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Tobias Helle

Tolerance Optimization with CeTol 6σ and optiSLang

Phoenix Contact GmbH & Co. KG

- electr. Connectors- and electr.
  Interface Components
  industrial automation
- 15.000 Employees worldwide
  Phoenix Contact Group include
  15 Companies
- 14 Manufacturing locations worldwide

Phoenix Contact Headquarter

PHOENIX CONTACT Electronics

Location Berlin

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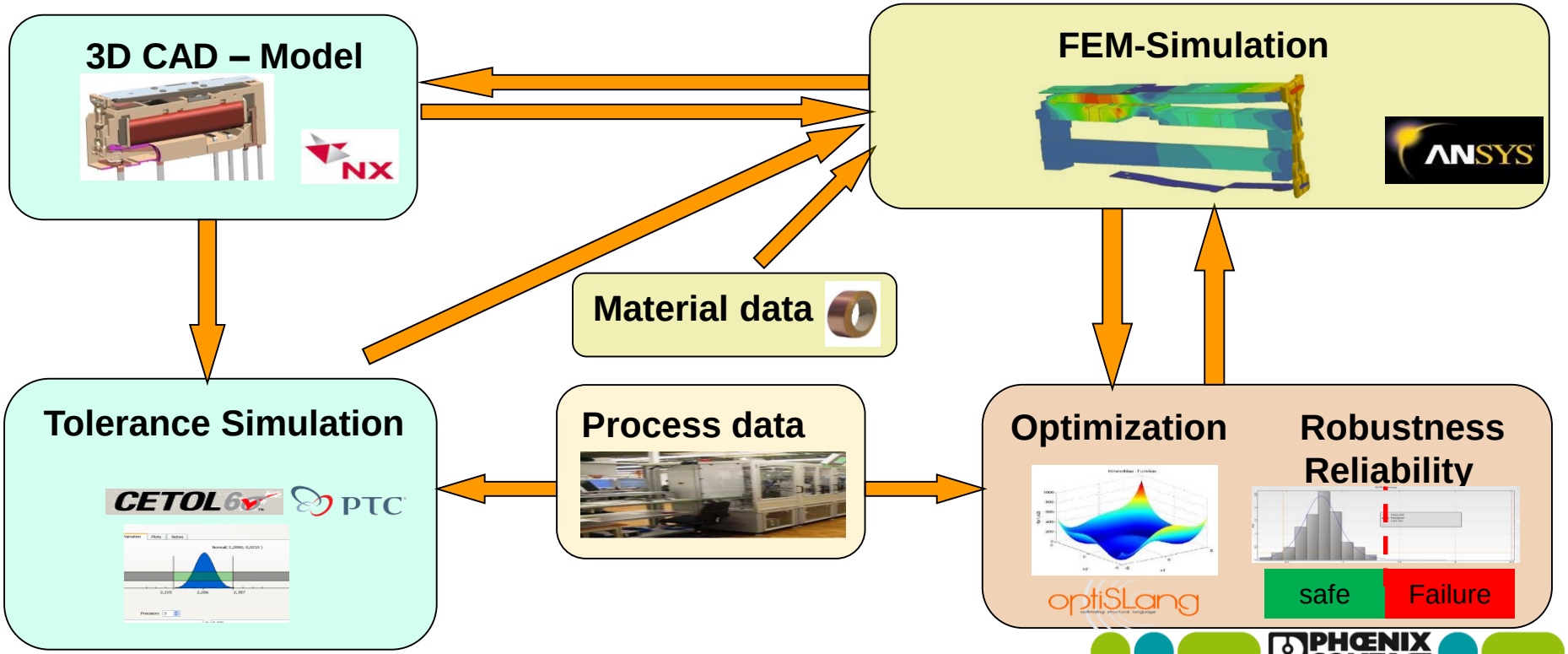
- 1 – Target: Motivation
- 2 – Method: Tolerance Simulation; Kinematic Model
- 3 – Solution Approach: Process Integration optiSLang
- 4 – Example: Tolerance Optimization Relay
- 5 – Outlook: Next steps

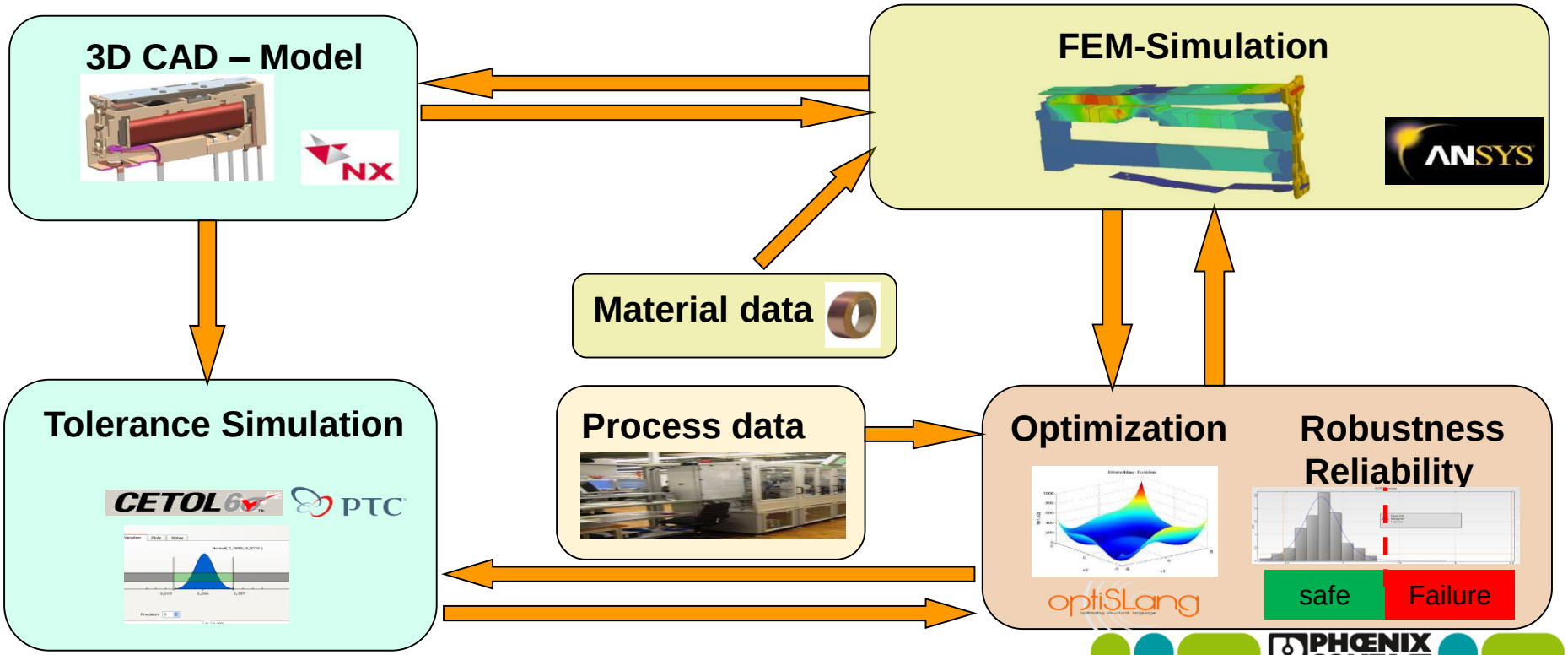
1. Target: Motivation

Workflow Robust Design Optimization Relay Development – until now



1. Target: Motivation

Workflow Robust Design Optimization Relay Development – Target

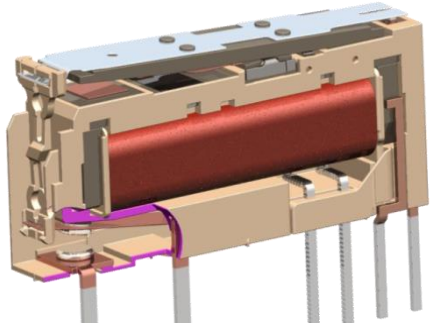


2. Method: Tolerance Simulation – Kinematic Model

Process data

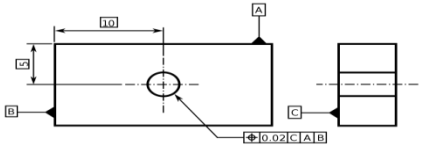
Kinematic model

CETOL 6



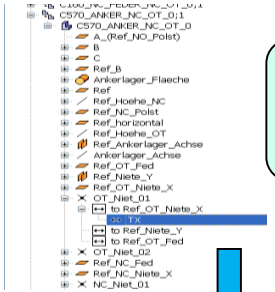
3D CAD - Model

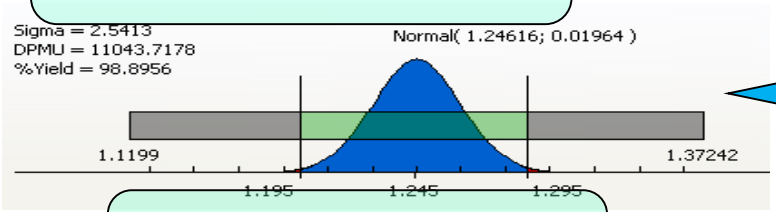
NX PTC



Drawing

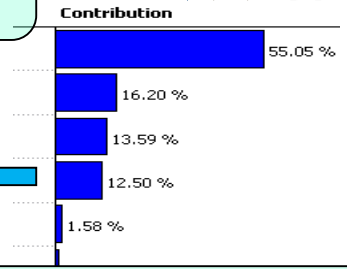
GD-Tolerances

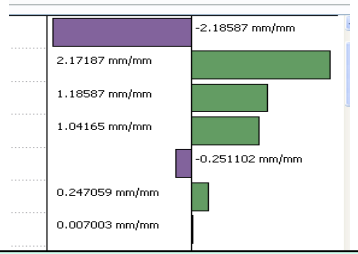




Measurement

worst-case / statistical

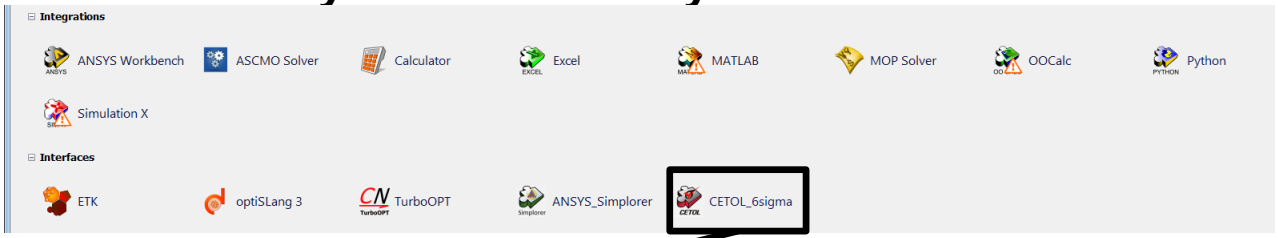


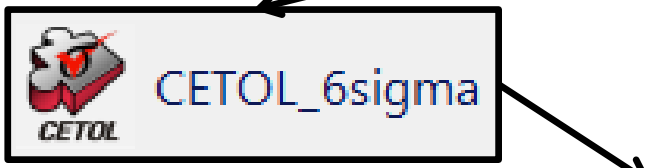


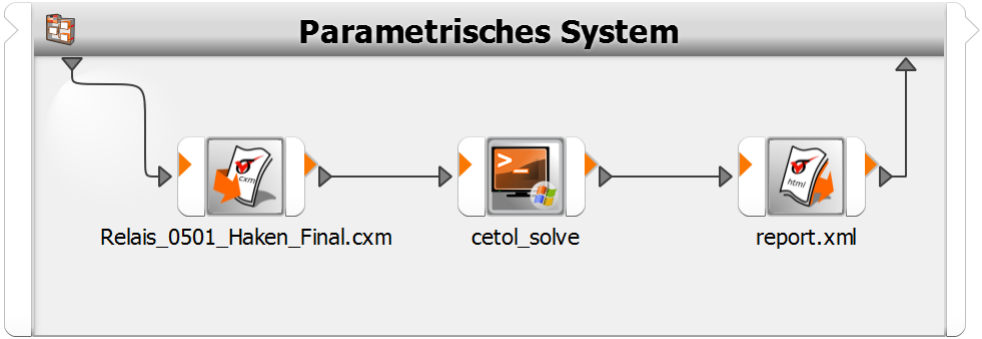
Contribution - Sensitivity

3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**

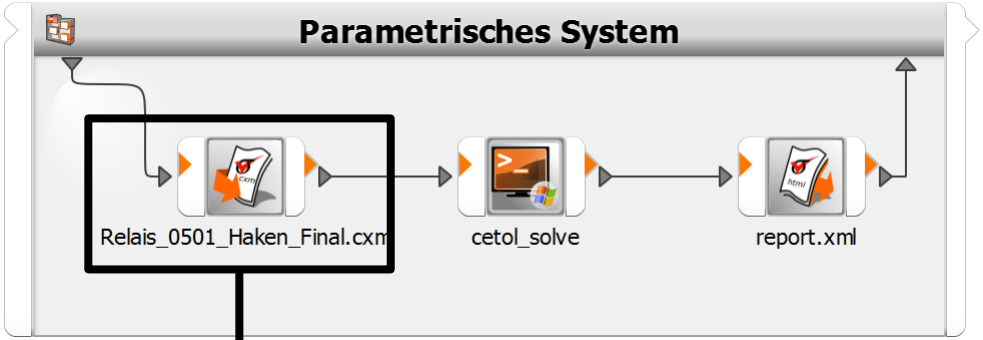


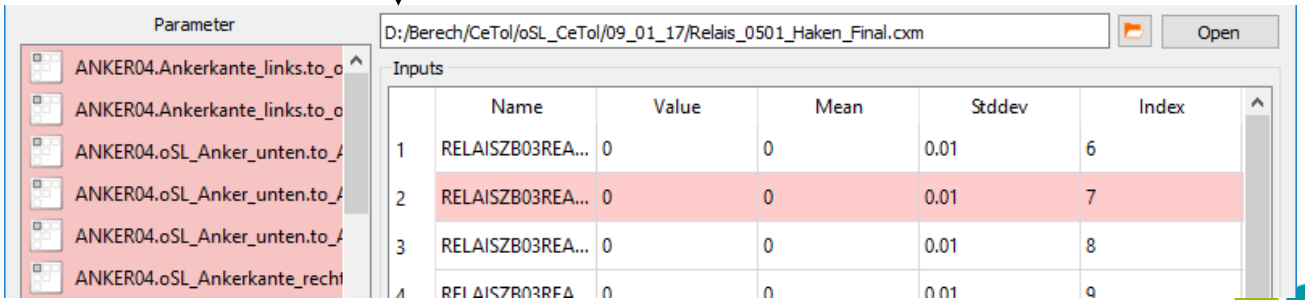




3. Solution Approach: Process Integration CeTol with optiSLang

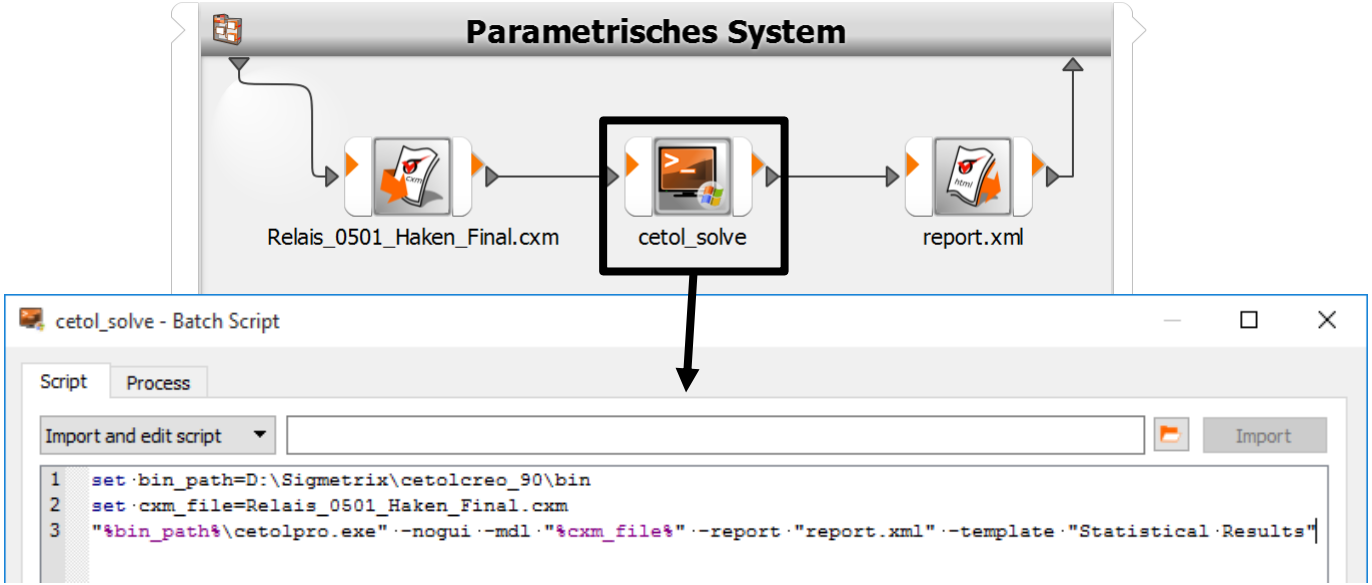
- **Parametrical System created by Wizard**
  Import parameter und tolerances from CeTol *.cxm-file by Input Node





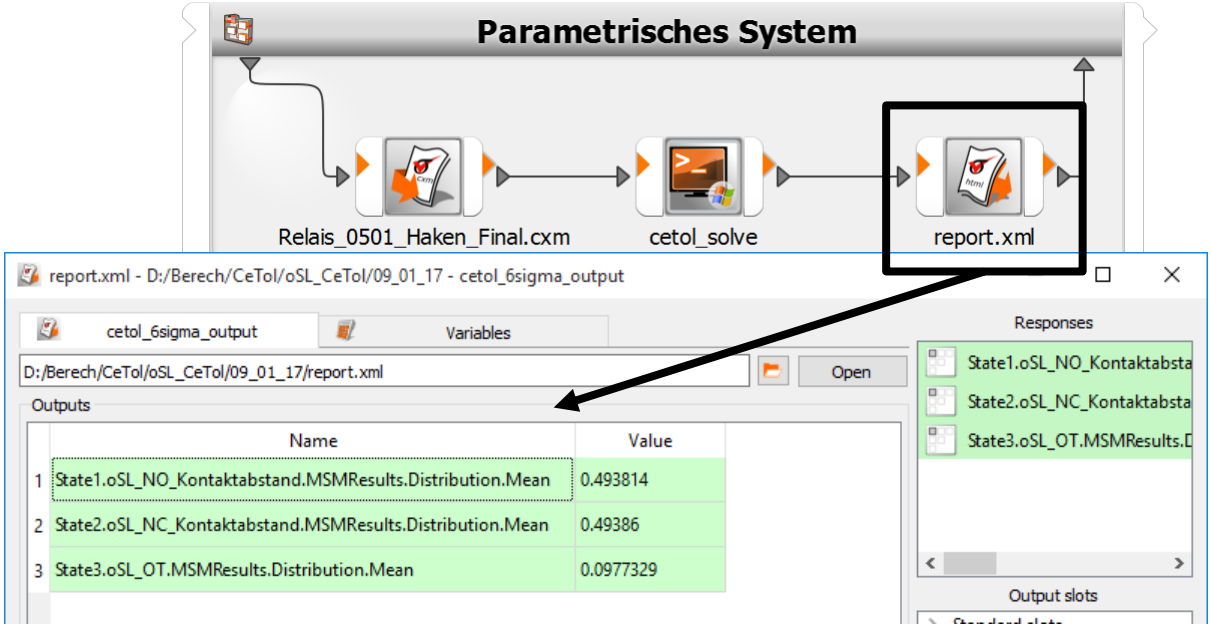
3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**
  CeTol solver call



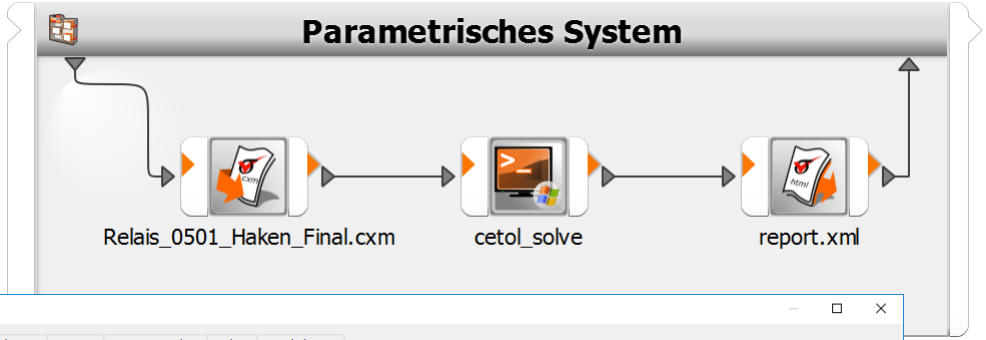
3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**
  Import results from CeTol result.xml-file by Output Node



3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**
  Parameter modification in parametric system possible



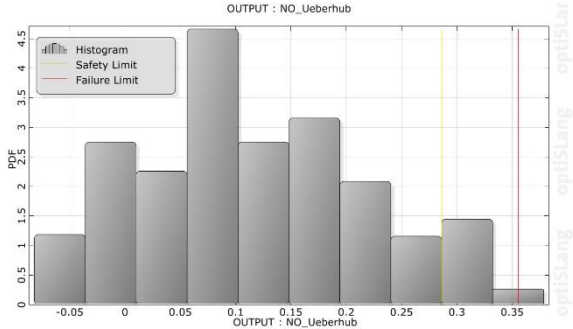
Sensitivity

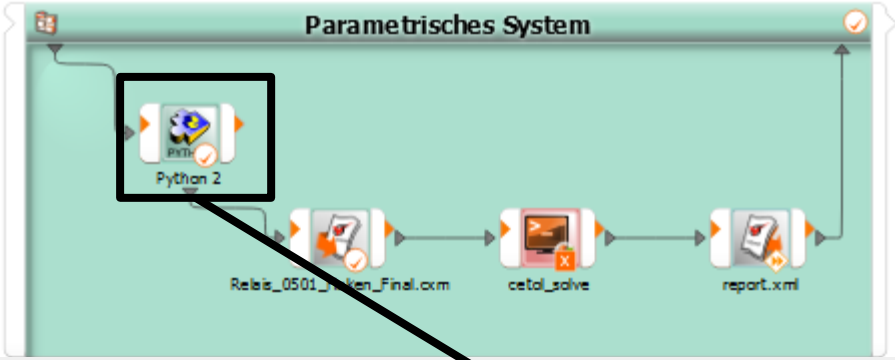
Parameter | Start designs | Criteria | Dynamic sampling | Other | Result designs

	Name	Parameter type	rence v	Constant	ra	Value type	Resolution	Range		Range plot	PDF	Type	Mean	Std. Dev.	CoV	Distributi
1	RELAISZB03READY.MCA03_1.oSL_...	Stochastic	0	☐		REAL	Continuo...					NO...	0	0.01	10...	0; 0.01
2	KJSPK03.KERN03_1.oSL_SKOERPER...	Opt.+Stoch.	0	☐		REAL	Continuo...	-0.5	0.5			NO...	0	0.01	10...	0; 0.01
3	KJSPK03.JOCH04_1.oSL_KERN03_1...	Stochastic	0	☐		REAL	Continuo...					NO...	0	0.00666...	10...	0; 0.00666
4	KJSPK03.JOCH04_1.oSL_KERN03_1...	Stochastic	0	☐		REAL	Continuo...					NO...	0	0.0833333	10...	0; 0.08333
5	KJSPK03.JOCH04_1.oSL_KERN03_1...	Stochastic	0	☐		REAL	Continuo...					NO...	0	0.0833333	10...	0; 0.08333
6	SKOERPERUBAUGRUPPE02.PIN03_...	Opt.+Stoch.	0	☐		REAL	Continuo...	-0.5	0.5			NO...	0	0.0166667	10...	0; 0.01666

3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**
  Python-Node



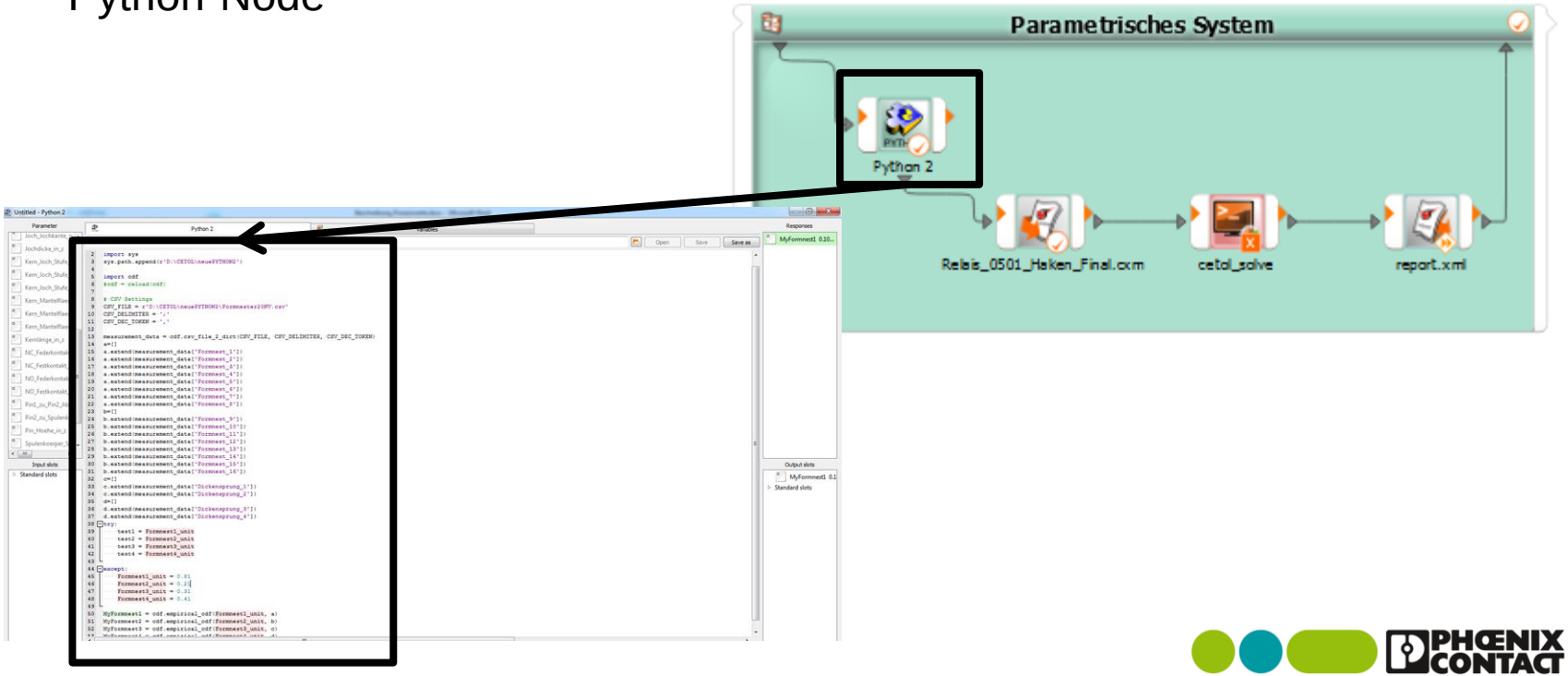


Parameter | Criteria | Other | Result designs

	Name	Parameter type	Value type	Resolution	Range		Range plot	PDF	Type	Mean	Std. Dev.
6	Pin2_zu_Spulenkoerper_Lage_in_z_Joint	Opt.+Stoch.	REAL	Continuo...	-...	0.5			NORMAL	0	0.0166667
7	Pin1_zu_Pin2_Abstand_in_z_Joint	Opt.+Stoch.	REAL	Continuo...	-...	0.5			UNIFORM		0.01

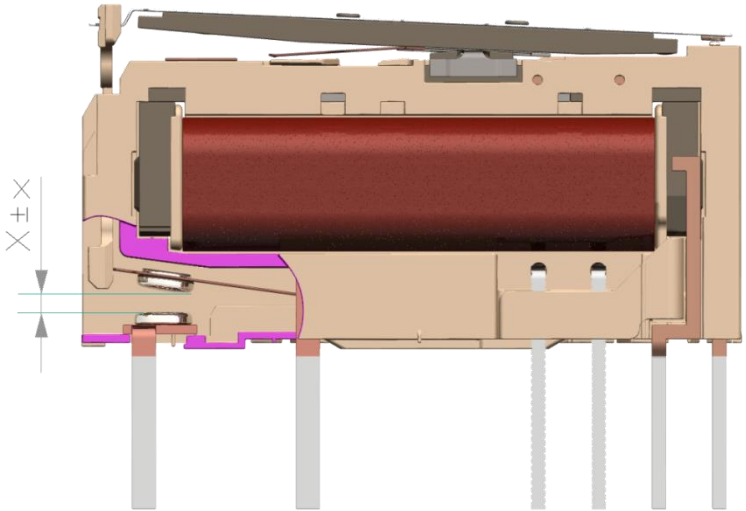
3. Solution Approach: Process Integration CeTol with optiSLang

- **Parametrical System created by Wizard**
  Python-Node



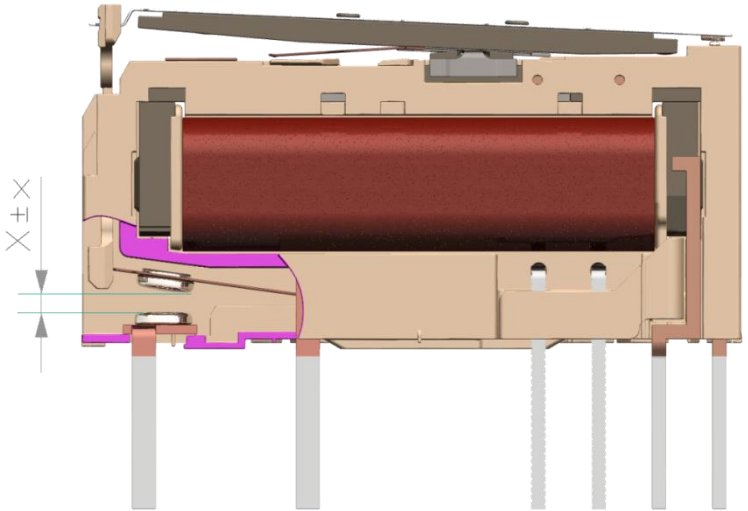
4. Example: Tolerance Optimization Relay

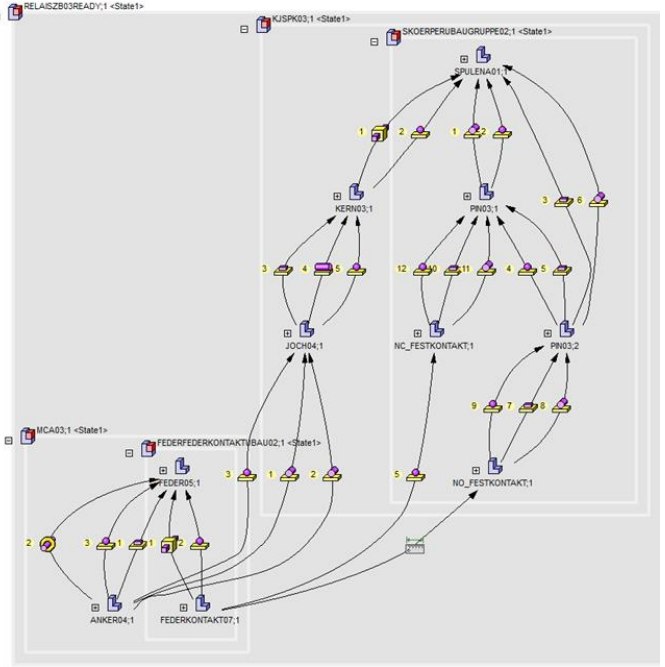
- **Optimization objectives 1: Contact Gap NO=0,25mm**



4. Example: Tolerance Optimization Relay

- **Optimization objectives 1: Contact Gap NO=0,25mm**

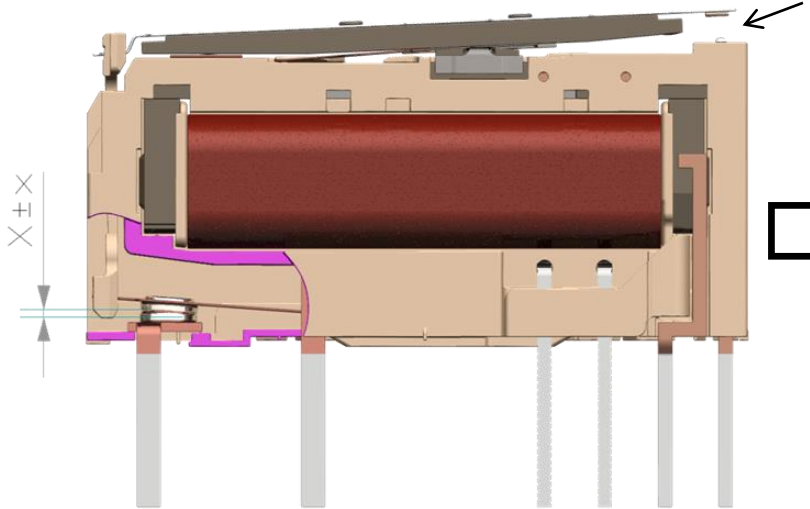


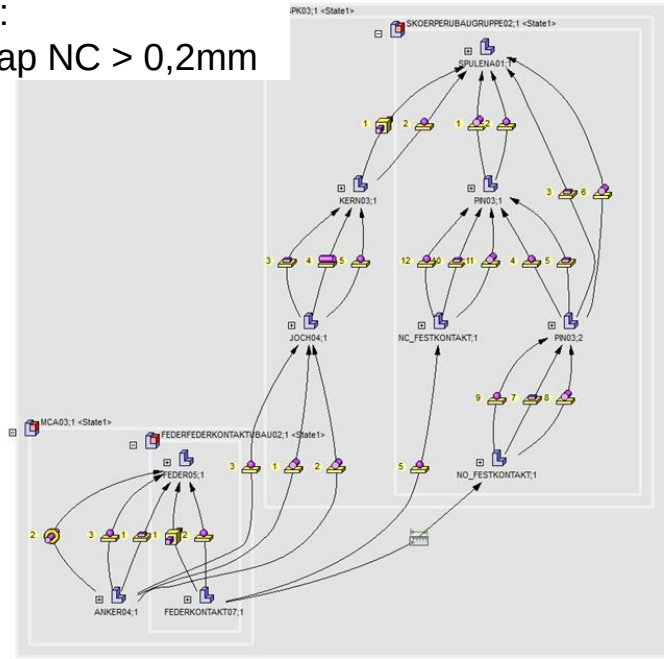


4. Example: Tolerance Optimization Relay

- **Optimization objectives 2: Overtravel NO=0,25mm**

Constraint:
Contact Gap NC > 0,2mm





4. Example: Tolerance Optimization Relay

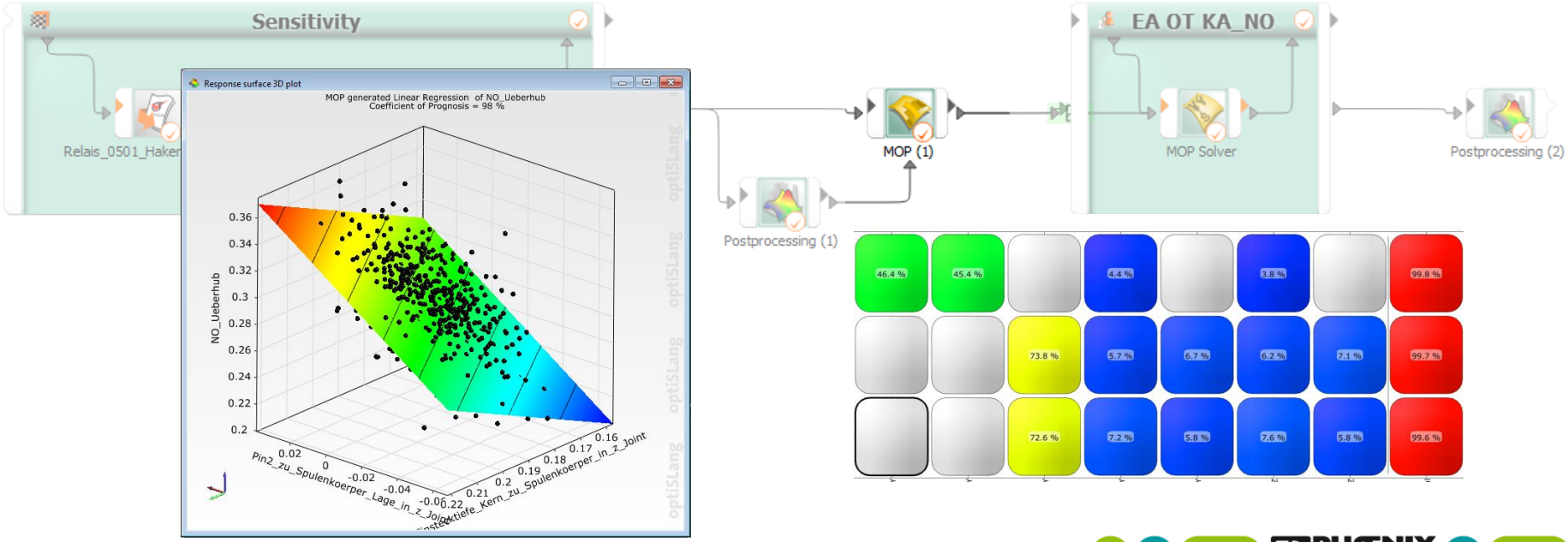
- **Results from Sensitivity Analysis**

Sensitivity Analysis: CeTol vs. optiSLang

Optimization based on MoP

4. Example: Tolerance Optimization Relay

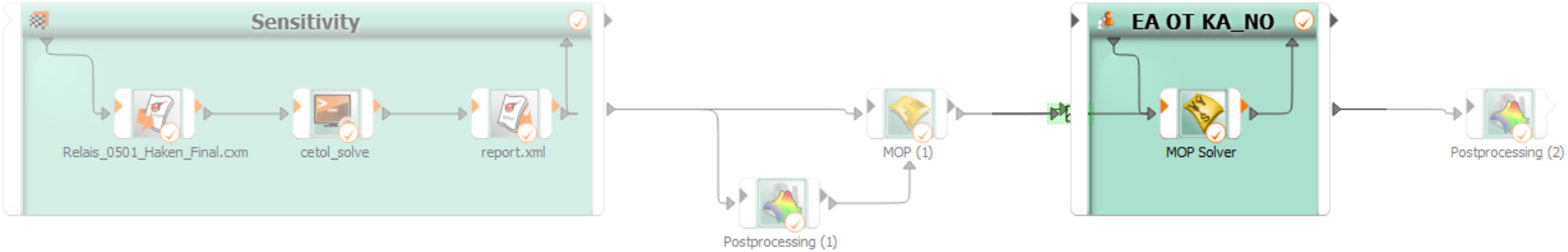
- **MoP from Sensitivity Analysis**
  CoP ≈ 100%



Tobias Helle: Tolerance Analysis with CeTol and optiSLang – WOST 2017

4. Example: Tolerance Optimization Relay

- **Settings**

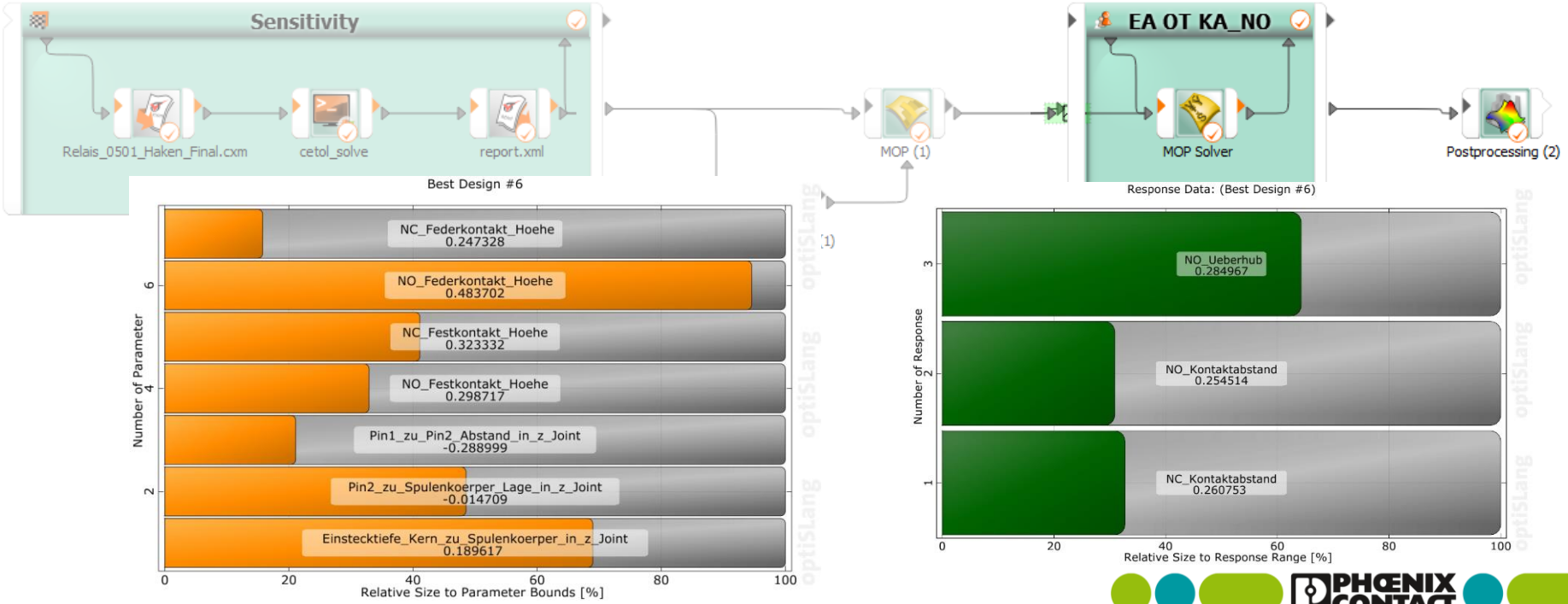


Criteria

Name	Type	Expression	Criterion	Limit
OT_obj	Objective	abs(State3.oSL_OT.MSMResults.Distribution.Mean-0.25)	MIN	
KA_NO_obj	Objective	abs(State1.oSL_NO_Kontaktabstand.MSMResults.Distribution.Mean-0.25)	MIN	
KA_NC_min	Constraint	State2.oSL_NC_Kontaktabstand.MSMResults.Distribution.Mean	≥	0.2

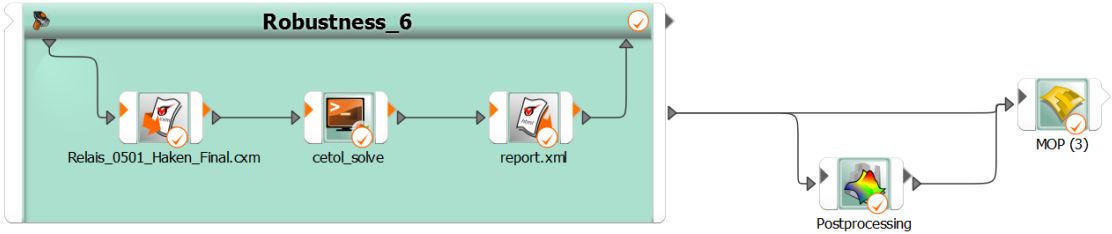
4. Example: Tolerance Optimization Relay

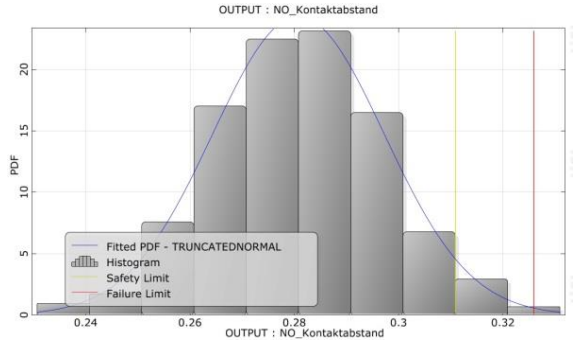
- **Serial Robust – Design Optimization**

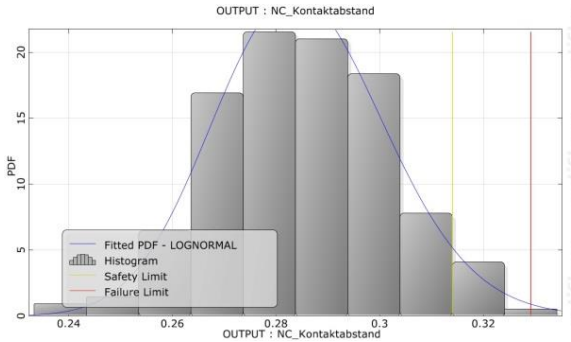


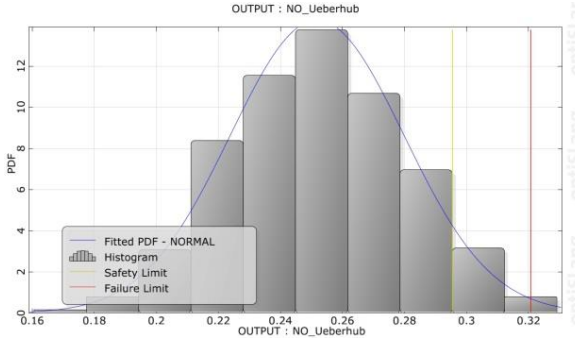
4. Example: Tolerance Optimization Relay

- **Serial Robust – Design Optimization 2nd Iteration**





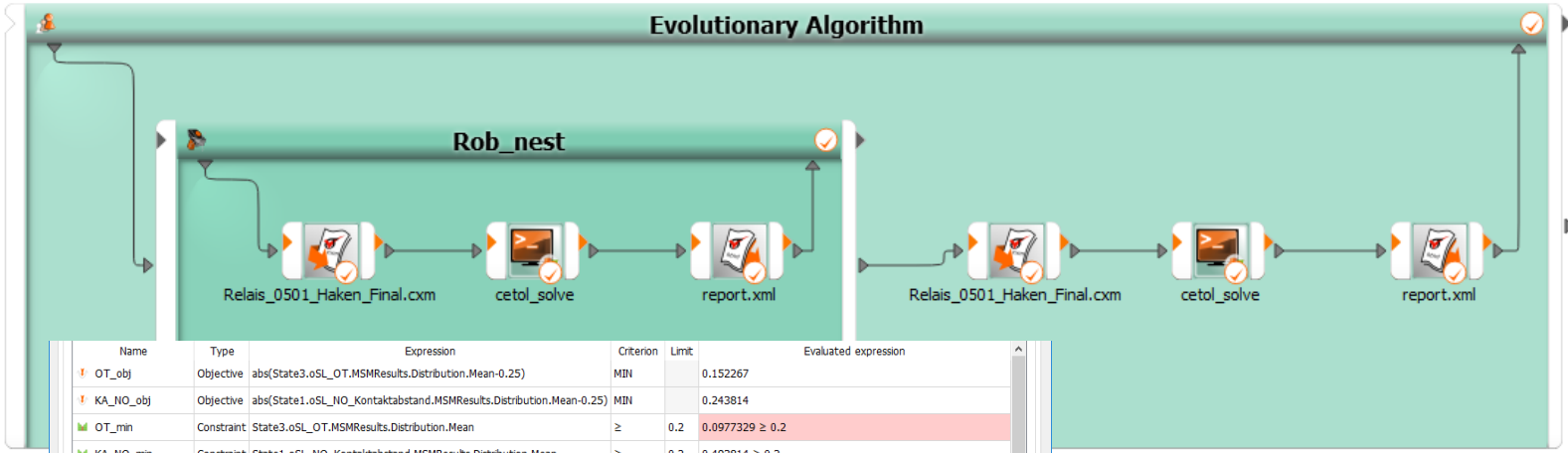




4. Example: Tolerance Optimization Relay

- **Nested Robust Design Optimierung**
- **Evaluation of robustness of results in every optimization step**

KA_NO_obj	OT_obj	KA_NC_min	KA_NO_min	OT_min
.179216	0.362104	0.0950478 ≥ 0.2	0.0707837 ≥ 0.2	0.612104 ≥ 0.2
.166902	0.304132	0.114343 ≥ 0.2	0.0830975 ≥ 0.2	0.554132 ≥ 0.2
.14813	0.328536	0.136437 ≥ 0.2	0.10187 ≥ 0.2	0.578536 ≥ 0.2
.0127491	0.0253343	0.236966 ≥ 0.2	0.237251 ≥ 0.2	0.224666 ≥ 0.2
.025131	0.0909772	0.27179 ≥ 0.2	0.275131 ≥ 0.2	0.159023 ≥ 0.2
.0244255	0.0184677	0.22624 ≥ 0.2	0.225575 ≥ 0.2	0.231532 ≥ 0.2



Name	Type	Expression	Criterion	Limit	Evaluated expression
OT_obj	Objective	abs(State3.oSL_OT.MSMResults.Distribution.Mean-0.25)	MIN		0.152267
KA_NO_obj	Objective	abs(State1.oSL_NO_Kontaktabstand.MSMResults.Distribution.Mean-0.25)	MIN		0.243814
OT_min	Constraint	State3.oSL_OT.MSMResults.Distribution.Mean	≥	0.2	0.0977329 ≥ 0.2
KA_NO_min	Constraint	State1.oSL_NO_Kontaktabstand.MSMResults.Distribution.Mean	≥	0.2	0.493814 ≥ 0.2
KA_NC_min	Constraint	State2.oSL_NC_Kontaktabstand.MSMResults.Distribution.Mean	≥	0.2	0.49386 ≥ 0.2
new					

5. Outlook: Next steps

- Improvement of design process due to automated geometrical modelling
- Apply Excel-MOP of tolerance model for manufacturing
- Link between geometrical conditions of CeTol-Kinematic model and ANSYS FEM-Model (deformed springs)