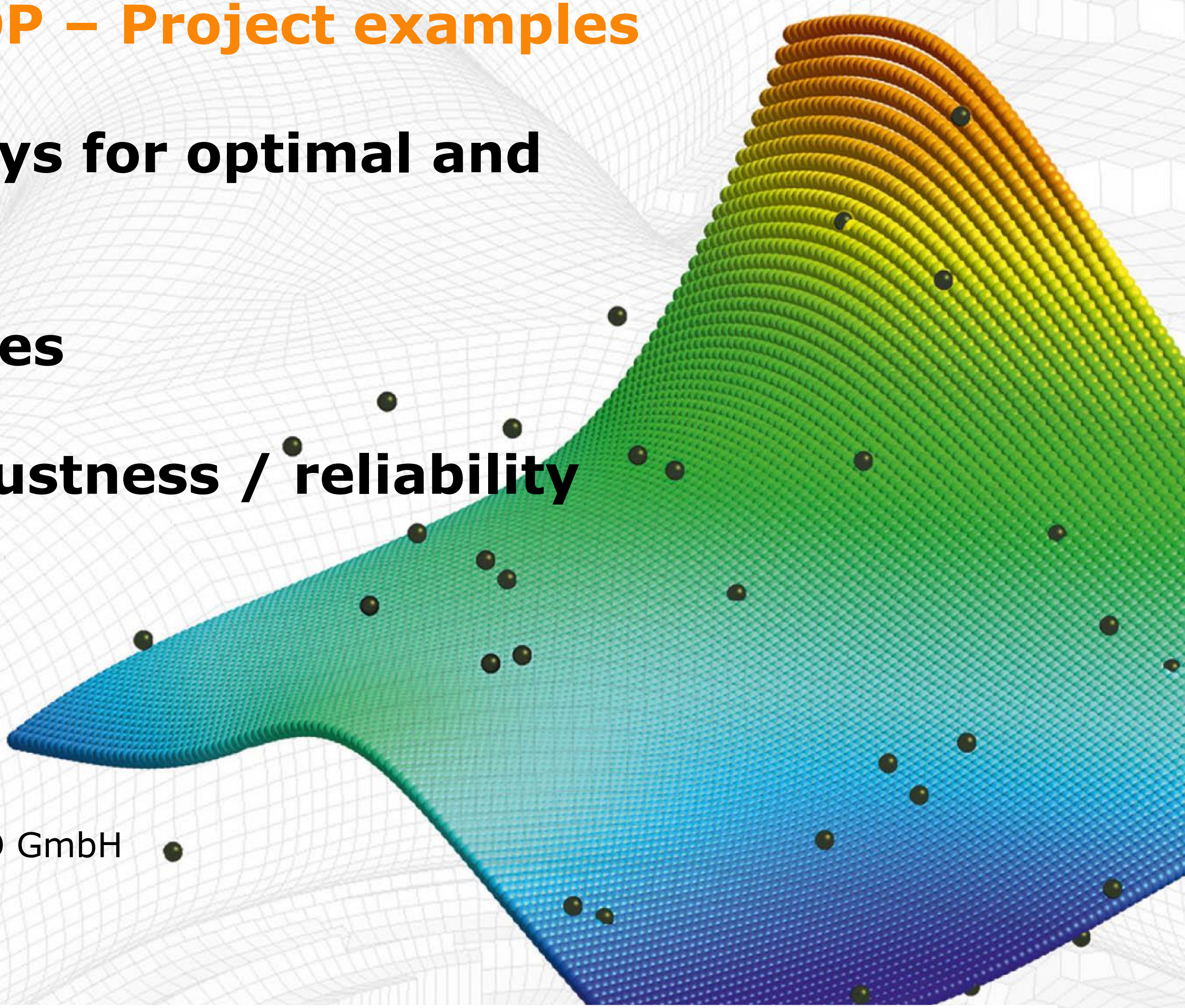
The Power of MOP – Project examples

Cost efficient ways for optimal and robust products

Support your Sales

Evaluate the robustness / reliability

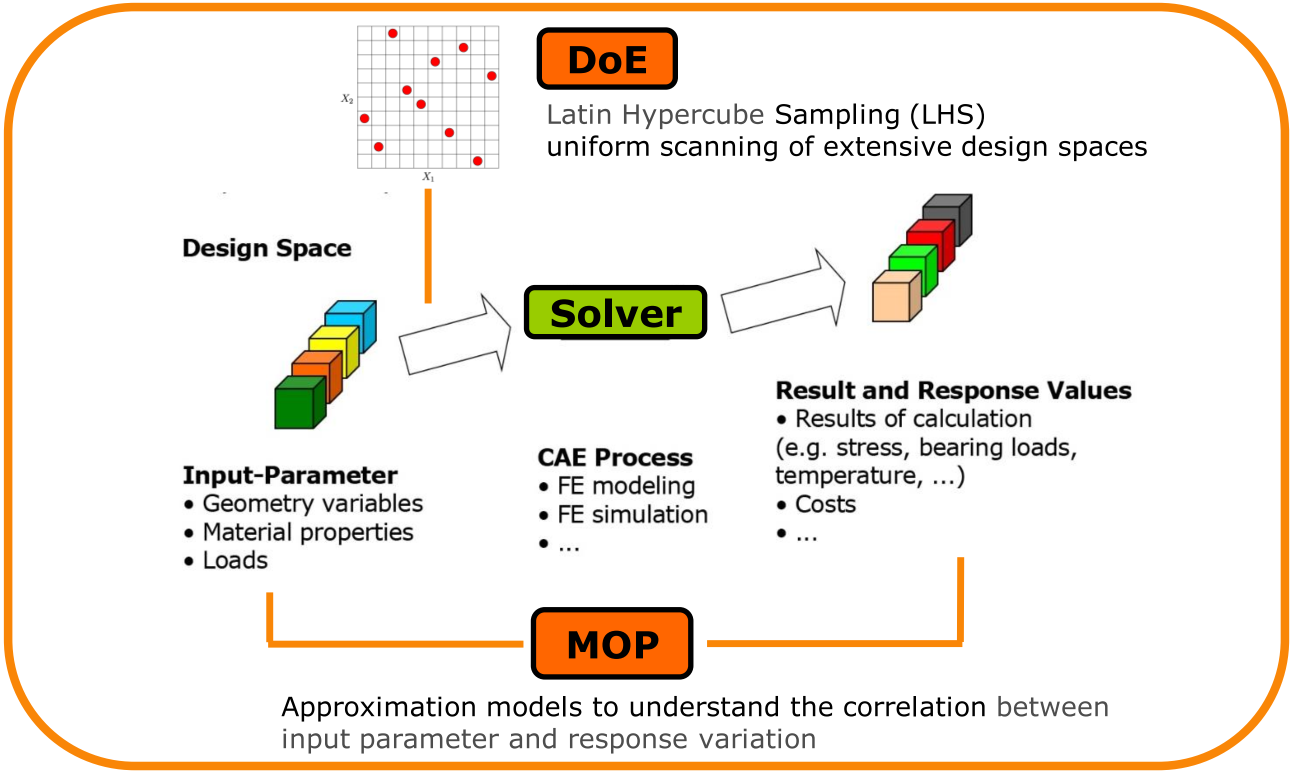


Dr.-Ing. Roger Schlegel
Consulting director DYNARDO GmbH

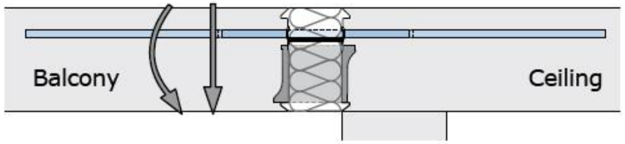
MOP- key to generate best possible functional models

- During a sensitivity analysis, **MOP**s (**M**etamodel of **O**ptimal **P**rognosis) functional models are determined by optiSLang to approximate and understand as best as possible the correlation between input parameter variation and response variation.

Sensitivity Analysis



Optimization using MOP



five analysis each per design:

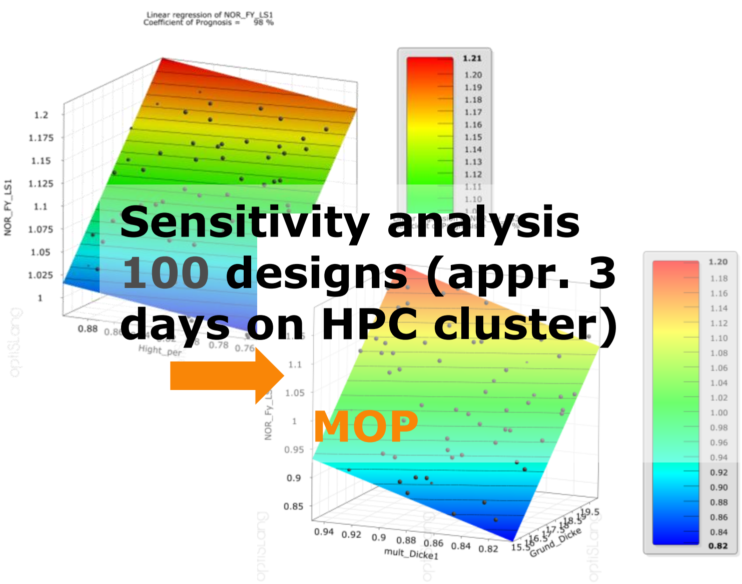
- two stationary thermal analysis (each with different constraints)
  for simulation of the PSI-value and
  for simulation of the FRSI-value and

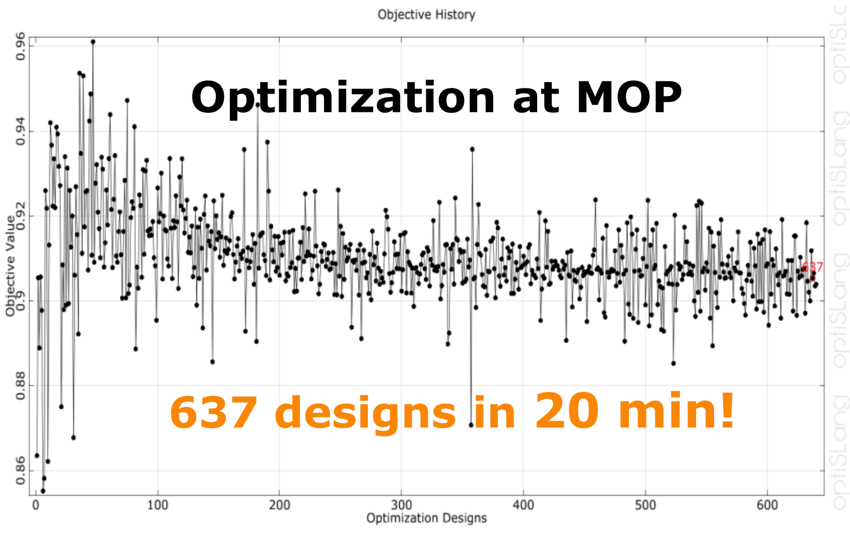
Duration of calculation 2x 5 Min

- three non-linear mechanical analysis for the three load cases
  LF1 - Concrete edge failure,
  LF2 – Support – compression failure
  LF3 – Support – shear failure

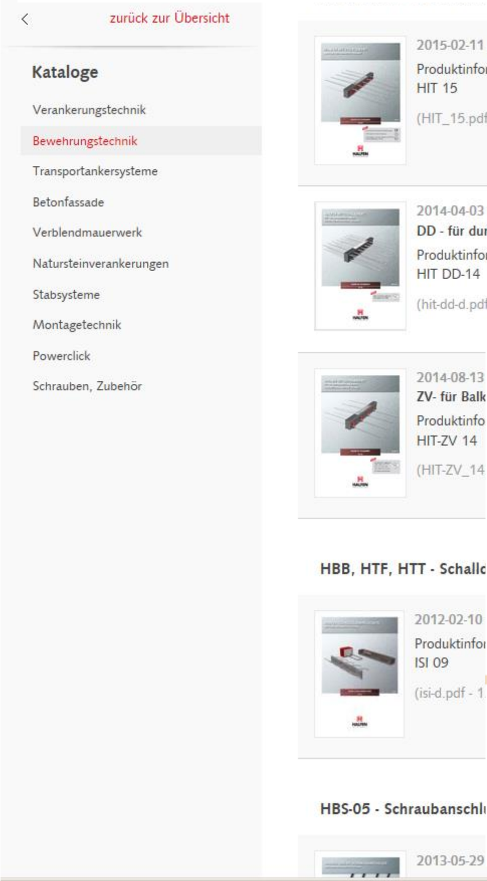
Duration of calculation 3 x 6 hr

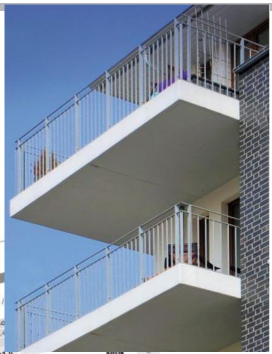
approx. 18 hr/design

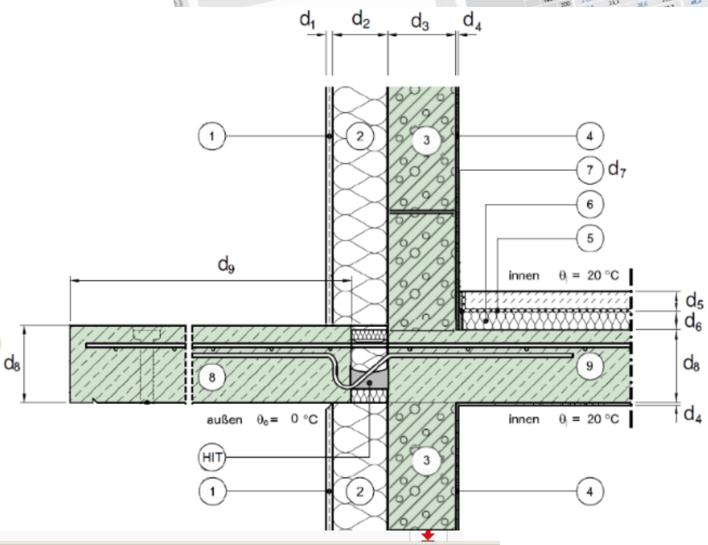


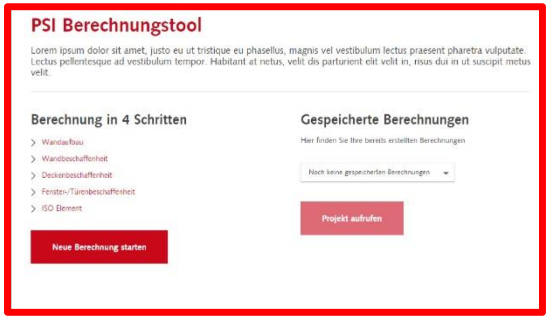


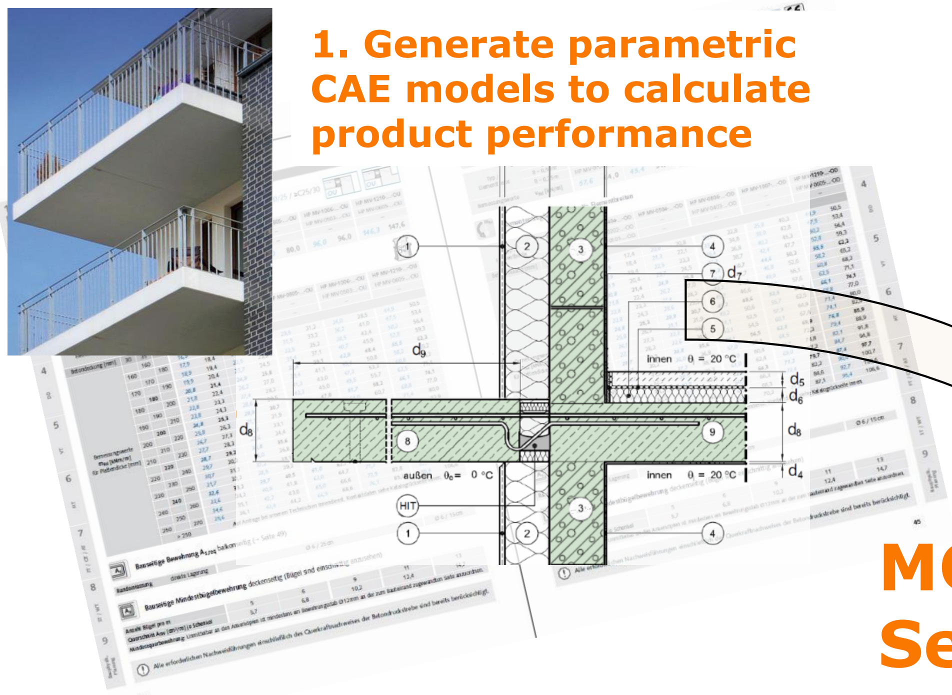
Include MOP's in your web services to provide customer best possible product selection





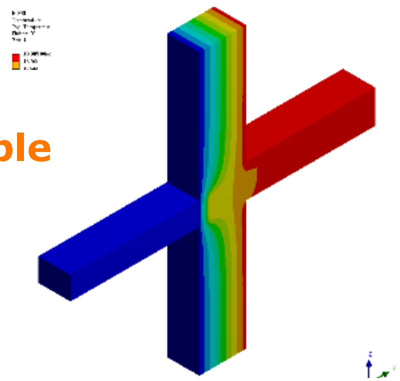




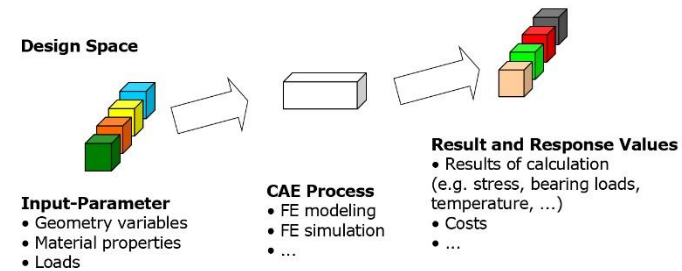


1. Generate parametric CAE models to calculate product performance

2. Validate the CAE models with available measurements

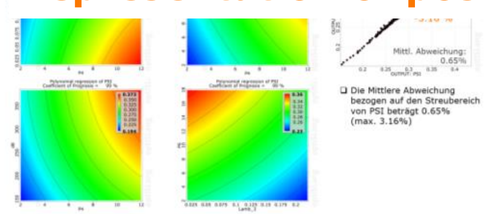


3. Scan possible product assemblies in advance using LHS sampling & Sensitivity analysis



MOP Service

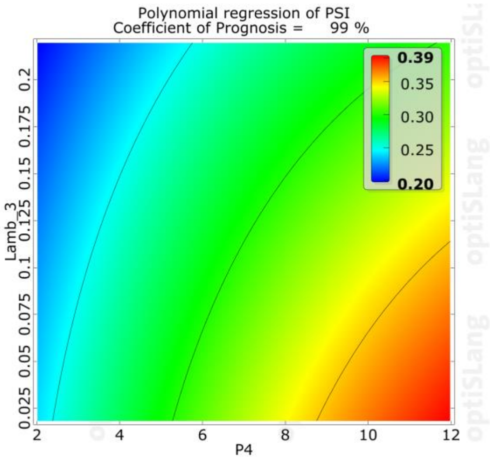
4. Generation and Verification of Meta models to have functional representation of possible variants

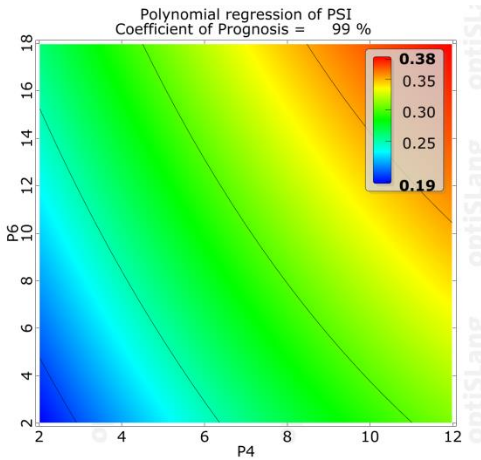


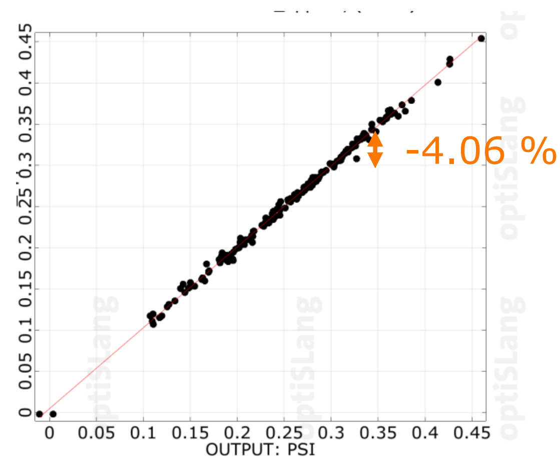
5. Use MOP's in Customer's sales tool to support product selection and assembly

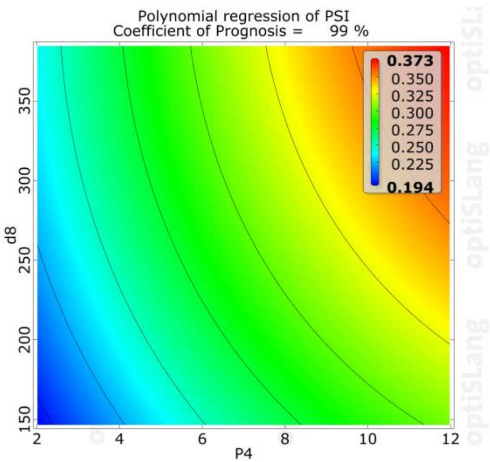
The Power of using MOP – support your sales

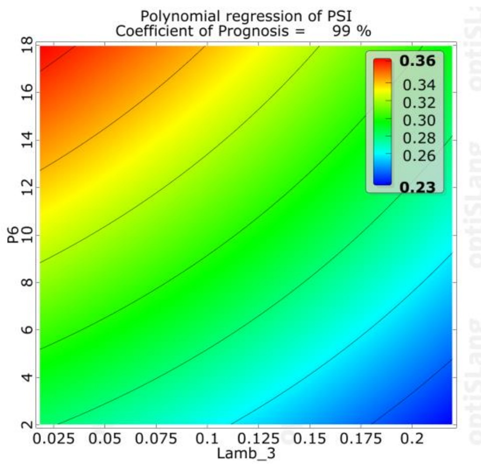
Verification of MOP's for mean (COP) and max error is very important





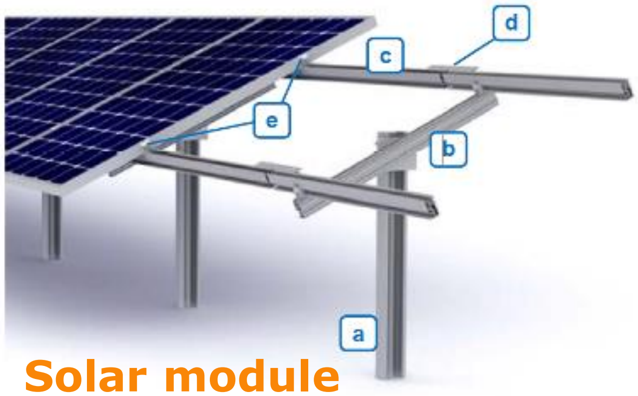




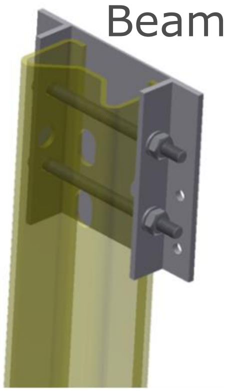


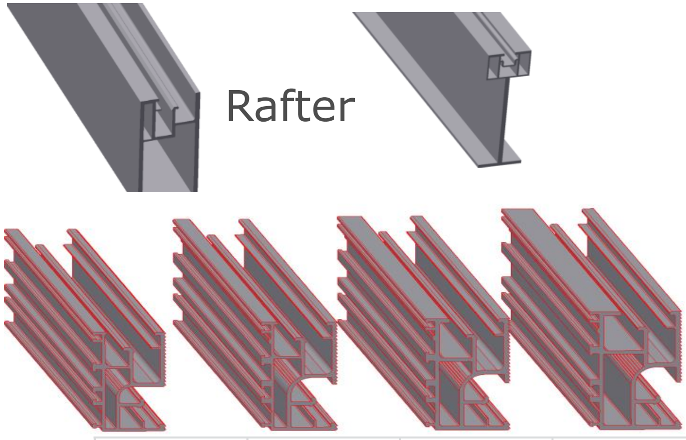
- ❑ mean error of the MOP is 0.69%
- ❑ max. error at MOP is 4.06% (local)

Select the optimal system configuration using MOP



Solar module

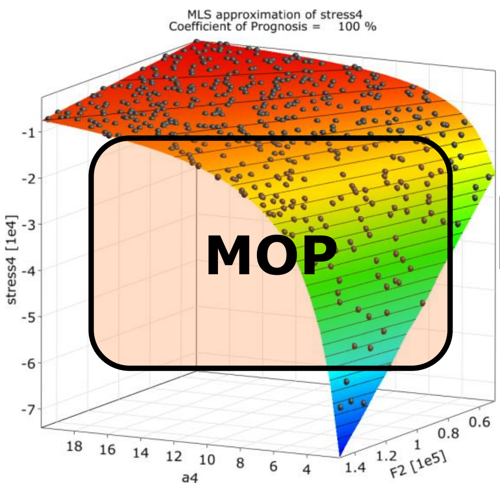




Module library

Optimization Goal: Module requirements like m² panel, solar surface, module arrangement

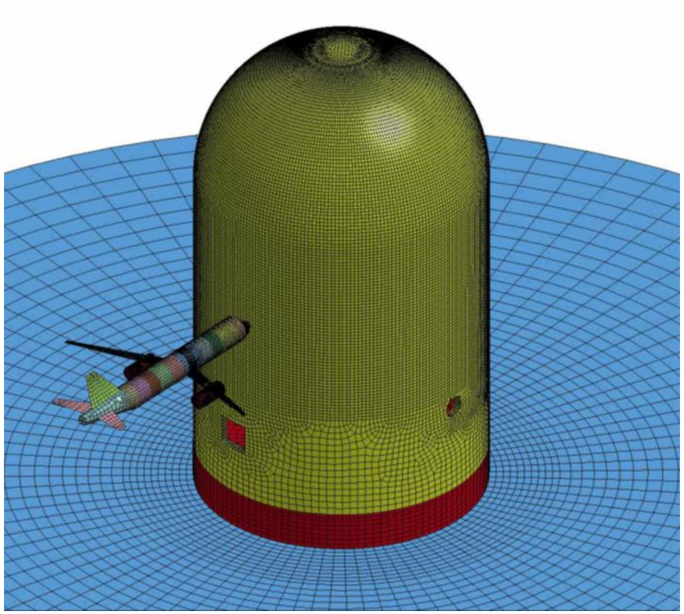
System Loading:
Dead weight, wind load, snow load, structure/foundation interaction)

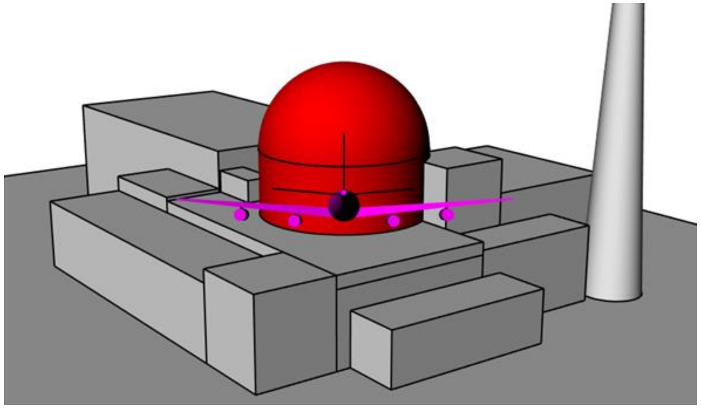


Search for cost-efficient configuration of System (minimized material consumption) from existing profile library

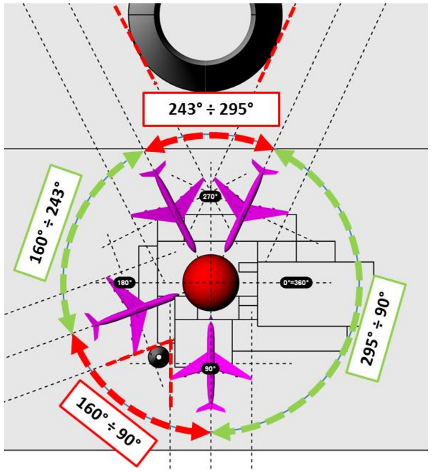
CAE-based reliability evaluation of critical construction components

airplane impact on nuclear power plant



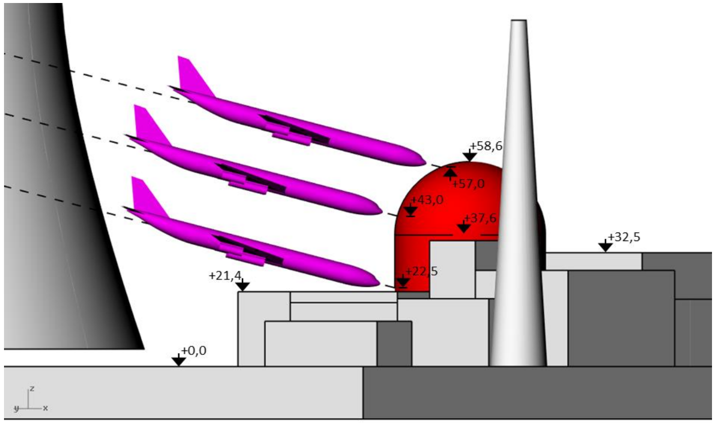


CAE-based reliability evaluation of critical construction components



Motivation:

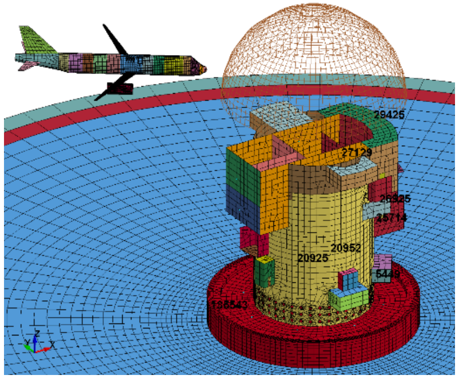
- Using Worst-case analysis is problematic?
  What is the worst-case and which safety factors needs to be chosen?
  How useful is the worst case criterion to evaluate an existing structure?
  How likely is the worst-case?
- As alternative to worst case scenarios <u>stochastic analysis </u>is possible. But stochastic analysis of non-linear CAE models in large dimensions of uncertainties needs many thousand's of design evaluations.
- Solution: scan the whole uncertainty space-generate MOP-apply stochastic analysis to the MOP – verify the estimated reliabilities



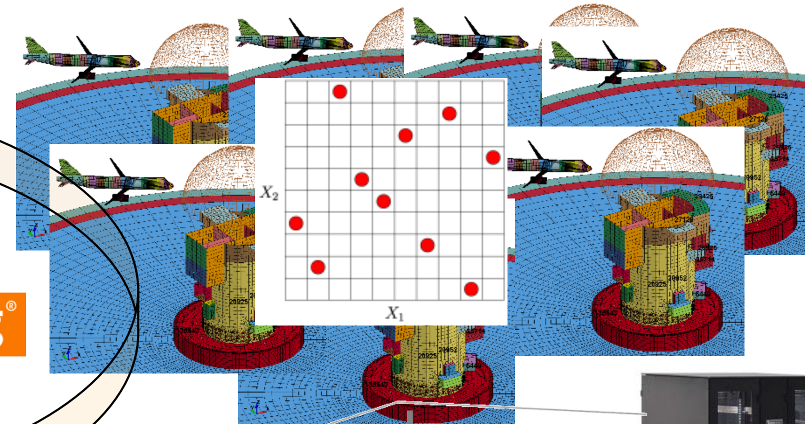
CAE-based stochastic analysis- generate MOP's

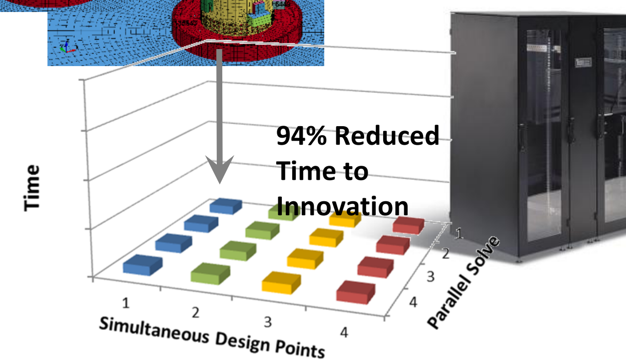
1) **Parametric CAE simulation model** to simulate an airplane impact with all known **uncertainties of loading and resistance**

2) Sampling **Latin Hypercube Sampling** (LHS) and simulation of n possible scenarios (approx. 100..200)

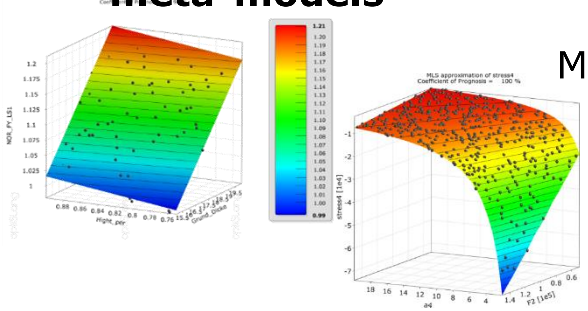


optiSLang®

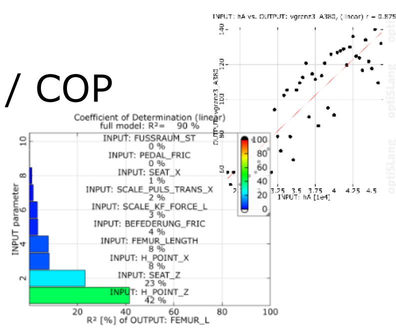




3) Definition of assesment criteria, **Sensitivity analysis** / Generation of **meta-models**

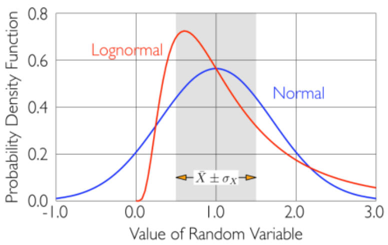


MOP / COP



CAE-based stochastic analysis – run stochastic analysis

4) Definition of distribution functions of input parameter



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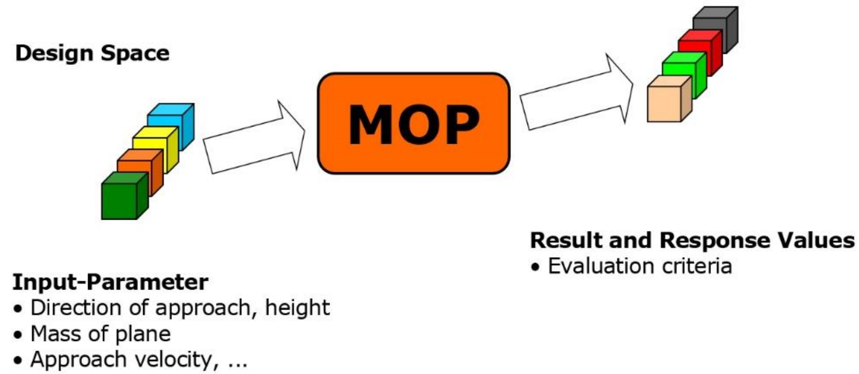
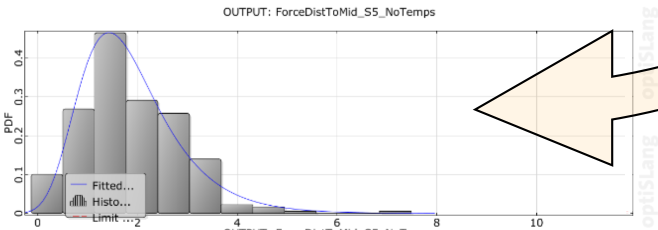
5) Perform reliability analysis replacing CAE with MOP's

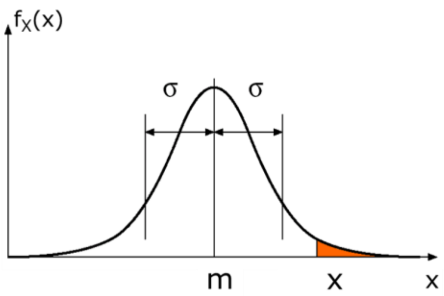
MOP as Solver: 10000 designs in 30 MIN





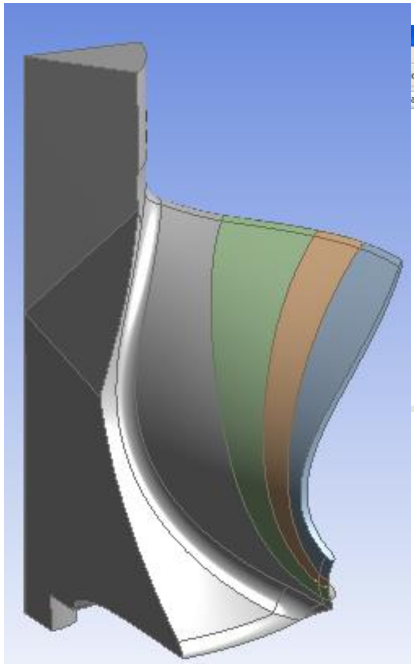
Statistic data			
Min:	-0.13	Max:	7.489
Mean:	1.886	Sigma:	1.012
CV:	0.5368		
Skewness:	1.011	Kurtosis:	5.755
Fitted PDF: Gumbel (Extreme Typ I Max)			
Mean:	1.886	Sigma:	1.012
Limit x = 11.82			
P_rel:	1	1 - P_rel:	0
P_fit:	0.999998	1 - P_fit:	1.91989e-006
Sigma-Level:	9.81328		
Probability P(X<x) = 1			
x_rel =	7.489	x_fit =	10.5174

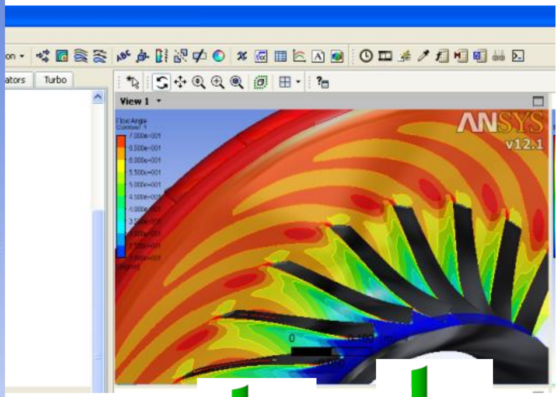
6) Estimate the probability of limit violations of evaluations criteria based on MOP.

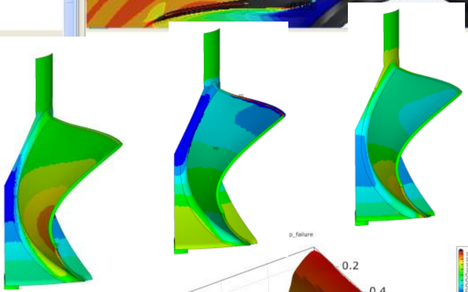


7) Verify the estimated probabilities using CAE-model

Optimization & robustness of turbocharger







MOP as fast Generator

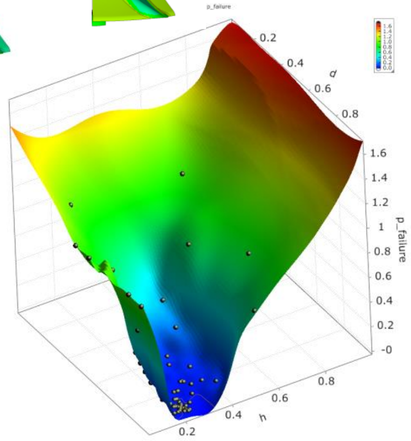
Parametric geometry definition using ANSYS BladeModeler & Workbench (Bézier-Parameter for blade geometry increase the complexitiy)

Task: robustness evaluation in a defined geometry tolerance range

Solution:

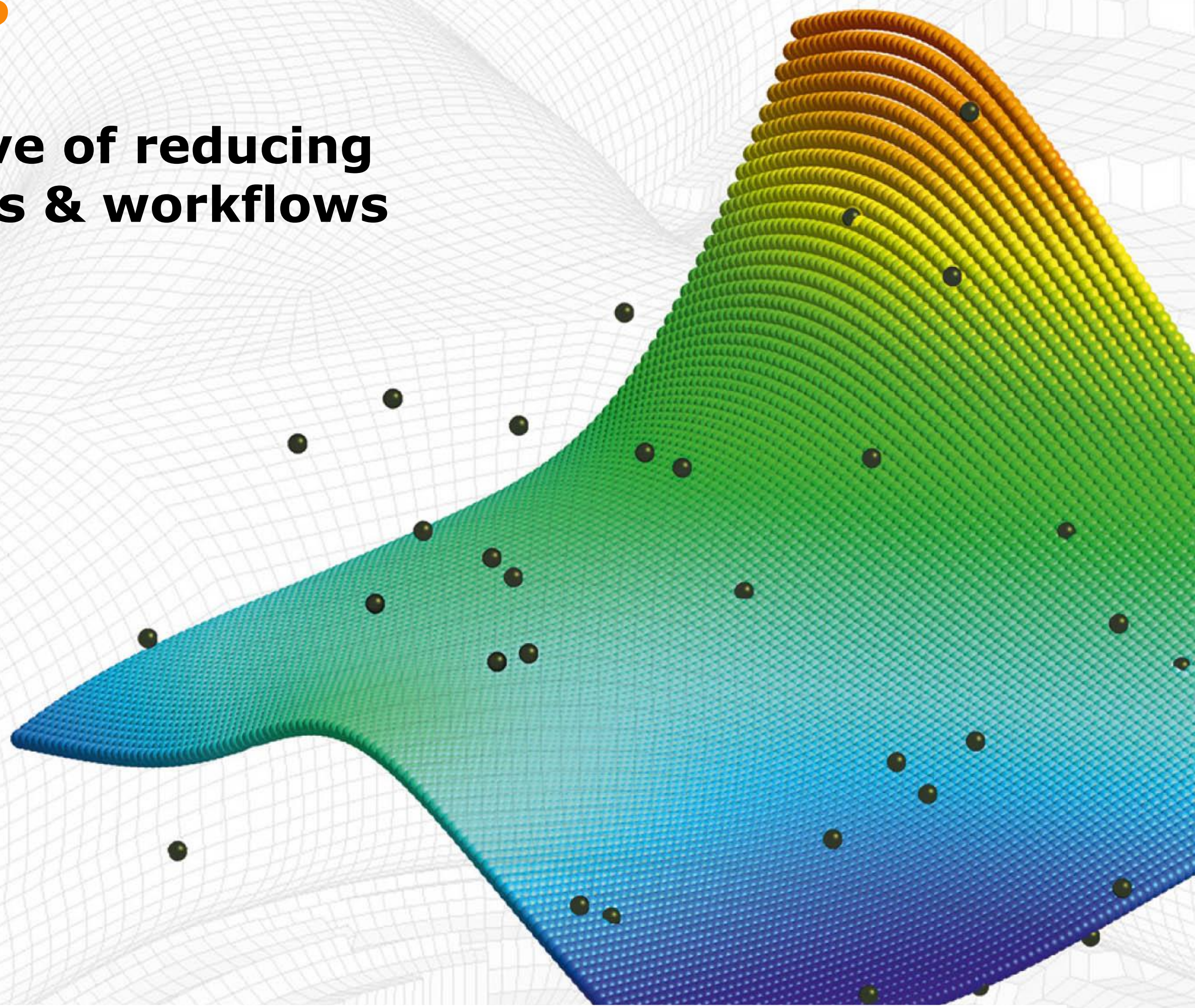
using Metamodel as fast Generator for imperfect geometry designs

using optiSLang as Filter for relevant design - space



The Power of MOP

Attractive alternative of reducing complex CAE models & workflows



Dr.-Ing. Johannes Will
CEO DYNARDO GmbH

Simulation is the key for time to market

offers to the market:

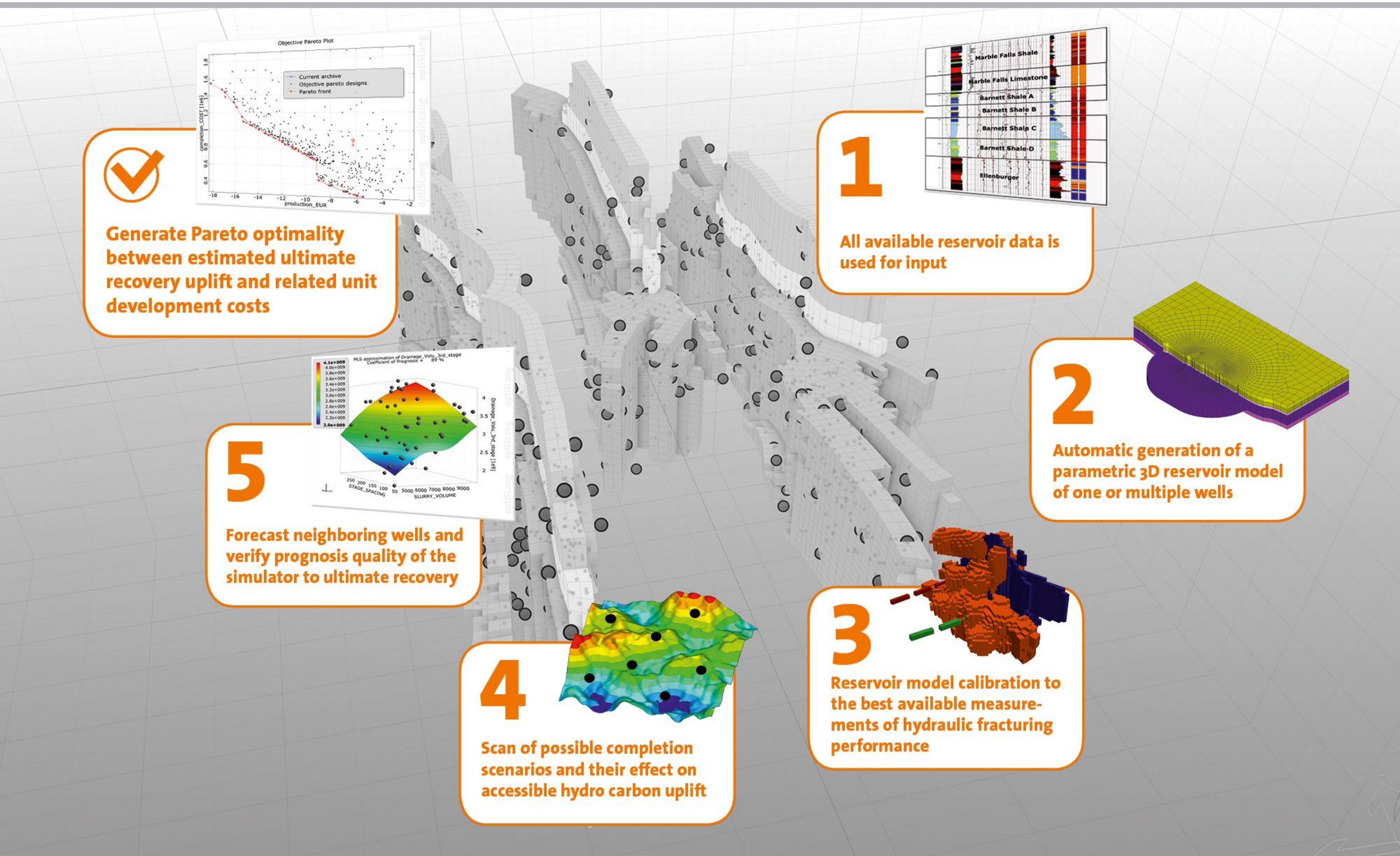
- **Software**
  - Parametric CAX modelling environment like **ANSYS Workbench** together with general purpose variation analysis tool **optiSLang** to support virtual prototyping & product optimization

- **Consulting service** to establish virtual product optimization at your company at different levels

  - establish parametrized CAX models & CAX process automation and integration

  - establish parametrized CAE workflows (vertical applications) and calibrated CAX models to be used in variation studies

  - establish functional relationships (MOP's) to approximate variation windows of optimization parameters or uncertainties based on simulation or/and tests



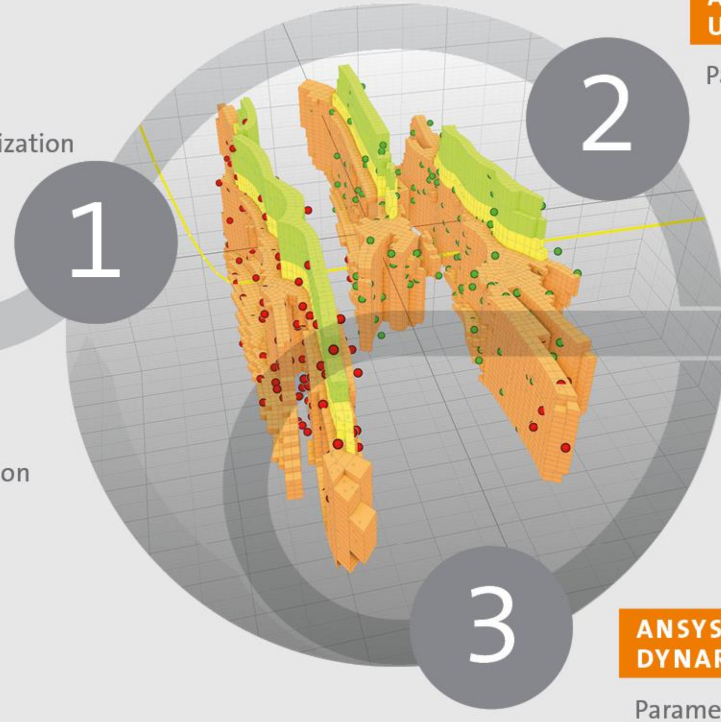
The Dynardo Hydraulic Fracturing workflow

DYNARDO HYDRAULIC FRACTURING SIMULATOR

ANSYS PRE + APDL PROGRAMMING

- Parametric 3D modelling
- in-situ stress initialization
- in-situ pre pressure initialization

Input files of parametric reservoir, well and completion



ANSYS MECHANICAL + APDL PROGRAMMING | USER MAT | USER ELEMENT

Parametric hydraulic fracturing simulation

Output files of stimulated rock volume, drainage volume, Estimated Ultimate Recovery (EUR)

ANSYS POST + DYNARDO POST PROCESSOR "TAMINO"

Parametric postprocessing

DYNARDO OPTISLANG

GENERATION OF THE METAMODEL OF OPTIMAL PROGNOSIS (MOP)

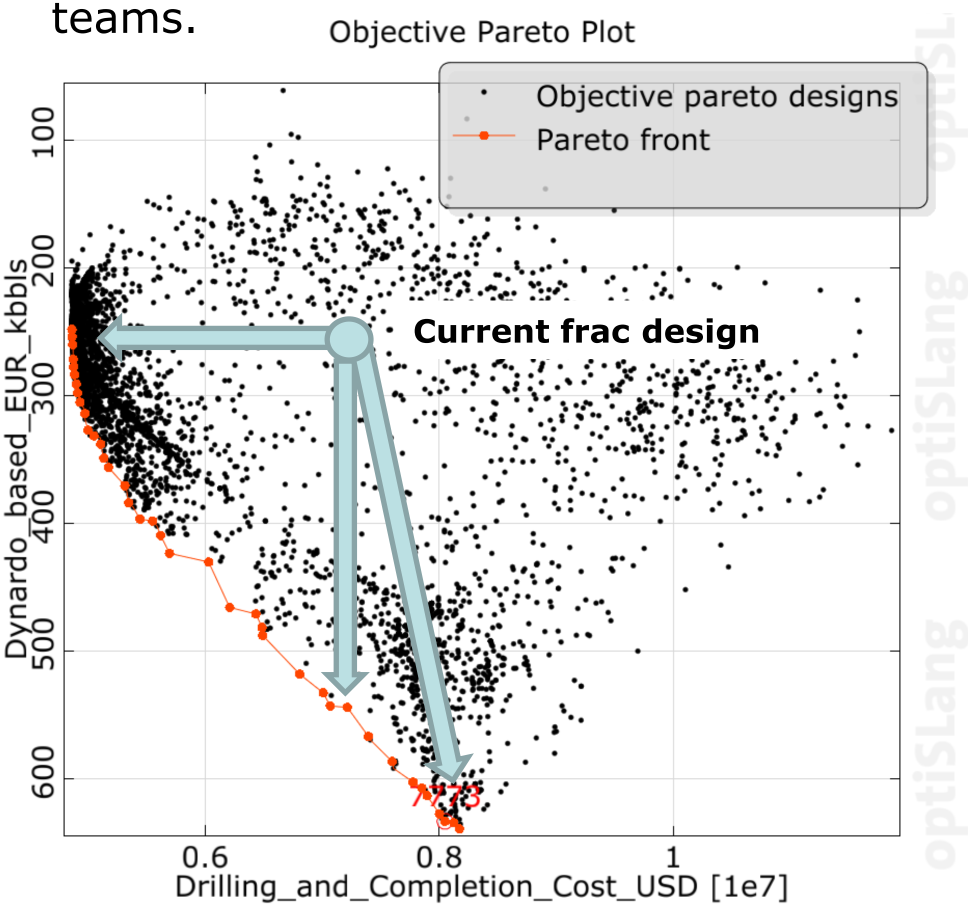
- Calibration of reservoir measurement
- Sensitivity analysis of operational parameter

OPTIMIZATION ESTIMATED ULTIMATE RECOVERY (EUR) / UNIT DEVELOPMENT COSTS (UDC)

Dynardo's Hydraulic fracturing Simulation Toolbox

Workflow over all relevant disciplines

We needed to include all relevant disciplines being able to convince the asset teams.



By using cost function and Dynardo meta models (MOP) we can produce Pareto Frontier between conflicting goals Cost reduction and EUR optimization.

optimal EUR, highest costs

Reduce cost, stay with EUR

Stay with cost, optimize EUR

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Example hydraulic fracturing in Oil and Gas

- **Software**
  - Classic approach: Deliver the software (ANSYS, Dynardo HF Extension, optiSLang) environment to the customer
    - But to establish the complex CAX workflow requires implementation time and team of experts
- **Consulting service** to establish the workflow
  - Deliver calibrated, parametrized reservoir models including software environment to the customer to continue with variation studies
  - Deliver MOP's to approximate variations windows of operational parameters and reservoir uncertainties and combine with cost functions in EXCEL

Use of MOP

- **Integrate cast model via EXCEL node and couple to production model MOP in optiSLang**