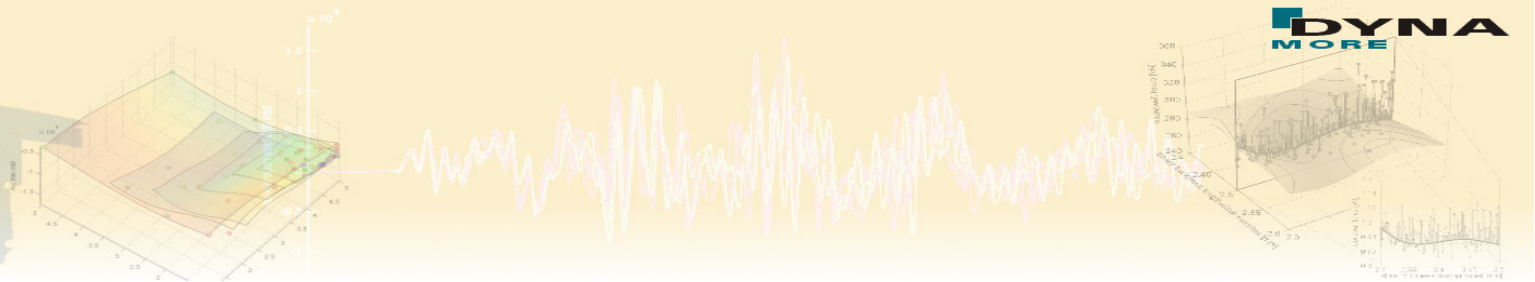


# Neue Möglichkeiten zur Visualisierung von Daten aus Optimierung, DOE-Studien und stochastischen Analysen

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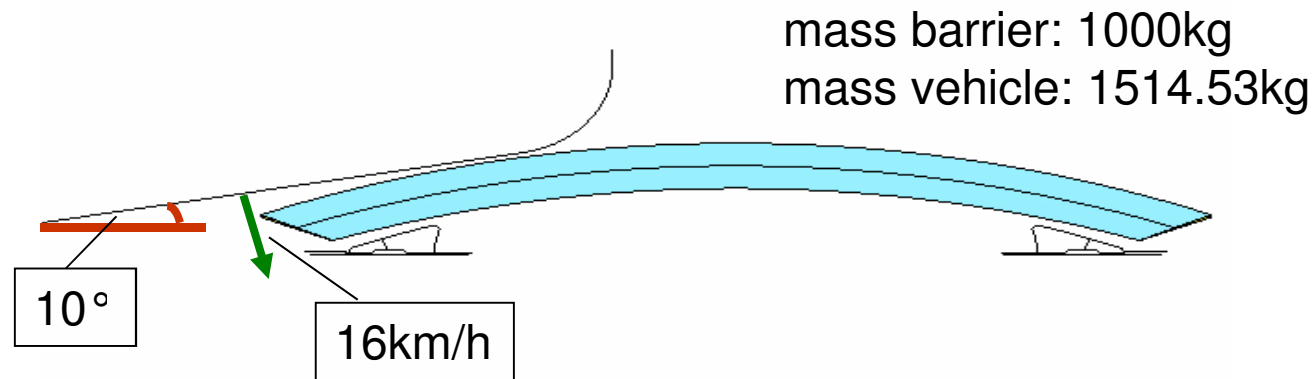
# Overview



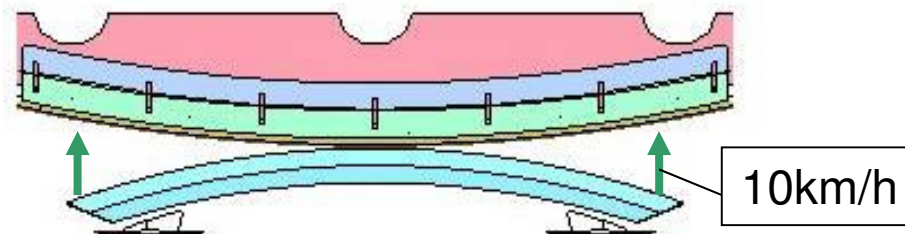
- Example: Optimization of a crash management system
  - *Problem description*
  - *Visualization of Pareto optimal solutions*
    - SOM
    - Parallel coordinate plot
  - *Visualization of history curves and predicted histories*
- Example: DOE study of a front crash
  - *Problem description*
  - *Visualization of sensitivities*
    - Correlation matrix
    - Linear ANOVA
    - Global sensitivities (Sobol)
    - Interpolator plot
- Summary

# Optimization of a Crash Management System

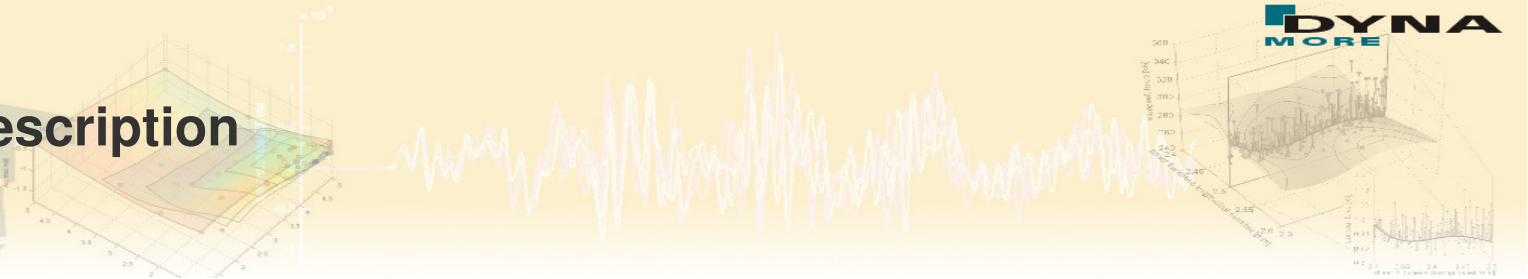
- Load case 1: AZT crash repair test



- Load case 2: RCAR test

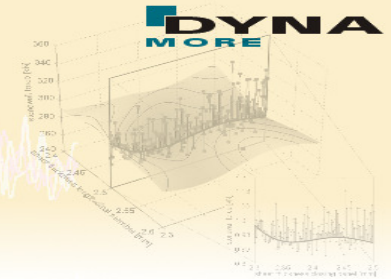


## Problem Description

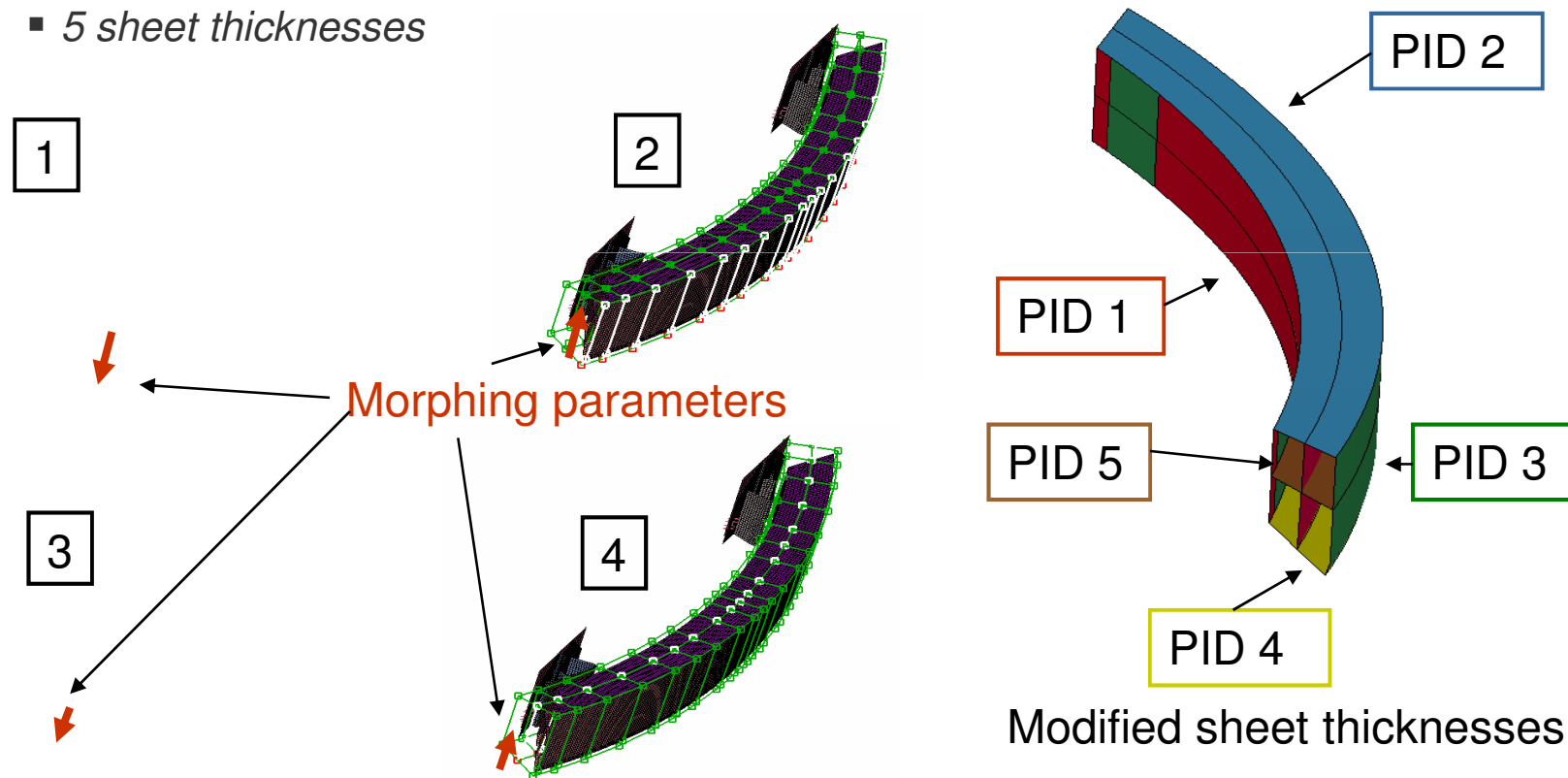


- Objective: optimize the energy absorption by plastic deformation of the bumper
- Given maximal force level for load case AZT (barrier contact force)
- Bumper has extruded section → constant cross section

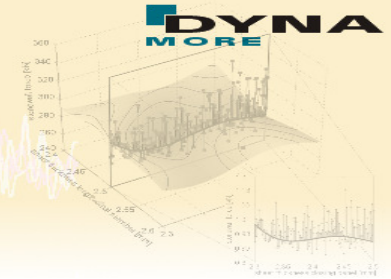
# Problem Description



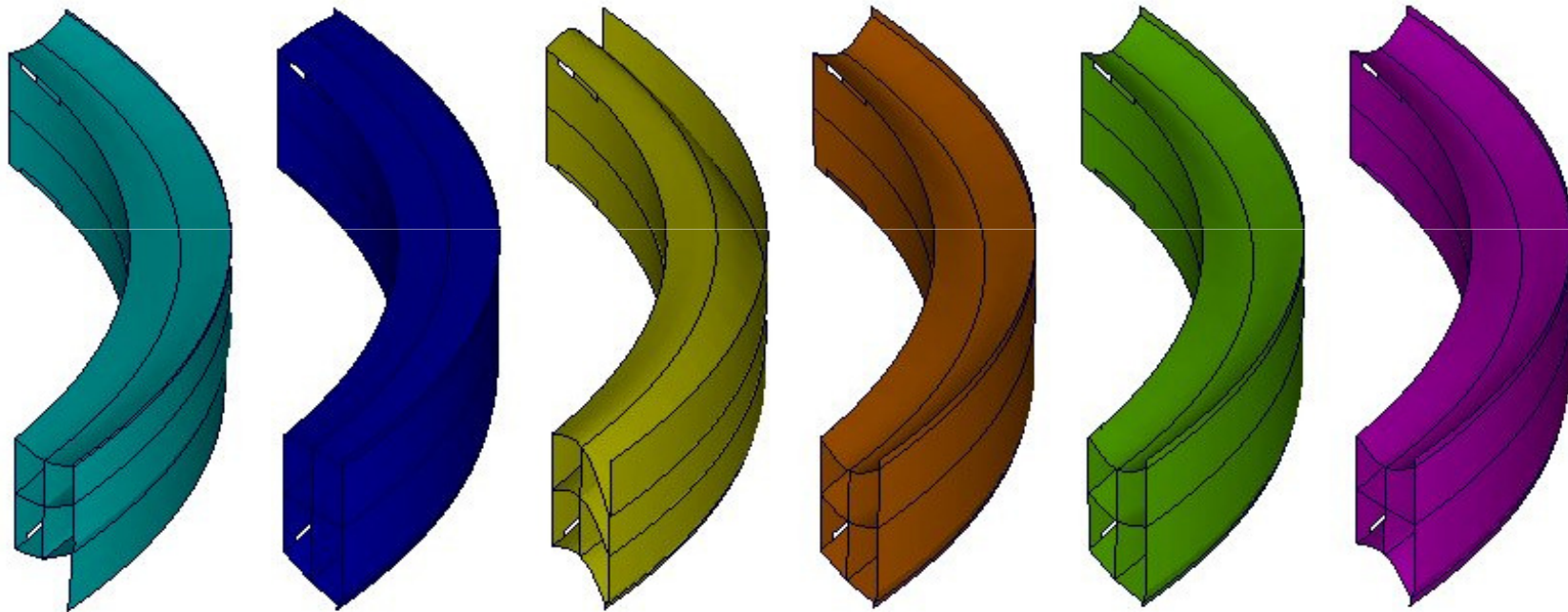
- 9 design variables
  - 4 *Morphing parameters* (ANSA as preprocessor in LS-OPT)
  - 5 *sheet thicknesses*



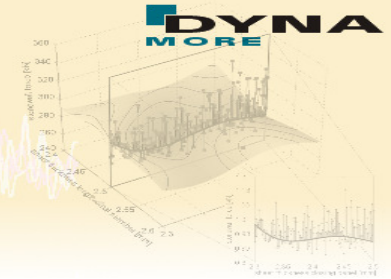
# Resulting Bumper Shapes



- Some resulting bumper shapes of ANSA morphing



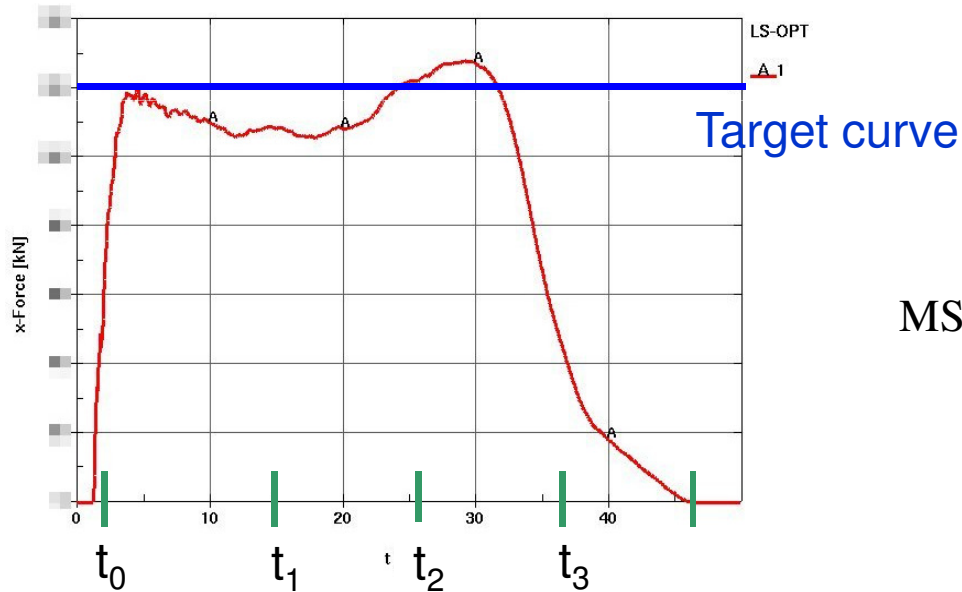
# Problem Description



- 3 Objectives

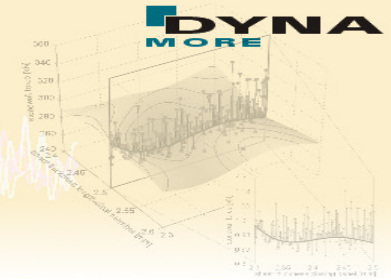
- MSE\_Force (load case AZT)

- sum of squares error between calculated contact force curve and given constant contact force  $c$



$$MSE\_Force = \sqrt{\sum_{i=0}^3 (F(t_i) - c)^2}$$

# Problem Description



- 3 objectives

- *Max\_Intrusion (load case RCAR)*

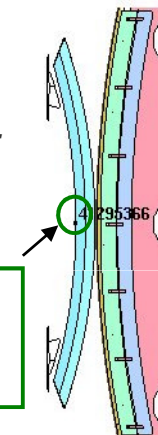
→ *Intrusion = displacement of center of mass of vehicle*

- *displacement of inner edge of bumper*

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center of mass  
of vehicle

node at inner  
edge of bumper



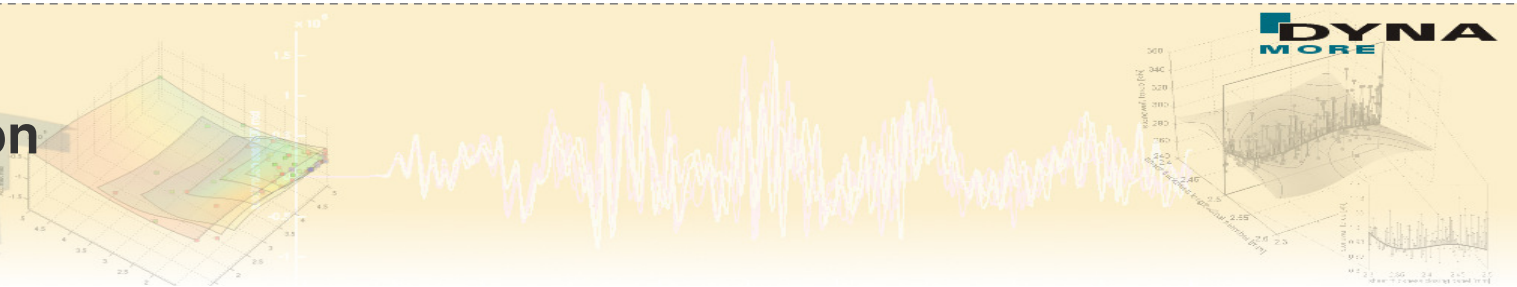
- *Total mass of the bumper*

- constraint: contact force < C

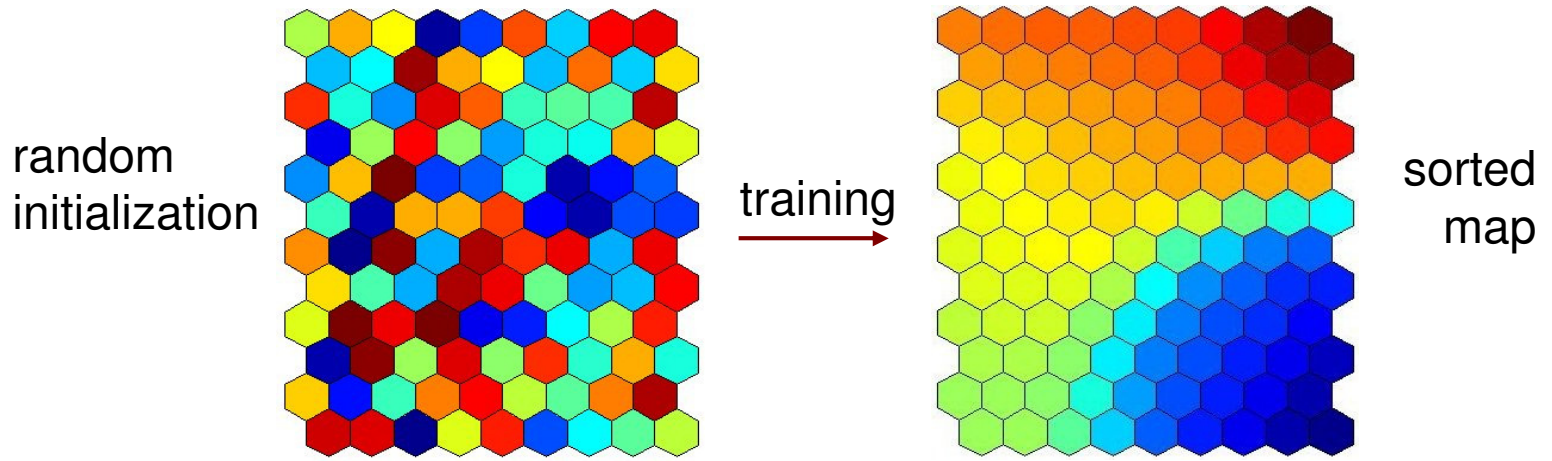
- Multi-Objective optimization → set of Pareto optimal solutions (metamodel-based)



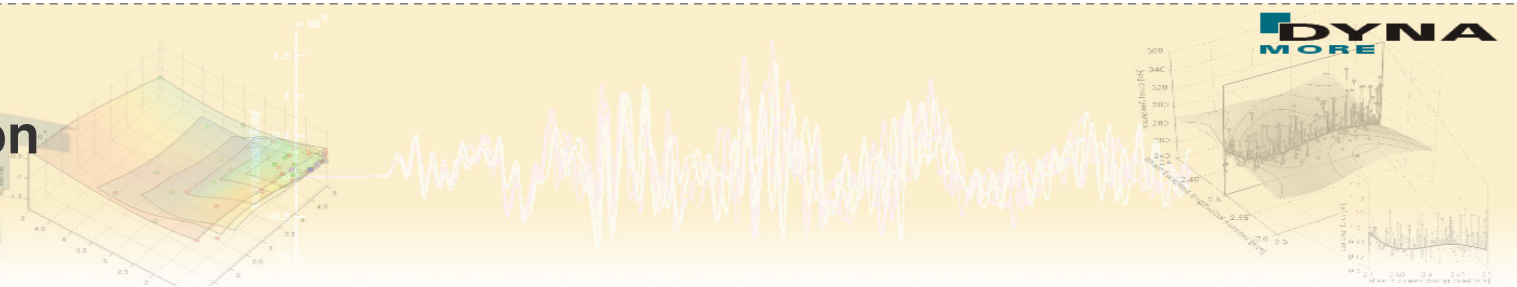
# Visualization



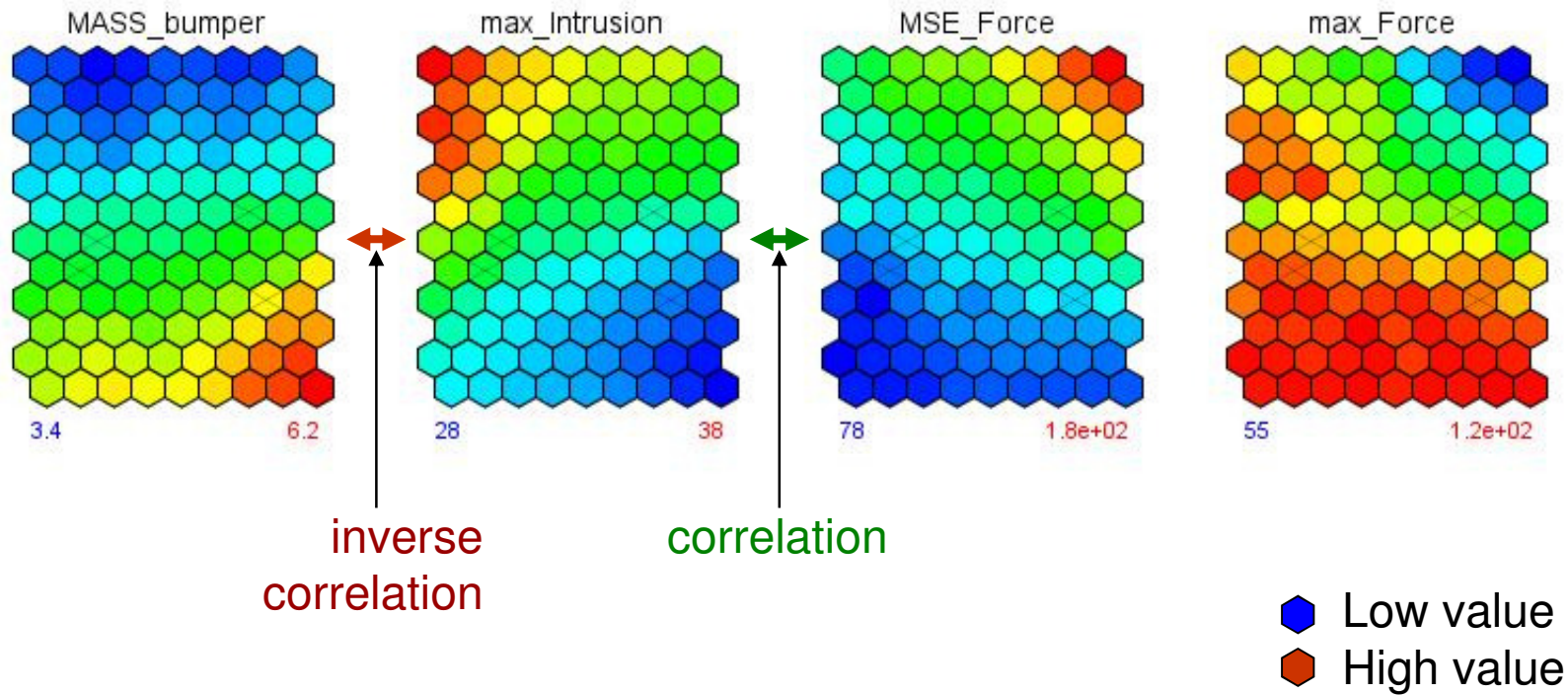
- Self organizing maps (SOM) → Conflicting objectives
  - *Unsupervised neural network algorithm*
  - *Projects n-dimensional data onto two-dimensional array of nodes*
  - *Each node is associated with n-dimensional weight vector*
  - *Algorithm sorts and adapts weight vectors such that similar data is mapped to the closest node*
  - *Component map: visualizes one component of weight vector by coloring the grid according to the value of selected component*



# Visualization

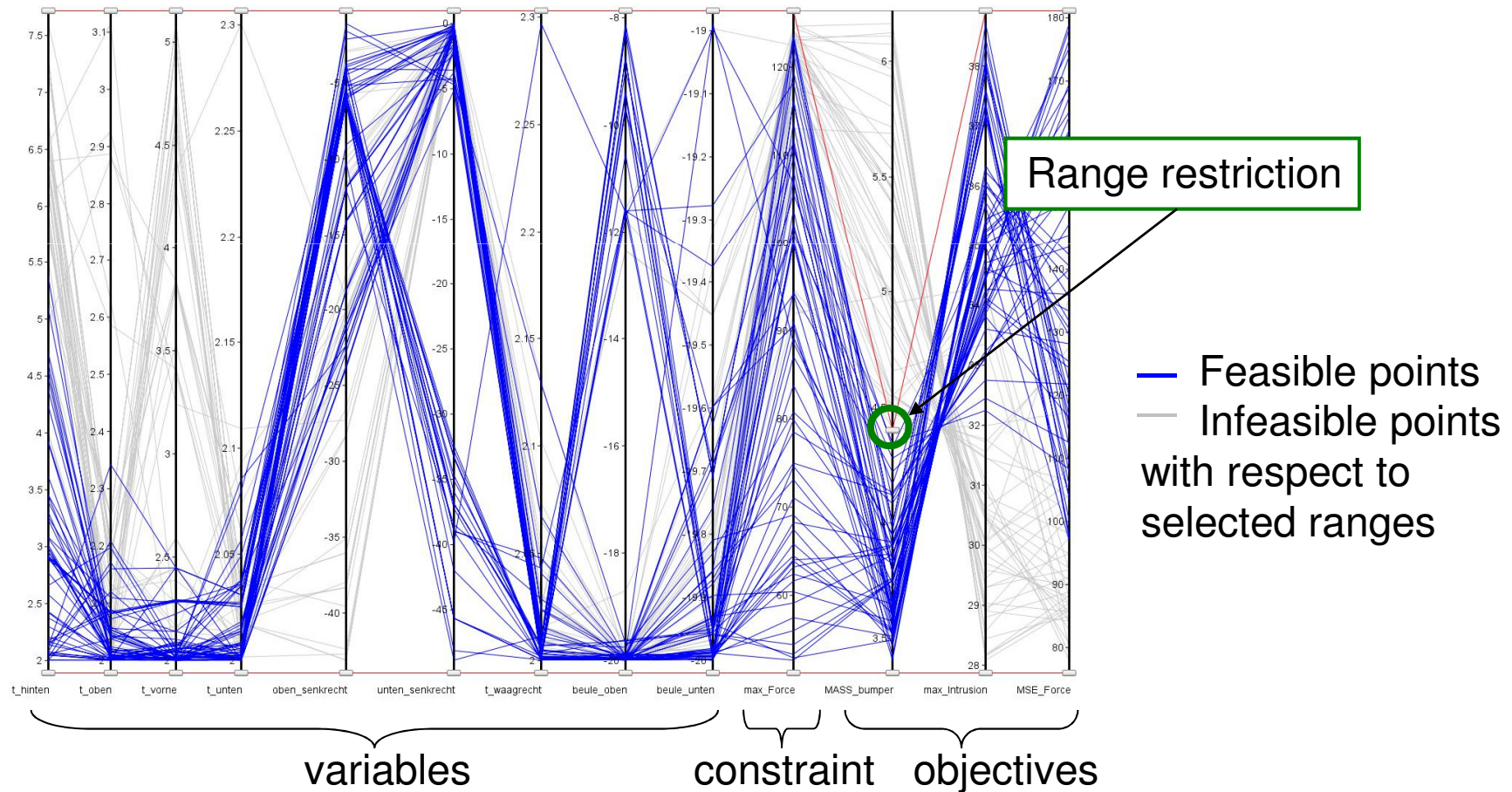


- SOM (Self Organizing Maps) → (inverse) correlation of entities
- Component maps of objectives and constraint

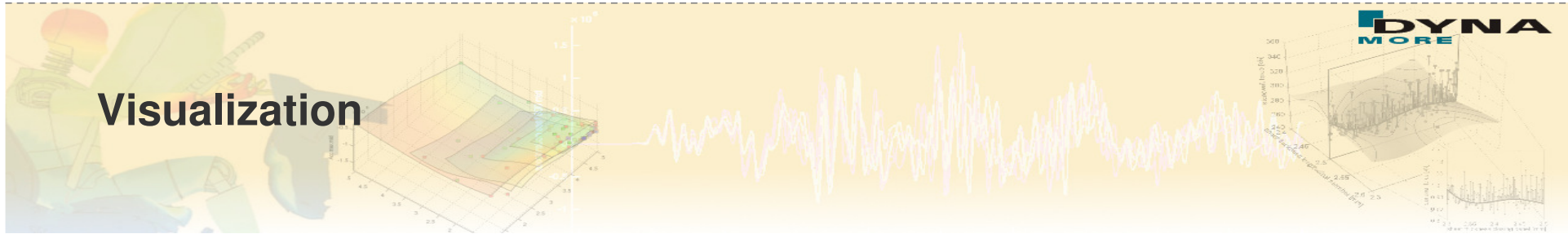


# Visualization

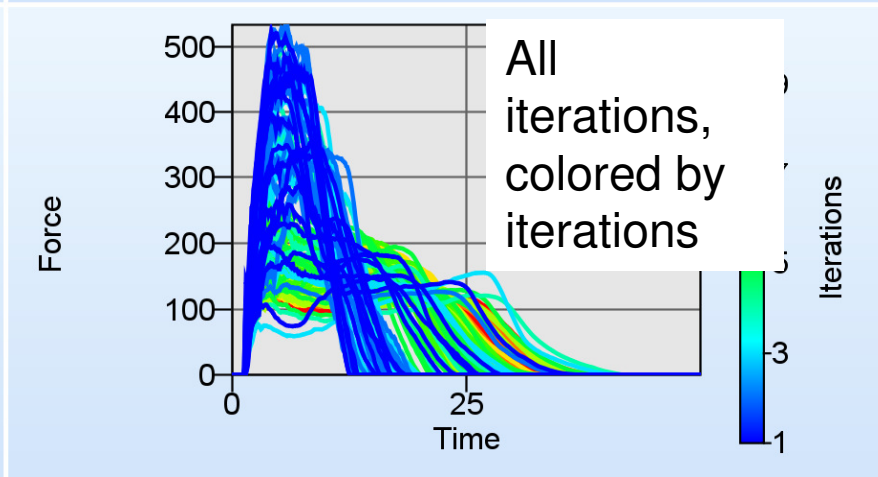
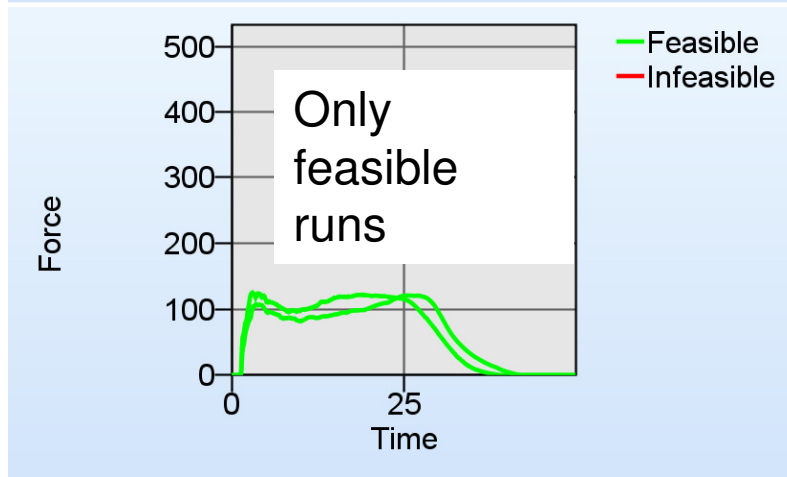
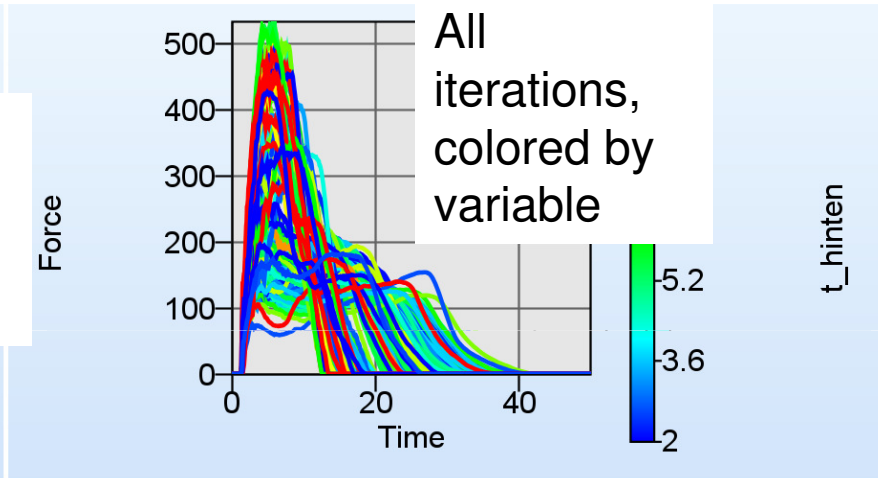
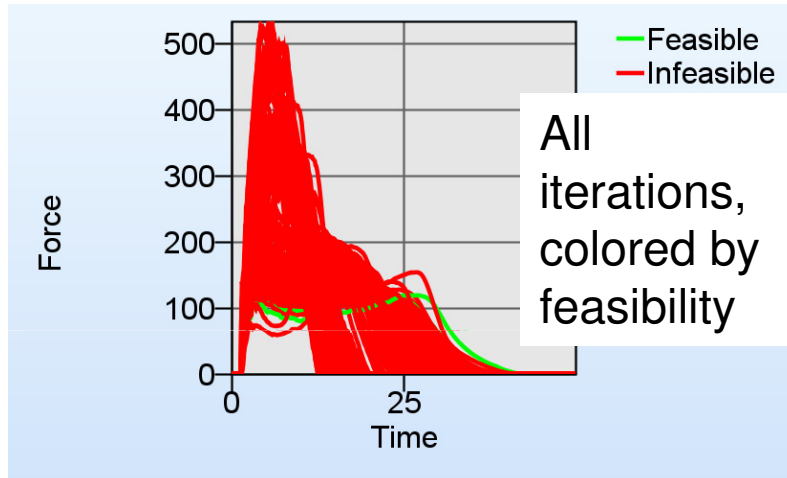
- Parallel Coordinate Plot → Reduce number of suitable solutions by restricting ranges of objectives



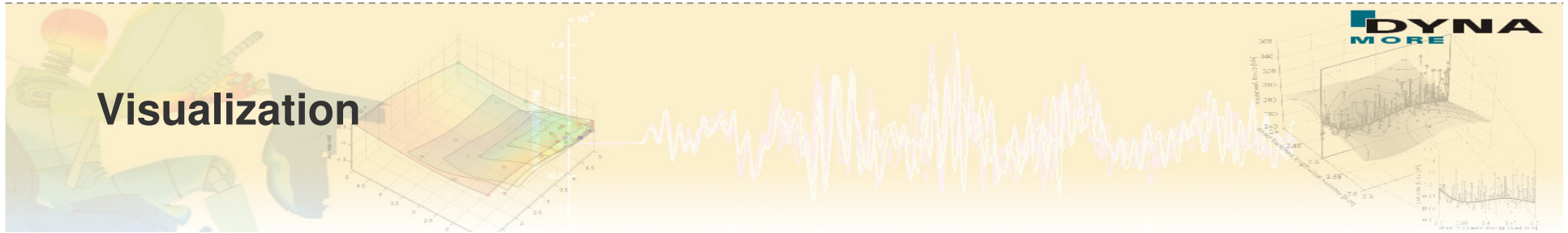
# Visualization



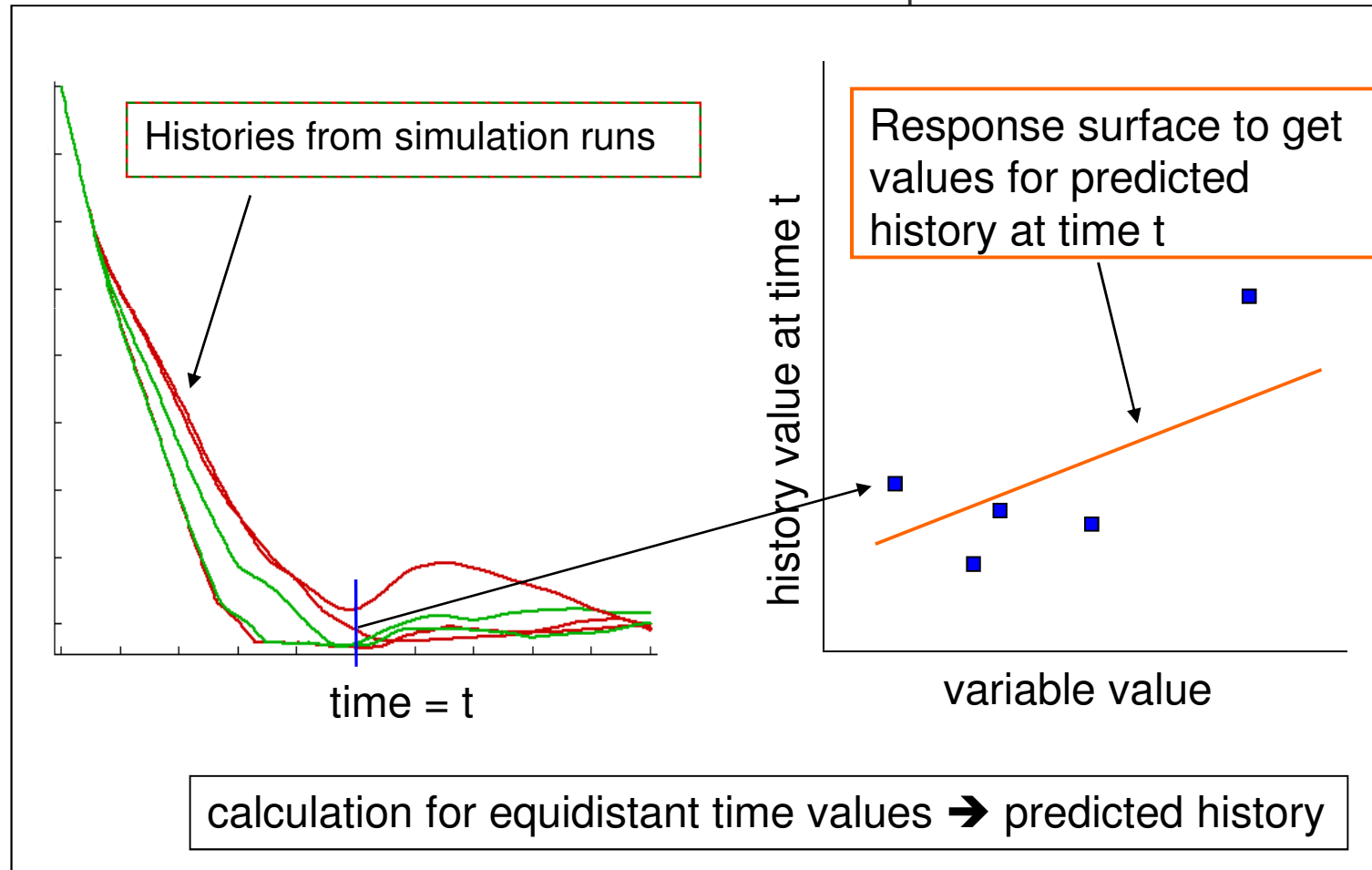
- History curves: contact force curve



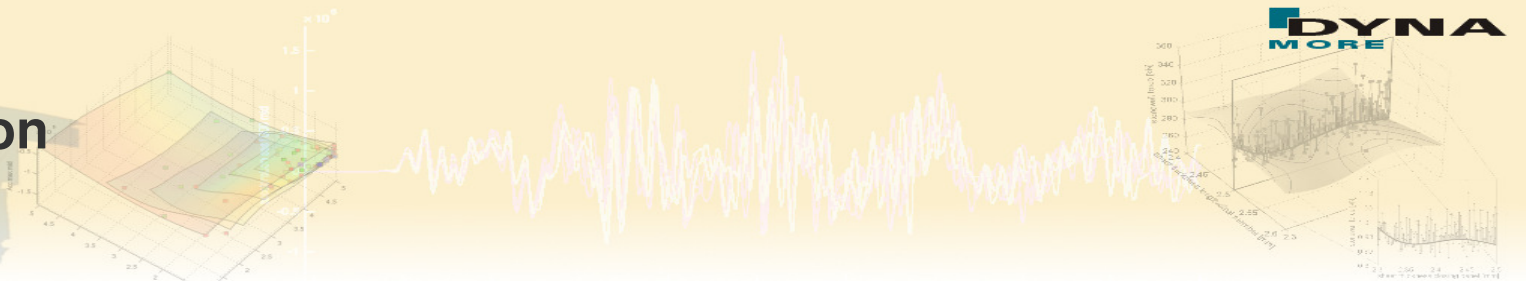
# Visualization



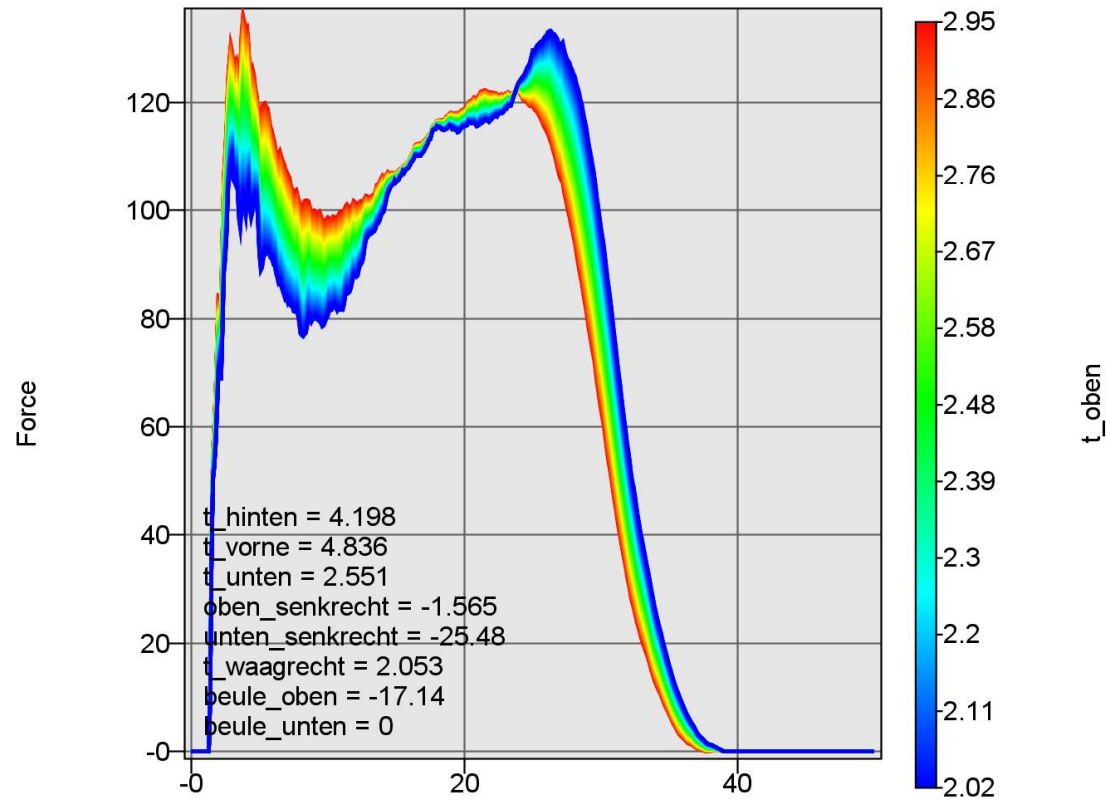
- Predicted Histories – extension of metamodel concept to curve data



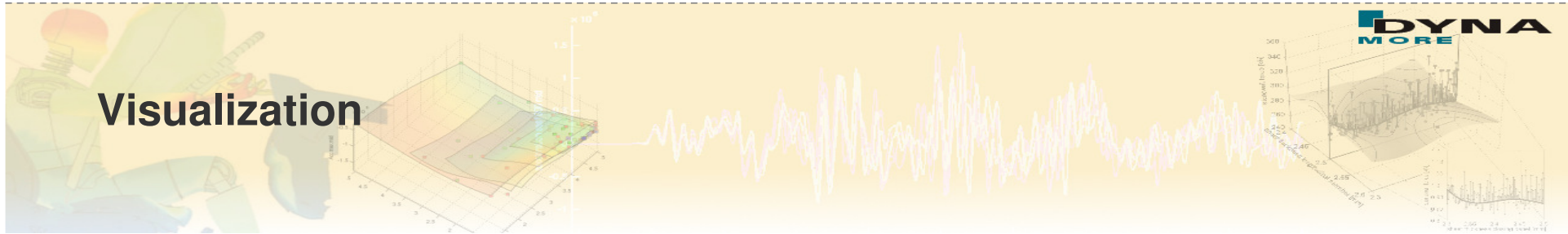
# Visualization



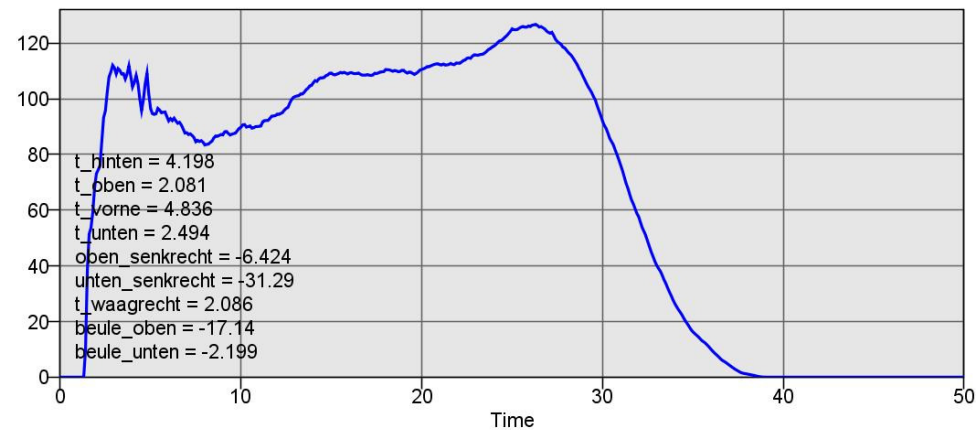
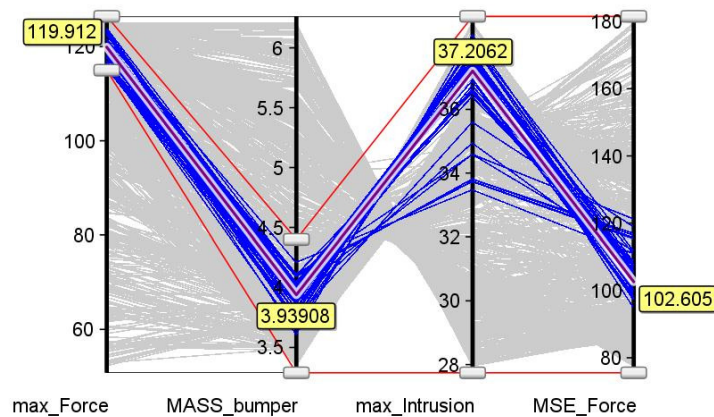
- Predicted History colored by variable
  - curves for the whole range of the selected variable are displayed
  - visualizes the effect of a single parameter on the curve



# Visualization

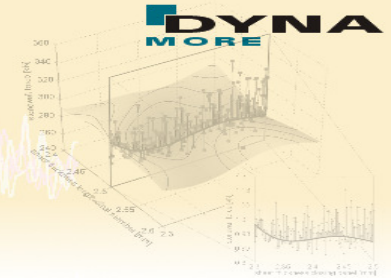


- Predicted History Plot with variable values evaluated from a selected Pareto optimal point

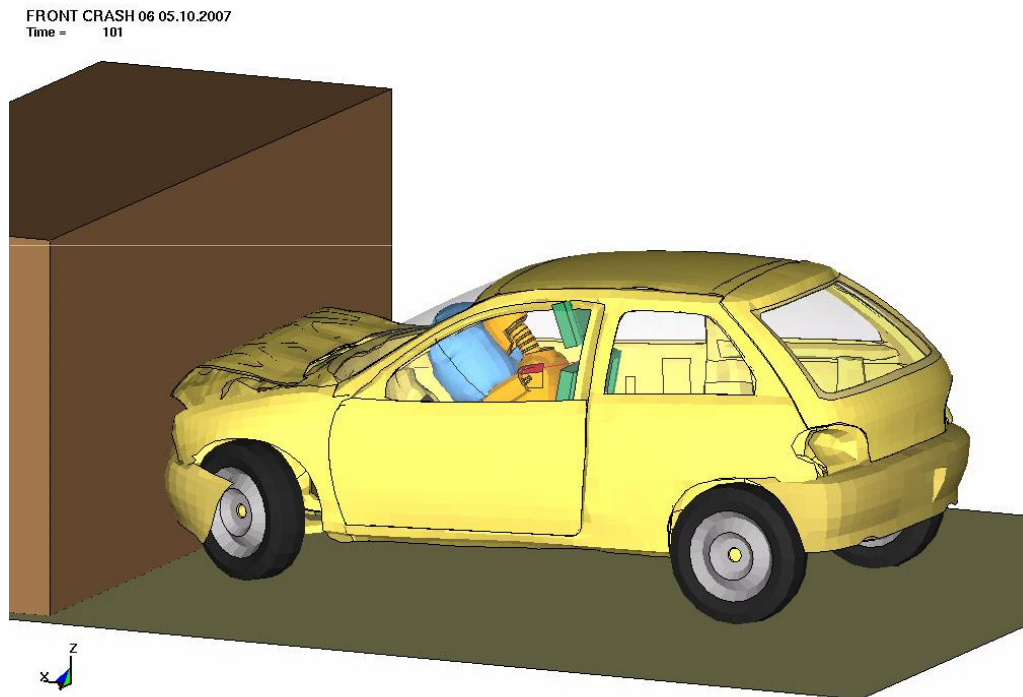


- Selection of suitable points out of the set of Pareto optimal solutions
  - Store variable values in a .csv file
  - user-defined sampling in LS-OPT
  - verification runs for the predicted results can be performed

# DOE Study of a Front Crash

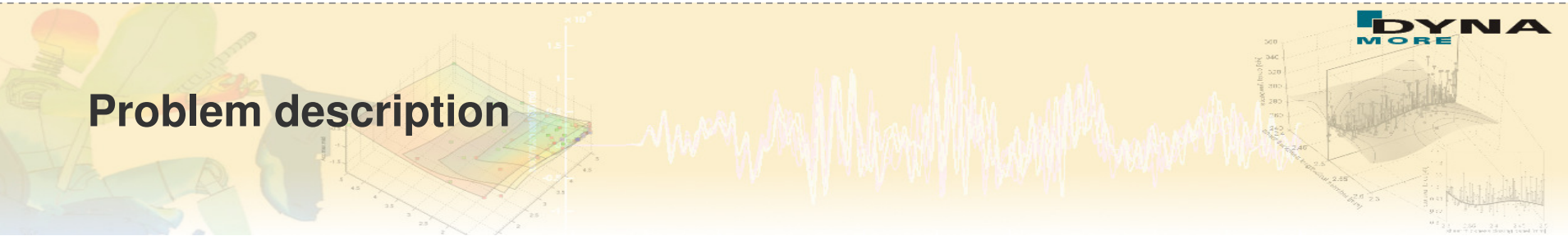


- Load case: frontal impact of a car on a rigid barrier
- Model from NCAC (National Crash Analysis Center) <http://www.ncac.gwu.edu>

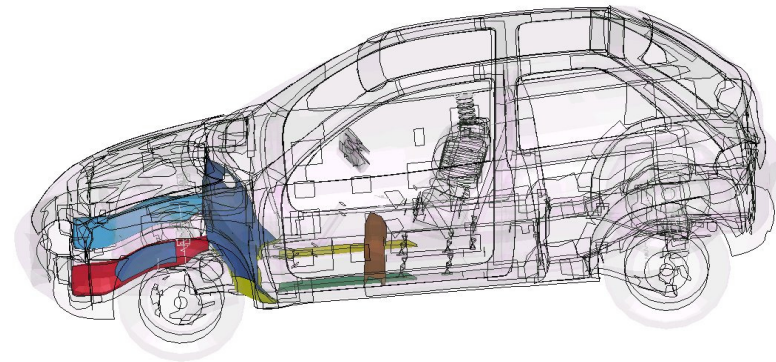




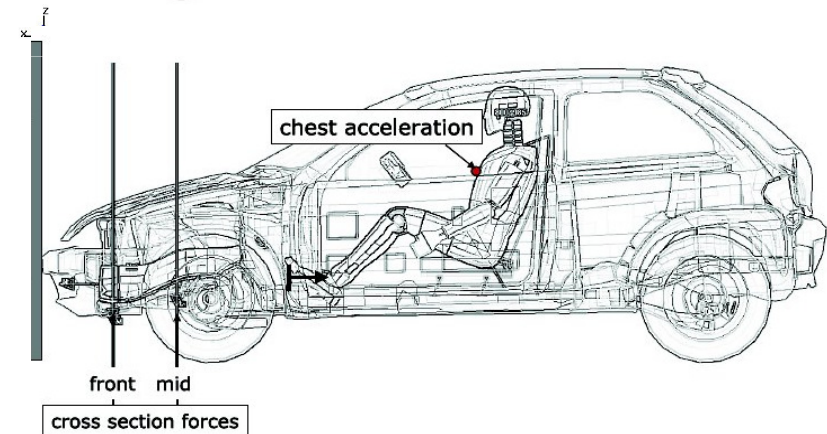
## Problem description



- 6 design variables
  - *sheet thicknesses of highlighted parts*

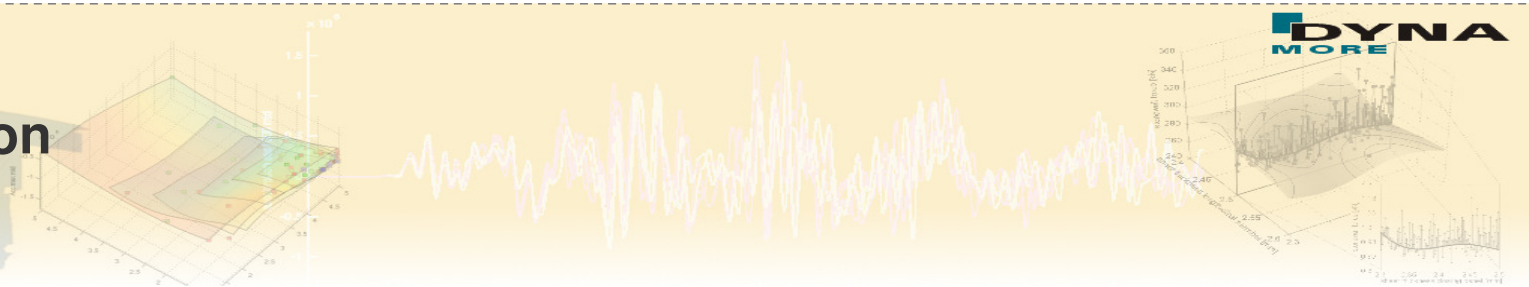


- Responses
  - *Chest acceleration of dummy*
  - *Forces evaluated at 2 cross sections*
  - *Constraint on mass of vehicle*

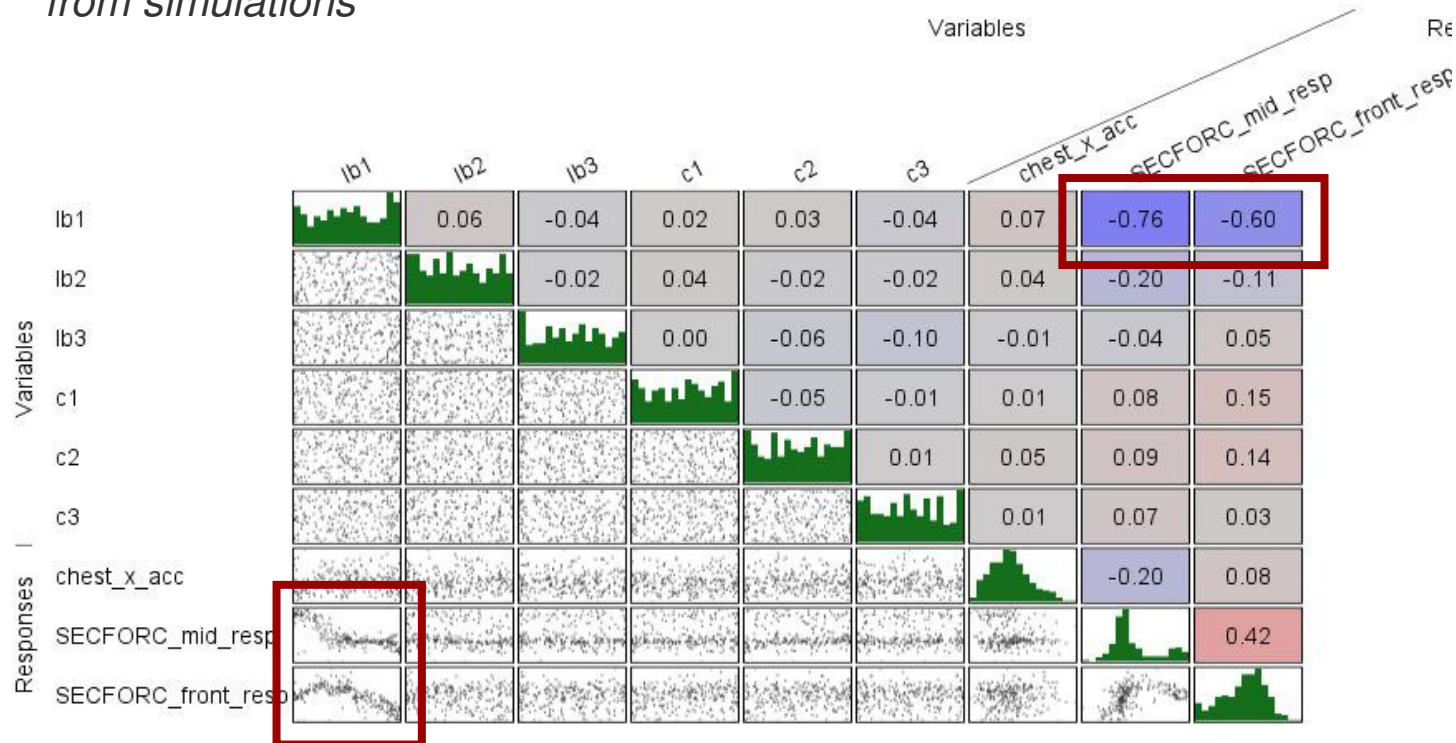


- 250 LS-DYNA simulations
- Sensitivities evaluated on RBF metamodel

# Visualization



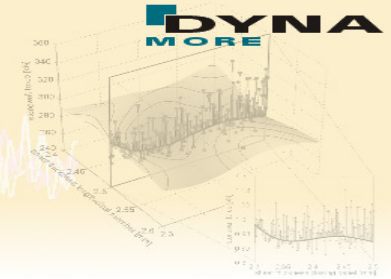
- Correlation Matrix
  - Scatter plots, histograms, linear correlation coefficient evaluated using values from simulations



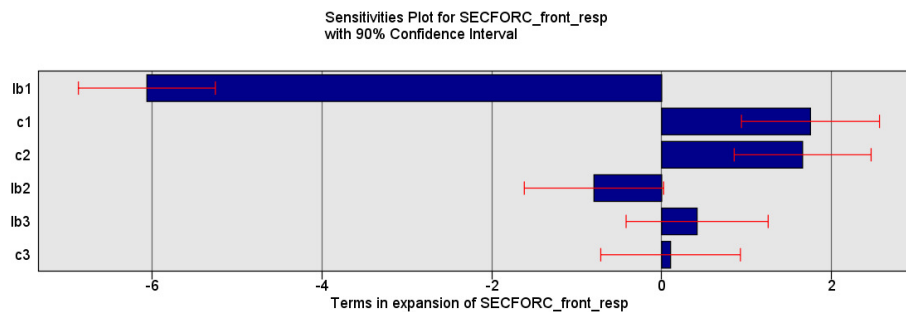
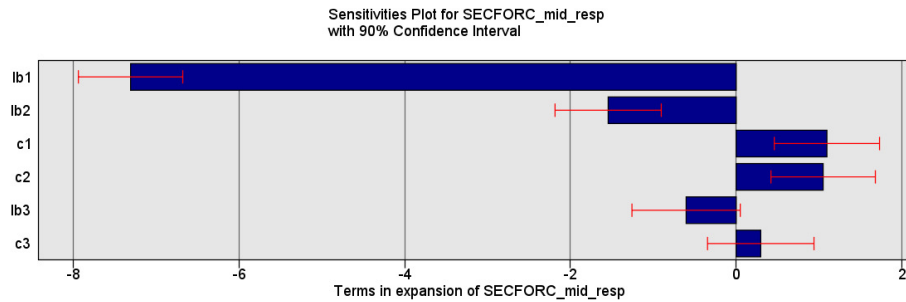
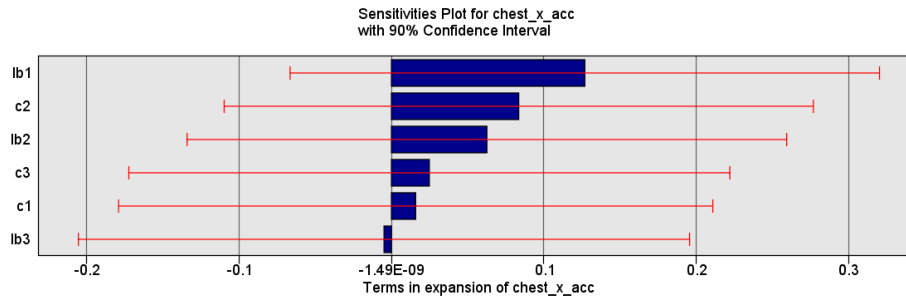
→ lb1 has a strong effect onto the section forces

→ all variables are insignificant on the chest acceleration

# Visualization



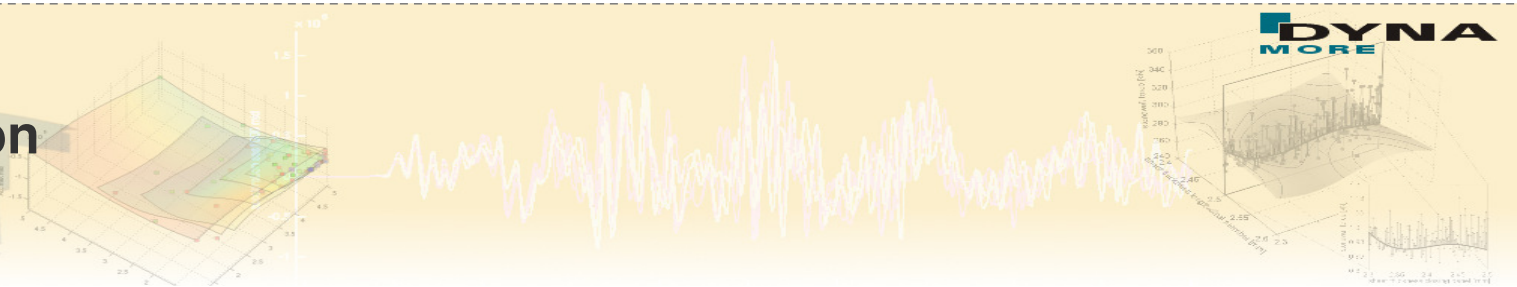
- ANOVA (Analysis of Variance) calculated on metamodel



Not meaningful  
→ large red error bars

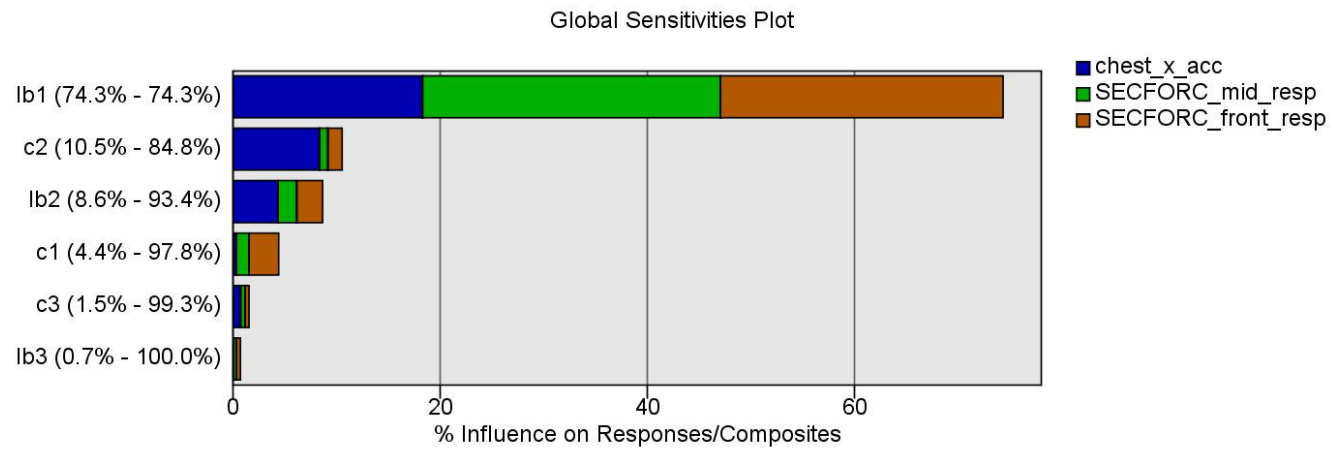
*lb1* strong effect  
on section forces  
→ agreement with  
correlation matrix  
results

# Visualization

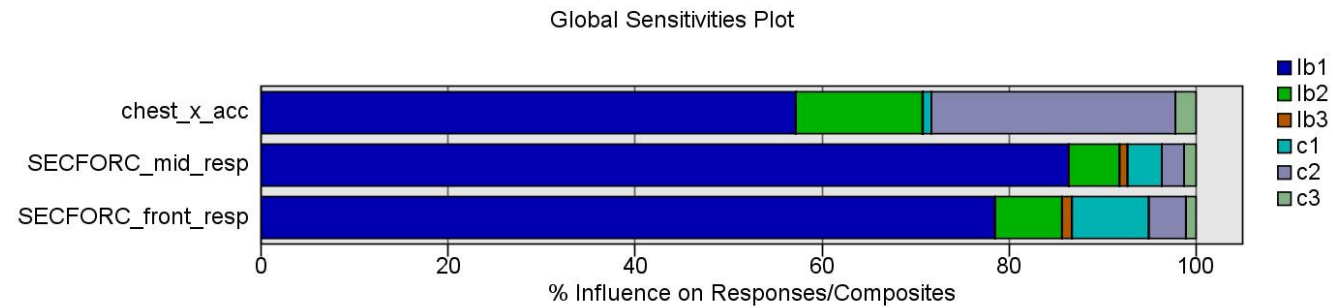


- Non-linear sensitivities: global sensitivities (Sobol)
- Each bar represents the contribution of a particular variable to the variance of the respective response

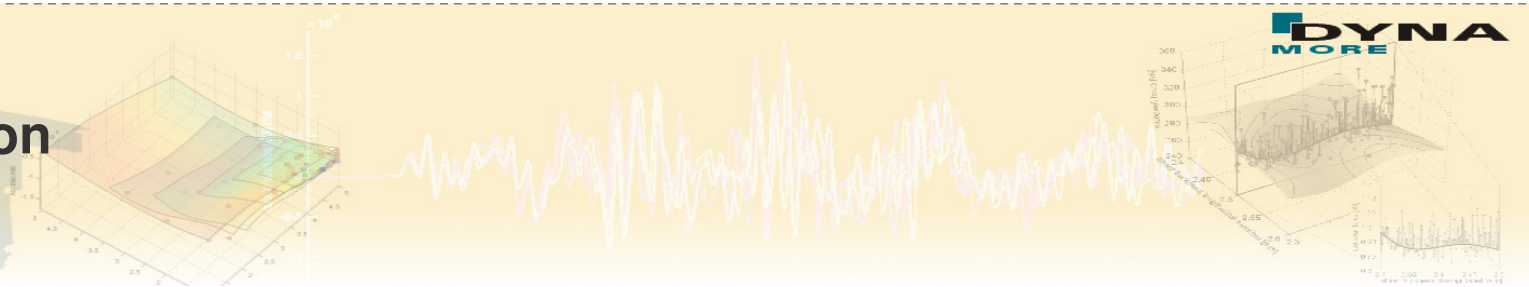
*lb1*  
strongest effect  
on whole problem



*lb1*  
strongest effect  
on section forces

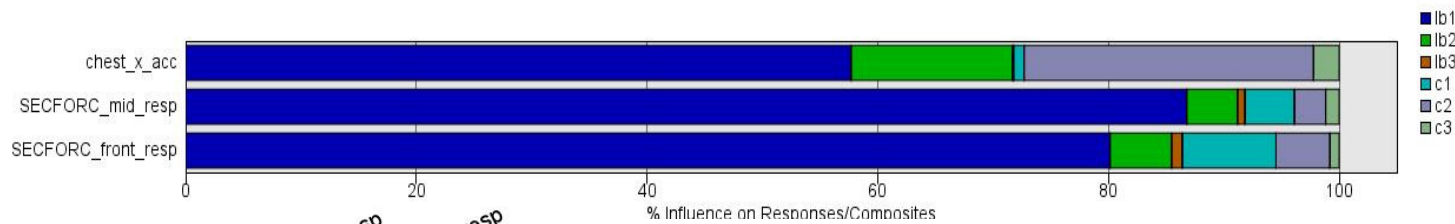


# Visualization



- Nonlinear sensitivities
- *lb1* also has a strong effect on the chest acceleration

Global Sensitivities Plot

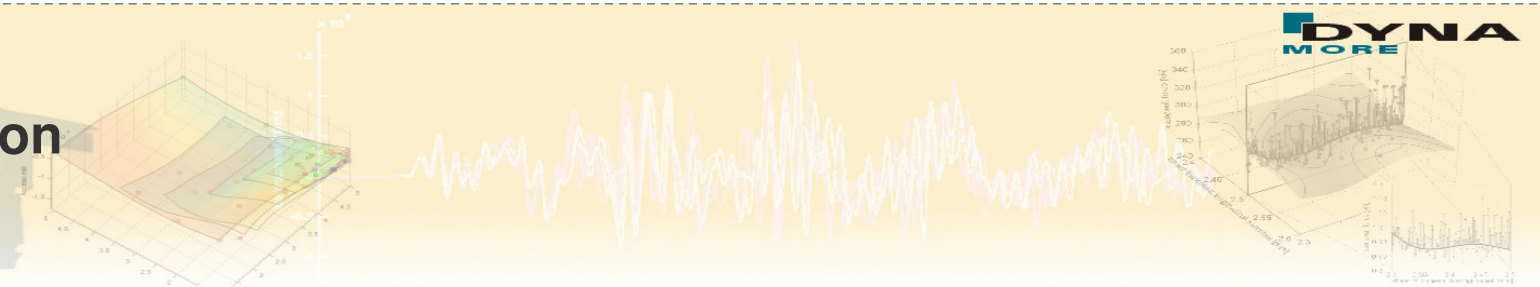


	chest_x_acc	SECFORC_mid_resp	SECFORC_front_resp
lb1	0.07	-0.76	-0.60
lb2	0.04	-0.20	-0.11
lb3	-0.01	-0.04	0.05
c1	0.01	0.08	0.15
c2	0.05	0.09	0.14
c3	0.01	0.07	0.03

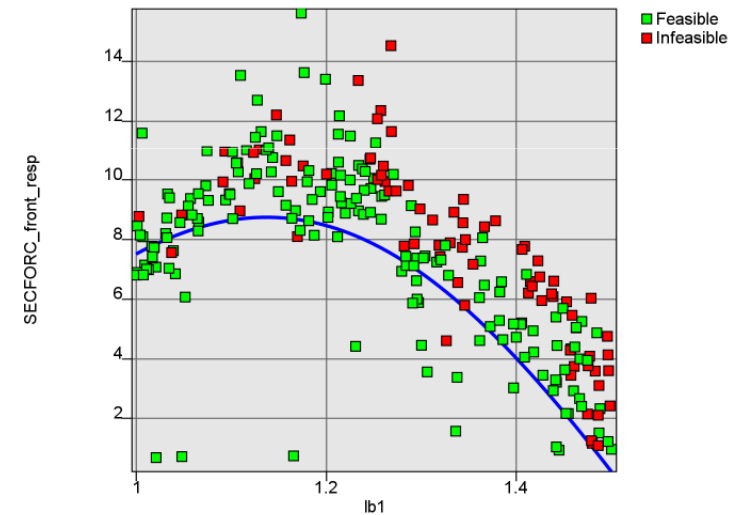
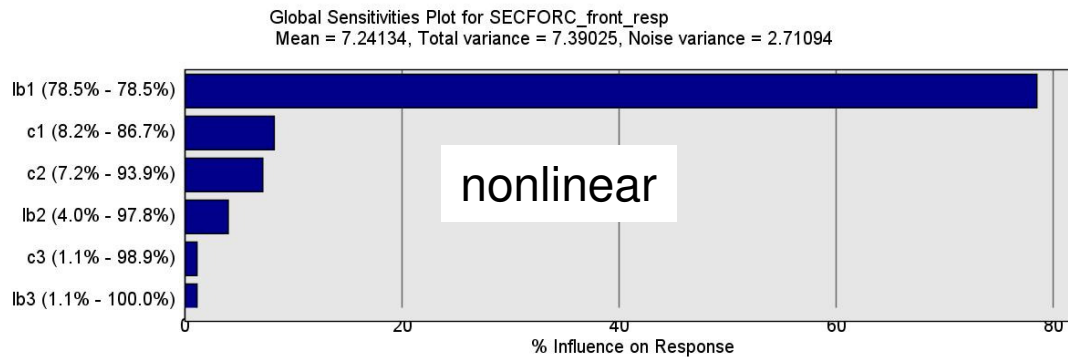
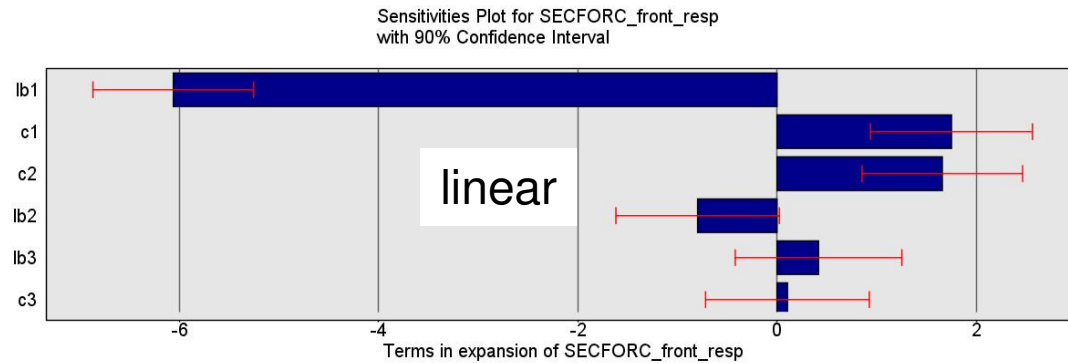
	Total variance
chest_x_accel	0.0013
SECFORC_mid_resp	5.16
SECFORC_front_resp	4.73

- Total variance of chest acceleration small → correlation coefficient small

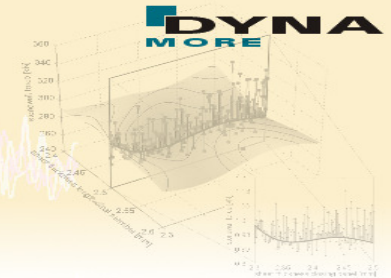
# Visualization



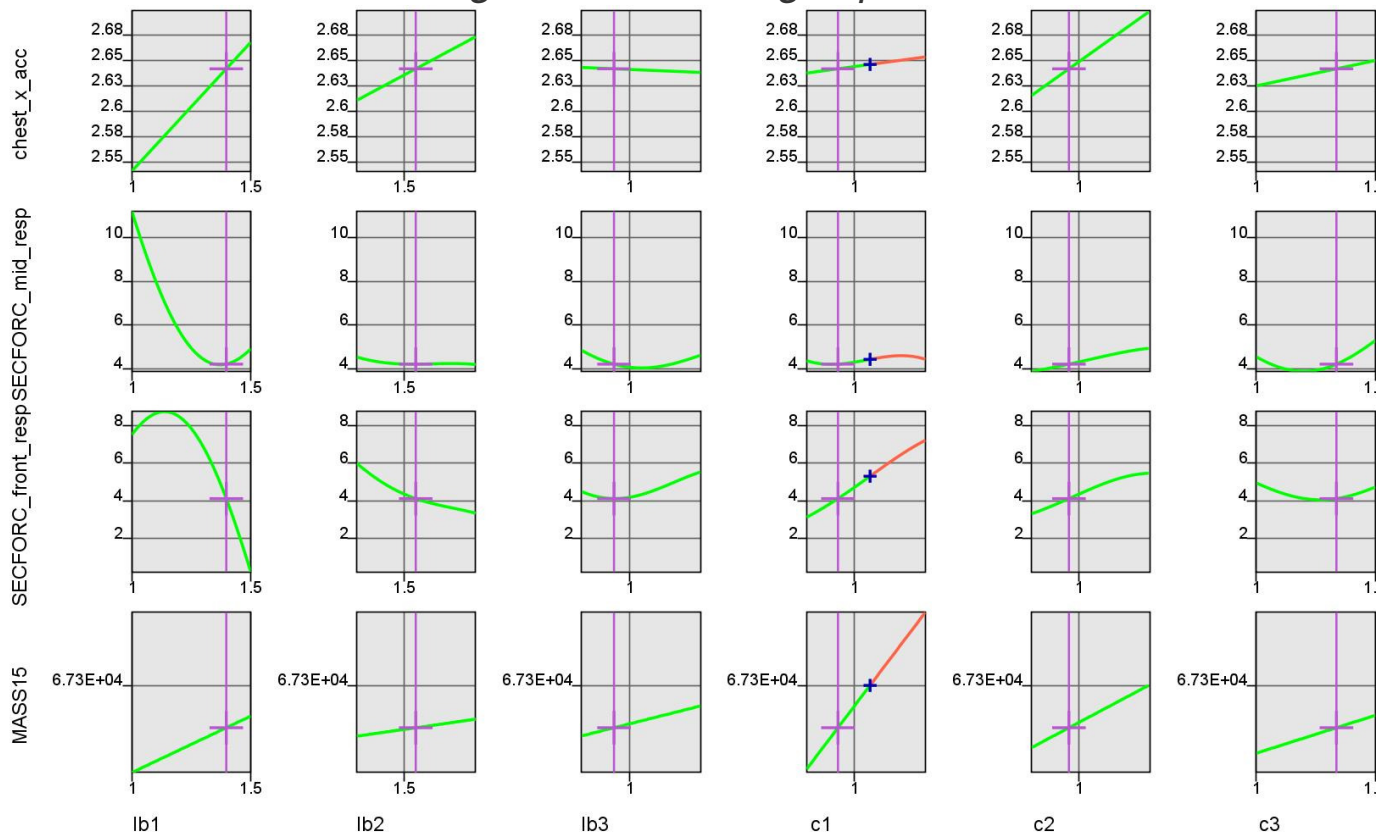
- linear and non-linear sensitivities → *lb1* is the most sensitive variable on *SECFORC\_front\_resp*,
- percentage in comparison to the other variables is higher for the non-linear correlation



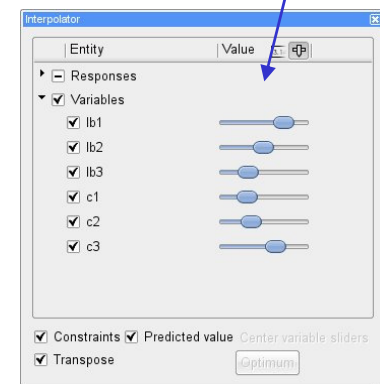
# Visualization



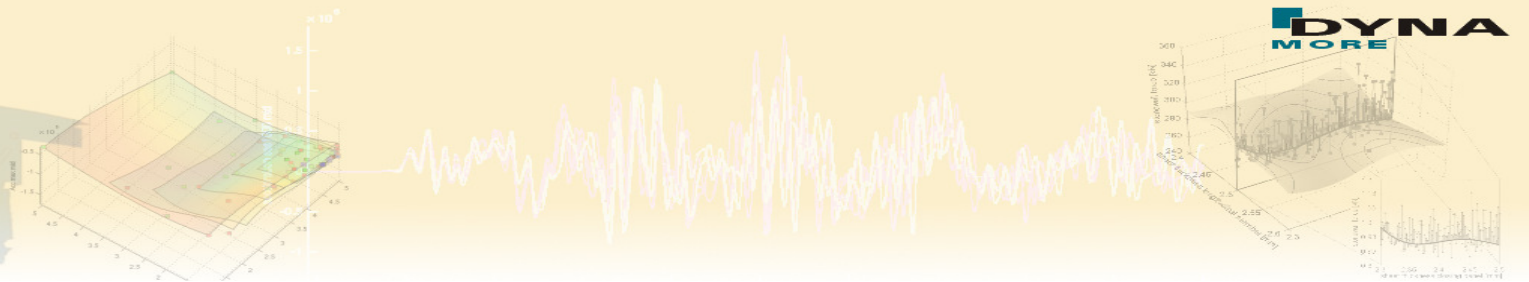
- Interpolator Plot – 2D surface plots
  - comparing the influence of variables on several responses
  - find feasible regions in the design space



- feasible
- infeasible
- + predicted value for selected variable values



# Summary



- The post-processing features of LS-OPT 4.1 have improvements in
  - visualizing results of multi-objective optimization
    - *SOM plot completes the visualization of high dimensional data together with*
      - Tradeoff Plot
      - Parallel Coordinate Plot
      - HRV Plot ()
  - visualization of curve data
    - *histories from simulation results*
    - *extension of the meta-models on curve data*
      - *predicted histories*
  - visualization of sensitivities
    - *features to visualize non-linear sensitivities (Sobol)*

} already available  
in LS-OPT 4.0