Nested systems and performance maps in optiSLang

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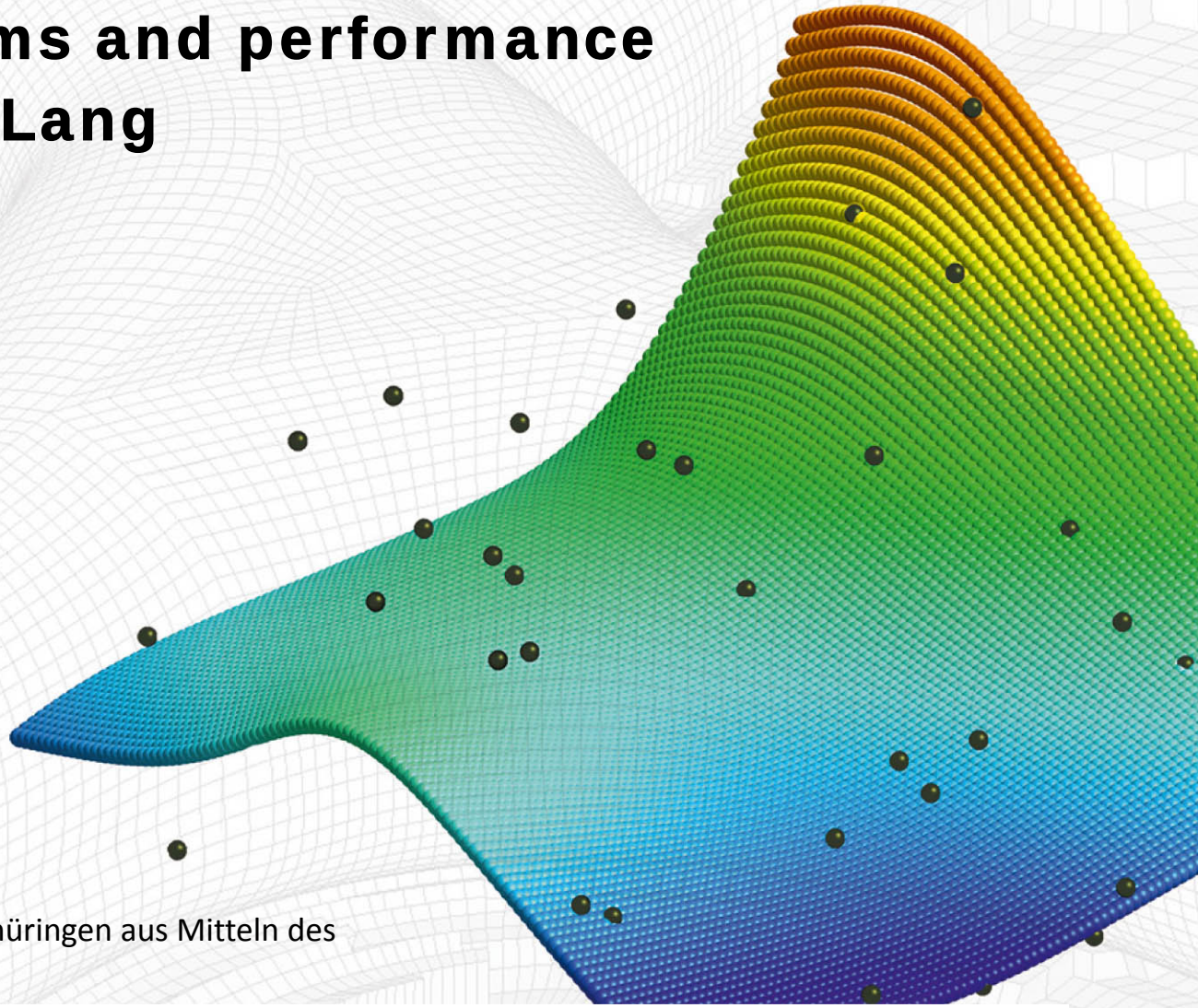

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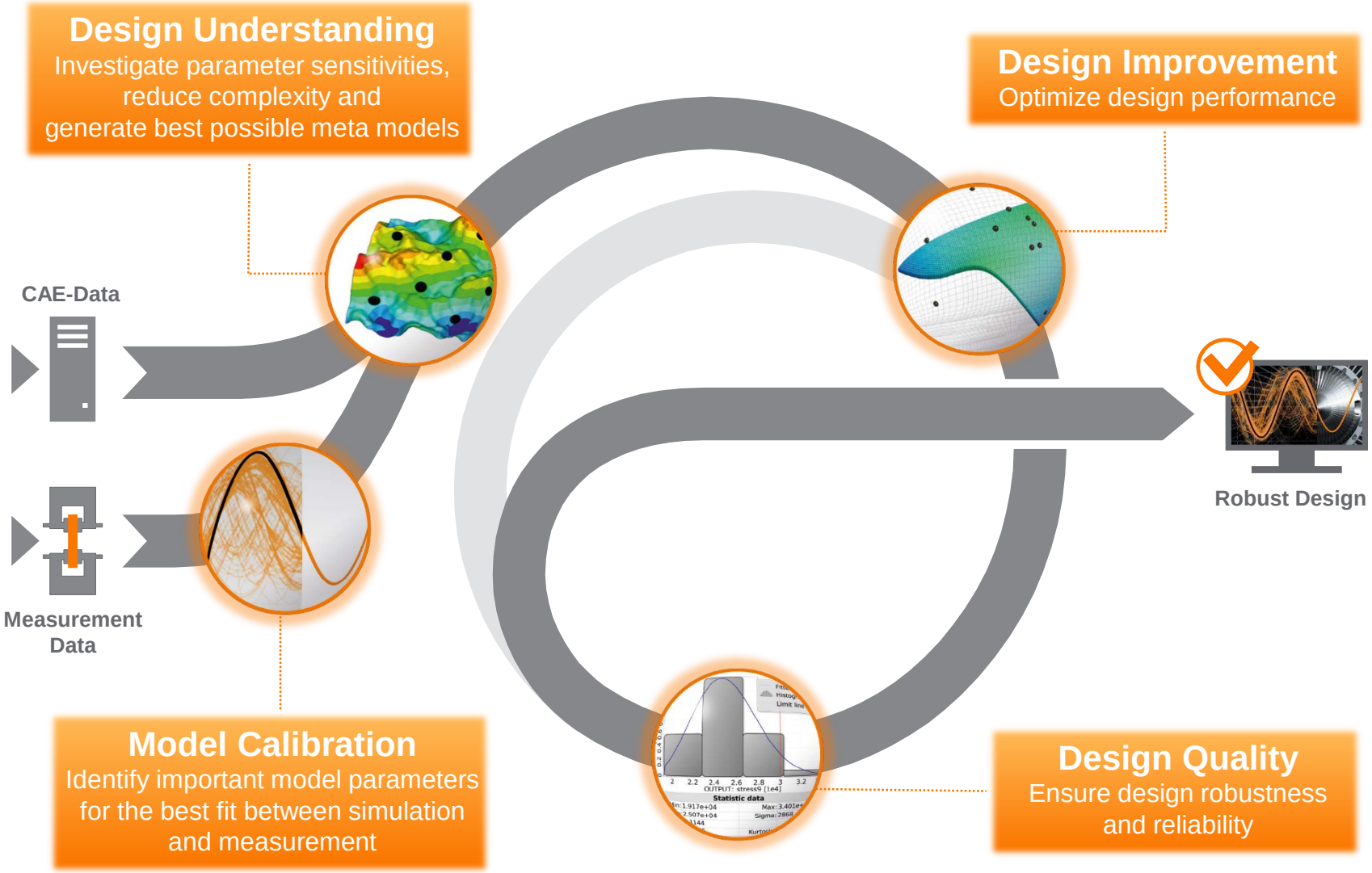
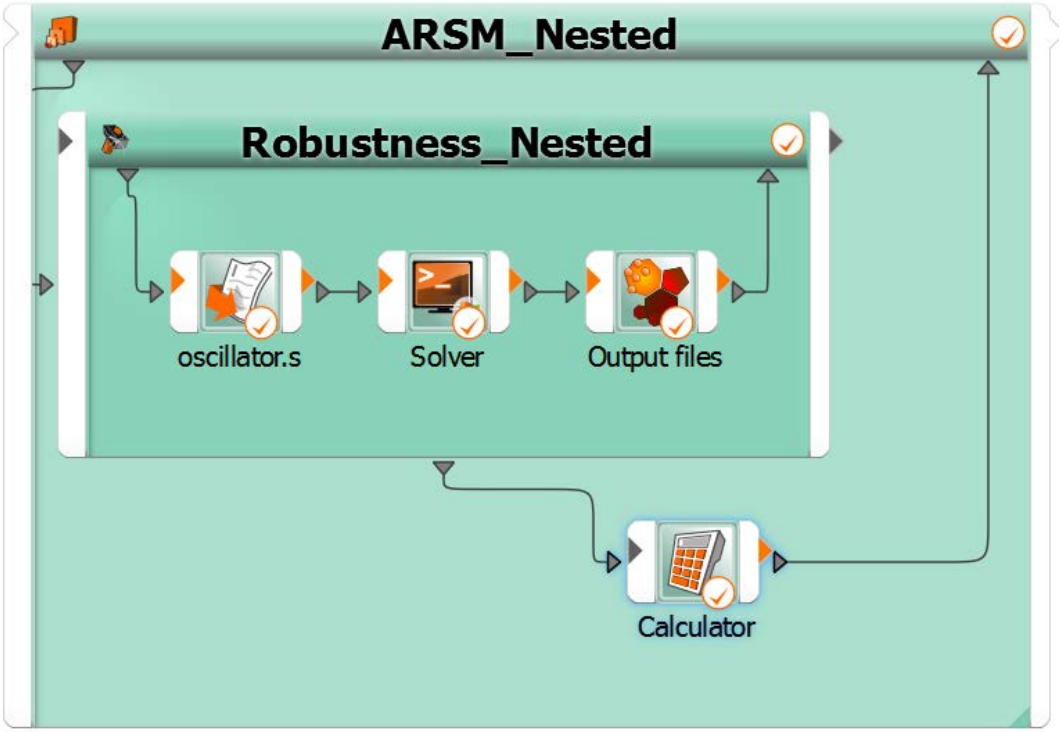

Design Understanding
Investigate parameter sensitivities, reduce complexity and generate best possible meta models
Design Improvement
Optimize design performance
CAE-Data
Measurement Data
Robust Design
Model Calibration
Identify important model parameters for the best fit between simulation and measurement
Design Quality
Ensure design robustness and reliability

Nested Systems- RDO

Nested systems allow for nested-loop analyses such as coupled RDO

- Outer System: Optimization
  - Inner System: Robustness



Tutorial: Help/Tutorials/Oscillator/Oscillator_Robustness

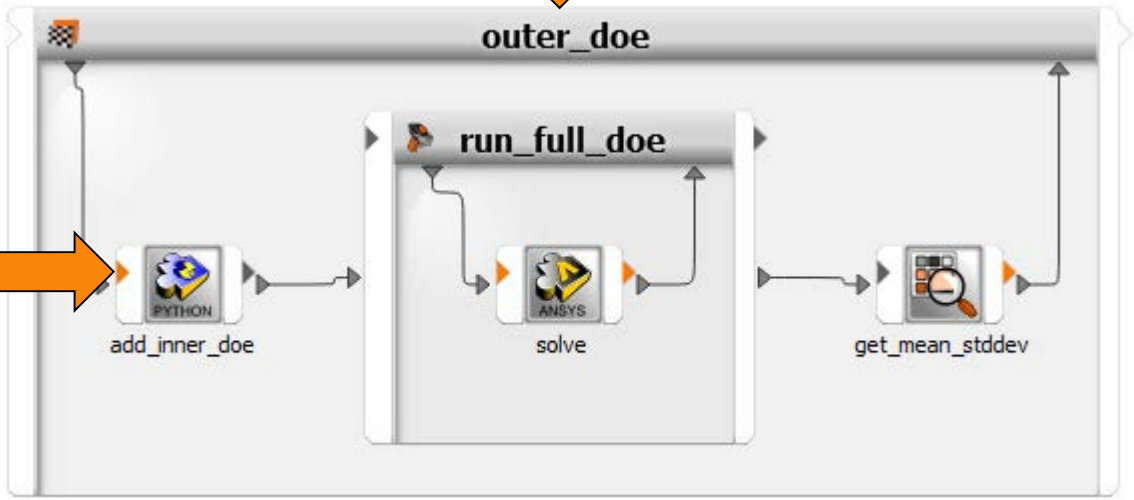
Nested Systems- TAGUCHI DOE

outer doe

	1	2	3	4	5	6	7	8	9
A	79500000000	80500000000	81500000000	79500000000	80500000000	81500000000	79500000000	80500000000	81500000000
B	-45	-45	-45	80	80	80	125	125	125

inner doe

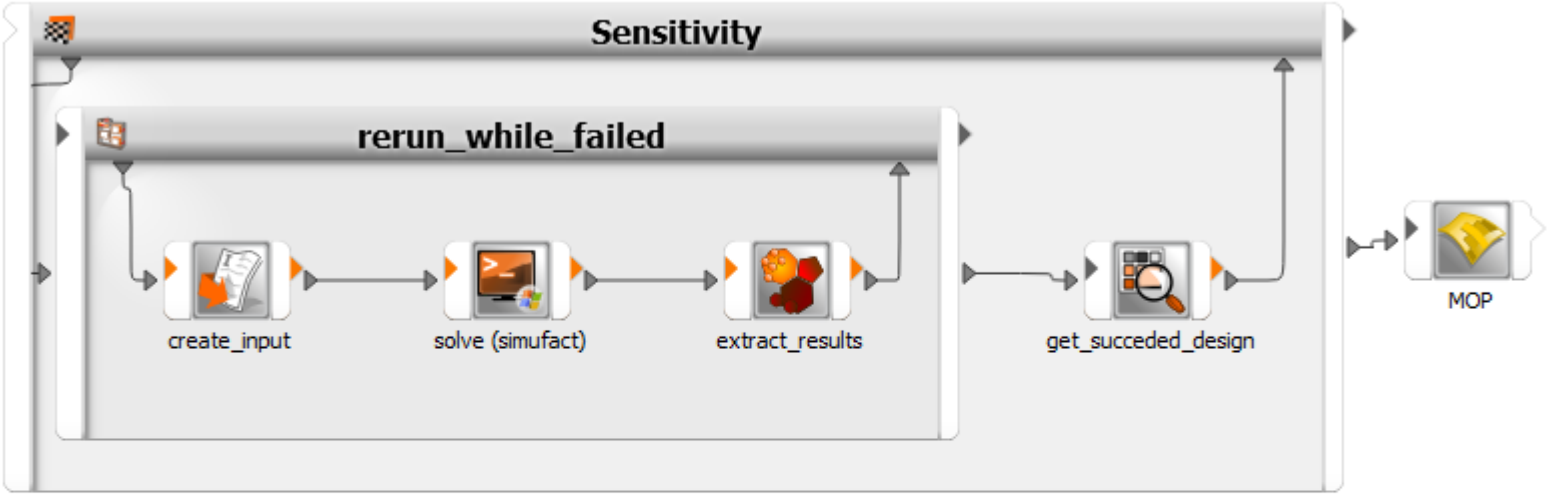
	C	D	E
1	44	5.5	3
2	41	7	3
3	44	5.5	1
4	41	4	2
5	41	4	1
6	38	7	1
7	38	4	1
8	44	4	1
9	44	7	2
10	38	7	3
11	44	7	3
12	41	7	1
13	38	7	2
14	41	5.5	1
15	38	5.5	2
16	41	5.5	2
17	41	5.5	3
18	44	7	1
19	38	4	3
20	38	5.5	3

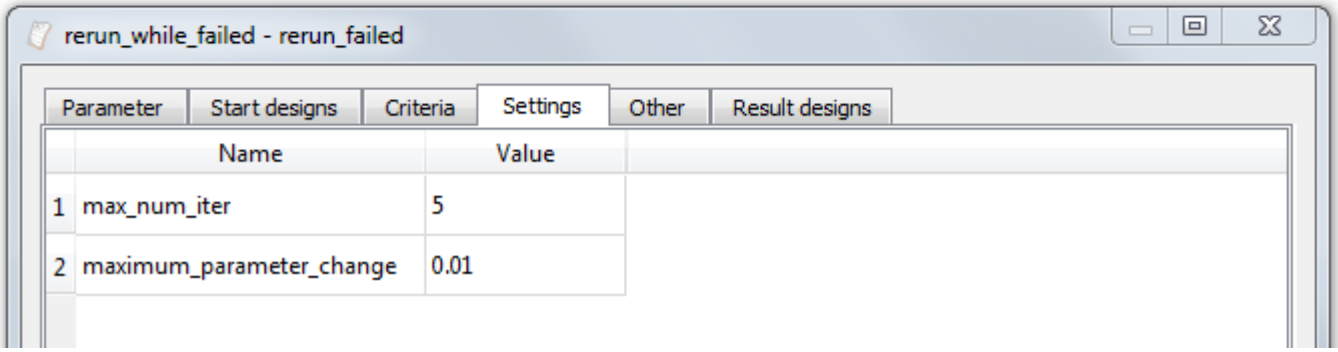


- Outer System: DOE
  - Inner System: Custom DOE (Custom Algorithm) for Robustness

Nested Systems- Run While Failed

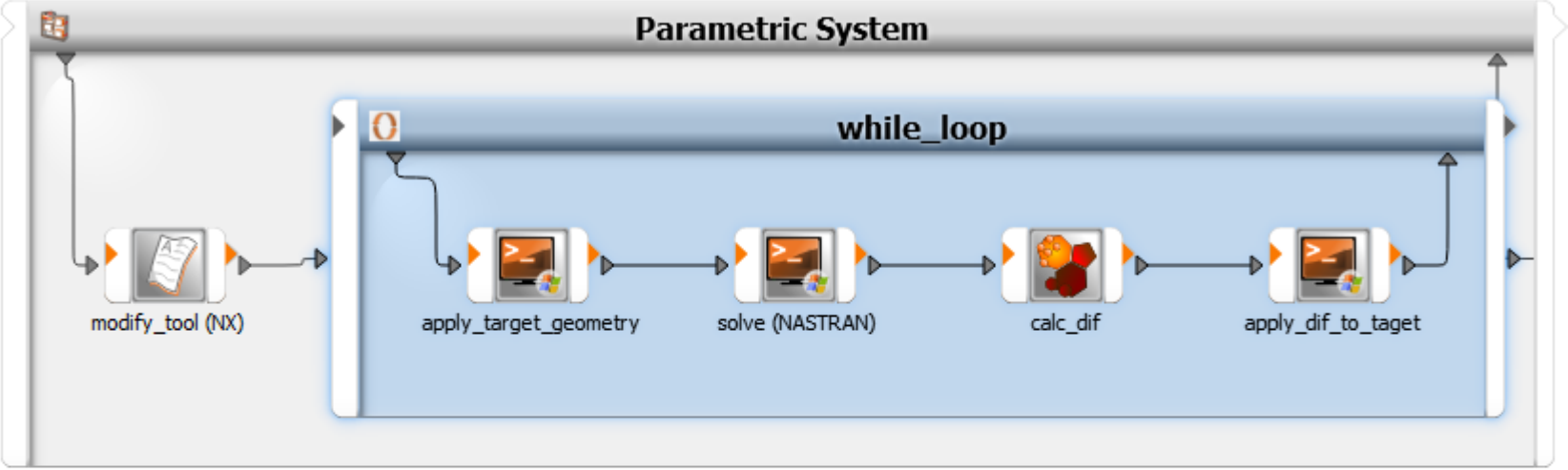
- Outer System: Sensitivity
  - Inner System: Custom DOE (Custom Algorithm)

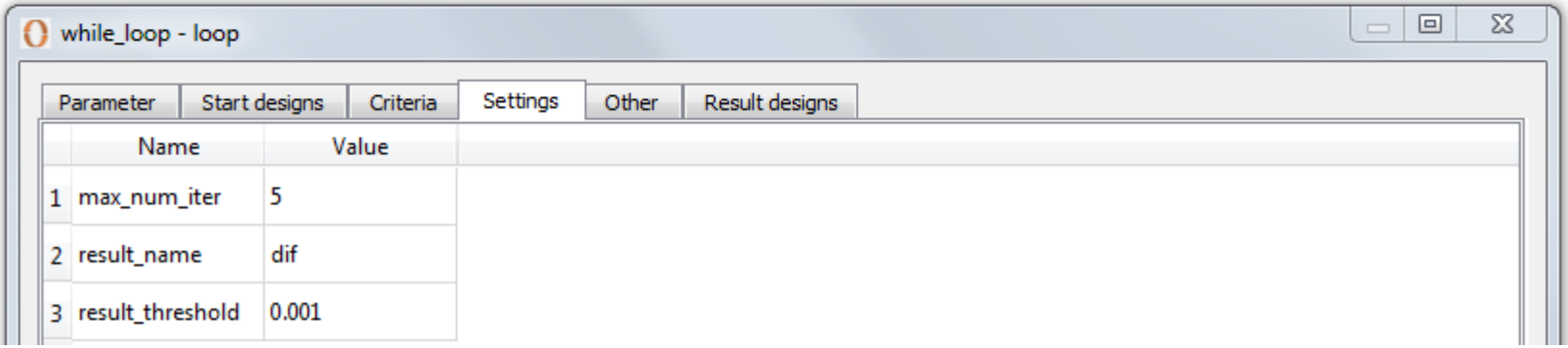




Nested Systems- Do While Loop

- Outer System: Parametric System
  - Inner System: Custom Algorithm

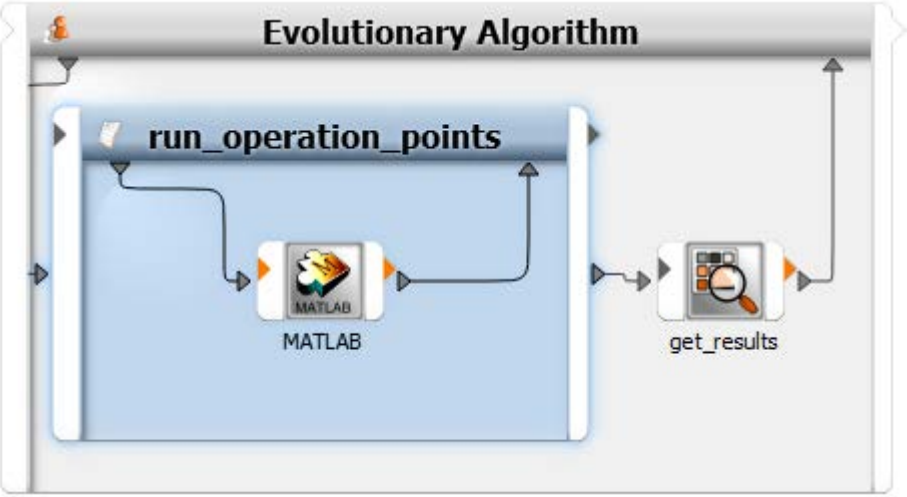




Nested Systems- Operating Points

Many technical systems run in different operating points

- Outer System: Optimization
  - Inner System: Sensitivity



Evolutionary Algorithm

Parameter | Start designs | Criteria | Initialization | Selection | Cross

	Name	Parameter type	Reference value	Constant
1	Geom_P1	Optimization	0	☐
2	Geom_P2	Optimization	0	☐
3	OP_P1	Optimization	0	☑
4	OP_P2	Optimization	0	☑

run_operation_points - replace_const

Parameter | Start designs | Criteria | Settings | Other | Result designs

	Name	Parameter type	Reference value	Constant
1	Geom_P1	Optimization	0	☑
2	Geom_P2	Optimization	0	☑
3	OP_P1	Optimization	0	☐
4	OP_P2	Optimization	0	☐

The E-Machine Performance Map Workflow

Case Study: IPM Machine 2D

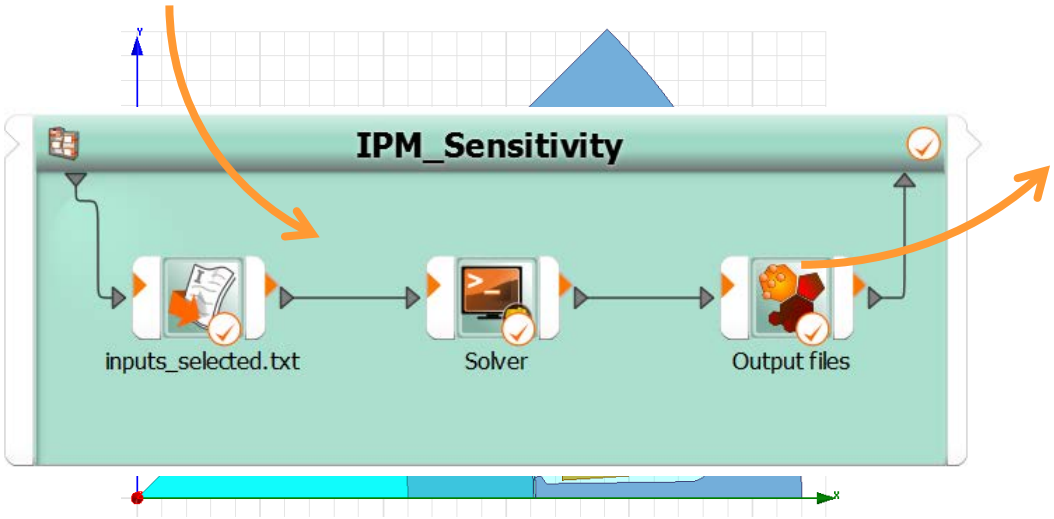
- Initial sensitivity study

Parameters

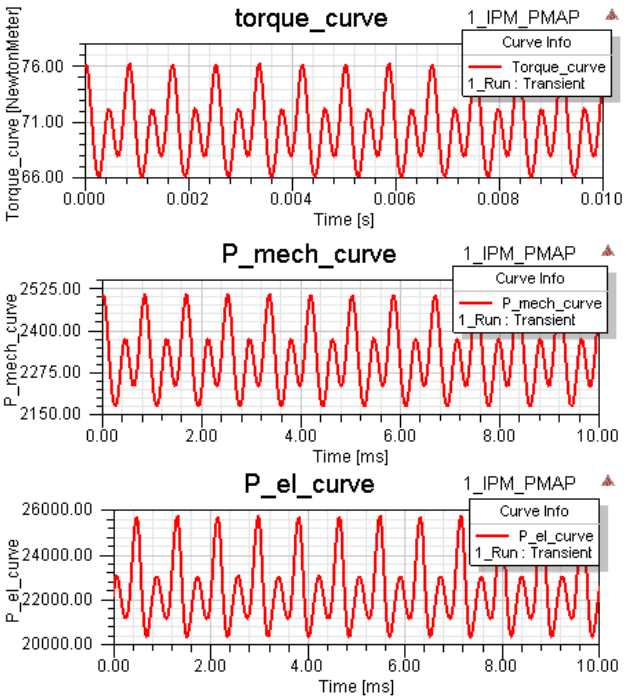
RPM: [200, 1e4] s^{-1}

Current: [2, 100] Ampère

Load angle: [0, 90] degrees



Responses



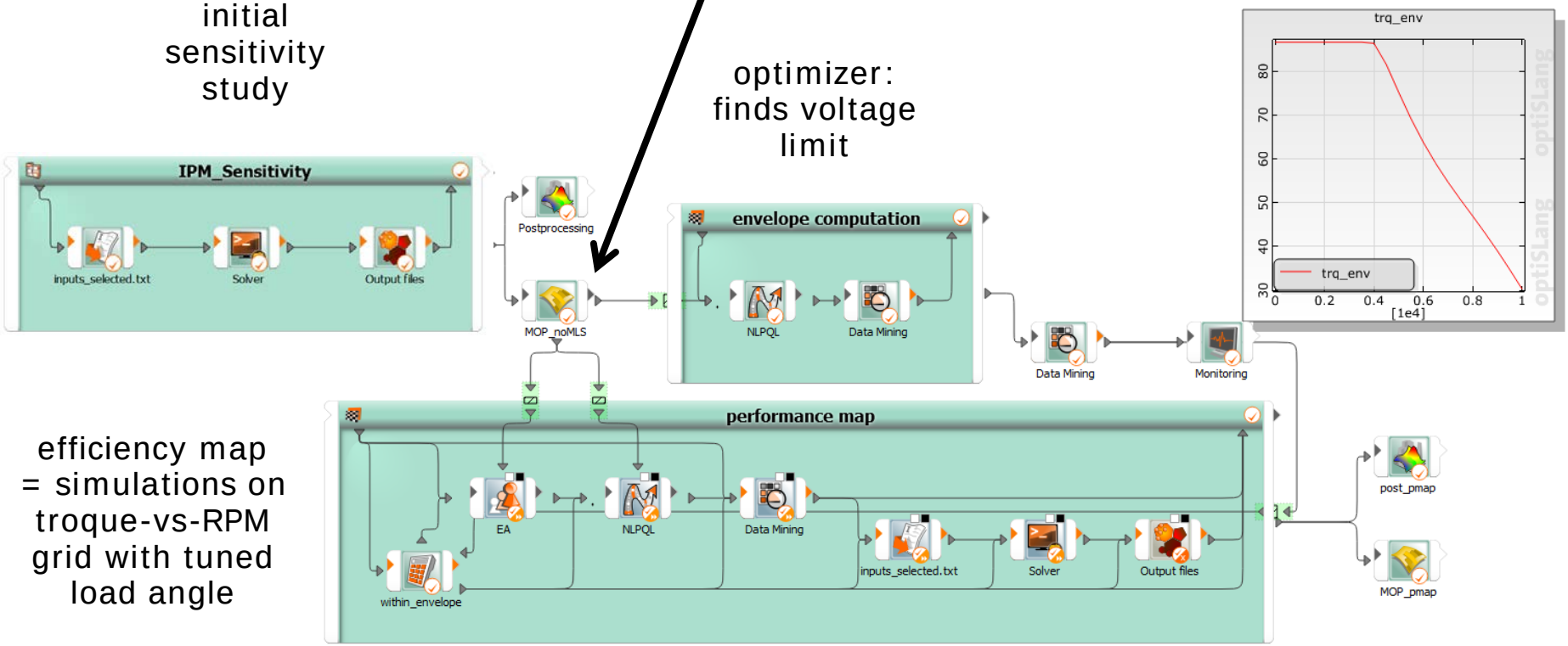
The E-Machine Performance Map Workflow

Workflow Overview

All the tuning is done on this MOP

initial sensitivity study

optimizer: finds voltage limit

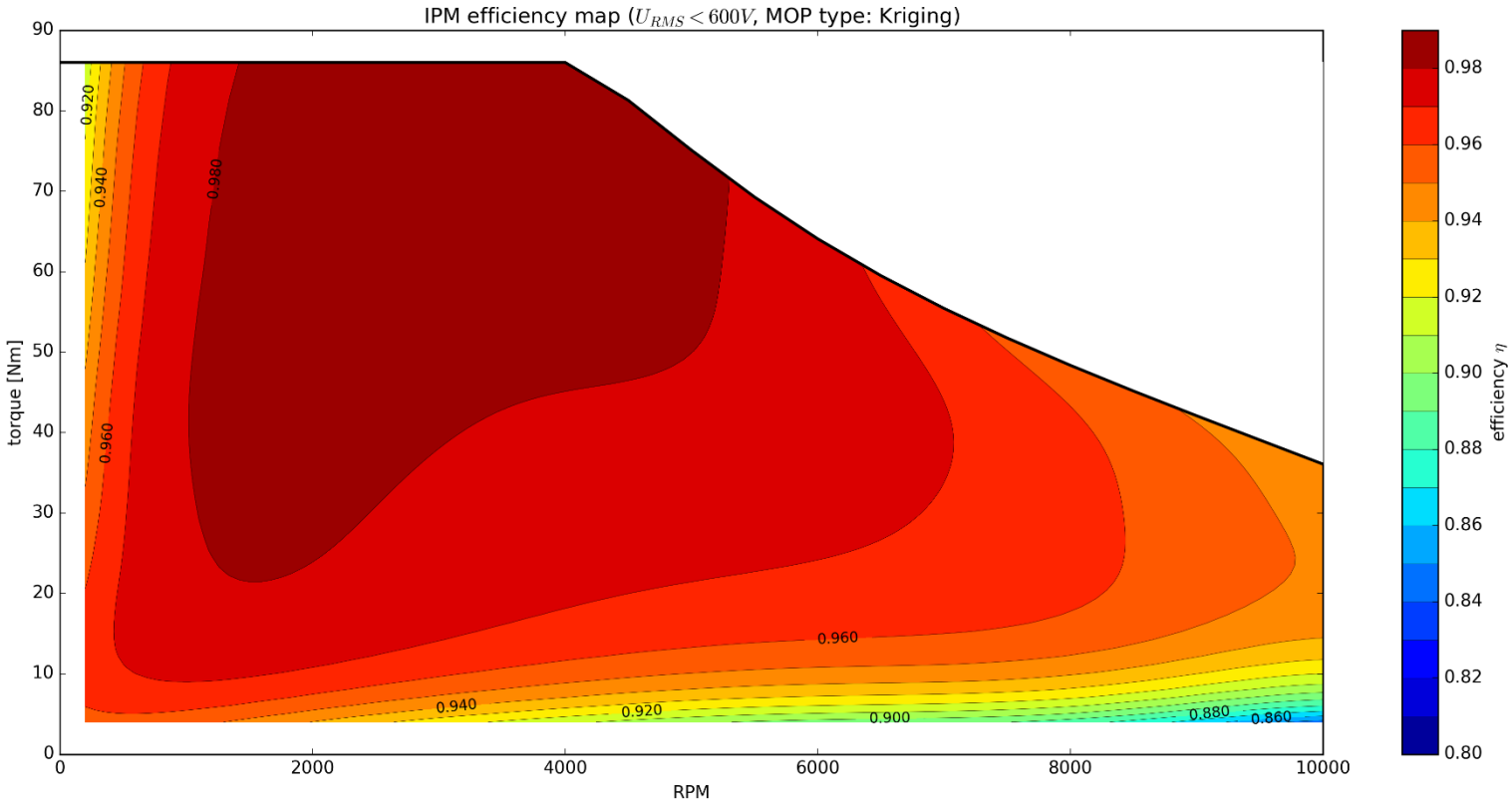


efficiency map = simulations on troque-vs-RPM grid with tuned load angle

The E-Machine Performance Map Workflow

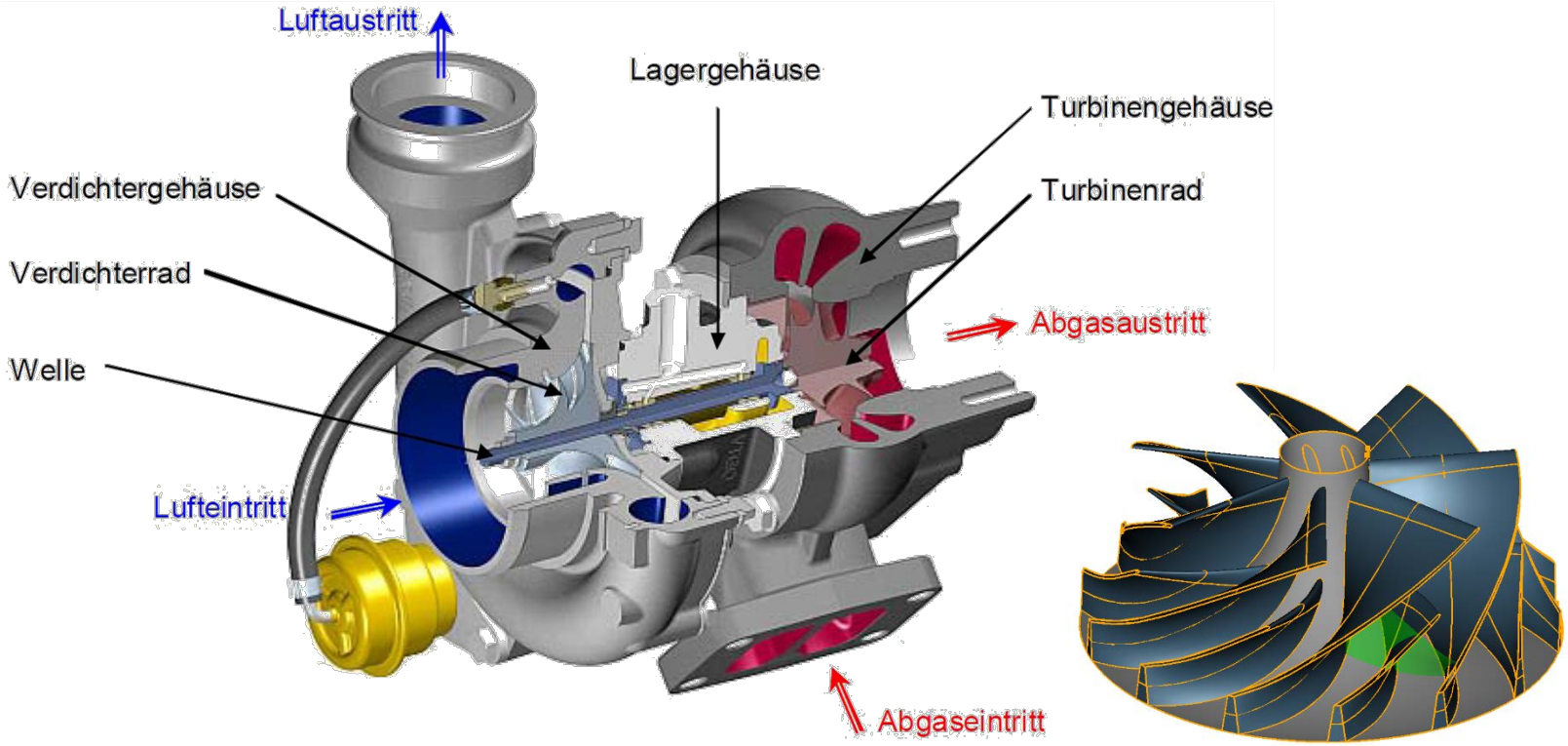
An exemplary efficiency map

- The graphically programmed workflow allows other paradigms
  → free choice of inputs, responses, objectives, constraints



The Turbocharger Performance Map Workflow- Aim of project

Structure and function of an exhaust gas turbocharger

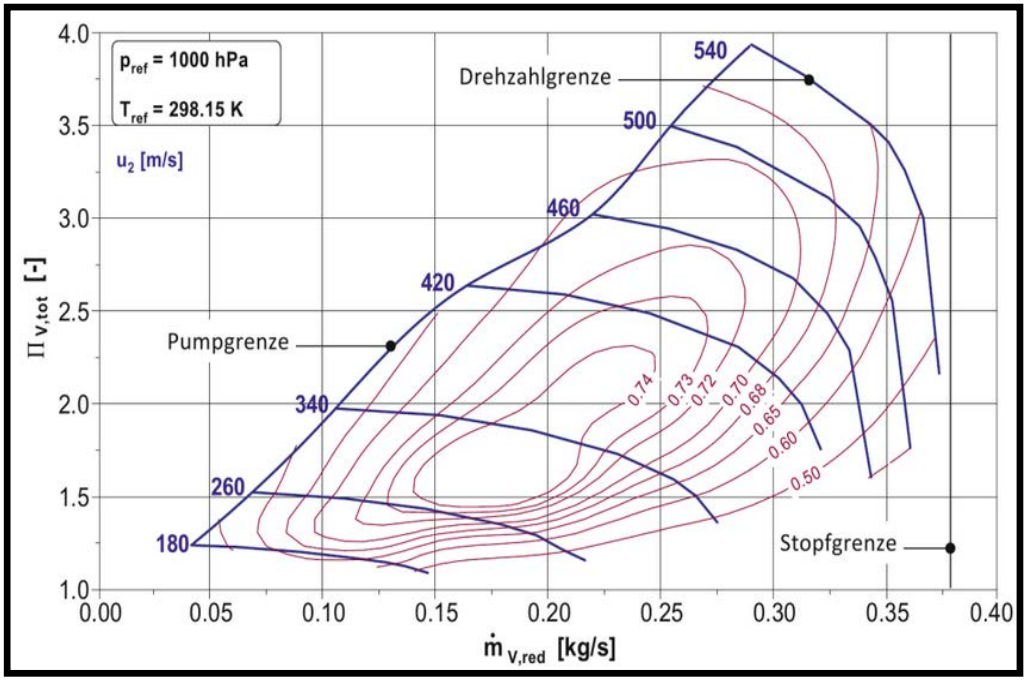


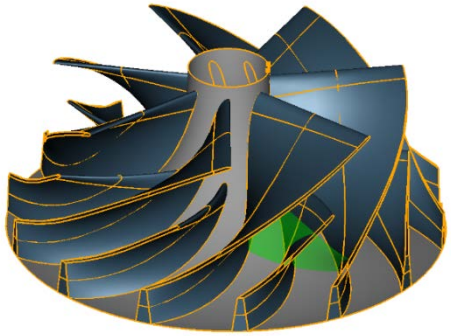
[1]

The Turbocharger Performance Map Workflow- Aim of project

main scientific issues is addressed:

- Implementation of an automated and standardized but also adaptive (in terms of the system´s response) process for numerical analysis considering all relevant operating points (performance maps)





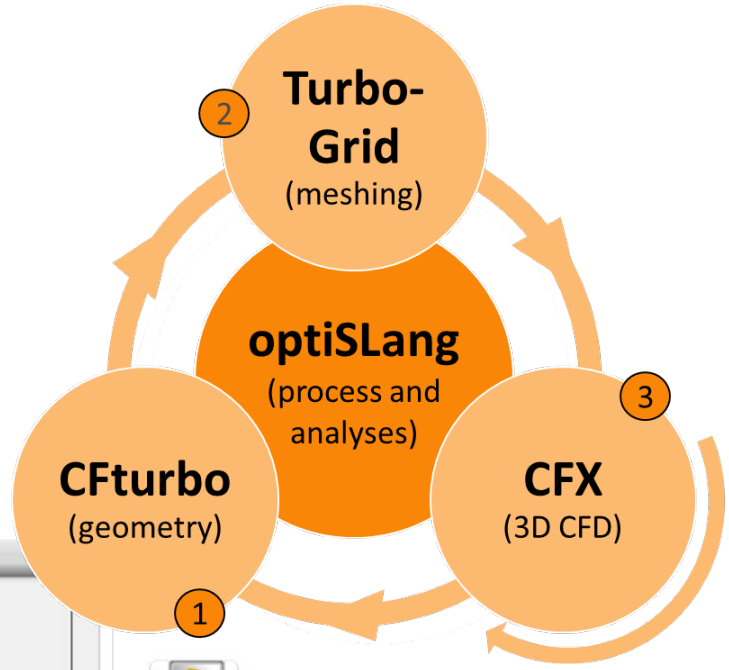
$$\pi_{tt} = \frac{p_{t\,2}}{p_{t\,1}} \qquad \eta_p = \frac{\frac{\kappa-1}{\kappa}\ln\left(\frac{p_{t\,2}}{p_{t\,1}}\right)}{\ln\left(\frac{T_{t\,2}}{T_{t\,1}}\right)}$$

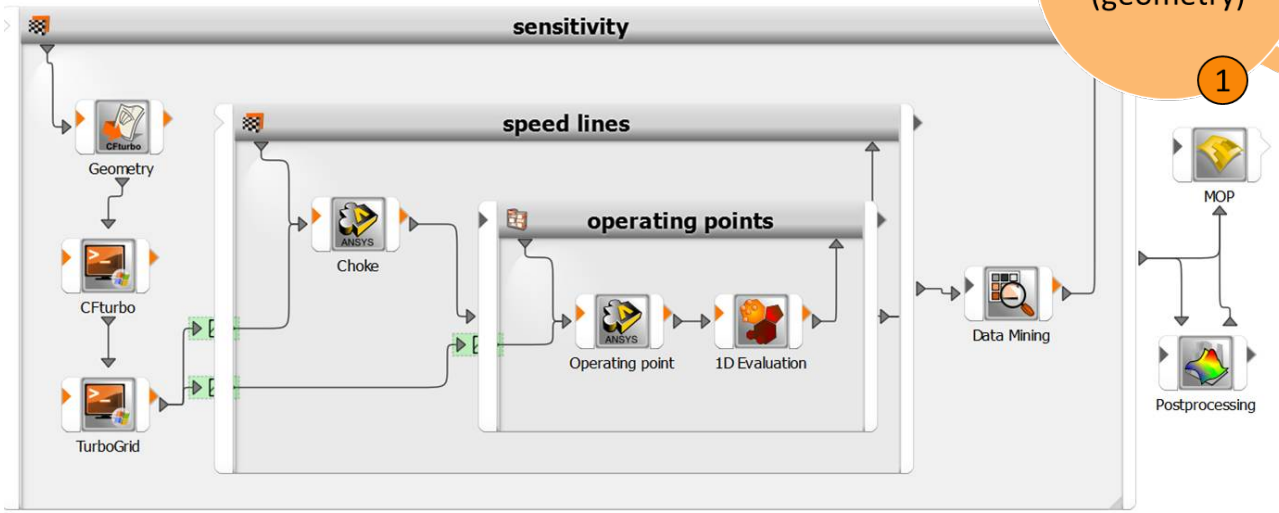
[2]

The Turbocharger Performance Map Workflow-Method Overview

Workflow:

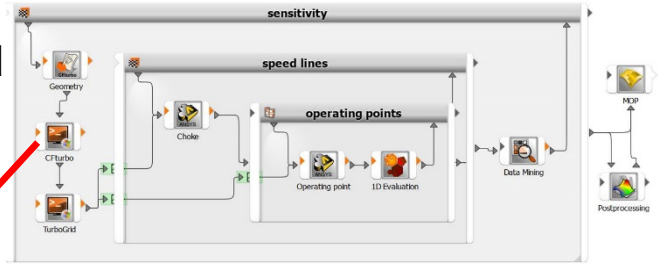
- Driven by optiSLang
- Geometry and the 1D flow computation (CFturbo)
- Meshing (TurboGrid)
- 3D CFD of performance map (CFX)

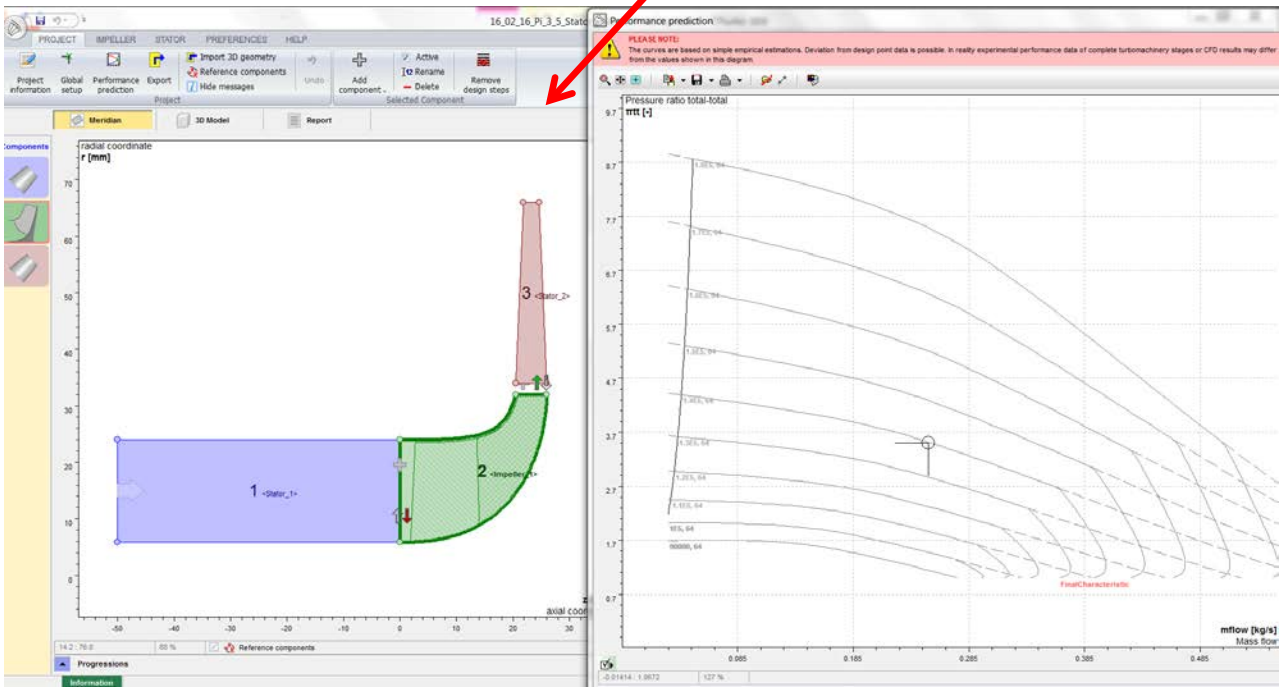




The Turbocharger Performance Map Workflow-Geometry (CFturbo)

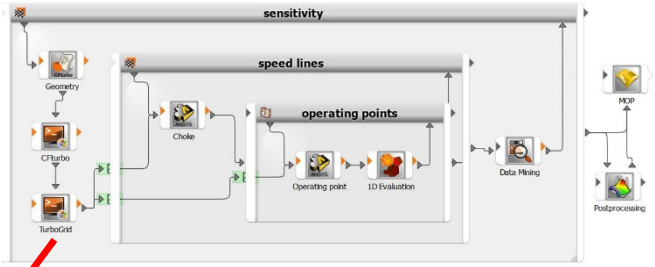
- geometry parameters are determined to generate a 3D geometry (left)
- 1D flow computation of output parameters E (right)

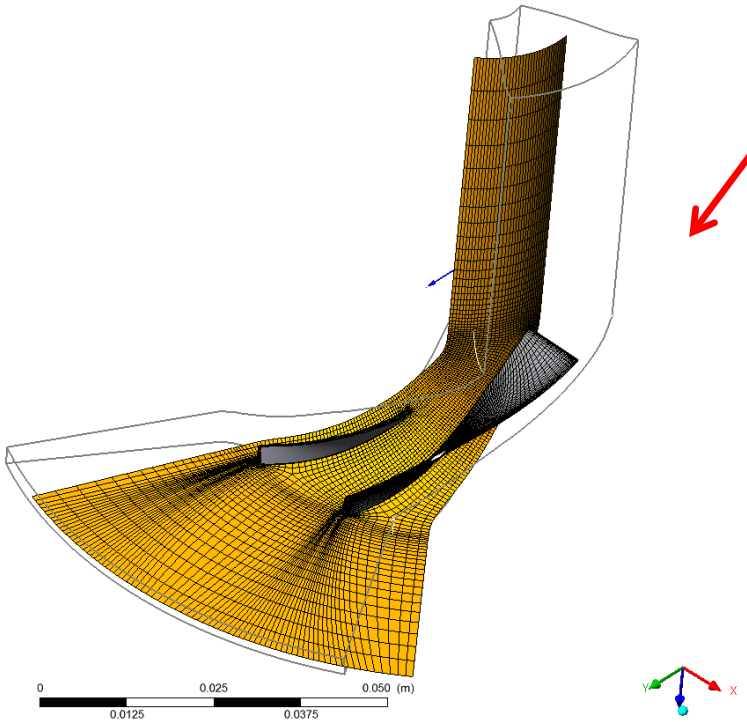


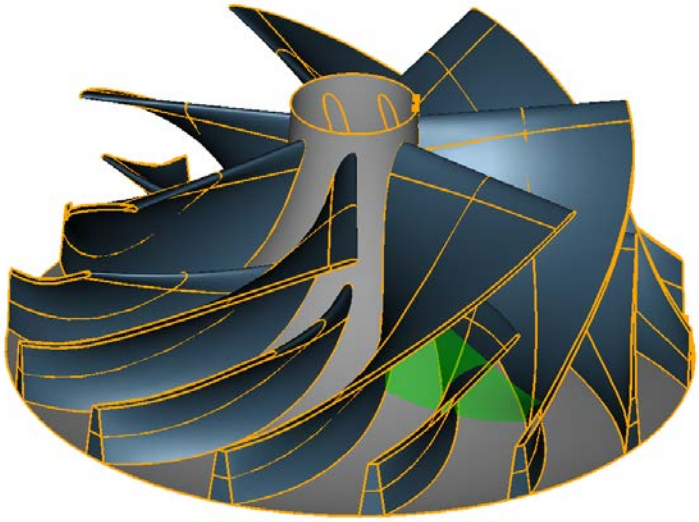


The Turbocharger Performance Map Workflow-Meshing (TurboGrid)

- 3D Geometry (right)
- Meshing of periodic segment with TurboGrid (left)

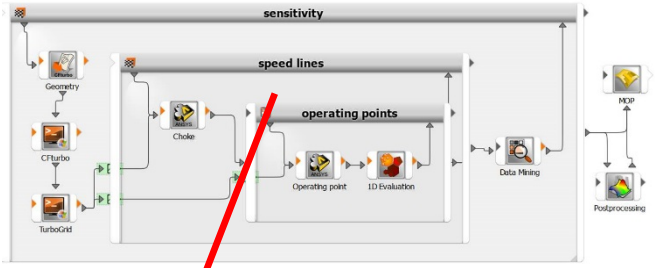


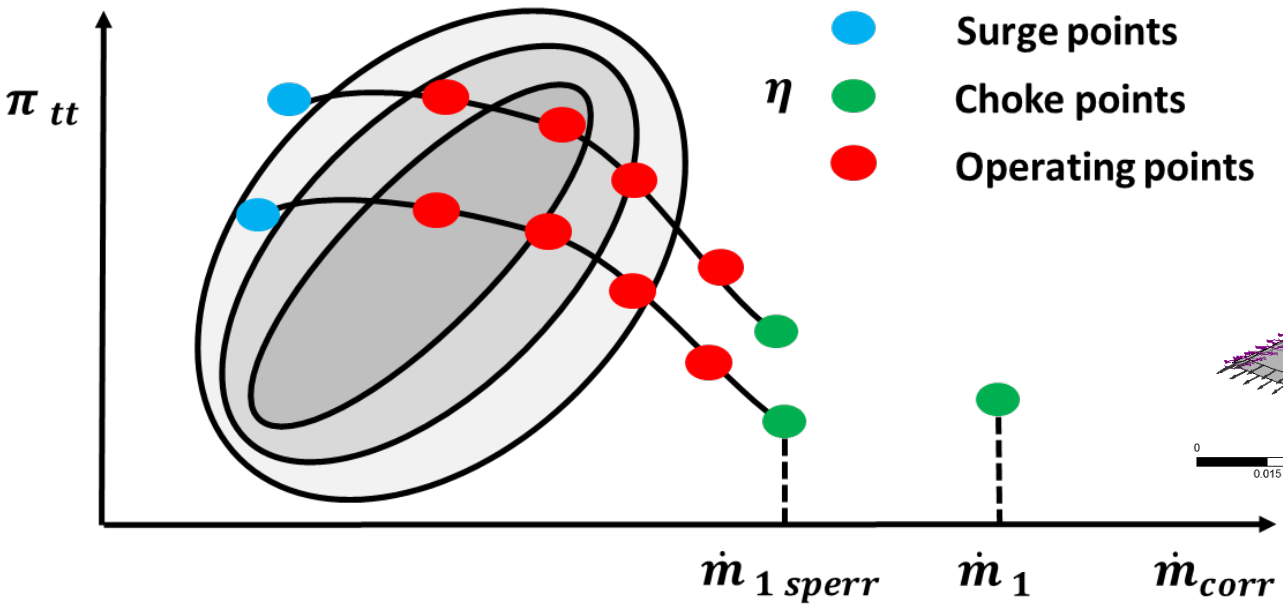


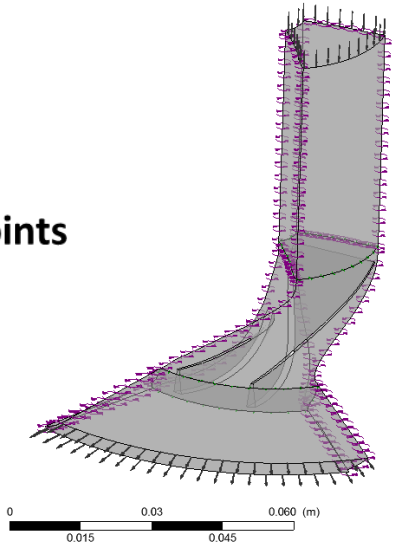


The Turbocharger Performance Map Workflow- 3D CFD (CFX)

- Calculation of Choke Points through laws of similarity
- Afterwards iterative reduction of the mass flow until highest poly. efficiency





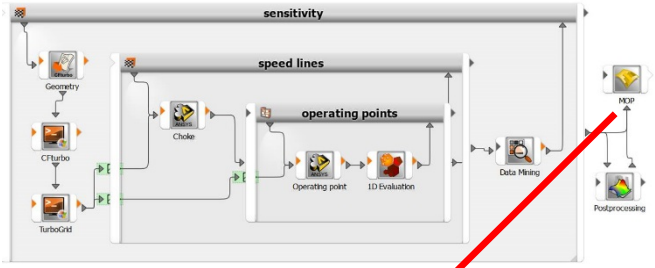


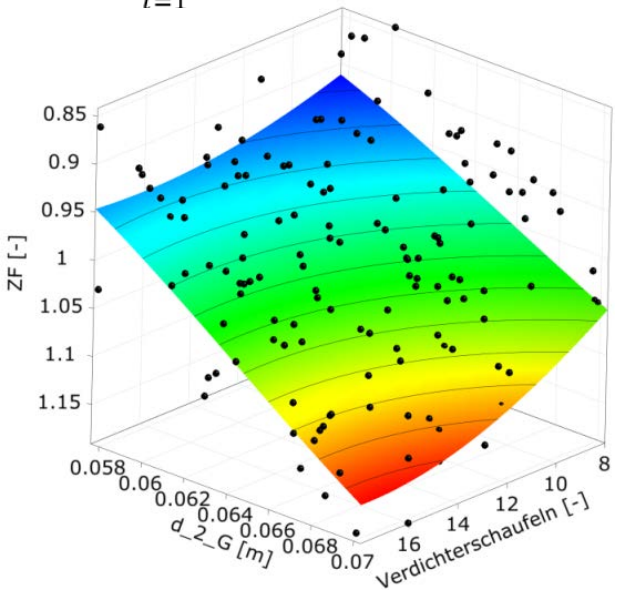
[3]

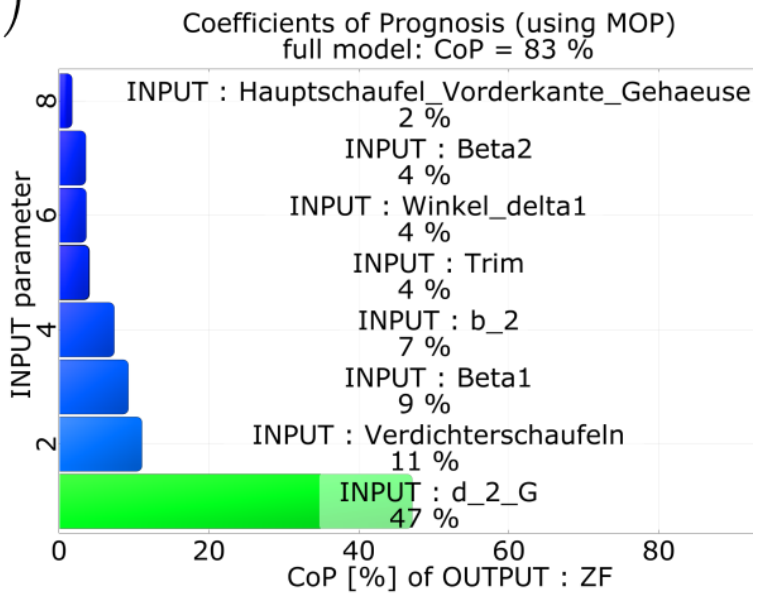
The Turbocharger Performance Map Workflow-Results Evaluation

- Calculation of correlations,…
- response surfaces (MOP) and the sensitivity of input parameters
- objective function (ZF):

$$ZF = \frac{1}{3n}\sum_{i=1}^{n}\left(\frac{\dot{m}_{sperr,i}}{\dot{m}_{ref,i}} + \frac{\eta_{p\,max,i}}{\eta_{p\,max\,ref,i}} + \frac{\pi_{tt\,max,i}}{\pi_{tt\,max\,ref,i}}\right)$$





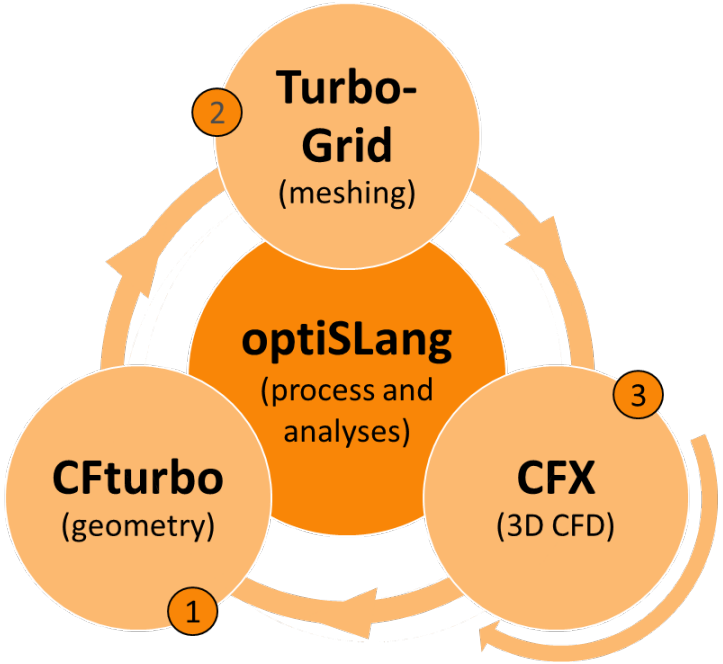


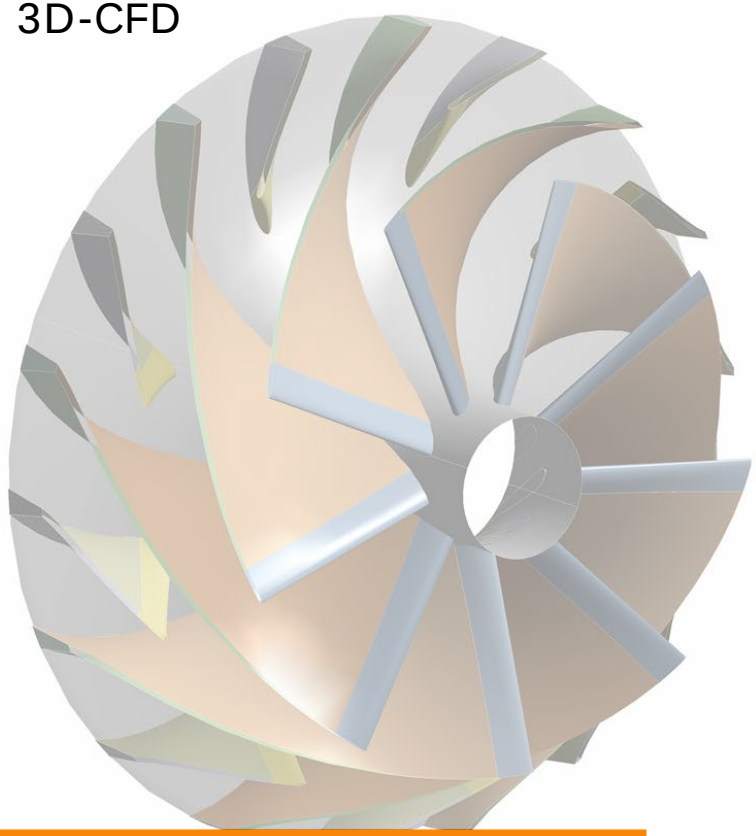
The Turbocharger Performance Map Workflow- Conclusion and outlook

Methodology of adaptive analysis of performance maps:

✓ In Sensitivity and Optimization on MOP successful applied

- enlarges method for performance maps in 3D-CFD





Conclusion and Outlook

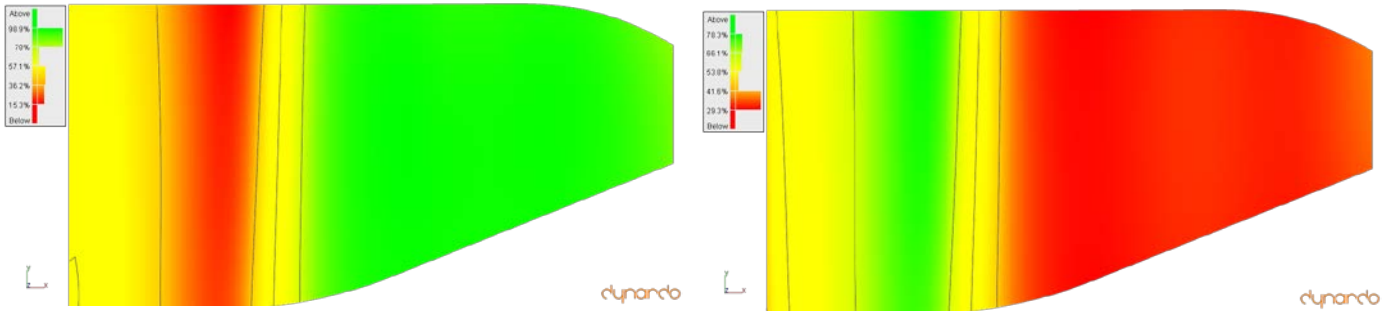
Different nested systems have been applied in practical

- Robustness in Optimization, Sensitivity in Sensitivity, Sensitivity in Optimization,…
- for specific requirements: use own algorithms to sample designs or to find optimal/robust solutions with Custom Algorithms

Next steps in the process : e.g.

Analyze importance of parameters in performance map with SOS

left: F-CoP y1 (88%), right: F-CoP y2 (36%)



Examples provided by Markus Stockmaier, Stefan Marth, Sebastian Wolf and Markus Wagner – please contact us at WOST or later

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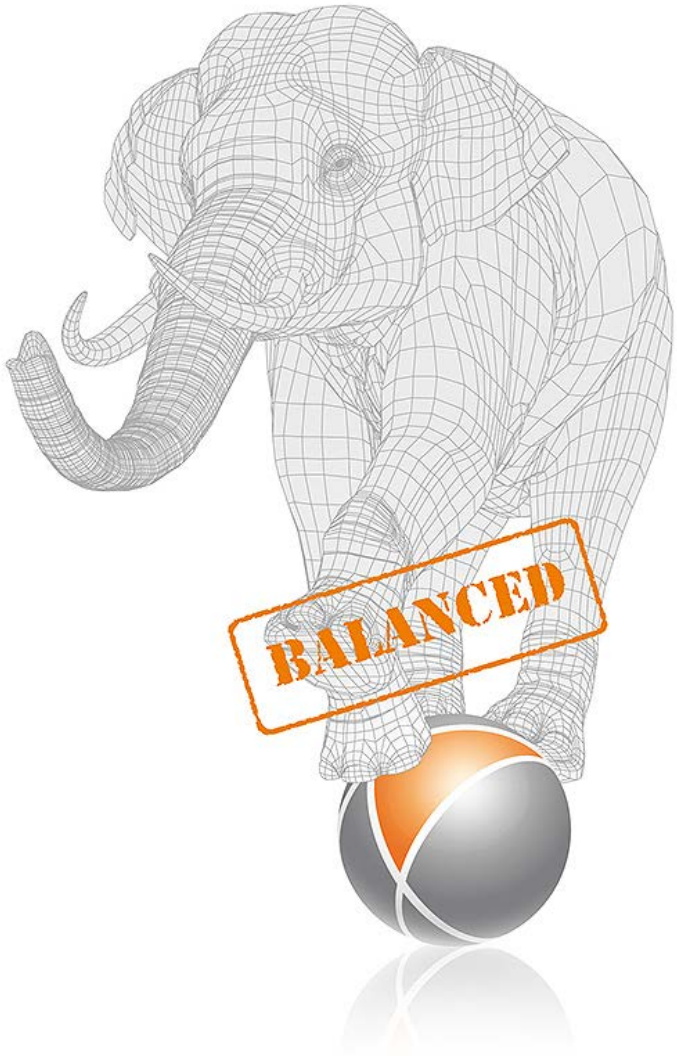

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List of references

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2	Merker, G.; Schwarz, C. und Teichmann, R.: Grundlagen Verbrennungsmotoren-Funktionsweise, Simulation, Messtechnik. 6.Auflage. Wiesbaden: Vieweg + Teubner Verlag, 2012
3	ANSYS: Strömungsberechnung von Turboverdichtern mit Ansys TurboGrid und CFX. Otterfing, ANSYS Germany GmbH, Schulung, Referent: Einzinger, Johannes, 2015

Attachment