



Neue Entwicklungen in LS-OPT 4.0 – Ausblick auf Version 4.1

New Developments in LS-OPT 4.0 – Outlook V4.1

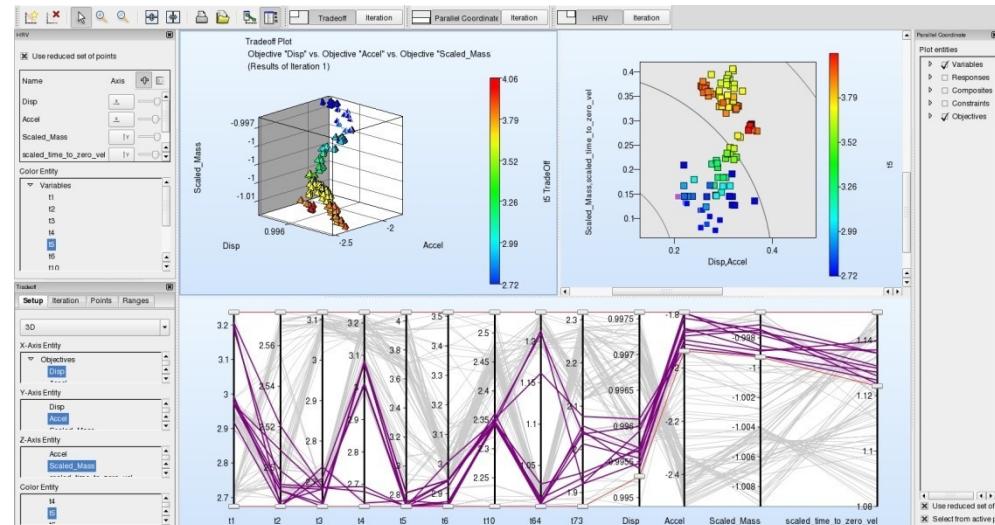
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Industriestraße 2
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<http://www.dynamore.de>



Overview

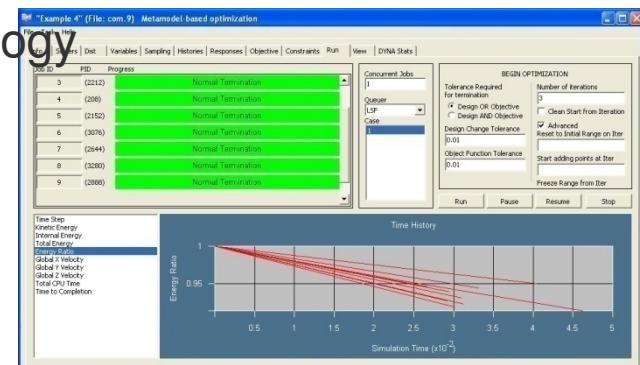
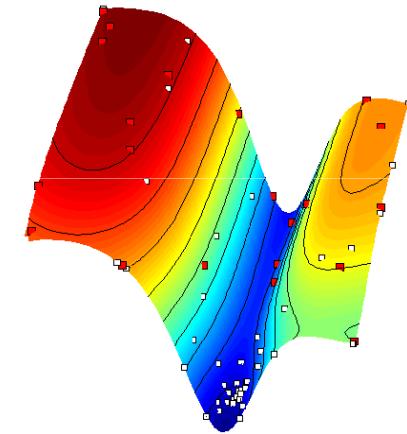
- Introduction/Features of current Version 4.0
- Methodologies – Optimization
- Methodologies - Robustness
- Examples - Optimization
- Examples – Robustness
- Outlook Version 4.1





About LS-OPT

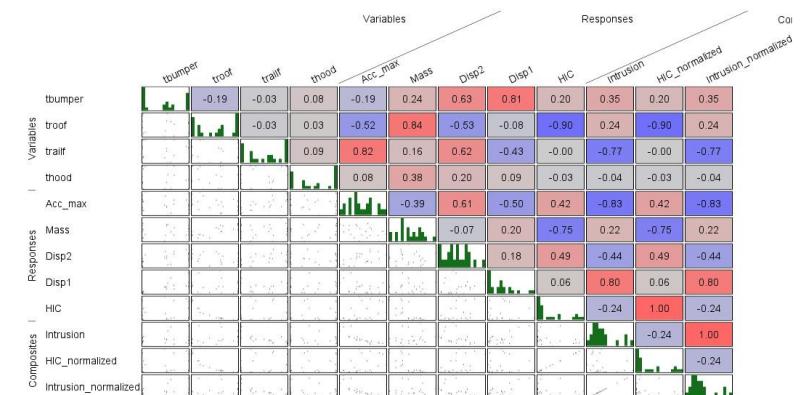
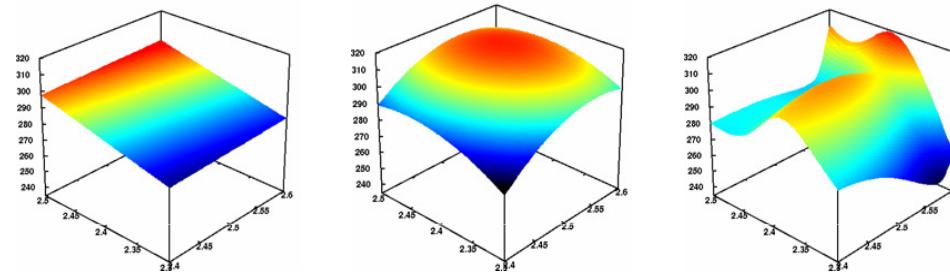
- LS-OPT is a product of LSTC, current version: V4.0
 - *major new release with many new feature particularly within the viewer (visualization of results)*
→ next presentation “Methoden zur Visualisierung von Ergebnissen aus Optimierungs- und DOE-Studien”
- Beta version 4.1 available by end of this year
- LS-OPT can be linked to any simulation code – stand alone optimization software
- Perfect suitable in combination with LS-DYNA
- Two main products LS-OPT and LS-OPT/Topology





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)
- Multi-Objective Optimization (Pareto Front)
- DOE-Studies (ANOVA, Sobol)
- Parameter/System Identification
- Stochastic/Probabilistic Analysis
- 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)

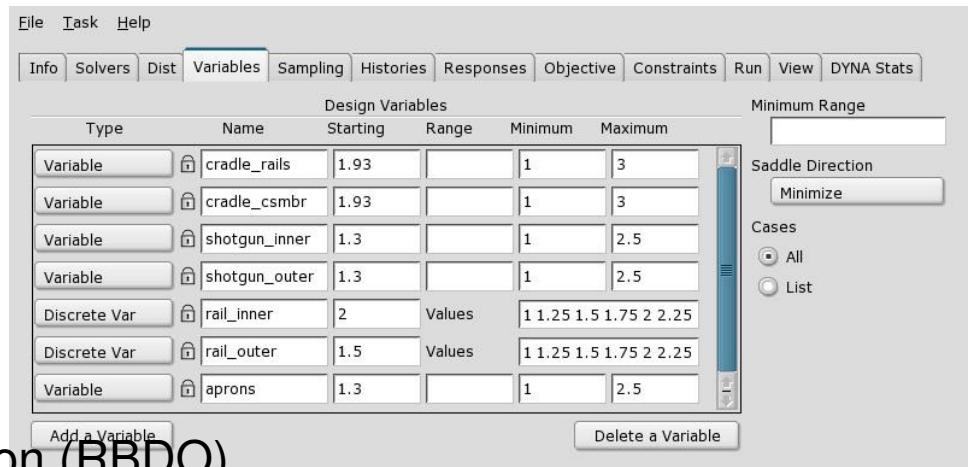
- *Improve/Maximizing the robustness of the optimum*

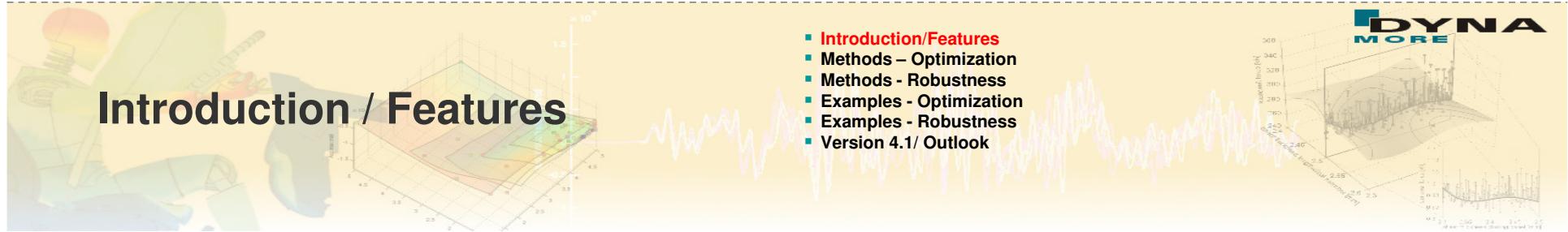
■ Reliability Based Design Optimization (RBDO)

- *Improve failure probability of optimum*

■ Visualization of Stochastic Results

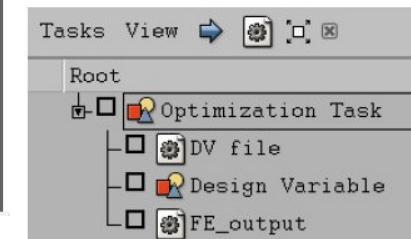
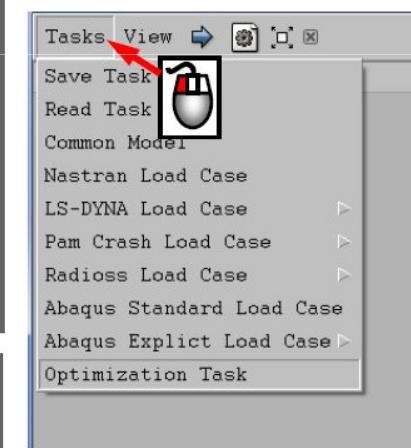
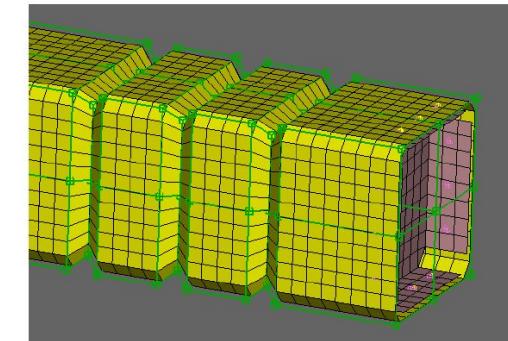
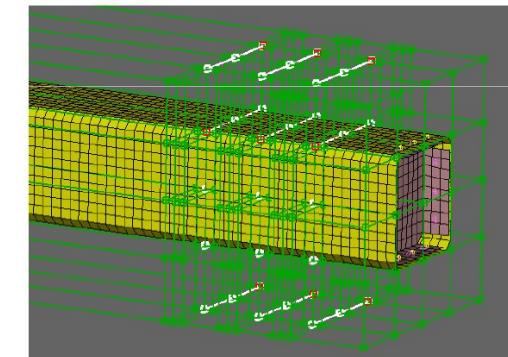
- *Confidence Intervals, reliability quantities*
- *Fringe of statistic results on the FE-Model*





About LS-OPT

- 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 (ANSO package)



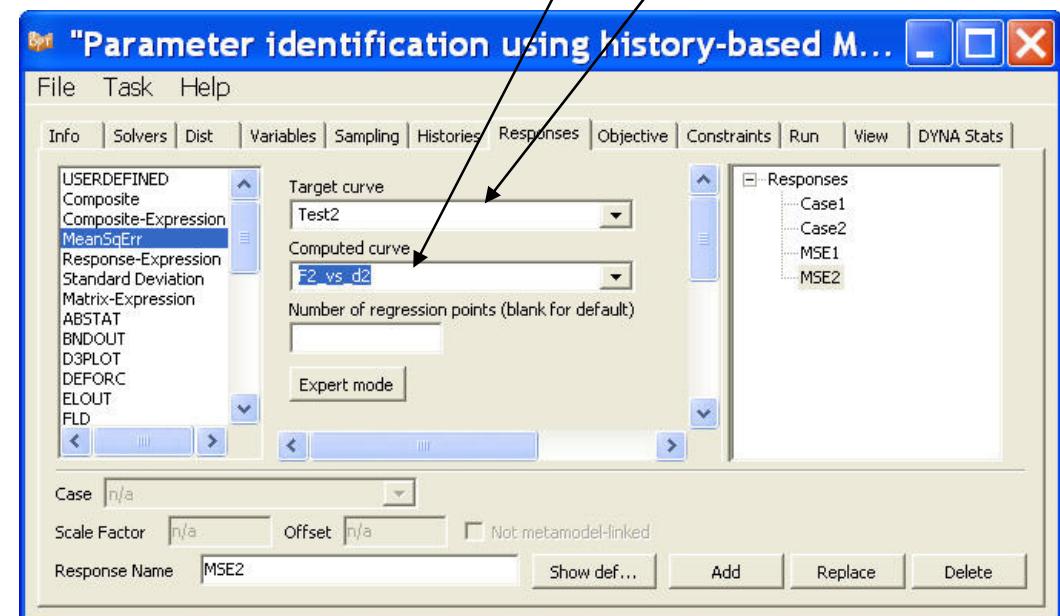


About LS-OPT

■ 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

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





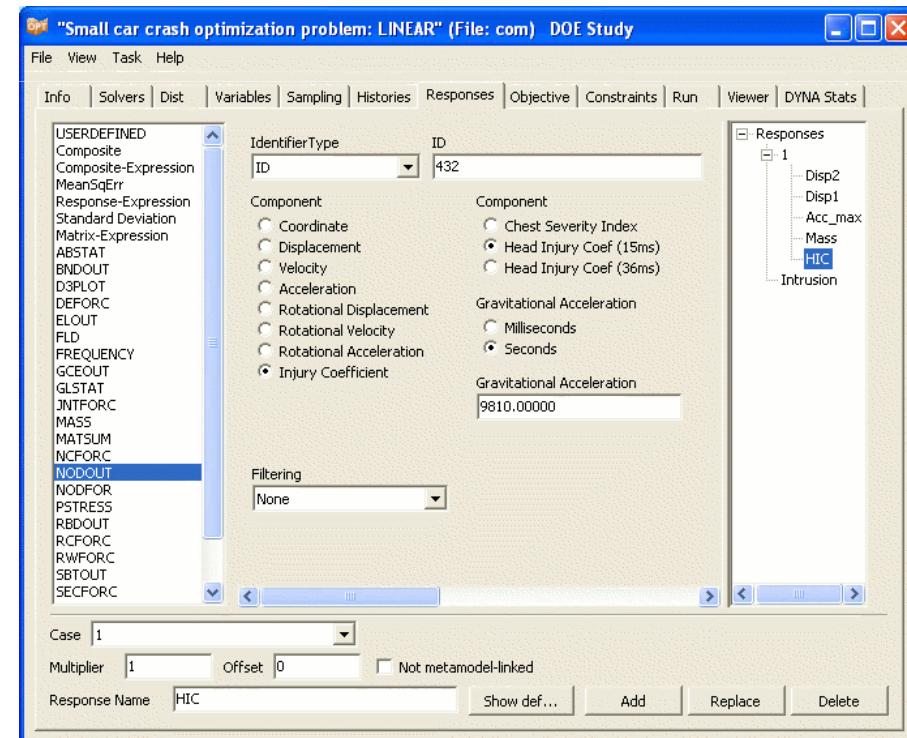
Introduction / Features

- Introduction/Features
- Methods – Optimization
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- Examples - Optimization
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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)*





Introduction / Features

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About LS-OPT

■ LS-OPT Supportwebpage -> www.lsoptsupport.com

■ *Many examples, tutorials, FAQs, HowTos...*

Welcome to LS-OPT Support Site... — LS-OPT Support Site - Mozilla Firefox

File Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe

■ Welcome to LS-OPT Support Site... ■ Index of/beta/lsopt/3.3/Training ■ Examples—LS-OPT Support Site

Search Site only in current section

LS-OPT Support

HOME EXAMPLES DOWNLOADS DOCUMENTS HOWTO'S

Welcome to LS-OPT Support Site...

— filed under: lsopt, optimization, stochastic analysis, ls-opt

LS-OPT

Home

- About LS-OPT
- Getting Started
- HowTos
- Documents
- Examples
- Glossary
- Downloads
- FAQs
- News
- About us

News

- LS-OPT 3.3 released Mar 14, 2008
- LS-OPT 3.2 released Jan 16, 2008
- More news...

Recent Content

- Which meta model to choose?
- LS-OPT 3.3
- Integrating ANSA
- Setting parameters for metamodel-based optimization strategies
- Getting Started

<http://www.lsoptsupport.com/examples>

Welcome to LS-OPT Support Site...

LS-OPT, the graphical optimization tool that interfaces perfectly with LS-DYNA, allows the user to structure the design process, explore the design space and compute optimal designs according to specified constraints and objectives. The program is also highly suited to the solution of system identification problems and stochastic analysis.

The graphical tool LS-OPTui interfaces with LS-DYNA and provides an environment to specify optimization input, monitor and control parallel simulations and post-process optimization data, as well as viewing multiple designs using LS-PREPOST.

Applications: Design Optimization, System Identification, Stochastic Analysis

Metamodels/approx. Schemes

- A **successive approximation procedure** allows refinement of the solution and convergence to an optimum. The method is known as SRSM (Successive Response Surface Method).
- **Feedforward neural networks**
- **Radial Basis Functions**
- **Polynomial response surfaces**

Stochastic Analysis

- **Monte Carlo analysis**
- **Robustness evaluation**

Optimization/Interfacing

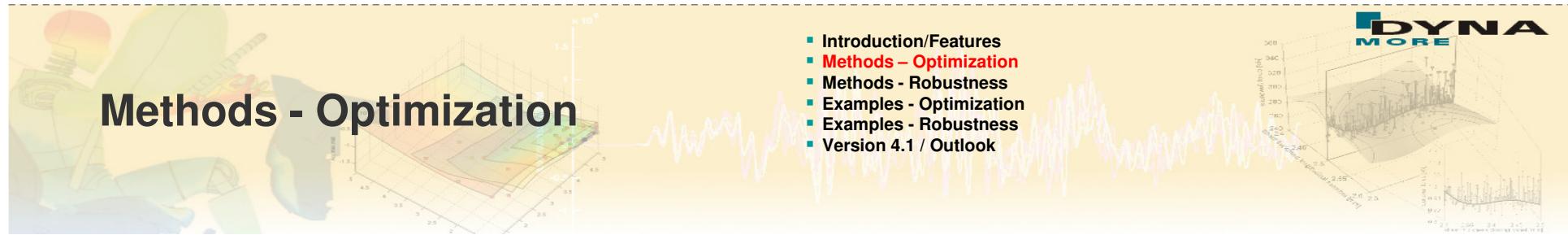
- A **command language** forms the basis for the description of the optimization formulation and process.
- **Preprocessors** as for example ANSA, Hypermesh or Truegrid can be incorporated into the design cycle in order to apply shape optimization.
- A **comprehensive LS-DYNA interface** allows access to the ASCII binary databases. Minima, maxima and averages can be requested. Response filtering can be used.
- **Mathematical expressions** may be used to

Meta models: Artificial Neural Networks

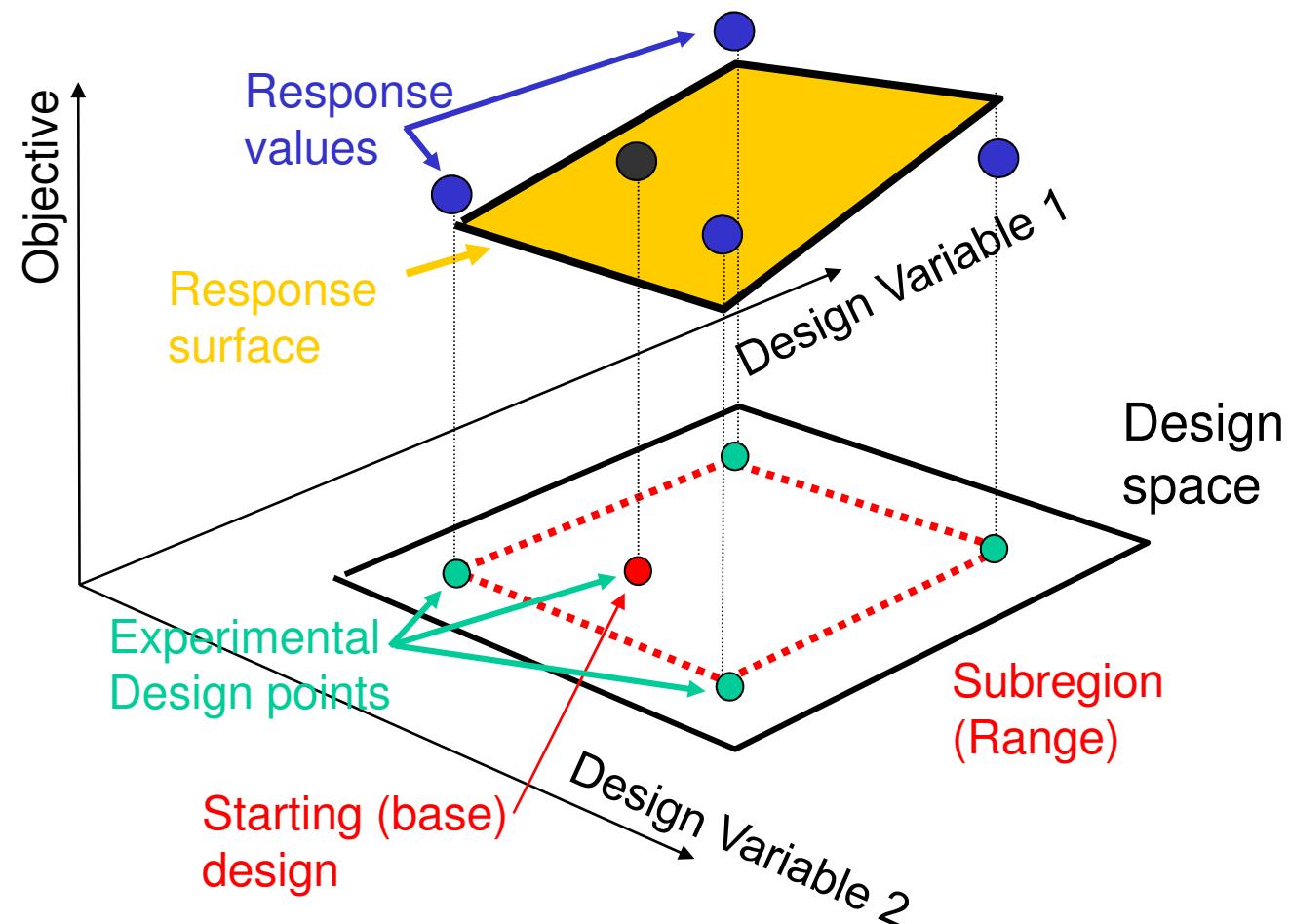
RPSM (Successive Response Surface Method)

Response Surface Based Variable Screening

Stochastic Simulation

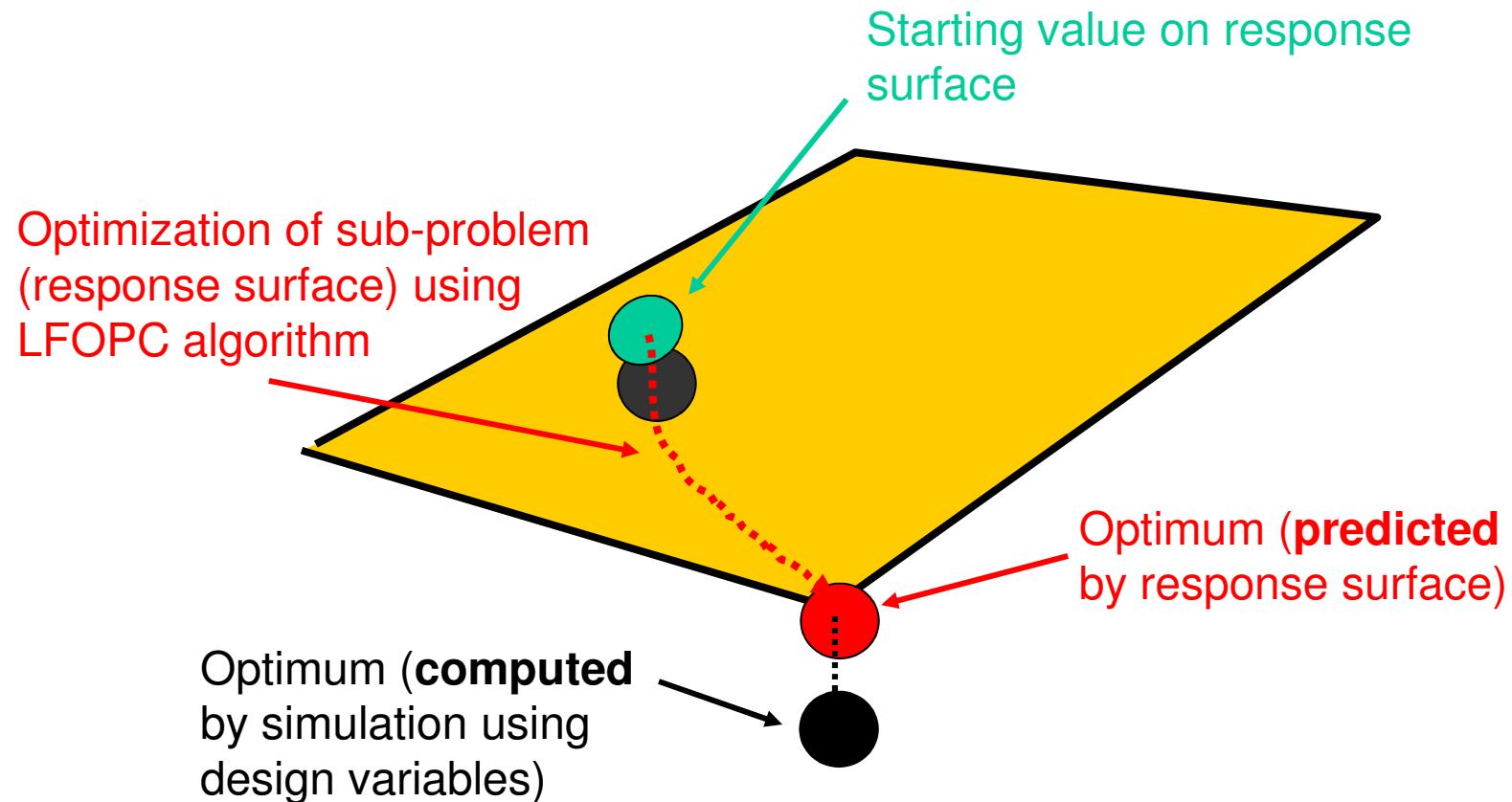


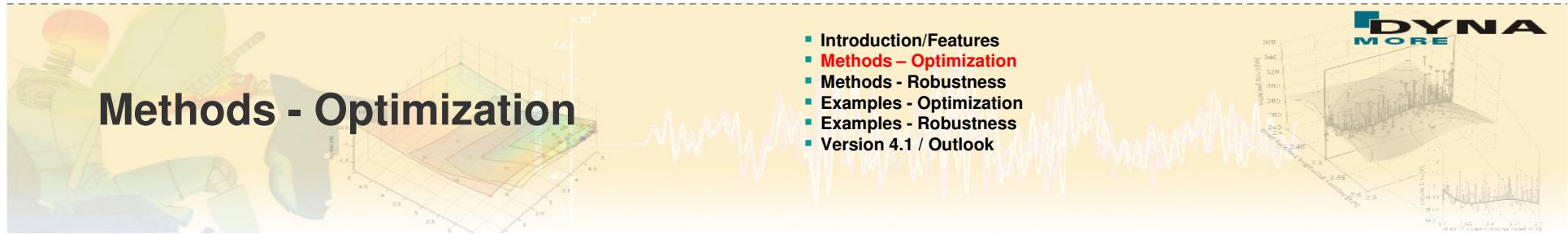
Response Surface Methodology - Optimization Process



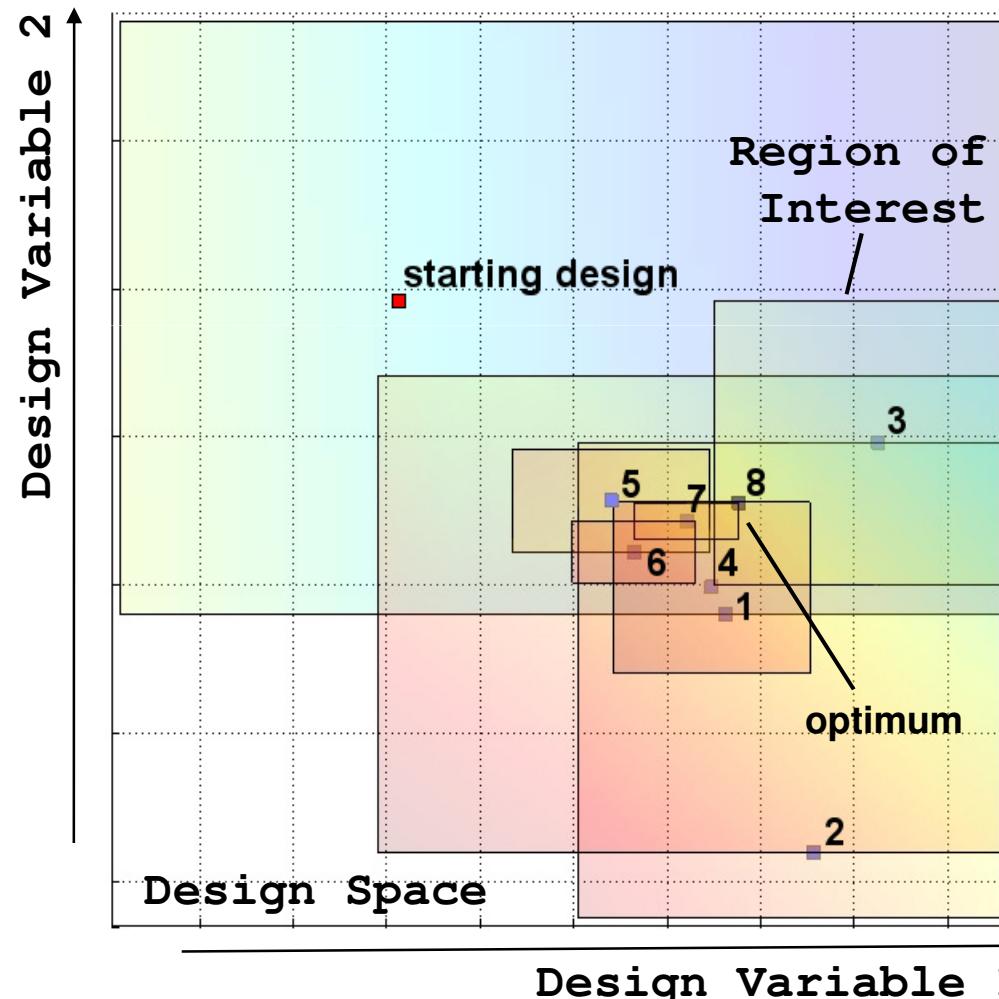


Find an Optimum on the Response Surface (one iteration)





Successive Response Surface Methodology

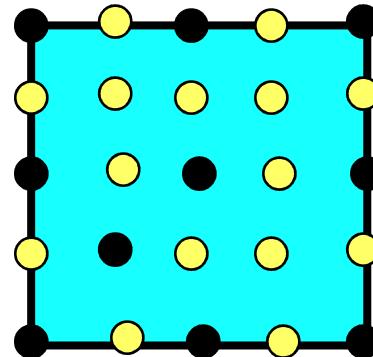




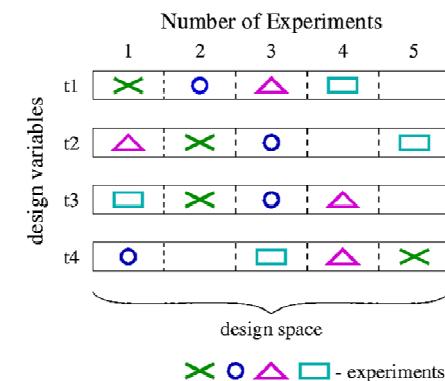
Design of Experiments (DOE) - Sampling Point Selection

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

$$\max |X^T X|$$



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



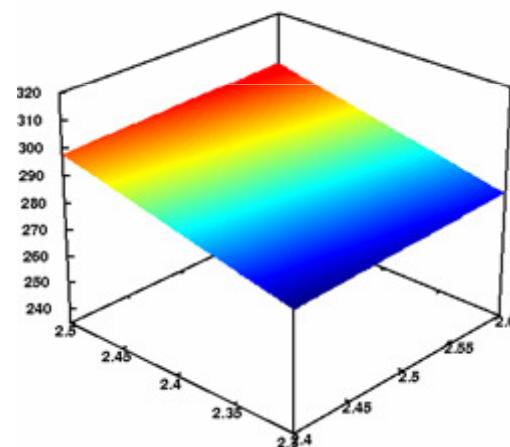


Methods - Optimization

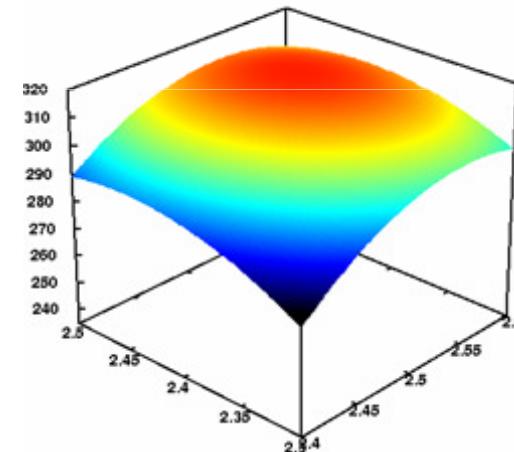
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Response Surfaces (Meta Models)

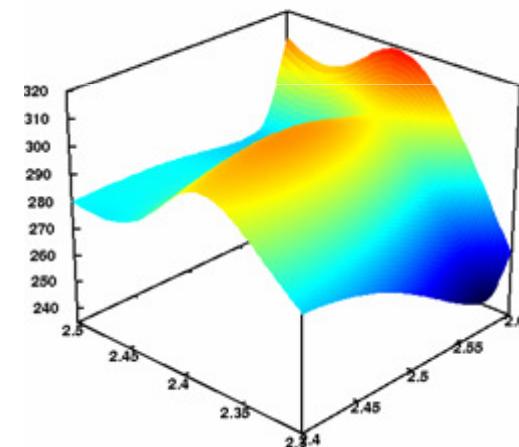
- Linear, Quadratic and Mixed polynomial based
- Radial Basis Functions, Feed Forward Neural Networks and Kriging for global approximations



linear polynomial



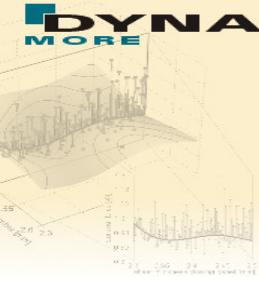
quadratic polynomial



neural network

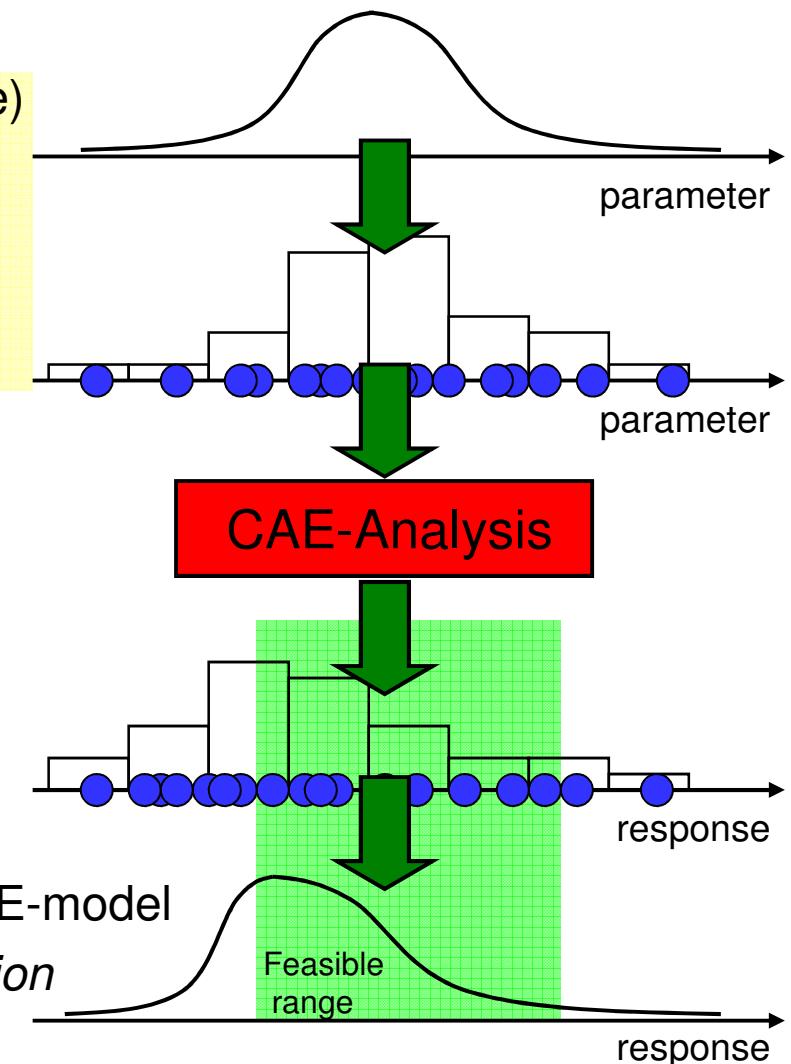
Methodologies – Robustness Investigations

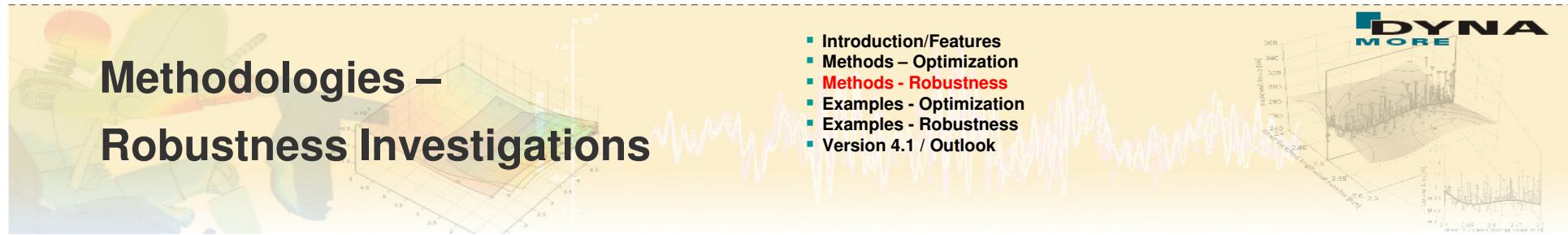
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Stochastic Analysis - Goals

- 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*

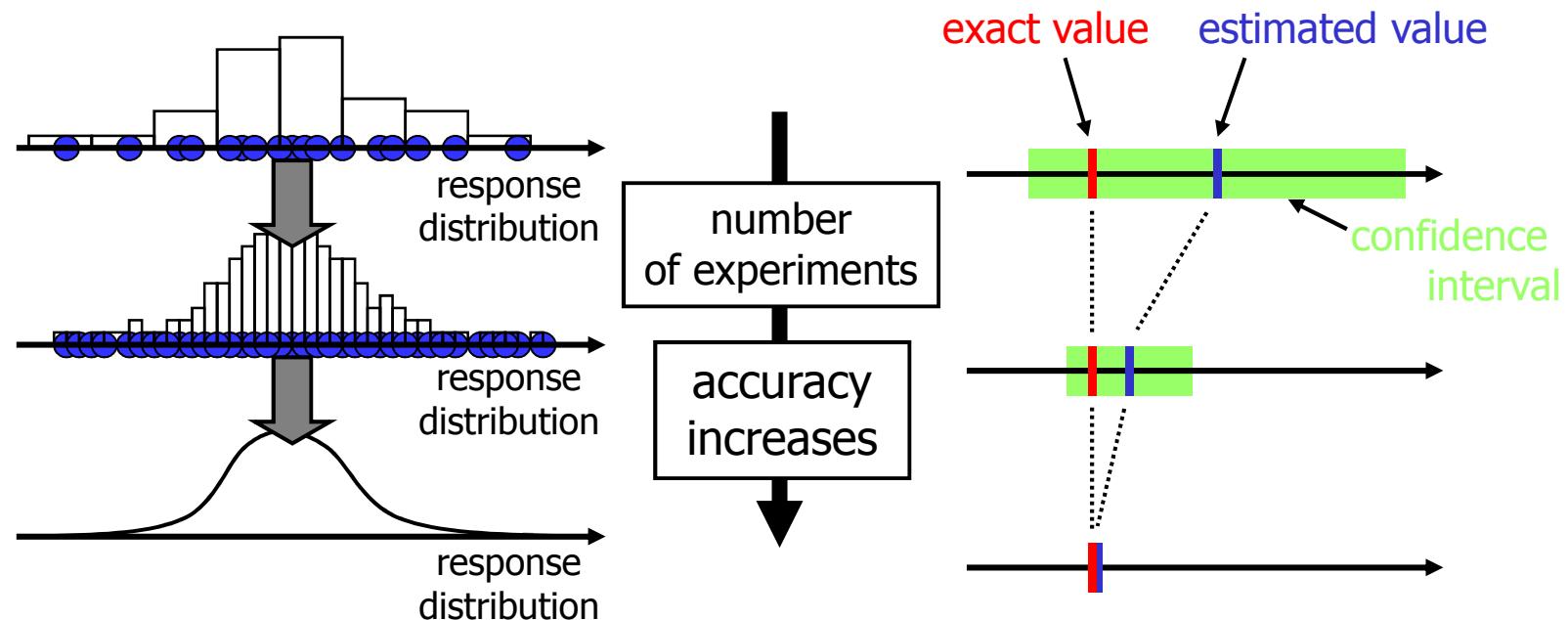




Statistical Quantities of Output due to Variation of Input

■ Direct Monte Carlo Sampling

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





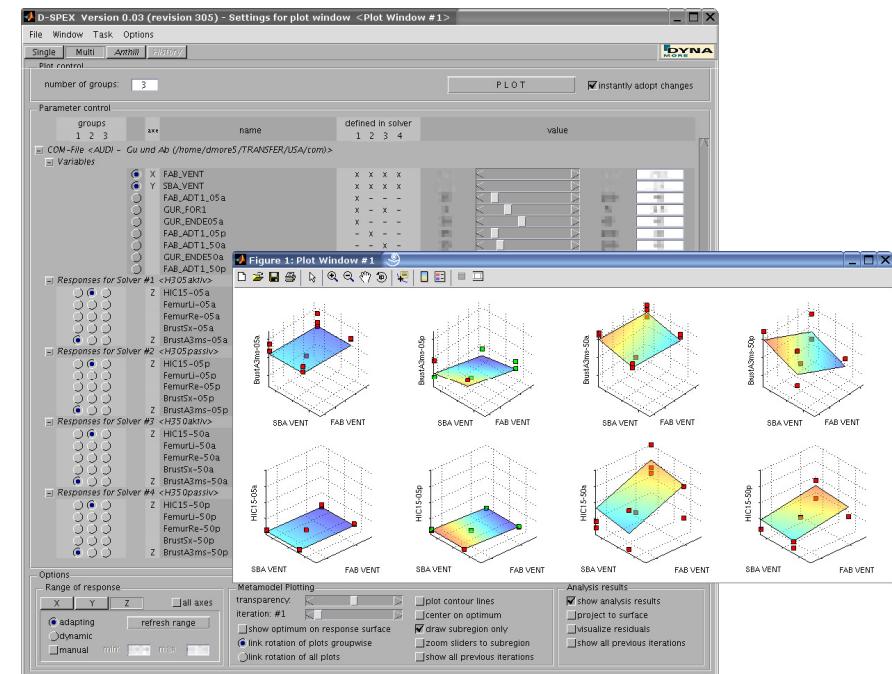
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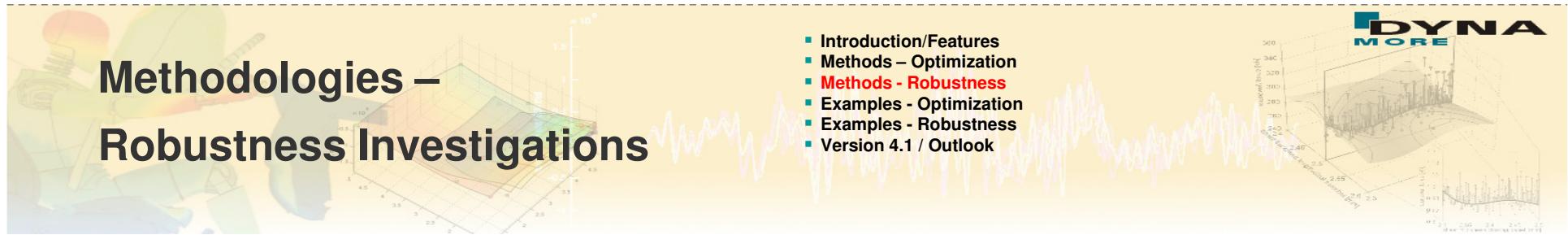
Statistical Quantities of Output due to Variation of Input

■ 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

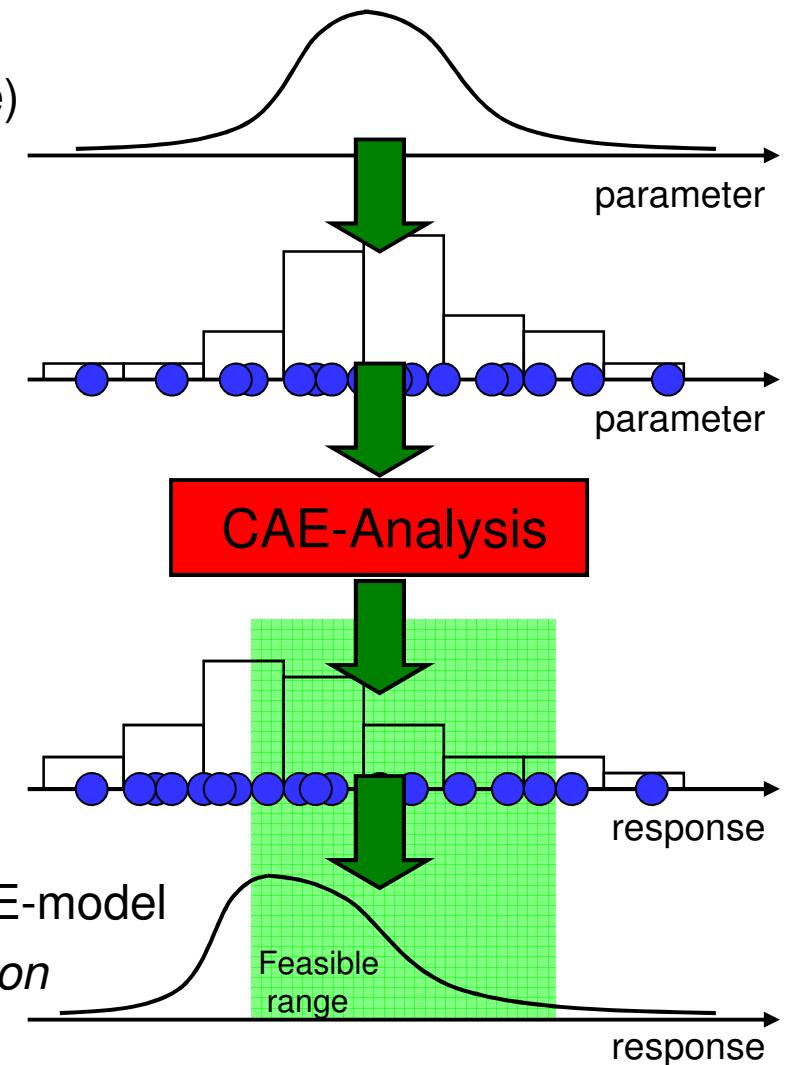


Multi Meta-Model exploration with D-SPEX



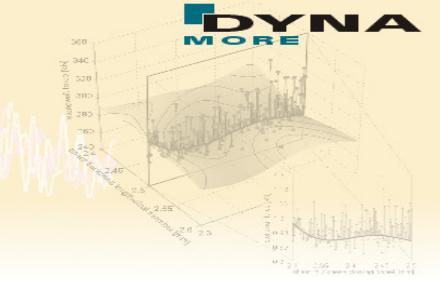
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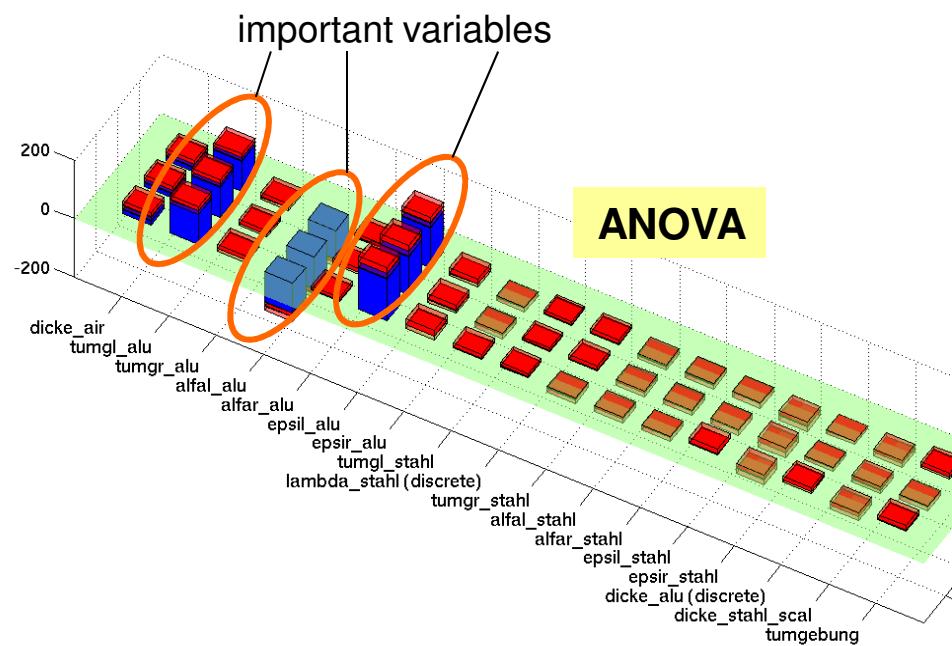
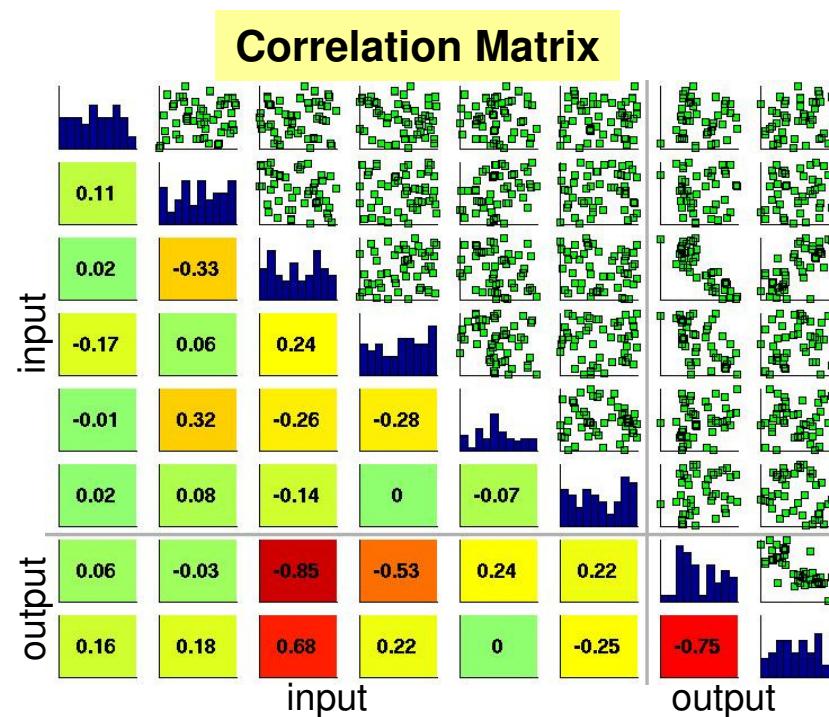
Methodologies – Robustness Investigations

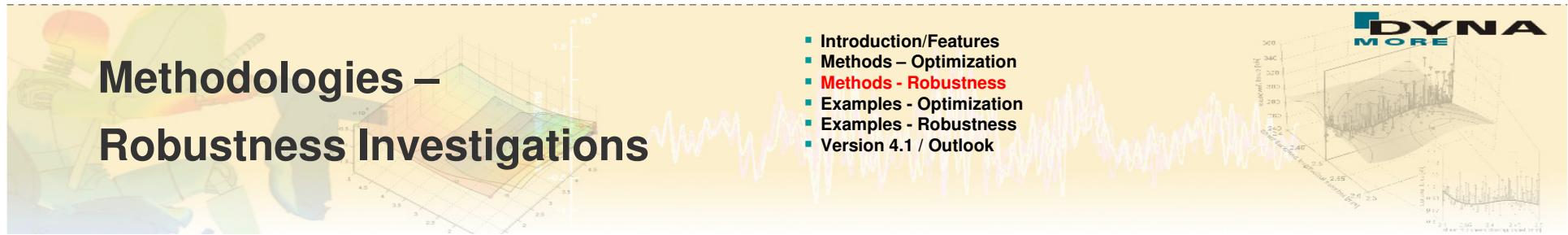
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Significance of Variables

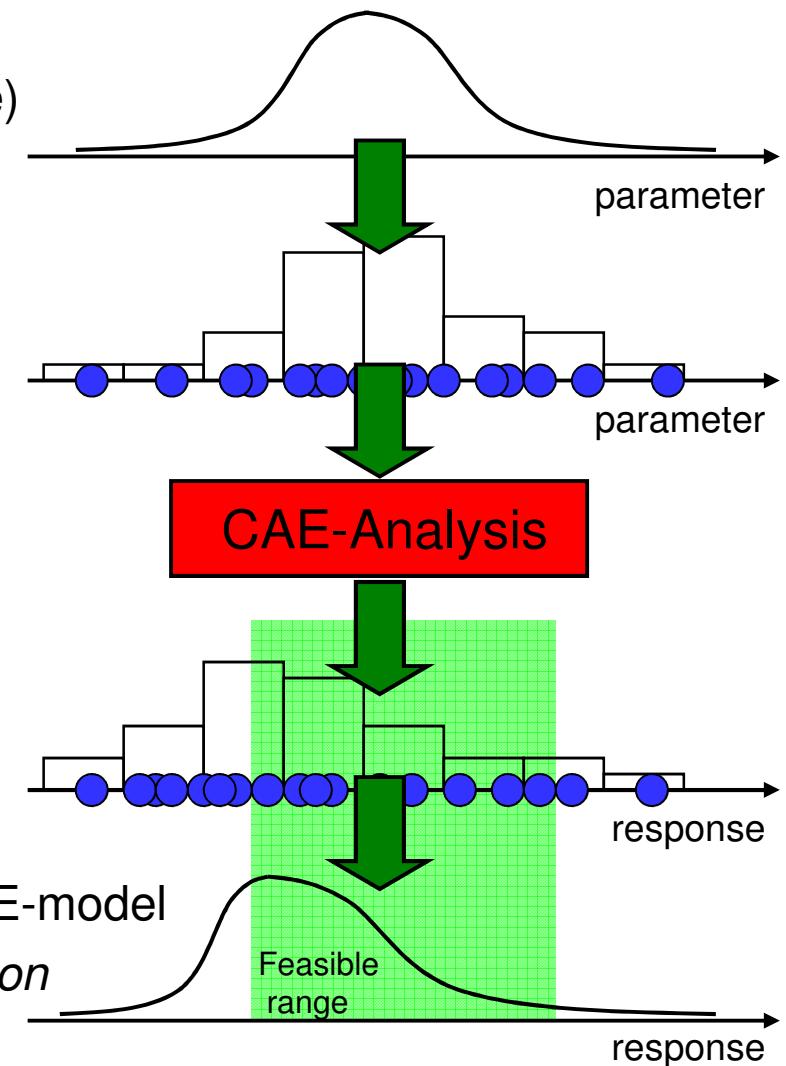
- Correlation Analysis
 - ANOVA - Meta-Model based
 - Stochastic Contributions – Meta-Model based

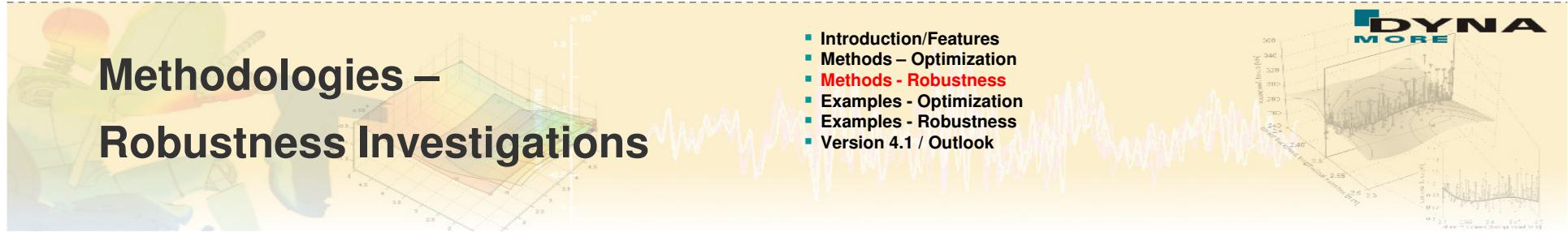




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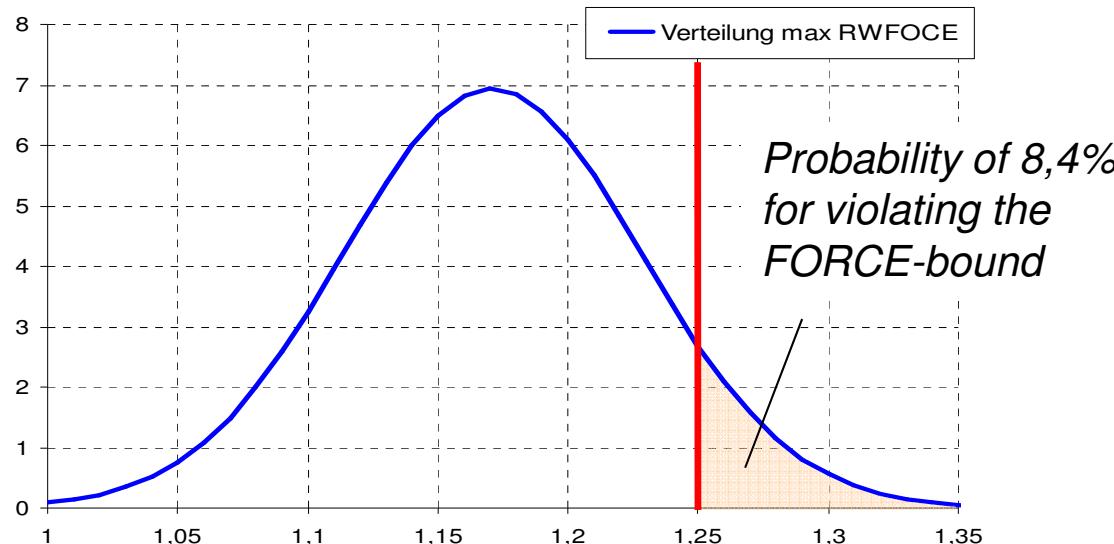




Methodologies – Robustness Investigations

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)*



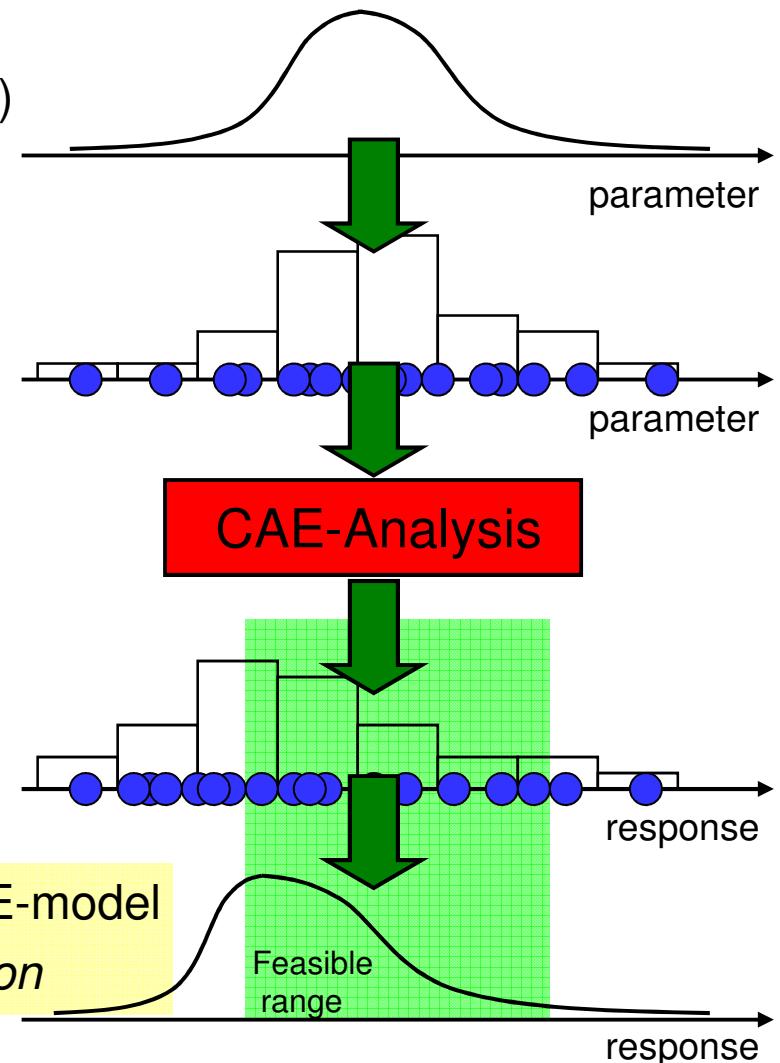
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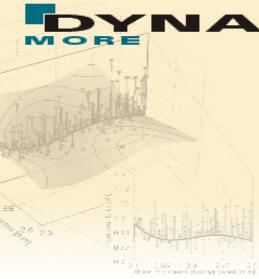
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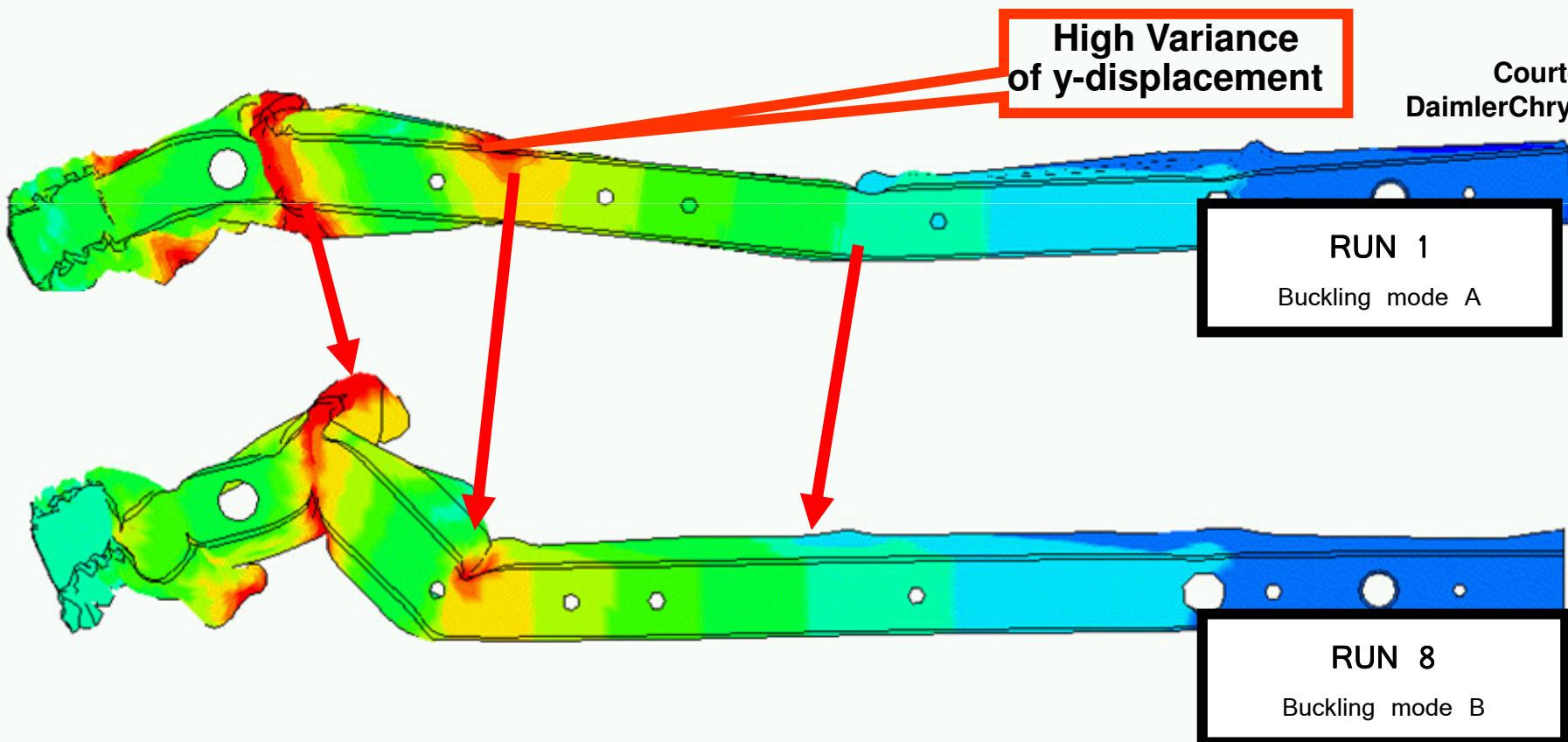
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Visualization of Statistical Quantities on FE-model

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





Example I - Optimization

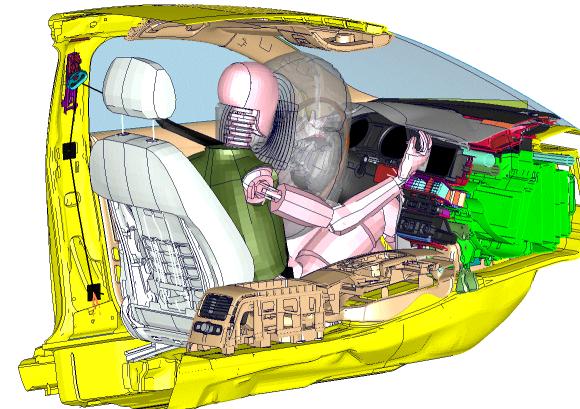
Optimization of an Adaptive Restraint System



- 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

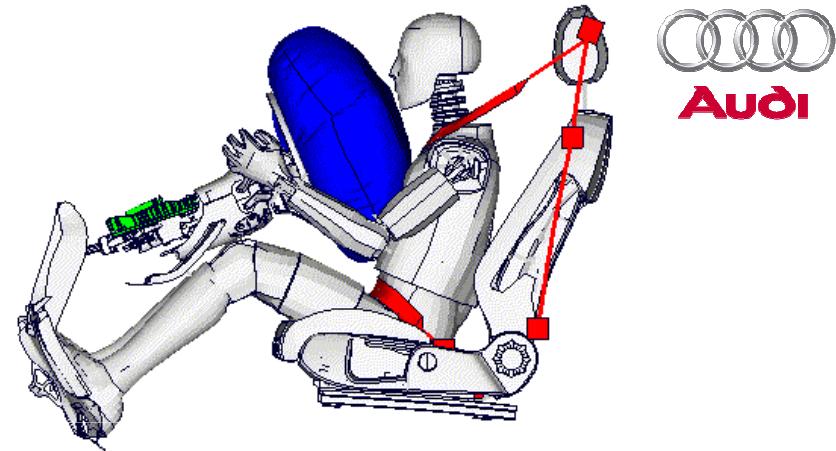
■ Constraints < 80% of regulation requirements

■ Head Injury Coefficient (15ms)

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

■ Femur Forces (left/right)

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

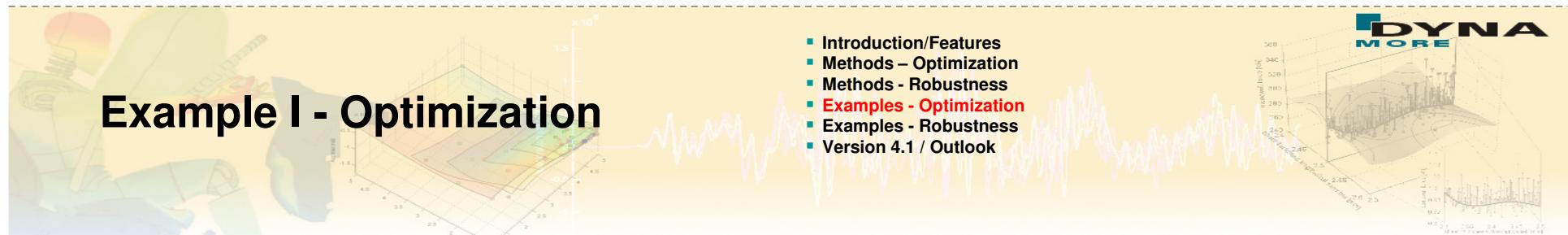


■ Thorax Intrusion

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

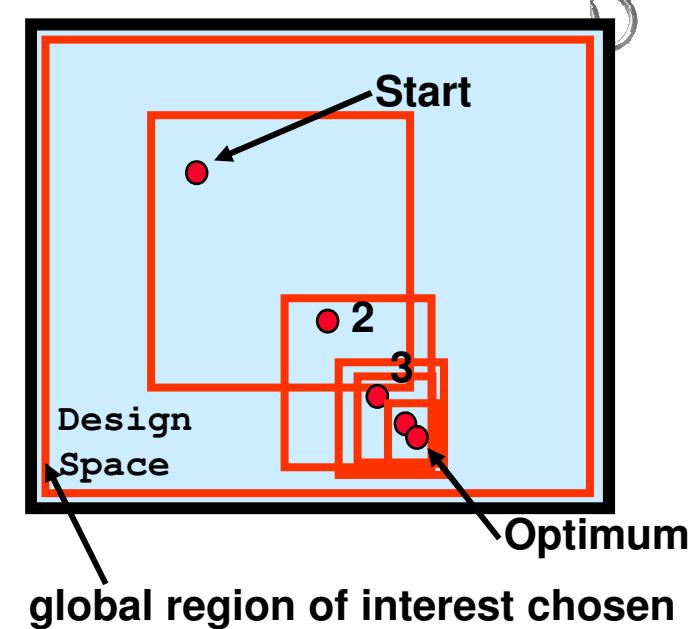
■ Thorax Acceleration

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



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*



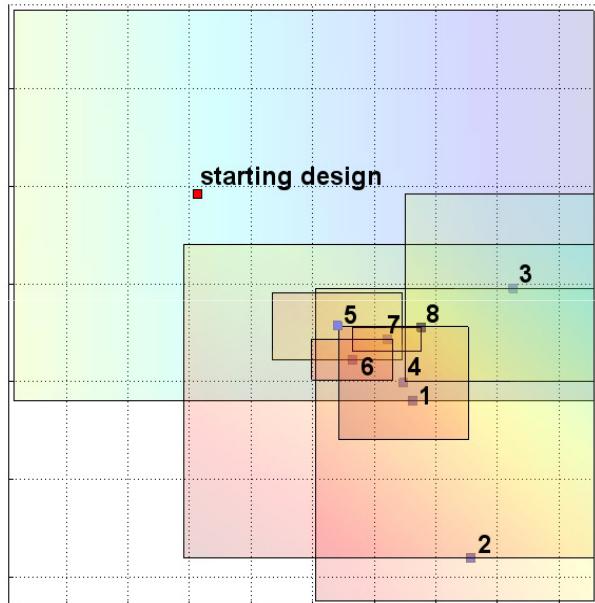


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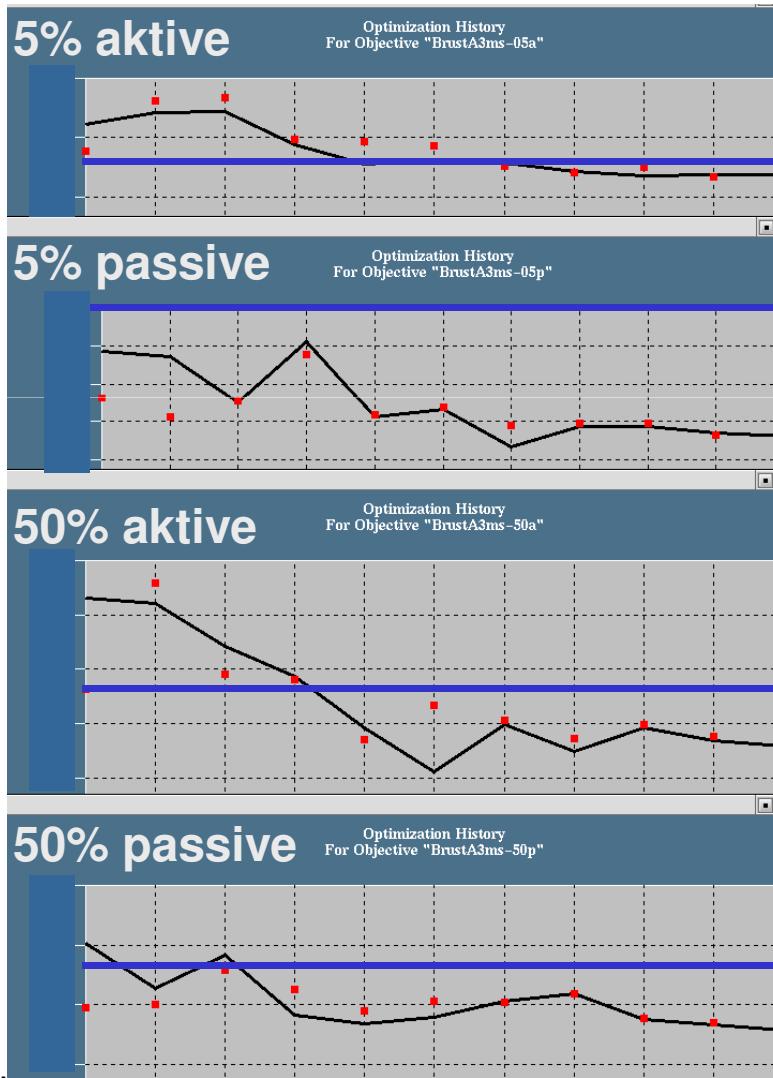
DYNA
MORE

Optimization Progress



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

History of Thorax Acceleration





Design Exploring with D-SPEX

plot type: 3D

Parameter control

name	value
FAB_VENT	315
SBA_VENT	3.78
FAB_ADT1_05a	35
X GUR_FOR1	3
Y GUR_ENDE05a	30
FAB_ADT1_05p	35
FAB_ADT1_50a	35
GUR_ENDE50a	30
FAB_ADT1_50p	35

variable and response selection

slider controls for interactive browsing

Metamodel Plotting

transparency: iteration: #1

checkboxes: plot contour, center on opt, draw subreg, zoom sliders, show all prev

checkbox: show optimum on response surface

Figure 2: Plot Window #1

Trigger Time Seatbelt and Force Limit vs. Thorax Acceleration



Parameter Identification of Plastic Material

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

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

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

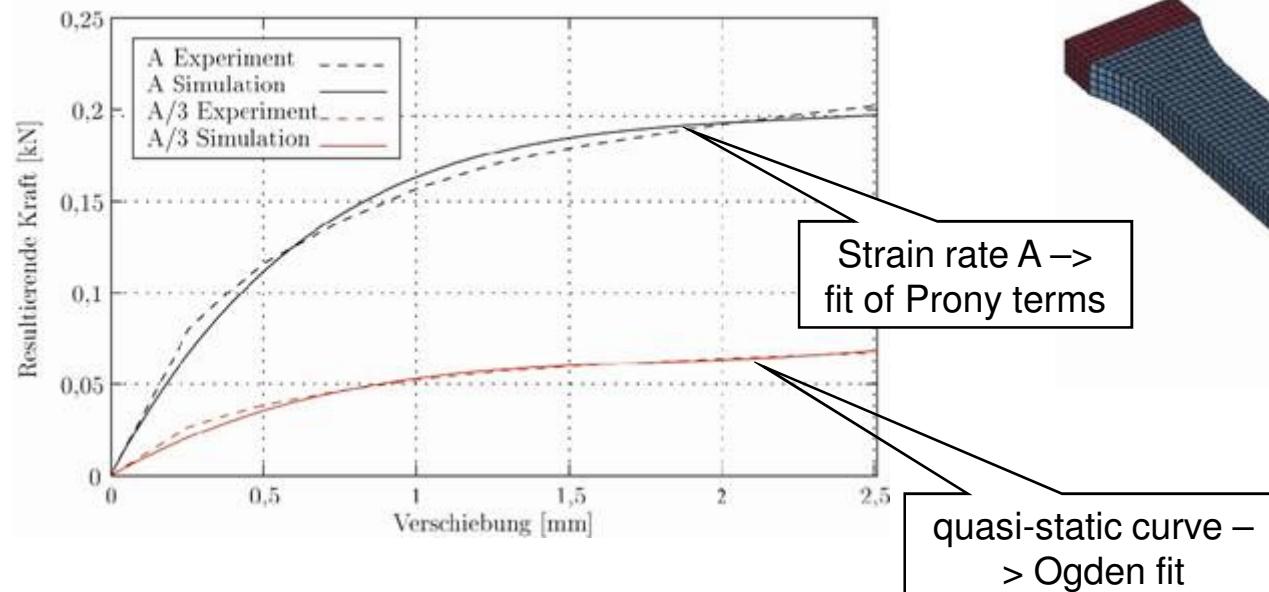
$$g(t) = \sum_{m=1}^N G_m e^{-\beta_m t} \quad ; \quad N=1, 2, 3, 4, 5, 6 \quad ; \quad \sigma_{ij} = \int_0^t g_{ijkl}(t-\tau) \frac{\partial \epsilon_{kl}}{\partial \tau} d\tau$$

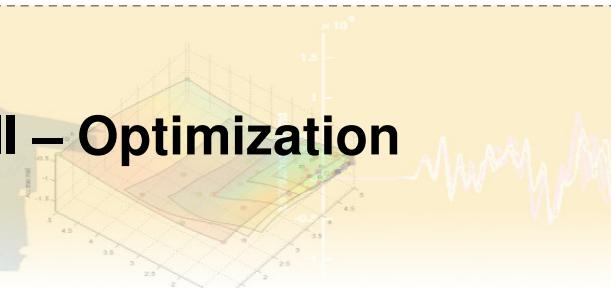


Parameter Identification of Plastic Material

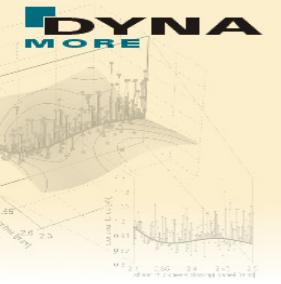
- Minimize the distance between experimental curve and simulation curve
- Least-Squares Objective Function

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





- Introduction/Features
- Methods – Optimization
- Methods - Robustness
- Examples - Optimization
- Examples - Robustness
- Version 4.1 / Outlook



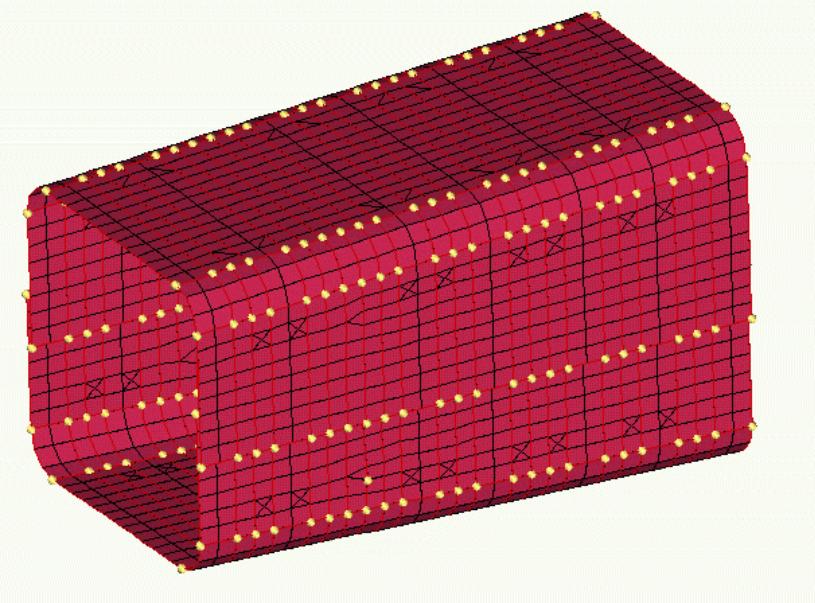
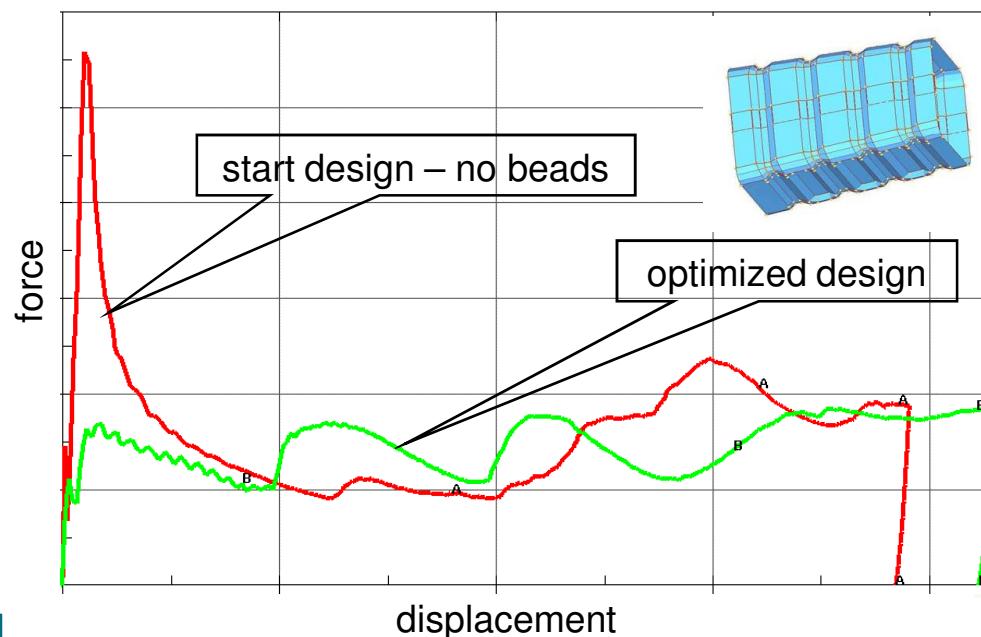
Example III – Optimization

Shape Optimization of a Crash Box

■ Scope of optimization:

- *minimize the maximum crash force*
- *steady-going force progression*

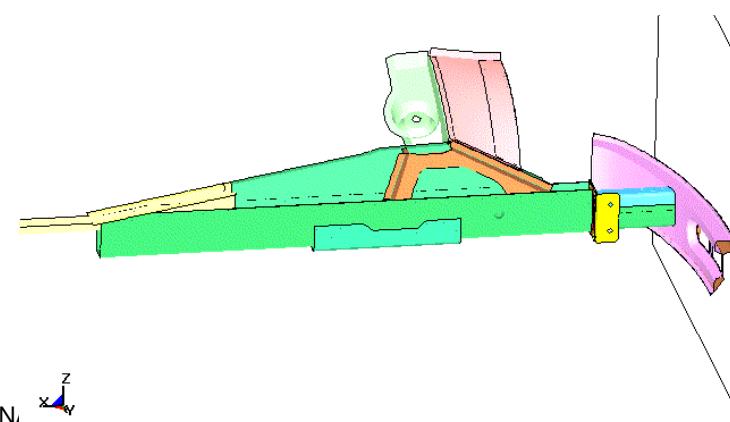
■ Shape variation by using Hypermorph and LS-OPT (20 design variables)





Robustness Investigations – Monte Carlo Analysis

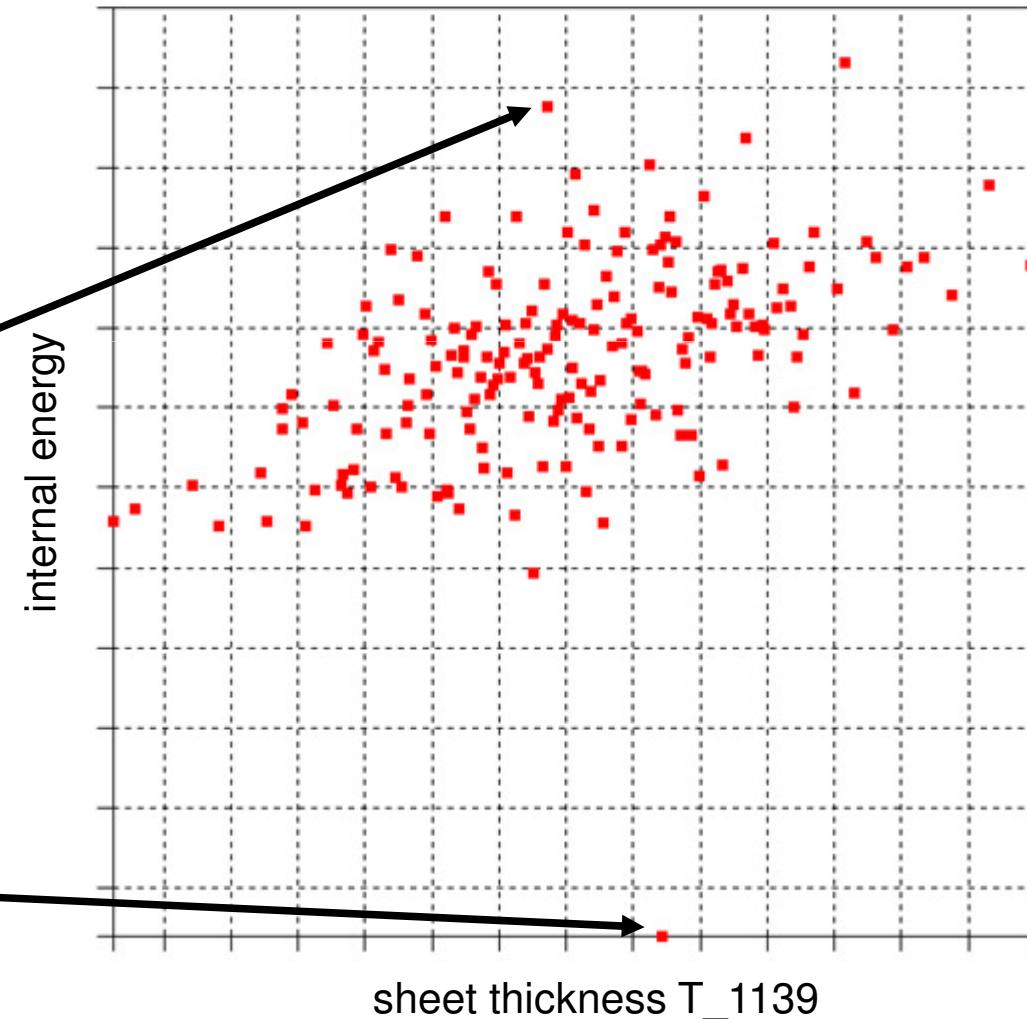
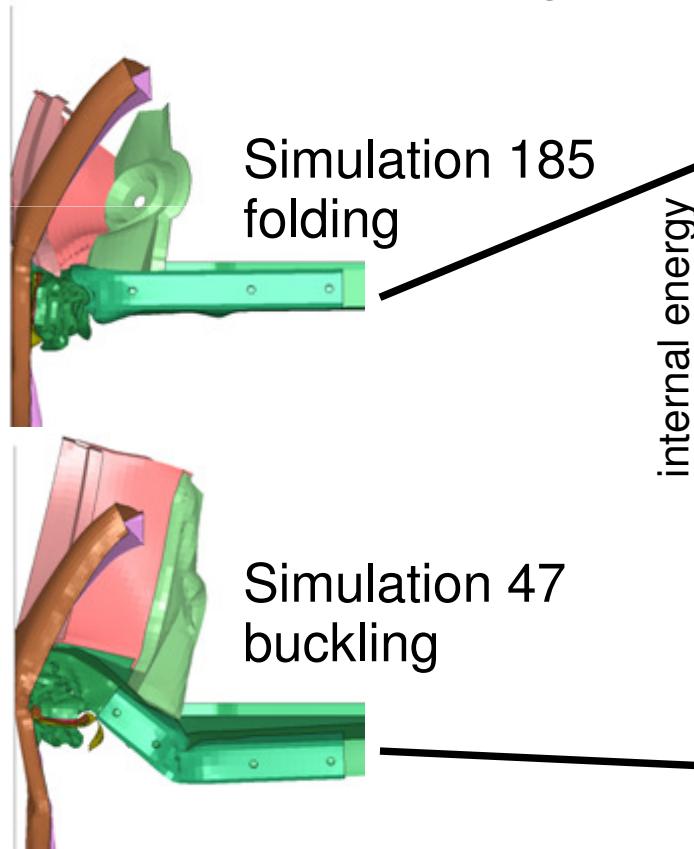
- Variation of sheet thicknesses and yield stress of significant parts in order to consider uncertainties
- Normal distribution is assumed
 - *T_1134 (Longitudinal Member)* *mean = 2.5mm; $\sigma = 0.05mm$*
 - *T_1139 (Closing Panel)* *mean = 2.4mm; $\sigma = 0.05mm$*
 - *T_1210 (Absorbing Box)* *mean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





Tradeoff Plot

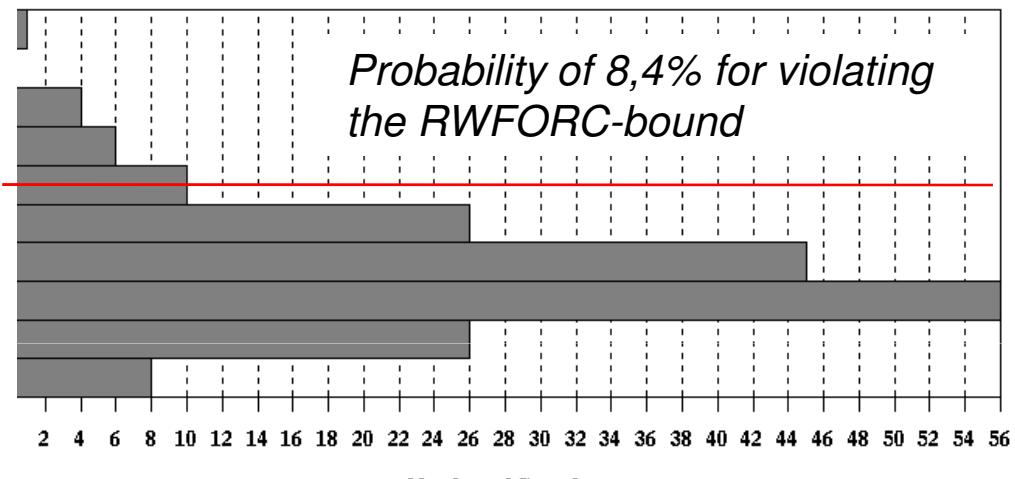
- Monte Carlo Simulation
- Identification of Clustering





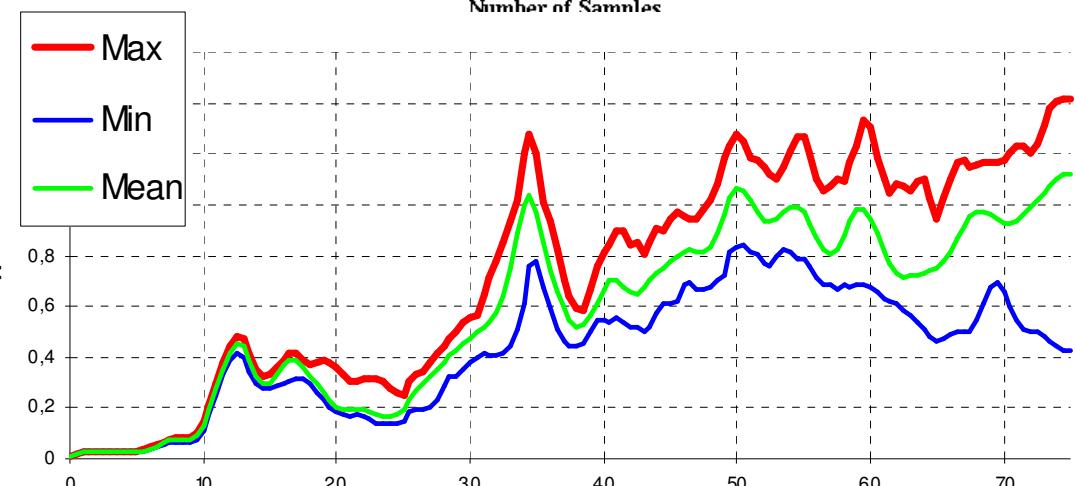
Reliability Analysis

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



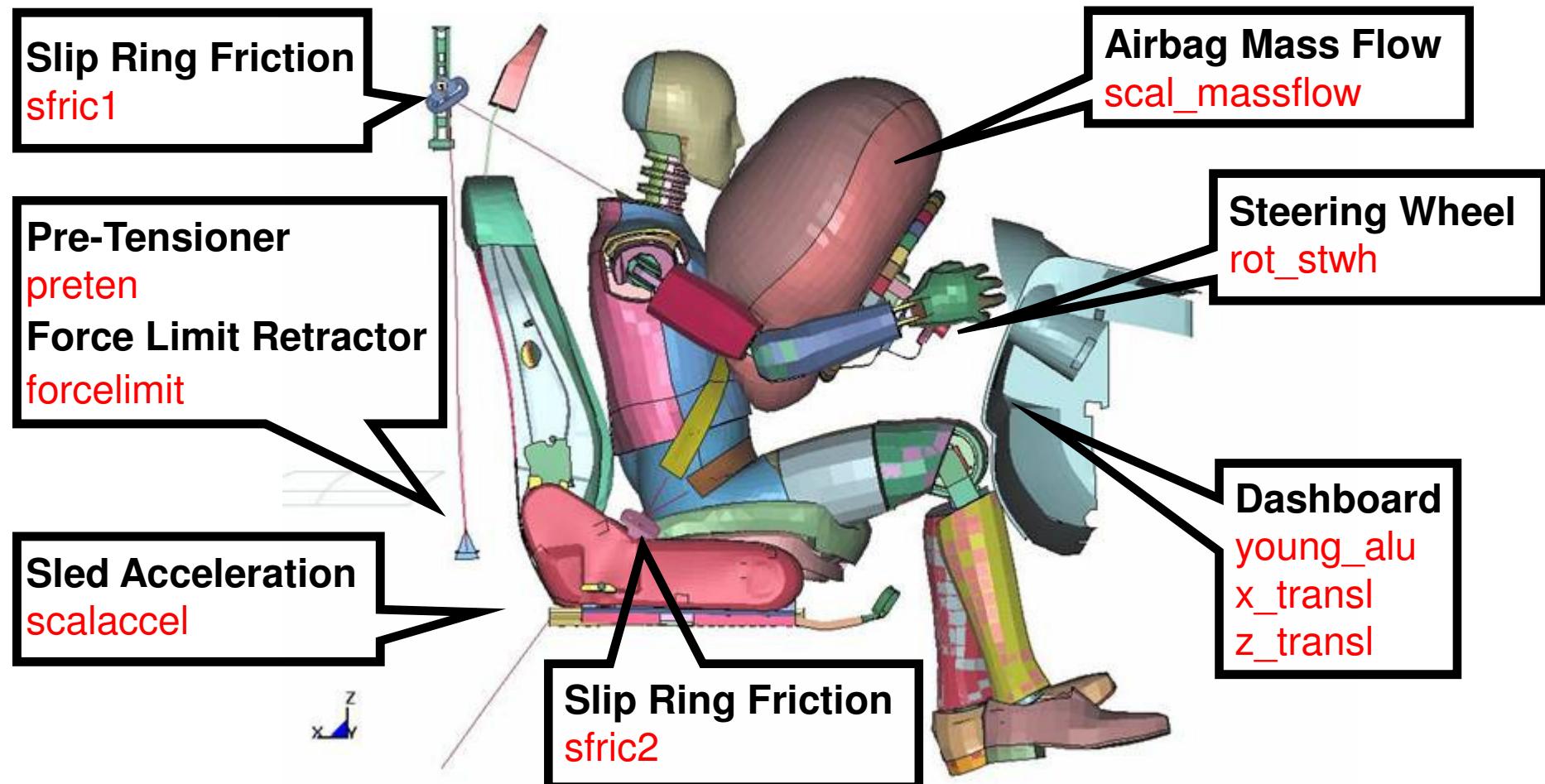
Min-Max Curves

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





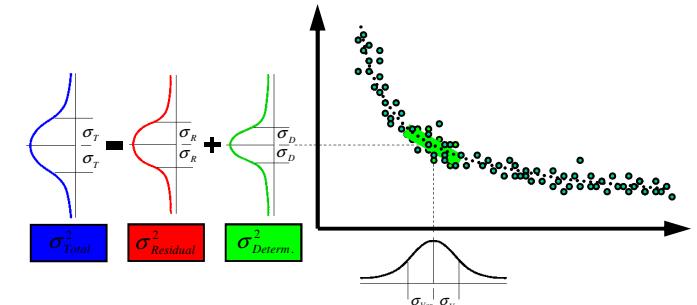
Design Variables - Uncertainties in Test Set-Up





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

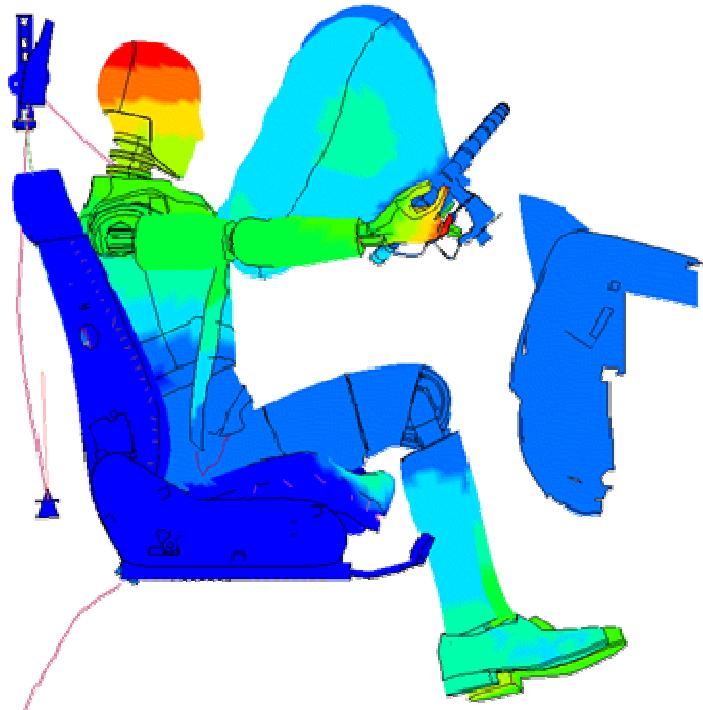
Residual space

Total Variation

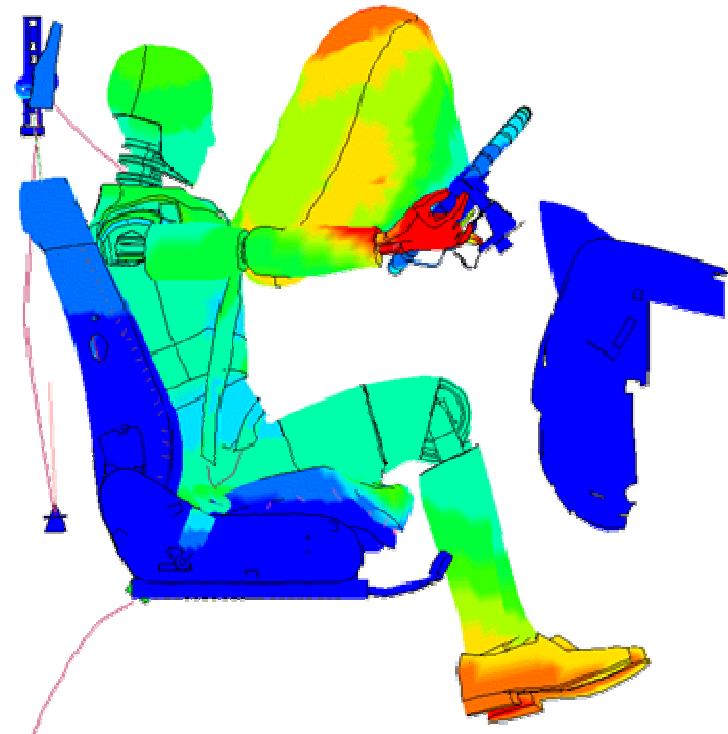


Standard deviation of x-displacements of each node (120 runs)

(a) Deterministic (Meta-Model)



(b) Residual (Outliers)



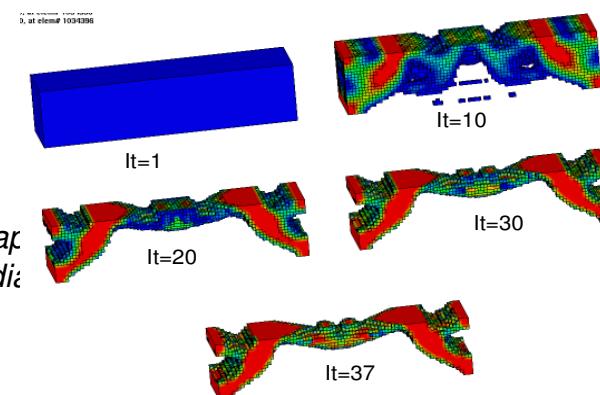


→ Outlook – Version 4.1

■ LS-OPT/Topology (available end 2009)

- *Nonlinear topology optimization*
- *LS-DYNA based*
- *Multiple load cases*
- *Linear as well as non-linear*
- *Design part selection*
- ***Methodology: Hybrid Cellular Automata***

Ref.: *Hybrid cellular automata with local control rules: a new approach*
 Quevedo W., Patel N., Renaud J. (University Notre-Dame, Indiana)
Structural and Multidisciplinary Optimization, 2005, Brazil





Outlook – Version 4.1

- Introduction/Features
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→ Outlook – Version 4.1

■ Generic File extractor

■ *Extraction of values from any ASCII input file*

■ Correlated Input Variables for Stochastic Investigations

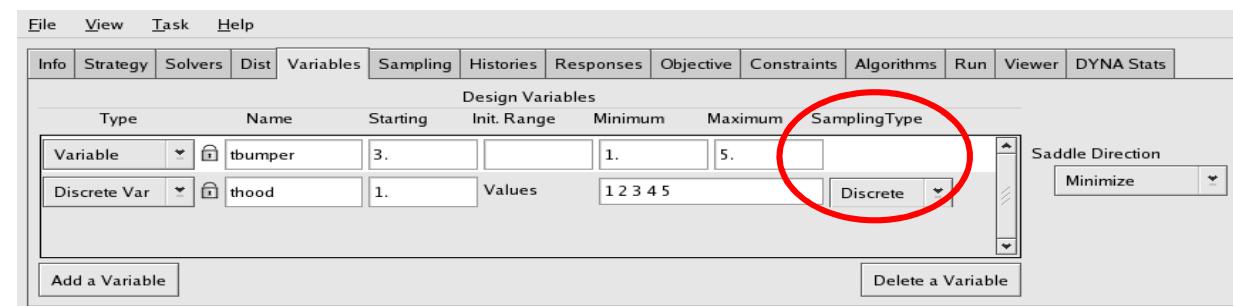
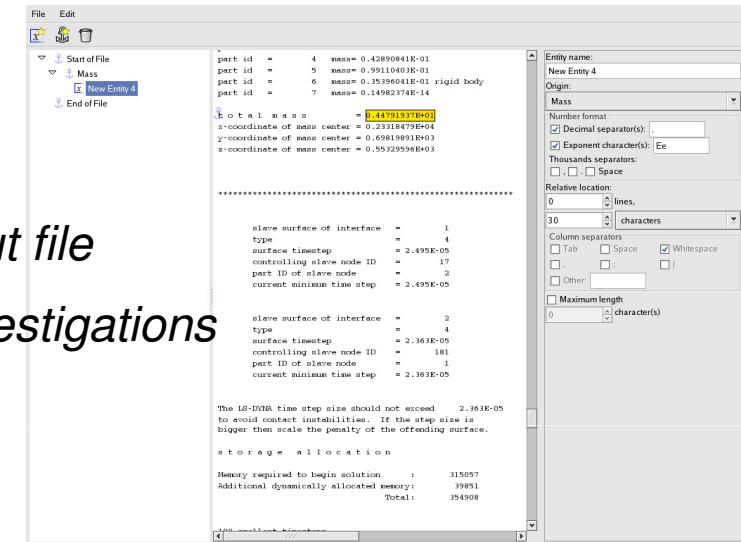
■ Additional injury criteria (DYNA extraction)

■ *IIHS, neck/tibia indices,...*

■ Full Factorial Discrete

■ *Schedule all combinations of discrete variables*

■ Discrete sampling on a variable basis





→ Outlook – Version 4.1

- Improved Space Filling algorithm
 - *Greater accuracy: more boundary points*
- Frequency/Mode Tracking
 - Available for NASTRAN
 - MAC and orthogonality criterion
- Global Sensitivity Analysis with Sobol Indices (GSA)
- Pareto Optimal Solutions
 - *Self-Organizing Maps (Ver. 4.1)*
- Many new Features within the “viewer”
 - *e.g. history curves visualization*

$$\max_i [(\boldsymbol{\varphi}_r^T \mathbf{M}_r) \boldsymbol{\varphi}_i]$$

