Design for real

Optimus®

Parametric Shape Optimization using Commercial Software Tools

Christine Schwarz, ISKO engineers AG

Bayreuther 3D-Konstrukteurstag 2012

19. September 2012, Bayreuth

Agenda

1. **Company Profile ISKO engineers AG**
2. **Introduction to Parametric Shape Optimization**
3. **Parametrization Technology in NX**
   - Integration of NX-CAE to Optimus
   - Optimization of a chassis element
4. **Shape Optimization with Matlab**
   - Parametric curves for defining geometry
   - Automated optimization process
5. **STAR-CCM+ for Shape Optimization**
   - Shape optimization in CFD
   - Automated shape optimization of a wing

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ISKO engineers AG

- Since 1996 we support our customers with high quality CAE-services and software solutions that are needed for an efficient product development at one stop
- It is our vision to competently assist our customers through all phases of the development process, thereby achieving the decisive competitive advantage for our customers
- Our long-term cooperations with partner companies in the field of design and testing completes our portfolio to cover the complete product development process
- ISKO engineers has about 85 employees at 5 locations

We offer you

Engineering Services

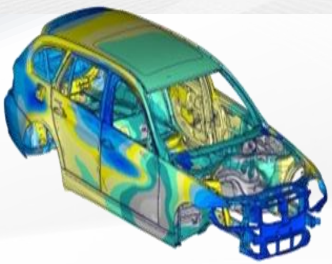
- highly competent engineering services
- CAE methods development
- Consulting and training

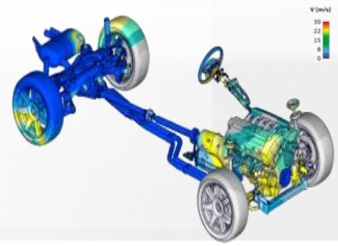
CAE-Software

- Introduction of new technologies
- Powerful CAE software solutions to drive your processes

Prozess integration

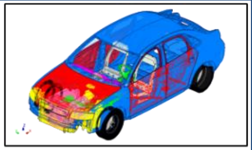
- Process ingetration and data management





ISKO engineers AG

Services



Modelling

Advanced CAE

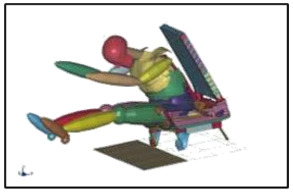
Multiphysics

Optimization

Automation

Simulation Data Management

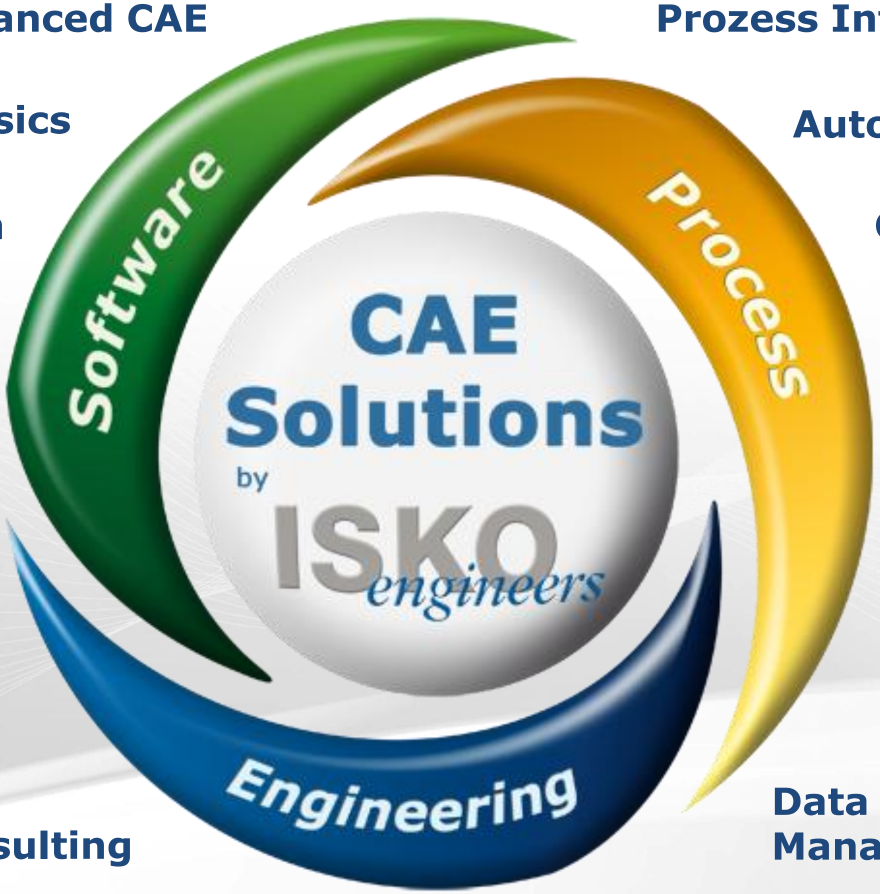
Engineering Services



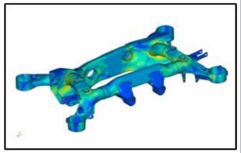
Safety

Consulting

Benchmarks



Prozess Integration

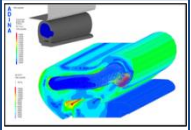


Durability

Automation

Optimization

Software Integration



CFD+FSI

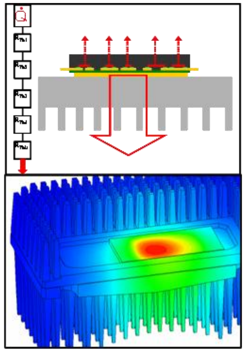
Interfaces

Coupling

Training

Data Management

Customizing



Mechatronics

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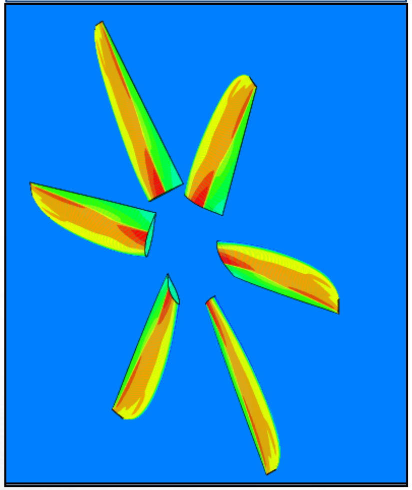
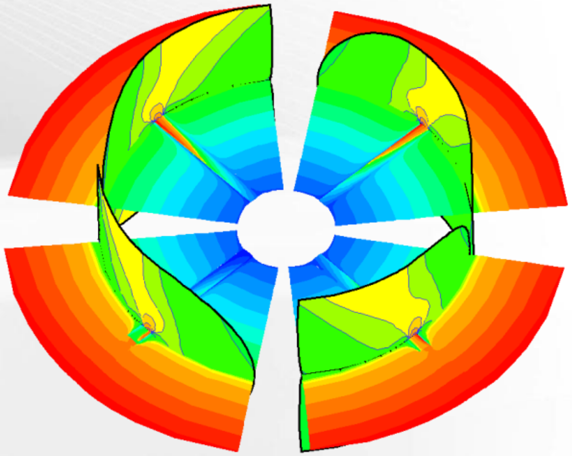
Parametric Shape Optimization

Introduction to Parametric Shape Optimization

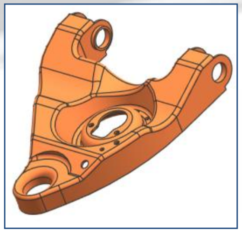
- A typical problem in engineering applications is to find the shape of a certain structure which is optimal in minimizing a certain **cost functional** while satisfying given **constraints**.
- Parameter based optimization is always based on a **parameterized input** for the optimization system. The parameters may be of different types:
  - Shell thicknesses and material properties
  - Geometric entities like radius, lengths or spline supporting points
  - Forces, boundary conditions
  - Any other parameter that may be accessed in the model
- The **finite element method** of analysis is used to evaluate the quality of the shape and typically the objective function, mass, is minimized.

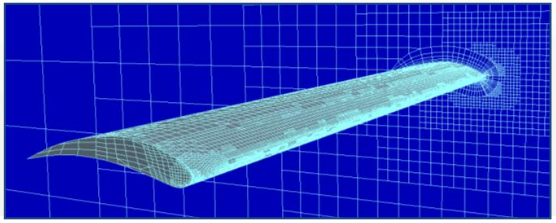
Helicopter Rotor Blade Optimization





- In this talk the problem is addressed from a practical standpoint and different numerical methods for shape optimization of structures are reviewed.
- The choice of the right optimization method depends on different conditions:
  - problem size
  - type of objectives and constraints
  - number of design variables, …
- Not only the suitable optimization strategy has to be selected but in many cases the parameterization of the inputs is also an important issue.
- Several steps in the **shape optimization process**, such as model description, finite element mesh generation, selection of the shape variables and objective function are reviewed in detail. This also includes the integration of the process into Optimus.
- **Three examples** of shape optimization of three-dimensional structural components characterizing different approaches in the shape optimization discipline are given.





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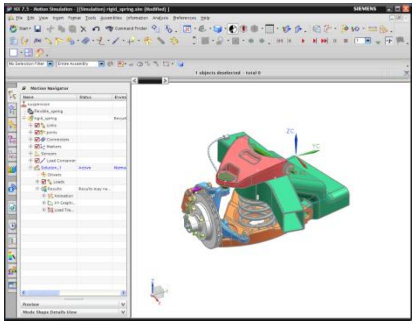
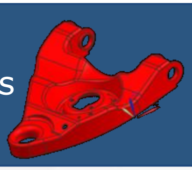
Parametrization Technology in NX

Datastructure of NX-CAE

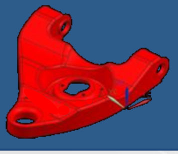


- NX-CAE is an interactive product development solution and can be used as a standalone pre/postprocessor.
- It uses parametric modelling for the geometry generation and all sketch parameters may be changed manually.
- The underlying datastructure consists of:

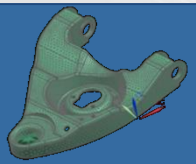
CAD Geometry
Native CAD geometry containing all geometric details



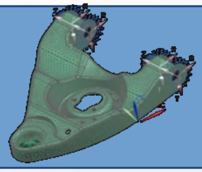
CAE Geometry
Idealized parts; fully assoziative geometry that is simplified for CAE; removal of small holes, fillets, …



CAE Mesh
Finite Element discretisation. Multiple meshes may be linked to geometry to consider requirements for different simulation disciplines



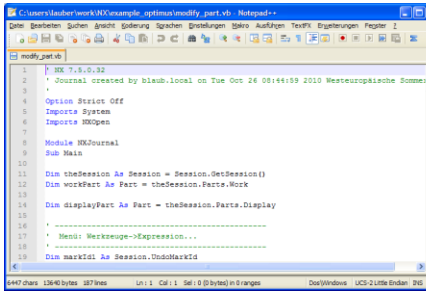
CAE Simulation
Definition of loads and constraints for the different analysis disciplines

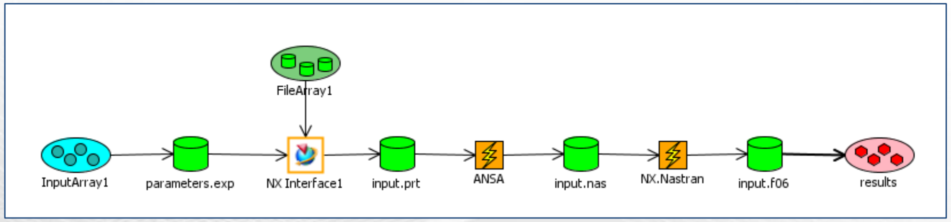


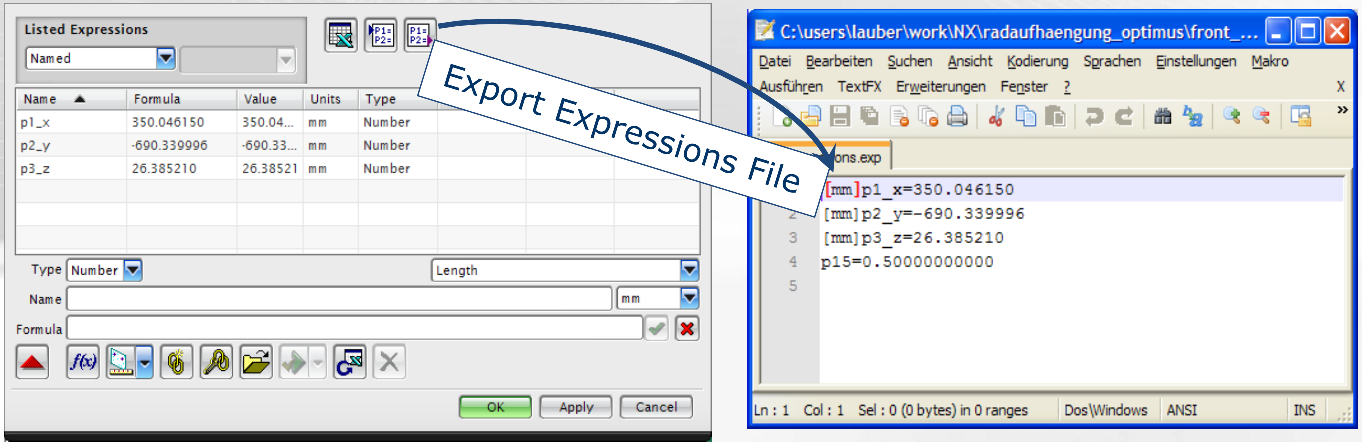
Parametrization Technology in NX

Automation and Integration of NX-CAE to Optimus

- Journal Files are used to record the users actions and can be played in NX. These files are automatically generated Visual Basic files that can be edited and enhanced with complete NX Open functionality (API to control NX objects).
- To drive NX-CAD in batch expression files may be imported. Expression files are ASCII files that are modified externally by OPTIMUS templates.

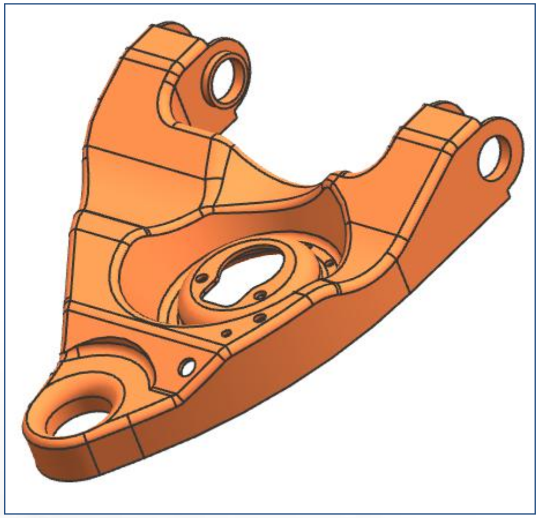






Parametrization Technology in NX

Parametrization of a chassis element

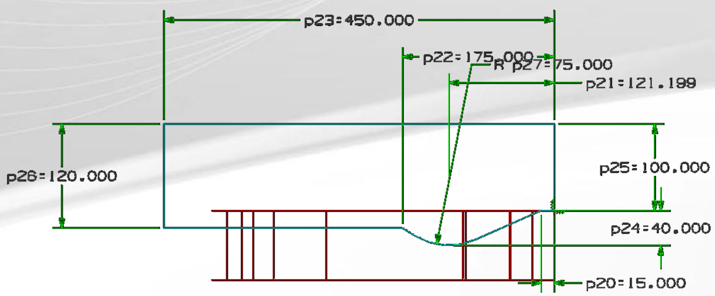


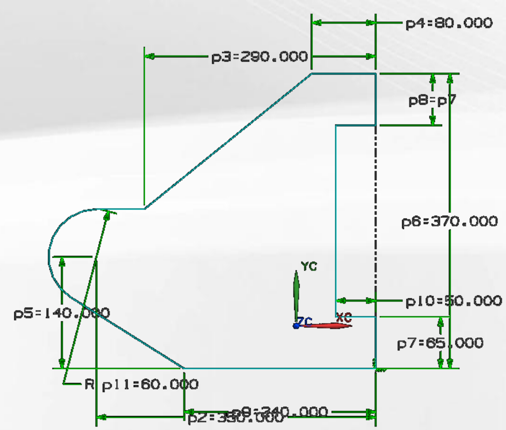
- **GOAL**: In this example the main focus is not on the optimization of certain output values, but in a first step prior to the optimization to detect the parameters effecting the responses the most

  => Sensitivity analysis:

  determining the important factors
- After identifying the influential factors the number of parameters can be reduced

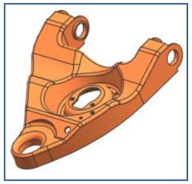
  => Reduction of dimensions
- This step is a basic task for determining the most important variables for getting good results in a subsequent optimization.



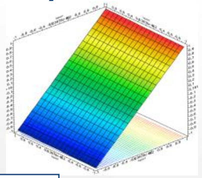


Parametrization Technology in NX

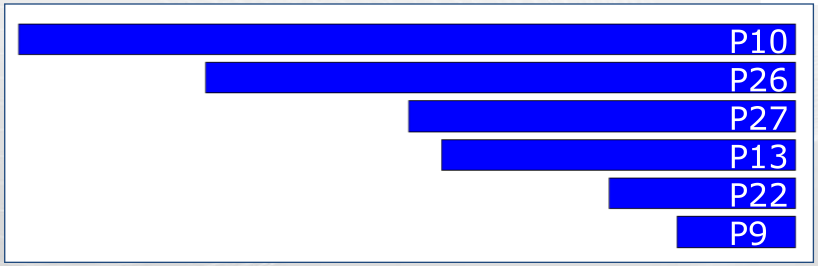
Parametrization of a chassis element



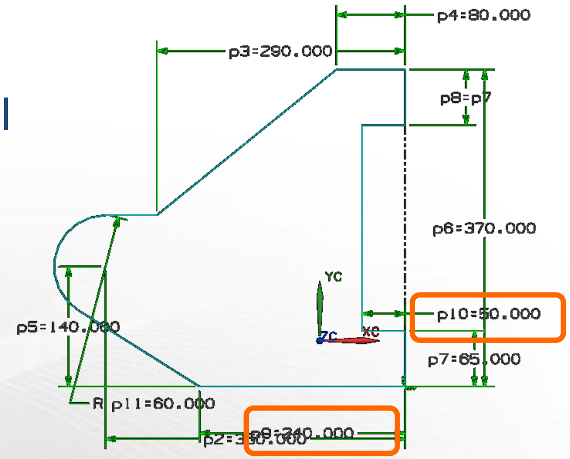
- **STEPS**: The goal is to determine the sensitivity of input parameters to different output values. In this case displacement and stresses are used as responses.
  - Calculate design table with 100 experiments
    => Latin Hypercube
  - Create new model using a linear Taylor model
    => Evaluate contribution plot

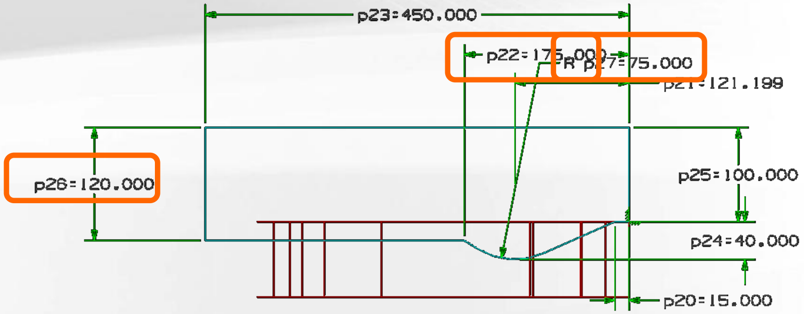


max. Displacement



max. Stress





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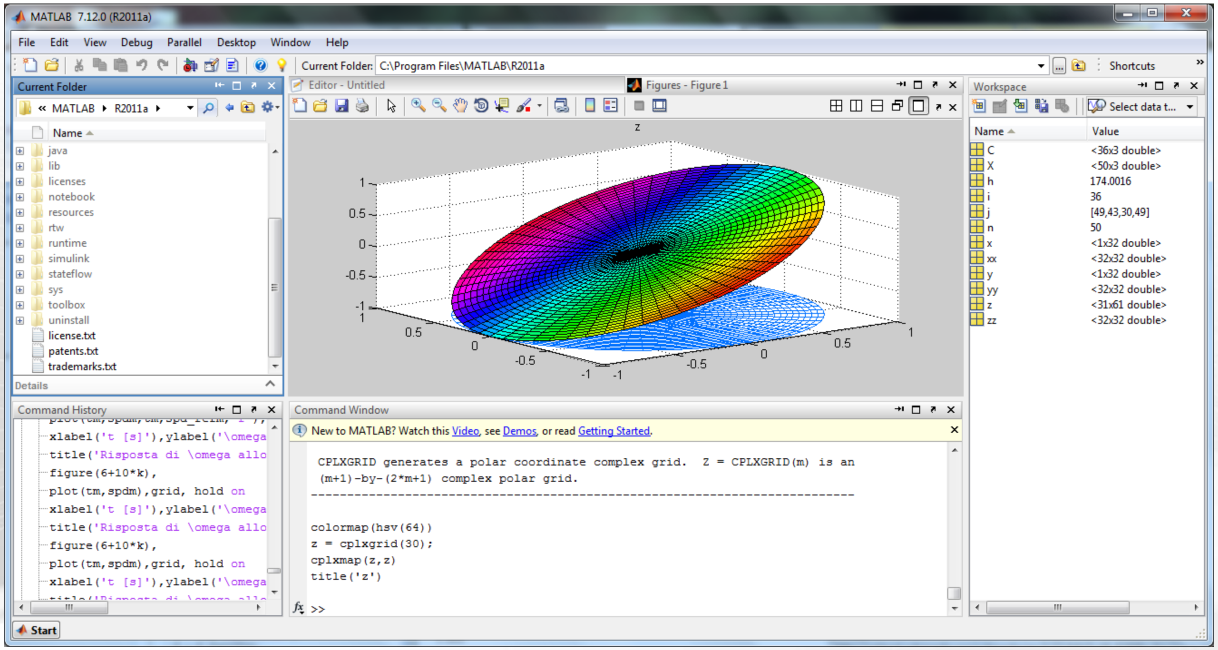
Shape Optimization using Matlab

- Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment.
- Functions and subroutines written in the C programming language can be called from within Matlab functions.

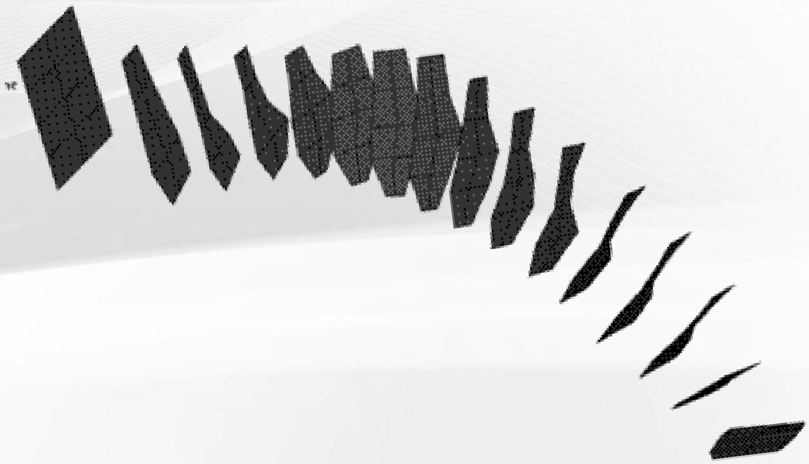


- In this case Matlab is used to build up a geometry (FE mesh) from given parameters and print out a valid Abaqus input deck for further computation.

Shape Optimization using Matlab

Parametric curves for defining geometry

- **GOAL**: The projects goal was to develop an easy-to-use process for users that are not familiar with Optimus.
- The problem setup and the definition of constraints was done outside of Optimus and the according workflow was built up in the background using the Python API of Optimus.
- The aim of the Optimus workflow was to determine the shape of a control arm with minimal mass while simultaneously fullfilling the following constraints:
  - meet a given buckling load
  - obtain a certain stiffness

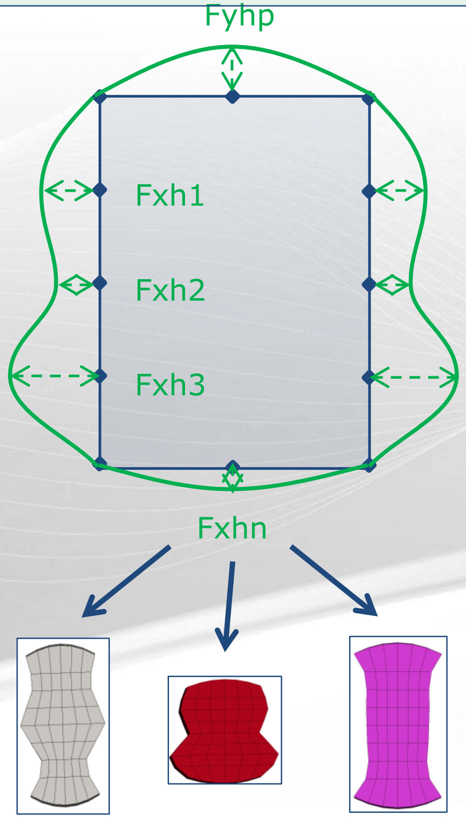


Shape Optimization using Matlab

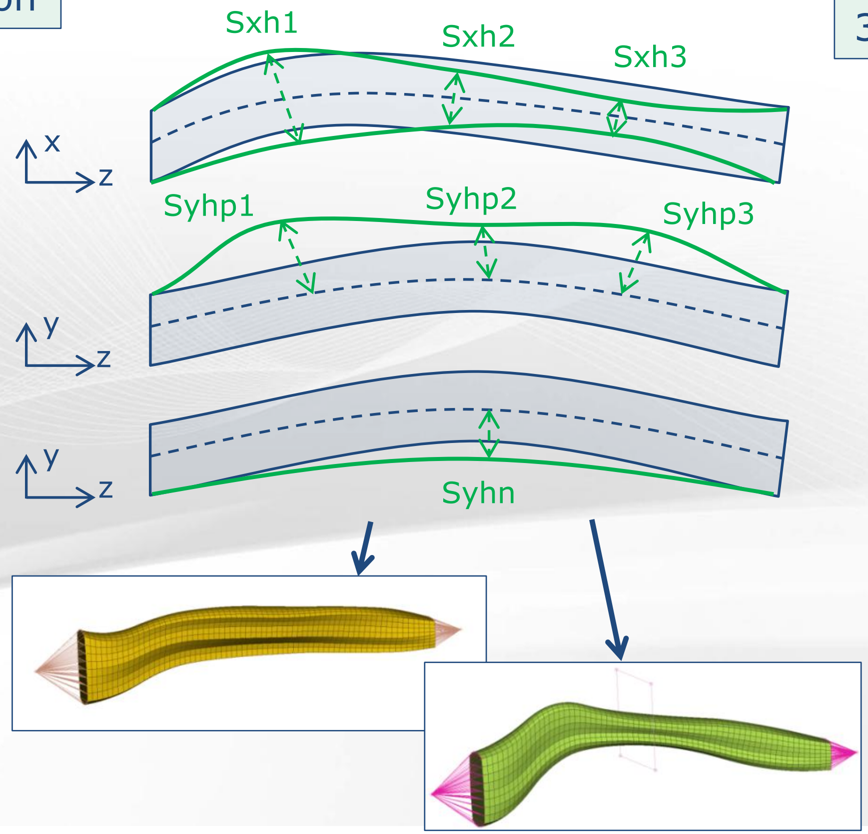
Parametric curves for defining geometry

- The difficulty in parametric shape optimization is to decide for few parameters that allow a very general description of the shape.
- For the control arm the following parameters were chosen:

1. Parametrization of cross section



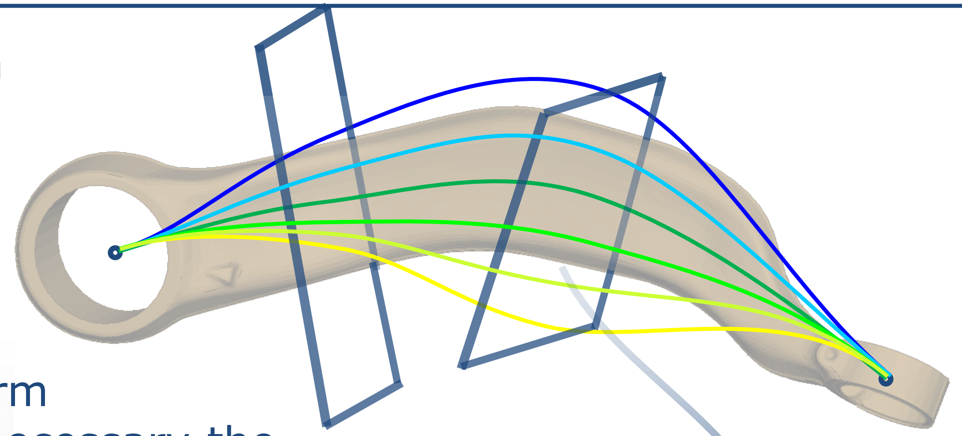
2. Scaling width and height



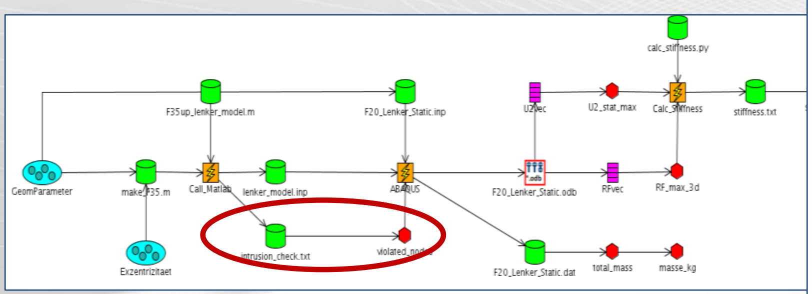
3. Rotation angle

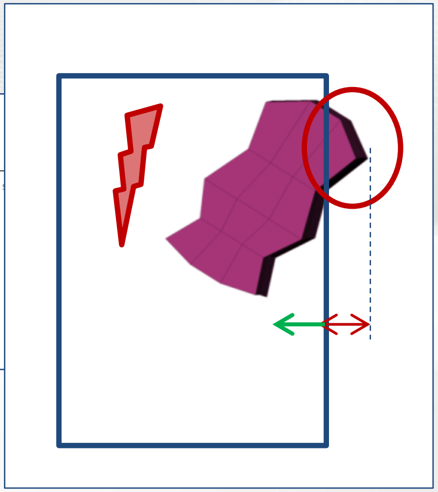
Shape Optimization using Matlab

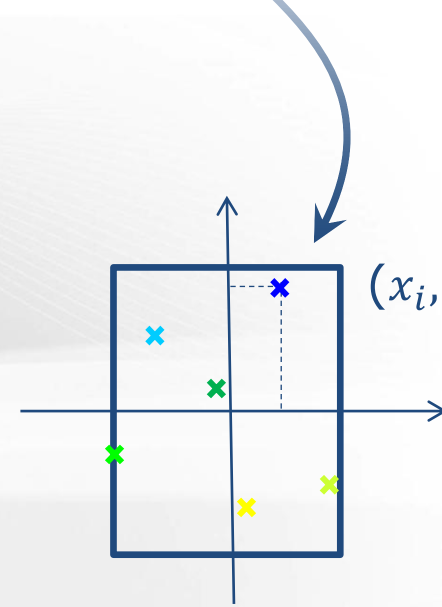
Parametric curves for defining installation space



- Additionally in this case an installation space had to be considered.
- Cutting the installation space in boxes allows us to parameterize the path through the boxes smoothly.
- To avoid invalid designs it is tested in the workflow whether the control arm intrudes the installation space and if necessary the arm is pushed back into place.



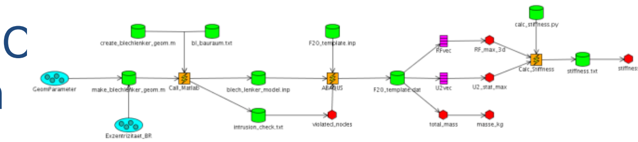




Shape Optimization using Matlab

Automated optimization process of a control arm

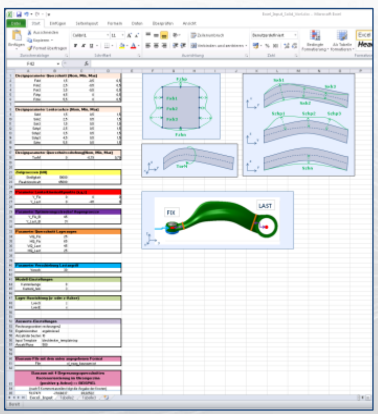
- **STEPS**: The realized optimization process uses the C
  Python functionality to automatically create and run
  the workflow depending on the given information.



User →

→

Excel-File



Result-Folder

User ←

←

OPTIMUS – PYTHON

Modification of Matlab-Files
(Used for Meshing and creating valid
Input decks for Abaqus)
Update of Template-Workflows

↓

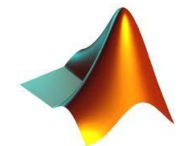
Optimization of excentricity/best
path through installation space

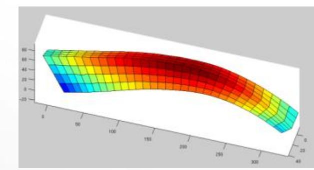
↓

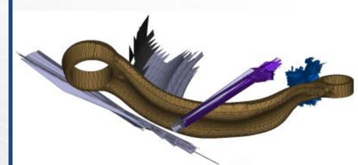
Optimization of arm geometry
based on the calculated
excentricity

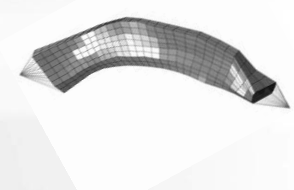
↓

Extraction of the 10 best designs and
refined calculation





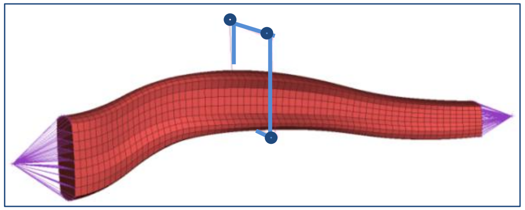


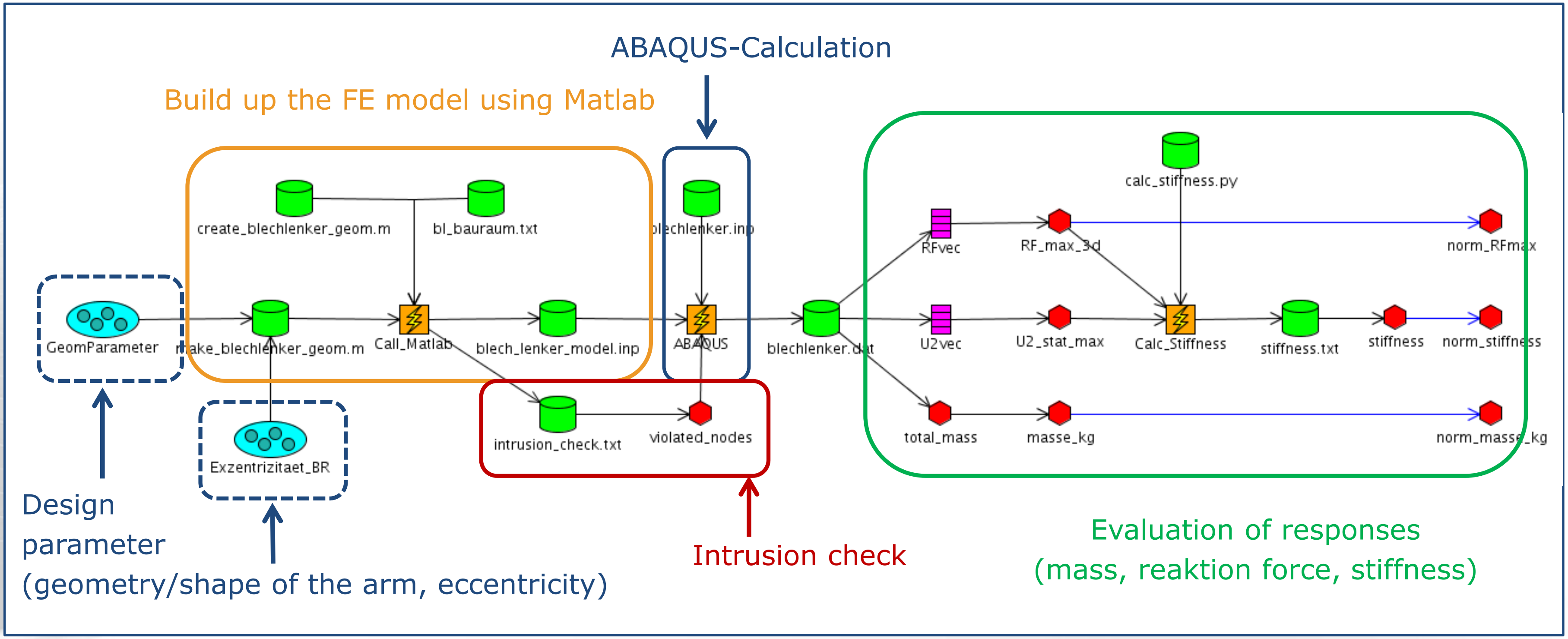


Shape Optimization using Matlab

Underlying Optimus Workflow

- The Python script was used to build up the following workflow:

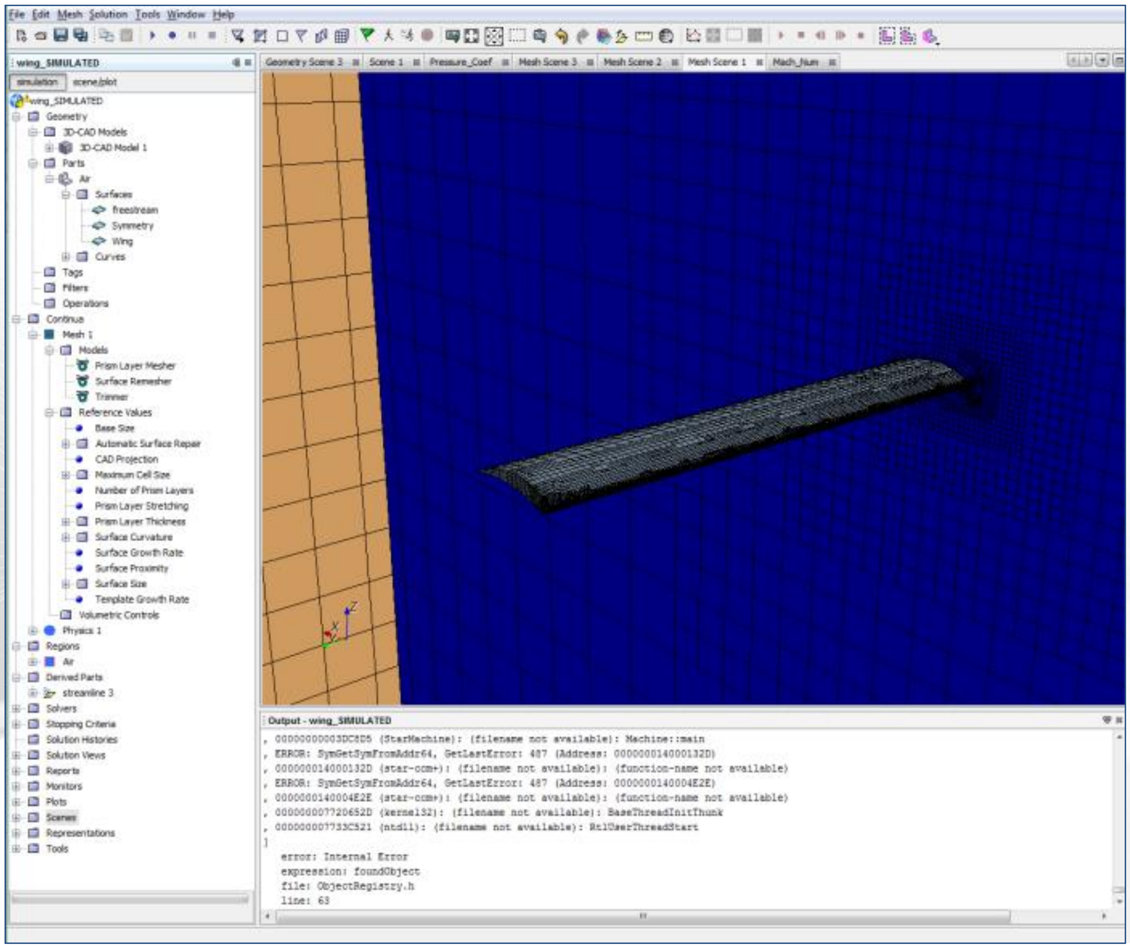




STAR-CCM+ for Shape Optimization

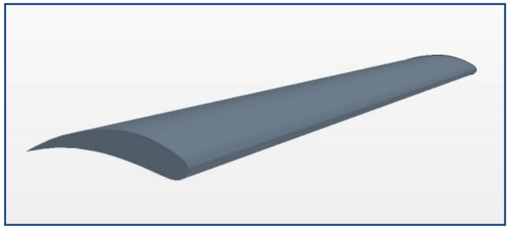
Shape optimization in CFD

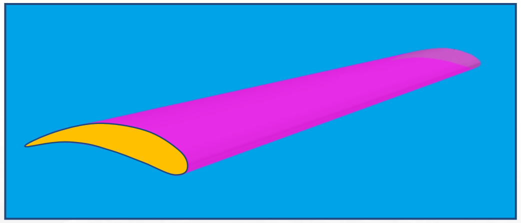
- STAR-CCM+ is an all-in-one tool for solving fluid dynamic and heat transfer problems, including all steps from creating the geometry to post processing the solver data



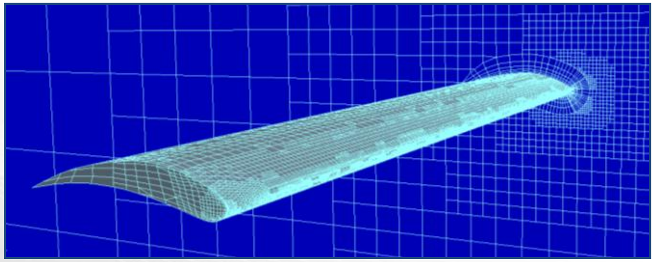
Problem Setup

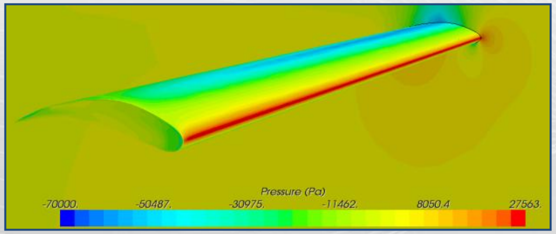
- Each problem can be split up in the following steps:

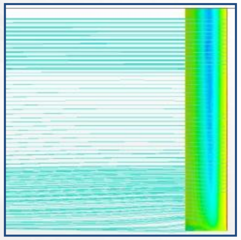




1. Geometry creation or import (from CAD-system)
2. Definition of boundaries and constraints
3. Automatic generation of the mesh
4. Starting the CFD & thermal simulation
5. Postprocessing and extracting the results





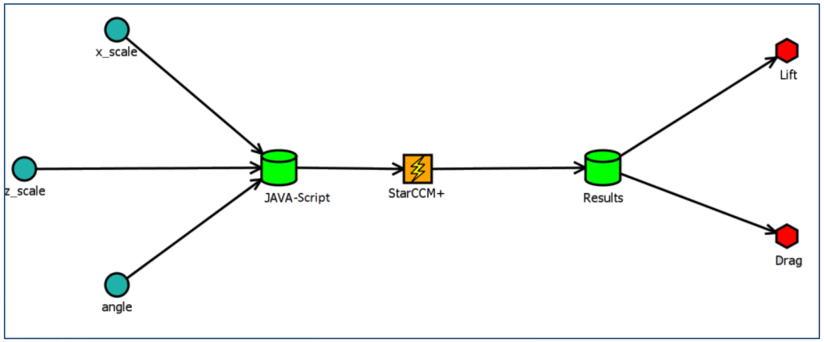


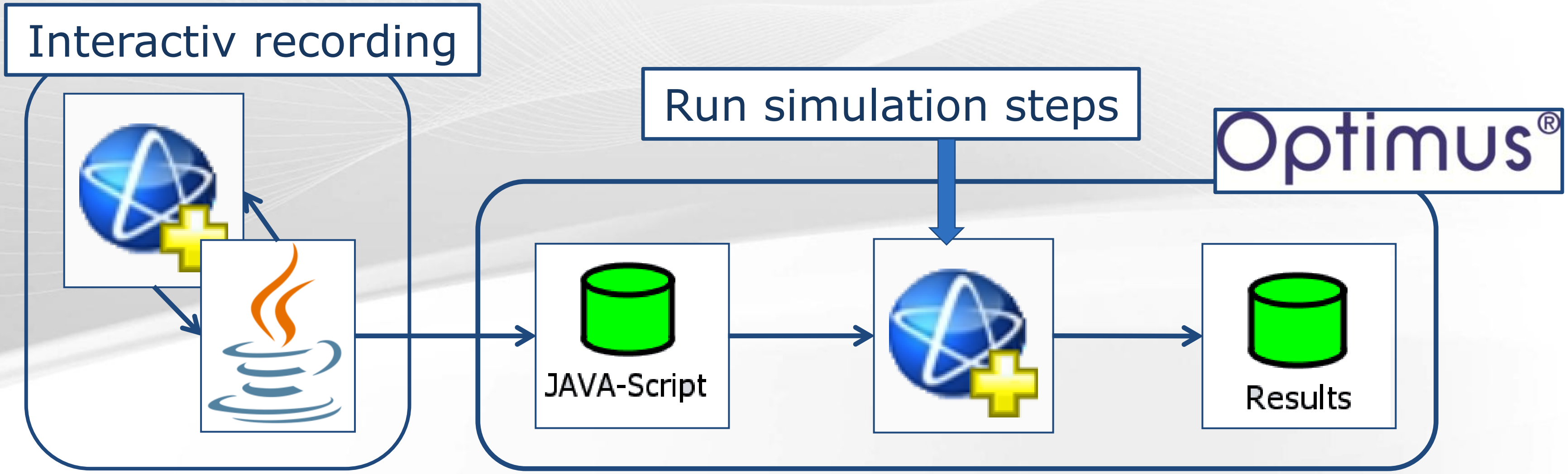
- All these steps can be controlled and automated through the JAVA-API

STAR-CCM+ for Shape Optimization

Automation Possibilities in STAR-CCM+

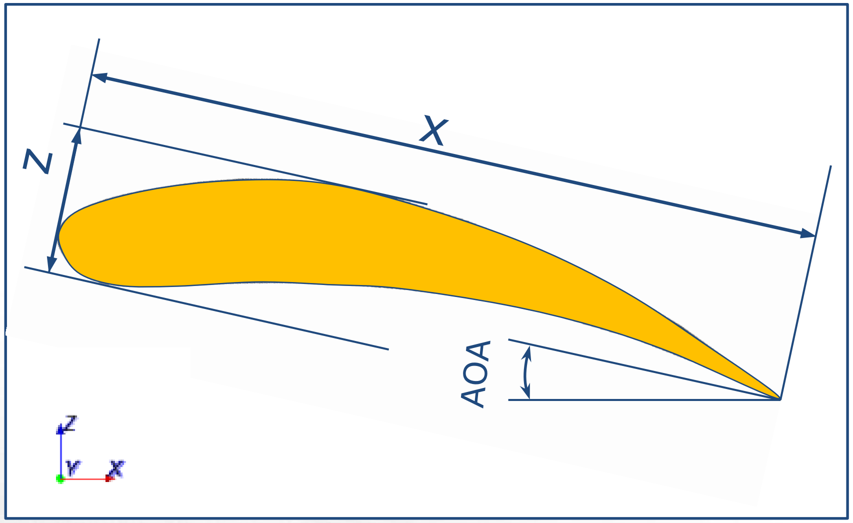
- The complete user actions during the setup of a simulation can be recorded with the JAVA-API and a JAVA-Script is created that can be used within Optimus.
- The journal also contains the definitions the geometrical or physical parameters.
- The JAVA-Script can be accessed and modified in the workflow and StarCCM+ will be called for the setup and calculation of a new experiment.





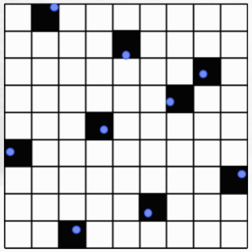
STAR-CCM+ for Shape Optimization

Goal and results of optimization



- **GOAL**: The goal is to determine the best height and width and also the angel of attack of the wing for:
  - maximum lift and
  - minimum drag

- **STEPS**: To keep the number of evaluations as small as possible and simultaneously get good results, the following strategy was chosen:
  1) Calculate a design table with 200 experiments
     => Latin Hypercube
  2) Build up a RSM and check quality criterion
     => ClearVu Analytics
  3) Run a multi-objective optimization on the model
     => Euclidean Distance Function/Global Criterion Method
  4) Validate the results on the analysis sequence with StarCCM+ simulations



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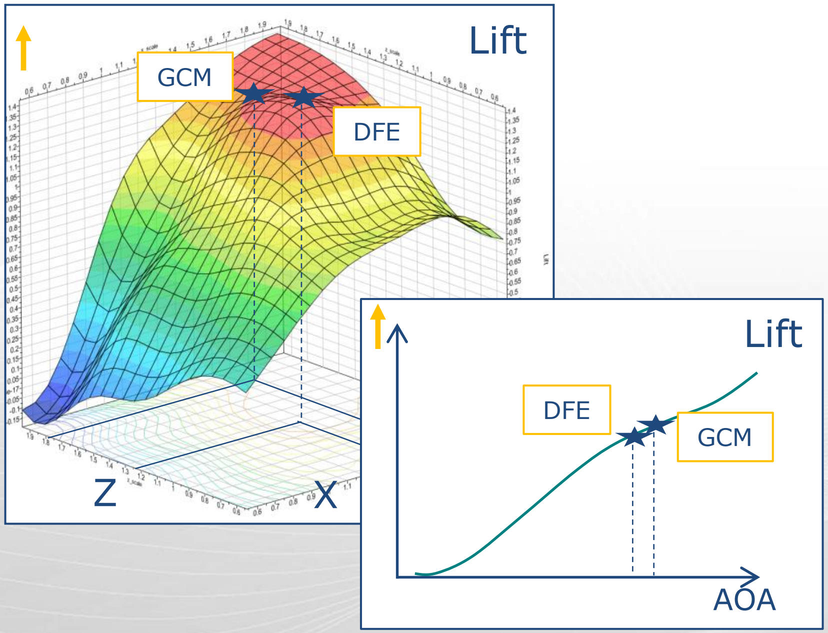
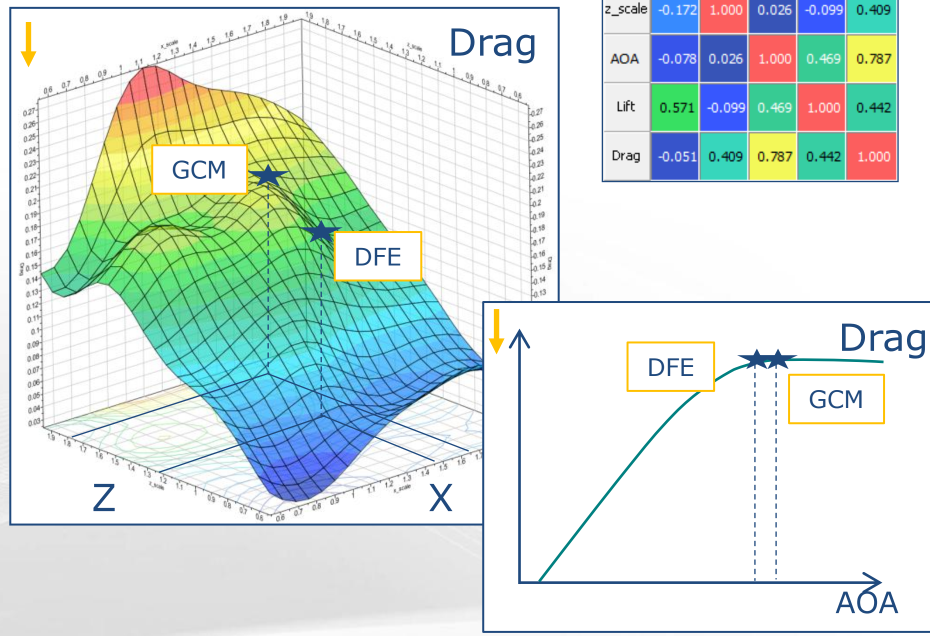
Goal and results of optimization

- Prior to the optimization the influence of the inputs on the outputs can be estimated with linear correlation factors:

	x_scale	z_scale	AOA	Lift	Drag
x_scale	1.000	-0.172	-0.078	0.571	-0.051
z_scale	-0.172	1.000	0.026	-0.099	0.409
AOA	-0.078	0.026	1.000	0.469	0.787
Lift	0.571	-0.099	0.469	1.000	0.442
Drag	-0.051	0.409	0.787	0.442	1.000





X	Z	AOA	Lift	Drag	Calculation Mode	Optimum
1,458	1,234	11,023	1,466	0,176	RSM	Distance Function Euclidean
1,458	1,234	11,023	1,35	0,171	Simulation	
1,642	1,797	12,334	1,256	0,093	RSM	Global Criterion Method
1,642	1,797	12,334	1,475	0,279	Simulation	

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Thank you for your attention