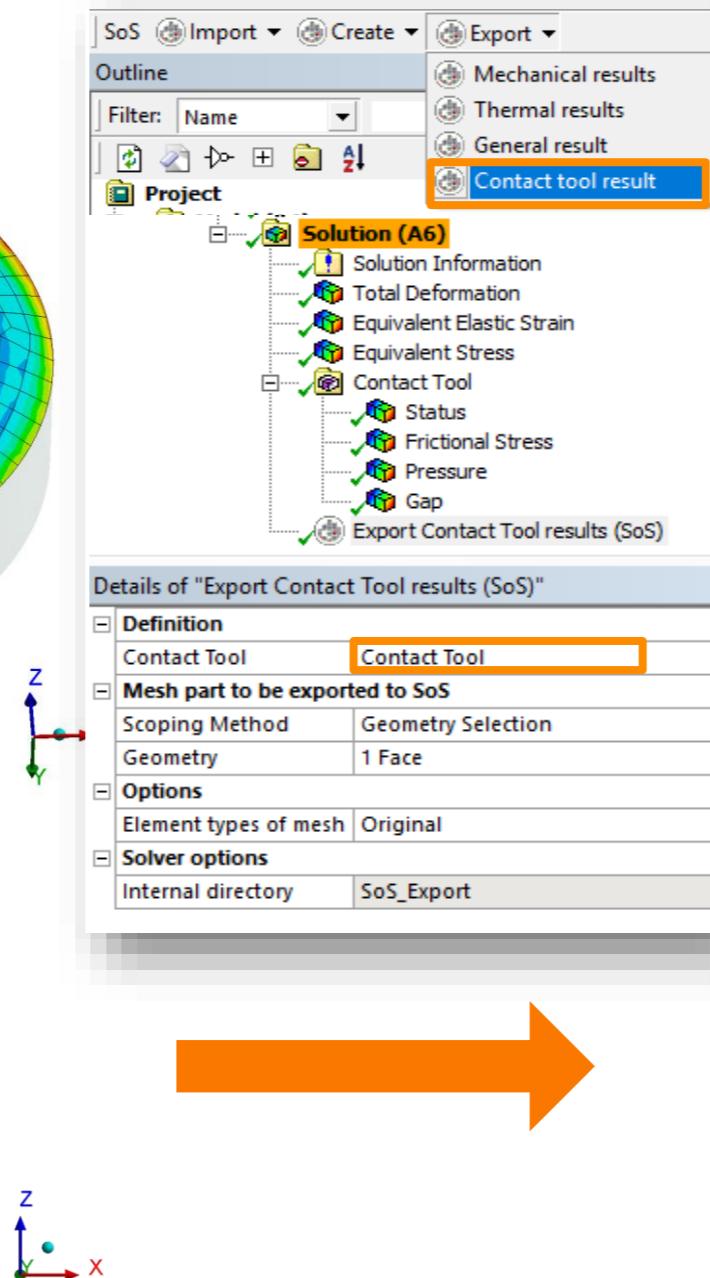
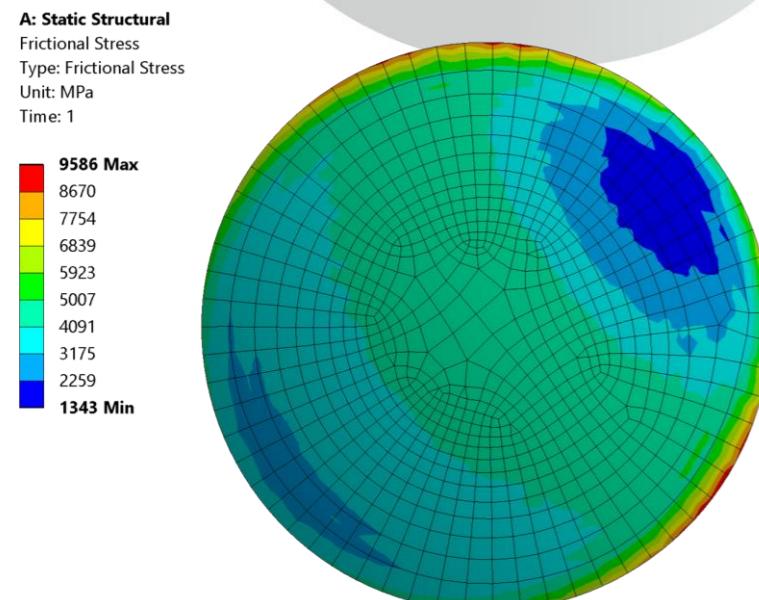
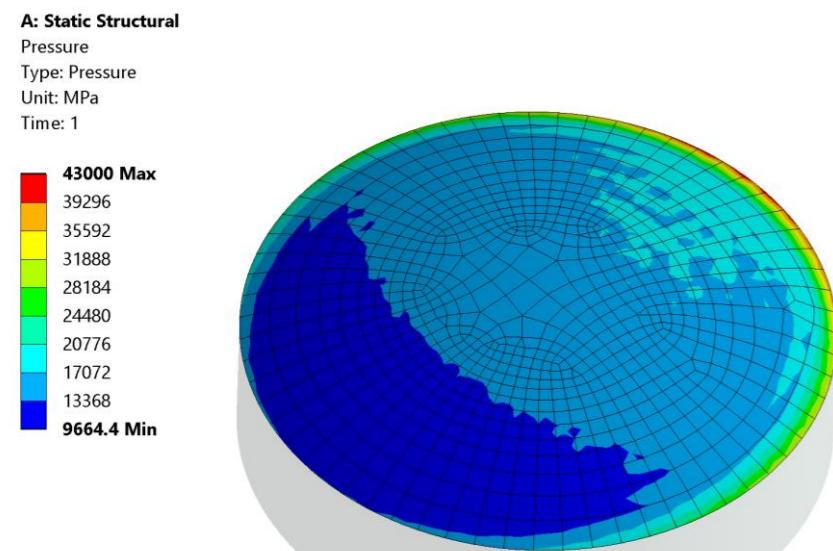
Performance map and image analysis

New: Visualization of gridded data in SoS



Integration with ANSYS Mechanical

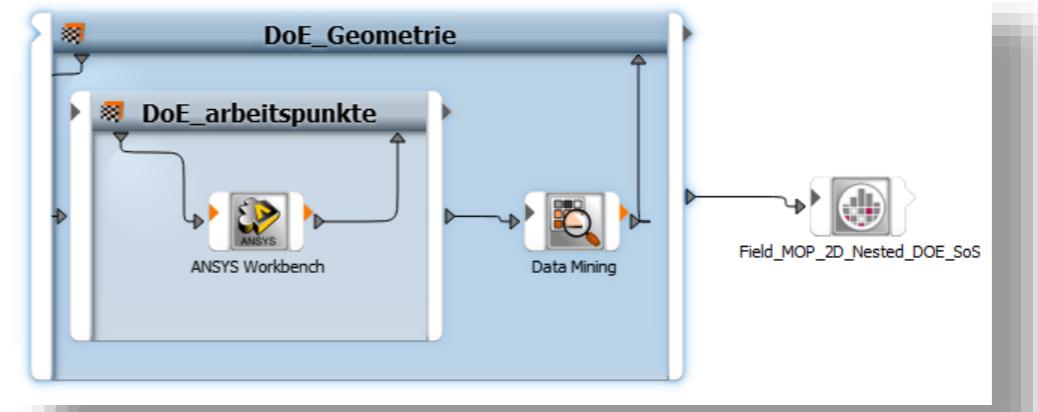
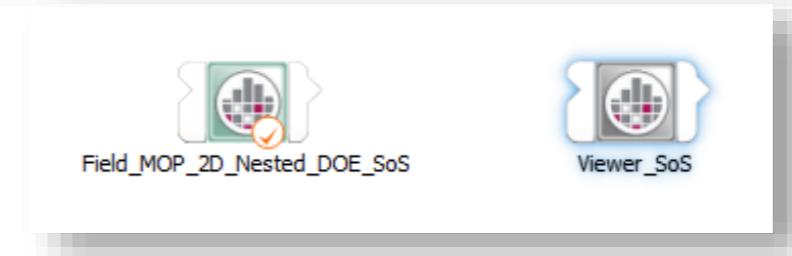
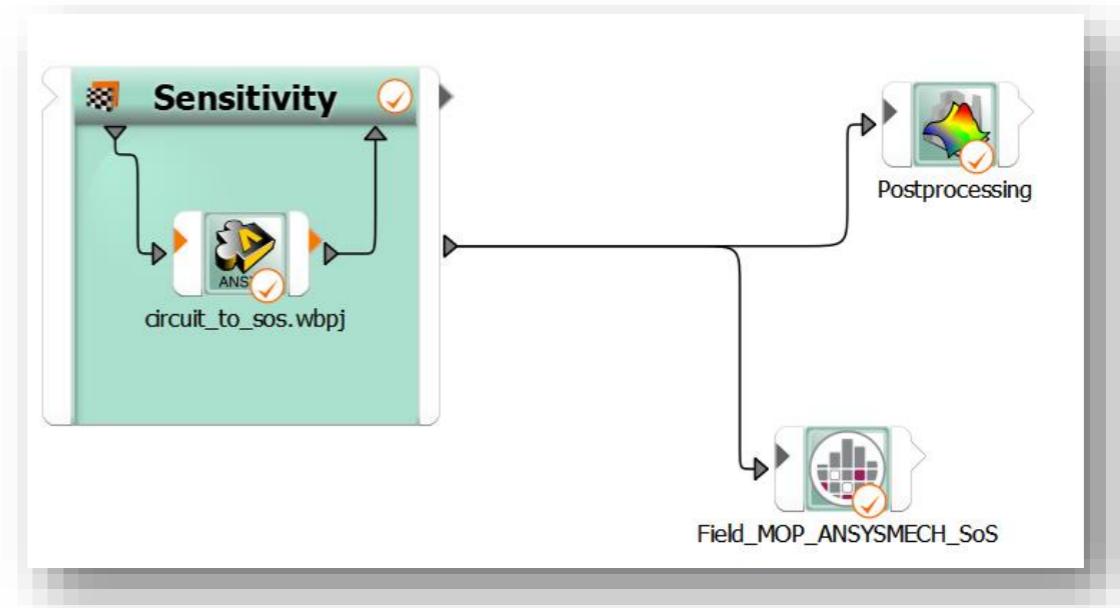
New: Contact results export



optiSLang integration

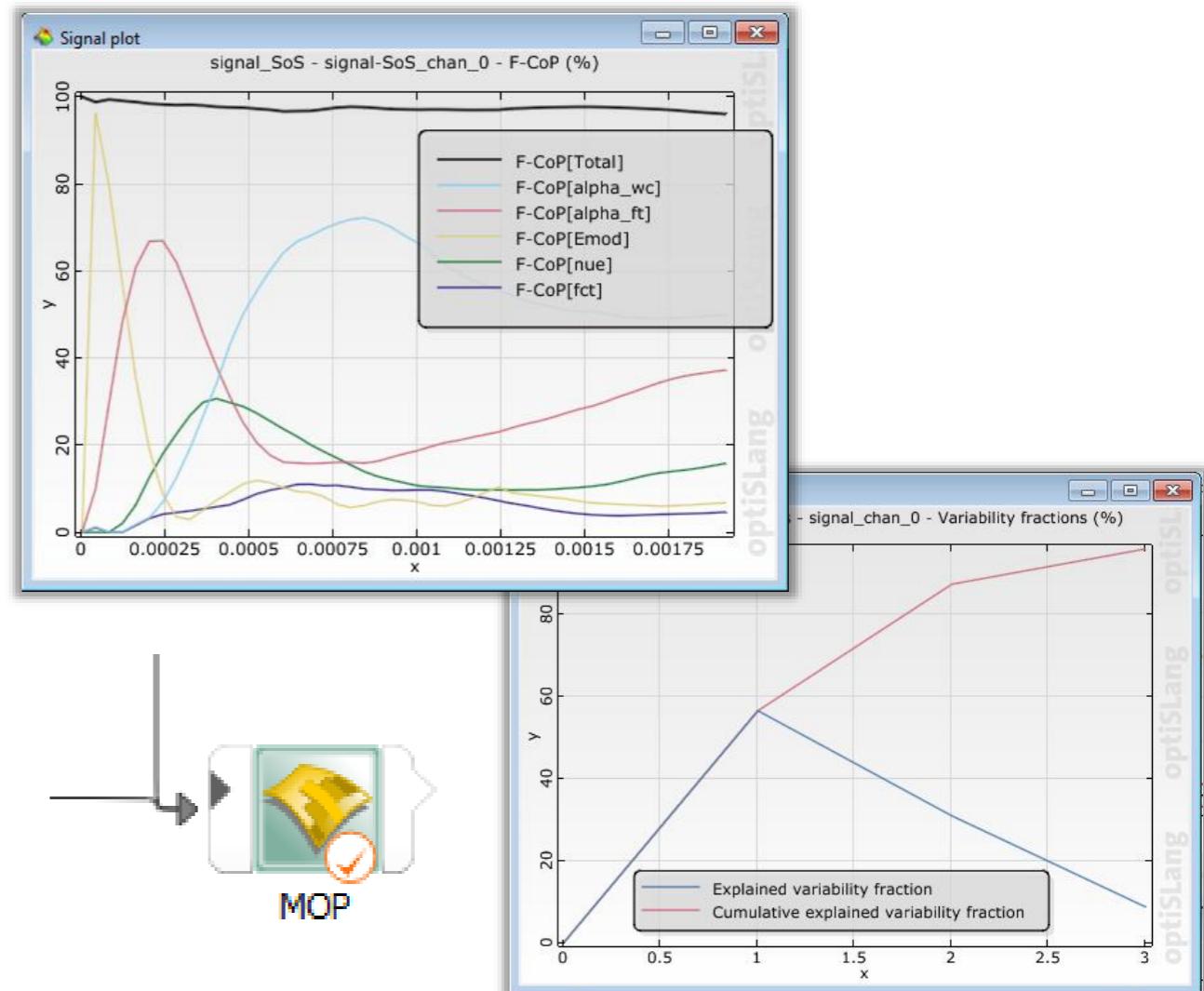
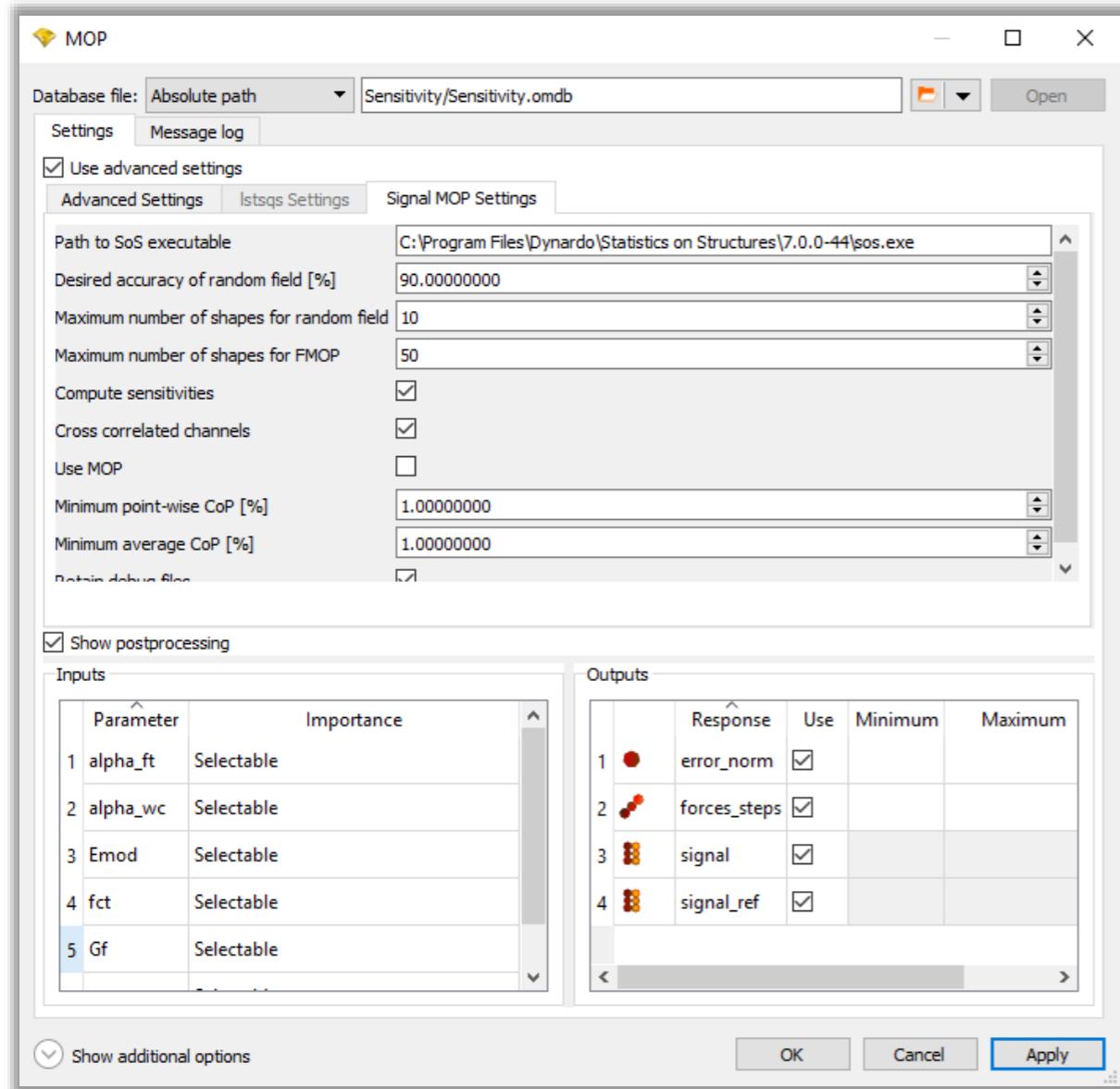
Improved integration of standard analysis types

- Create Field MOP and analyze simple statistics inside optiSLang
 - of ANSYS Mechanical models (using ANSYS SoS plugin)
 - of 2D performance maps inside optiSLang based on CSV files
 - of 2D performance maps based on nested systems



Improvements: SignalMOP (1D) integrated in optiSLang

- SignalMOP integrated into MOP and MOP-Solver nodes since optiSLang 7.3



Applications



Performance map analysis

- How are performance maps (e.g. different operating points of engines, generators, valves etc.) influenced by design parameters ?
- How to assess changes of images as obtained in optical simulations ?

Performance map analysis – Example valve Motivation

How to analyse the performance map of a valve with respect to geometric changes ?

Geometric parameters:

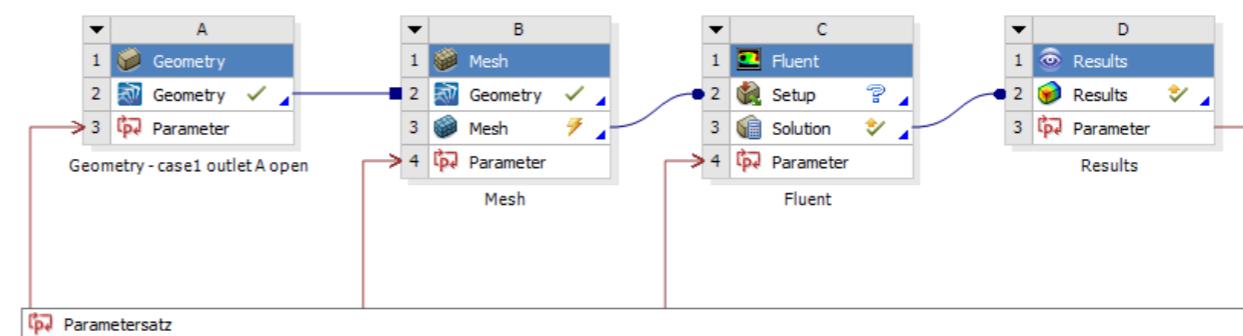
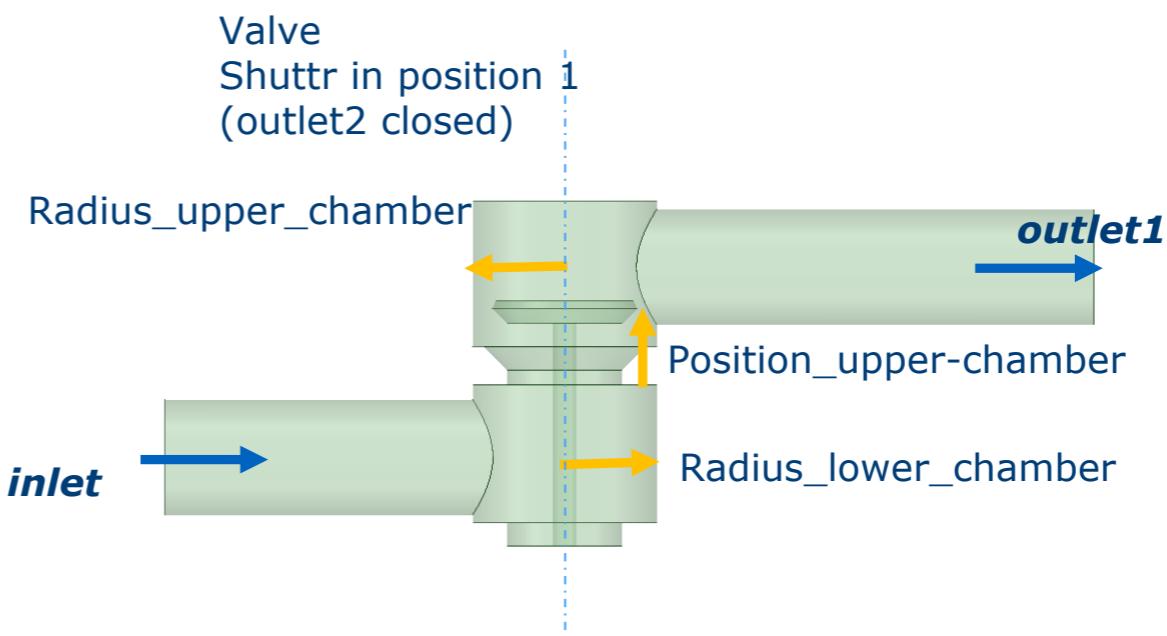
- Radius 1
- Radius 2
- Position upper valve chamber

Parameters of performance map:

- Mass flow
- Viscosity (depends on temperature)

Target:

- Delta P (pressure loss between inlet and outlet)



With courtesy of CADFEM (Neuhierl CASCON 2018)

Performance map analysis – Example valve Field MOP 2D for nested DOE systems

optiSLang + SoS

Geometric parameters:

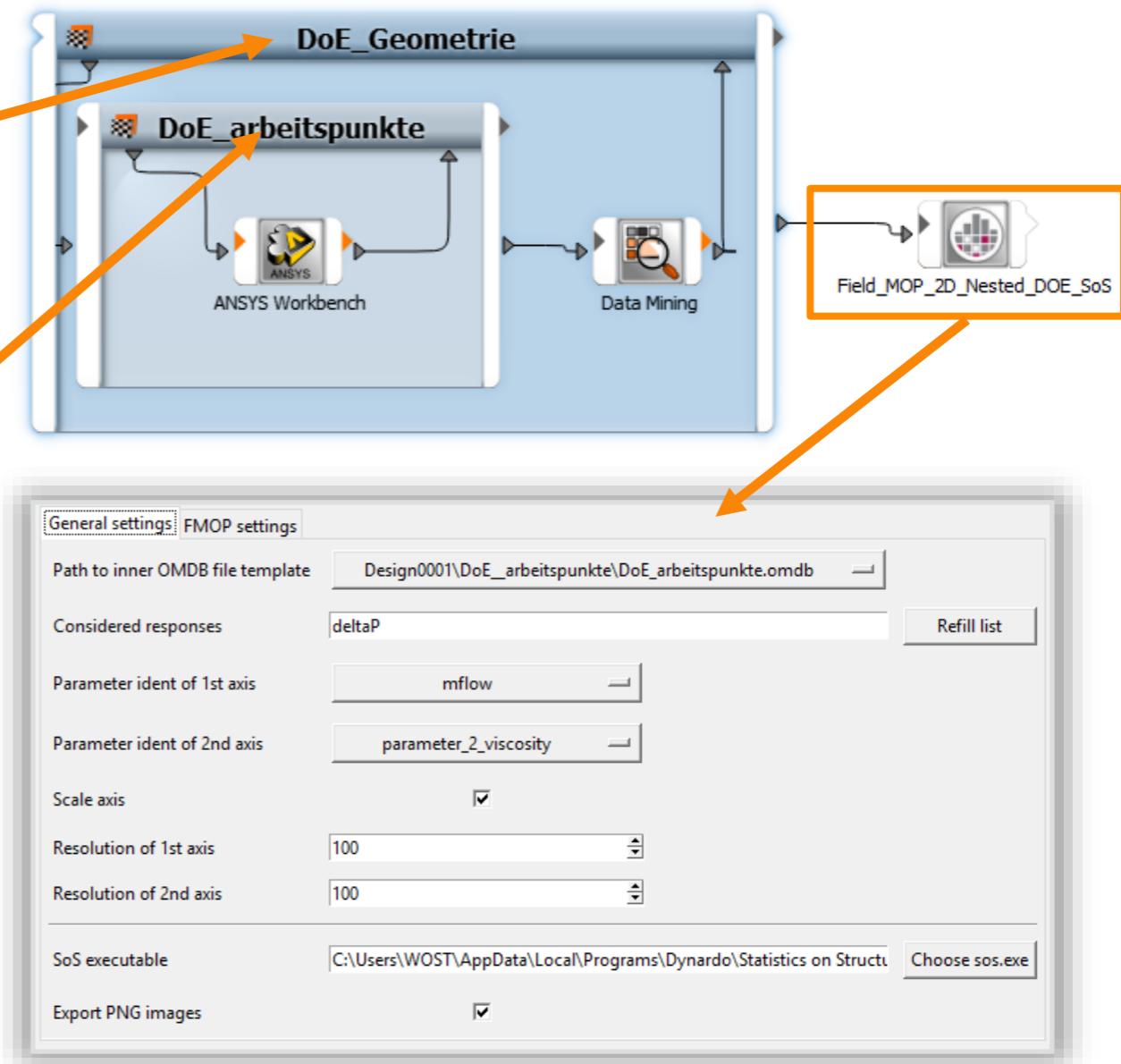
- Radius 1
- Radius 2
- Position upper valve chamber

Parameters of performance map:

- Mass flow
- Viscosity (depends on temperature)

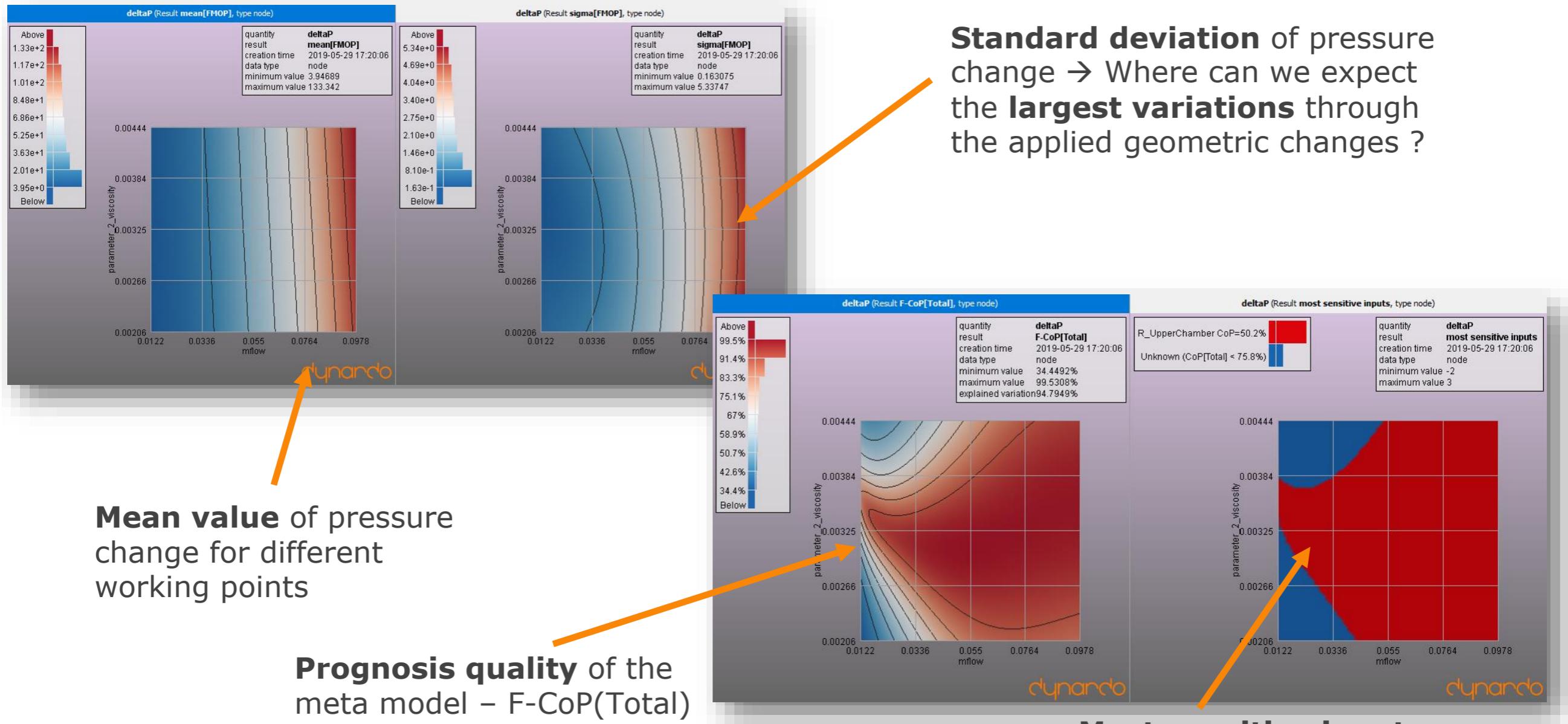
Target:

- Delta P (pressure loss between inlet and outlet)



With courtesy of CADFEM (Neuhierl CASCON 2018)

Performance map analysis – Example valve Results

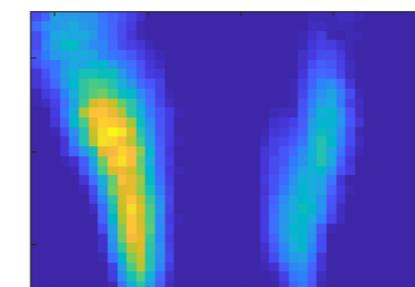
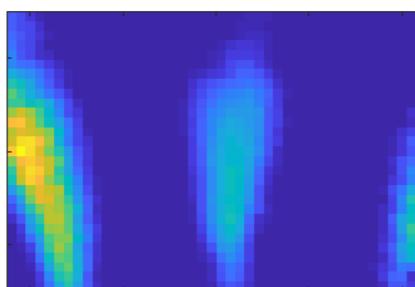
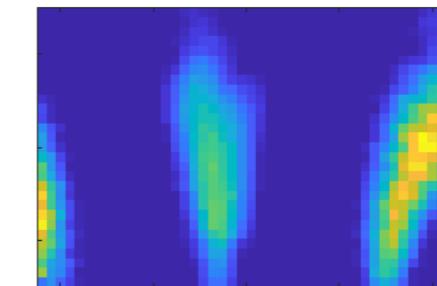
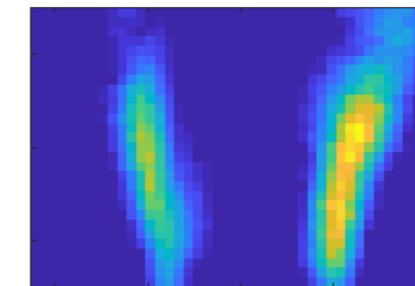
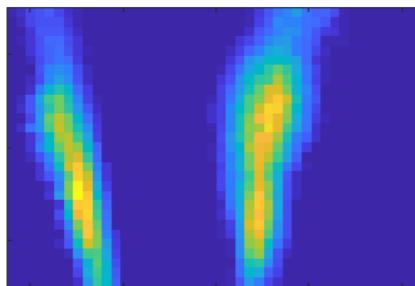


With courtesy of CADFEM (Neuhierl CASCON 2018)

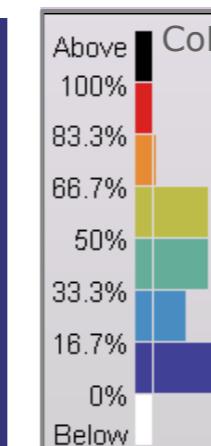
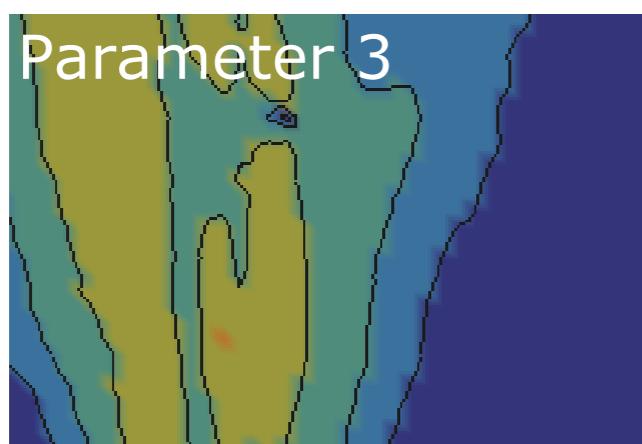
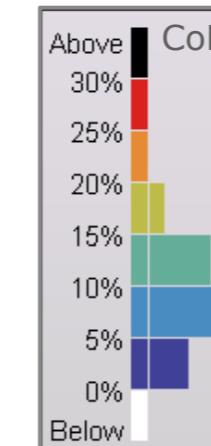
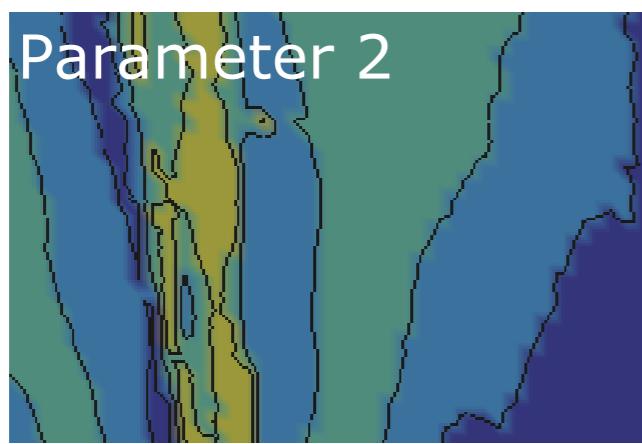
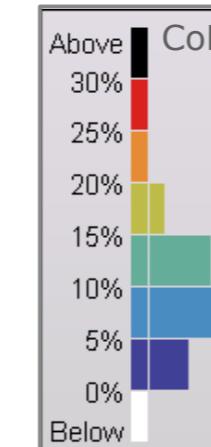
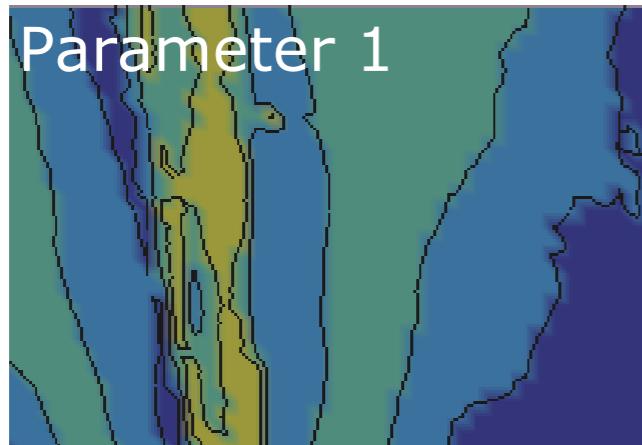
Data set

Example: Optical Image (Map) analysis

- Start set including 1000 designs
- 5 images including a matrix of ~30x40 data points
- Approx. 10% designs with zero output information



Analysis of Images

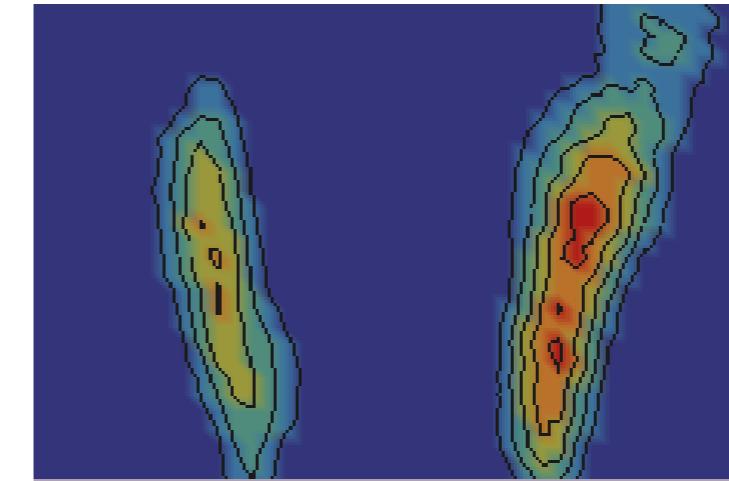
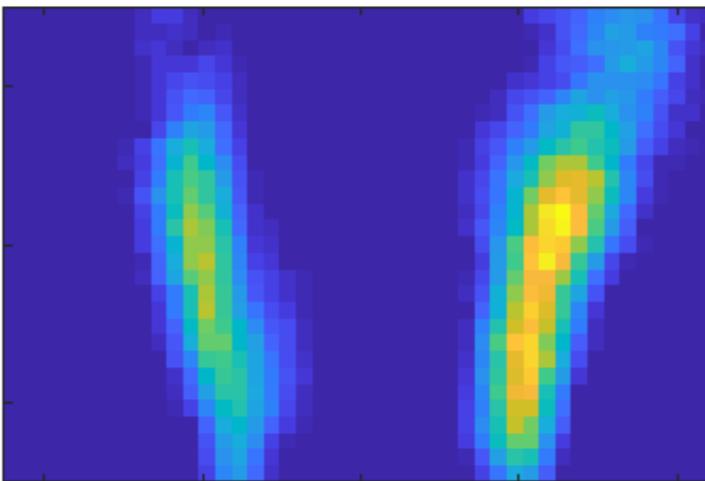


Example: Optical Image (Map) analysis

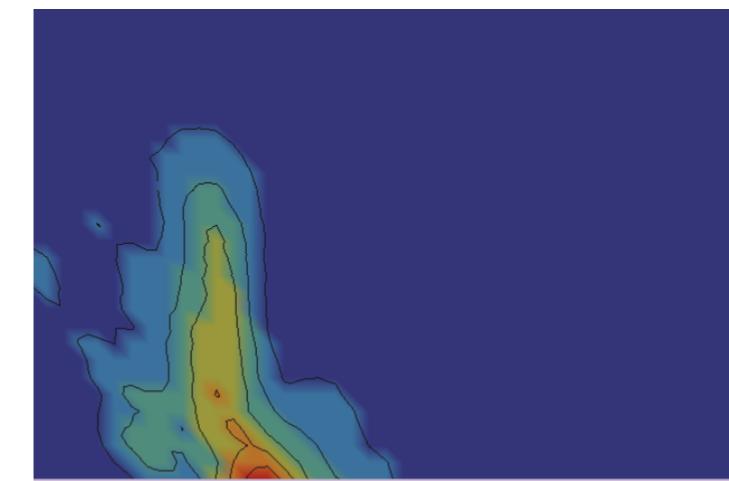
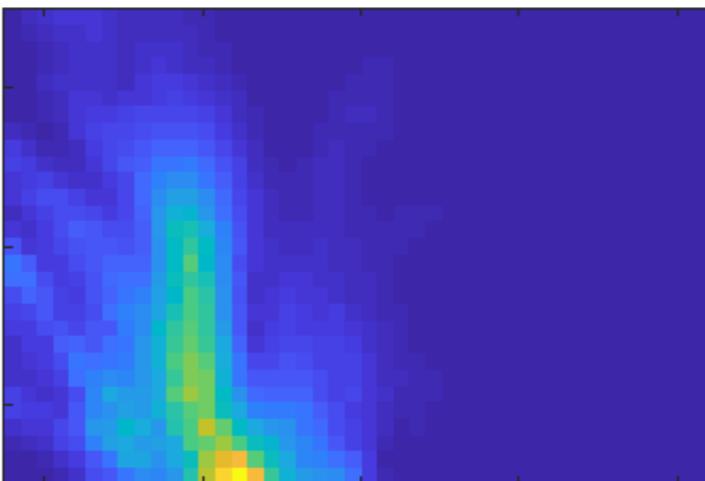
- Here, the analysis results of image2 are shown (Total CoP: 95%)
- Spatial influence of each input parameter is visualized (selection)
- Color corresponds to influential strength (Single-CoP)
- Parameter 3 has highest influence (see scale).
- The spatial distribution of its influence is pretty similar to the other two parameters.

Analysis of Approximation Quality

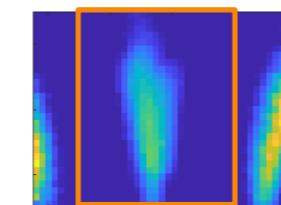
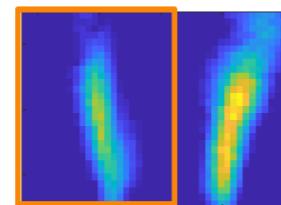
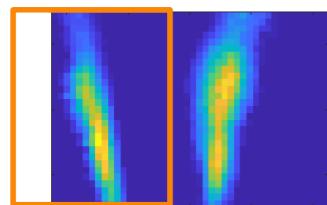
- Original data vs approximation design 668, Image2



- Original data vs approximation design 48, Image2

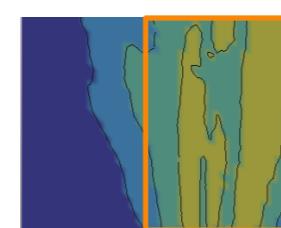
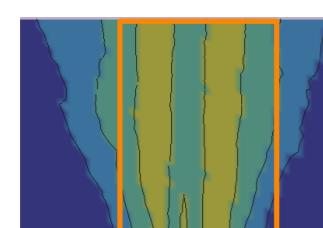
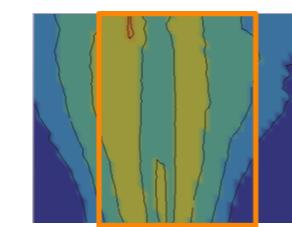
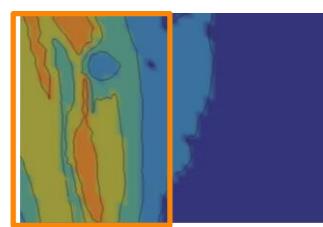
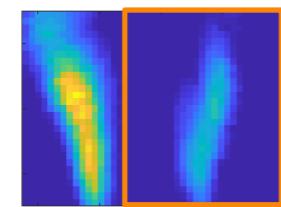
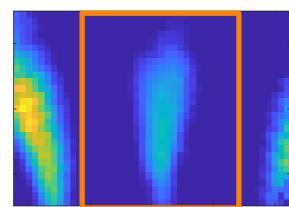


Correlation of Images with each other



Original data (images):

- A “movement” of the structure from left to right can be observed visually



Analysis with SoS:

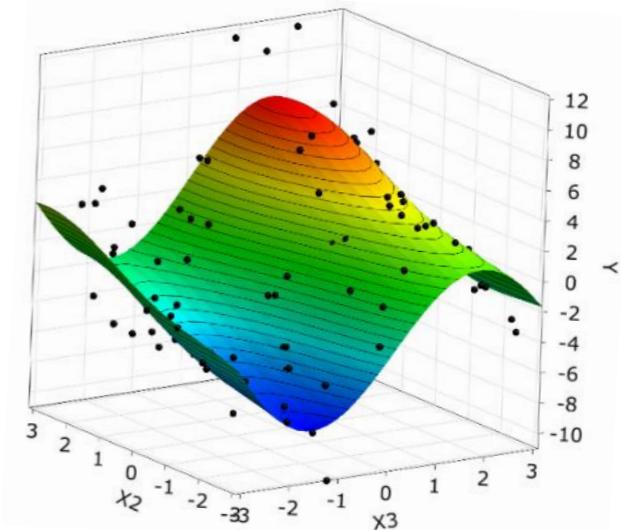
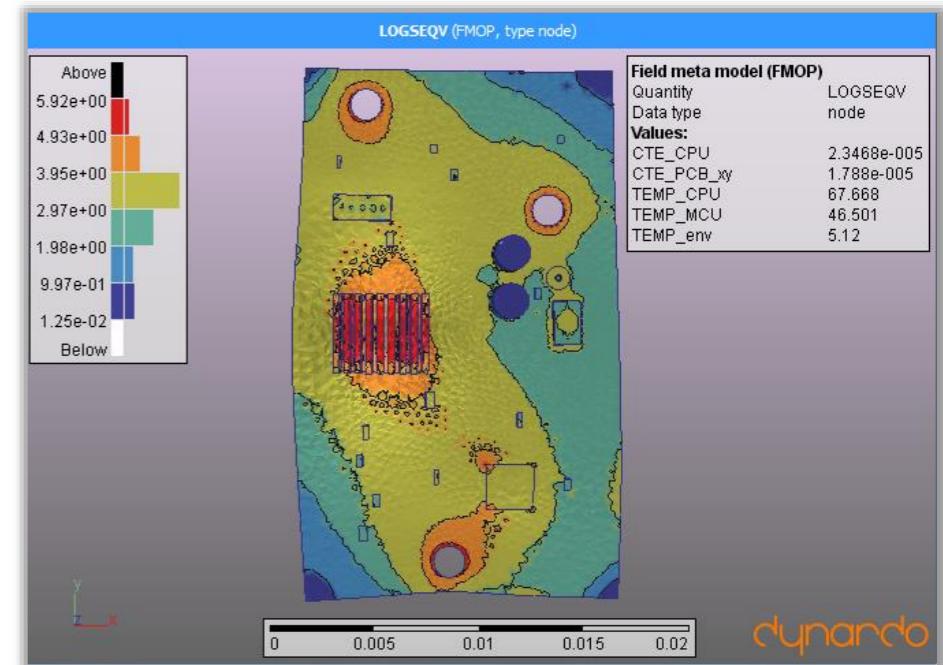
- Influence of Parameter 3 in each image is visualized
- The “movement” of the parameter influence from left to right can be observed

Digital Twins for predictive maintenance

- Objective: Fast analysis of transient load cycles based on
 - Representative load cycles during design phase
 - Measured load cycles during lifetime
- **Key to solution:** Replace nonlinear simulation model by approximation model of the FEM model – DYNARDO ROM
- Steps:
 - Design of Experiments in optiSLang
 - Create and validate Data based ROM (optiSLang and/or SoS)
 - Connect (“feed”) ROM with sensor data
 - Fatigue analysis (e.g. rainflow counting) in e.g. MATLAB or directly in SoS

Dynardo ROM's

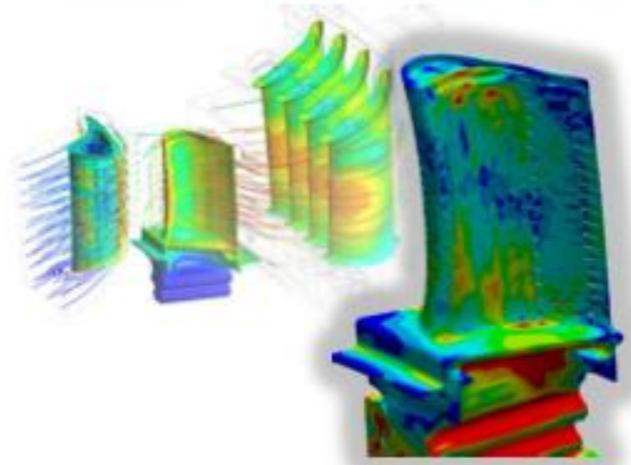
- **Data based – physics agnostic**
- **Data & Solver agnostic**
Supports CAE solver formats
Analysis of measurements (CSV,STL, images)
- **MOP workflow automatically reduce dimensionality and select best possible subspace and metamodel regarding forecast quality!**
 - **MOP integrated third party metamodel and machine learning algorithms**
- **optiSLang: Scalar MOP, Signal MOP**
- **SoS+optiSLang: Field MOP**
- **Real time field surrogate models possible**
3D Field-MOP in time



Predictive maintenance example



Predictive Maintenance



LHT: Motivation

ITB: Technical Solution

CASCON 2018

Presented by H. Schulze Spüntrup – ITB

1 CASCON 2018 - Predictive Maintenance



Lufthansa Technik

dynardo
dynamic software & engineering

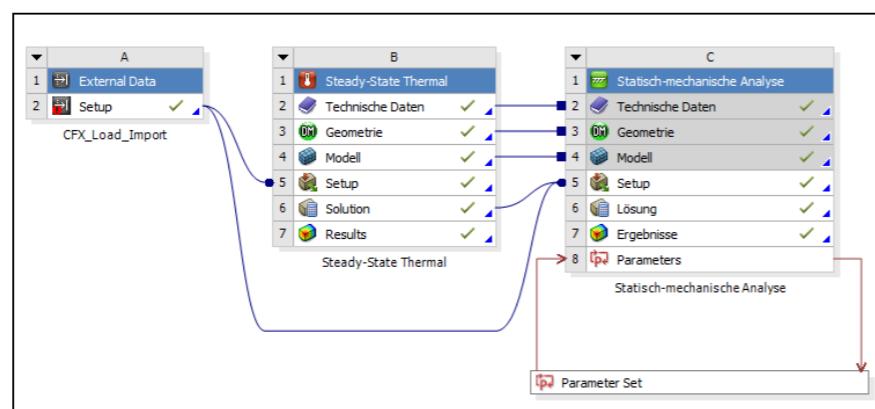


[1] M.Eng. Holger Schulze Spüntrup (ITB Ingenieurgesellschaft für technische Berechnungen mbH)
Real-time processing with 3D meta models for predictive maintenance of aircraft engines
CASCON 2018

Predictive maintenance example

Setting up the 1-way FSI simulation models

- Creation of a FE-model of the High-Pressure-Turbine-Blade



Assessed part: HPTB

Global Number of Nodes: ~ 6 million

12 CASCON 2018 - Predictive Maintenance

 **Lufthansa Technik**

 **dynardo**
dynamic software & engineering

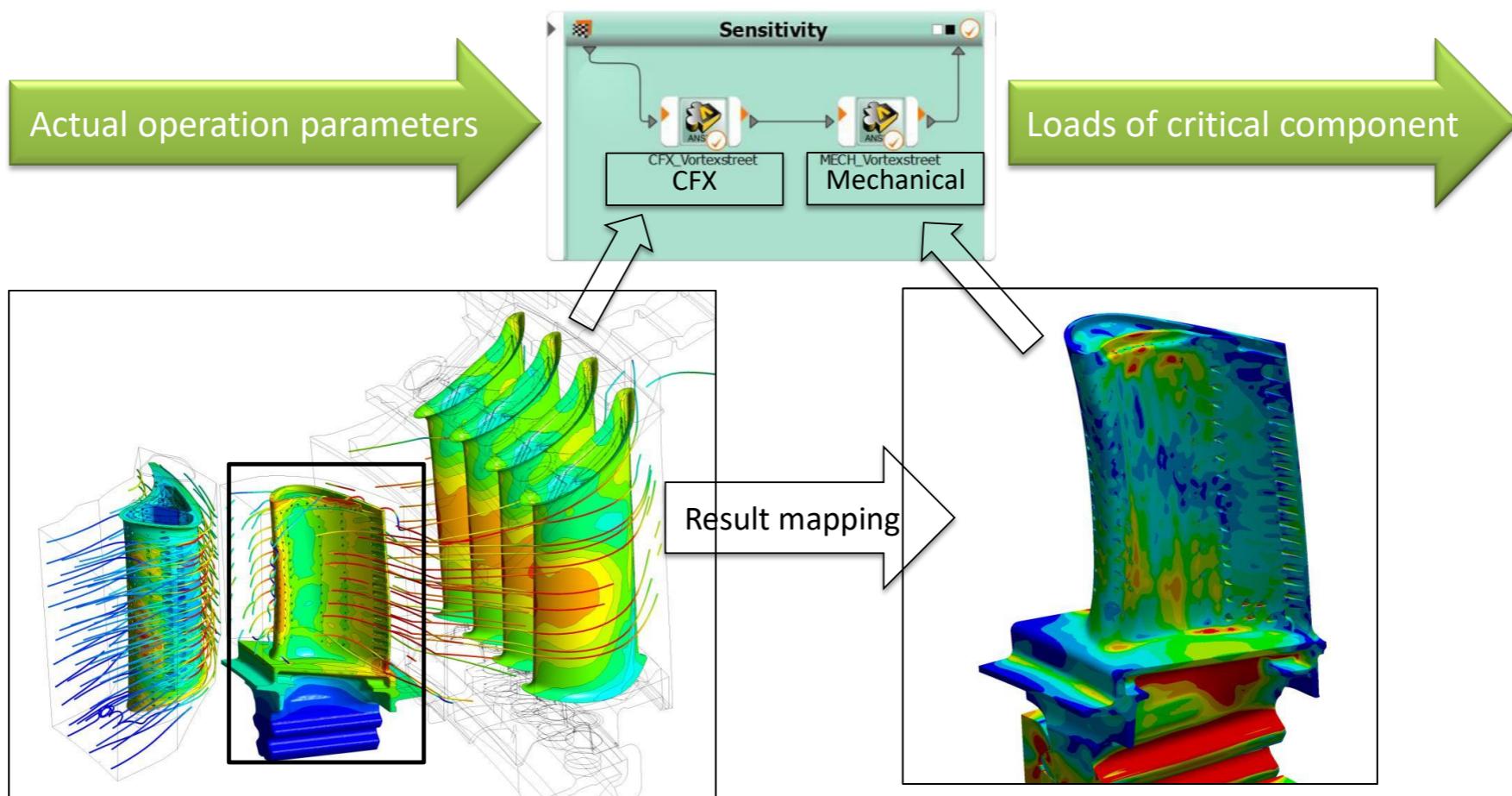
 **itb**

[1] M.Eng. Holger Schulze Spüntrup (ITB Ingenieurgesellschaft für technische Berechnungen mbH)
Real-time processing with 3D meta models for predictive maintenance of aircraft engines
CASCON 2018

Predictive maintenance example

Implementing the simulation models in an *optiSlang* workflow

■ Simulation loop in *optiSlang*



Predictive maintenance example

Results

- FMOP in *Statistics on Structures*

List of available individual objects/samples:

| | S1 | S2 | S3 | SX | SXY | SXZ | SY | SYZ | SZ | TEMP |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| F-CoP[Total] | 95.37 % | 91.52 % | 91.96 % | 96.49 % | 92.38 % | 93.27 % | 92.00 % | 92.08 % | 95.01 % | 99.21 % |

File includes the FE-results of the validation points for direct comparison
Statistics on Structures 3.3.1
4,90 GB

Maximum Principle Stress S1 [MPa]

FE-Results FMOP Result accuracy
Perfect match = 100 %

19 CASCON 2018 - Predictive Maintenance

Lufthansa Technik

dynardo
dynamic software & engineering

itb

[1] M.Eng. Holger Schulze Spüntrup (ITB Ingenieurgesellschaft für technische Berechnungen mbH)
Real-time processing with 3D meta models for predictive maintenance of aircraft engines
CASCON 2018

Predictive maintenance example

Transient real-time load stepping on the basis of field meta models (FMOP) for electro-thermal-mechanical FE simulations



36. CADFEM ANSYS Simulation Conference
10.-12.10.2018

Robert Bosch GmbH:

K. Riester, Dr. C. Faust-Ellsässer, Dr. T. Rupp

DYNARDO:

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



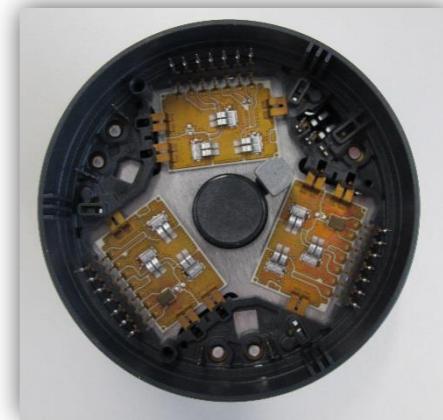
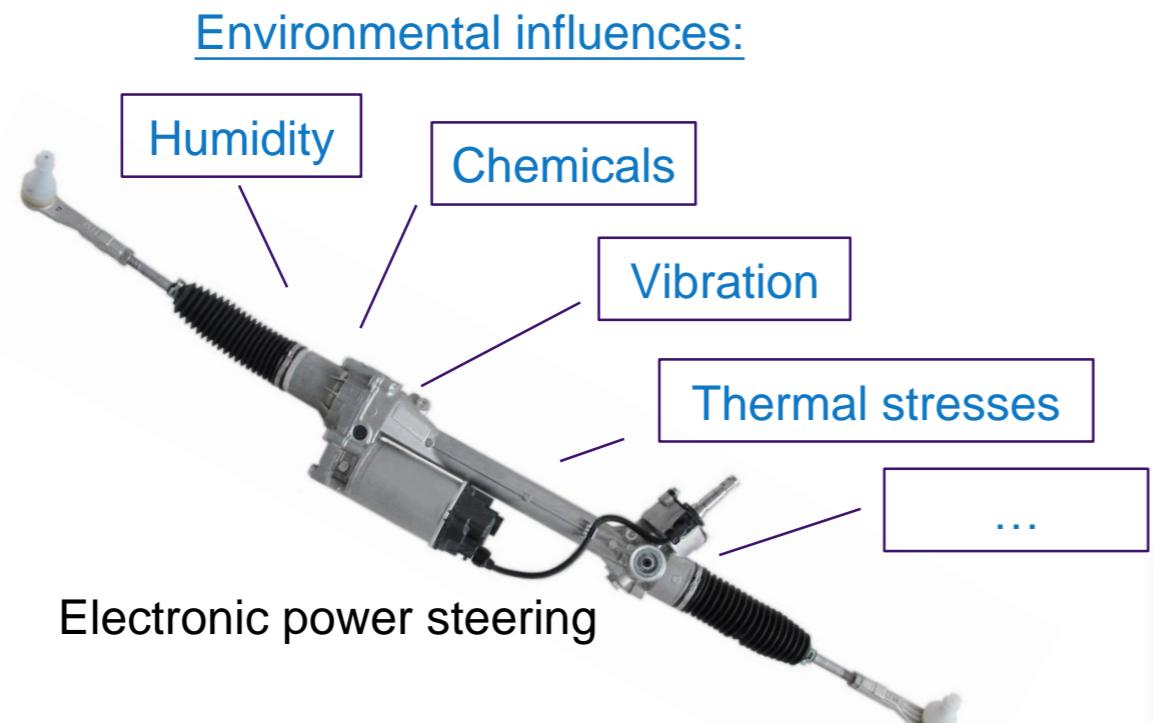
[2] Dipl.- Math.techn. Konrad Riester (Robert Bosch GmbH)

Transient real-time load stepping on the basis of field meta models in electro-thermal-mechanical FE simulations, CASCON 2018

Predictive maintenance example

Real-time load stepping on the basis of FMOP for electro-thermal-mechanical FE simulations

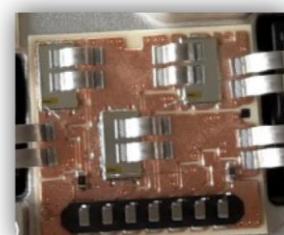
Electronic power steering



Electronic control unit
(ECU)



Power pack



DBC

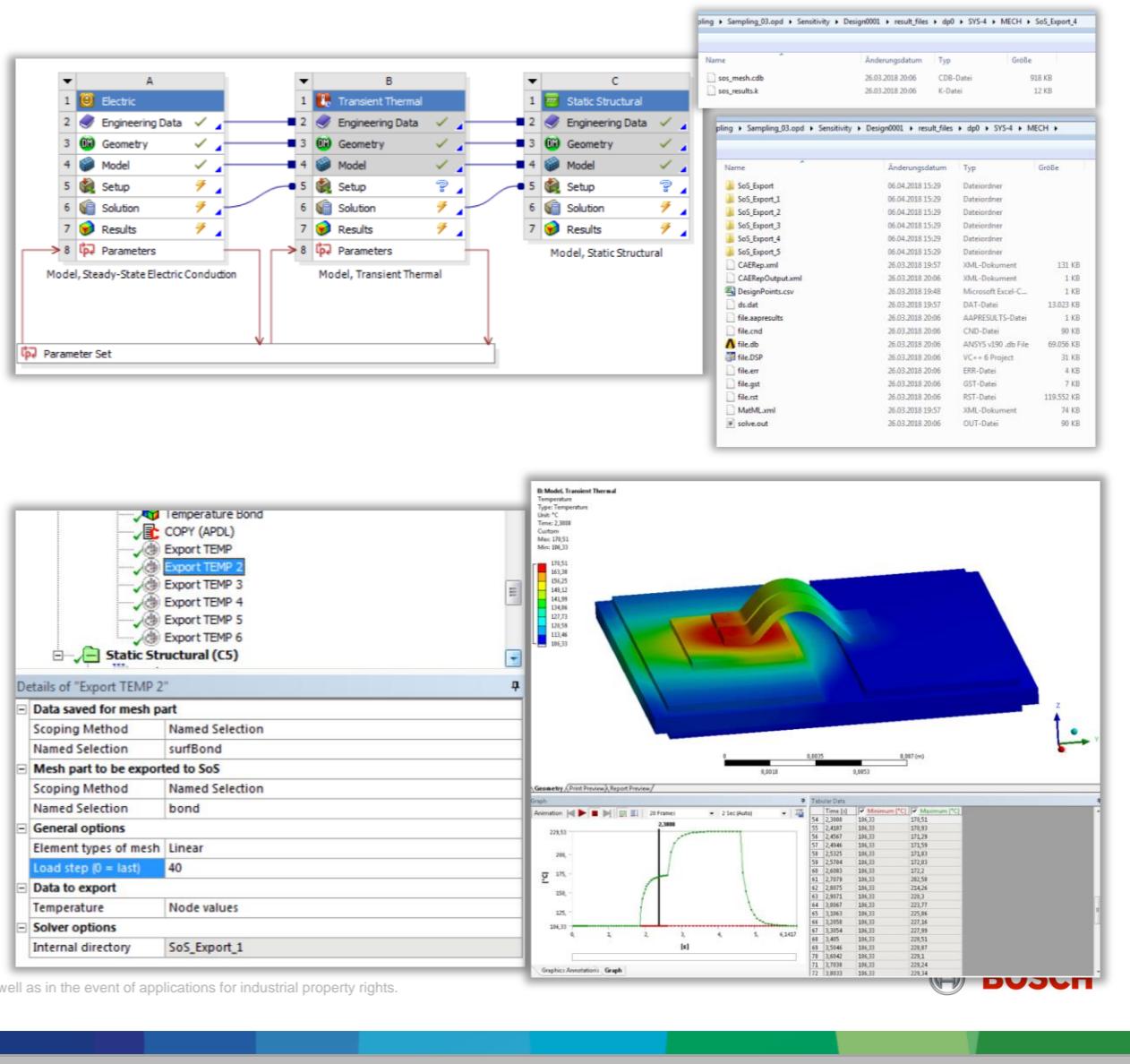
[2] Dipl.- Math.techn. Konrad Riester (Robert Bosch GmbH)

Transient real-time load stepping on the basis of field meta models in electro-thermal-mechanical FE simulations, CASCON 2018

Predictive maintenance example

Real-time load stepping on the basis of FMOP for electro-thermal-mechanical FE simulations
ANSYS WB model

- ANSYS WB: connects 3 different physics and data transition between 3 ANSYS Mechanical models:
 Transient electrical loading leads to an increase in the temperature of the domain and, subsequently, to thermally induced stresses.

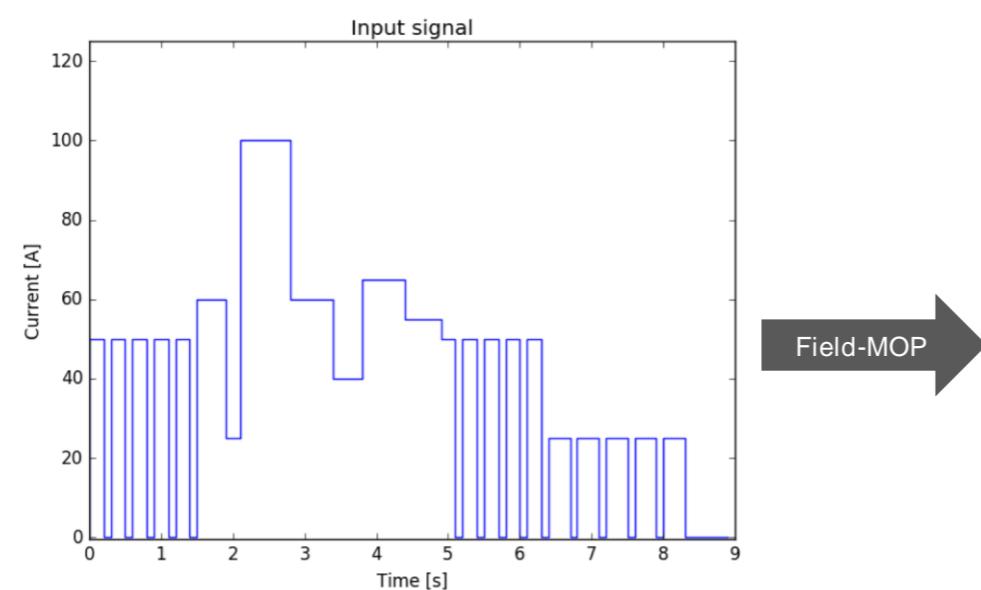


- ANSYS APDL: Define load transients based on external parameters
- SoS for ANSYS: Plugin for Mechanical exports result data directly to SoS for FMOP creation

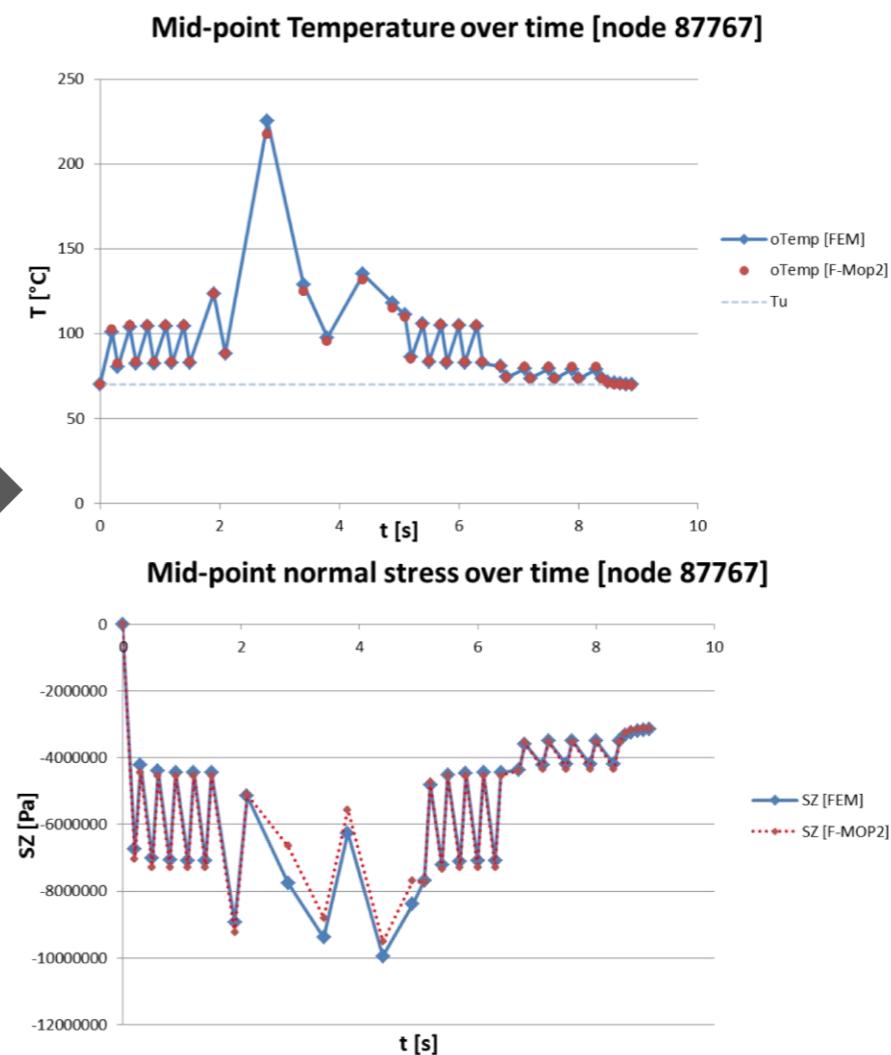
[2] Dipl.- Math.techn. Konrad Riester (Robert Bosch GmbH)
Transient real-time load stepping on the basis of field meta models in electro-thermal-mechanical FE simulations, CASCON 2018

Predictive maintenance example

Real-time load stepping on the basis of FMOP for electro-thermal-mechanical FE simulations
FMOP result validation



Field-MOP →



Output at point of the contact:

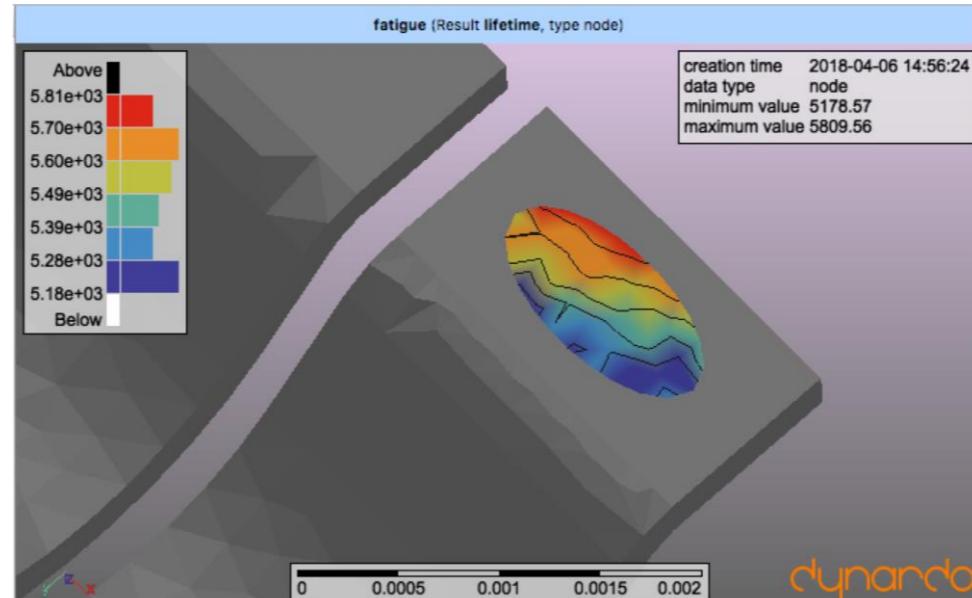
- Excellent approximation result for transient temperature and contact stresses.

Predictive maintenance example

Real-time load stepping on the basis of FMOP for electro-thermal-mechanical FE simulations

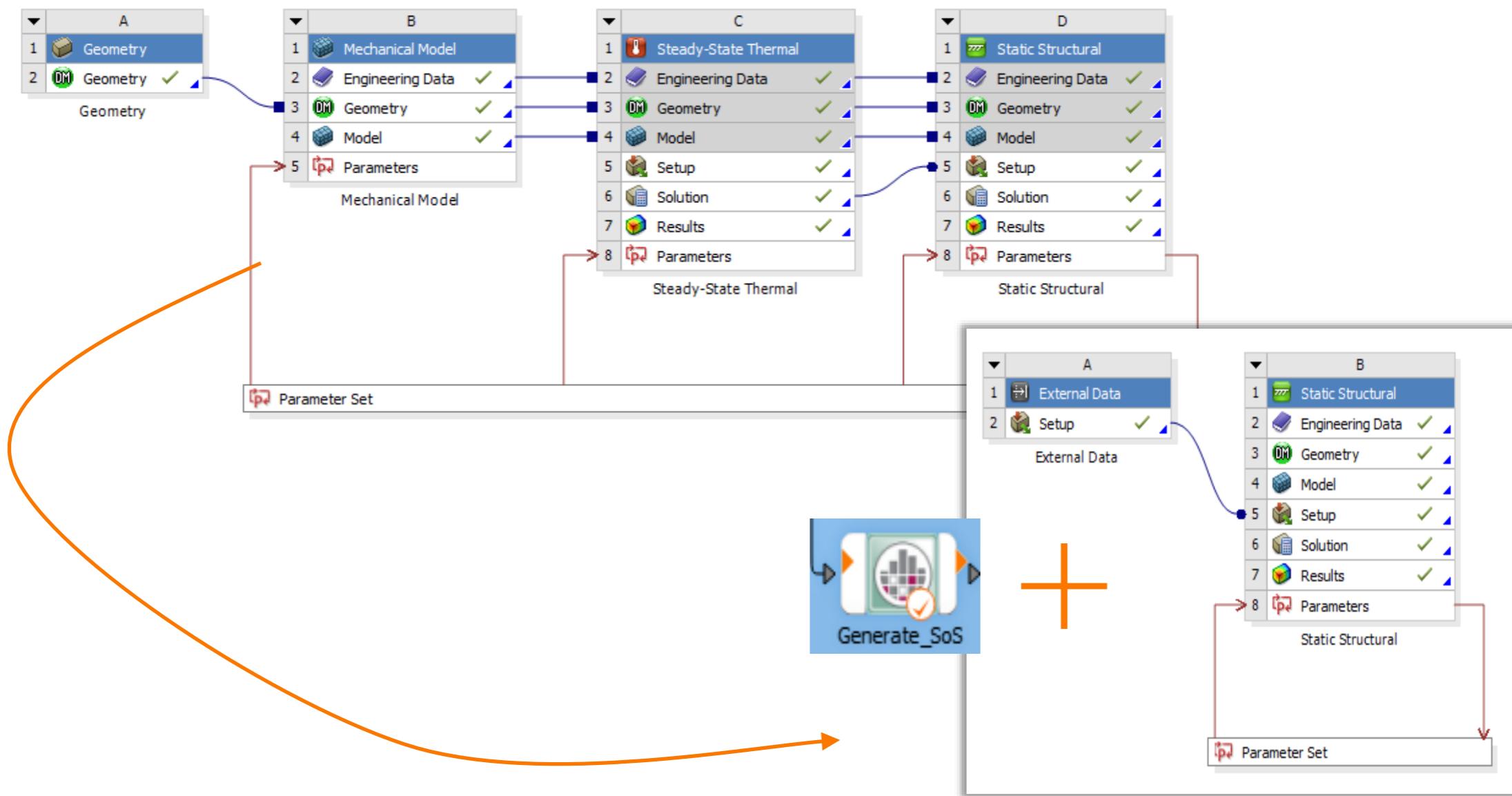
Transient solver: As SoS script

- Based on SoS script API one can solve the system given a load transient directly from Windows Explorer
- Integrated rainflow counting to assess critical number of load cycles and visualization of expected lifetime in SoS:



Substituting simulation parts with Field MOP Motivation

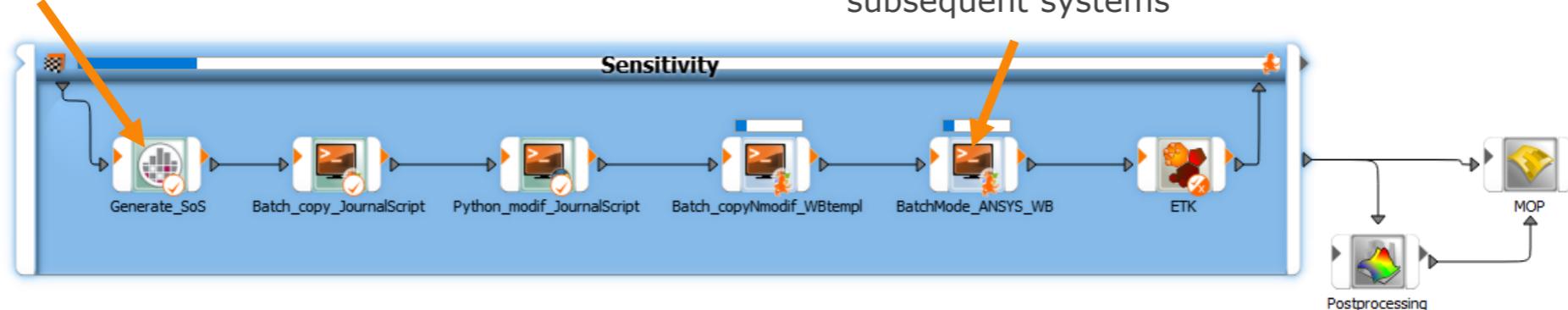
How to implement the field meta model in an existing ANSYS Workbench project? How to replace time-consuming parts of a simulation model ?



Substituting simulation parts with Field MOP

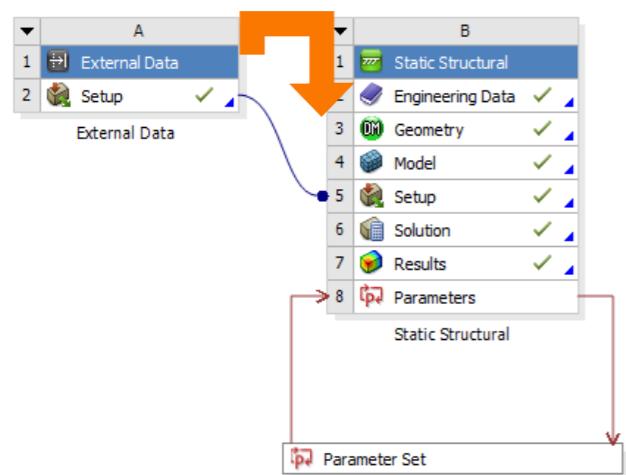
Workflow & results

Field MOP evaluation of temperature field

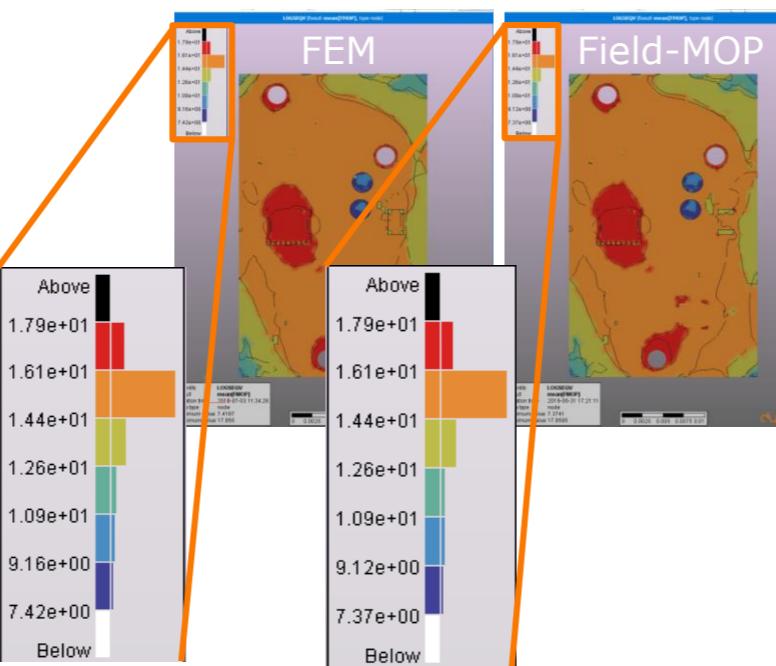


Direct simulation evaluation of subsequent systems

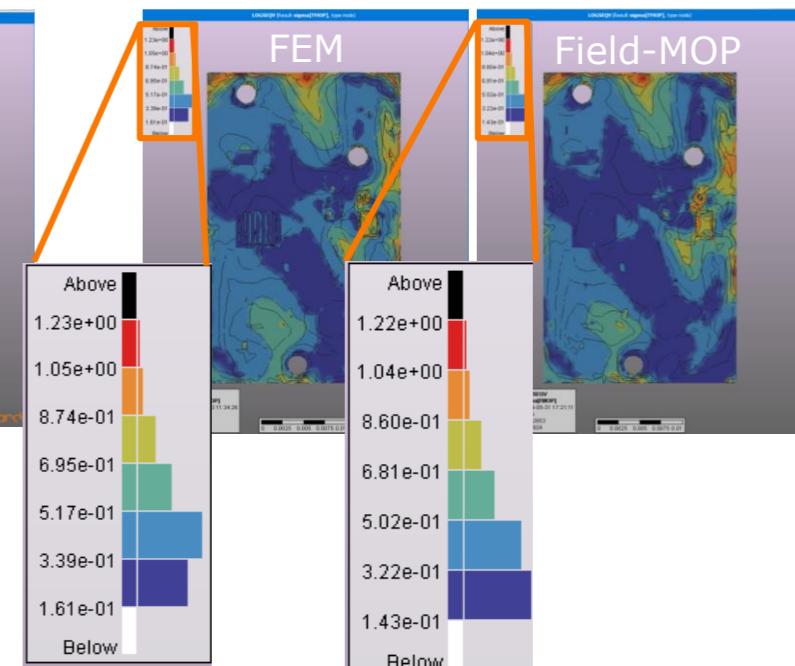
Modified Workbench project



LOGSEQV (mean)



LOGSEQV (sigma)



Substituting simulation parts with Field MOP

External data format created by SoS

| | A | B | C | D |
|----|--------------|--------------|--------------|-------------|
| 1 | X Coordinate | Y Coordinate | Z Coordinate | Temperature |
| 2 | 0.012372 | 0.0151266 | 0.00045 | 31.2042 |
| 3 | 0.0124282 | 0.0150433 | 0.00045 | 31.2504 |
| 4 | 0.0124474 | 0.0149289 | 0.00045 | 31.3196 |
| 5 | 0.0124112 | 0.014815 | 0.00045 | 31.3968 |
| 6 | 0.0123563 | 0.0147283 | 0.00045 | 31.4584 |
| 7 | 0.0119589 | 0.0146605 | 0.00045 | 31.5411 |
| 8 | 0.0122856 | 0.0151179 | 0.00045 | 31.199 |
| 9 | 0.012222 | 0.0152094 | 0.00045 | 31.1753 |
| 10 | 0.0120614 | 0.0151862 | 0.00045 | 31.2123 |
| 11 | 0.0119203 | 0.0151006 | 0.00045 | 31.295 |

| | A | B | C | D | E |
|---|--------|--|-----------|-----------------|---------------------|
| 1 | Column | Data Type | Data Unit | Data Identifier | Combined Identifier |
| 2 | A | X Coordinate | m | | File1 |
| 3 | B | Y Coordinate | m | | File1 |
| 4 | C | Z Coordinate | m | | File1 |
| 5 | D | Temperature | C | Temperature1 | File1:Temperature1 |
| | | Not Used X Coordinate Y Coordinate Z Coordinate Node ID Element ID Temperature Pressure Heat Transfer Coefficient Heat Flux Heat Generation Heat Rate Thickness Displacement Force Velocity Stress Strain Body Force Density | | | |

Read SoS output in ANSYS WB (External data)

Set up the X,Y,Z coordinates of data points and the data to be used as load,
Here: temperature (generated by SoS)

Types of random fields

Depending on task and number of input data

| Model type | Inputs | Properties | Application |
|------------------------------|-----------------------|---|--|
| Empirical random field | Many measurements | Accurate description of reality | Robustness analysis, Quality control, Maintenance |
| Synthetic random field model | Few measurements | mean+stddev from measurements, spatial correlation from assumption | Robustness analysis: Predict Pf based on true magnitude of variations |
| Free-form model | Few measurements | Mean+stddev from measurements | Needs more parameters, but can localize effects on structure |
| Synthetic random field model | Single/no measurement | Artificial, global | Check if variation has impact |
| Free-form model | No measurement | Artifical, local | Shape optimization and sensitivity analysis |

Robustness analysis related to geometric and material scatter



[2] Marion Ballweg (SIEMENS)
Robustheitsbewertungen gegenüber Geometrie- und Materialtoleranzen für einen Pressverband, CASCON 2018

Robustness analysis related to geometric and material scatter

Motivation

SIEMENS

Ingenuity for life

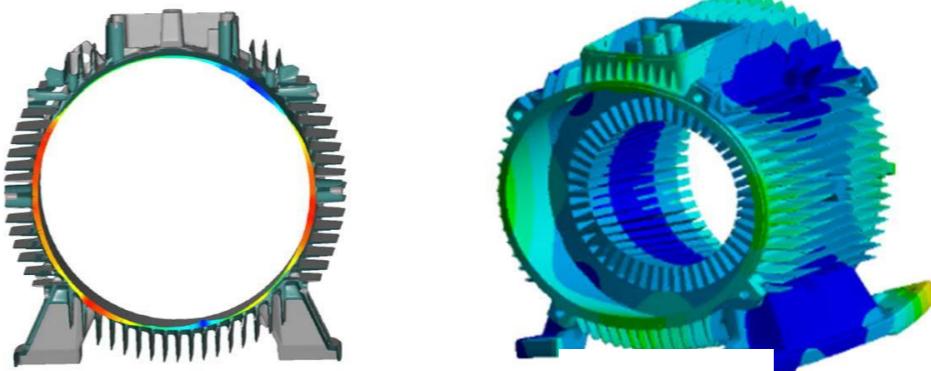
Produktion

- herstellungsbedingte Geometrieschwankungen
- herstellungsbedingte Schwankungen der Materialkennwerte

Montage

- Pressverband beeinflusst Steifigkeit

Einflusses auf dynamischen Kennwerte?



Frei verwendbar © Siemens AG 2018

Page 4

11/10/2018

M: Ballweg PD LD P R&D 2 2 3

[2] Marion Ballweg (SIEMENS)

Robustheitsbewertungen gegenüber Geometrie- und Materialtoleranzen für einen Pressverband, CASCON 2018

Robustness analysis related to geometric and material scatter

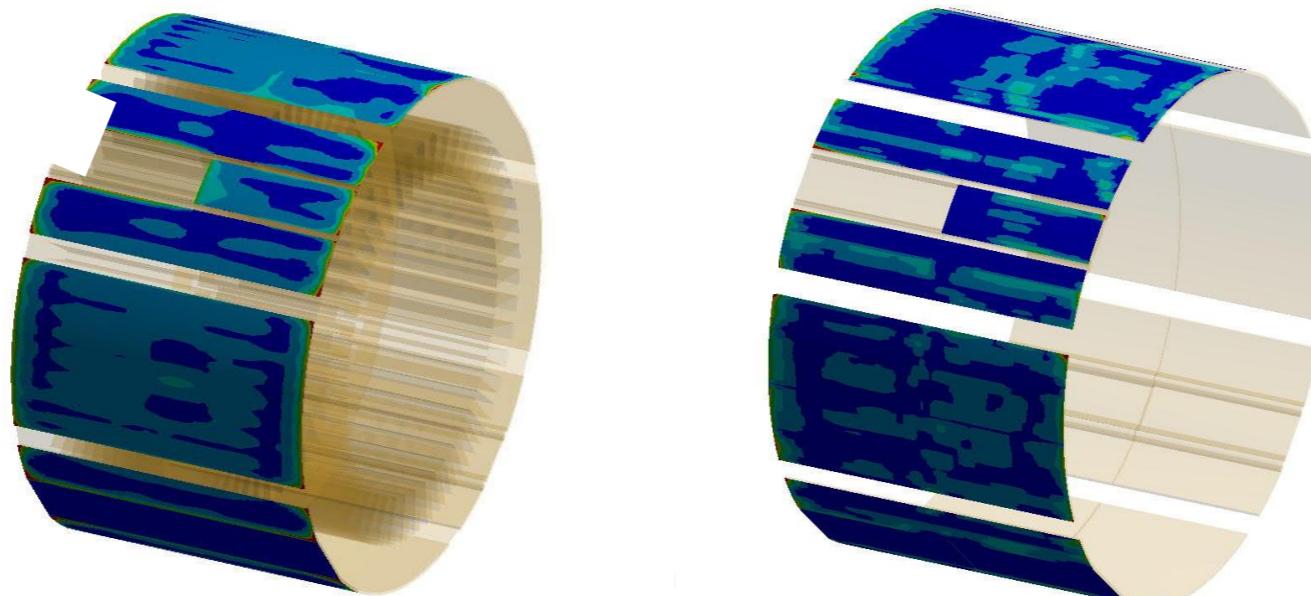
Ergebnisse – Nominalgeometrie vs. Referenzimperfektion

SIEMENS
Ingenuity for life

■ Anpressdruck [MPa]

Nominalgeometrie

Referenzimperfektion



Frei verwendbar © Siemens AG 2018

Seite 13

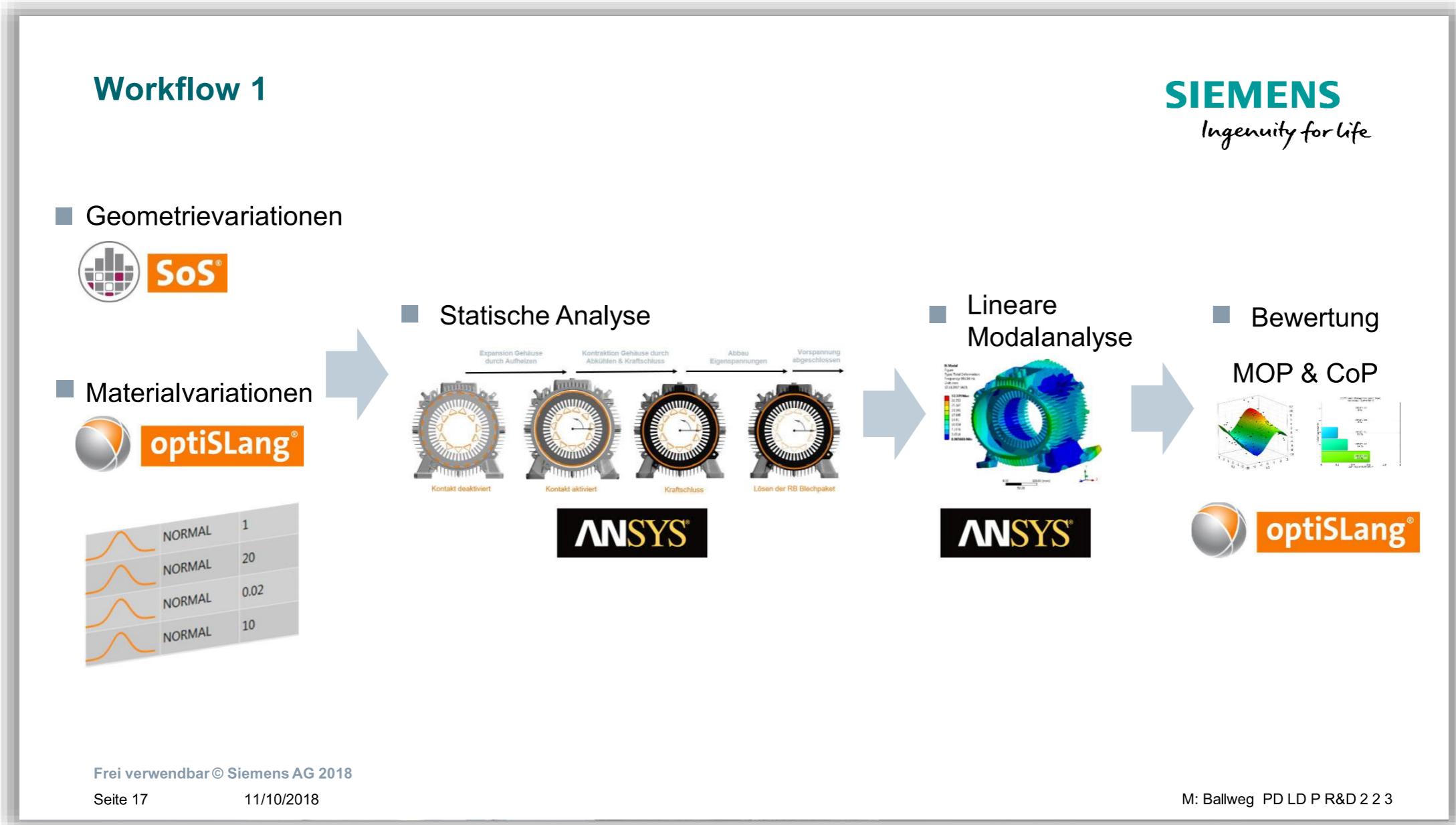
11/10/2018

M: Ballweg PD LD P R&D 2 2 3

[2] Marion Ballweg (SIEMENS)

Robustheitsbewertungen gegenüber Geometrie- und Materialtoleranzen für einen Pressverband, CASCON 2018

Robustness analysis related to geometric and material scatter



[2] Marion Ballweg (SIEMENS)
Robustheitsbewertungen gegenüber Geometrie- und Materialtoleranzen für einen Pressverband, CASCON 2018

Summary

- New advances in
 - Digital twins and real-time approximation
 - Performance map and optical image analysis
 - Random field modelling
 - Simplification of user interface and analysis

WELCOME TO

WOST

2019

Premium Sponsor

CADFEM[®]

Sponsor

BETA
SIMULATION SOLUTIONS

Exhibitors

CAESES

**MATH
2 MARKET**

esi
get it right[®]