Topology Optimization Result Interpretation using ANSYS optiSLang CATIA-Integration

Headquarter Research & Technology / Z-FB – Development Services

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PASSION FOR TECHNOLOGY.

Ansys WOST CONFERENCE

RHEINMETALL

Rheinmetall – **Five divisions under one roof**

VEHICLE SYSTEMS

Tactical Vehicles · Logistic Vehicles · Turrets · CBRN* Solutions

WEAPON AND AMMUNITION

Weapon and Munition · Protection Systems · Propulsion Systems

ELECTRONIC SOLUTIONS

Integrated Electronic Systems · Air Defence and Radar Systems · Technical Publications · Cyber Security

SENSORS AND ACTUATORS

Pumps · Actuators · Air Emission Systems · Solenoid Valves · Commercial Diesel Systems

MATERIALS AND TRADE

Trade · Bearings · Castings (50:50 Joint Venture)

*Chemical, Biological, Radiological and Nuclear

Key figures **2020**

5,875 **Sales** € million

426 **Operating Result** € million

301 **Capital Expenditure** € million

25,329 **Employees**

13.4 **Order Backlog** € billion

6.3 **R&D Intensity** %

Agenda

- Motivation & Project Background
- CATIA & optiSLang
- Use Case Example & Results
- Summary & Conclusion

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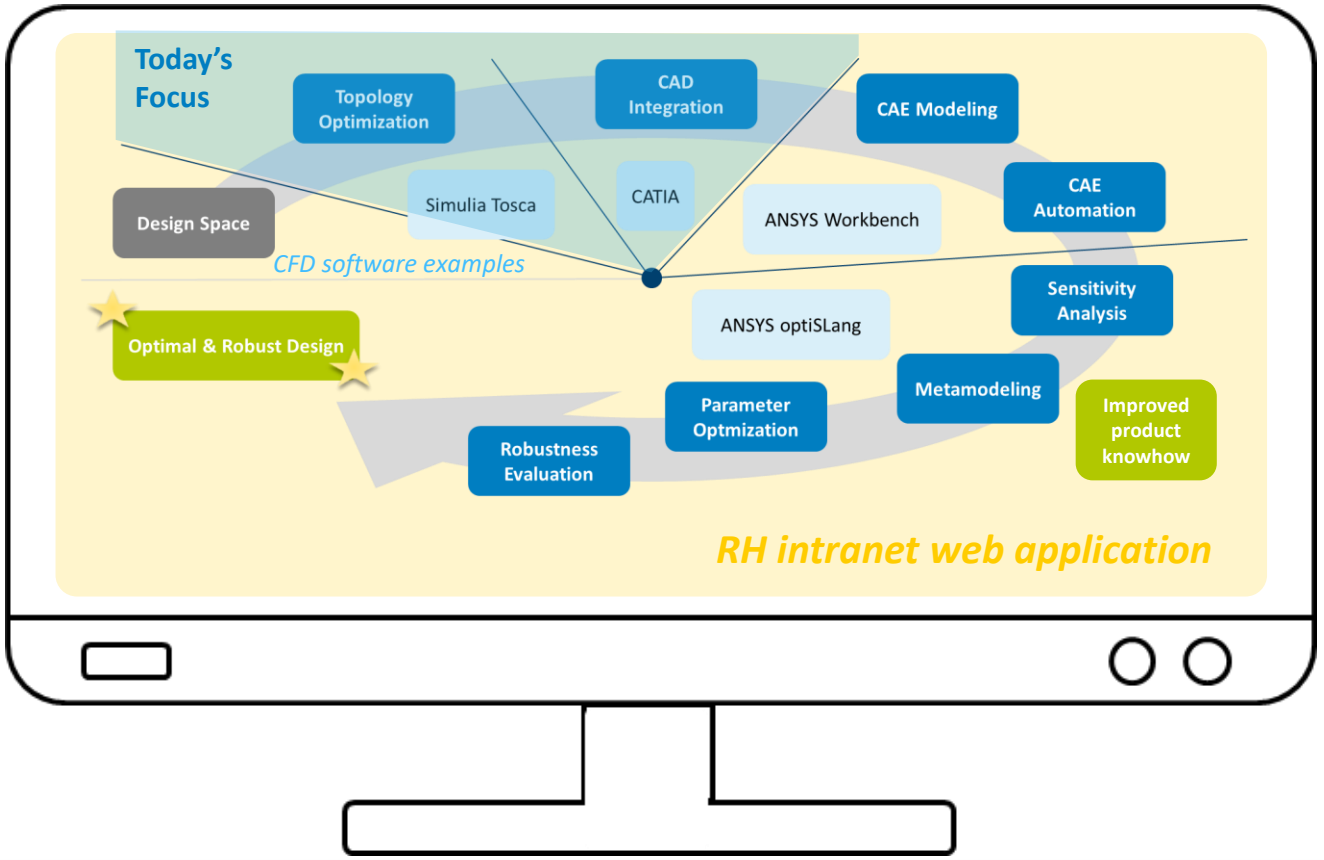
Continuous Workflow @ RH S+A Simulation

From Topology Optimization to Robustness Evaluation

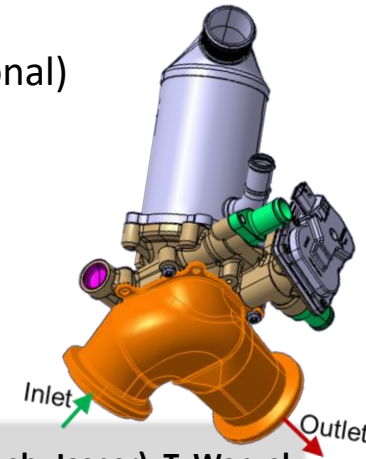


- Simulation-driven design optimization
- Modular setup: usage of numerous CAE software (FEA, CFD, MATLAB, …)
- Frontloading: Support product development processes already in concept phase.

Methodological framework

- Parametric CAE models (n-dimensional)
- Automated CAE workflows
- Variance-based sensitivity analysis
- Metamodeling (ROM)

→ **Enabler for high-quality non-expert simulation.**

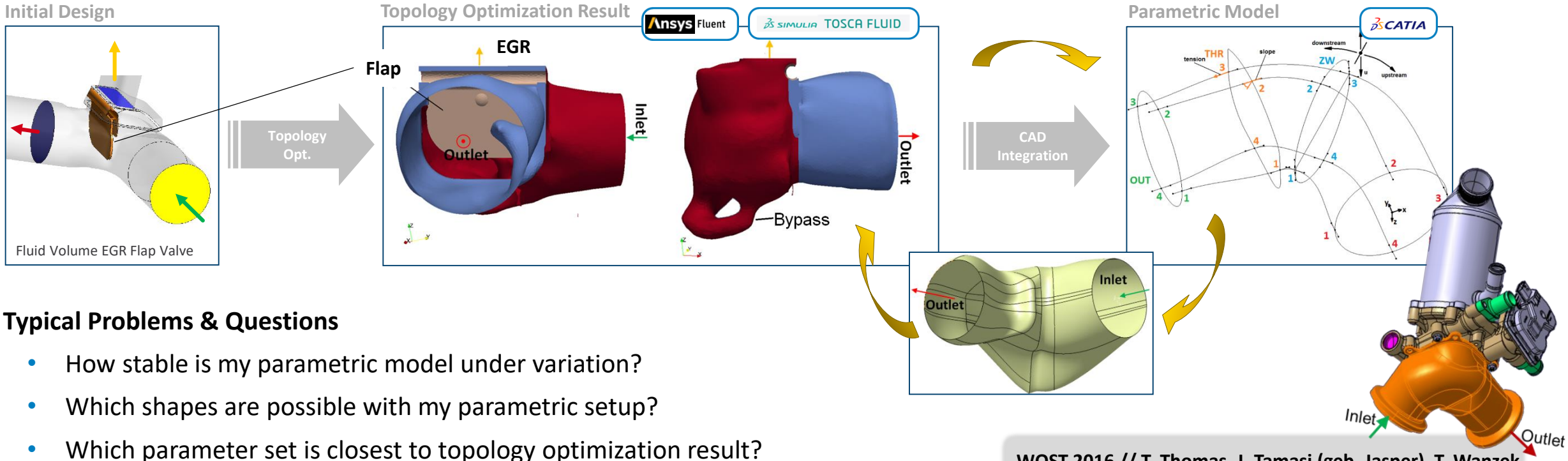


WOST 2016 // T. Thomas, J. Tamasi (geb. Jasper), T. Wanzek
Numerische Strömungsoptimierung eines AGR-Klappenventils

Early innovative design concepts & substantiated suggestions for improvements.

Motivation

Typical Workflow



Typical Problems & Questions

- How stable is my parametric model under variation?
- Which shapes are possible with my parametric setup?
- Which parameter set is closest to topology optimization result?
- …

WOST 2016 // T. Thomas, J. Tamasi (geb. Jasper), T. Wanzek
Numerische Strömungsoptimierung eines AGR-Klappenventils

Need for relief in defining appropriate parametric setup for variants analysis.

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CATIA & optiSLang

Technology

- New in optiSLang v8.0 (beta status)
- Python-based interface
- Uses CATIA COM-interface for parameter exchange
- CATIA start in batch

Possible Use Cases

- **Geometry return after topology optimization**
- Stability check for parametric CATIA model under stochastic variation
- Collision detection between parts with varying contours
- Pre-optimization (i.e. cross-sectional area characteristic)
- …

Benefits

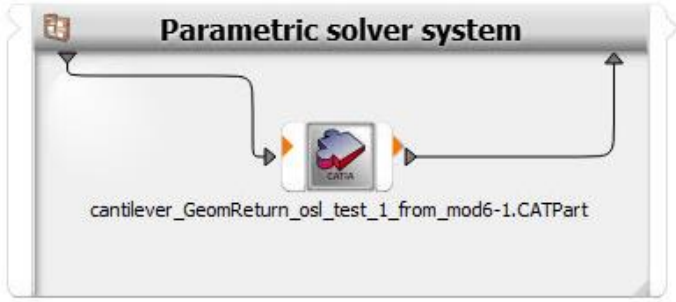
- Direct coupling with CATIA (no DesignModeler etc.)
- Only CATIA & optiSLang license required (no CADnexus etc.)
- Quick setup & parameter registration
- Design evaluation only needs seconds → candidate for direct optimization (i.e. NOA)
- Automatic design screenshots (+ registration for postprocessing)

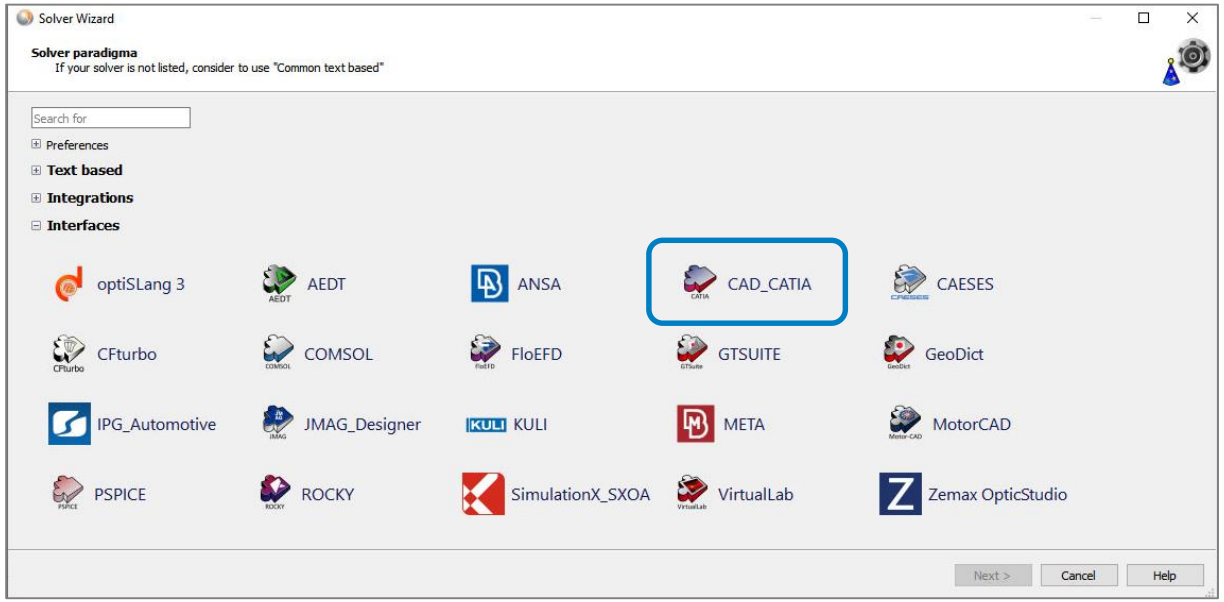
Direct, python-based interface. Comfortable usage. Many use cases.

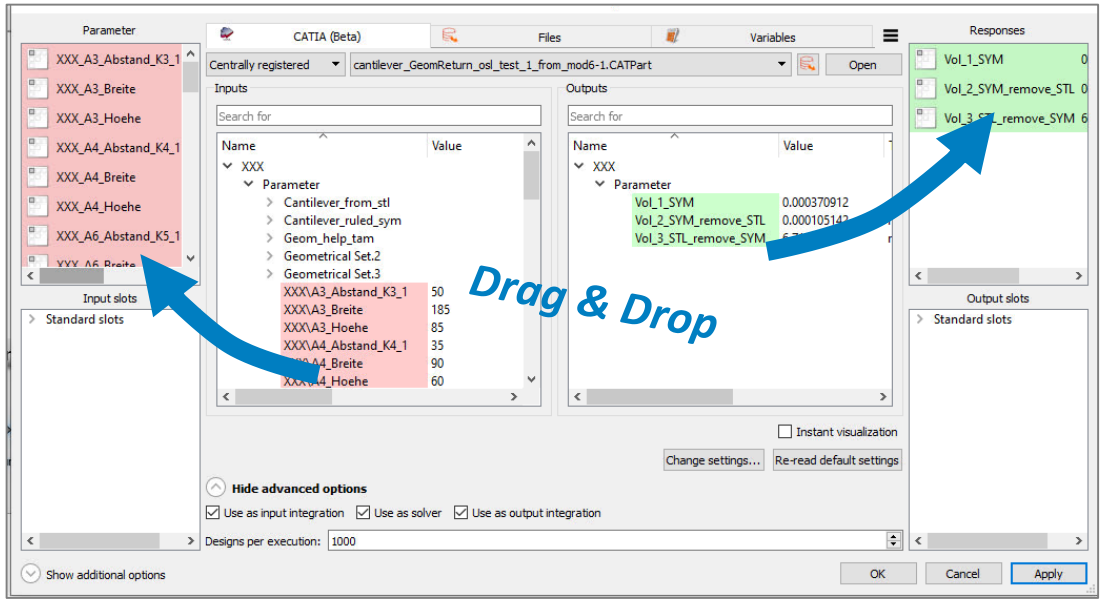
Preparation Effort

@ CATIA → Define parametric CAD model.

@ optiSLang → Use solver wizard!







Main effort is on defining the parametric CAD model in CATIA.

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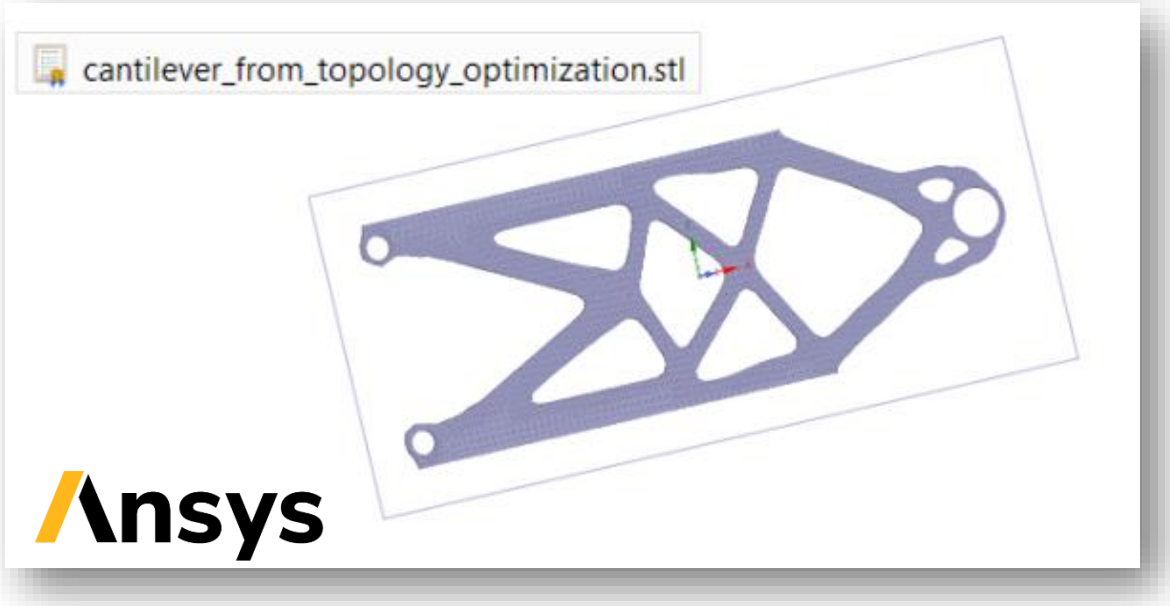
Example for present talk

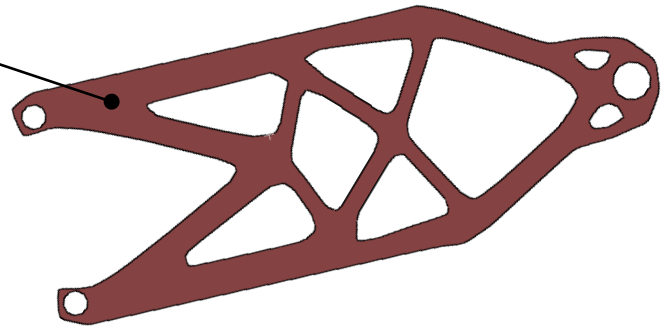
ANSYS cantilever



- STL from ANSYS Learning Hub
- No IP Restrictions & easy to understand

Preparation work @ RH S+A simulation

- Create volume body from STL
  (i.e. NURBS technology)
  = template



- Setup parametric CAD model
- Boolean operation (“Remove”) → measure for deviation between parametric body and template
- Coupling with optiSLang using solver wizard

Optimization task: find parametric set which represents template the best.

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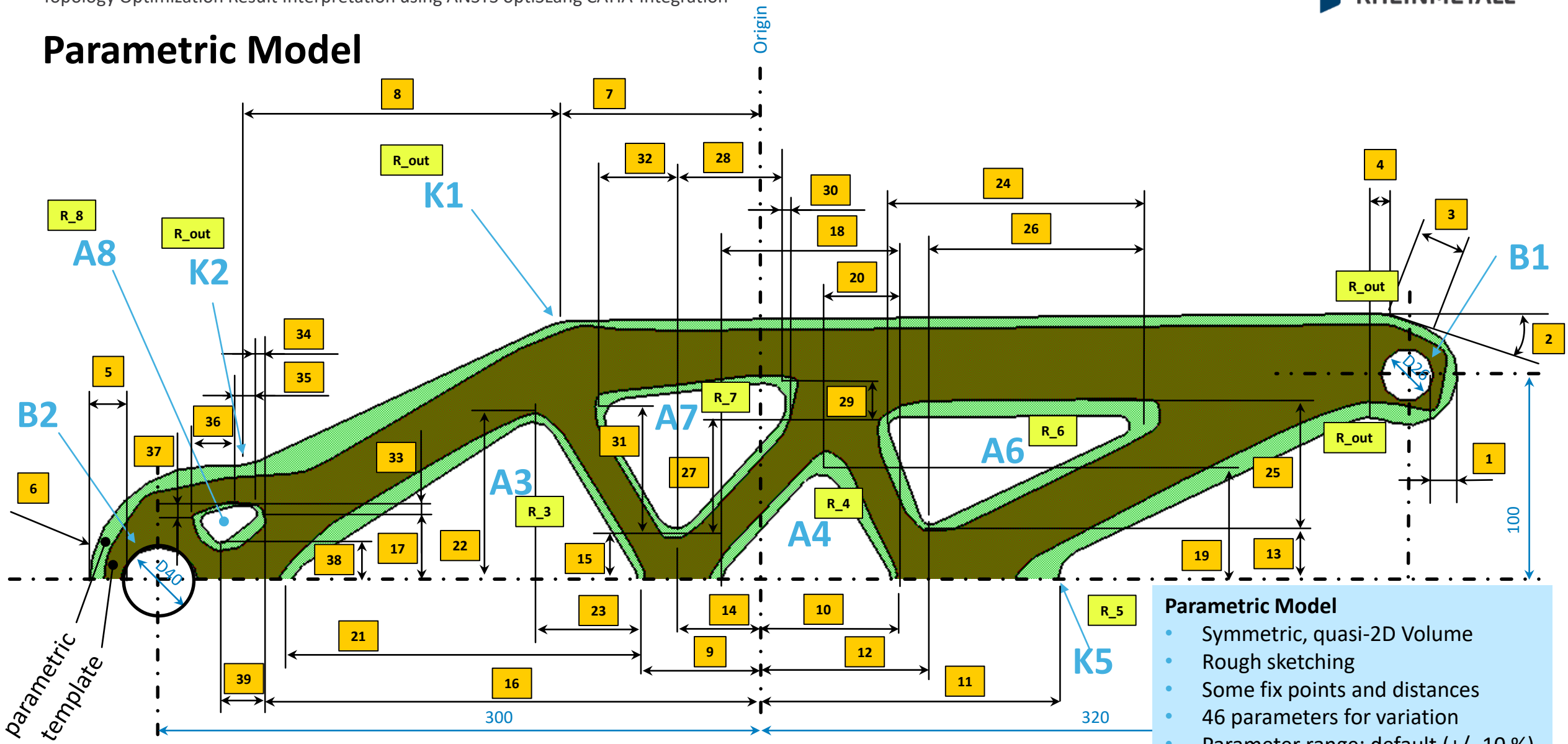
Parametric Model

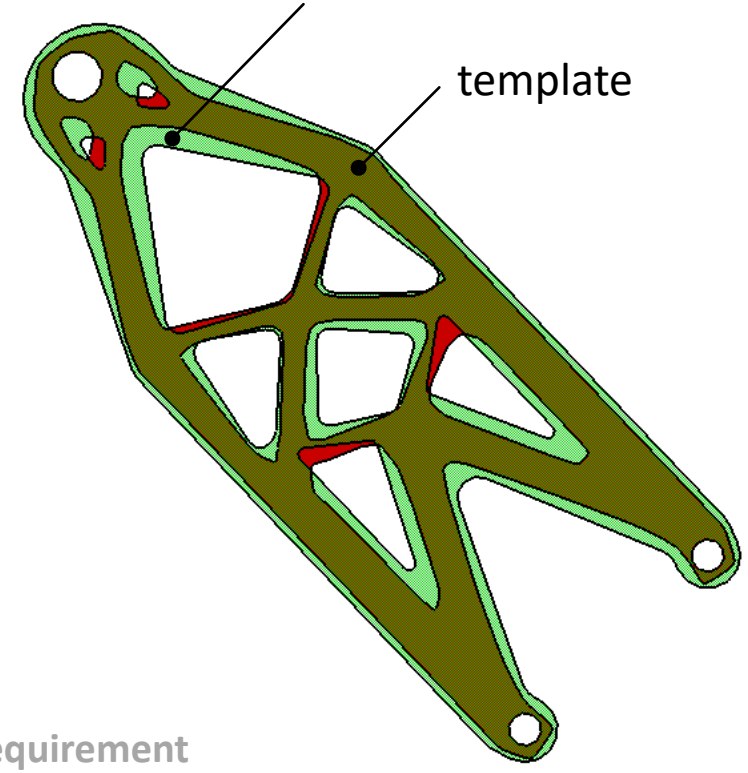


Parametric Model

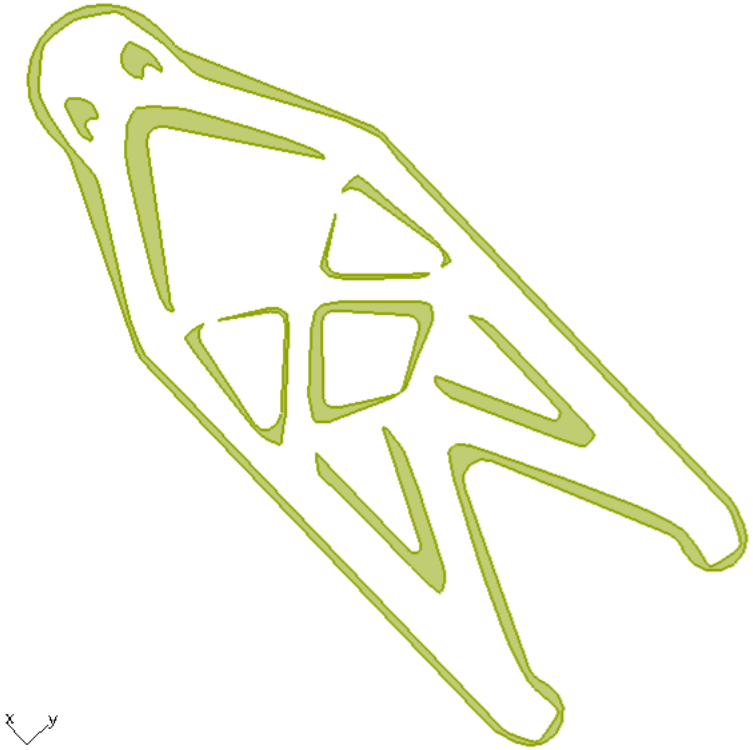
- Symmetric, quasi-2D Volume
- Rough sketching
- Some fix points and distances
- 46 parameters for variation
- Parameter range: default (+/- 10 %)
- Radius = fillet feature parameter

Boolean Operations

Objectives & Constraints



1) template - parametric



2) parametric - template

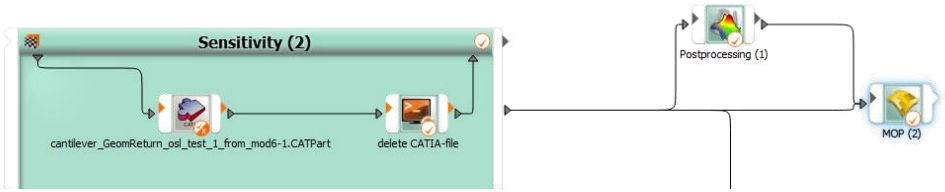
Objective
Min(Volume(template-parametric))

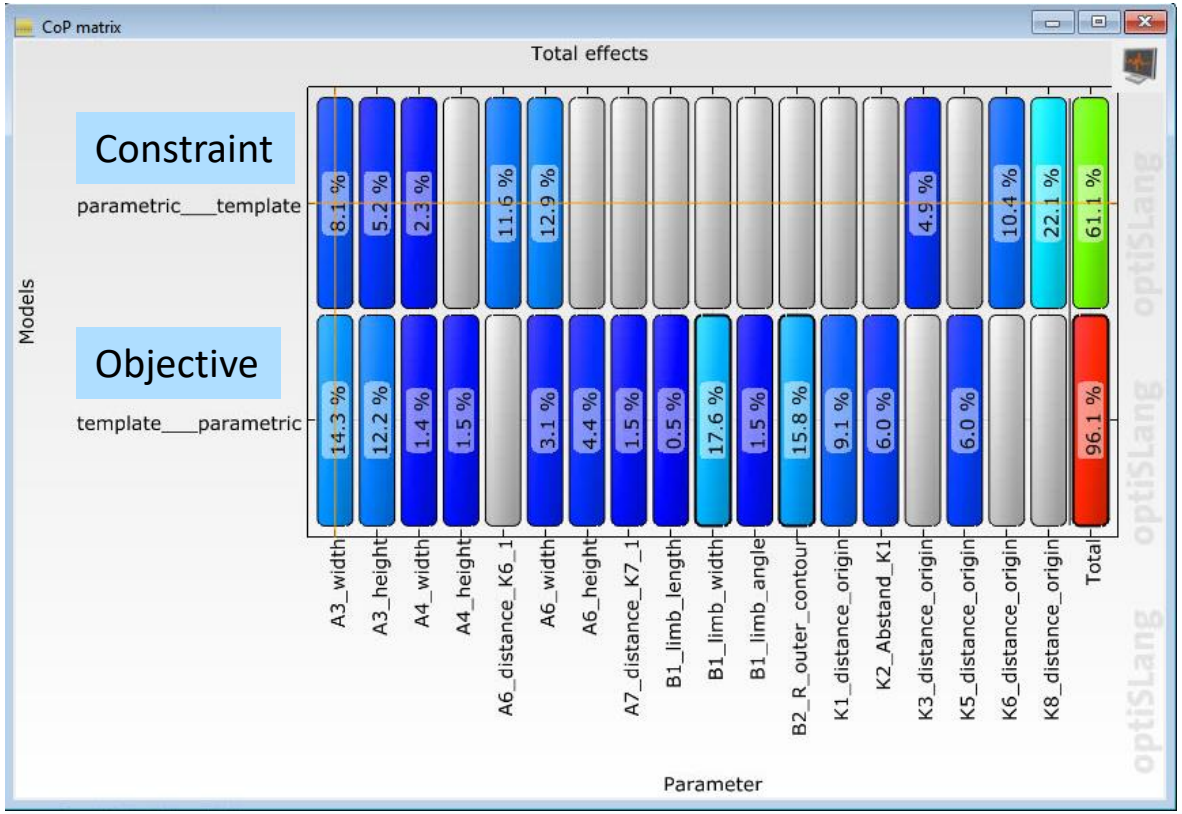
Constraint
Volume(parametric-template) < 1*10e-9 m³

Requirement
Parametric contour outside template contour = red volume offcuts are unwanted

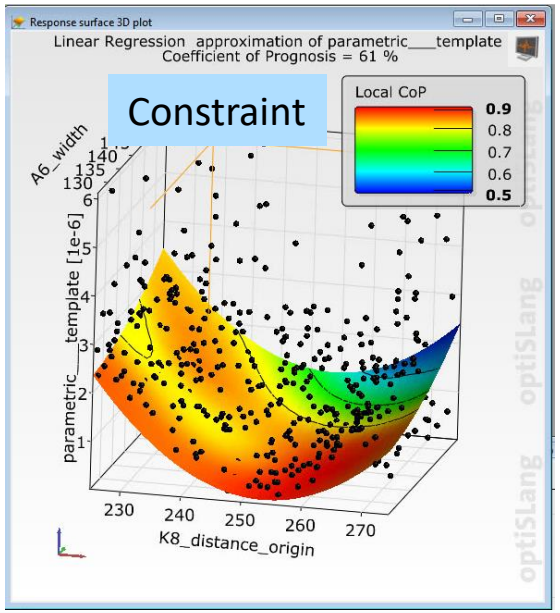
Use volume offcuts to rate fit quality.

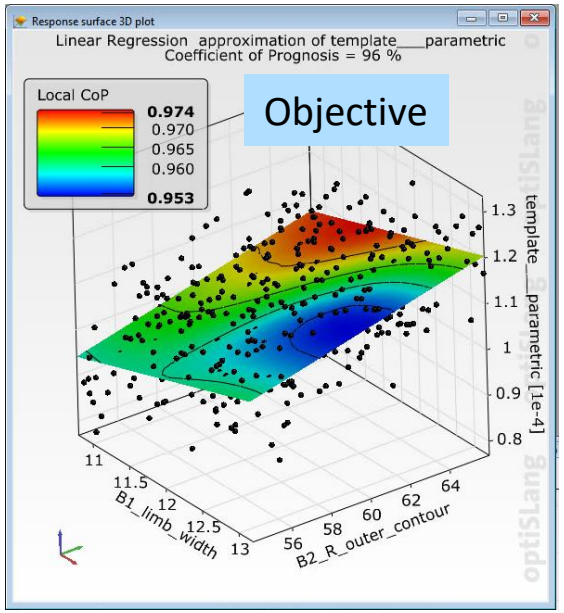
Sensitivity





- DoE: 500 aLHS designs
  - 459 succeeded
  - 41 failed
  - No feasible design
- Default MOP
  - Low total CoP for constraint
  - 18 important parameters
    - → main dimensions
    - → plausible





MOP not sufficient for "Opt. on MOP". Challenge: find feasible designs.

Optimization

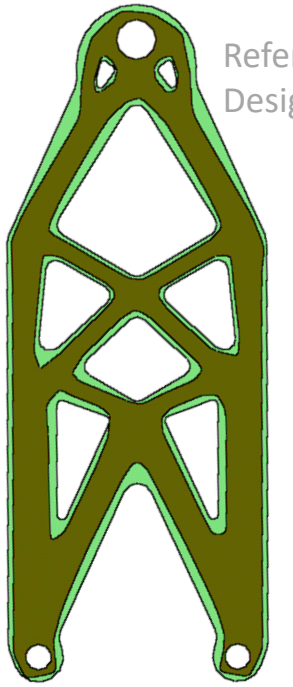
Geometry Fit

Large number of parameters (46), short evaluation time (5s), challenge to find feasible designs.

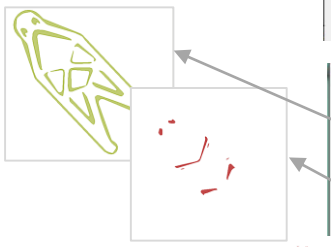
→ Why not trying new "Nature Inspired Optimization (NOA)" Algorithm?

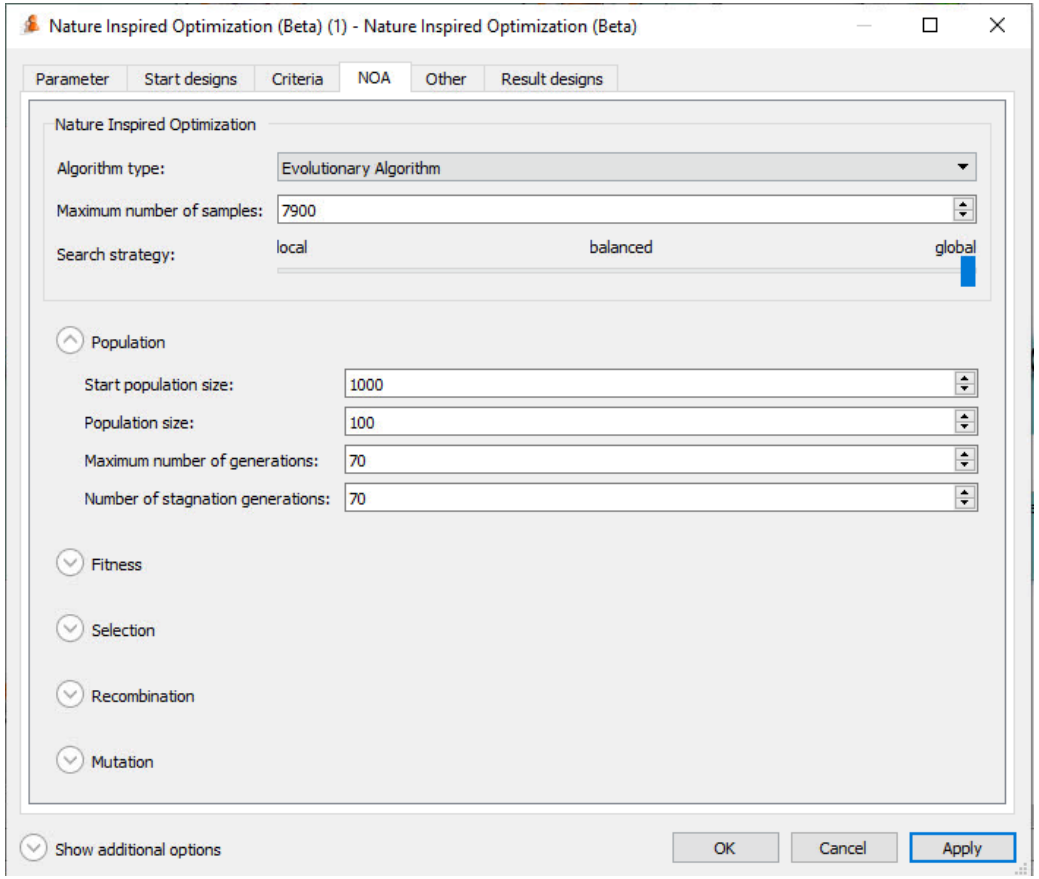
NOA run setup

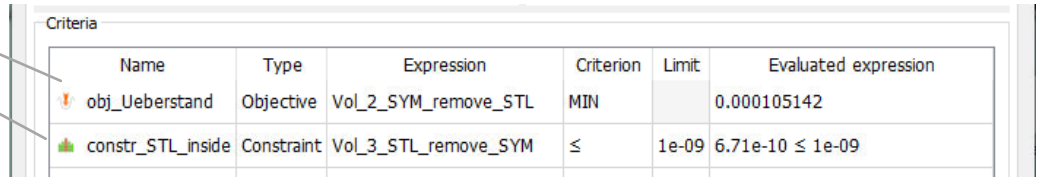
- Global search
- Large start population
- No start designs
- Population size: 100 designs
- 7,900 designs (forced)
- Other settings: default



Reference Design







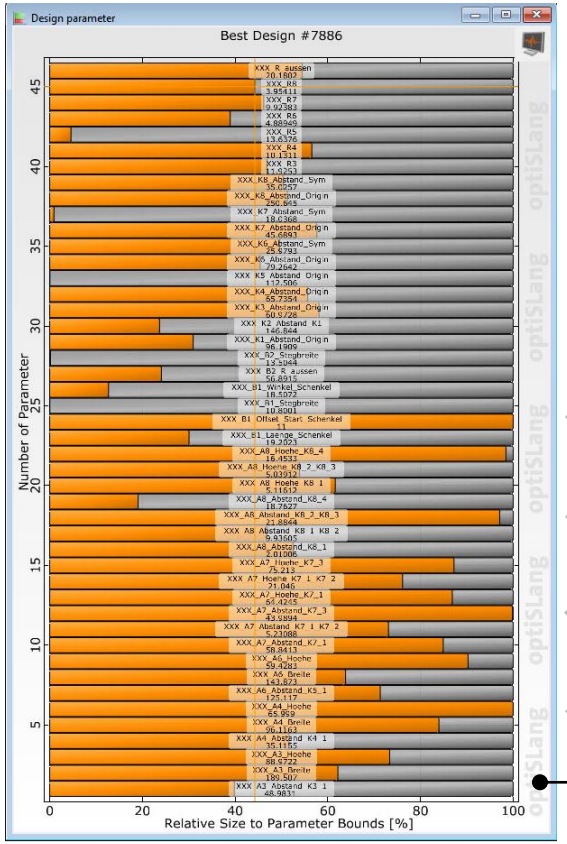
Direct optimization using NOA from evolutionary algorithm (EA) group.

Stepwise Approach

Parameter Space Handling

Min. bound adjustment in next run

Max. bound adjustment in next run



From NOA run to NOA run

- Adjust parameter setup
- Start from best design of previous run

Overall 4 NOA runs

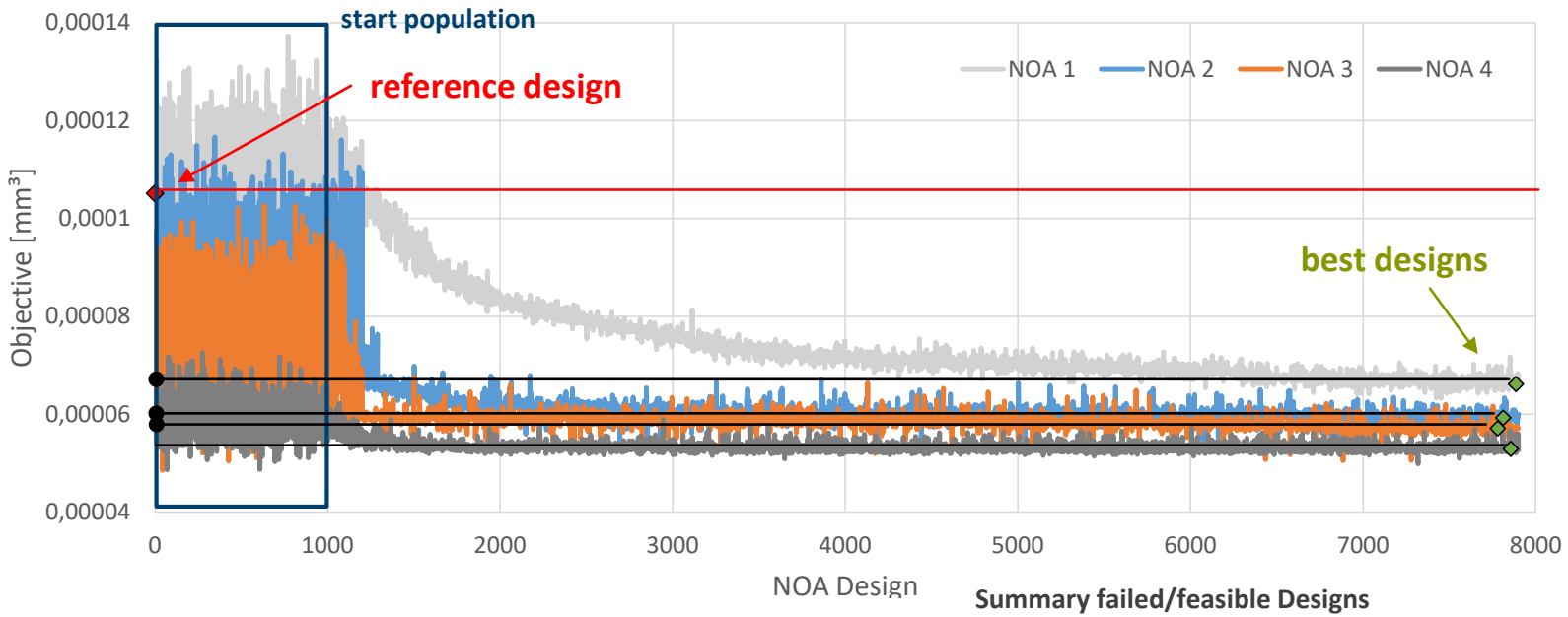
- Each 7,900 designs
- Each approx. 13h (over night)

NOA 1	NOA 2	NOA 3	NOA 4
Reference Design Initial Parameter Set	**Reference Design** Best Design NOA 1	**Reference Design** Best Design NOA 2	**Reference Design** Best Design NOA 3
Active Parameters 46	**Active Parameters** 41	**Active Parameters** 26	**Active Parameters** 6 (A6)
Locked Parameters 0	**Locked Parameters** 5 (A3)	**Locked Parameters** 20 (A3, A4, A7)	**Locked Parameters** 40
Initial Bounds	**Adjust Bounds** 6 x Min 6 x Max	**Adjust Bounds** 3 x Min 1 x Max	**Adjust Bounds** 2 x Min 6 x Max
Best Design #7886	**Best Design** #7812	**Best Design** #7780	**Best Design** #7855

Best design at borders of design space requires adjustment of parameter setup.

NOA

Results & Convergence

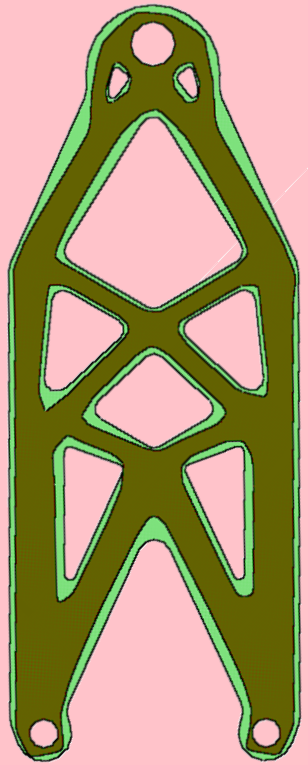


- Failed designs in start population
- NOA learns during start population where to find feasible designs
- Best Design in last NOA iterations

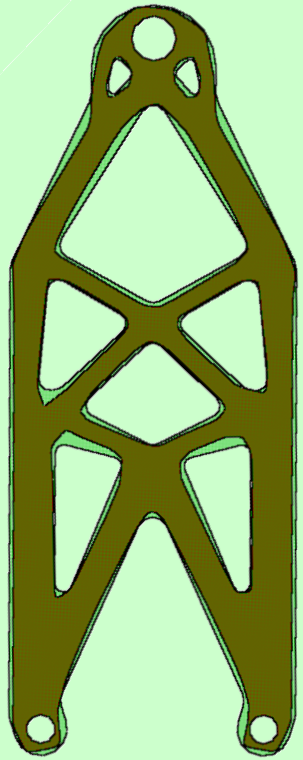
Summary failed/feasible Designs

	in start population	complete run
NOA 1	86 / 1	264 / 3581
NOA 2	95 / 1	100 / 2592
NOA 3	47 / 2	49 / 3052
NOA 4	3 / 30	15 / 2368

Reference Design
Objective: 100%

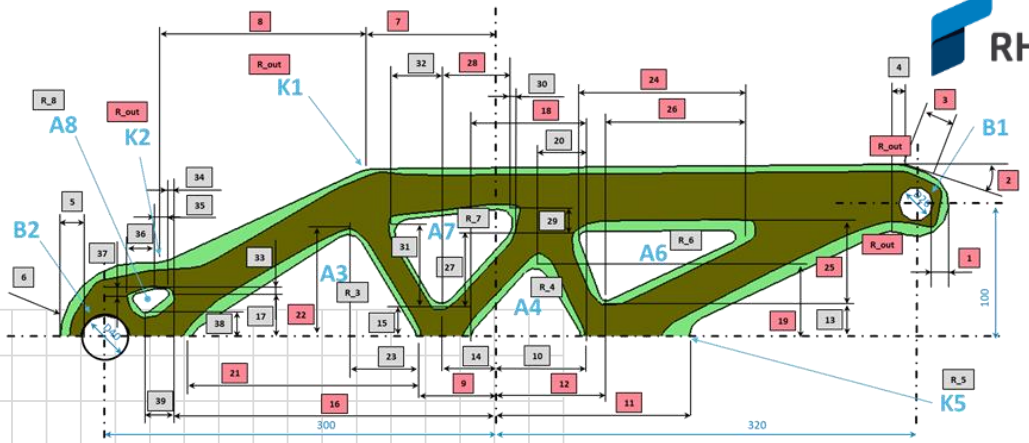


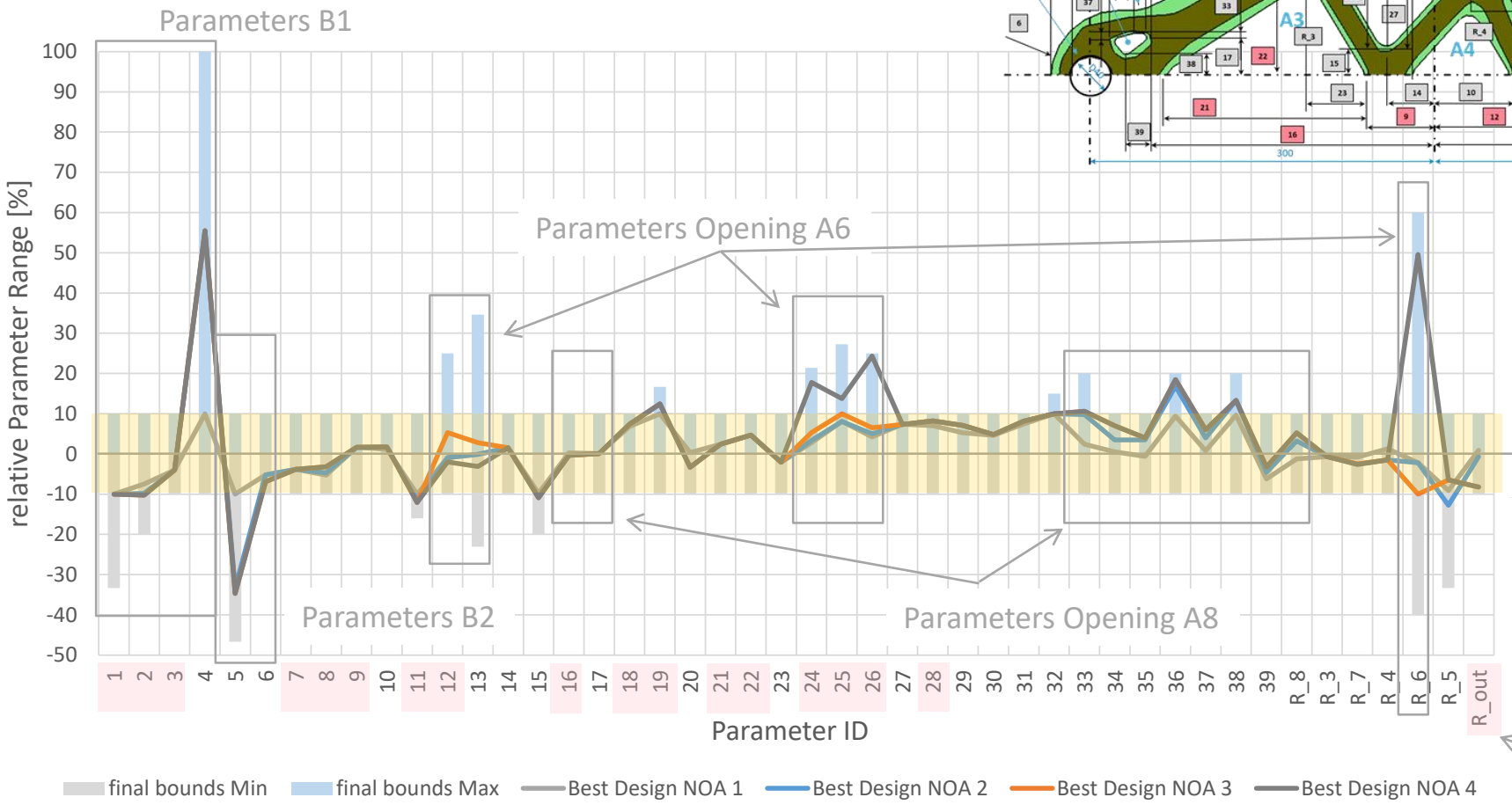
Best Design NOA 4
Objective: 50,4 %



Main objective improvement in 1st NOA run (-37%) – but further -13% after 4th NOA run.

Best Designs
of NOA Runs





- Best Design from NOA 4 is outside of initial (=default) parameter range.
- Opening A6 is challenging to fit with chosen parametric setup

Reference Design

optiSLang
default parameter range (+/- 10%)

Sensitivity result:
Important parameters

Successful geometry fit. Appropriate parameter range is essential.

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Lessons Learned & Best Practice

→ Strategy for minimum run duration

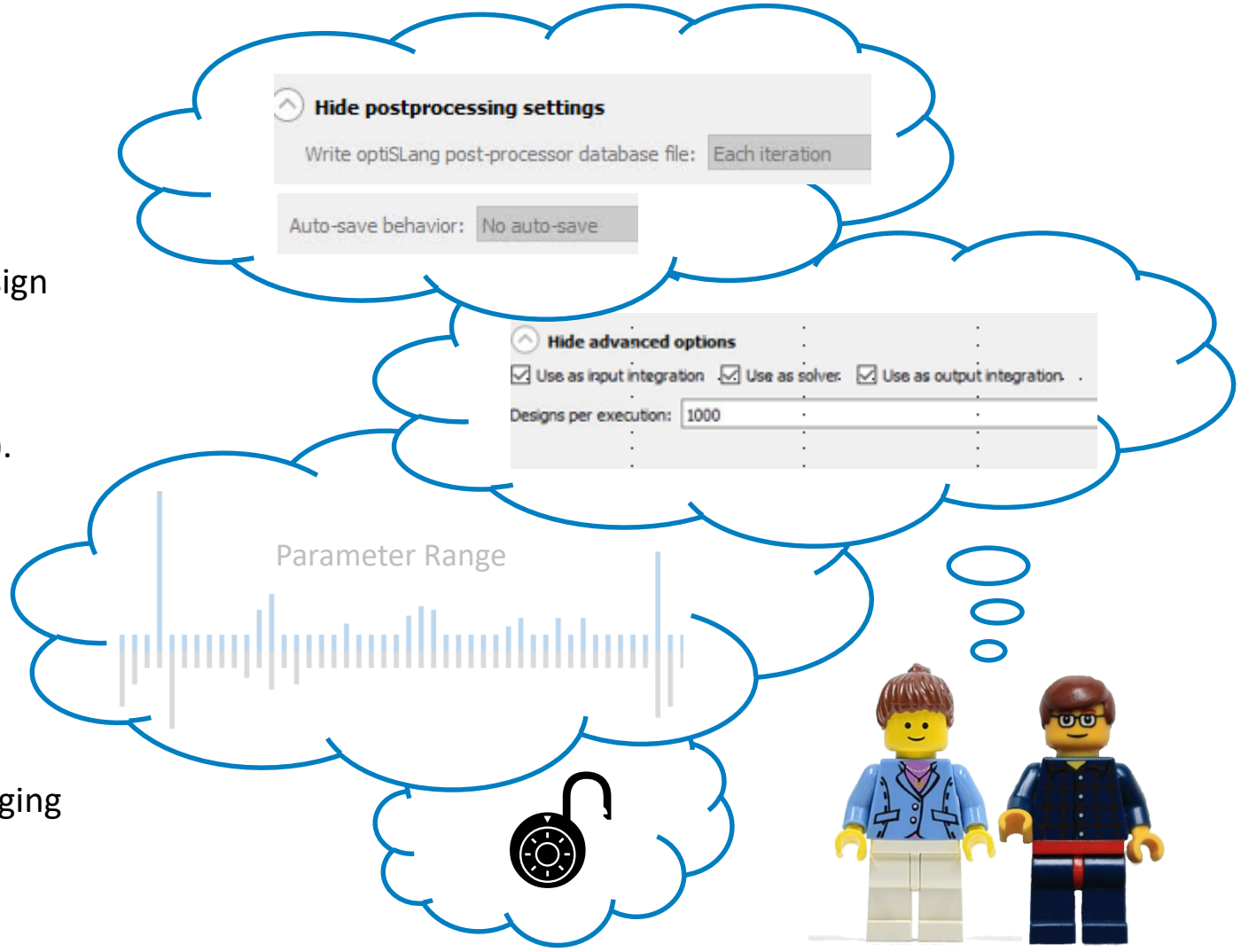
- As little CATIA starts as possible → Enable multiple design launch in config-file!
- Save project data as seldom as possible.
- Reuse designs from previous runs (i.e. in start iteration).
- Define appropriate NOA convergence criteria.

→ Parametric Concept/Range

- +/- 10% as initial parameter range could be too small.

→ NOA

- Large start population size for applications with challenging criteria fulfillment or many failed designs.
- Do not lock parameter for NOA.



Pic source: www.brick-shop.de

10,000s designs need special handling in optiSLang. Parameter range is essential.

Summary & Conclusion

- Topology optimization: essential part of continuous simulation workflow @ RH S+A.
- Challenge: Topology optimization result interpretation → define appropriate parametric CAD model for variants analysis.

CATIA & optiSLang

- Successful Geometry Fit for Use Case “ANSYS Cantilever” with Nature-Inspired Optimization Algorithm
- Learn a lot about parametric model behavior.
- Ready for next steps after geometry fit (i.e. optiSLang study including FEA responses).

Keep in Mind

- 10,000s designs need special handling in optiSLang.
- Parameter range is essential.

Potential for Improvement

- Option to delete CATIA-file in design folder (at the moment separate batch script needed).
- optiSLang performance for large data sets (10,000s designs).

optiSLang & CATIA: powerful combination, comfortable usage. Reliefs parametric geometry definition.

Thank you for your Attention.

Any Questions?

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