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Recent Developments of Field Meta Models

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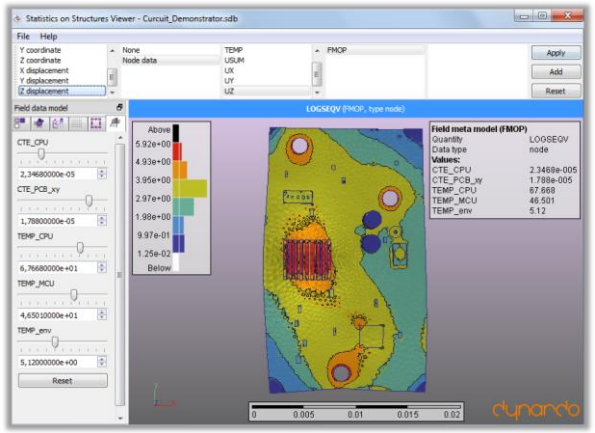
Director R&D optiSLang

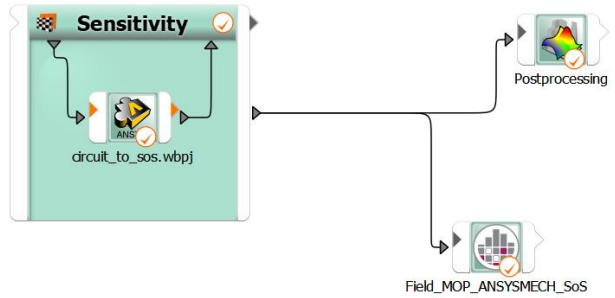
Ansys

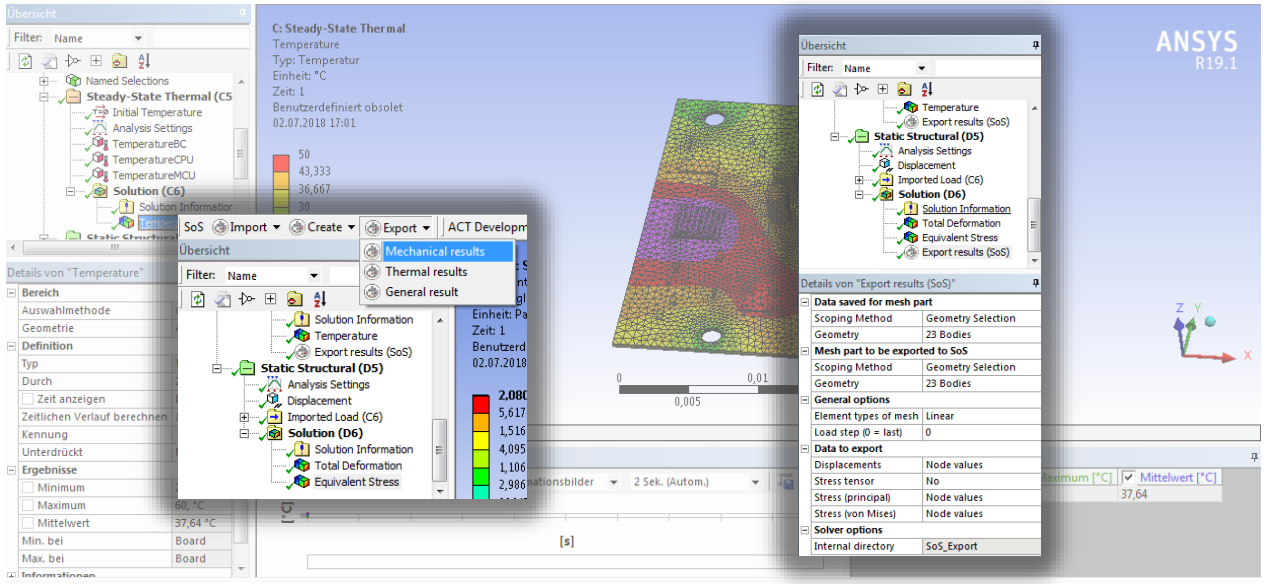
Statistics on Structures

- Integrate into ANSYS optiSLang Enterprise:
  - Shared license
  - 2D/3D Pre + Post GUI in optiSLang installer
  - SoS integration nodes in optiSlang workflows:
    - Open 3D Viewer
    - Create Field MOP
    - Solver for Field MOP and Random Fields
  - Mechanical/Workbench Plugin
  - SoS Python module + FMOPSolver.dll

- Recent developments in
  - Signal MOP (1D)
  - Field MOP (2D/3D)
  - Morphing for Uncertainty Quantification







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Field meta models

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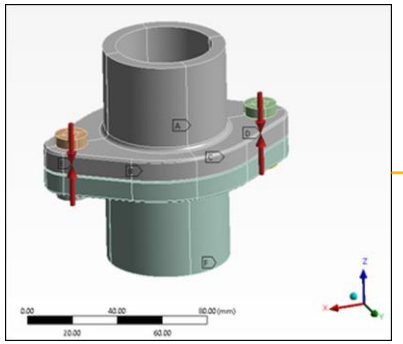
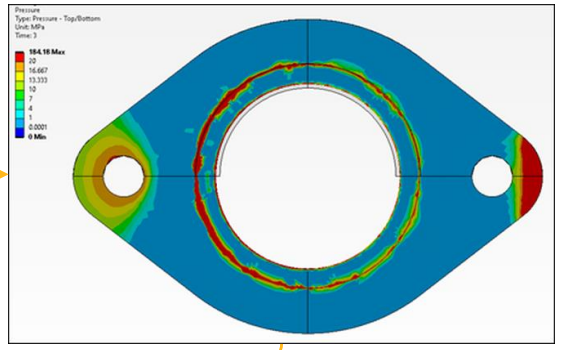
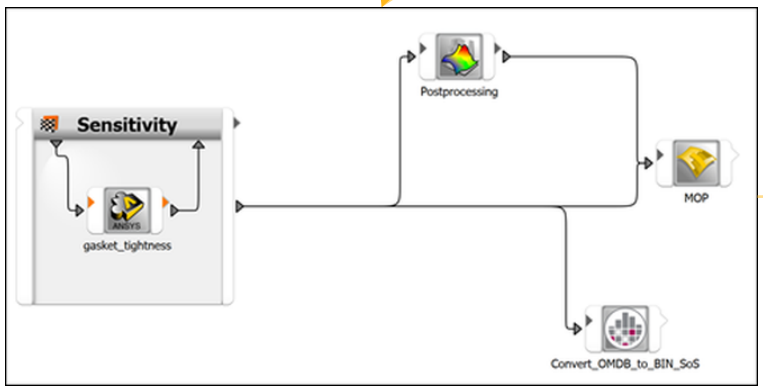
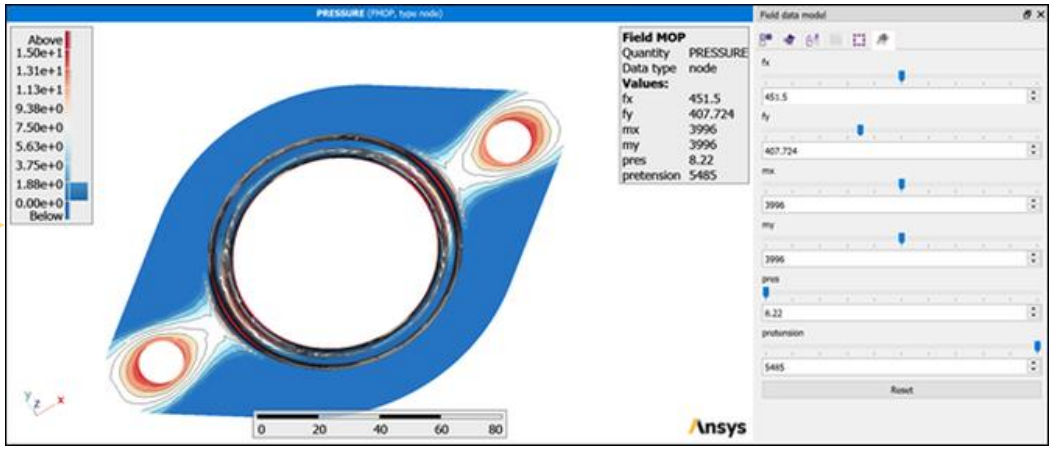
Customer example: ROM for real-time design studies

- Validate if a gasket is „tight“ in real-time what-if-scenarios
- Need to approximate resulting temperature, contact pressure and flow fields in real-time
- Based on these: analyse in 3D if the gasket is tight (true/false)



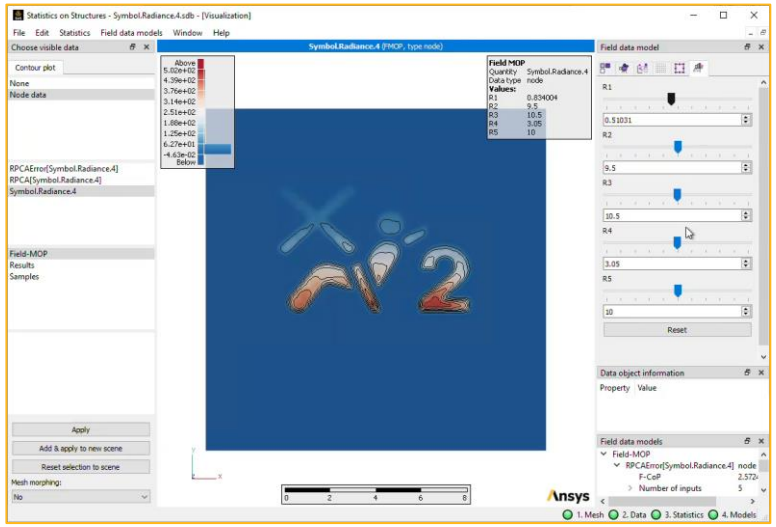


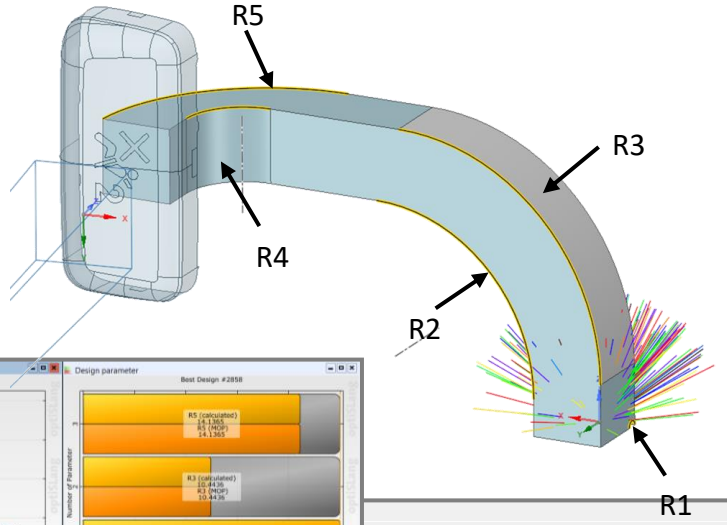


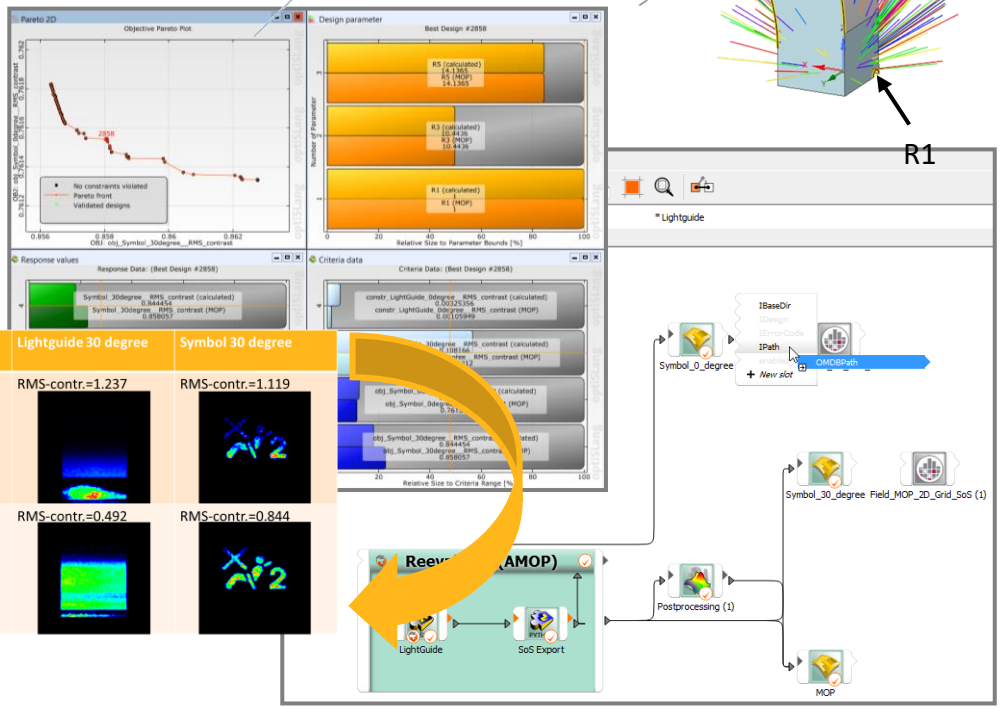


Customer Example: Optimize interior Lightguide layout using scalar & field analysis

- Optimize the shape of the light guide to get the best RMS-contrast
- Perform live design exploration and what-if analysis regarding luminance homogeneity with Field MOP







	Lightguide 0 degree	Symbol 0 degree	Lightguide 30 degree	Symbol 30 degree
Initial Design	RMS-contr.=0.703	RMS-contr.=0.805	RMS-contr.=1.237	RMS-contr.=1.119
Best Design	RMS-contr.=0.597	RMS-contr.=0.762	RMS-contr.=0.492	RMS-contr.=0.844

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From Scalars to Signals and 2D/3D Fields

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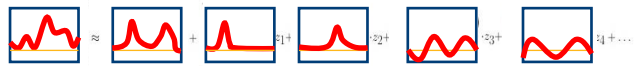
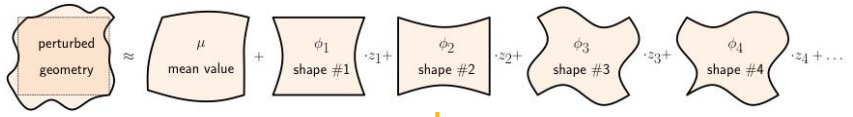
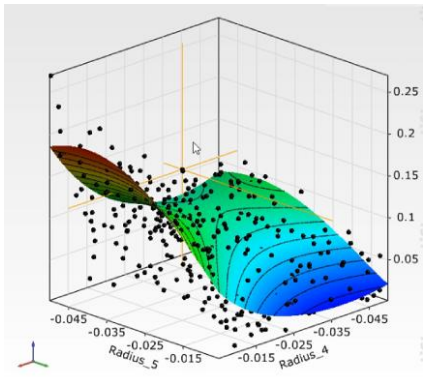
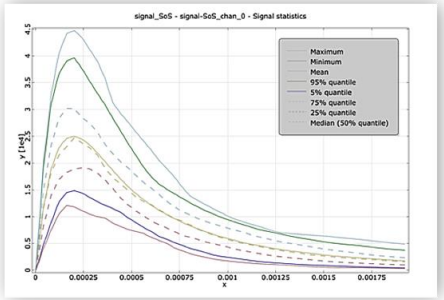
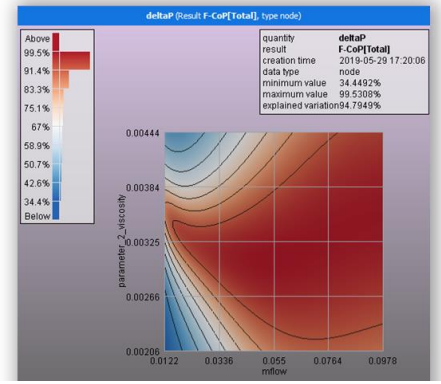
0D: Scalars	1D: Signal	2D: e.g. Wavefronts, Performance maps	3D: Stress fields, deformations
Ansys / OPTISLANG [Premium]	Ansys / OPTISLANG [Enterprise] module Statistics on Structures	Ansys / OPTISLANG [Enterprise] Statistics on Structures	Ansys / OPTISLANG [Enterprise] Statistics on Structures
MOP	**Signal-MOP**	**Field-MOP**	











Prognosis quality: Field Coefficient of Prognosis (F-CoP)

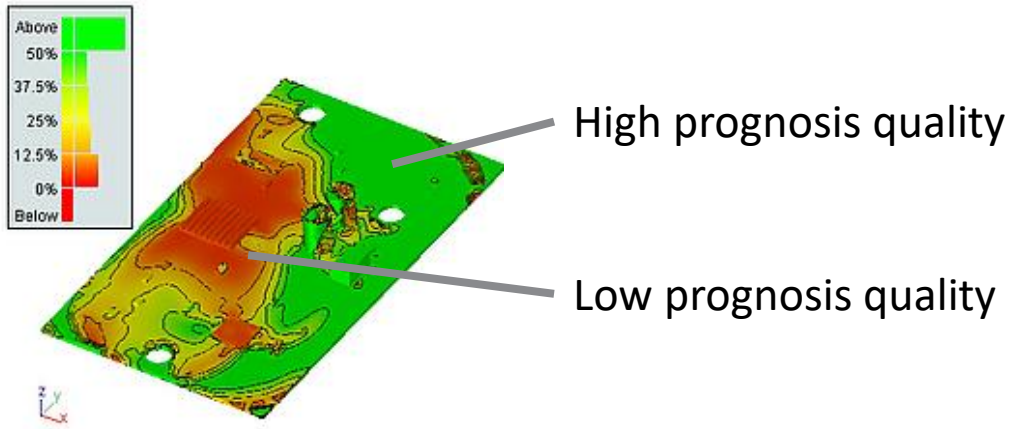
- Check prognosis quality in Field CoP matrix:
  - Single value (“easy to use”)
  - Indicates high or low model accuracy at a glance
  - Is an average value of the CoP in space

	LOGSEQV	TEMP	UX	UY	UZ
F-CoP[CTE_CPU]	7.75 %	2.29 %	1.75 %	1.67 %	1.95 %
F-CoP[CTE_PCB_xy]	18.73 %		15.92 %	14.99 %	4.01 %
F-CoP[TEMP_CPU]	31.42 %	31.63 %	53.71 %	43.62 %	87.40 %
F-CoP[TEMP_MCU]	12.91 %	5.52 %	4.18 %	2.84 %	1.59 %
F-CoP[TEMP_env]	55.24 %	61.74 %	28.39 %	40.77 %	5.09 %
F-CoP[Total]	84.42 %	94.52 %	94.86 %	94.84 %	94.99 %

Sensitivity to inputs

Prognosis quality

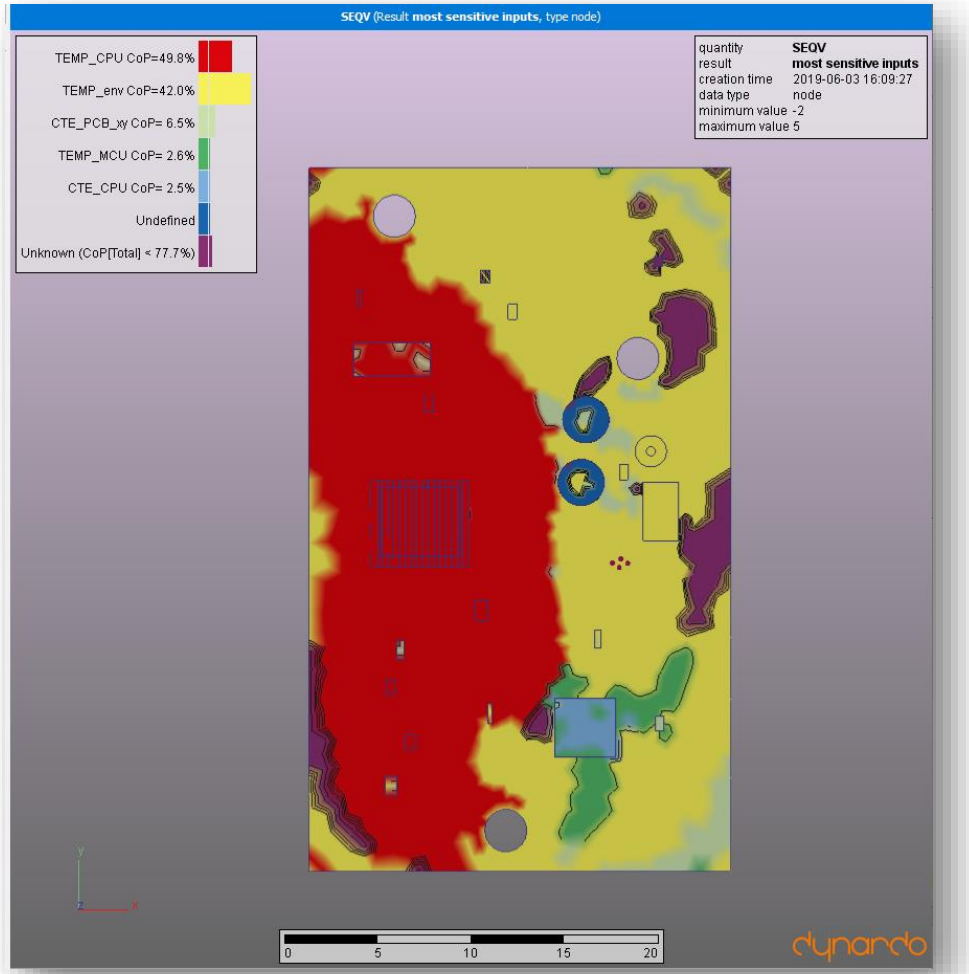
- Check prognosis quality in Field-CoP 3D plot:
  - Plots prognosis quality for each position
  - Compare with standard deviation as an indicator of the magnitude of variation
- Accept / Repair model / Add designs ?



Sensitivity analysis: See all in a single plot

- Which parameter has the largest influence at what location ?
- Where has the ROM a too low accuracy ?

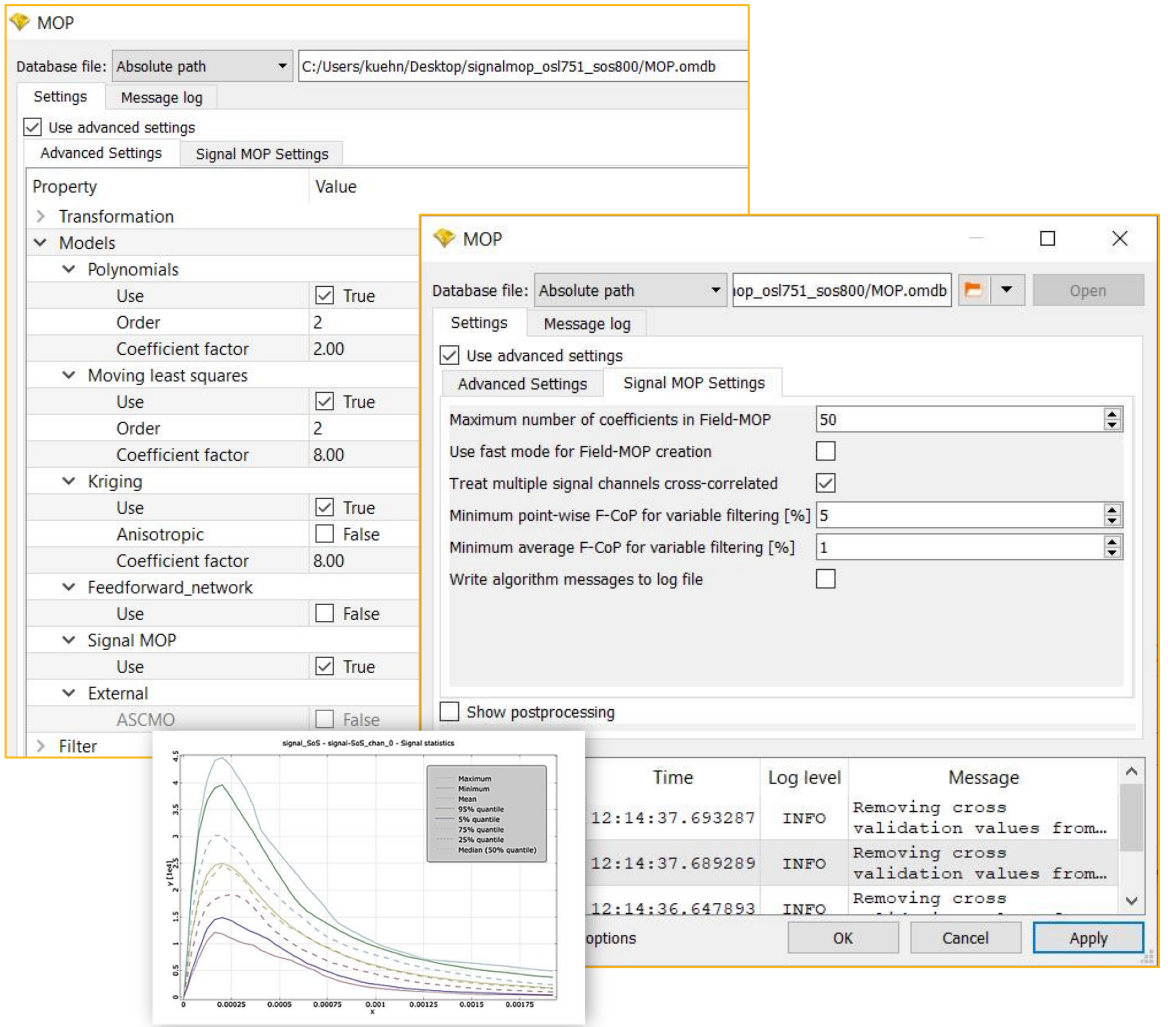
- Further post processing:
  - Use statistical measures to understand the statistics of variations at each position (e.g. mean value, standard deviation, quantiles….)
  - Plot variation patterns to identify correlations in space



21R2: Improved Signal MOP creation in optiSLang GUI

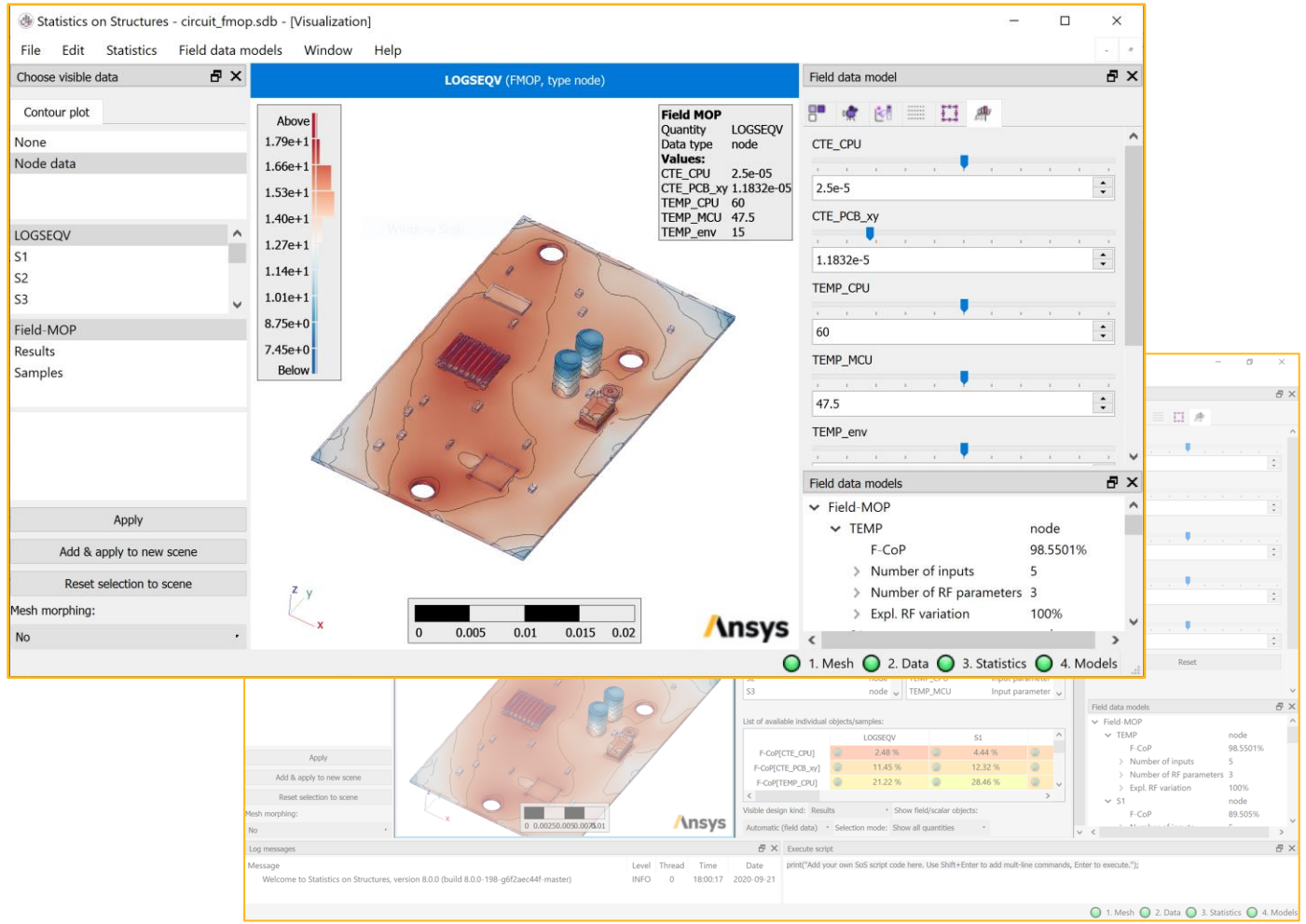
- Move Signal MOP from external models to „All internal models“
- Simplify settings of Signal MOP
  - Lean settings,
  - Easy to understand,
  - Improved consistency with scalar MOP and with Field MOP in SoS GUI

  - Removed features:
    - separate options for random signal modelling,
    - FMU export (can be done manually in SoS GUI)



21R1: New SoS GUI for 3D Pre & Post Processing

- New user experience for beginners and advanced users
  - Central focus is 3D visualization and plotted data
  - Traffic light bar shows status and leads beginners through analysis
  - Configurability: Allow advanced access to log messages, data table, script terminal, autosave log etc.
  - Move user's guide and tutorials to ANSYS website



21R1: Python3 module for optiSLang

- SoS Python3 module
  - Includes TMATH module for linear algebra
  - 100% compatible with Numpy arrays
  - Full access to all SoS functions except visualization

```
1  from sos_package import sos, tmath
```

- Can be called from Custom Integration nodes or Python node in optiSLang

```
1  sos_importer = sos.ImportDesigns( sos.referenceDesign() )
2  sos_importer.base_path = join( designs_base_dir, ".." )
3  sos_importer.design_name_format = "Design_?(\\d+)"
4  sos_importer.scanDesignRanges()
```

- Script API Documentation available on the Ansys Help API Documentation site.

- 21R1: Introduce first API
- 21R2: Introduce API doc (beta)

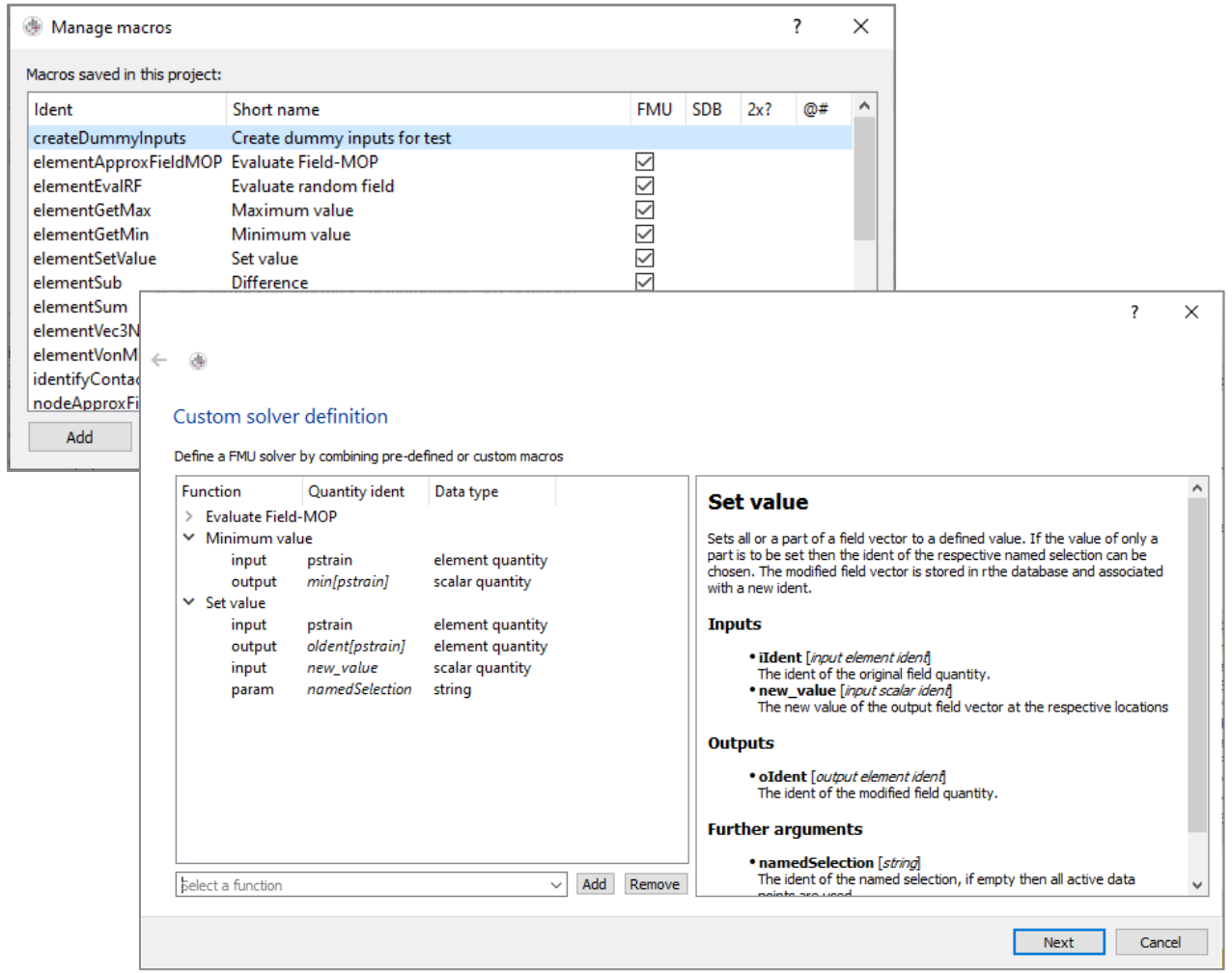
Towards user-friendly consumption of *n*D-ROMs

Macro Workflows

- Provide a user-extensible calculator for operations on field data

- Easy-to-use connection of
  - nD ROMs with optimization through FMU
  - Field MOP Solvers / 3D ROMs with 3rd party
  - No scripting necessary, but still flexible + fast

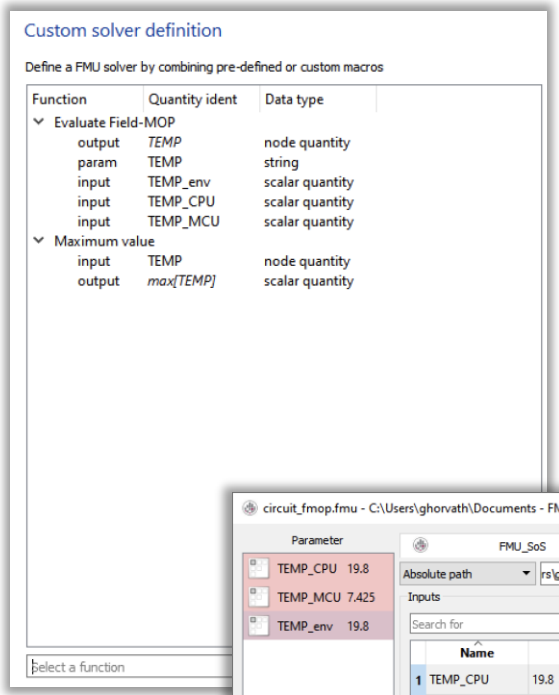
- Operators:
  - Linear algebra on vectors
  - Statistics
  - Extract data
  - Approximate random fields and Field MOP

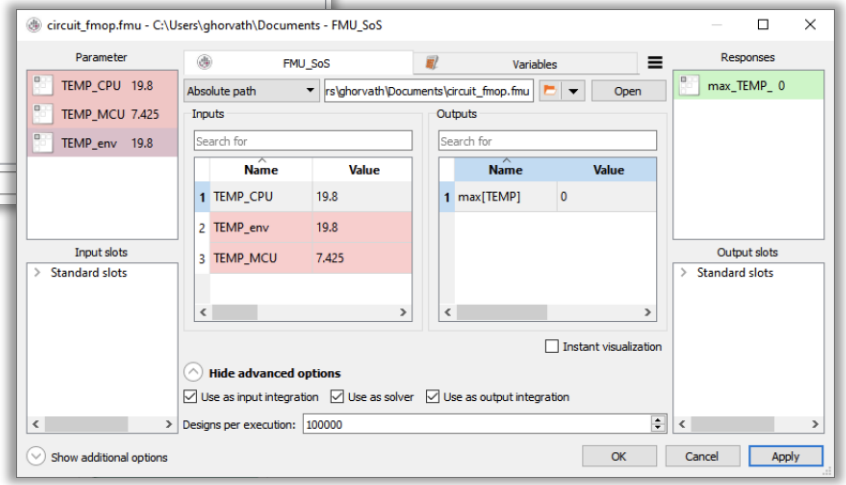


Use macros inside FMU 2.0

- Combine multiple macros into a single automated analysis
- Export entire workflows to FMUs
- Consume FMU in optiSLang or TwinBuilder
- Visualize all 3D fields afterwards in SoS post processing

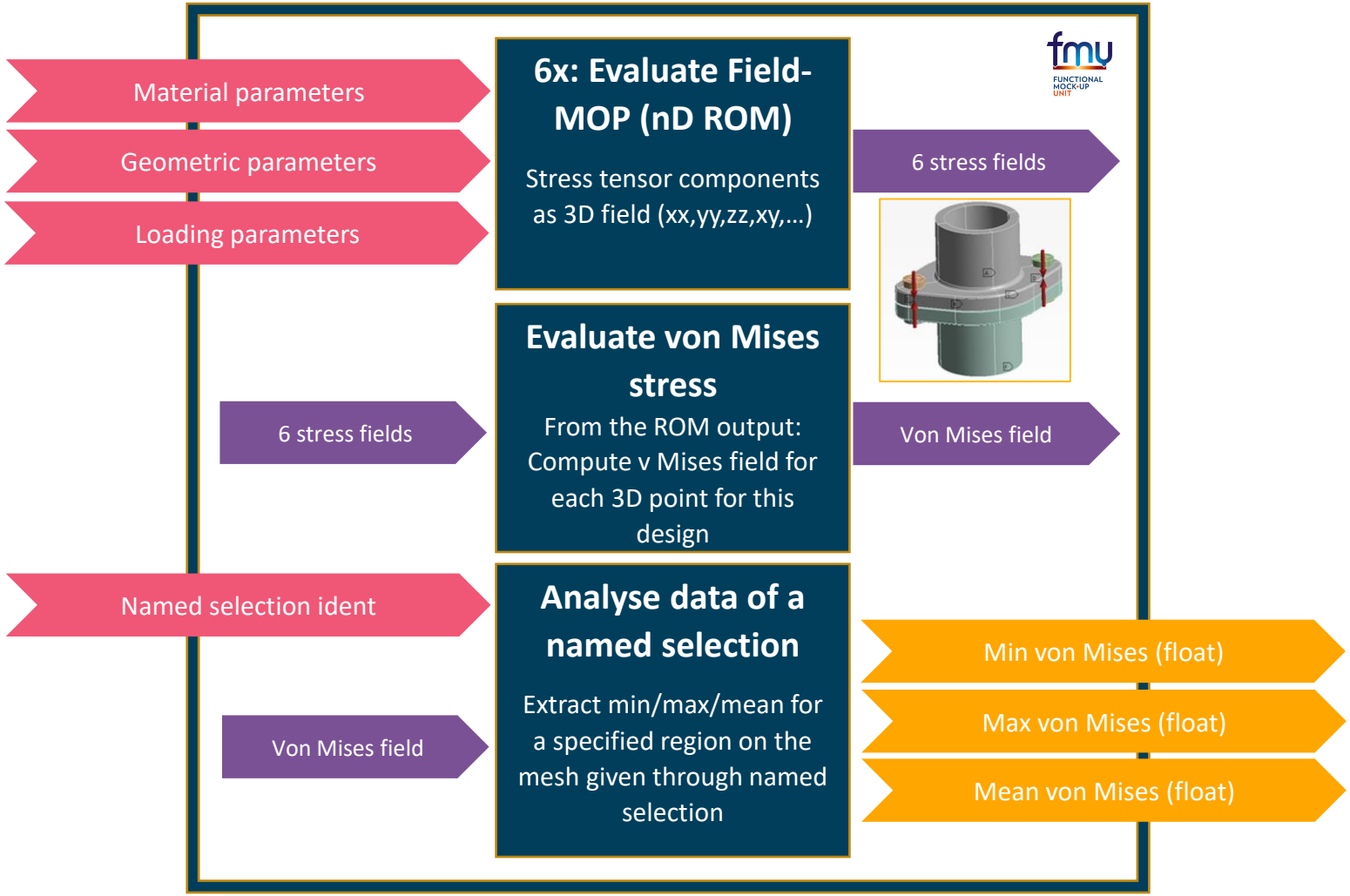
- 8.0: Initial version (FMU 2.0 model exchange)
- 21R1: Export both types – model exchange and co-simulation - into a single FMU file
- 21R2: Use more built-macros, improve consumption of SoS FMUs in optiSLang workflows





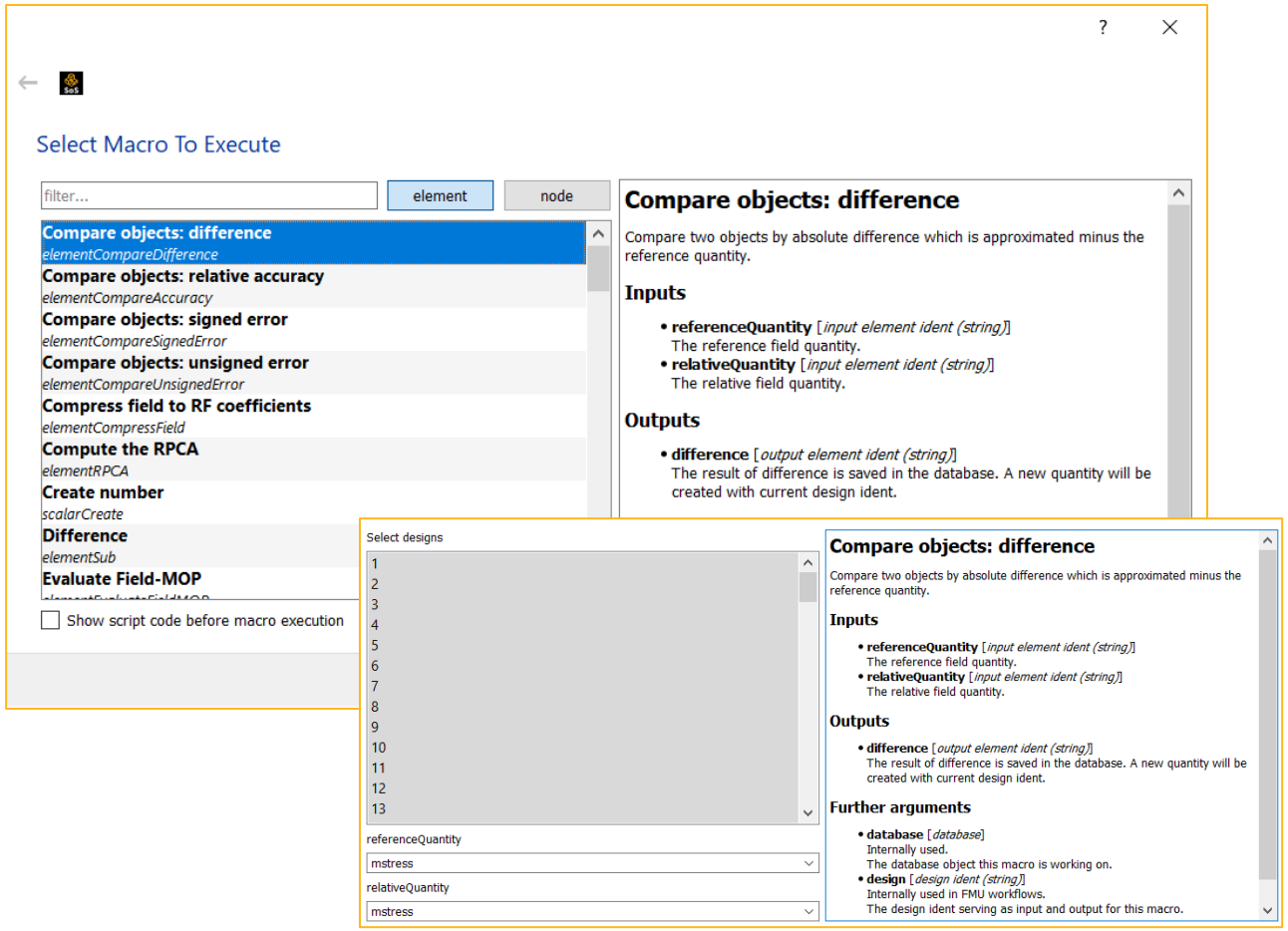
Example FMU workflow: Standard macros

- Approximate stress tensor with Field MOP
- Evaluate von Mises stress
- Extract min/max/mean at specific sub region
  - Or: Extract sub space components for efficient system simulation
- Save an SDB file with all intermediate results for interactive post processing



21R2: Use macros inside SoS GUI

- Call and apply macros to data being already loaded in SoS GUI
- Set parameters of macros (designs, inputs, outputs, etc.)
- Save and visualize results in .SDB
- Write and test macros for your customers, deployed as an .SDB file.



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Modeling of imperfect structures for UQ

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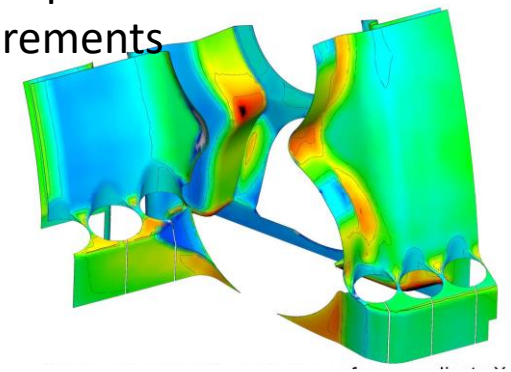
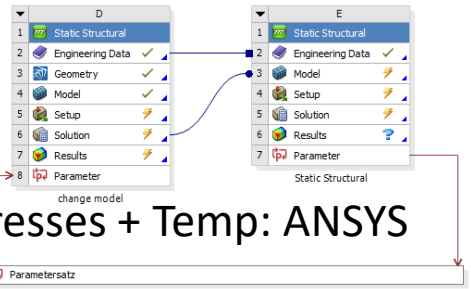
Customer story:
How do manufacturing tolerances affect low-cycle fatigue ?

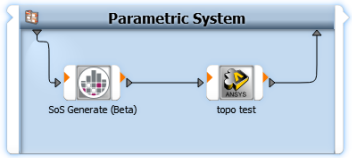
- Casting process (here: gas turbine housings)
- Question: How do geometric imperfections in production influence stress / fatigue behavior ?

Mean imperfection from measurements



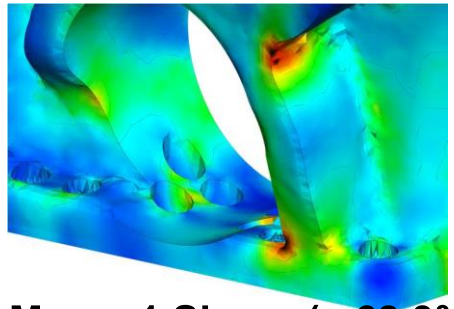


Stresses + Temp: ANSYS

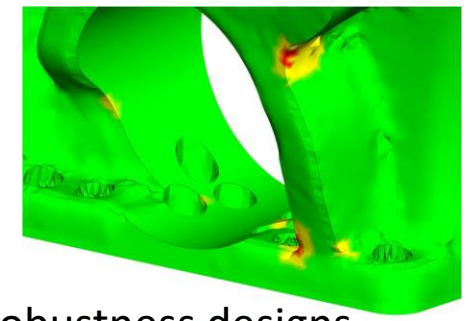


optiSLang: 100 robustness designs

Mean stress



Mean+1·Sigma (~ 68,3%)



With courtesy of SIEMENS (source: Lohse et al, DVM Probabilistic Workshop 2016)

How to deal with measurements in FEM, e.g. geometries ?

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a) Validation
Apply measurement

- Create CAD0 geometry and mesh
- Determine geometric deviations to measurement (STL)
- Morph mesh and compute structural performance

b) Uncertainty quantification
Robustness and Reliability Analysis

- Create CAD0 geometry and mesh
- Determine geometric deviations to several measurements (STL)
- Create a **statistical shape model**
- **Generate artifical geometries** for DOE and use morphed FEM meshes in CAE

Ansys

Apply Measurement of Scanned Models

- General Scheme of the Workflow:

1. STL File from GOM Measurement
2. ANSYS Mechanical Mesh of nominal Geometry

Import into SoS

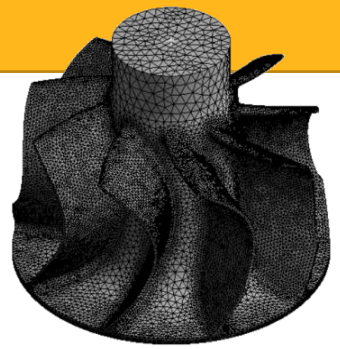
Automizable workflow using optiSLang for variational analysis

Statistics on Structures

- Differences between STL and Mesh are evaluated
- SoS automatically generates APDL commands for mesh morphing inside ANSYS to fit the nominal mesh to the real (STL) geometry

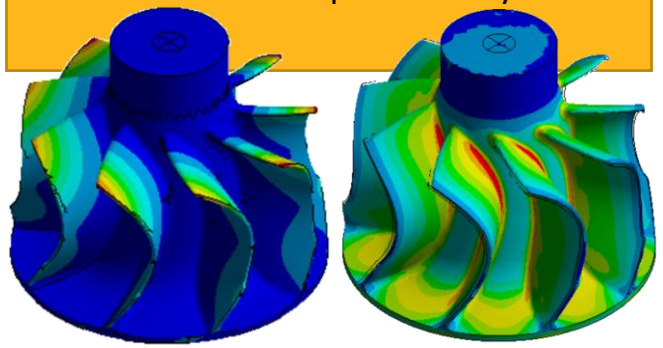
ANSYS Mechanical Mesh Update

- Morphing commands are imported into ANSYS Mechanical
- Mechanical Mesh update

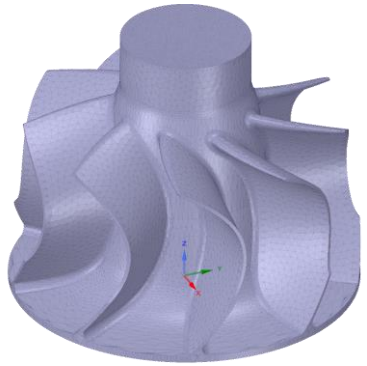


ANSYS Mechanical Analysis on updated Mesh

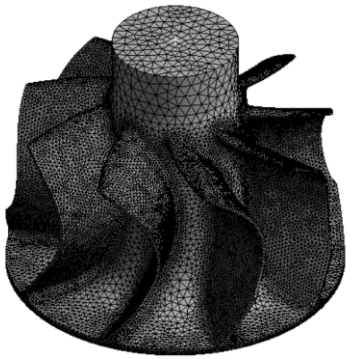
- Static Structural Analysis
- Modal Analysis
- Forced Response Analysis



Apply Measurement of Scanned Models
1:1 morphing

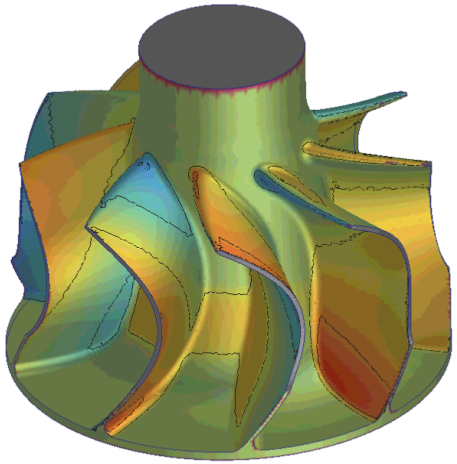


Scanned Geometry STL File

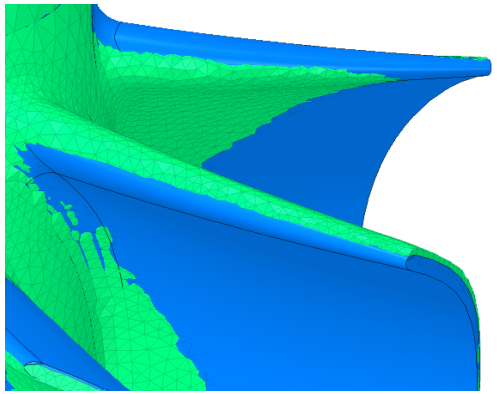


Meshed Nominal Geometry as ANSYS DAT or CDB File

Statistics on Structures



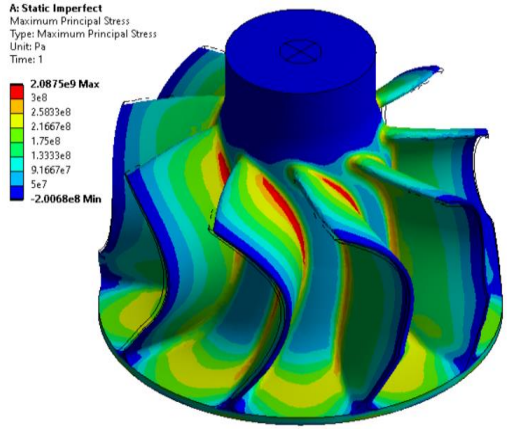
Visualize Deviation between Nominal and Real Geometry



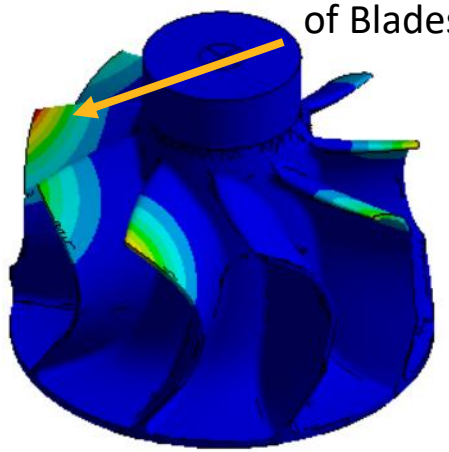
Morphed Mesh

Impact on, e.g. Structural or Modal Analysis

Static Analysis of Real (imperfect) Geometry



Modal Analysis of Real (imperfect) Geometry

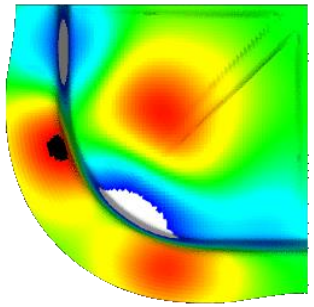


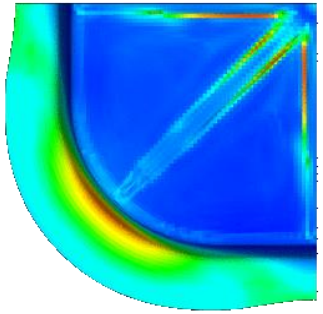
Local Modes of Blades

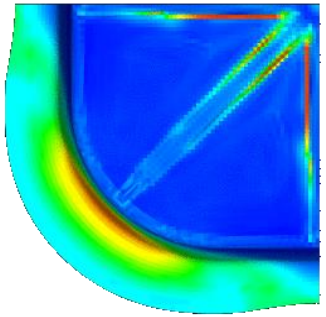
UQ: Random fields depending on available data

Parameterization of geometric shapes

1. **No/single measurement**:
   assumptions
   (synthetic random field model)
2. **3-5 measurements**:
   empirical mean+stddev
   assumed correlation
   (synthetic random field model)
3. **Many measurements**:
   Empirical random field model
   Anisotropic, inhomogeneous,
   Non-Gaussian



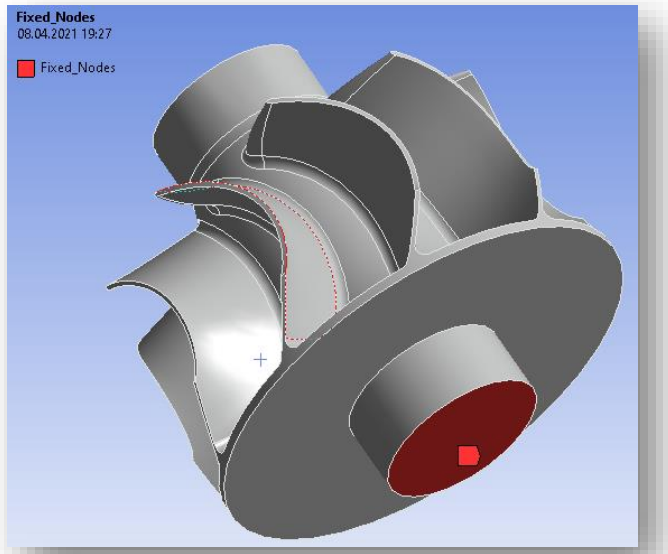


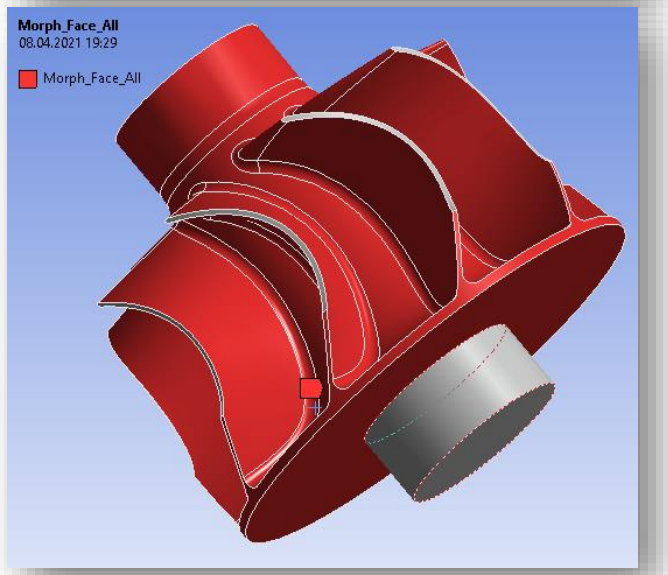


21R2: Apply Measurement with SoS ACT Plugin (1/2)

ANSYS Mechanical:

1. Prepare measured (laser scan) data in a carefully sanitized mesh format (STL)
2. Define named selections:
   - Fixed nodes (top)
   - Nodes to be morphed to target location (bottom)

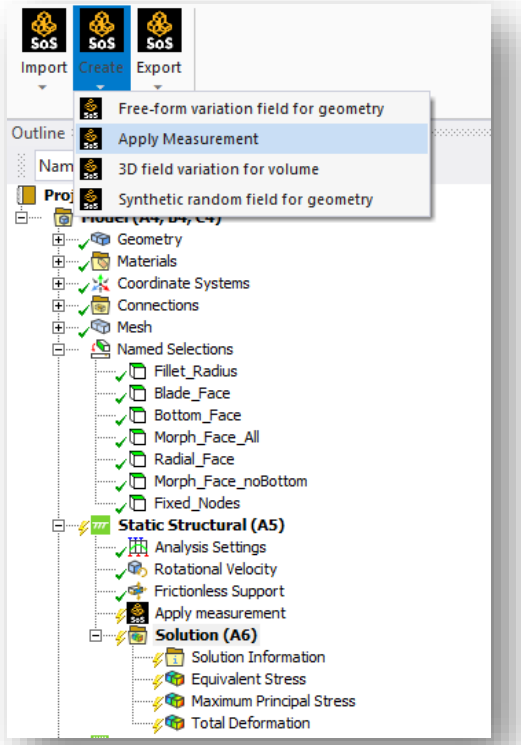


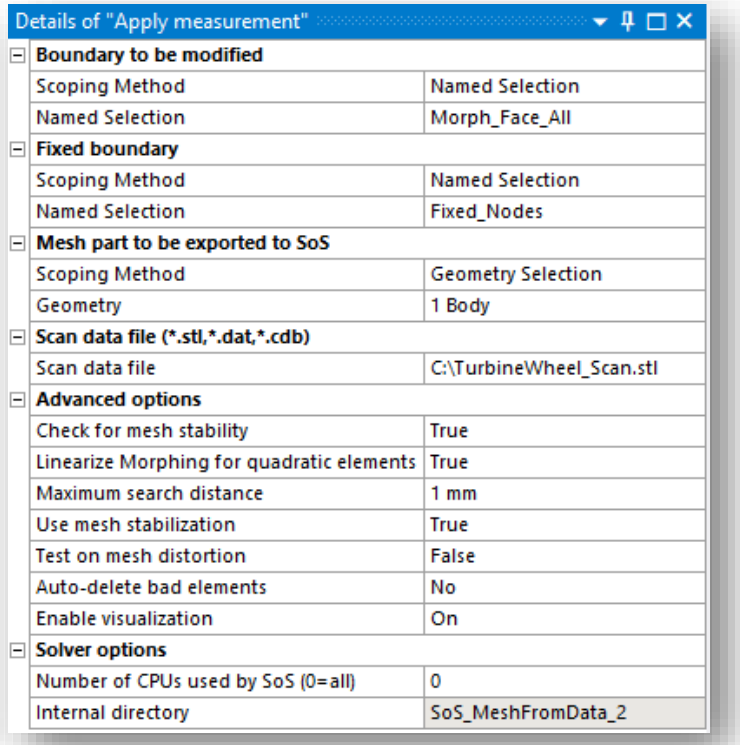


21R2: Apply Measurement with SoS ACT Plugin (2/2)

New:

- Easy-to-use: directly perform mesh mapping + morphing within Ansys Mechanical.
- SoS‘ mesh mapper is running in the background





Summary: optiSLang SoS 2021 R2

Powerful analysis tools for model understanding and approximation

ROM: Improves operations on Field meta models using macros, FMU, simplified GUI and Python

UQ: Simplifies 1-to-1 mapping + morphing inside Mechanical plugin

Ansys

WOST

CONFERENCE