Ansys WOST CONFERENCE

Optimization of optical and opto-mechanical systems

June 18, 2021

Ansys

Agenda

1. **Introduction to Ansys optiSLang**
2. **Robust design optimization of a light guide**
3. **Optomechanical Workflow with OpticStudio STAR module, Ansys Mechanical & optiSLang**
4. **How to get started**
5. **Q&A**

Introduction to Ansys optiSLang

Ansys optiSLang - a tool for Process Integration and Design Optimization (PIDO)

Ansys Digital Transformation Portfolio

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Ansys / CLOUD — **High Performance Computing**

Ansys / OPTISLANG — **Process Integration and Design Optimization**

FLUIDS | STRUCTURES | ELECTROMAGNETICS | SEMICONDUCTOR POWER | MISSION-CRITICAL EMBEDDED SOFTWARE | OPTICAL

Ansys / GRANTA — **Materials Information Management**

Ansys / MINERVA — **Simulation Process and Data Management**

Ansys optiSLang

Process Integration, Simulation Workflow Building & Automation

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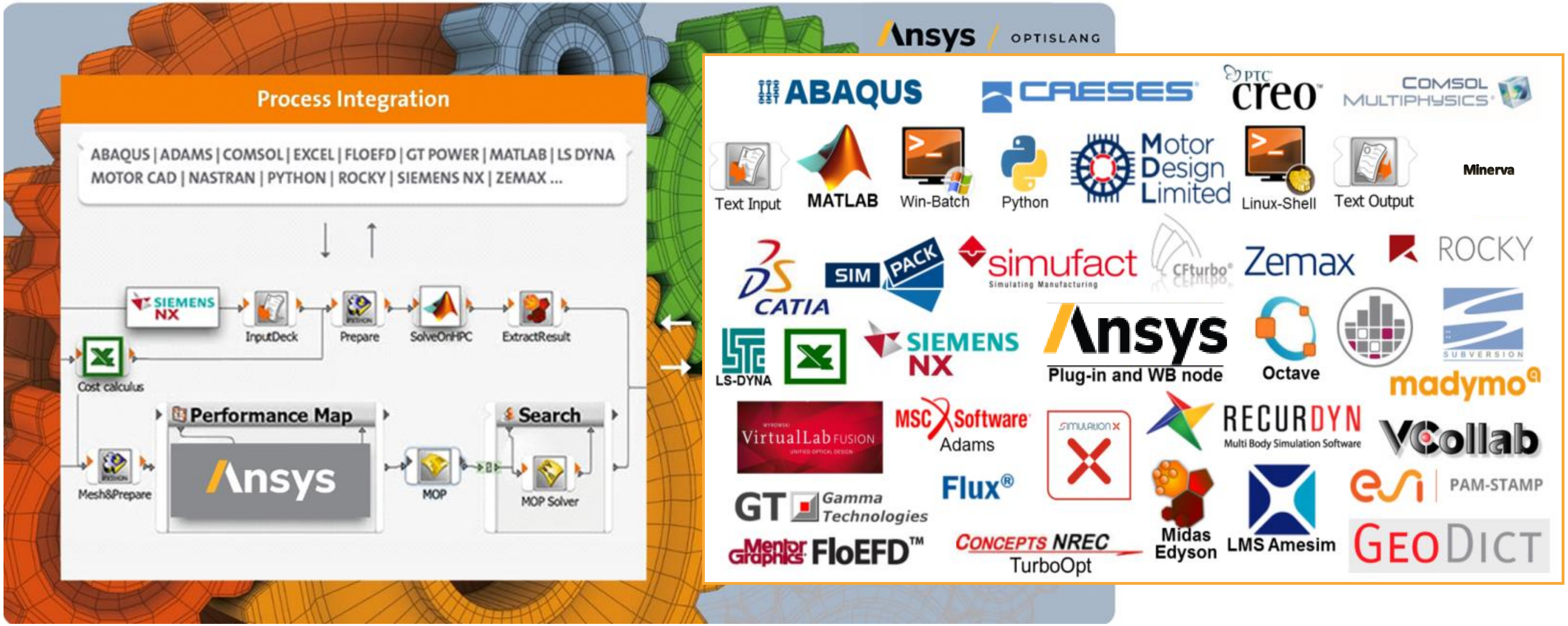

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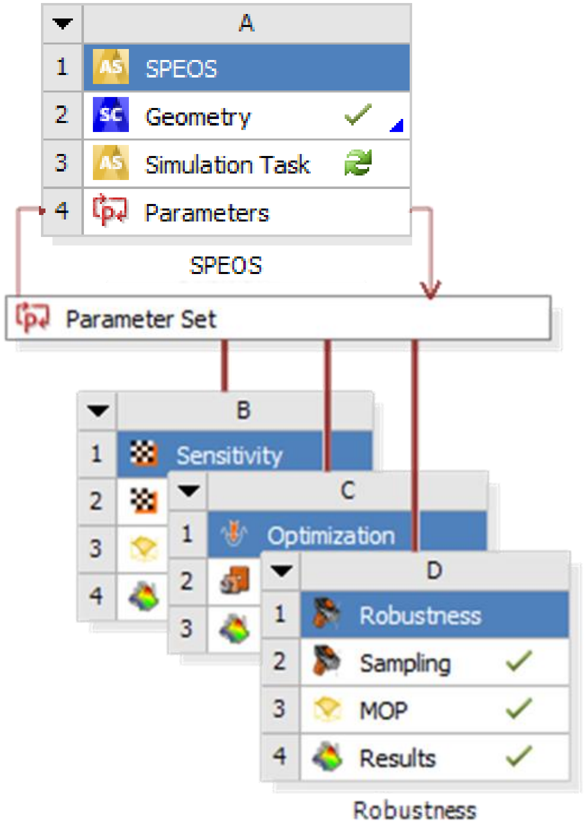
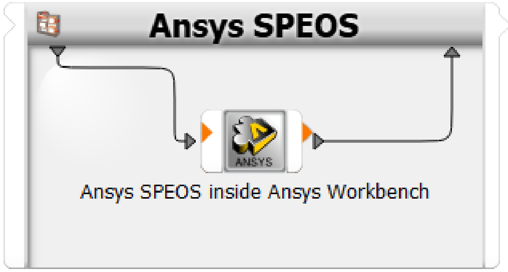
Process Integration: SPEOS & optiSLang

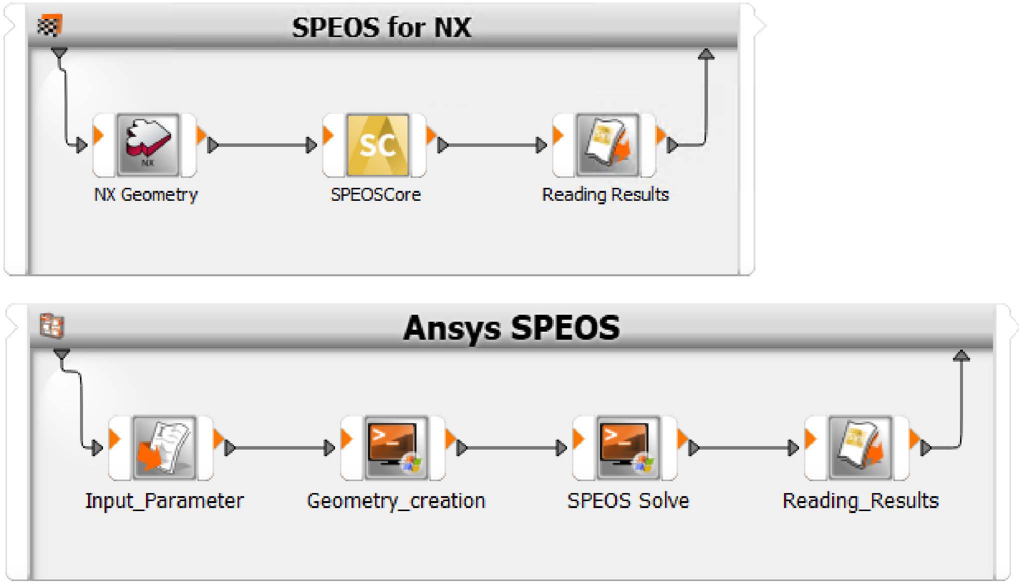
A) optiSLang inside Workbench



B) Workbench inside optiSLang

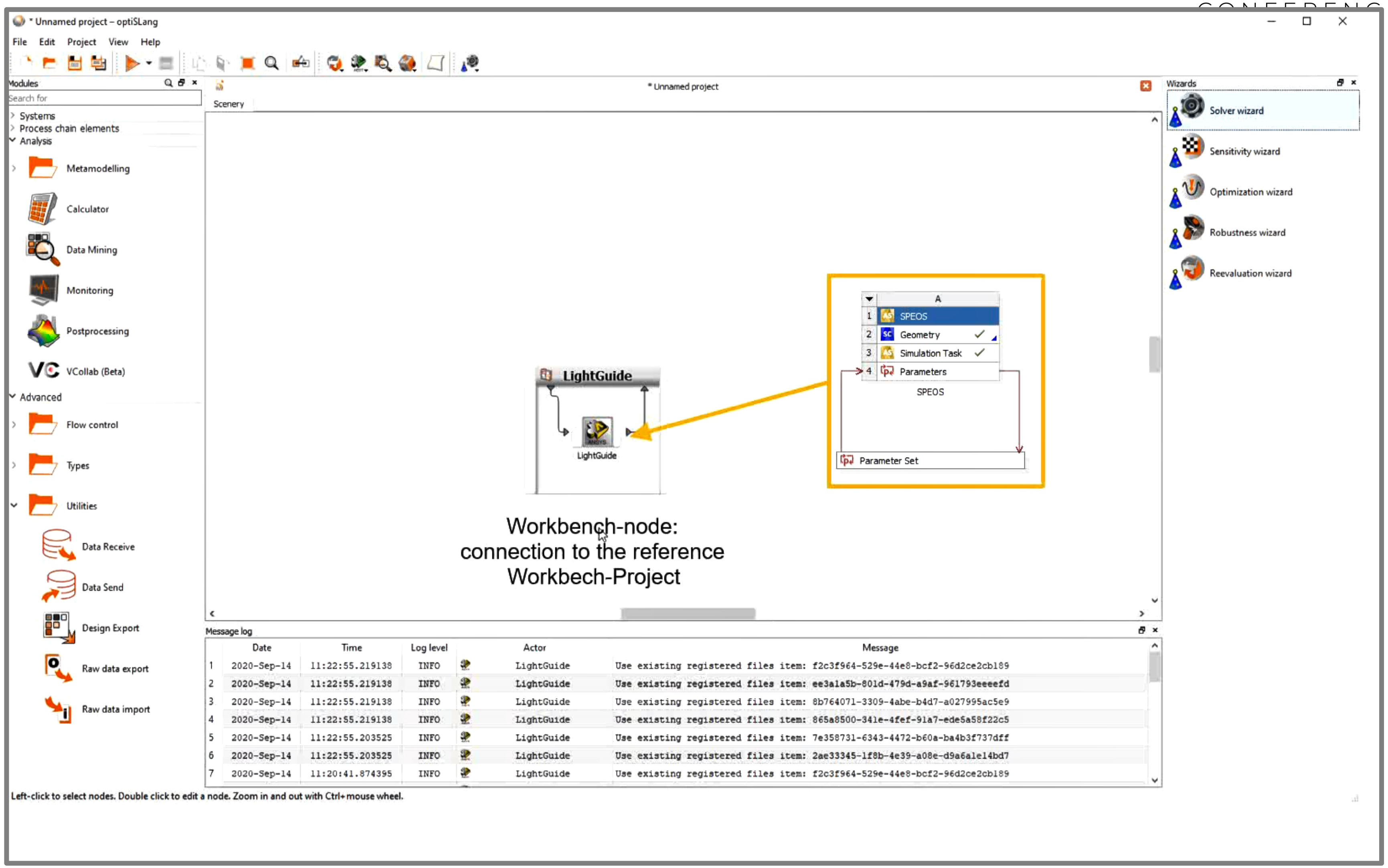


C) Direct integration via scripts

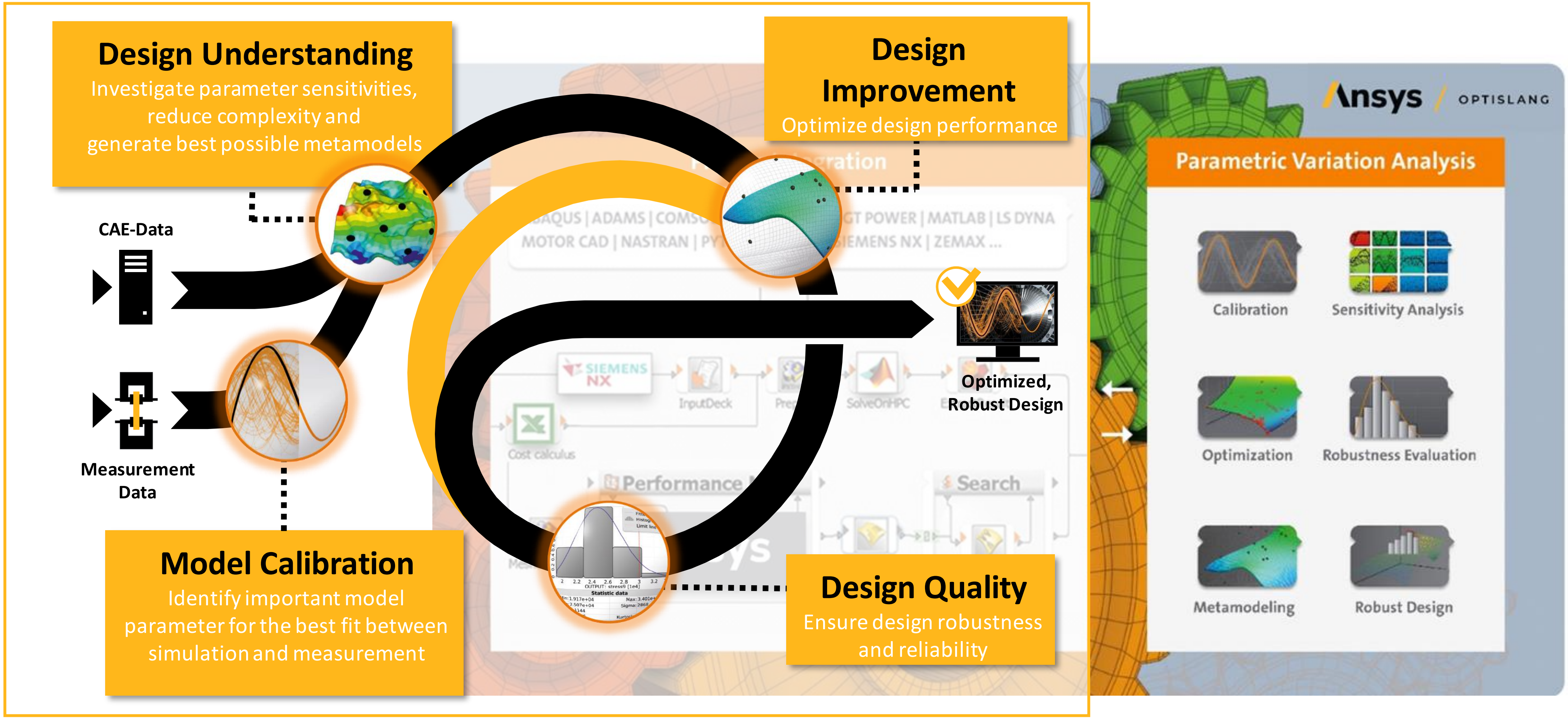


Ansys SPEOS simulation driven by optiSLang

- Wizard driven integration for automatic workflow generation
- Easy setup of sensitivity analysis and optimization



Multidisciplinairy Robust Design Optimization Strategy



Ansys optiSLang User Concept

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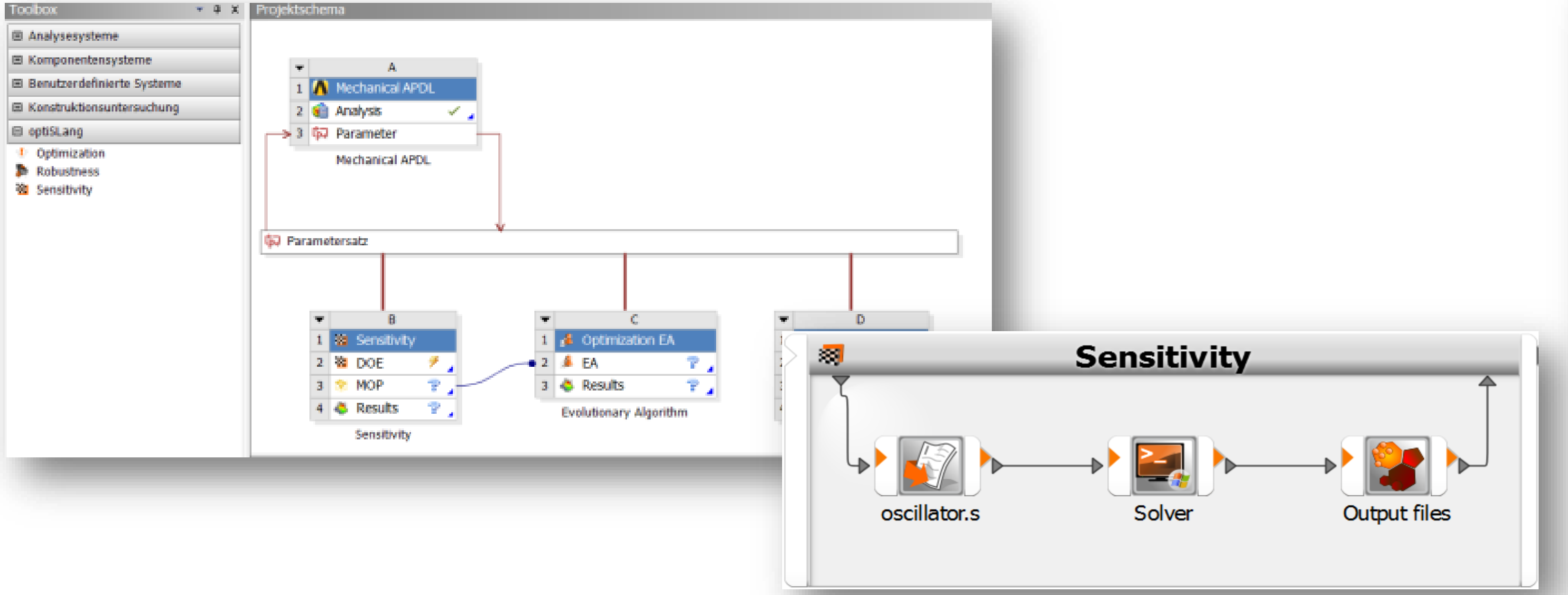
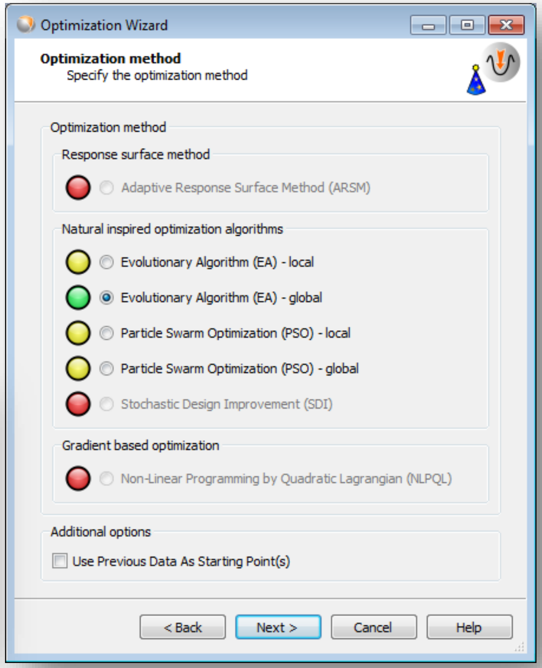
- No expertise in choosing **settings or algorithms** needed
- **Minimal user input due to wizards** (sensitivity, optimization, robustness)
- Easy building of workflows with drag & drop
- **Customization** of postprocessing, integrations, algorithms etc.





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Robust design optimization of a lightguide

Lightguide feature Applications


Side mirror


Daytime running light


Dashboard


Rear lamp

Lightguide


Door panel


Cup holder


Console


Footwell

Initial Design

Light Guide Parameters

Send light in Optical Axis

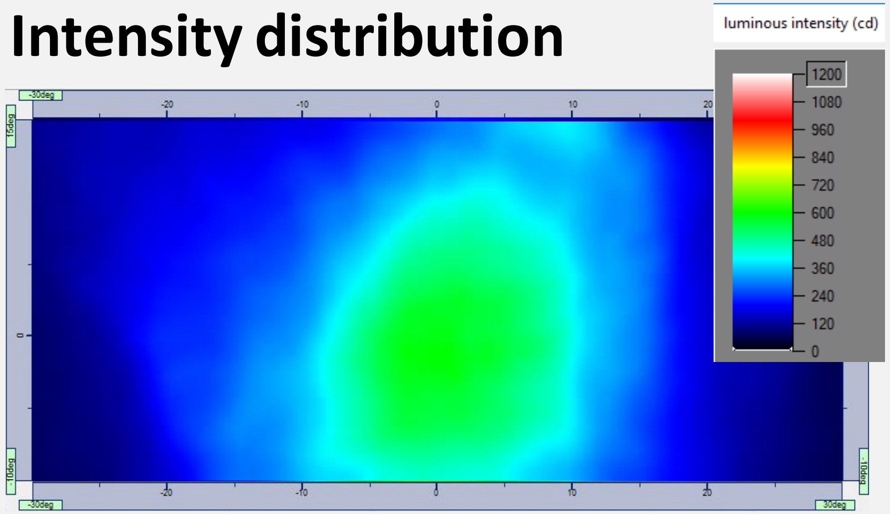
End angle control points (6)

Position	Value
0 %	8,3
5 %	9,6
10 %	11,7
30 %	12,9
65 %	14,4
100 %	16,7

Trimming ratio control points (6)

Position	Value
0 %	30
5 %	20
10 %	20
30 %	15
65 %	5
100 %	0

Intensity distribution



Regulation

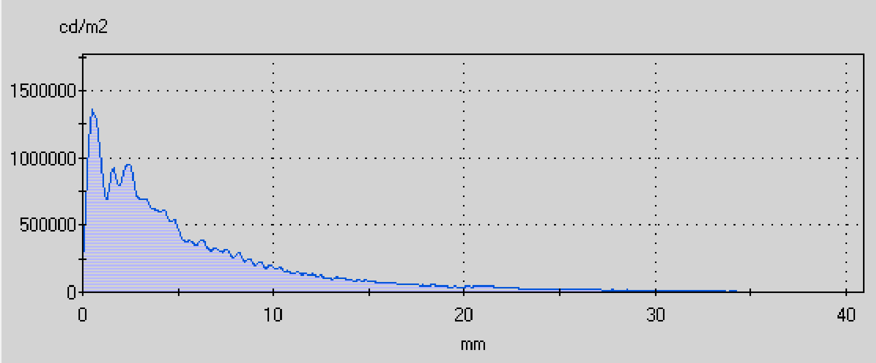
Status: passed

Minimum MARGIN: 31 %
Maximum MARGIN: 403 %

Area	Value	Rule	Test	Target	Margin
5D-20L	201.271 cd	5D-20L_1 (passed)	>=	40 [40]	403.2 %
H-20L	228.925 cd	H-20L_1 (passed)	>=	100 [100]	128.9 %
5U-20L	198.449 cd	5U-20L_1 (passed)	>=	40 [40]	396.1 %
5D-10L	352.666 cd	5D-10L_1 (passed)	>=	80 [80]	340.8 %
H-10L	335.432 cd	H-10L_1 (passed)	>=	280 [280]	19.8 %
5U-10L	293.542 cd	5U-10L_1 (passed)	>=	80 [80]	266.9 %
H-5L	526.97 cd	H-5L_1 (passed)	>=	360 [360]	46.4 %
10U-5L	322.759 cd	10U-5L_1 (passed)	>=	80 [80]	303.4 %
5D-V	552.011 cd	5D-V_1 (passed)	>=	280 [280]	97.1 %
HV	584.774 cd	HV_1 (passed)	>=	400 [400]	46.2 %
5U-V	513.487 cd	5U-V_1 (passed)	>=	280 [280]	83.4 %
10U-V	388.577 cd	10U-V_1 (passed)	>=	80 [80]	385.7 %
H-5R	527.44 cd	H-5R_1 (passed)	>=	360 [360]	46.5 %
10U-5R	379.167 cd	10U-5R_1 (passed)	>=	80 [80]	374.0 %
5D-10R	340.935 cd	5D-10R_1 (passed)	>=	80 [80]	326.2 %
H-10R	366.825 cd	H-10R_1 (passed)	>=	280 [280]	31.0 %
5U-10R	347.17 cd	5U-10R_1 (passed)	>=	80 [80]	334.0 %
5D-20R	132.631 cd	5D-20R_1 (passed)	>=	40 [40]	231.6 %
H-20R	142.07 cd	H-20R_1 (passed)	>=	100 [100]	42.1 %
5U-20R	143.007 cd	5U-20R_1 (passed)	>=	40 [40]	257.5 %

Lit appearance

Cross section analysis



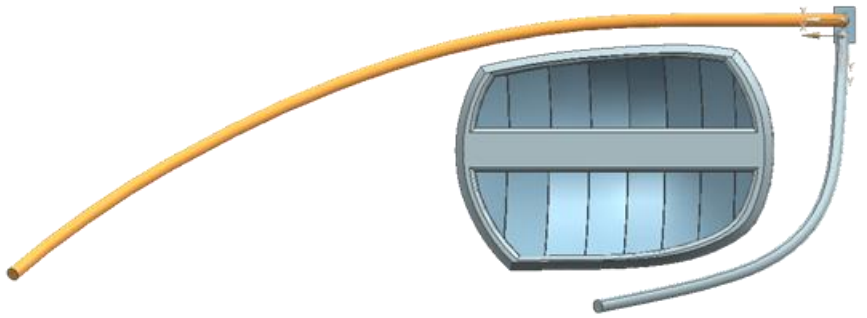
Homogeneity

Luminance :

RMS contrast : 1.63
Average : 159 kcd/m²
Minimum : 529 cd/m²
Maximum : 1 333 kcd/m²

Multi-objective optimization of the lightguide

- Achieve **photometric regulations** for a daytime running lamp, consider national and **customer specifications**
- Obtain a **homogeneous lit appearance**

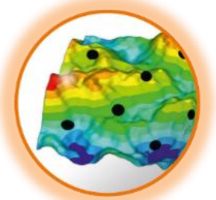


DOE & Sensitivity Analysis

Understand the "what happens if?"

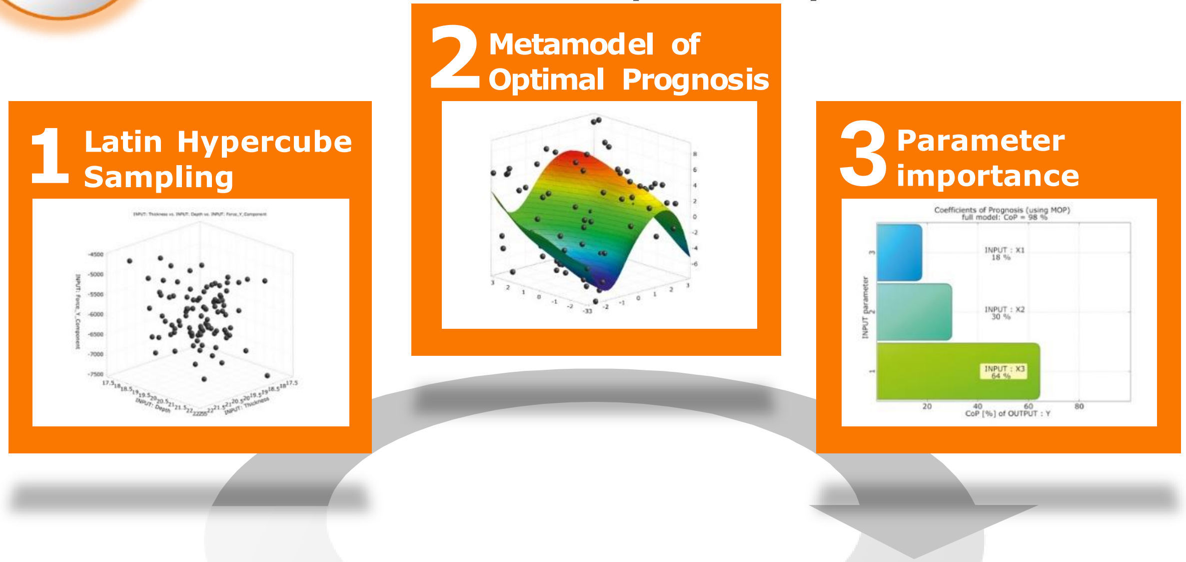
Understand your possibilities:

- Take a deep look at the space of opportunities
- Learn which design parameter is important and how to define the goals and the limitations to find the right way



Sensitivity Analysis

Understand the most important input variables



Automatic workflow with a minimum of solver runs to:

Identify the important parameters for each response

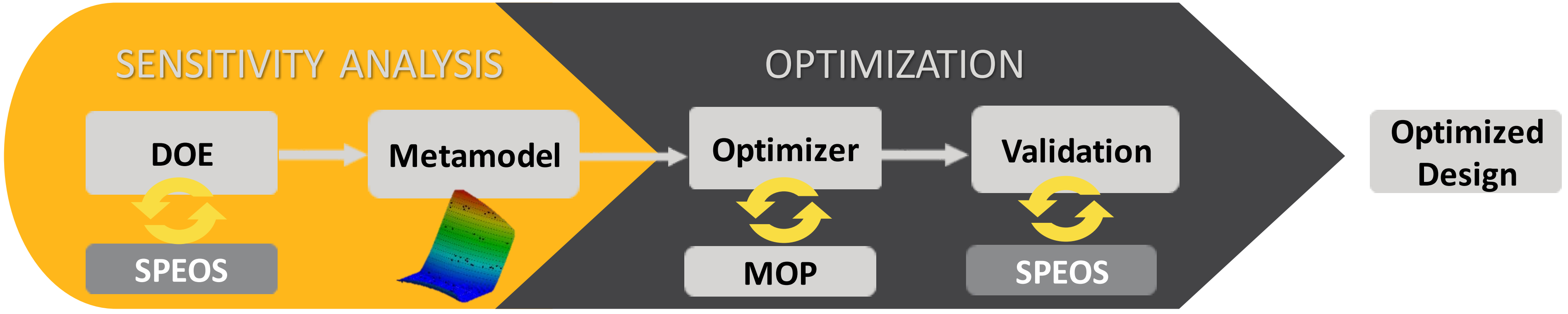
Generate best possible metamodel (MOP) for each response

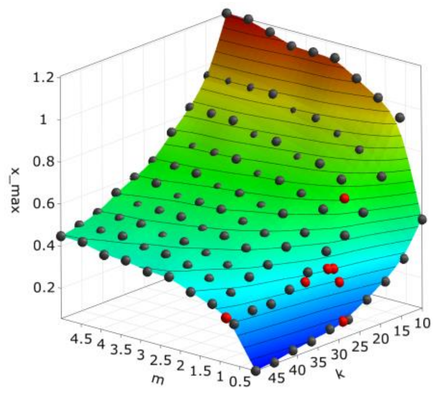
Understand and reduce the optimization task

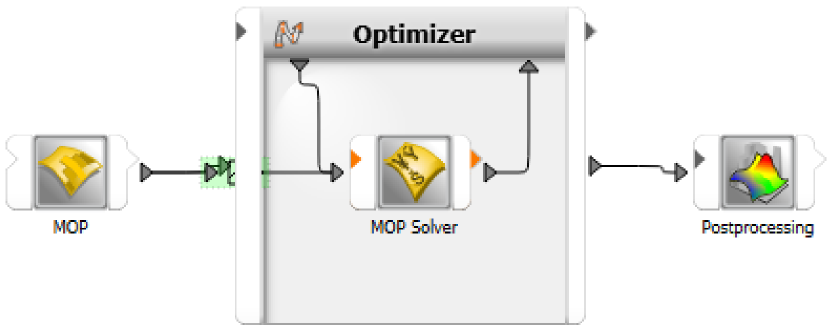
Check solver and extraction noise

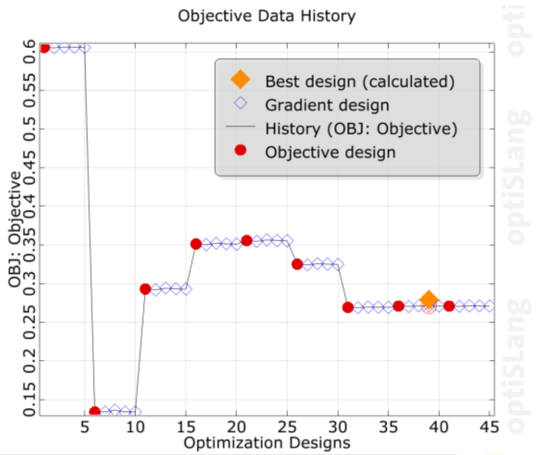
Optimization strategy

- Best practise workflow



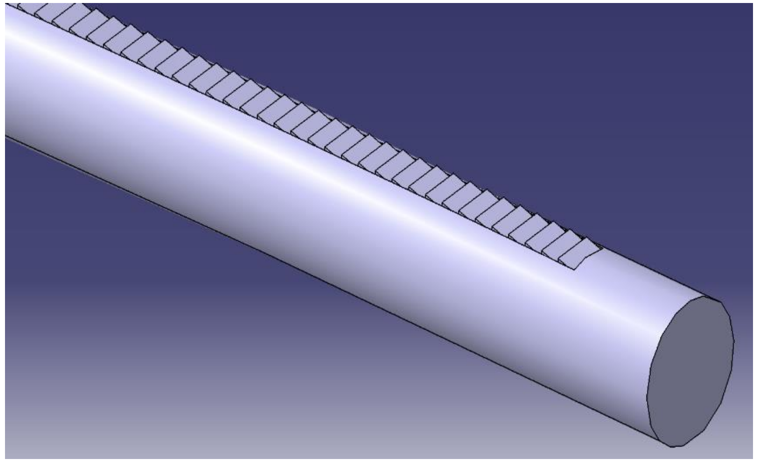


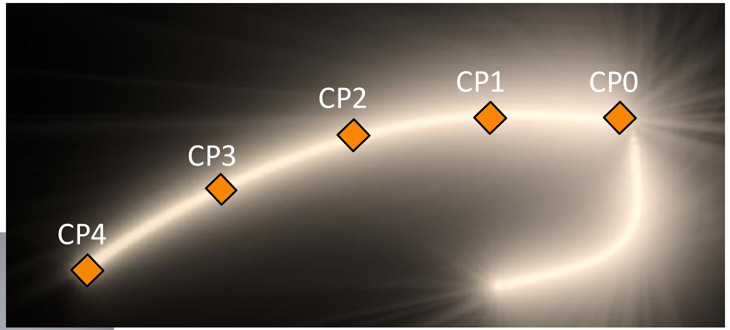


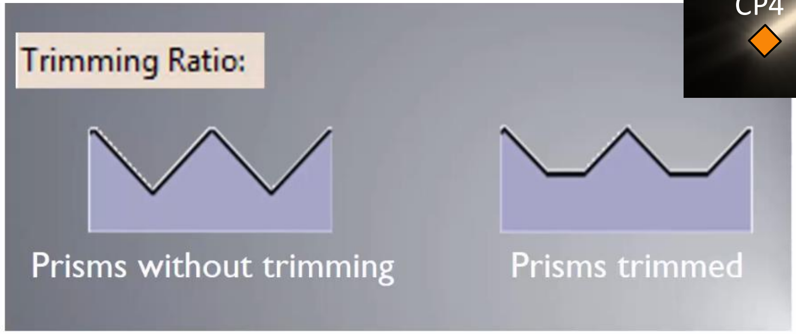


Parametrization

- **Inputs:**
  - trimming ratio at 5 control points of prisms on the lightguide
  - width of the prisms
  - start angle of the prisms
  - end angle of the prisms at 6 control points over the light guide
- **Outputs:**
  - RMS contrast
  - Average [cd/m²]
  - Minimum [cd/m²]
  - Maximum [cd/m²]
- **Objective**:
  - Minimize *RMS contrast*
  - Maximize *average luminance*
- **Constraint**
  - Number of failed Rules = 0

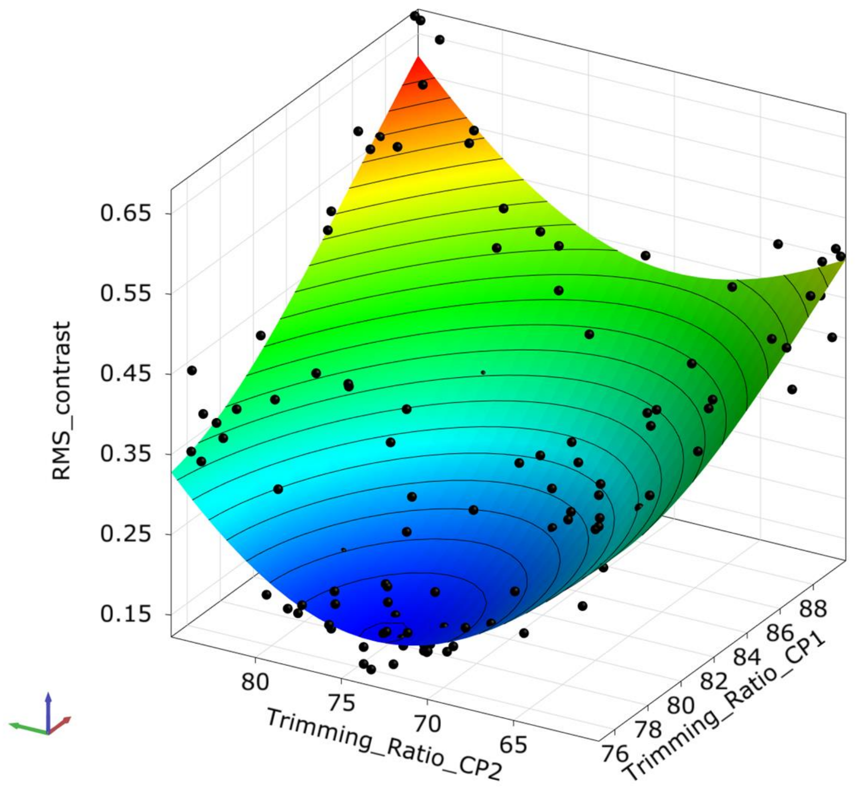


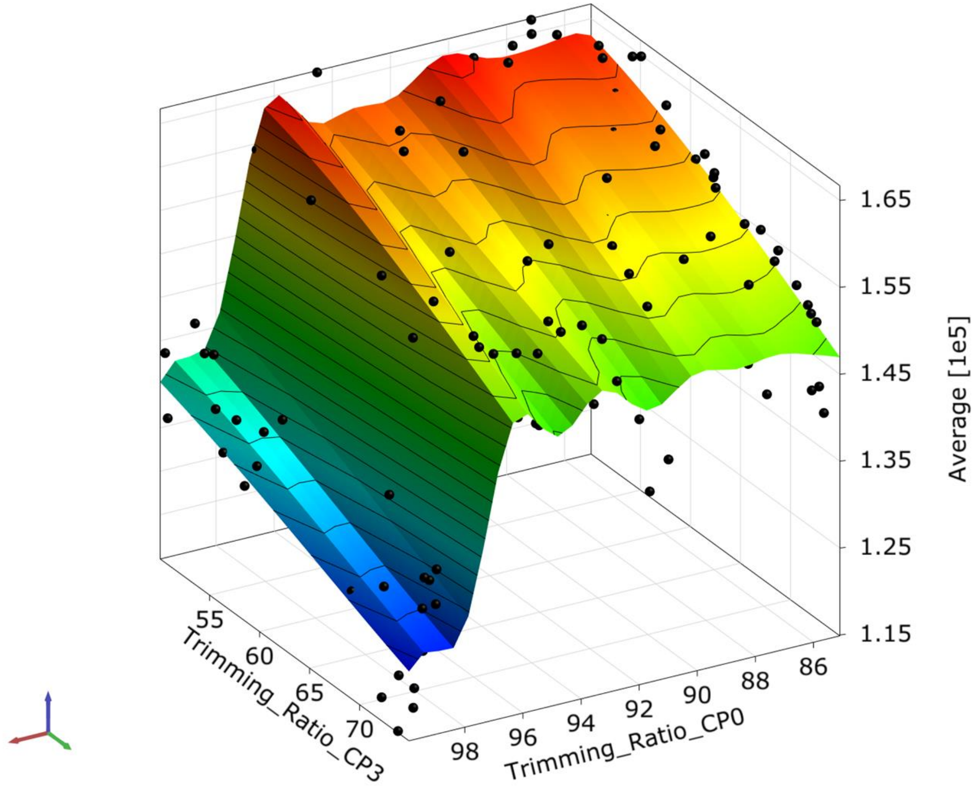




Results Sensitivity analysis

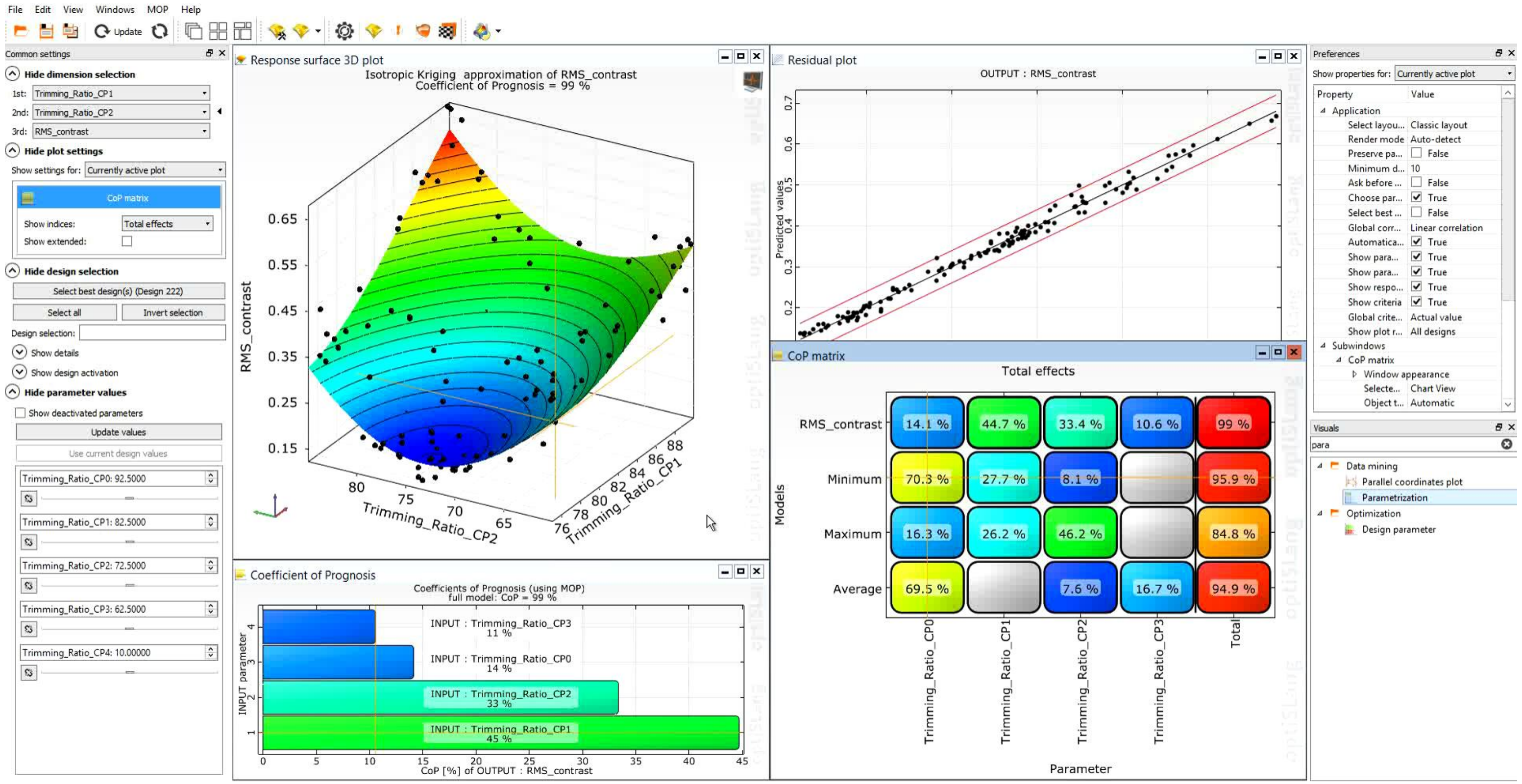
- Metamodels





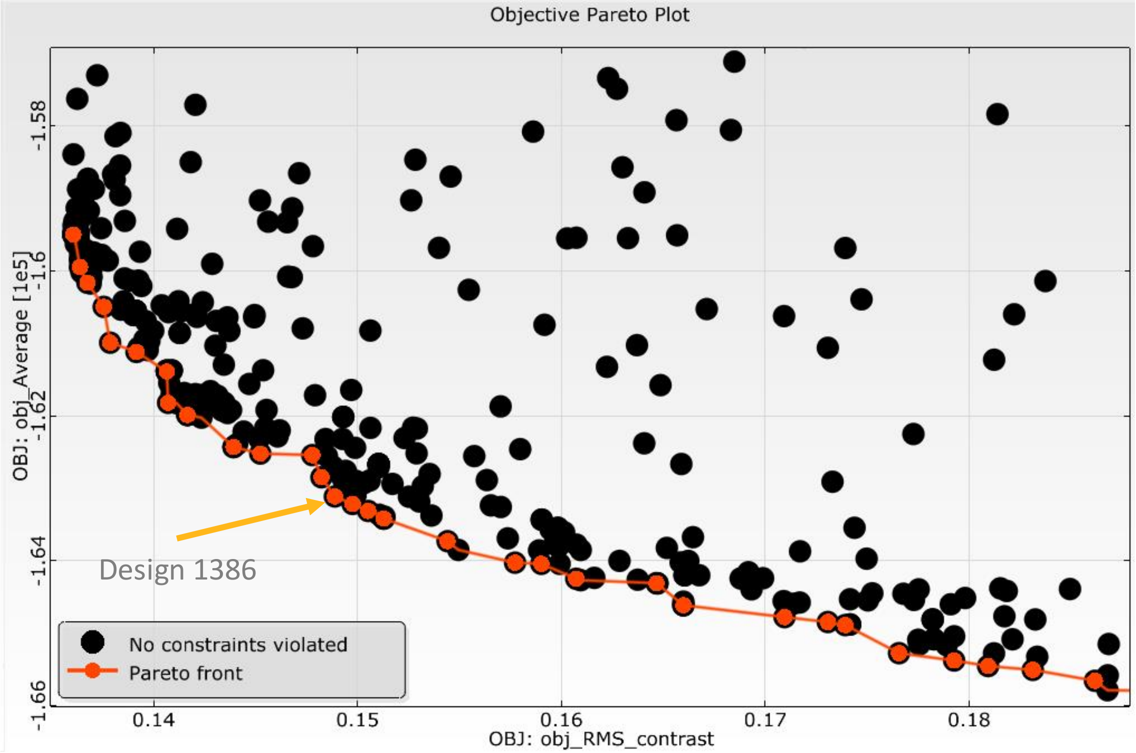
Results Sensitivity analysis

- Postprocessing of the sensitivity analysis in optiSLang



Results optimization

- **Fast optimization** on Metamodel
- **Trade off** between RMS-contrast and average gets visible
- Choose a best design (in this case no. 1386)
- Verification of best design(s) with SPEOS simulation in an **automated manner**



Results optimization

- Best design chosen from the optimization

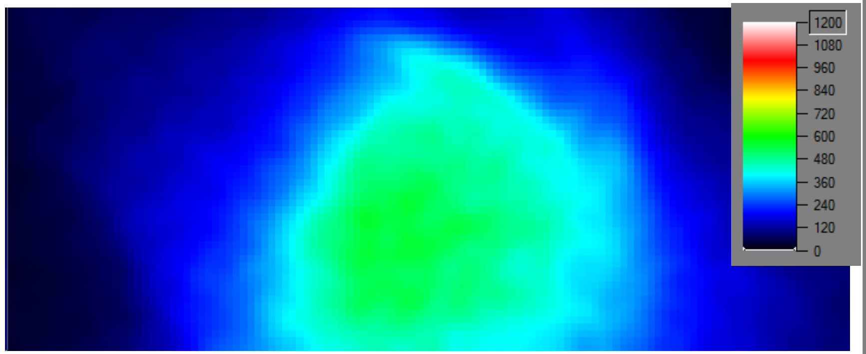
Geometry parameter

Light_Guide_StartAngle	85
Light_Guide_Width	2
Speos_Light_End_Angle_CP0	11
Speos_Light_End_Angle_CP1	11
Speos_Light_End_Angle_CP2	12.69
Speos_Light_End_Angle_CP3	13.88
Speos_Light_End_Angle_CP4	15.43
Speos_Light_End_Angle_CP5	17.69
Trimming_Ratio_CP0	86.3163
Trimming_Ratio_CP1	76.7445
Trimming_Ratio_CP2	69.5204
Trimming_Ratio_CP3	52.5202
Trimming_Ratio_CP4	7.50777

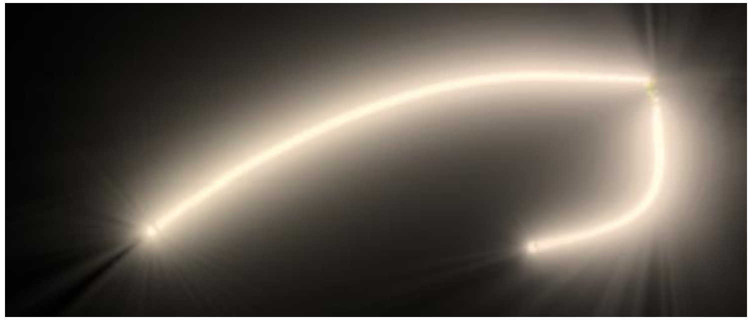
all Regulations with status: passed

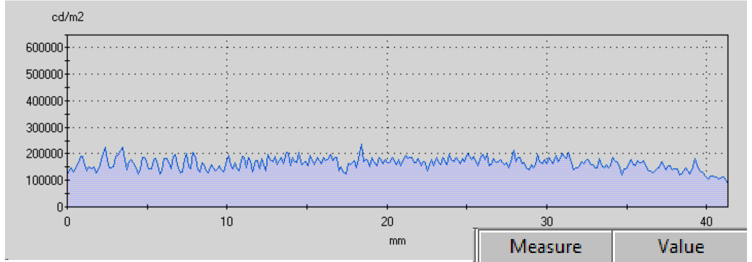
Area	Value	Rule	Minimum	Maximum	Minimum Specification	Maximum Specification
Beam_pattern	70.1479 cd	Beam_pattern_1 (passed)	1 [1]			
	563.584 cd	Beam_pattern_2 (passed)		1200 [1200]		1000 [1000]
5D-20L	142.944 cd	5D-20L_1 (passed)	40 [40]		60 [60]	
	142.944 cd	5D-20L_2 (passed)		1200 [1200]		1000 [1000]
H-20L	159.324 cd	H-20L_1 (passed)	100 [100]		150 [150]	
	159.324 cd	H-20L_2 (passed)		1200 [1200]		1000 [1000]
5U-20L	130.04 cd	5U-20L_1 (passed)	40 [40]		60 [60]	
	130.04 cd	5U-20L_2 (passed)		1200 [1200]		1000 [1000]
5D-10L	383.088 cd	5D-10L_1 (passed)	80 [80]		120 [120]	

Intensity distribution



Lit appearance and cross section analysis





Measure	Value
RMS_contrast	0.144106
Average	163147 cd/m2
Minimum	91002 cd/m2
Maximum	236709 cd/m2

Robustness analysis of the lightguide

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- Parametrization:
  - **Inputs**:
    - Trimming ratio
    - Level of polishing
    - energy light source (Flux)
    - Milling radius
  - **Outputs**:
    - RMS contrast
    - Average [cd/m²]
    - Minimum [cd/m²]
    - Maximum [cd/m²]
    - Number of failed Rules
  - **Constraint**
    - Number of failed Rules = 0

	Name	Parameter type	Reference value	PDF	Type	Mean	Std. Dev.	CoV	Distribution parameter
1	Flux	Stochastic	200		TRUNCATEDNORMAL	268.827	36.6272	13.6248 %	280; 45; 1; 330
2	Milling	Stochastic	0.3		NORMAL	0.3	0.054	18 %	0.3; 0.054
3	Trimming_ratio	Stochastic	1		NORMAL	1	0.03	3 %	1; 0.03
4	Level_polishing	Stochastic	0.15		TRUNCATEDNORMAL	1.5	0.716259	47.7506 %	1.5; 0.9; 0; 3

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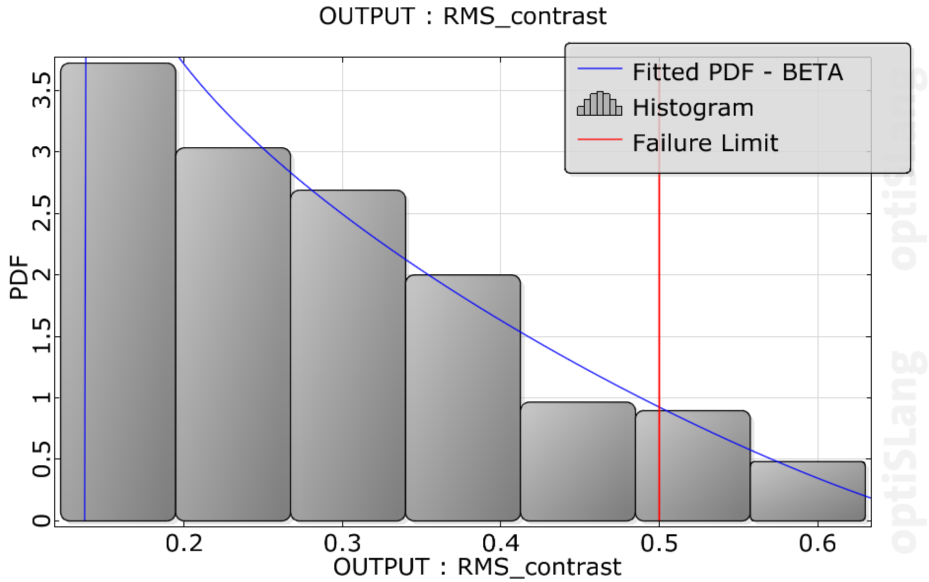
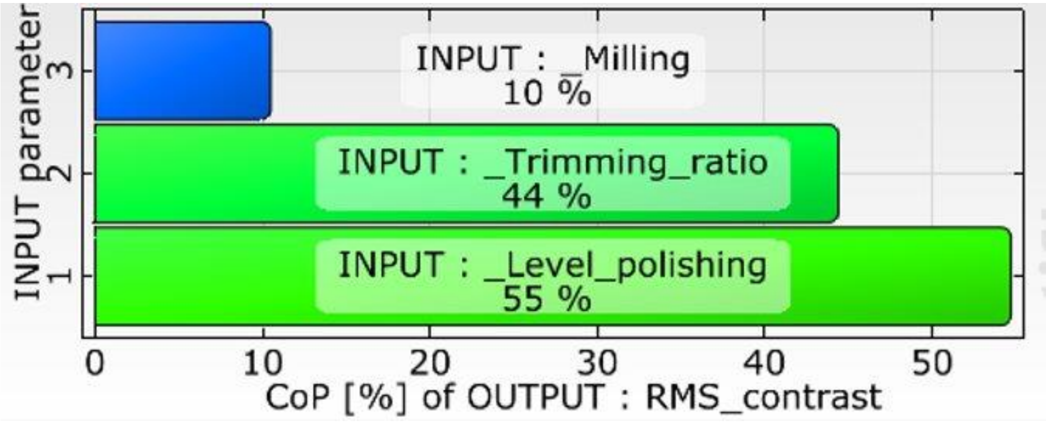
Robustness analysis of the lightguide

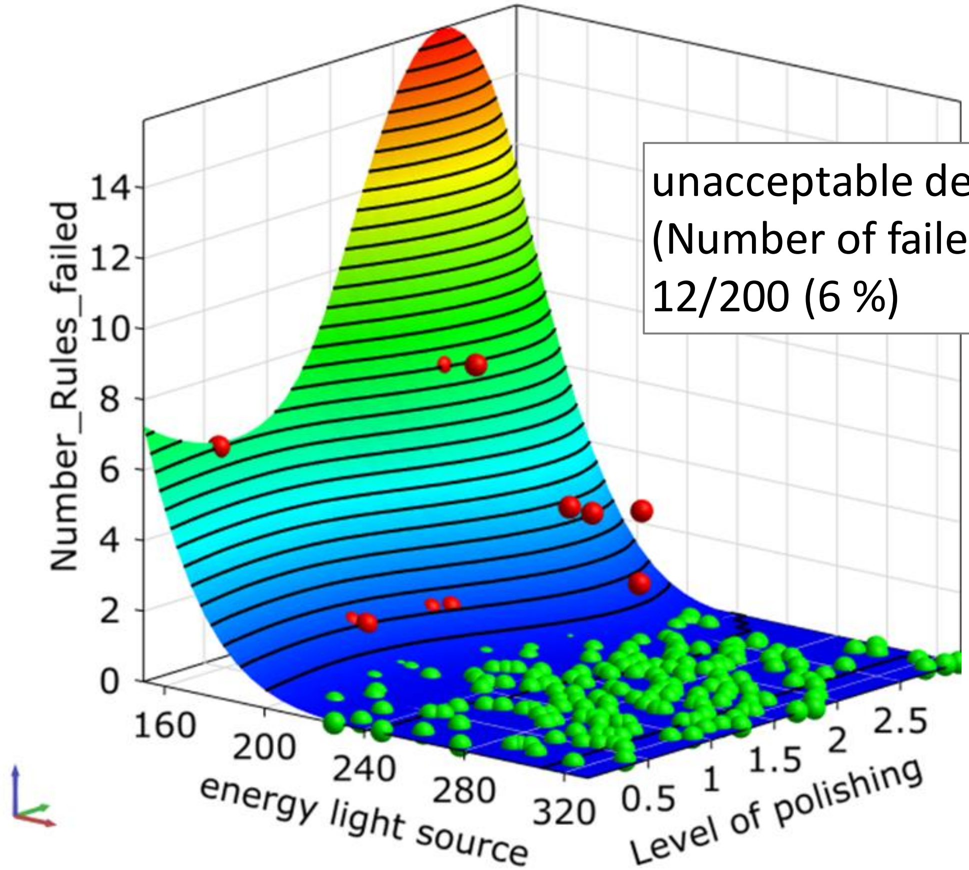
- Results



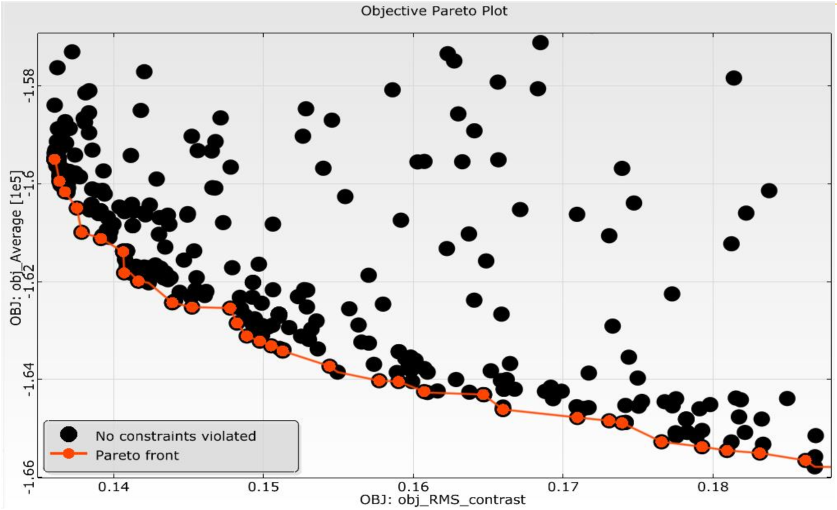
Statistical data			
Min:	0.12213	Max:	0.630073
Mean value:	0.292409	Standard deviation:	0.121909
CoV:	0.416914		
Skewness:	0.7631	Excess kurtosis:	-0.254197

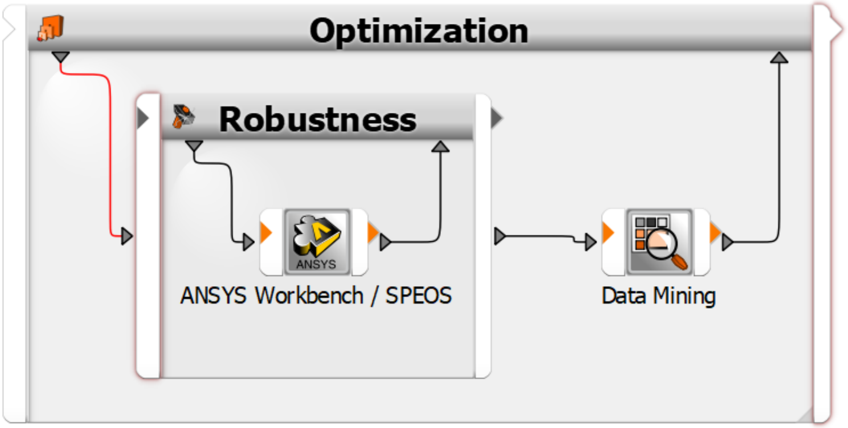


Robustness analysis of the lightguide



unacceptable designs
(Number of failed Rules > 0):
12/200 (6 %)





Robust design optimization in a full automated manner

Multidisciplinairy Robust Design Optimization Strategy

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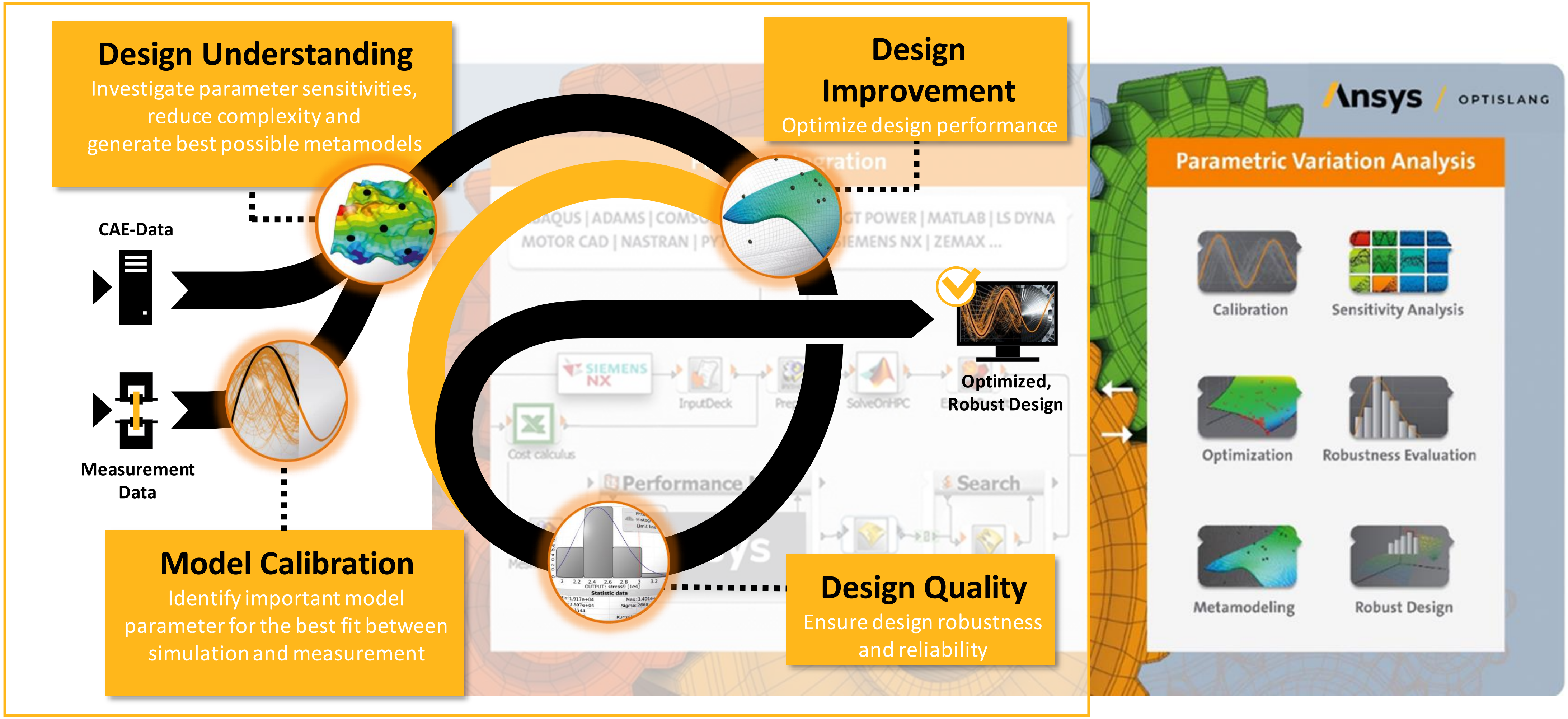

Daytime running lamp

Robust Design Optimization of a Lightguide

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Customer Goals

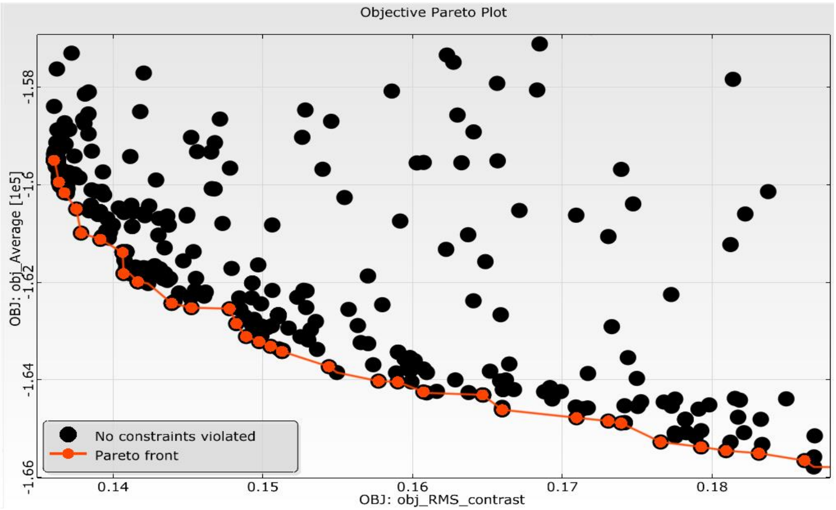
- Achieve a high number of requirements for
  - **Optimization:**
    - photometric regulations,
    - customer specifications,
    - homogeneous lit appearance
  - **Robustness:** insensitivity to tolerances

Solution

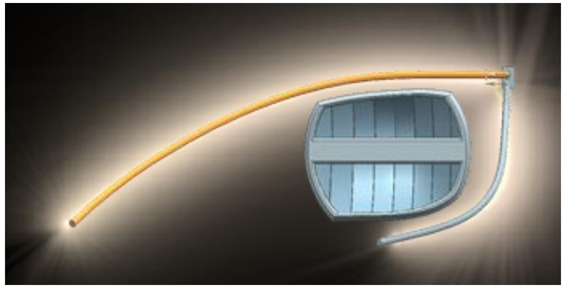
- Multi-Objective Optimization & robustness analysis with multiple criteria

Benefits

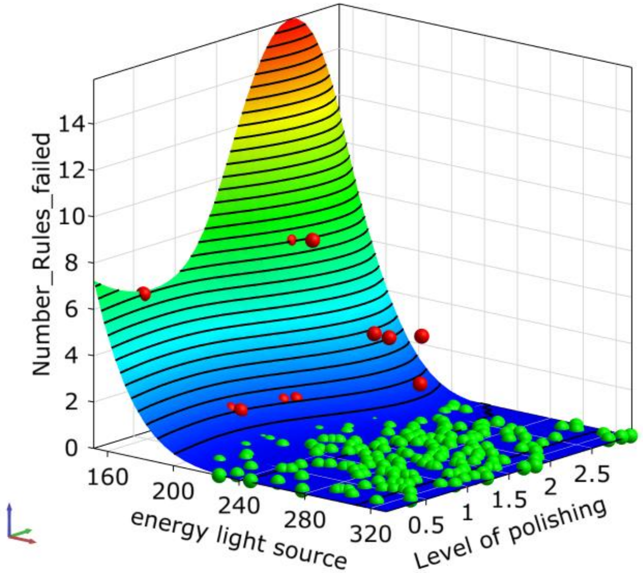
- Meet all requirements by finding the best possible trade-off automatically with a minimum number of simulations
- Much more homogeneous lit appearance (factor 10 compared to start design)



Find best trade-off between requirements



Headlamp with lightguide

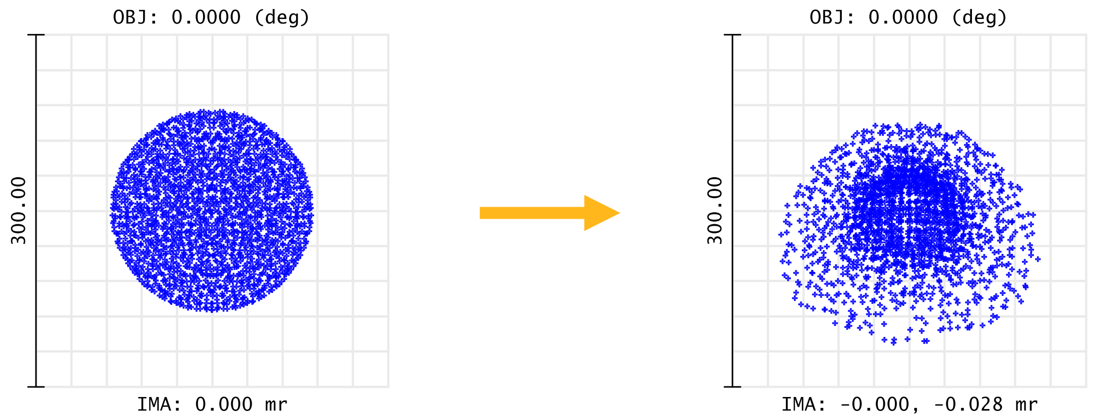


Understand where requirements are met

Optomechanical Workflow with OpticStudio STAR module, Ansys Mechanical & optiSLang

Motivation

- Thermo-mechanical effects on optical systems can dramatically reduce the system’s optical performance.
- For the optimization of optical systems the knowledge of the impact of the thermo-mechanical effects is necessary in order to match the demands under real world conditions.

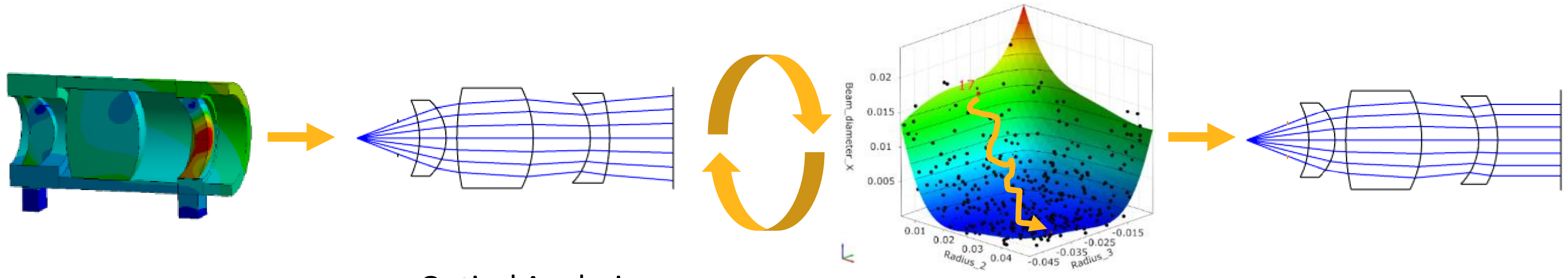


Ideal Spot

Real Spot

Motivation

- Thermo-mechanical effects on optical systems can dramatically reduce the system’s optical performance.
- For the optimization of optical systems the knowledge of the impact of the thermo-mechanical effects is necessary in order to match the demands under real world conditions.



Thermo-Mechanical Analysis

Optical Analysis

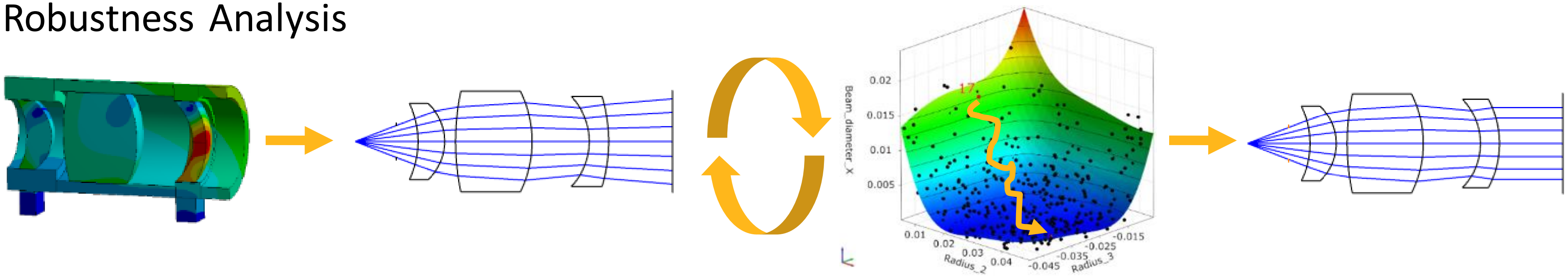
Initial Design

Design understanding with metamodeling and robust design optimization

Optimized Design

Motivation

- **Automation of workflows**
  - Integration optical and mechanical simulation tools in Ansys optiSLang
  - Built complex workflows
- **Robust Design Optimization**
  - Sensitivity Analysis
  - Optimization
  - Robustness Analysis



Thermo-Mechanical Analysis

Optical Analysis

Initial Design

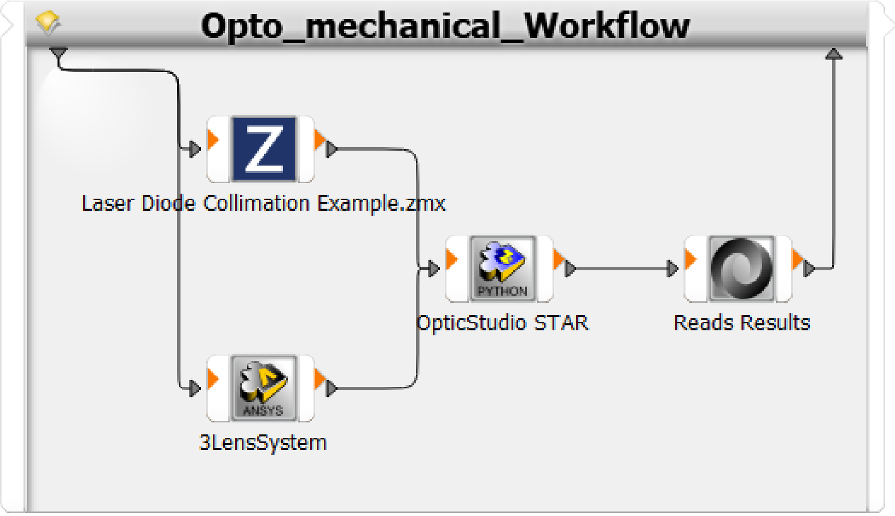
Design understanding with metamodeling and robust design optimization

Optimized Design

Simulation Tools

Integrating Optical, Structural and Thermal Physics using

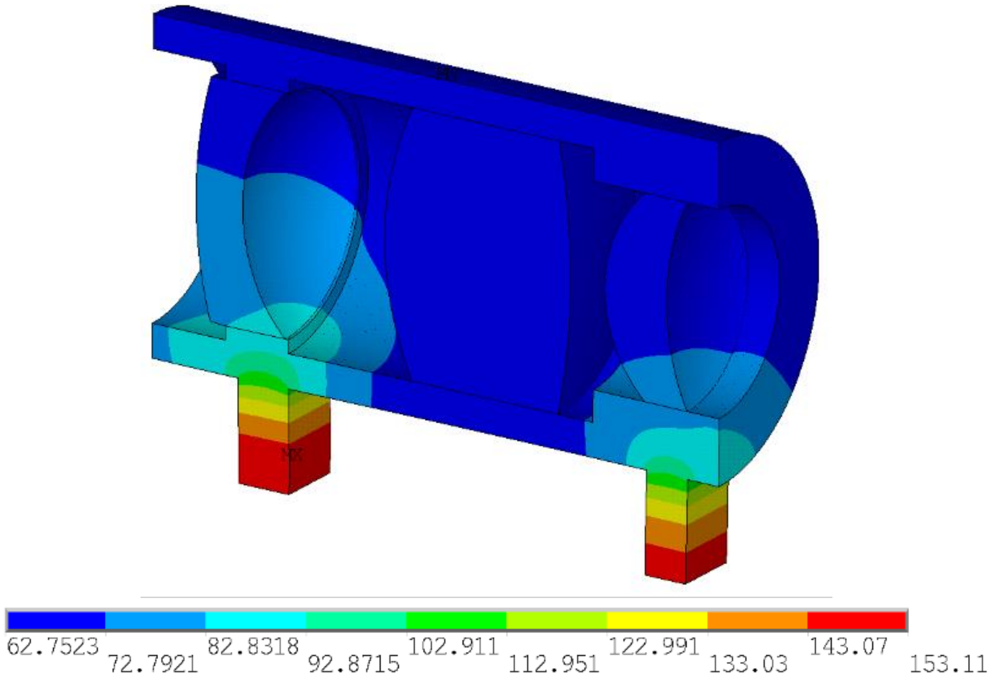
- Ansys Mechanical incl. STAR ACT
  - Thermo-Mechanical Analysis
- Zemax OpticStudio
  - Optical Analysis
- Structural, Thermal Analysis & Results module (STAR)
  - Maps thermo-mechanical data onto optical system
- Ansys optiSLang
  - Workflow Automation



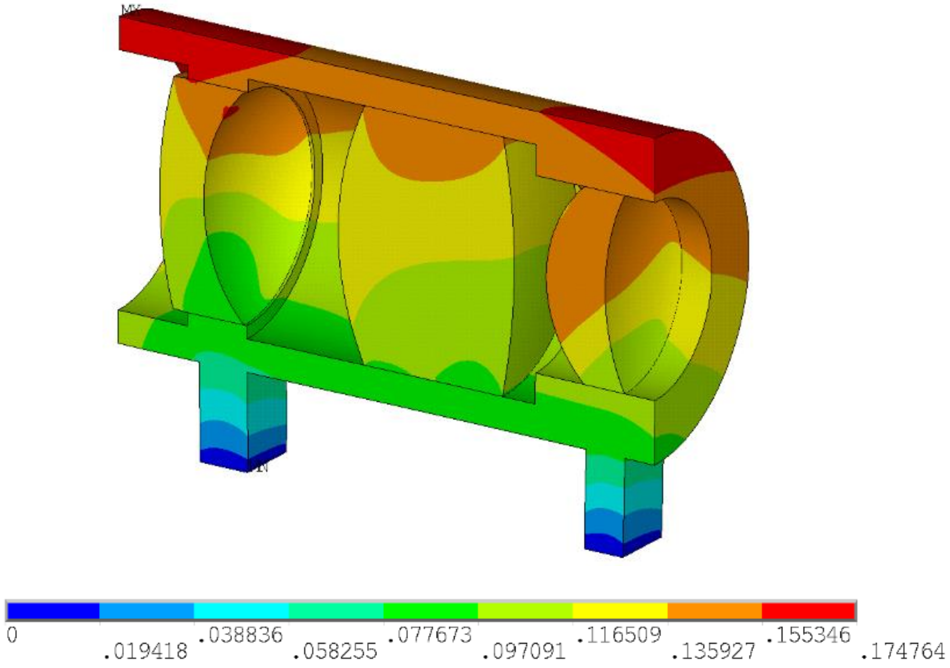
Thermal & Structural FEA

Steady-state thermal analysis for the determination of lens temperature profile due to thermal impact

Static-structural analysis for the determination of lens deformations due to lens mounting

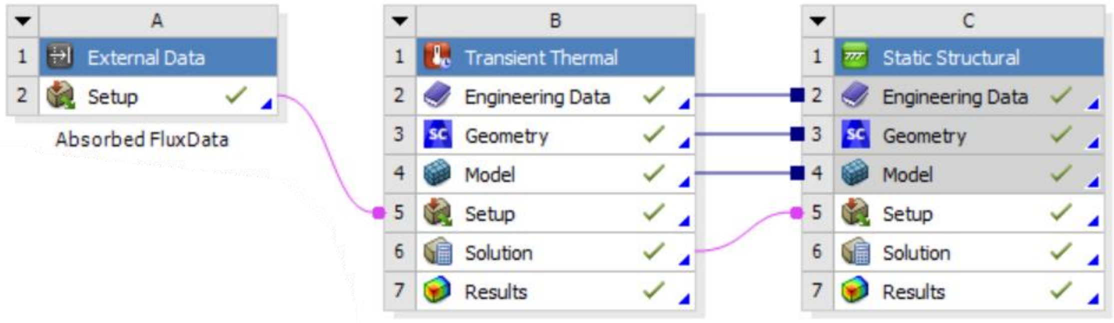


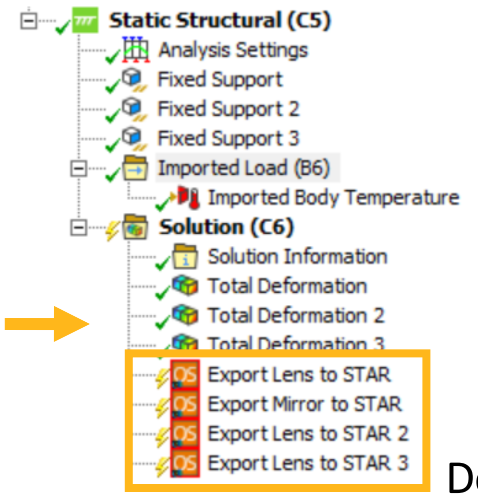
Temperature - Simulation in Ansys Mechanical

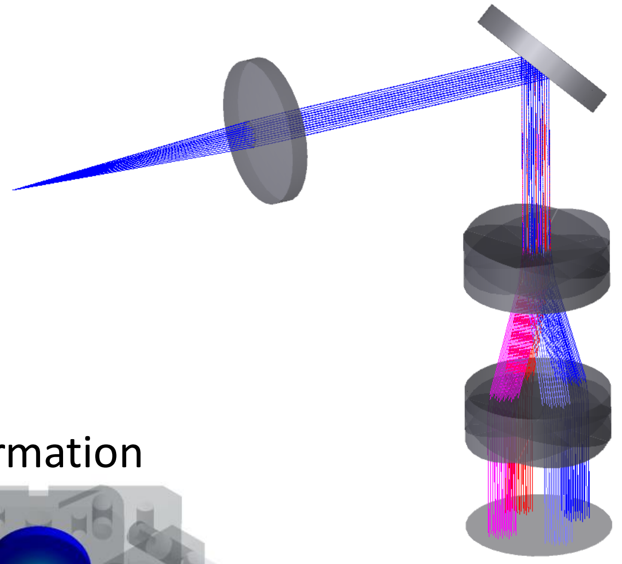


Deformation - Simulation in Ansys Mechanical

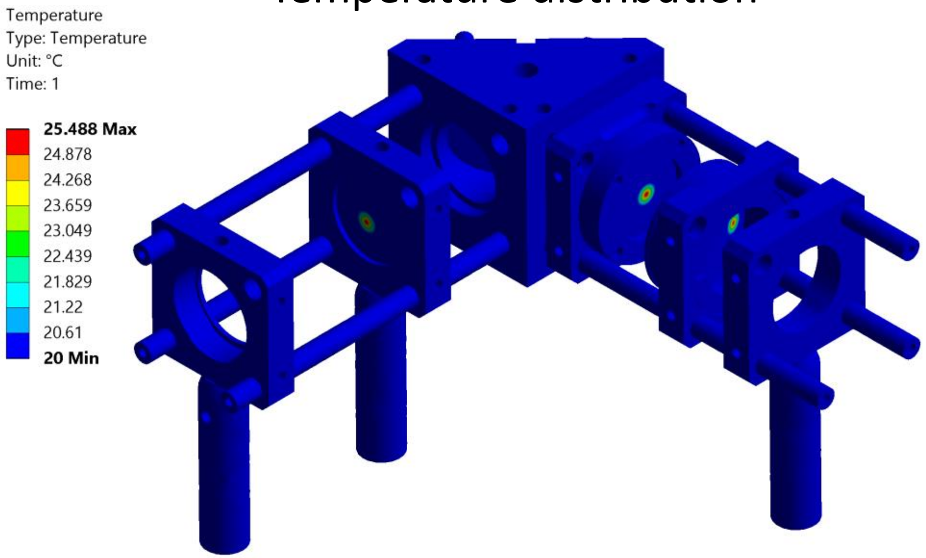
Thermal & Structural FEA



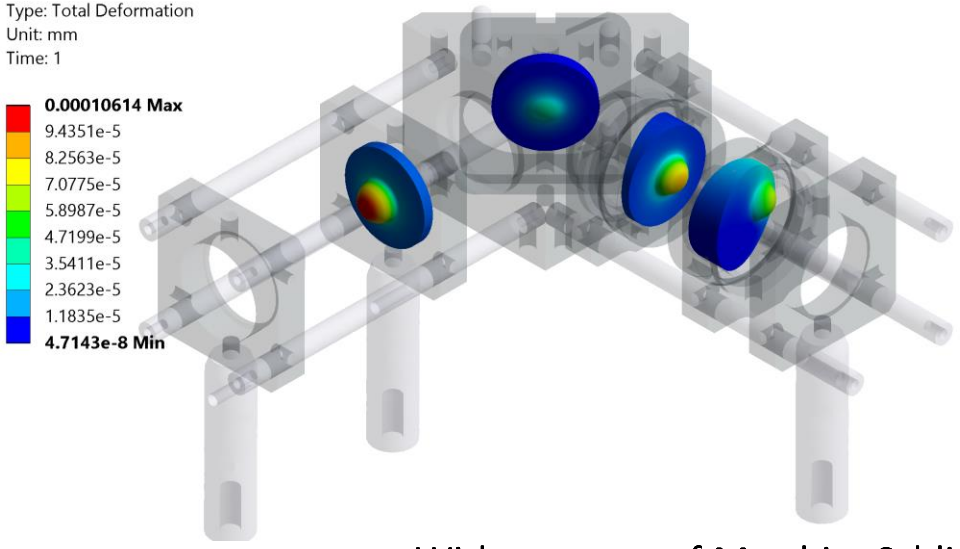




Temperature distribution

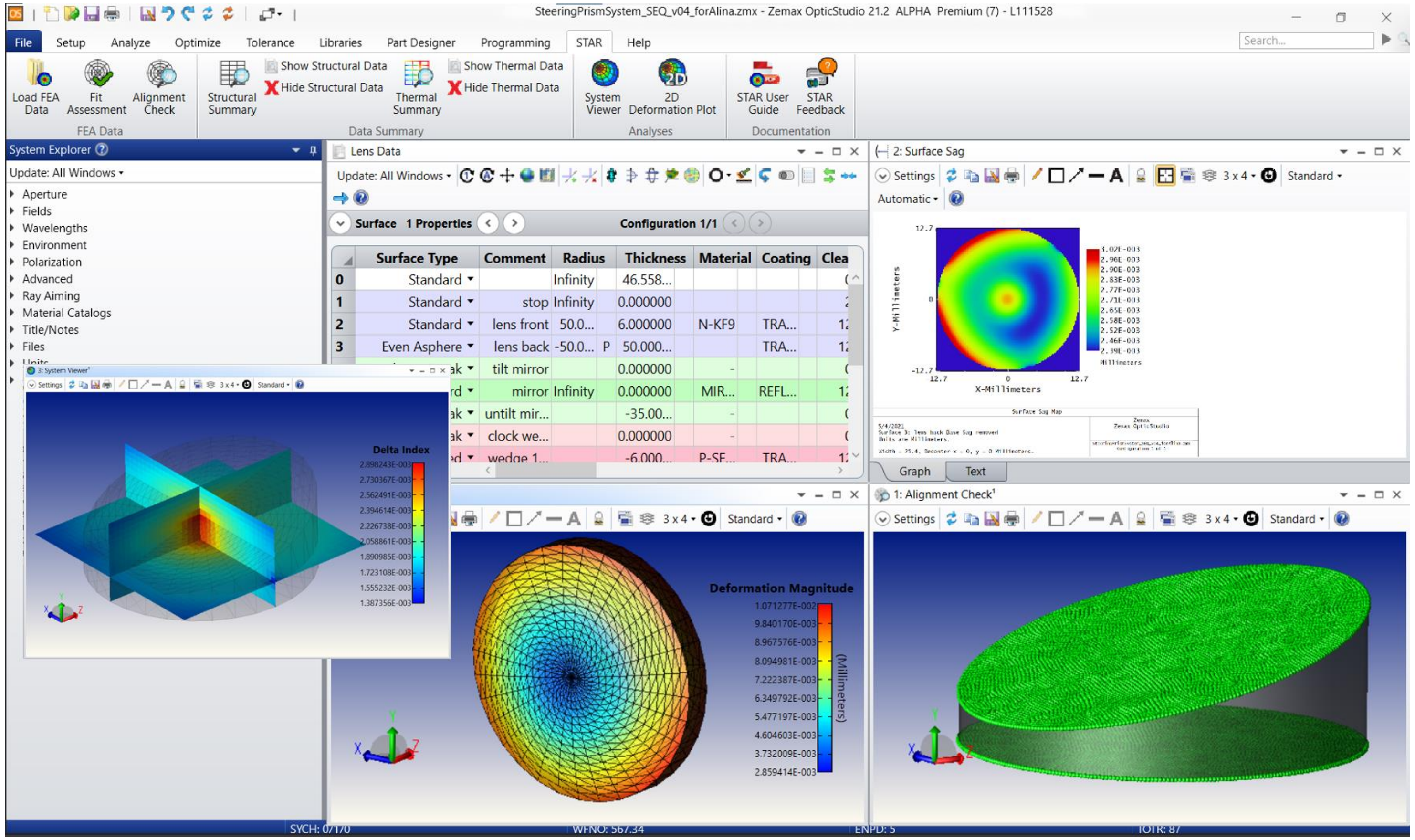


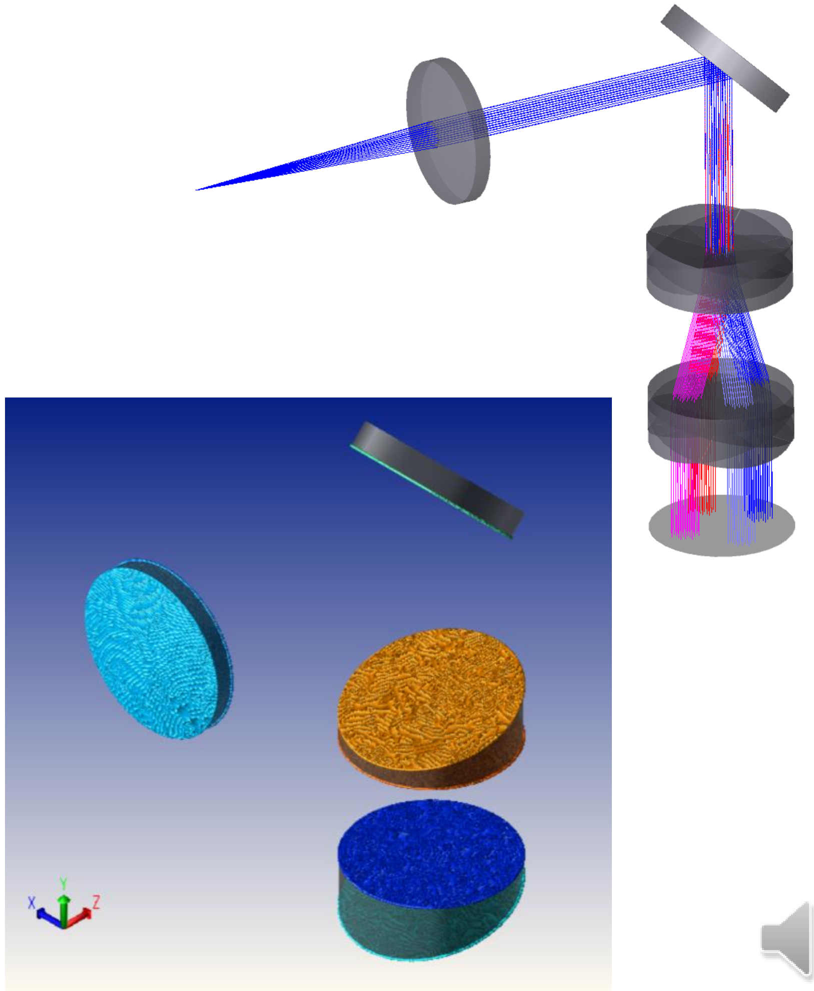
Deformation



With courtesy of Matthias Schlich, Zemax

Load FEA data into OpticStudio with STAR module





With courtesy of Matthias Schlich, Zemax

How to automate the optomechanical Analysis?

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Zemax OpticStudio

-1.96831946503	-1.88705637474	1.12034480681	28.7038192749
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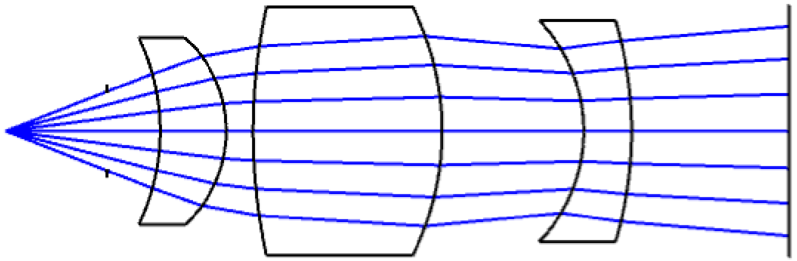
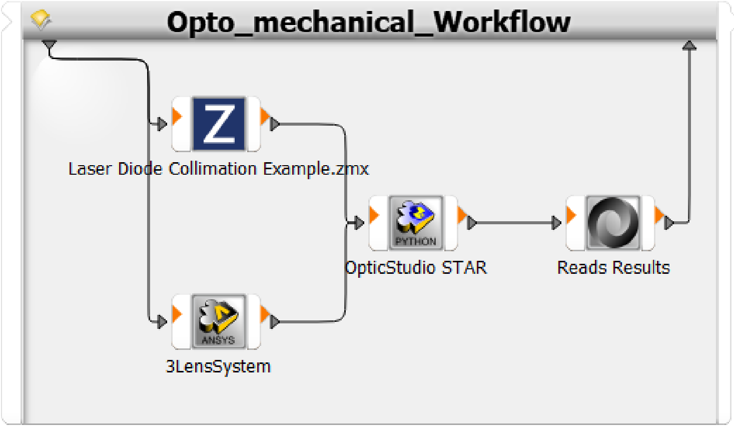




Get deformation and temperature data

- Simulate inside Ansys Mechanical
- Export results

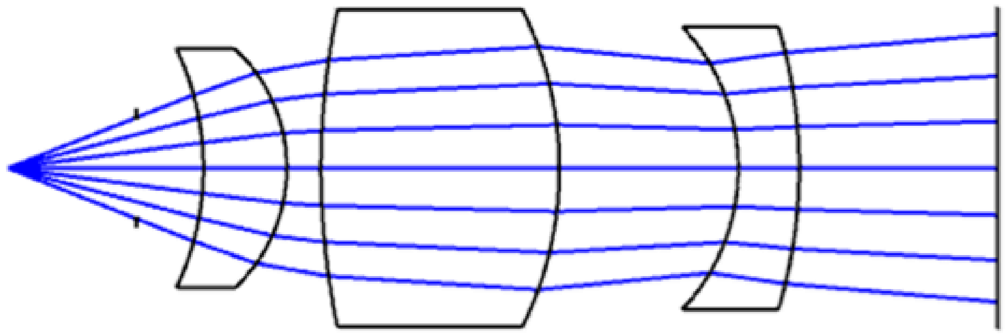
Map data onto the Geometry in Zemax OpticStudio

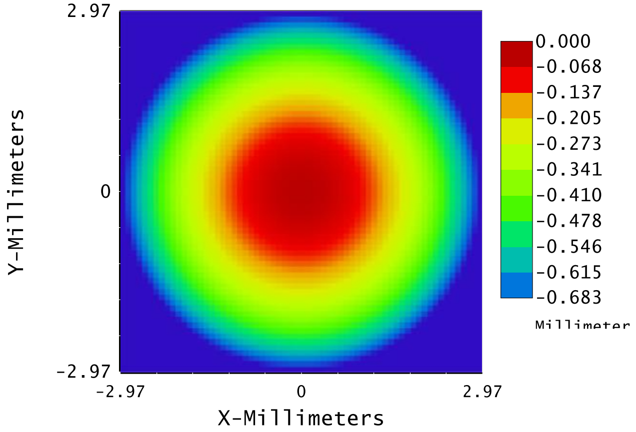
- Import geometry and thermo-mechanical results in Zemax OpticStudio
- Simulate the design

Process automation in Ansys optiSLang

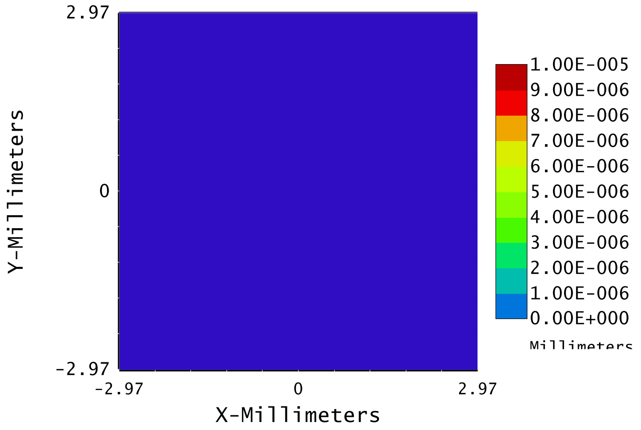
- Process automation
- Design optimization & exploration

Optical Reference Design

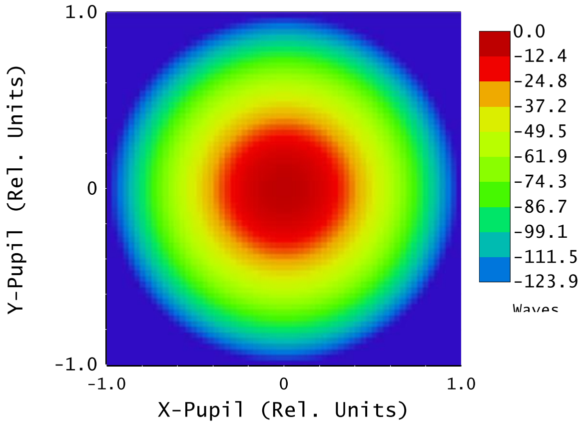




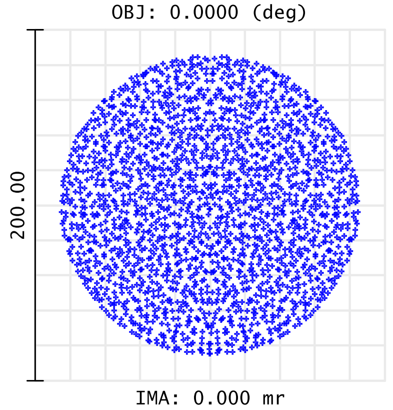
Surface Sag Map



Difference Surface Sag Map



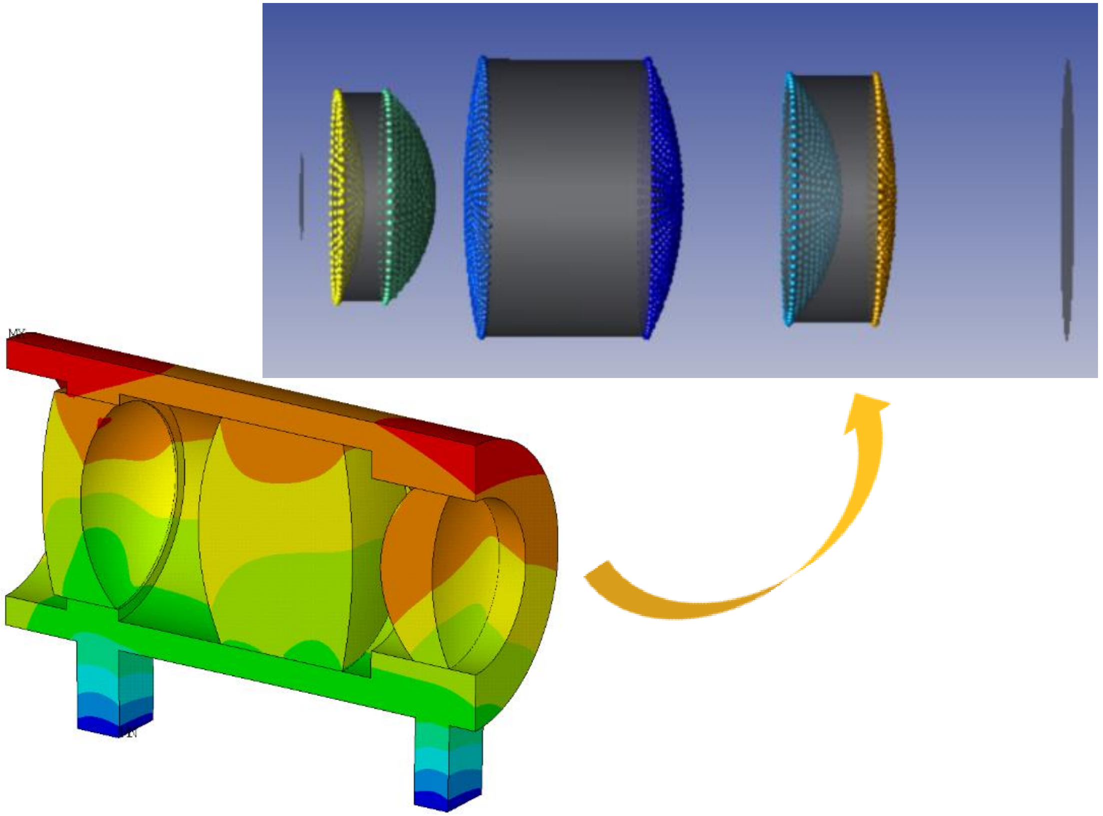
Wavefront Map



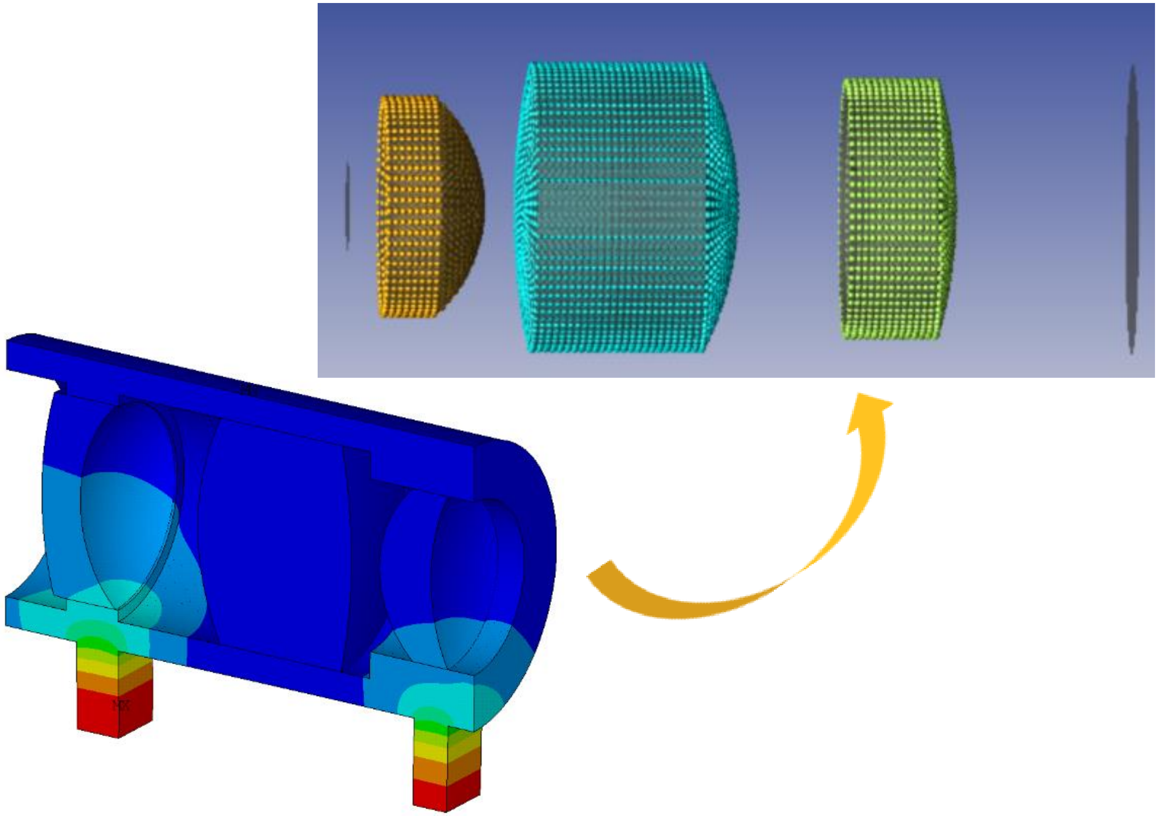
Spot Diagram

Load FEA Data

Structural deformation

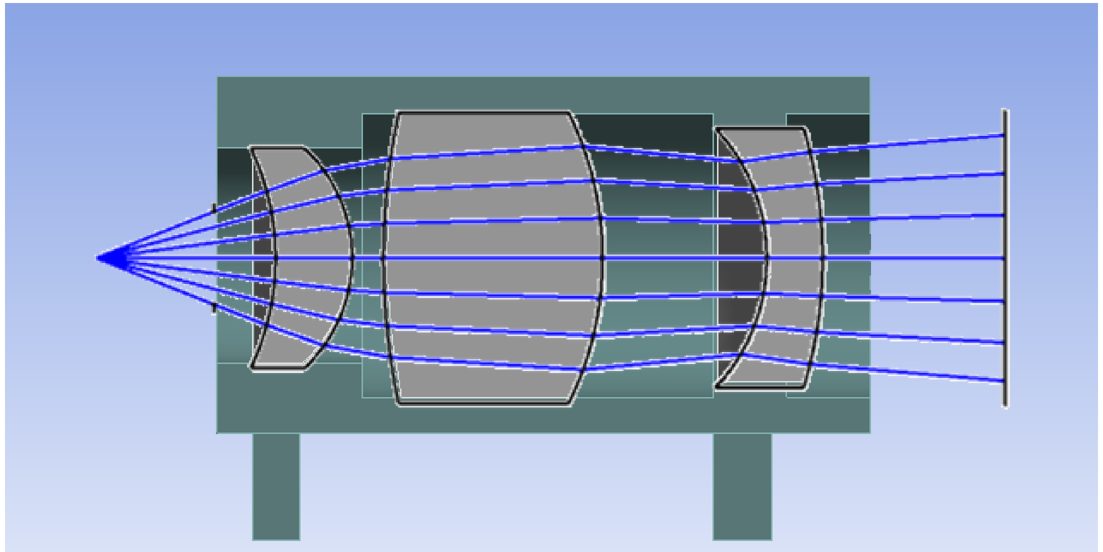


Temperature profile

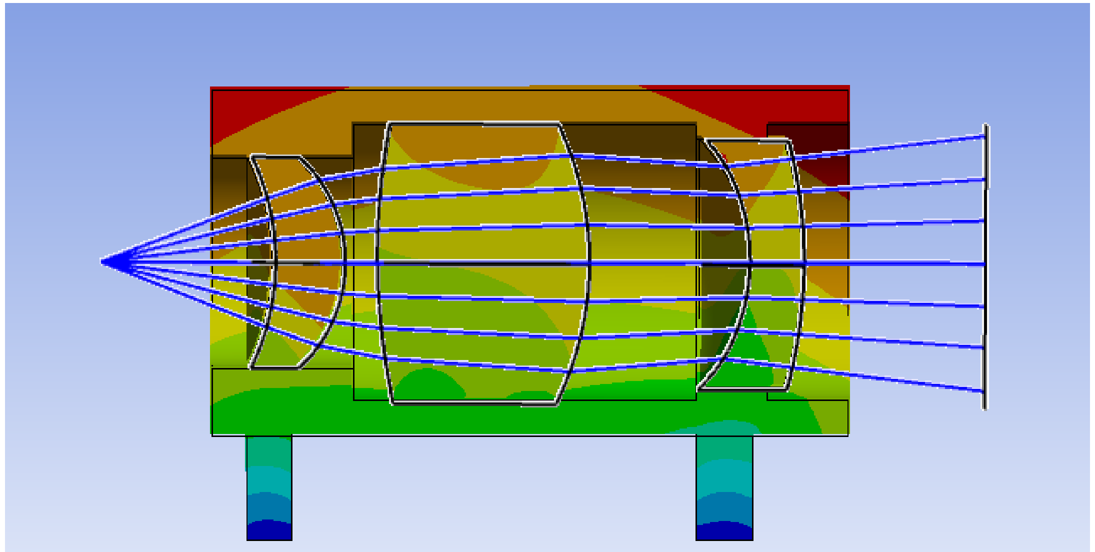


Load FEA Data

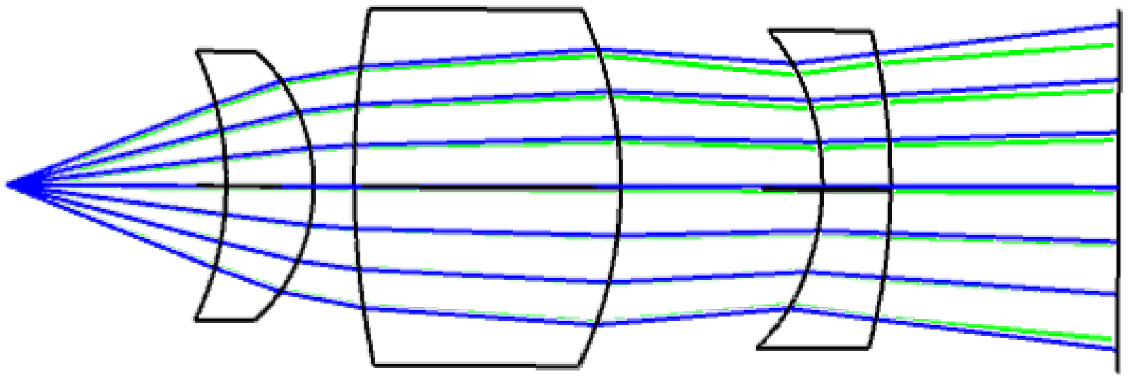
Reference design <u>without</u> thermo-mechanical data



Reference design <u>with</u> thermo-mechanical data



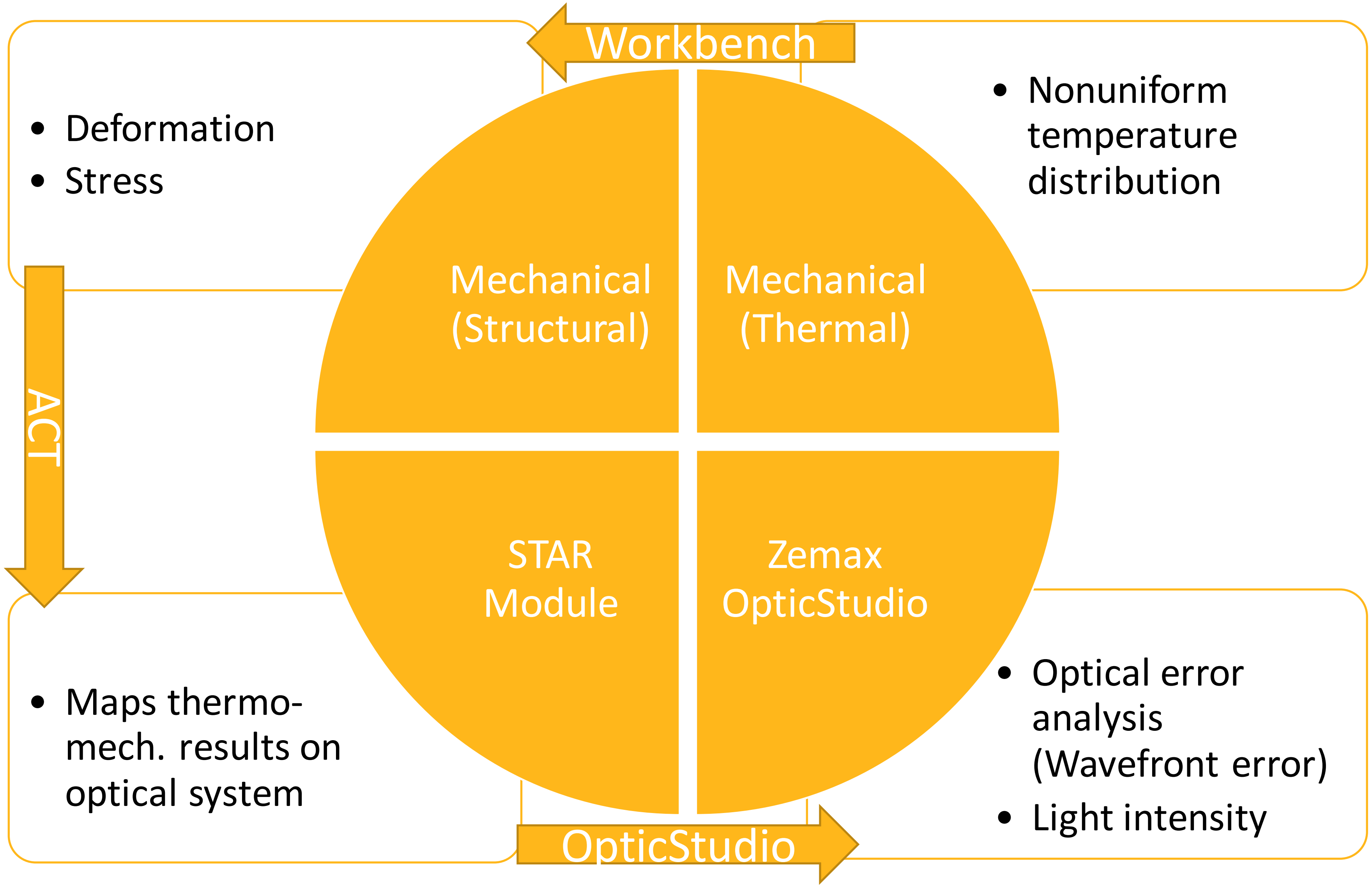
Load FEA Data



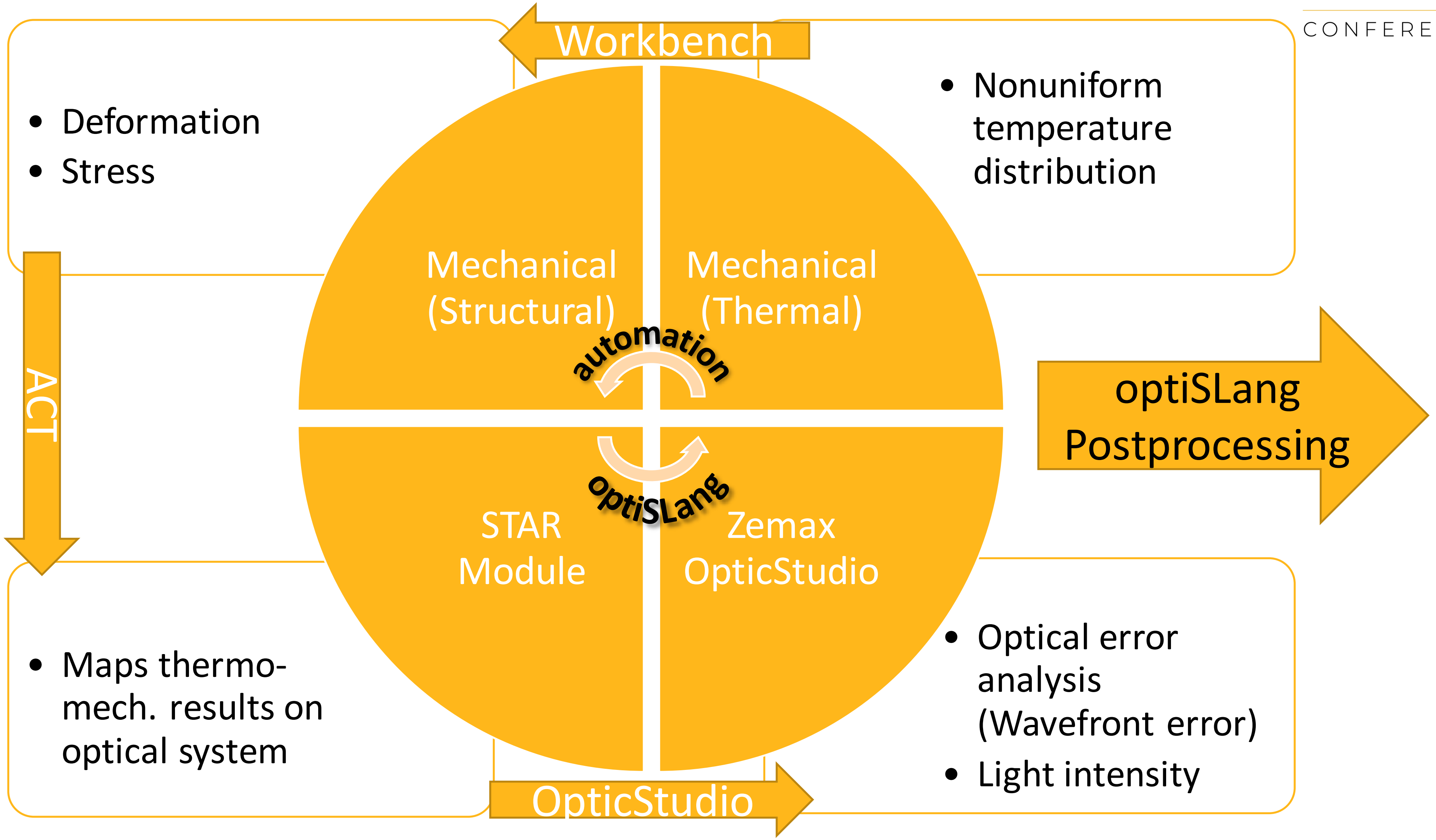
Ray path without thermo-mechanical data

Ray path with thermo-mechanical data

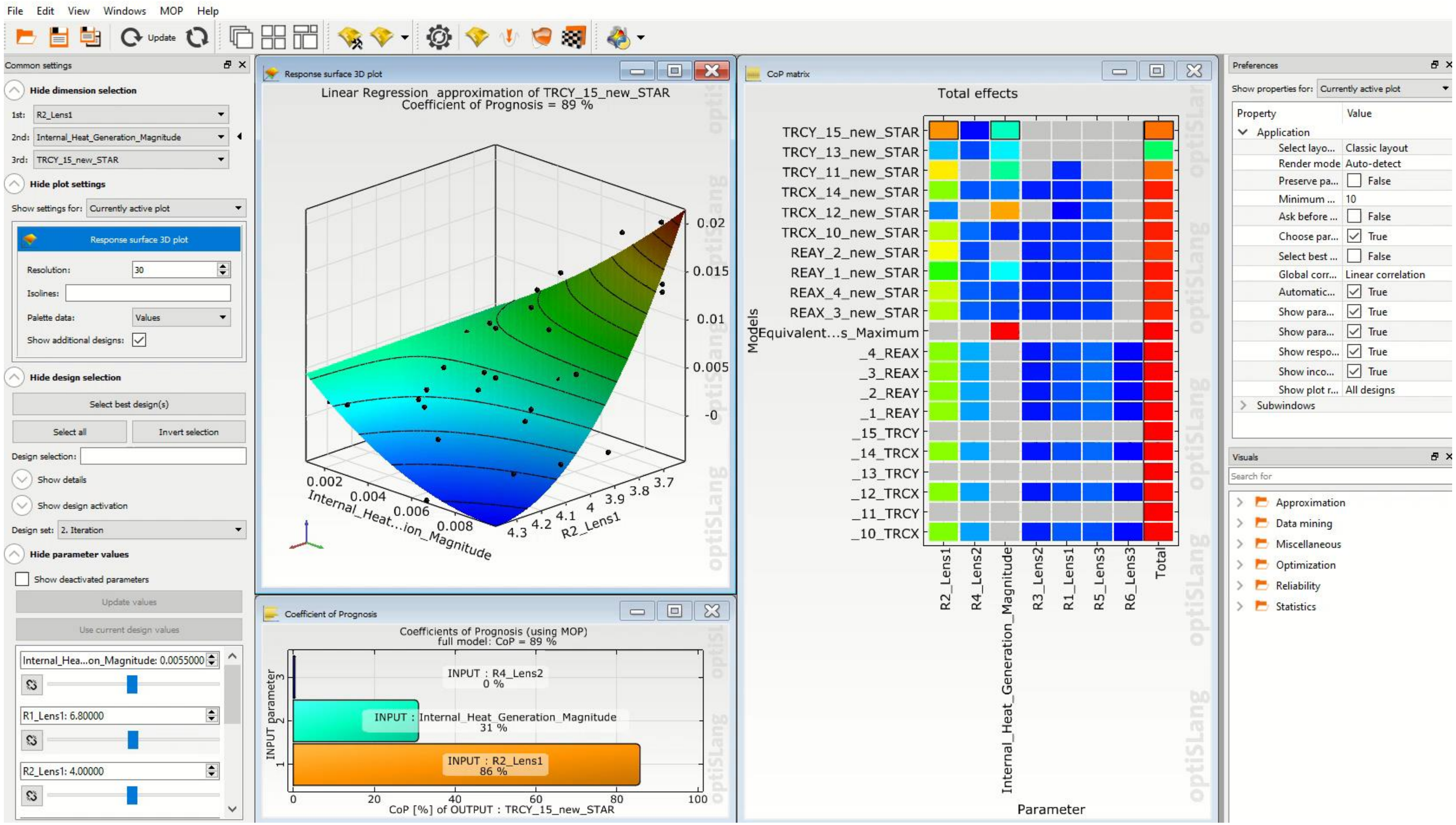
Opto-mechanical Workflow



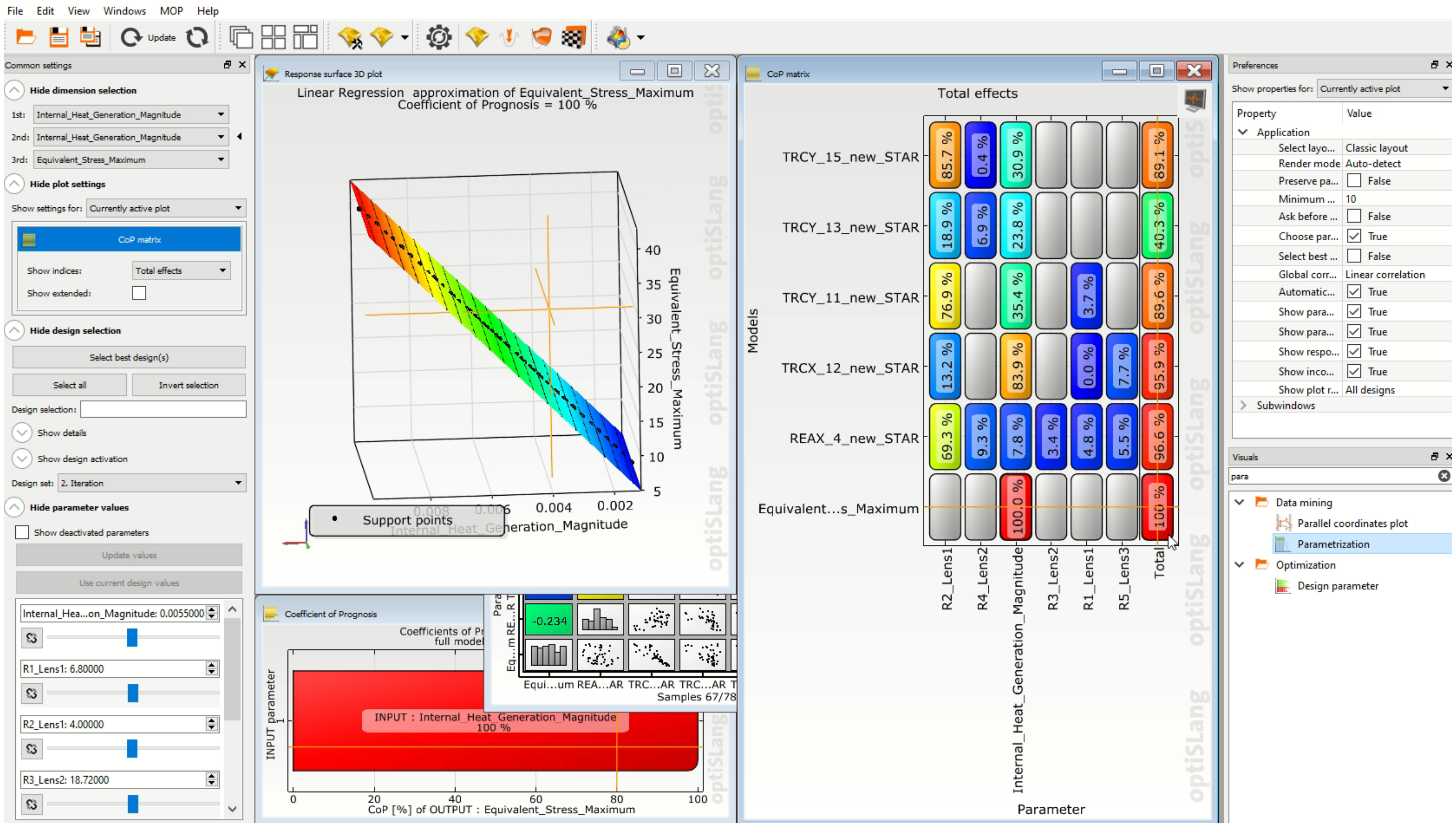
Automated opto-mechanical Workflow



Sensitivity Analysis - Demo



Sensitivity Analysis - Demo



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