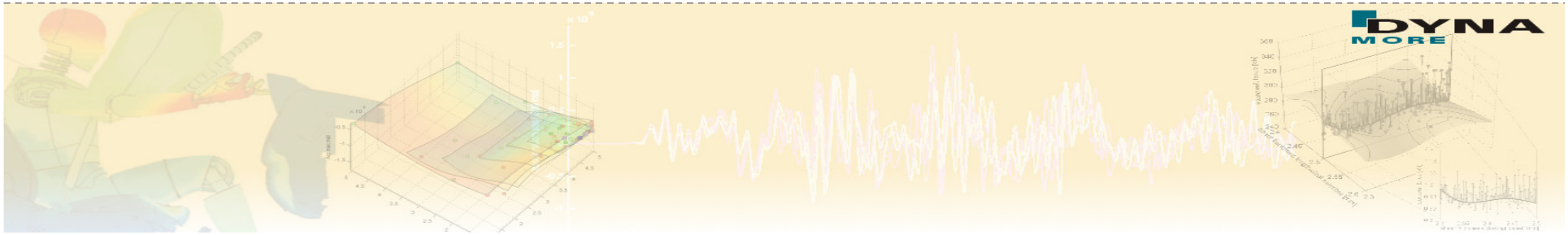


Neue Entwicklungen in LS-OPT 4.1 – Ausblick auf zukünftige Versionen

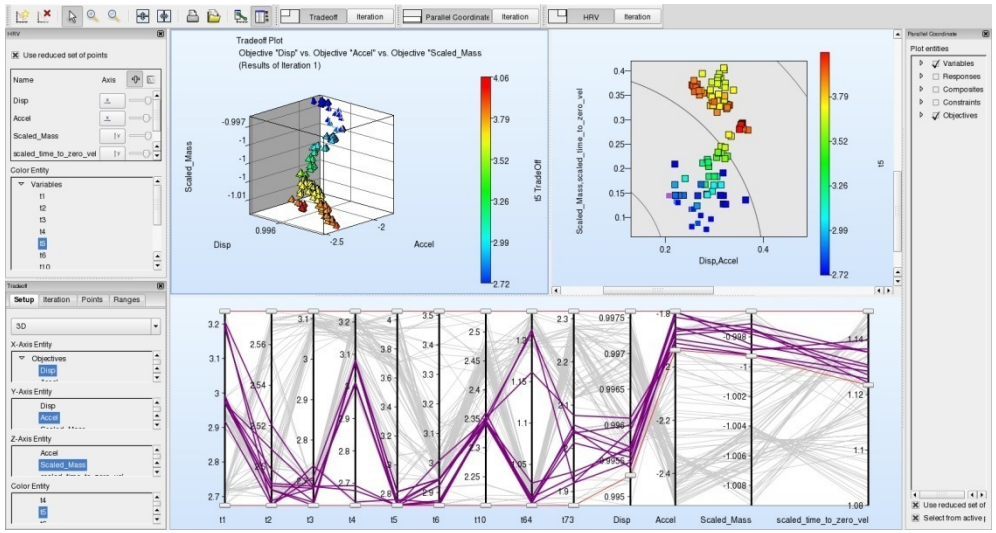
New Developments in LS-OPT 4.1 – Outlook

Heiner Müllerschön
hm@dynamore.de

DYNA*more* GmbH
Industriestraße 2
70565 Stuttgart
http://www.dynamore.de

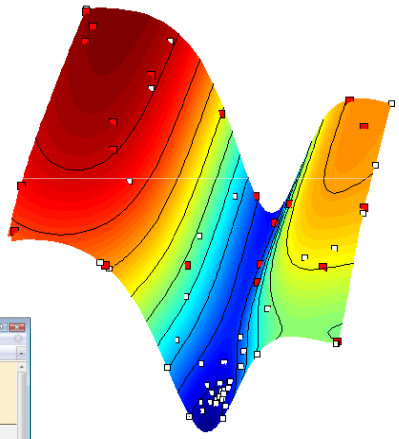
Overview

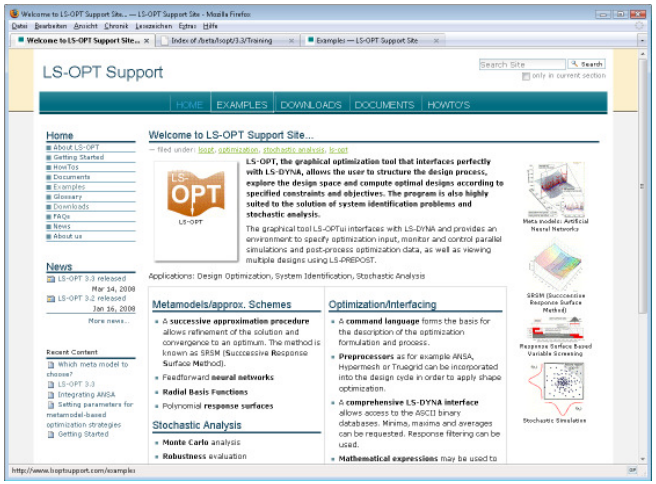
- Introduction/Features of current Version 4.1
- Methodologies – Optimization
- Methodologies - Robustness
- Examples - Optimization
- Examples – Robustness
- Outlook



➔ About LS-OPT

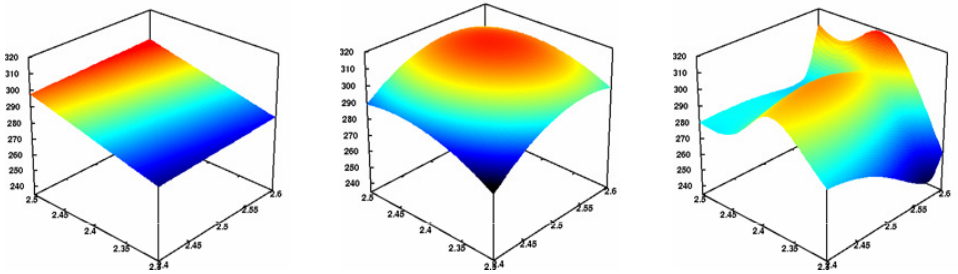
- LS-OPT can be linked to any simulation code – stand alone optimization software, but perfect suitable with LS-DYNA
- Two main products LS-OPT and LS-OPT/Topology
- Current production version is LS-OPT 4.1 – Version 4.2 will be released end of 2010
- LS-OPT Support web page -> www.lsoptsupport.com
  - *Download of Executables*
  - *Tutorials*
  - *HowTos / FAQs*
  - *Documents*
  - *….*



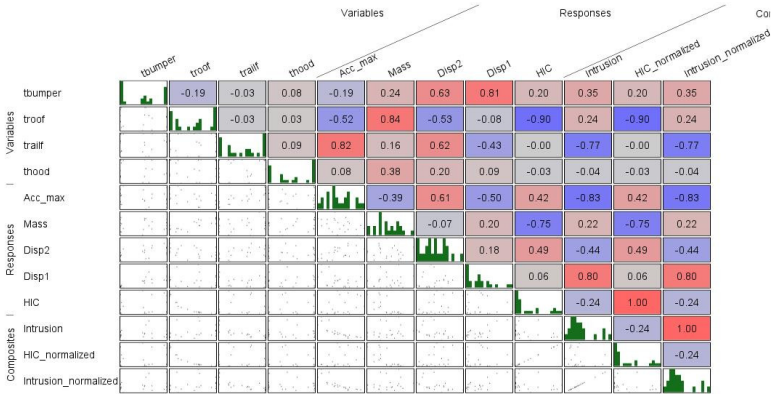


LS-OPT – Overview Methodologies

- Successive Response Surface Method (SRSM)
- Meta-Models
  - *Polynomials*
  - *Radial Basis Functions*
  - *Neural Nets (FFNN)*

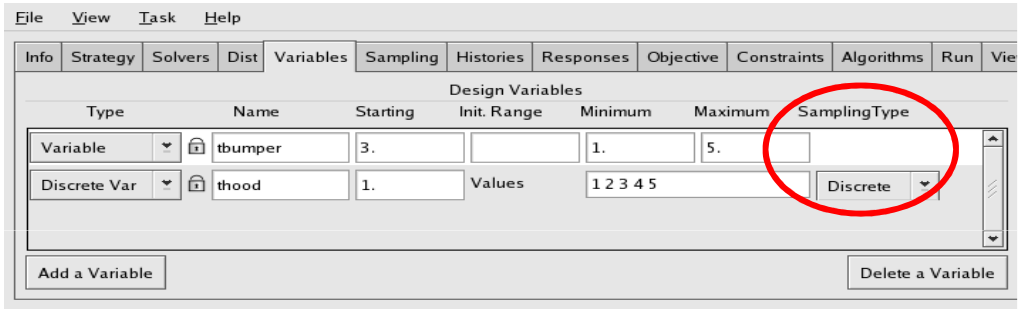


- Genetic Algorithm (MOGA->NSGA-II)
- Multidisciplinary optimization (MDO)
- DOE-Studies (ANOVA, Sobol)
- Stochastic/Probabilistic Analysis
  - *Evaluation of stochastic quantities: mean, std.-dev., correl.-coeff.,…..*
  - *Confidence Intervals*
- Monte Carlo Analysis using Meta-Models

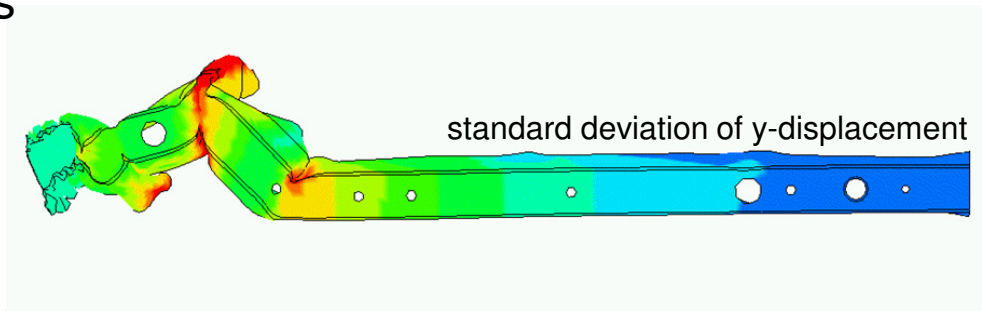


LS-OPT – Overview Methodologies

- Mixed Discrete-Continous Optimization
  - *Specify sets of discrete variables (e.g. sheet thicknesses)*

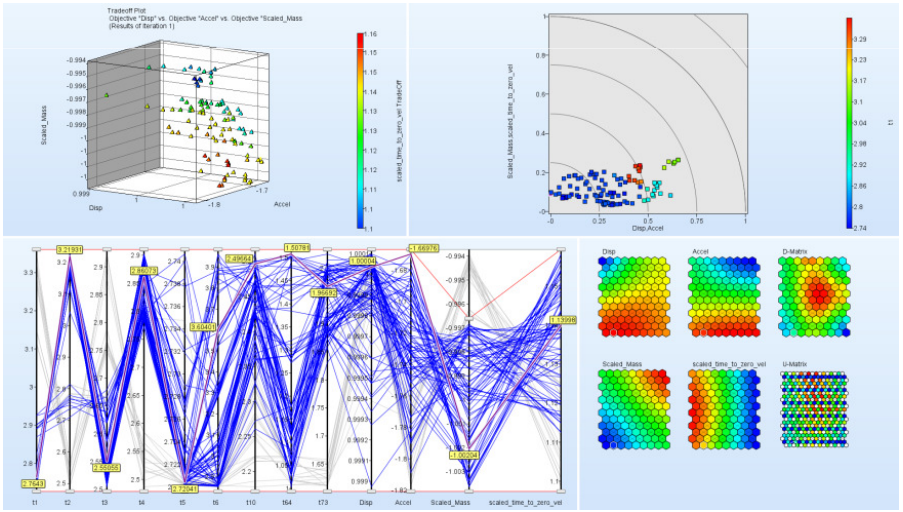


- Robust Parameter Design (RDO)
  - *Improve/Maximizing the robustness of the optimum*
- Reliability Based Design Optimization (RBDO)
  - *Improve failure probability of optimum*
- Visualization of Stochastic Results
  - *Fringe of statistic results on the FE-Model*



➔ LS-OPT – Multi-Objective Optimization

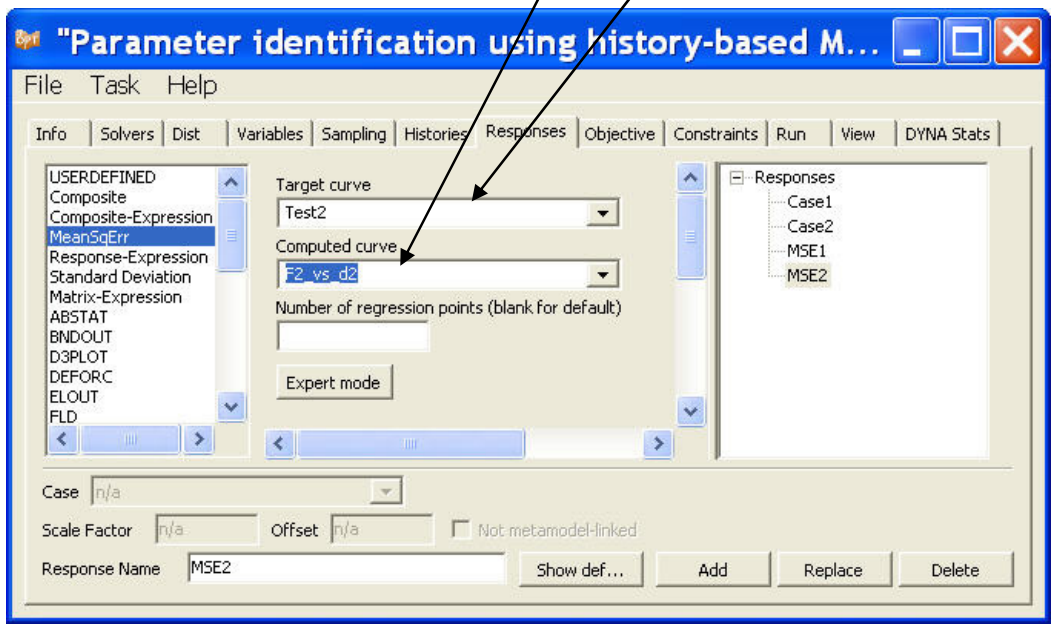
- Genetic Algorithm (MOGA->NSGA-II) for Multi Objective Optimization (Pareto Frontiers)
- Visualization Strategies for Pareto Optimal Data
  - Parallel Coordinate Plots
  - Hyper-Radial Visualization
  - Self Organizing Maps



About LS-OPT

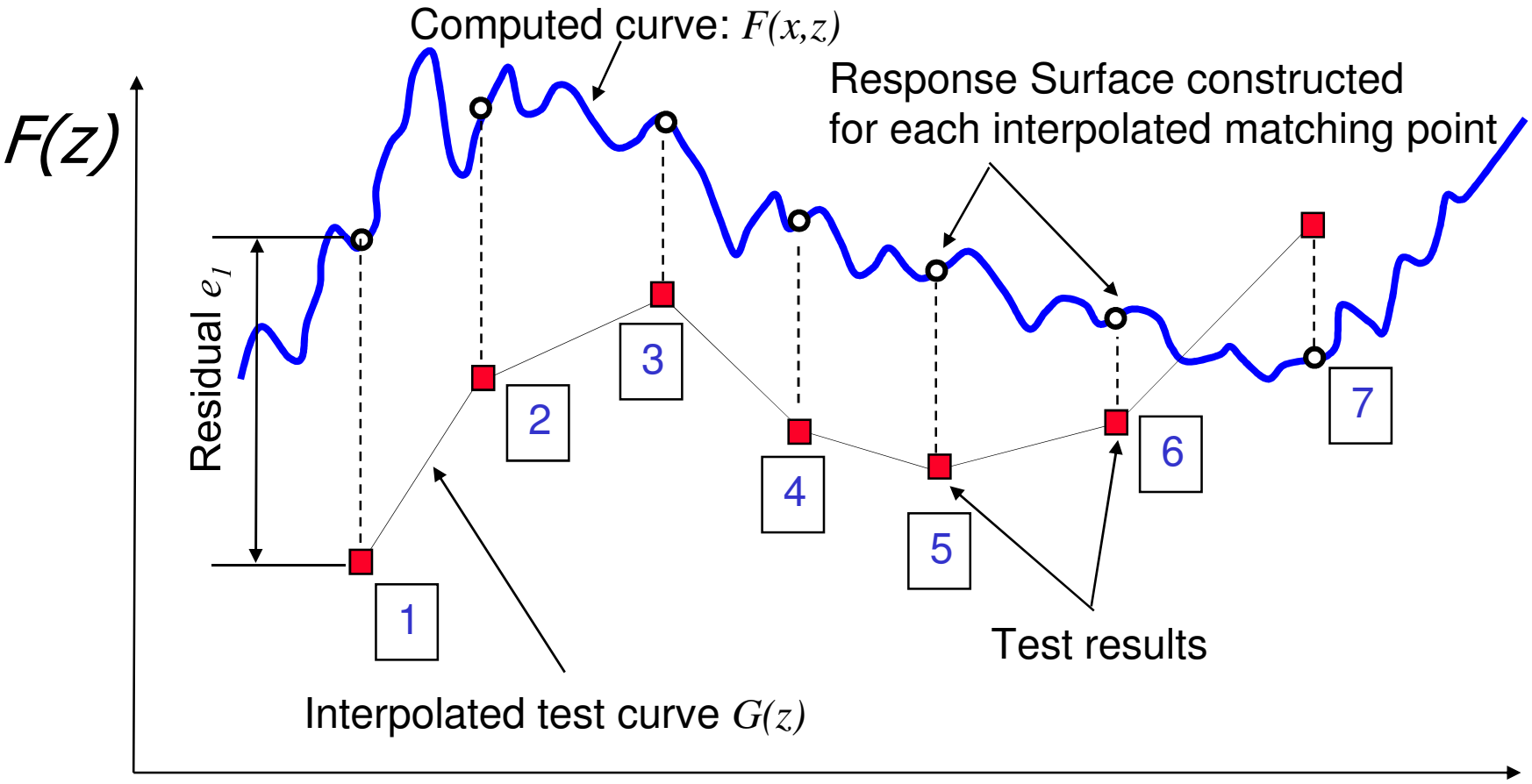
- Parameter Identification Module
  - *Handles "continuous" test curves*
  - *Automated use of test results to calibrate materials/systems*
  - *Simplify input for system identification applications*
  - *Visualization of test and simulation curve to compare*
  - *Confidence intervals for individual parameters in parameter identification*

$$\frac{1}{P}\sum_{p=1}^{P} W_i \left(\frac{F_i(\boldsymbol{x}) - G_i}{s_i} \right)^2$$



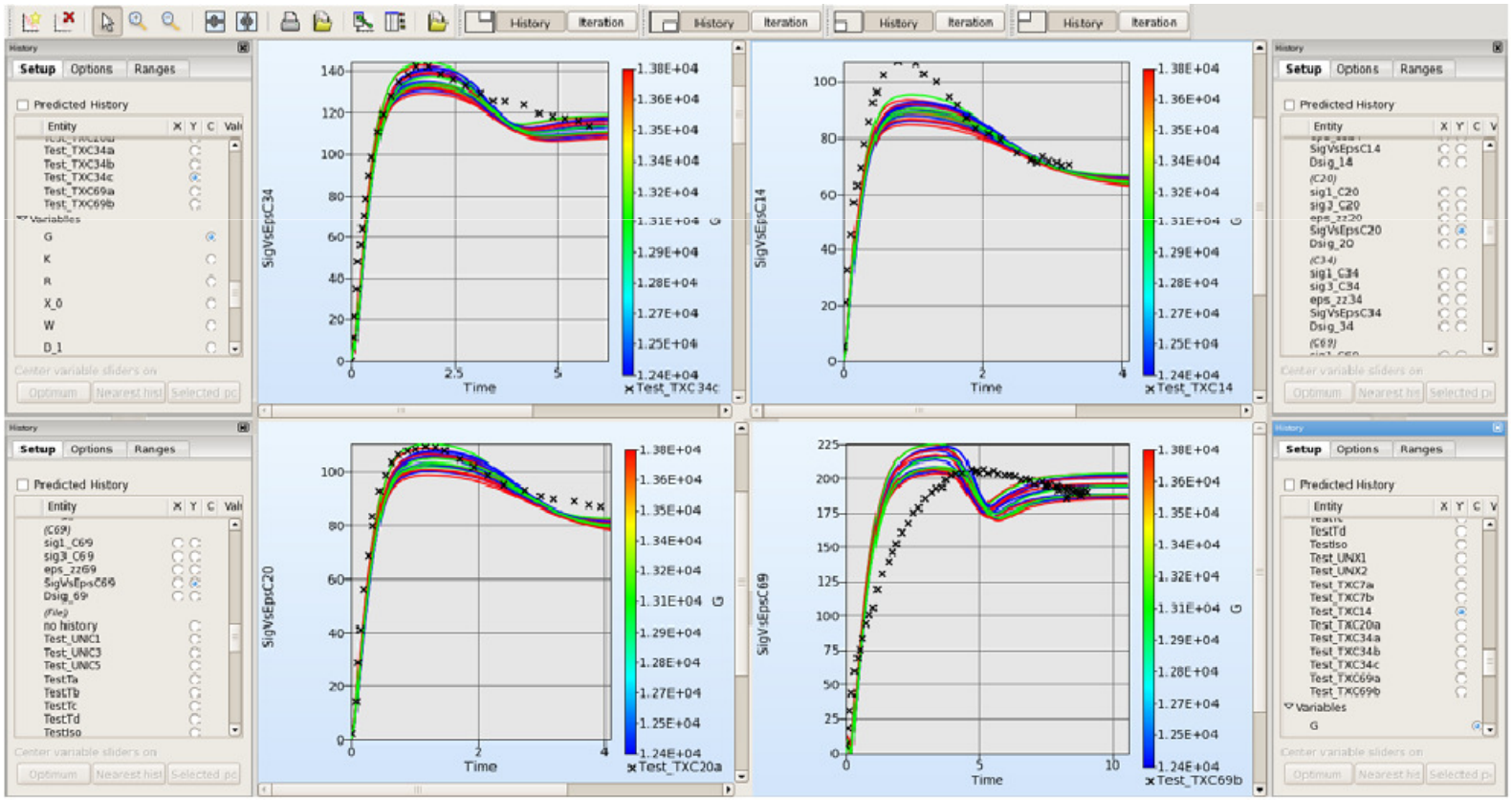
About LS-OPT

- Parameter Identification with Test Curves



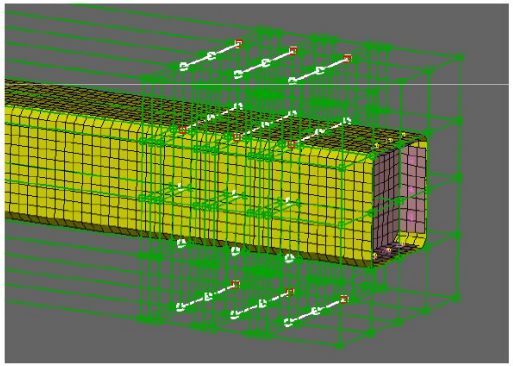
➔ About LS-OPT

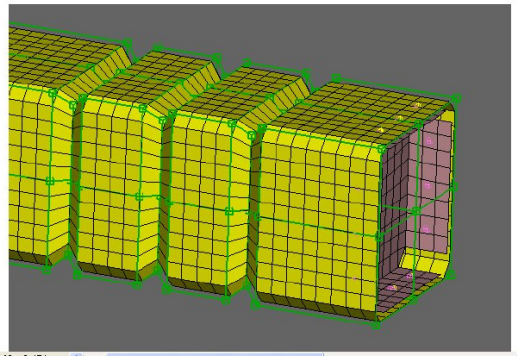
- Computed history curves vs. Target curves

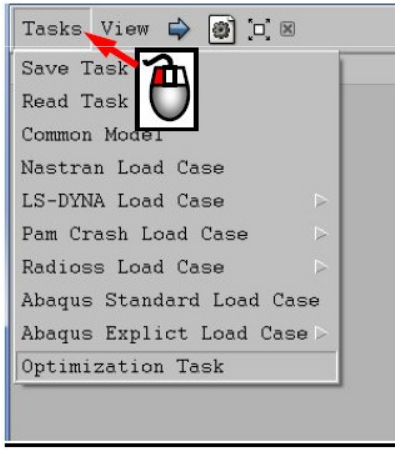


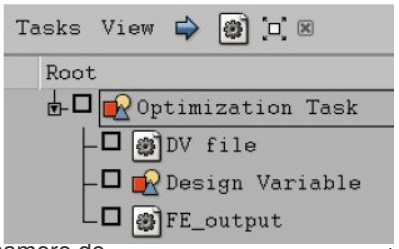
➔ About LS-OPT – General Aspects

- Job Distribution - Interface to Queuing Systems
  - *PBS, LSF, LoadLeveler, SLURM, AQS, etc.*
  - *Retry of failed queuing (abnormal termination)*
- LS-OPT might be used as a “Process Manager”
- Shape Optimization
  - *Interface to **ANSA**, HyperMorph, DEP-Morpher, SFE-Concept*
- META Post interface
  - *Allows extraction of results from any package (Abaqus, NASTRAN, …) supported by META Post (ANSA package)*



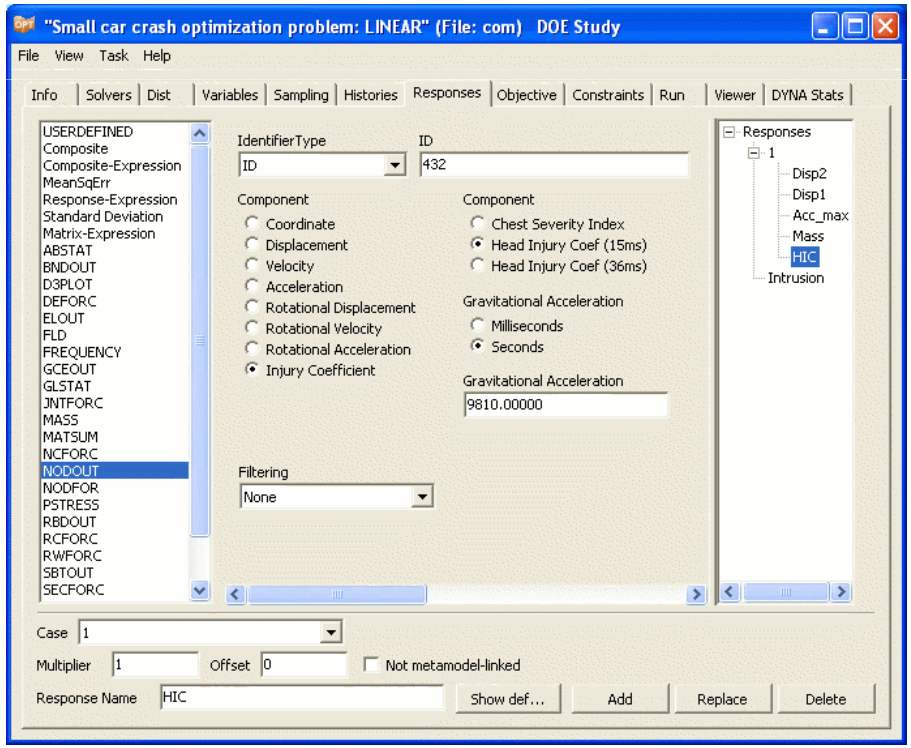






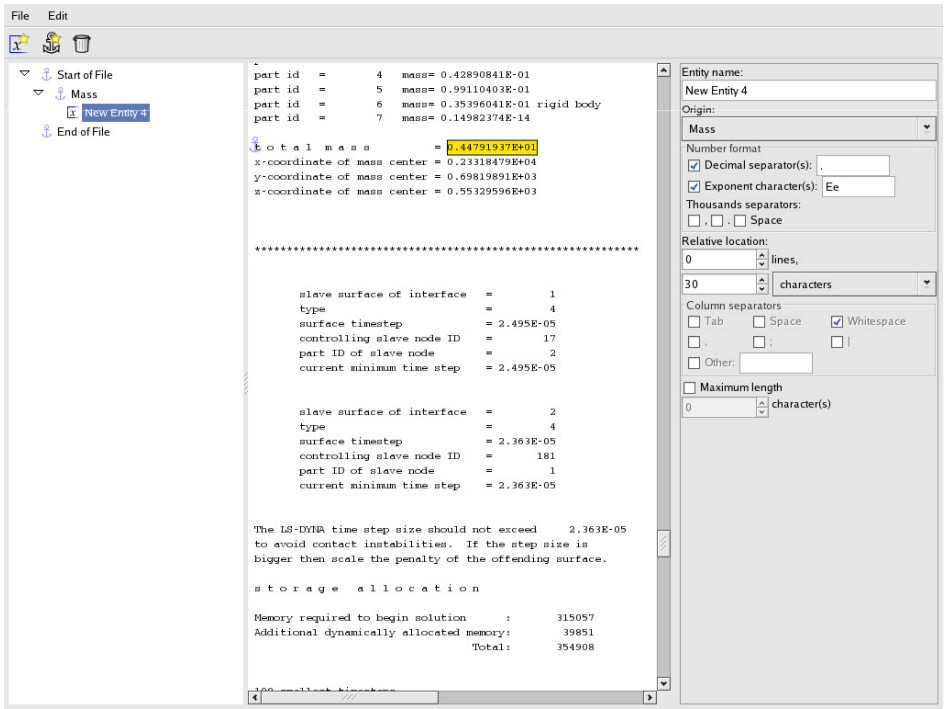
➔ About LS-OPT

- LS-DYNA Integration
  - *Checking of Dyna keyword files (*DATABASE_)*
  - *Importation of design parameters from Dyna keyword files (*PARAMETER_)*
  - *Monitoring of LS-DYNA progress*
  - *Result extraction of most LS-DYNA response types*
  - *D3plot compression (node and part selection)*



➔ About LS-OPT - New Features in LS-OPT V4.1

- Generic File extractor
  - *Extraction of values from any ASCII input file*
- Injury criteria (DYNA extraction)
  - *VC (Viscous Criterion)*
  - *Chest Compression*
  - *A3ms (Acceleration level for 3ms)*
  - *More added in V4.2*



About LS-OPT - New Features in LS-OPT V4.1

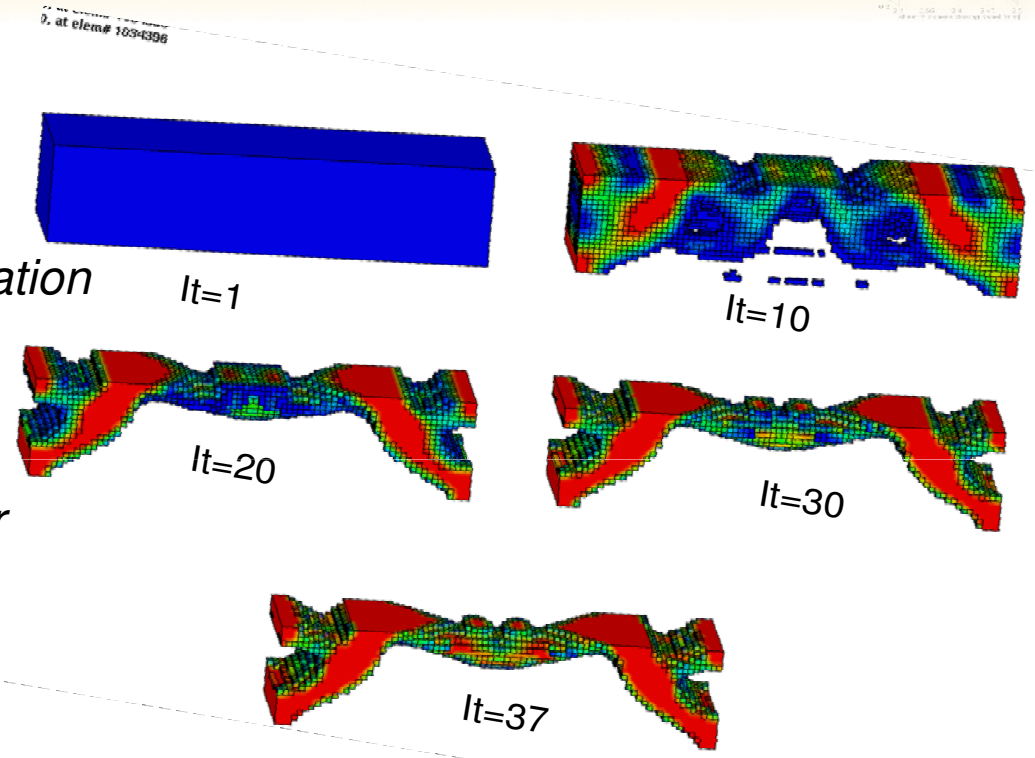
- Frequency/Mode Tracking
  - *NASTRAN Frequency with Mode tracking added*
  - *Previously existed only for LS-DYNA*
  - *Industry tested in an automotive multidisciplinary setting*

$$\max_i[(\varphi_r{}^T \mathbf{M}_r)\varphi_i]$$

- Additional Result Interfaces for LS-DYNA
  - *SPH: Strains, Stresses*
  - *Acoustics binary database: DBBEMAC*
  - *LS-DYNA *CASE supported*

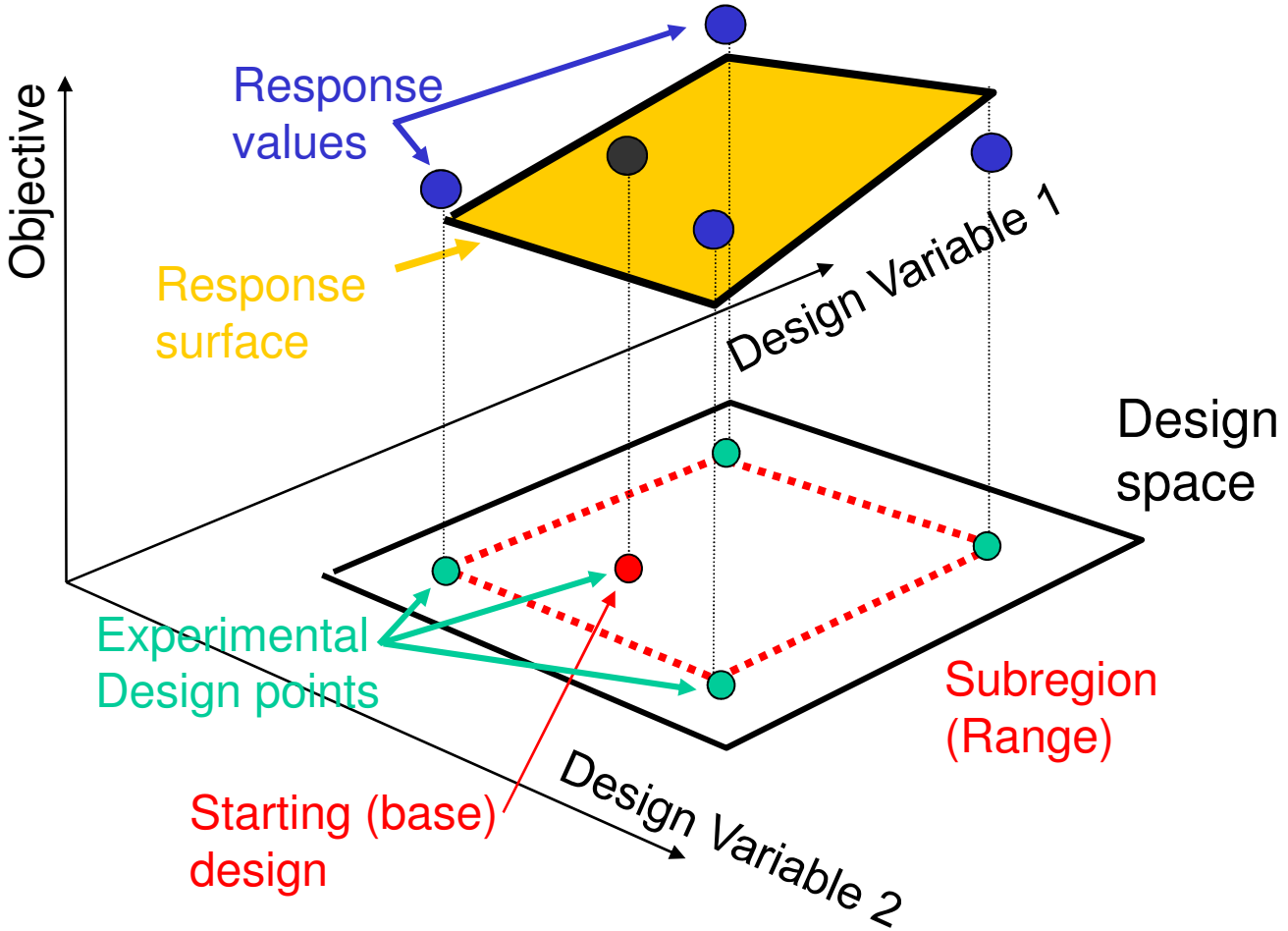
About LS-OPT

- LS-OPT/Topology
  - *Nonlinear topology optimization*
  - *LS-DYNA based*
  - *Multiple load cases*
  - *Linear as well as non-linear*
  - *Design part selection*
- Methodology
  - Hybrid Cellular Automata*
  - For elastic-plastic problems, every finite element must contribute to absorb internal energy (U) which includes both elastic strain energy and plastic work during loading.

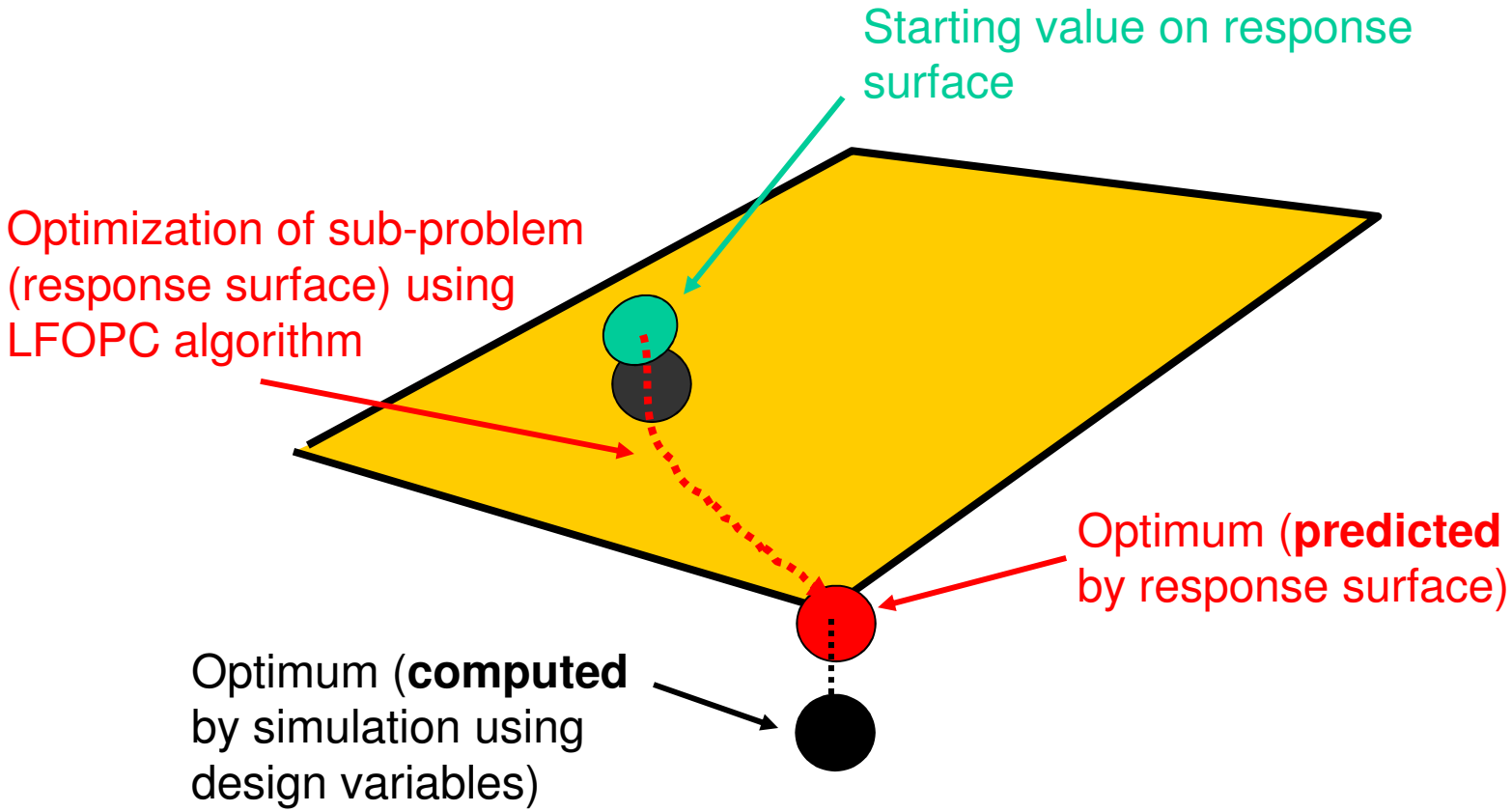


*Ref.: Hybrid cellular automata with local control rules: a new approach to topology optimization, Tovar A., Quevedo W., Patel N., Renaud J. (University Notre-Dame, Indiana, USA), 6th World Congress of Structural and Multidisciplinary Optimization, 2005, Brazil

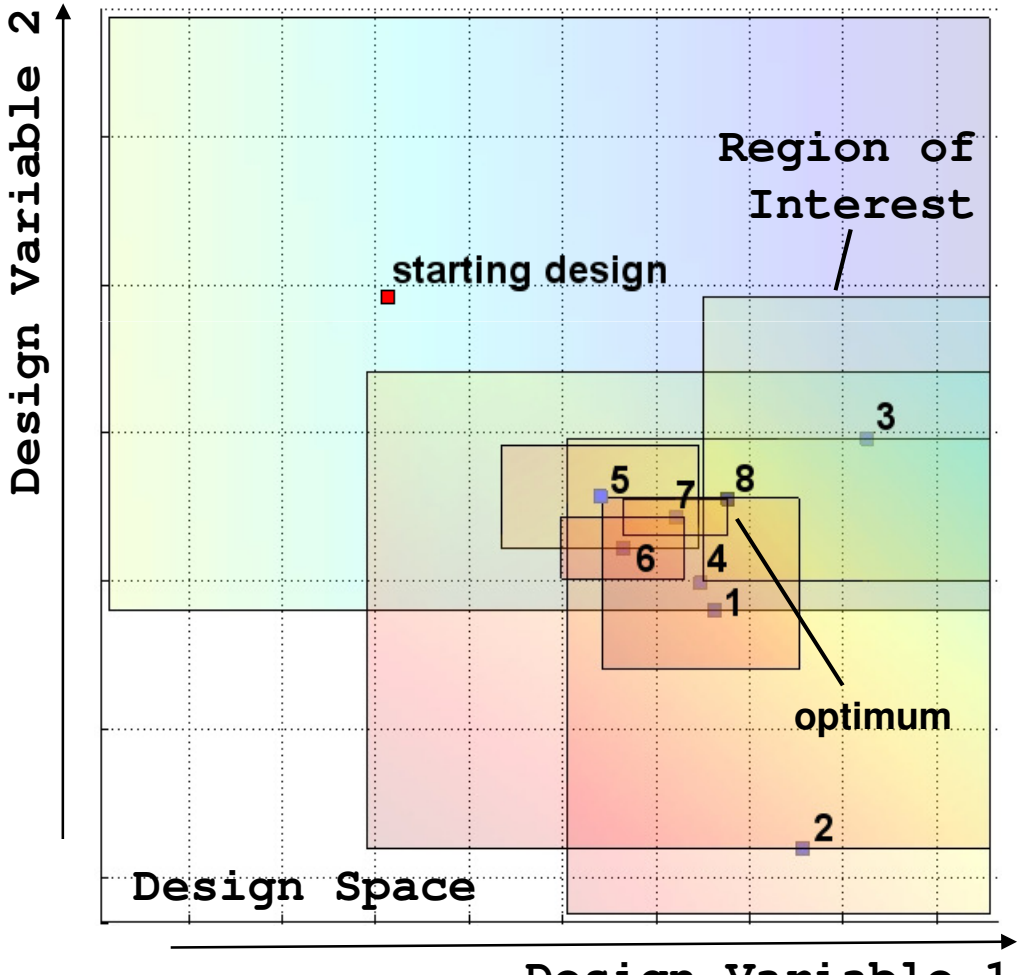
Response Surface Methodology - Optimization Process



Find an Optimum on the Response Surface (one iteration)



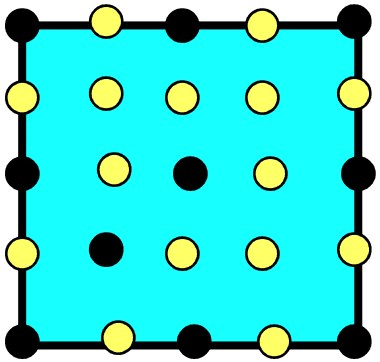
Successive Response Surface Methodology



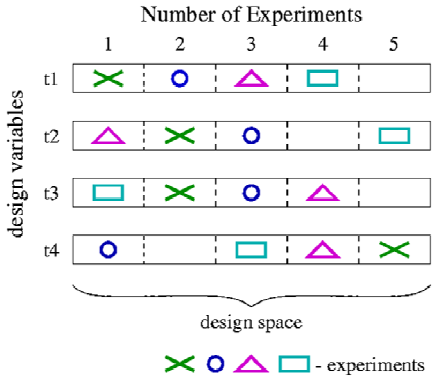
Design of Experiments (DOE) - Sampling Point Selection

- Koshal, Central Composite, Full Factorial
- D-Optimality Criterion - Gives maximal confidence in the model

$$\max \left| X^T X \right|$$

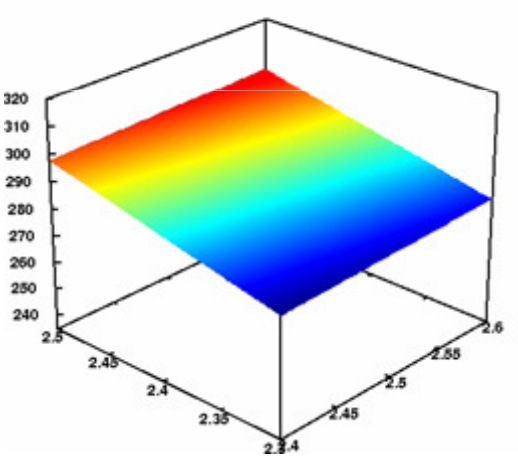


- Monte Carlo Sampling
- Latin Hypercube Sampling (stratified Monte Carlo)
- Space Filling Designs
- User Defined Experiments

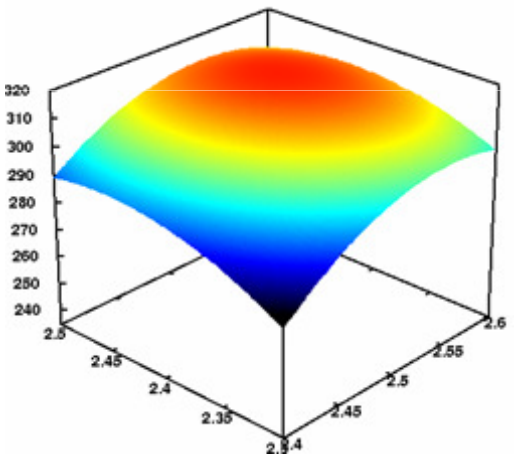


Response Surfaces (Meta Models)

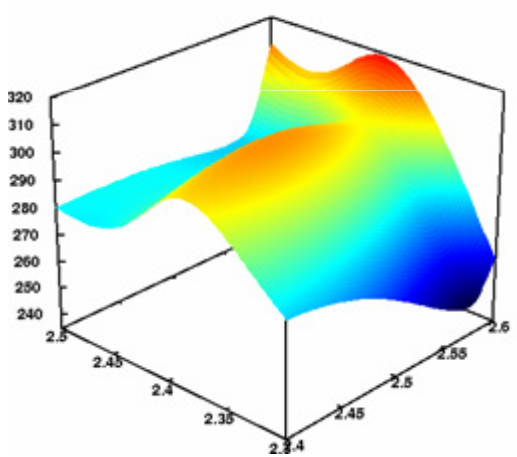
- Linear, Quadratic and Mixed polynomial based
- Radial Basis Functions, Feed Forward Neural Networks and Kriging for global approximations



linear polynomial



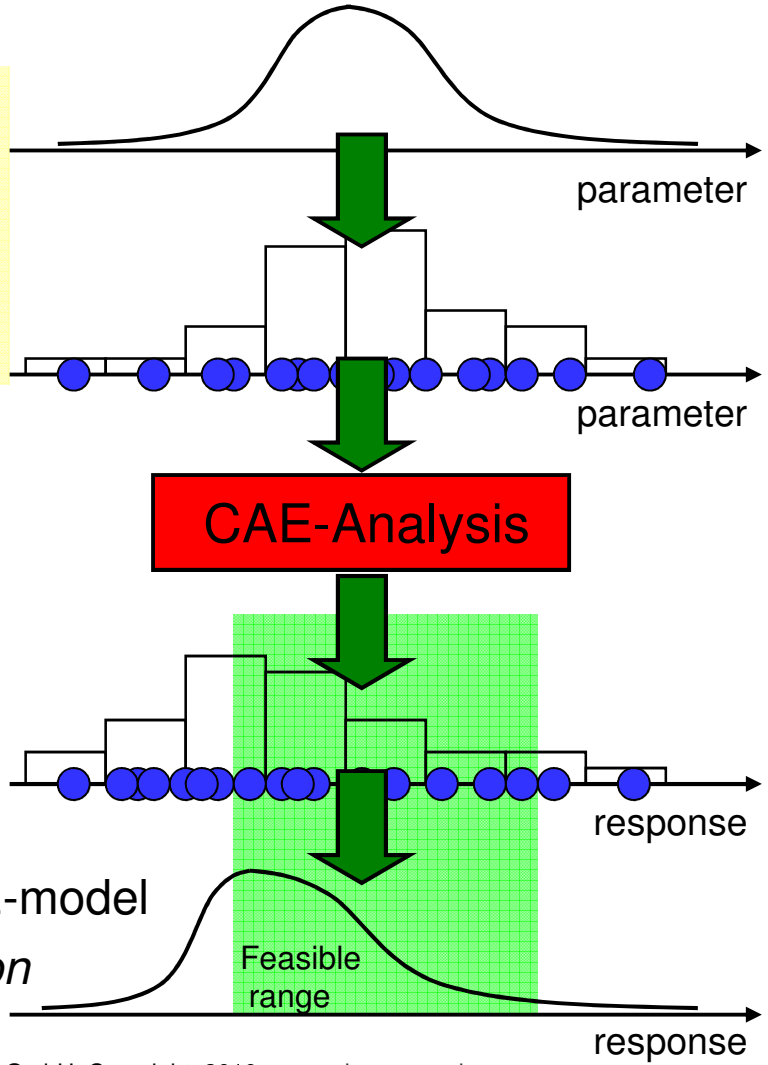
quadratic polynomial



neural network

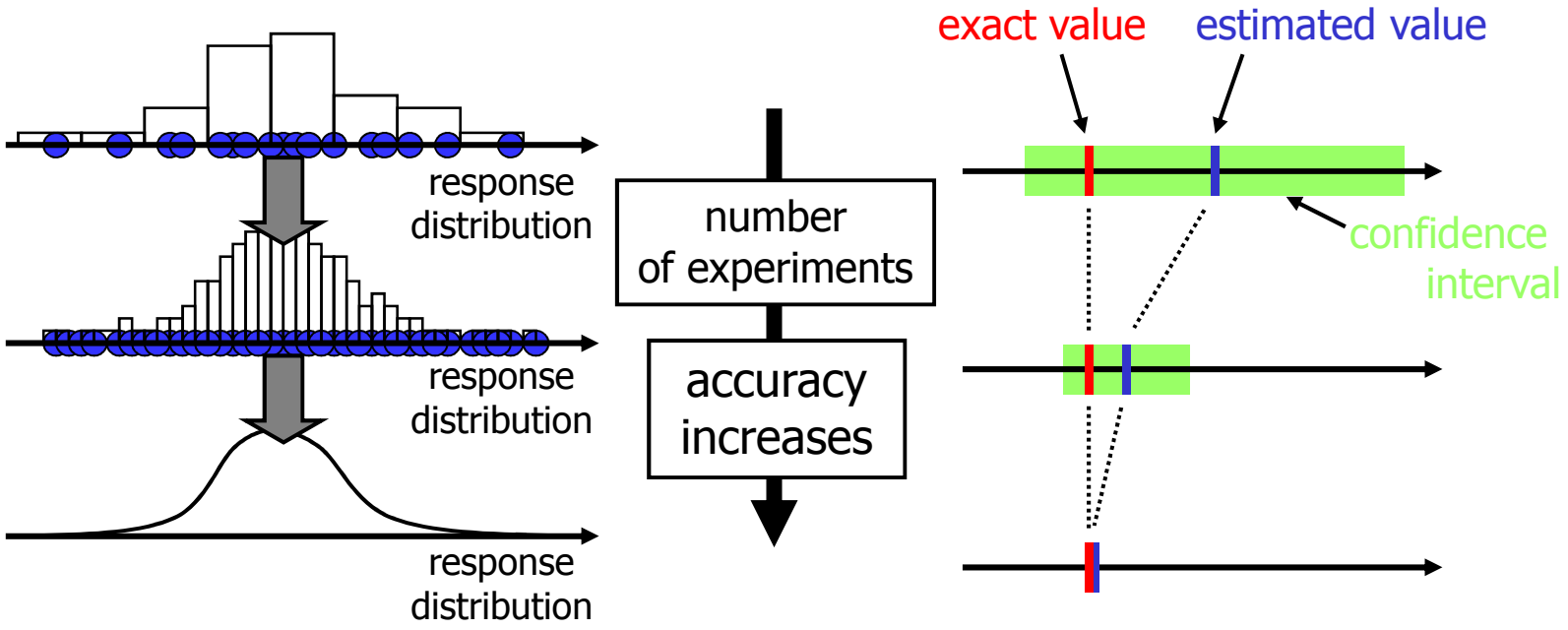
Stochastic Analysis - Goals

- Statistical Quantities of Output (Response) due to Variation of Input (Parameter)
  - *Mean*
  - *Standard deviation*
  - *Distribution function*
- Significance of Parameter with respect to Responses
  - *Correlation analysis*
  - *Stochastic contributions*
  - *ANOVA – analysis of variance*
- Reliability Issues
  - *Probability of failure*
- Visualization of statistical quantities on FE-model
  - *Spatial detection of variation/correlation*



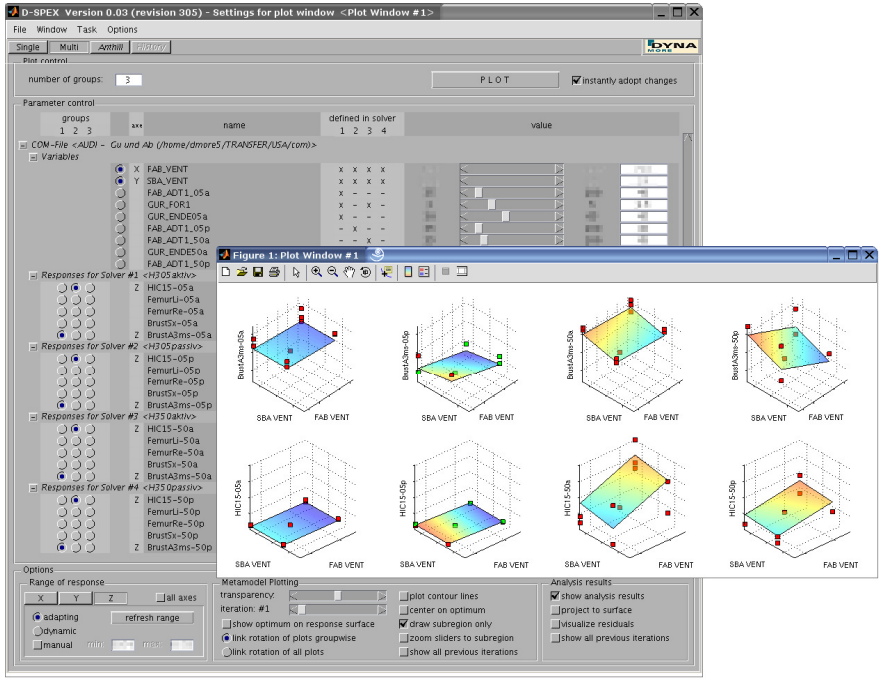
Statistical Quantities of Output due to Variation of Input

- Direct Monte Carlo Sampling
  - *Latin Hypercube sampling*
  - *Large number of FE runs (100+)*
  - *Consideration of confidence intervals for mean, std. dev., correlation coeff.*



Statistical Quantities of Output due to Variation of Input

- Monte Carlo using Meta-Models
  - *Response Surface / Neural Network*
  - *Medium number of FE runs (10 – 30+)*
  - *Number of runs depend on the dimension of the problem (number of variables) and the type of the response surface*
  - *Identify design variable contributions clearly*
  - *Exploration of parameter space ->D-SPEX*



Multi Meta-Model exploration with D-SPEX

Stochastic Analysis - Goals

- Statistical Quantities of Output (Response) due to Variation of Input (Parameter)
  - *mean*
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- Significance of Parameter with respect to Responses
  - *correlation analysis*
  - *stochastic contributions*
  - *ANOVA – analysis of variance*
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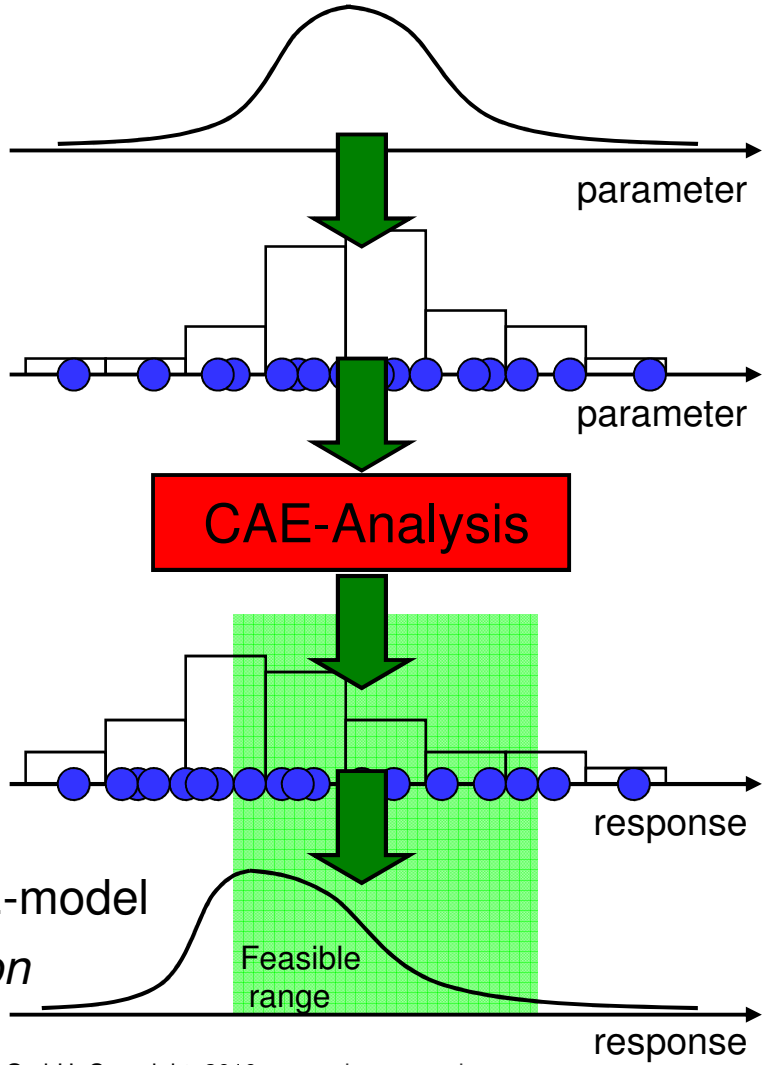
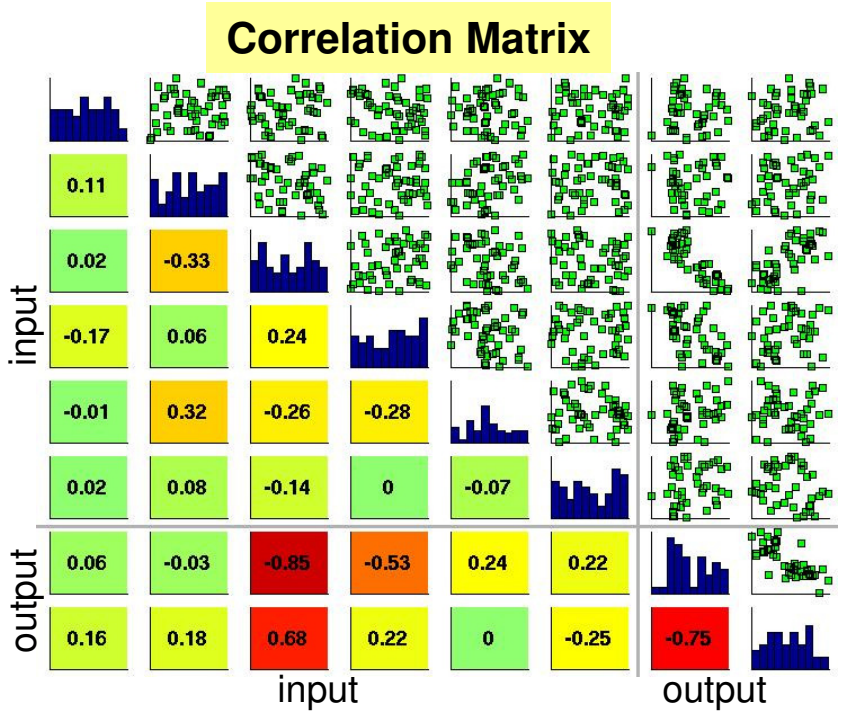
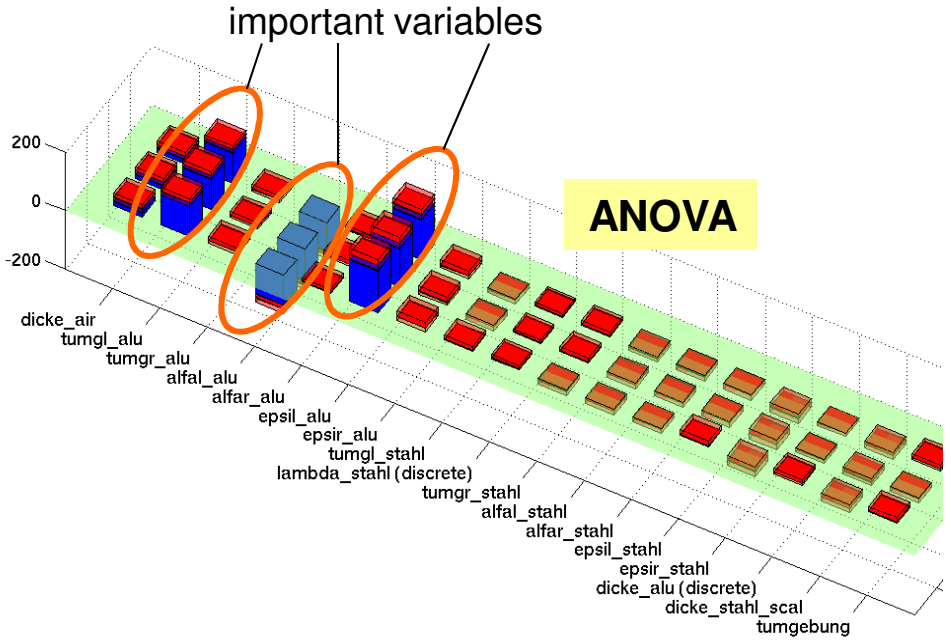


Significance of Variables

- Correlation Analysis
- ANOVA - Meta-Model based
- Stochastic Contributions – Meta-Model based





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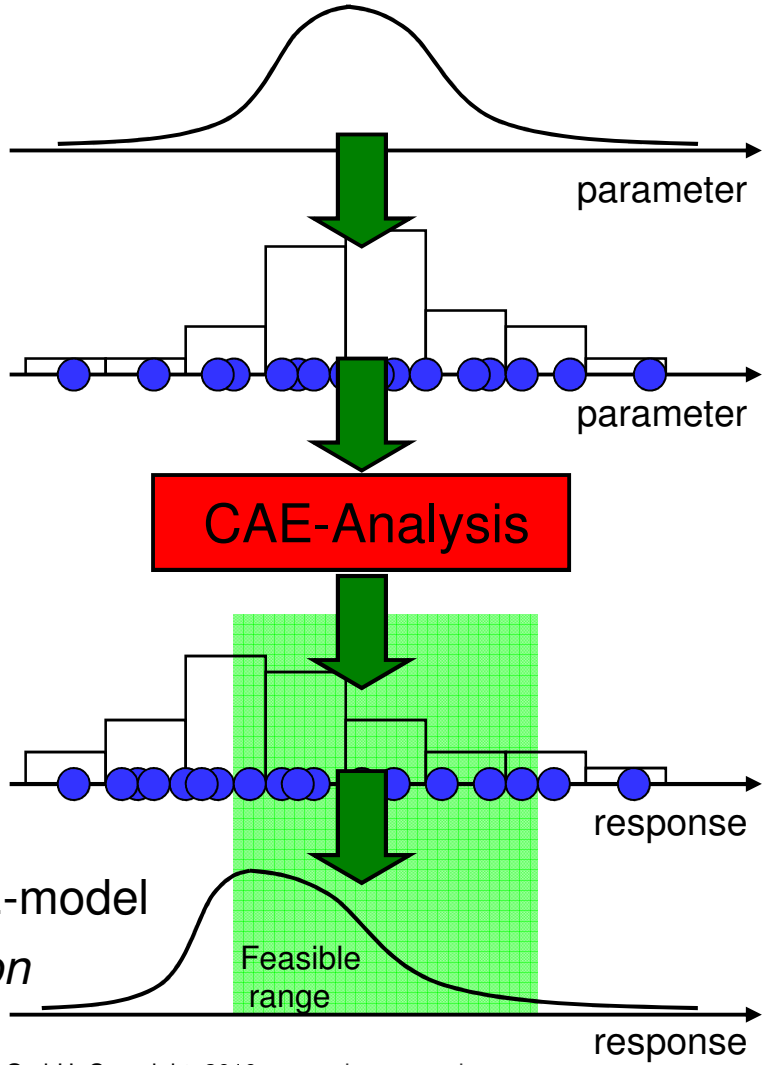
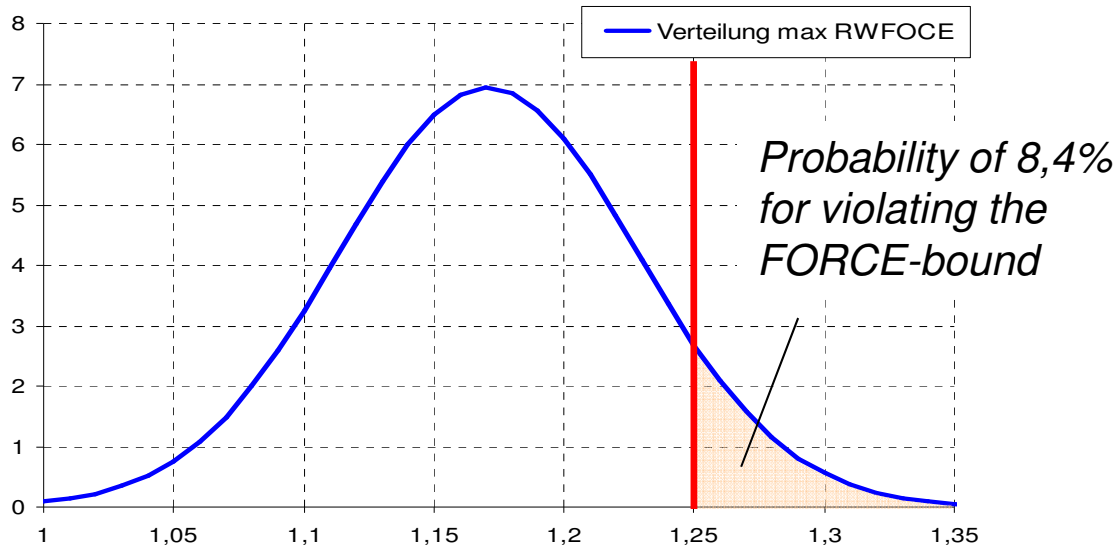


Reliability Analysis

- Probability of failure
- Evaluation of confidence interval
- Prediction error (confidence interval) depends
  - *on the number of runs*
  - *on the probability of event*
  - *not on the dimension of the problem (number of design variables)*



Stochastic Analysis - Goals

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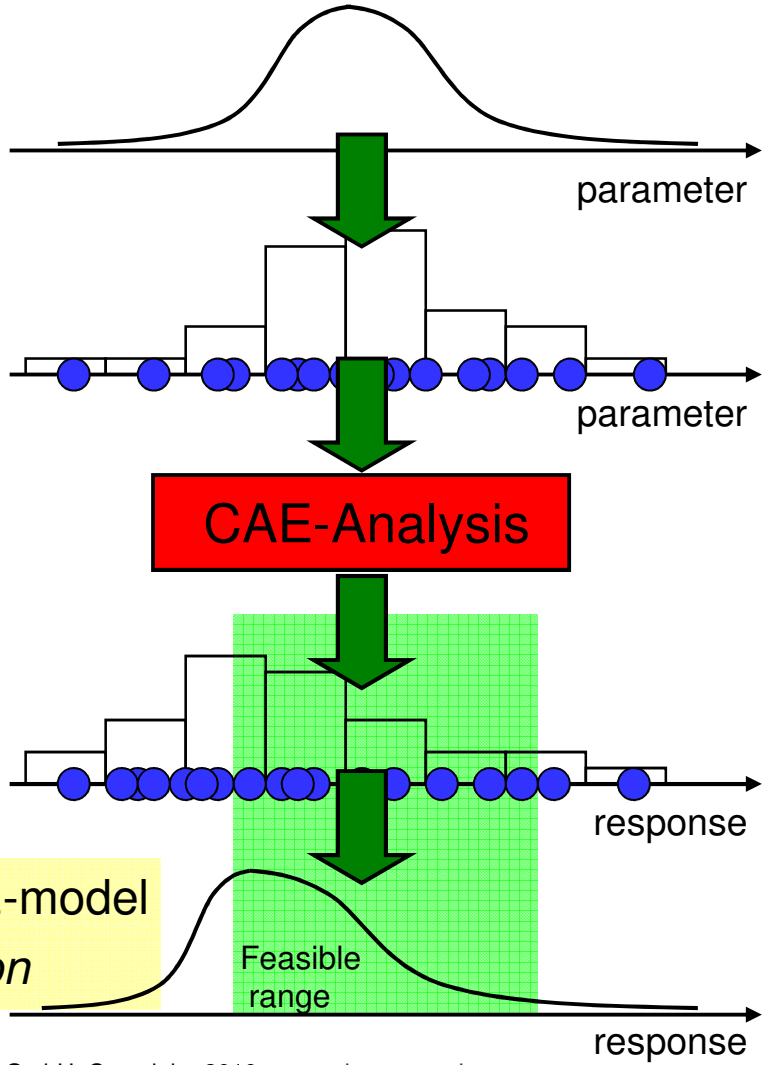
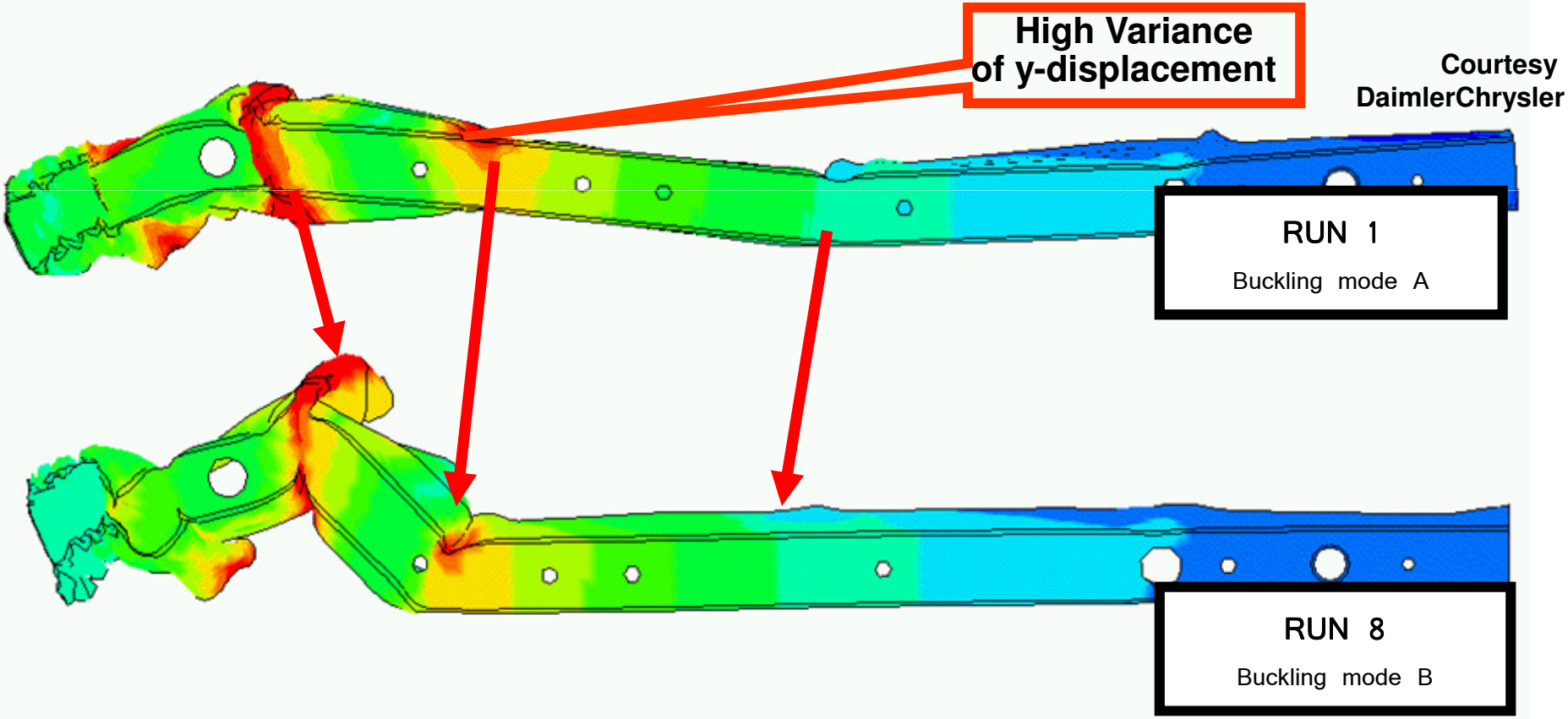


Visualization of Statistical Quantities on FE-model

- Standard deviation of y-displacements of each node (40 runs)



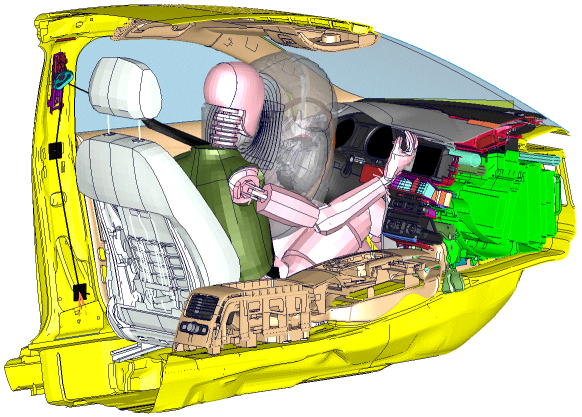
Example I - Optimization

Optimization of an Adaptive Restraint System

- Four Different Front-Crash Load Cases (FMVSS 208)

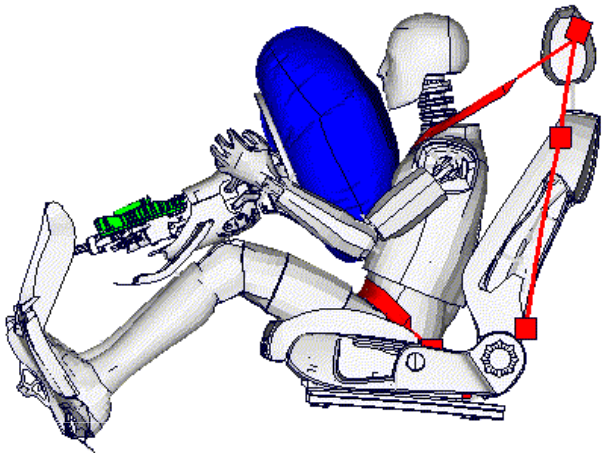
Dummy	56 km/h – belted	40 km/h – not belted
Hybrid III 5th Female	**H305a**(ktiv)	**H305p**(assiv)
Hybrid III 50th Male	**H350a**(ktiv)	**H350p**(assiv)

- PAM-Crash Model
  - *about 500000 elements*
  - *wall clock simulation time ~19 h, 4 cpus, distributed memory*
- Load Case Detection available
  - *Differentiation of the loadcases **belted** / **not belted** and **“Hybrid III 5th Female“** / **„Hybrid III 50th Male“** possible*
  - *Trigger time for seatbelt, airbag and steering column might be different*



Example I - Optimization

Optimization Problem



- Objective
  - *Minimize Thorax Acceleration*

    -> min BrustA3ms-05a
    -> min BrustA3ms-50a
    -> min BrustA3ms-05p
    -> min BrustA3ms-50p

- Constraints < 80% of regulation requirements
  - *Head Injury Coefficient (15ms)*

    -> HIC15-05a
    -> HIC15-50a
    -> HIC15-05p
    -> HIC15-50p

  - *Femur Forces (left/right)*

    -> FemurLi-05a
    -> FemurLi-50a
    -> FemurLi-05p
    -> FemurLi-50p

  - *Thorax Intrusion*

    -> BrustSx-05a
    -> BrustSx-50a
    -> BrustSx-05p
    -> BrustSx-50p

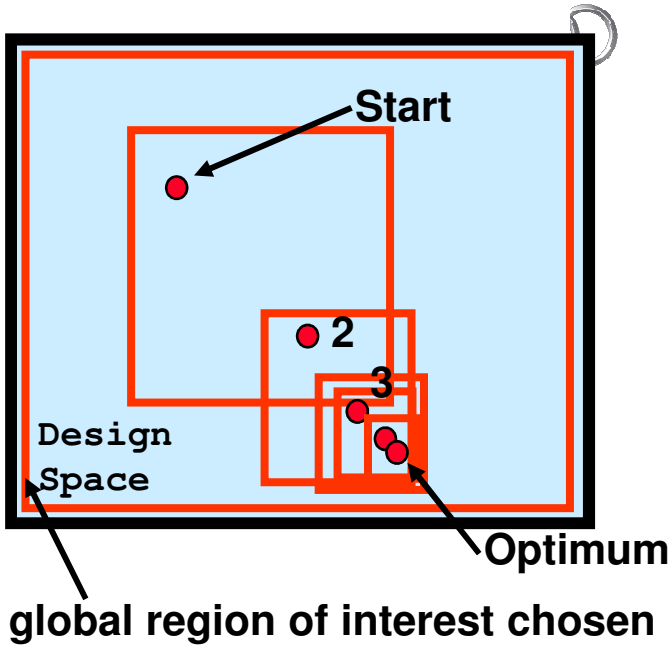
  - *Thorax Acceleration*

    -> BrustA3ms-05a
    -> BrustA3ms-50a
    -> BrustA3ms-05p
    -> BrustA3ms-50p

Example I - Optimization

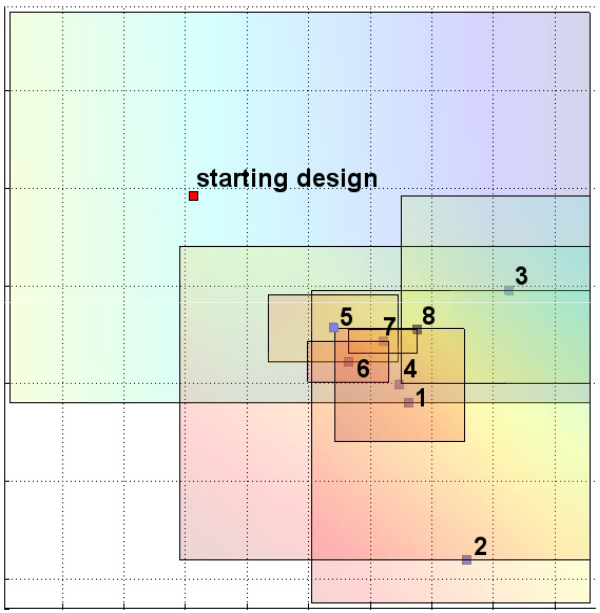
Application of Optimization

- Preferred Configuration at AUDI
  - *Adaptive Restraint System only for Airbag and Seatbelt*
  - *Reduction to 9 Variables in total (active=6, passive=3)*
- LS-OPT Approach: Successive Response Surface Methodology (SRSM) using linear polynomial approximations
  - *34 runs per iteration*
  - *D-optimal Design of Experiments (DOE)*
- Results
  - *8 iterations - total runs: 276*
  - *all constraints are fulfilled*
  - *minimization of multi-objective (second step) not applied*



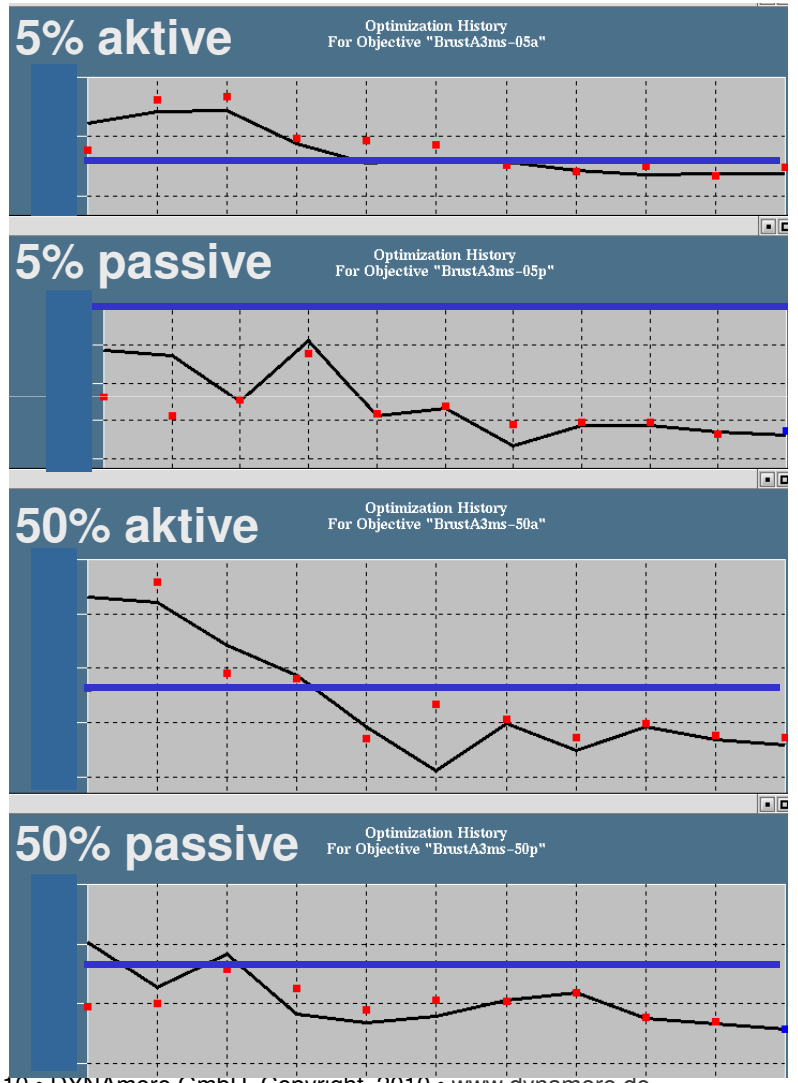
Example I - Optimization

Optimization Progress



a result which meets all requirements is gained in 8 iterations, each with 34 shots

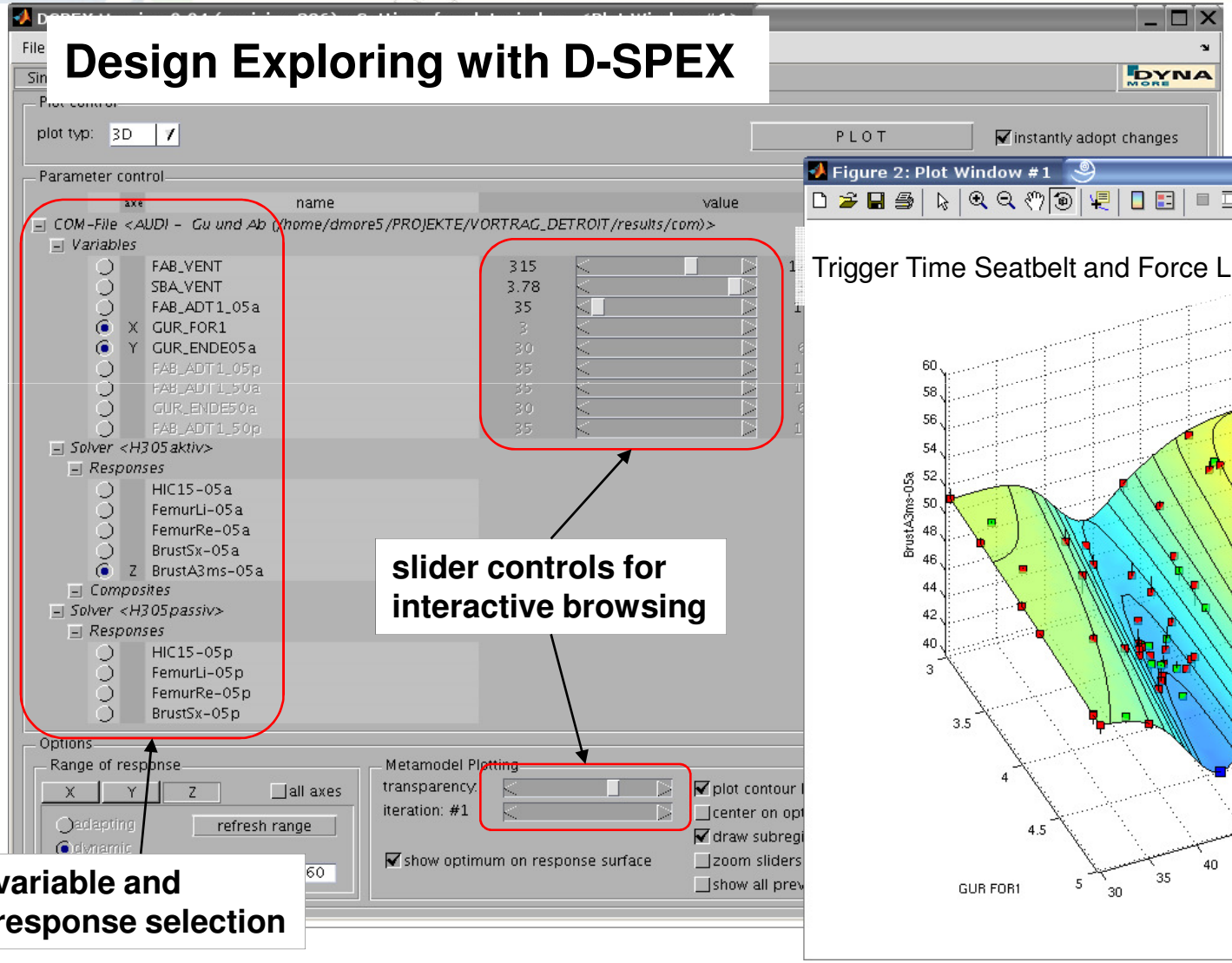
History of Thorax Acceleration



Example I - Optimization

- Introduction/Features
- Methods – Optimization
- Methods - Robustness
- Examples - Optimization
- Examples - Robustness
- Outlook

Design Exploring with D-SPEX



slider controls for interactive browsing

variable and response selection

Parameter Identification of Plastic Material

- Material properties: nonlinear visco-elastic behaviour
- LS-DYNA hyperelastic/viscoelastic formulation - *MAT_OGDEN_RUBBER (#77)
- Hyperelasticity

$$W = \sum_{i=1}^{3} \sum_{j=1}^{n} \frac{\mu_j}{\alpha_j}\left(\lambda_i^{\alpha_j} - 1\right) + \frac{1}{2} K (J-1)^2$$

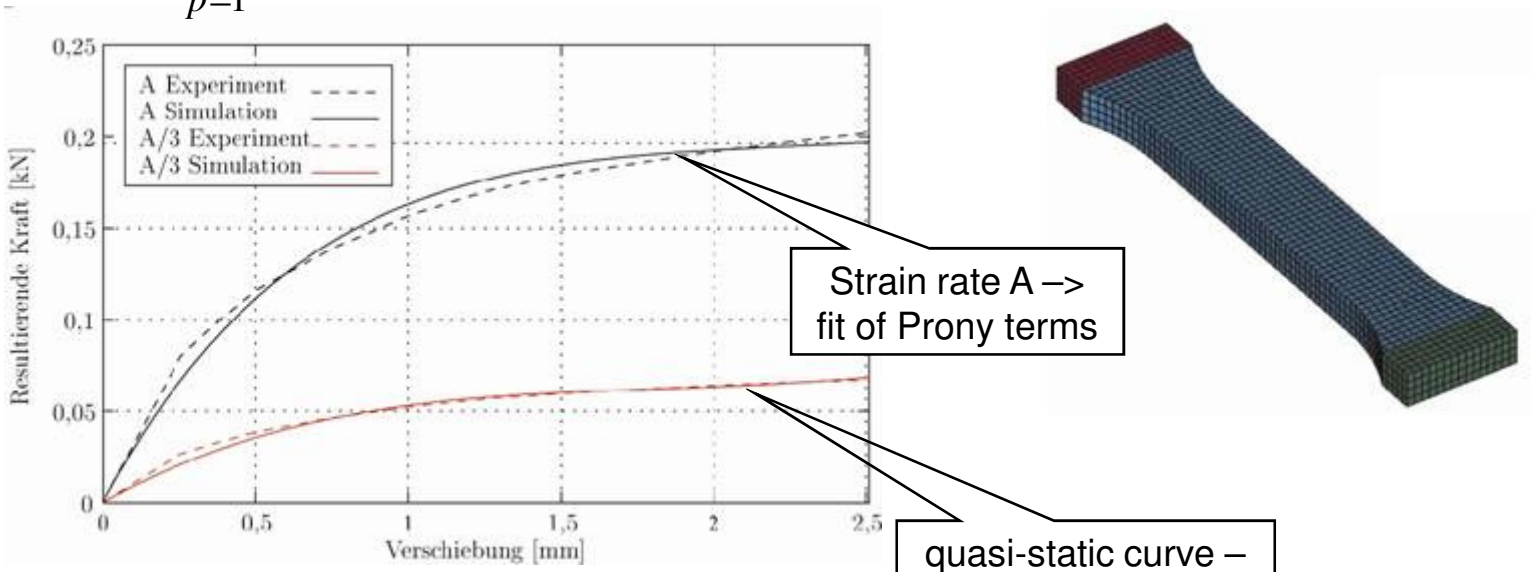
- Prony series representing the viscos-elastic part (Maxwell elements):

$$g(t) = \sum_{m=1}^{N} G_m e^{-\beta_m t} \quad ; \text{ N=1, 2, 3, 4, 5, 6} \quad ; \quad \sigma_{ij} = \int_0^t g_{ijkl}(t-\tau) \frac{\partial \varepsilon_{kl}}{\partial \tau} d\tau$$

Parameter Identification of Plastic Material

- Minimize the distance between experimental curve and simulation curve
- Least-Squares Objective Function

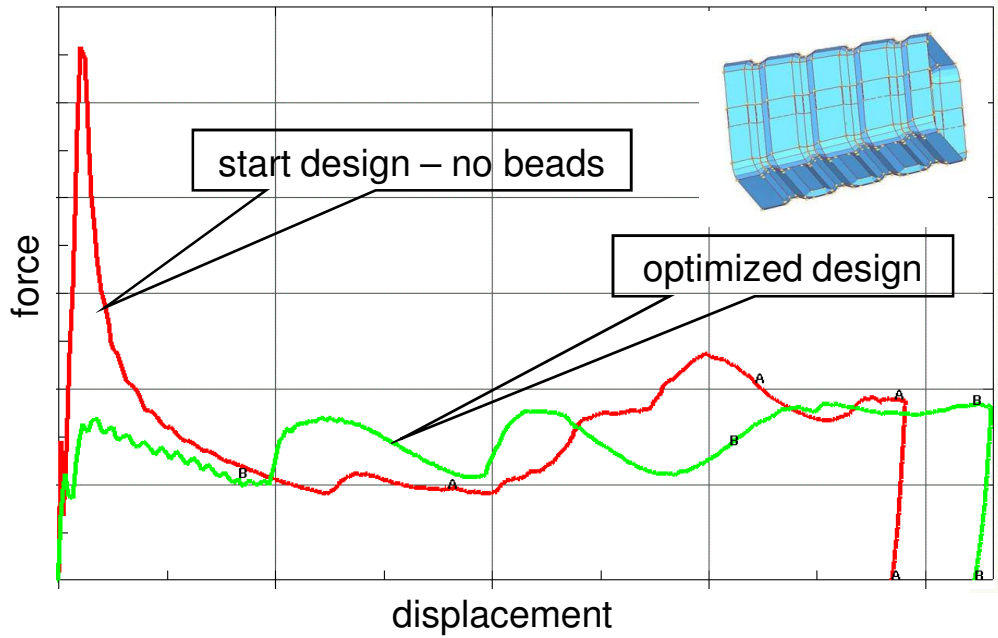
$$F(\mathbf{x}) = \sum_{p=1}^{P} \{[y(\mathbf{x}) - f(\mathbf{x})]^2\} \rightarrow \min F(\mathbf{x})$$

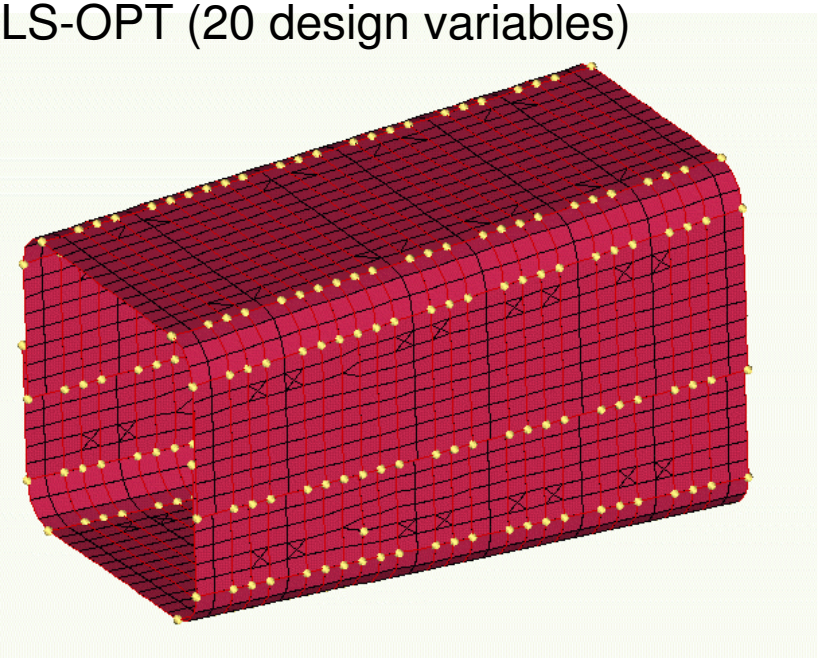


Example III – Optimization

Shape Optimization of a Crash Box

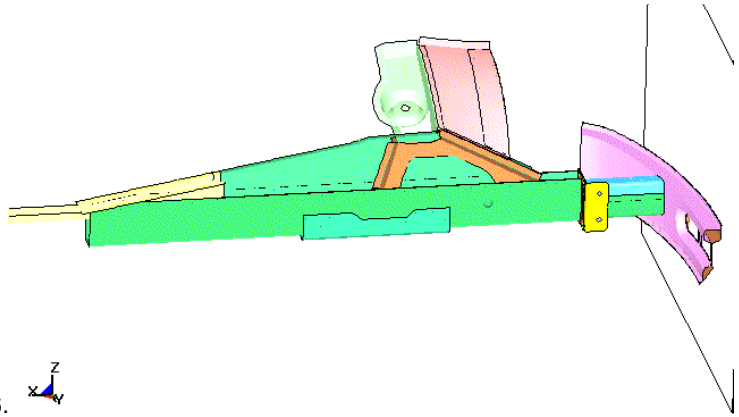
- Scope of optimization:
  - *minimize the maximum crash force*
  - *steady-going force progression*
- Shape variation by using Hypermorph and LS-OPT (20 design variables)





Robustness Investigations – Monte Carlo Analysis

- Variation of sheet thicknesses and yield stress of significant parts in order to consider uncertainties
- Normal distribution is assumed
  - *T_1134 (Longitudinal Member)* — *mean = 2.5mm; σ = 0.05mm*
  - *T_1139 (Closing Panel)* — *mean = 2.4mm; σ = 0.05mm*
  - *T_1210 (Absorbing Box)* — *mean = 0.8mm; σ = 0.05mm*
  - *T_1221 (Absorbing Box)* — *mean = 1.0mm; σ = 0.05mm*
  - *SF_1134 (Longitudinal Member)* — *mean = 1.0 ; σ = 0.05*
- Monte Carlo analysis using 182 points (Latin Hypercube)



Example I – Robustness

Tradeoff Plot

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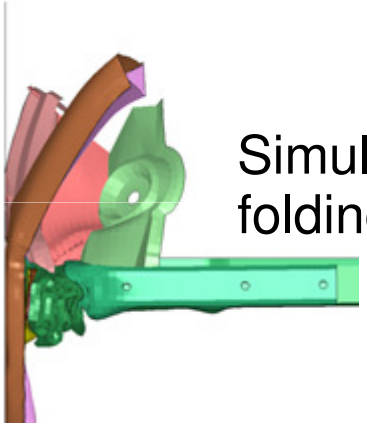
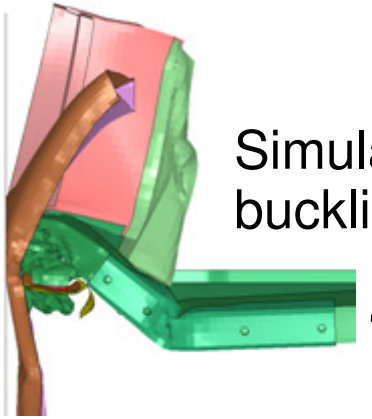
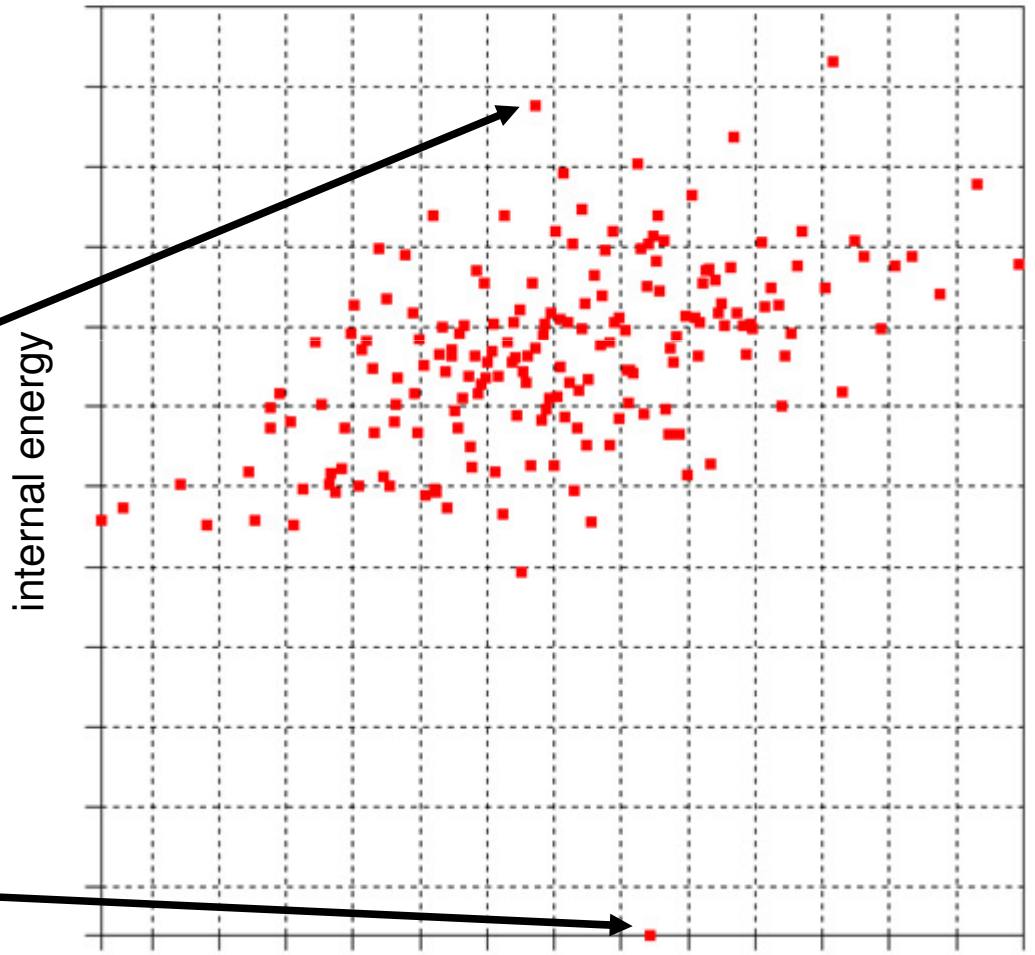
- Monte Carlo Simulation
- Identification of Clustering



Simulation 185
folding



Simulation 47
buckling



Example I – Robustness

Reliability Analysis

- Histogram of distribution
- Probability of exceeding a constraint-bound

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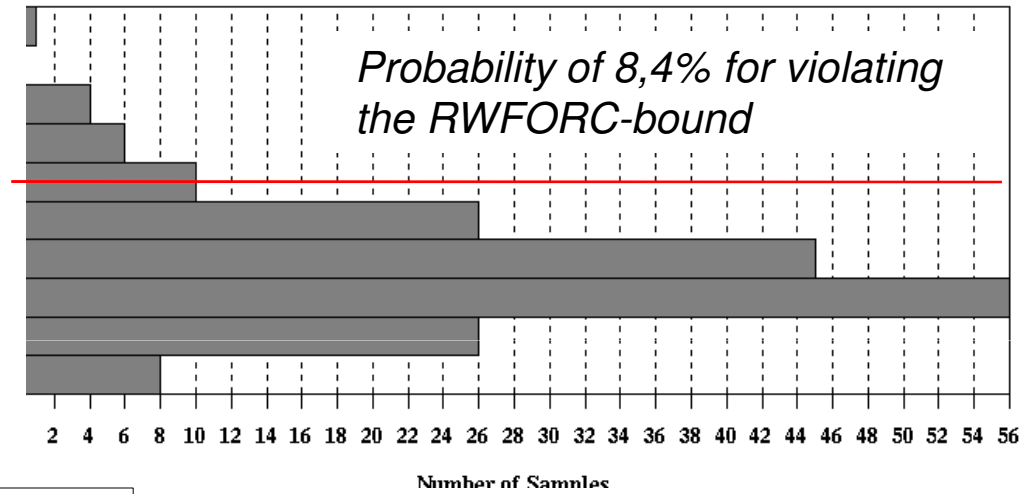
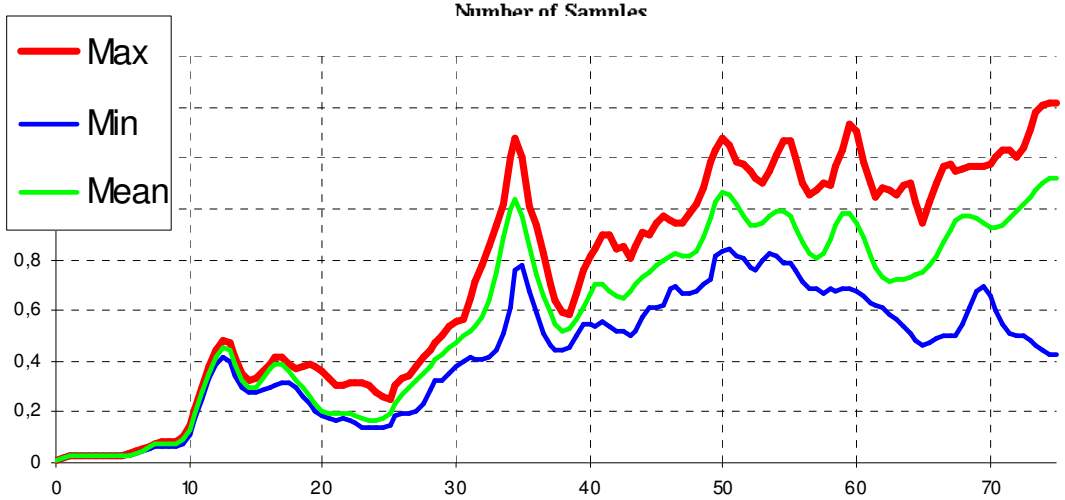
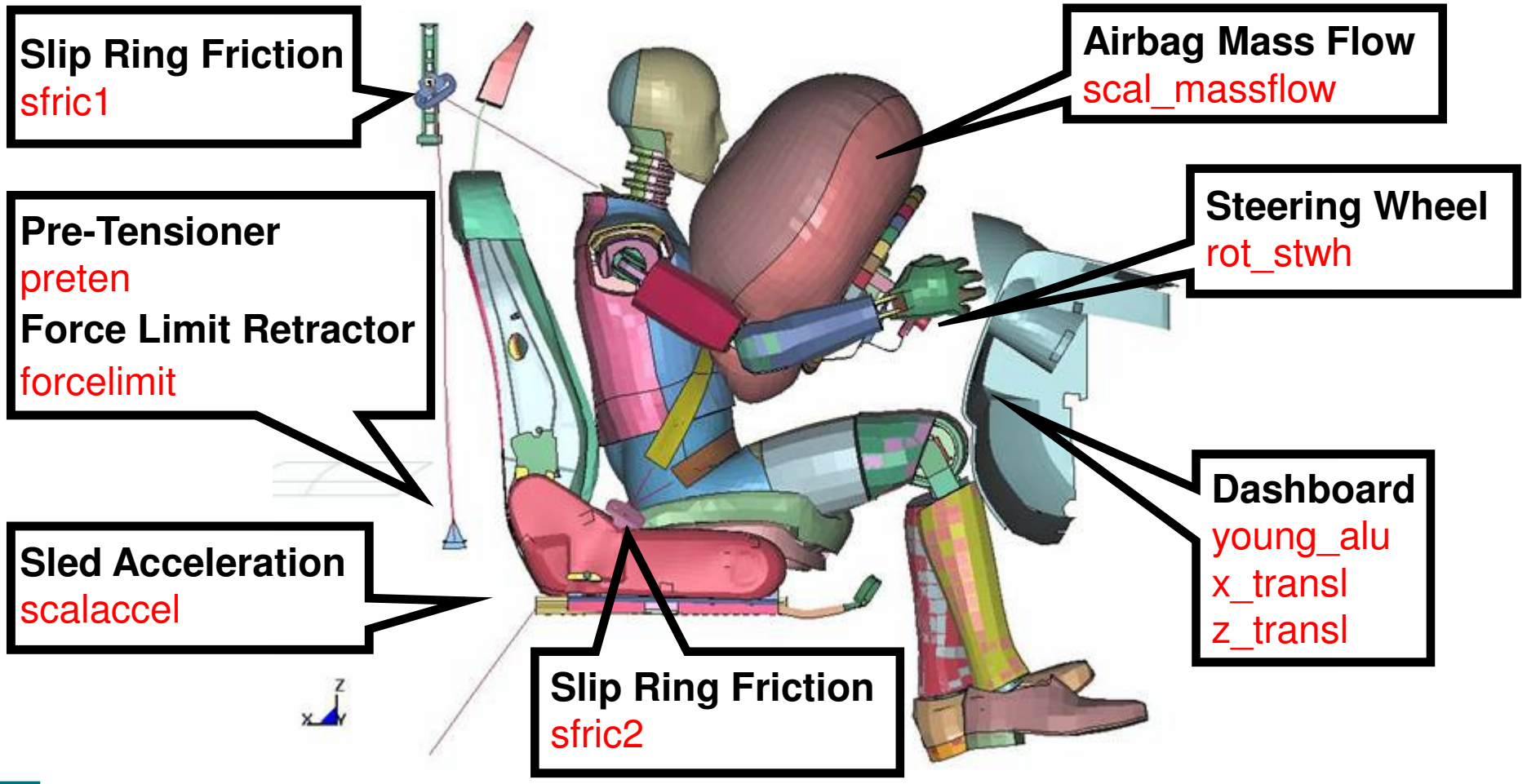


Min-Max Curves

- Plot of minimum, maximum and mean history values
- Gives a confidence interval of history values

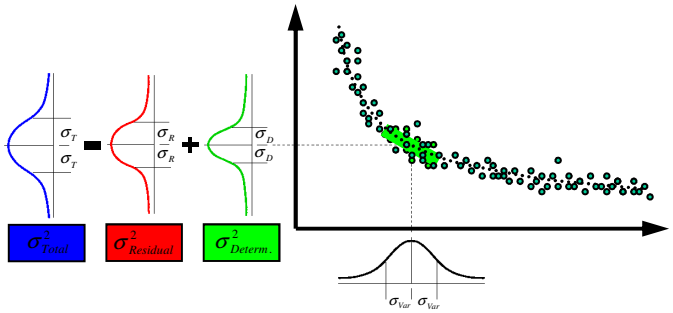


Design Variables - Uncertainties in Test Set-Up



Stochastic Contribution - Results of 30 Experiments

Design Variable	Standard Deviation of Design Variable	Standard Deviation Contribution					
		HIC36	max_chest_intru	max_b_f_shoulder	max_bf_pelvis	max_chest	max_pelvis
scalaccel	2,5%	3,1%	1,5%	0,1%	2,3%	1,9%	2,9%
sfric1	25,0%	1,3%	0,6%	4,1%	1,8%	0,7%	0,7%
sfric2	25,0%	0,5%	0,6%	0,1%	3,7%	0,1%	0,1%
preten	4,4%	0,0%	0,5%	0,0%	1,1%	0,3%	0,2%
forcelimit	5,6%	1,3%	0,4%	4,4%	0,6%	1,4%	0,2%
rot_stwh	4,8%	0,5%	0,1%	0,1%	0,0%	0,1%	0,1%
transl_x	50,0%	0,1%	0,1%	0,7%	4,5%	0,5%	0,8%
transl_z	50,0%	1,2%	1,0%	0,3%	1,6%	0,2%	0,9%
scalmassflow	5,0%	1,8%	1,8%	0,6%	2,2%	0,6%	0,9%
young_alu	5,0%	0,3%	0,3%	0,0%	0,5%	0,1%	0,1%
all variables		4,3%	2,8%	6,1%	7,2%	2,6%	3,4%
residuals		4,7%	1,9%	1,8%	6,0%	3,5%	2,3%
Total		**6,4%**	**3,4%**	**6,3%**	**9,4%**	**4,3%**	**4,1%**



Contribution of variation of design variables to variation of results

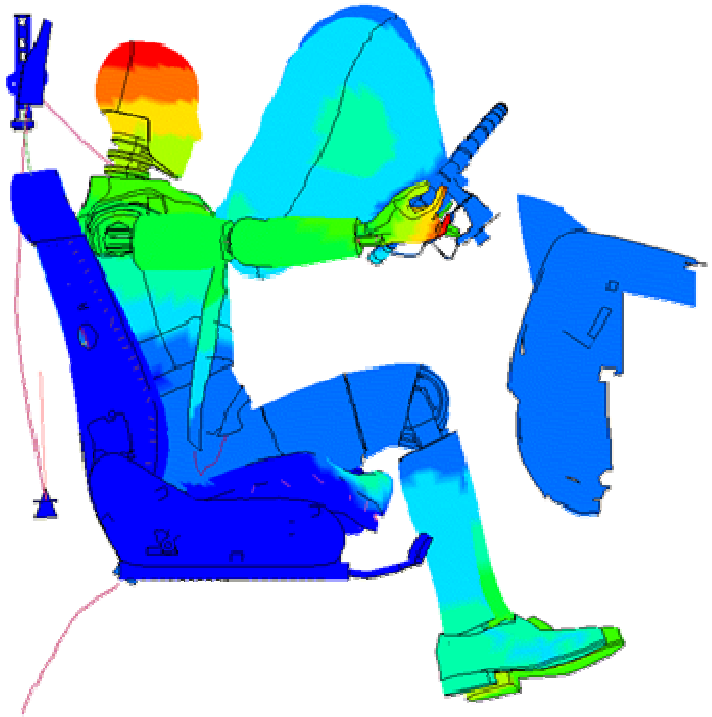
Meta-model space

Residual space

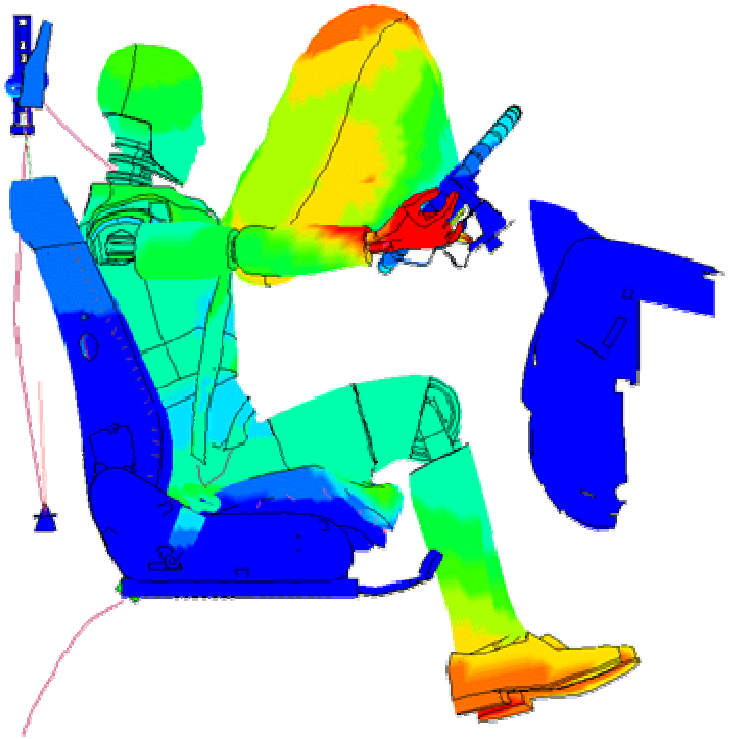
Total Variation

Standard deviation of x-displacements of each node (120 runs)

（a） Deterministic （Meta−Model）

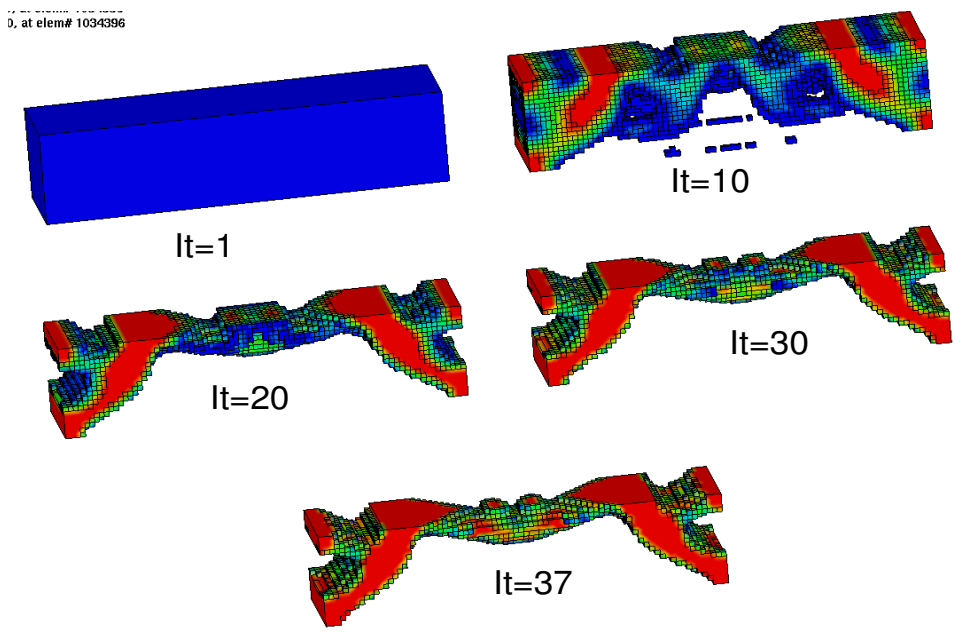


（b） Residual （Outliers）



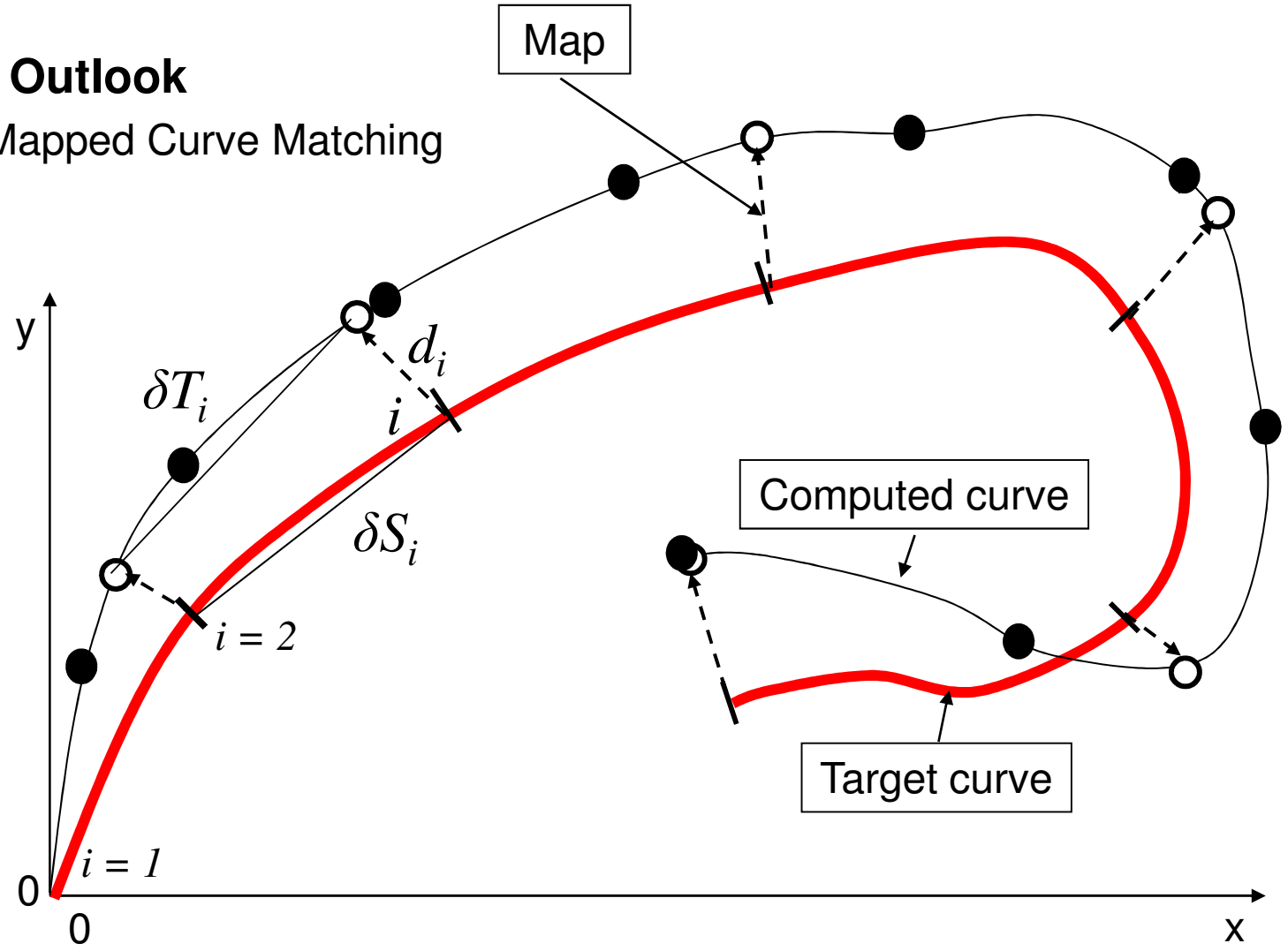
➔ Outlook

- LS-OPT/Topology V2.0
  - *More constraints: Displacement, Force,…*
  - *Shells in addition to solids*
  - *Other materials as MAT_24*
  - *More contact types*
  - *Performance*
  - *Integration LS-PP*



➔ Outlook

- Mapped Curve Matching



Outlook – Version 4.1

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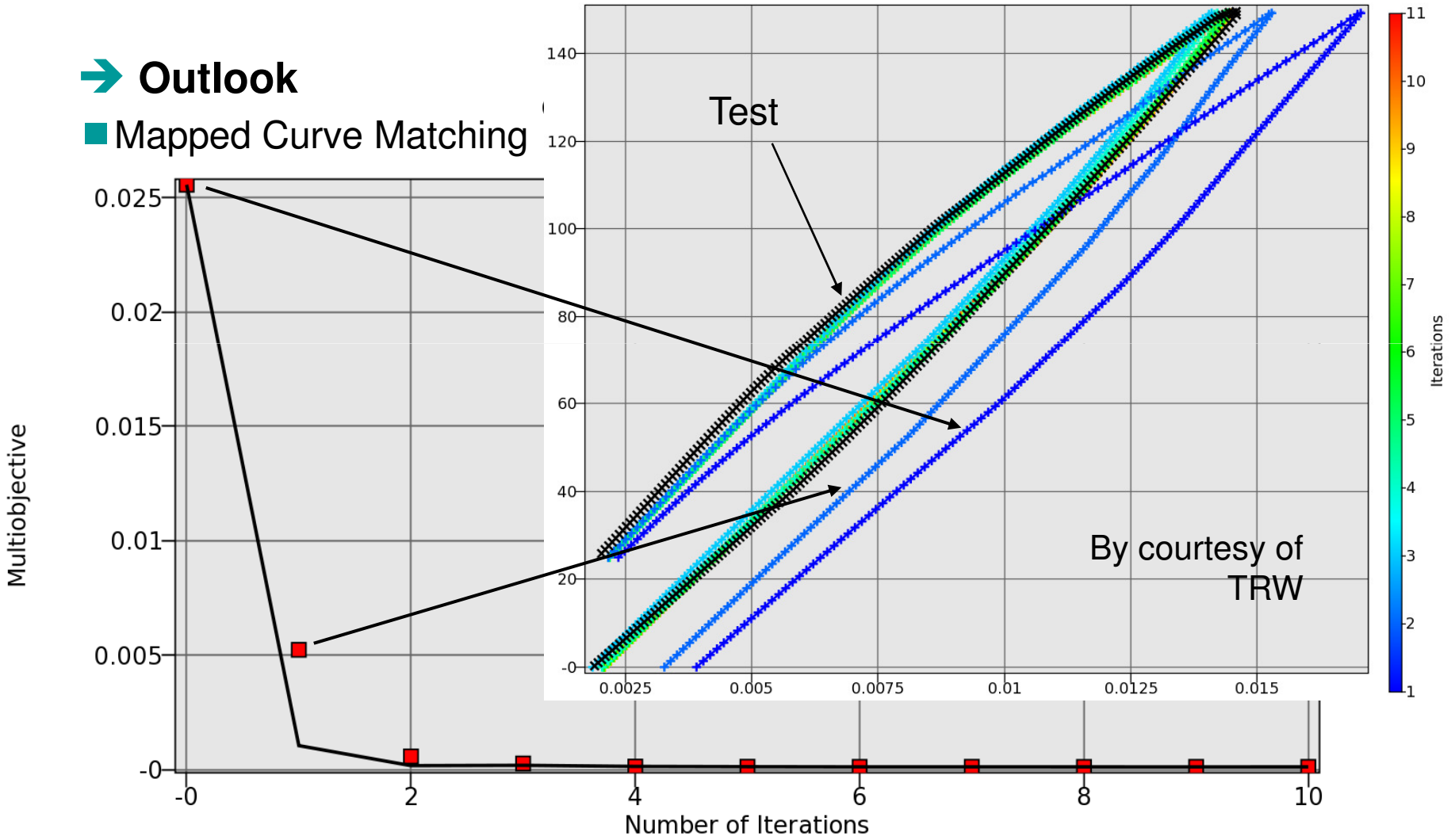
➔ Outlook

- Mapped Curve Matching



Outlook – Version 4.1

→ Outlook

- Process Simulation integrated with Optimization
  - *Series of simulations: applies to manufacturing (stamping, forging, injection molding, …)*
  - *Major GUI enhancements in V5*
- Pre-Processing Interfaces
  - *LS-PrePost (added to V4.1)*
  - *DEP Meshworks*
- Viewer: Self-Organizing Maps for simulation results
- String Variables for discrete optimization
  - *E.g. Material = {Steel, Aluminum, HighStrengthSteel}*
- Generic Extraction (GenEx) of histories
- GUI support for Special Functions, e.g. Integral, Derivative, Min, Max, etc.