Begrüßung und Einführung in LS-OPT

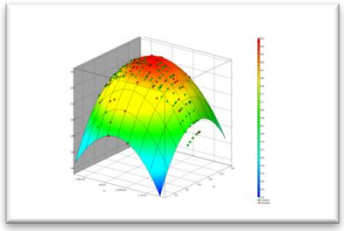
Heiner Müllerschön
DYNAmore GmbH

Stuttgart, 21. Mai 2012

Agenda

Kurzportrait

Übersicht Optimierungslösungen



LS-OPT

FuE-Projekte

DYNAmore GmbH - Einleitung

- ~75 Mitarbeiter insgesamt
- Zentrale in Stuttgart-Vaihingen
- Niederlassungen
  - Ingolstadt
  - Dresden
  - Langlingen (Wolfsburg)
  - Fürstenwalde (Berlin)
- Vor-Ort-Büros
  - Sindelfingen
  - Untertürkheim
  - Weissach
  - Ingolstadt
- Tochterfirmen
  - DYNAmore Nordic AB (Linjöping, Schweden)
  - DYNAmore Swiss GmbH (Zürich)

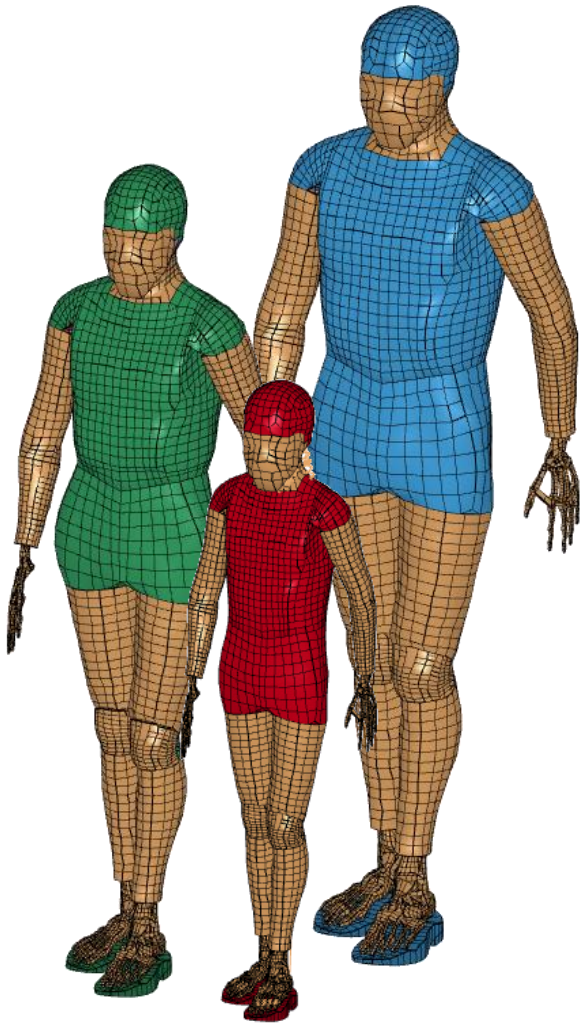
Stuttgart [Zentrale]

Ingolstadt

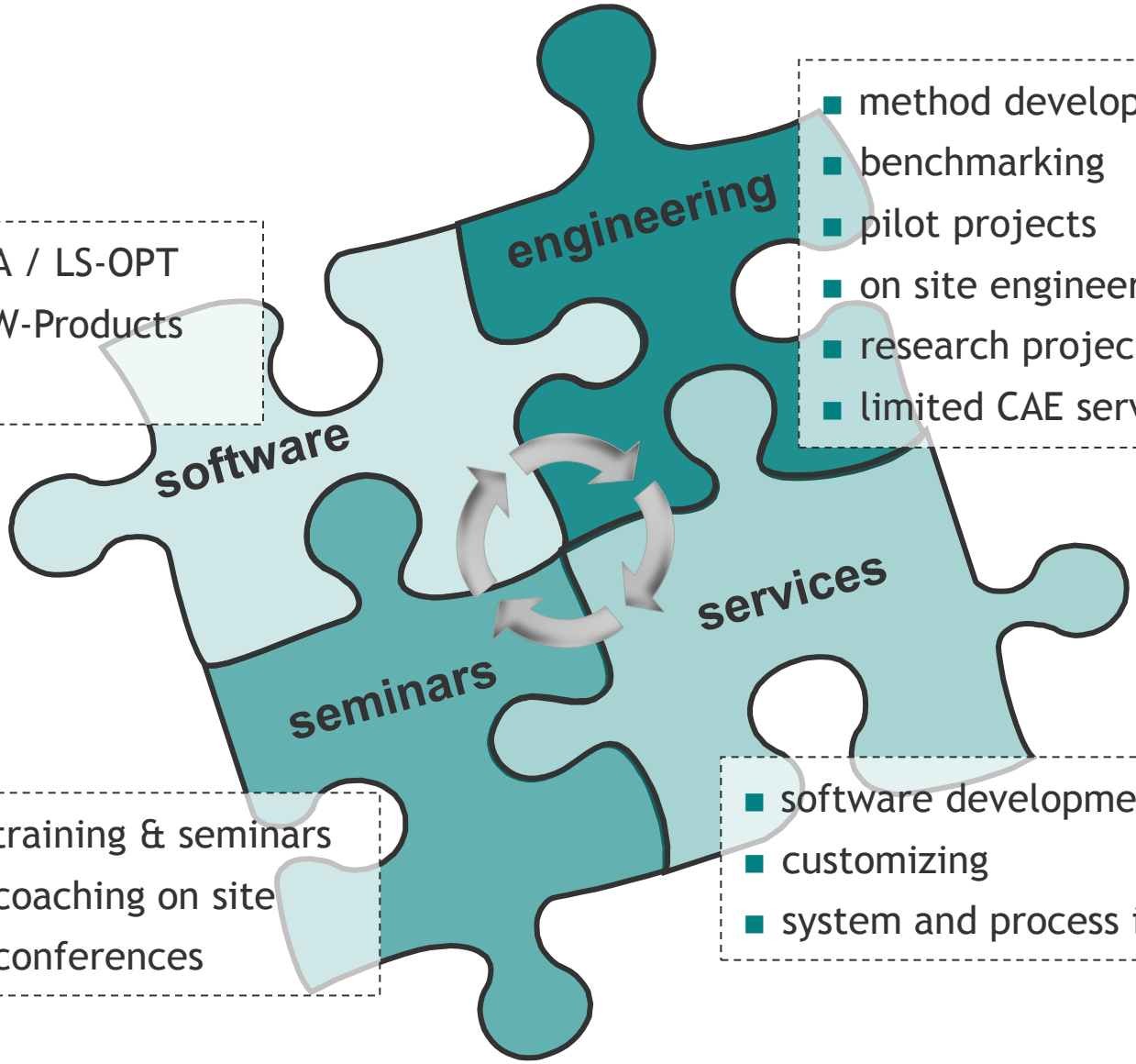
Dresden

DYNAmore Tätigkeitsgebiete

- Kerngeschäft
  - Nichtlineare FEM-Lösungen, insbesondere Kurzzeitdynamik
  - IT-Lösungen für SDM und CAE/CAT-Prozesse
- Softwarevertrieb/Support /Schulungen
  - Produkte: LS-DYNA, LS-OPT, LS-PrePost, DYNAform, Primer, FE-Modelle
  - Alle OEMs in D und FIAT in I sind Kunden
  - Distributionsgebiet Europa (ohne F und GB)
- Softwareentwicklung
  - Finite Elemente Softwareentwicklung
    - Materialgesetze
    - Elementtechnologien
    - Kundenspezifische Erweiterungen
  - Optimierungssoftware
  - Systemintegration, Prozess- und Datenmanagement



DYNAmore Tätigkeitsgebiete



- method development
- benchmarking
- pilot projects
- on site engineering
- research projects
- limited CAE services

- LS-DYNA / LS-OPT
- more SW-Products
- Support

- training & seminars
- coaching on site
- conferences

- software development
- customizing
- system and process integration

LS-DYNA / LS-OPT / LS-PrePost

- since 1986 cooperation between Dr. Hallquist (LSTC) and Prof. Dr. Schweizerhof (DYNAmore)
- core development of products at LSTC, 10 developers at DYNAmore

LSTC
Livermore Software Technology Corp.

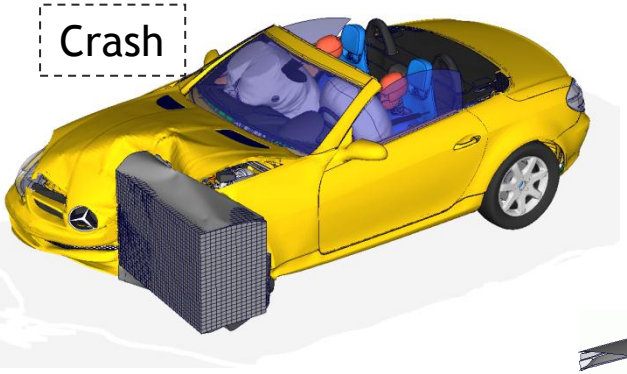
-founded in 1987 by Dr. John Hallquist
-located in Livermore, California
-more than 600 customers
-worldwide distribution

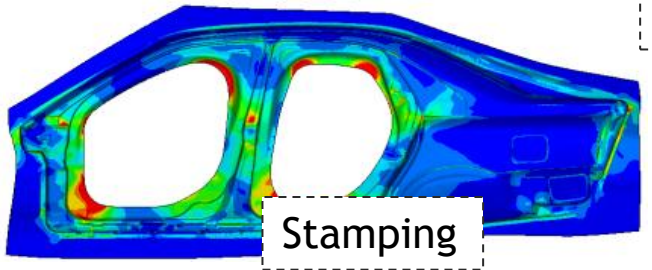
DYNA MORE

-LS-DYNA master distributor
-related software products
-support, seminars, projects …
-further development and customization in collaboration with LSTC

LS-DYNA Applications

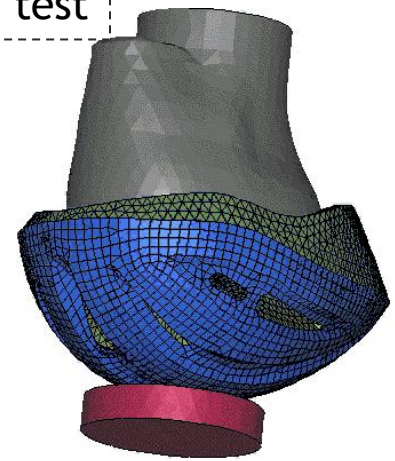
Crash

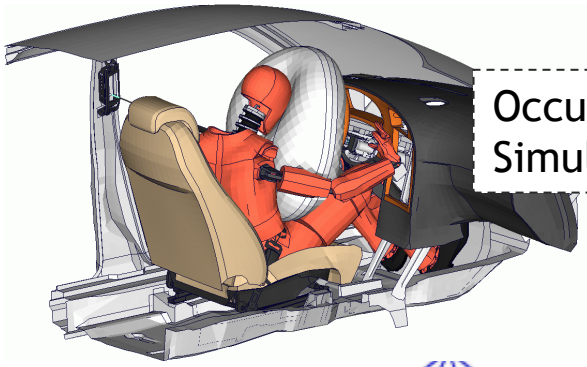




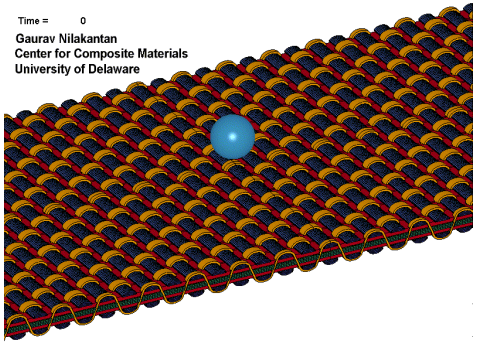
Stamping

Drop test

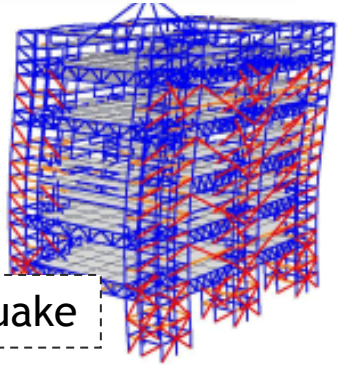




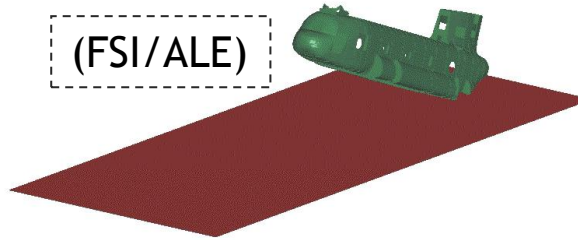
Occupant Simulation



Defense



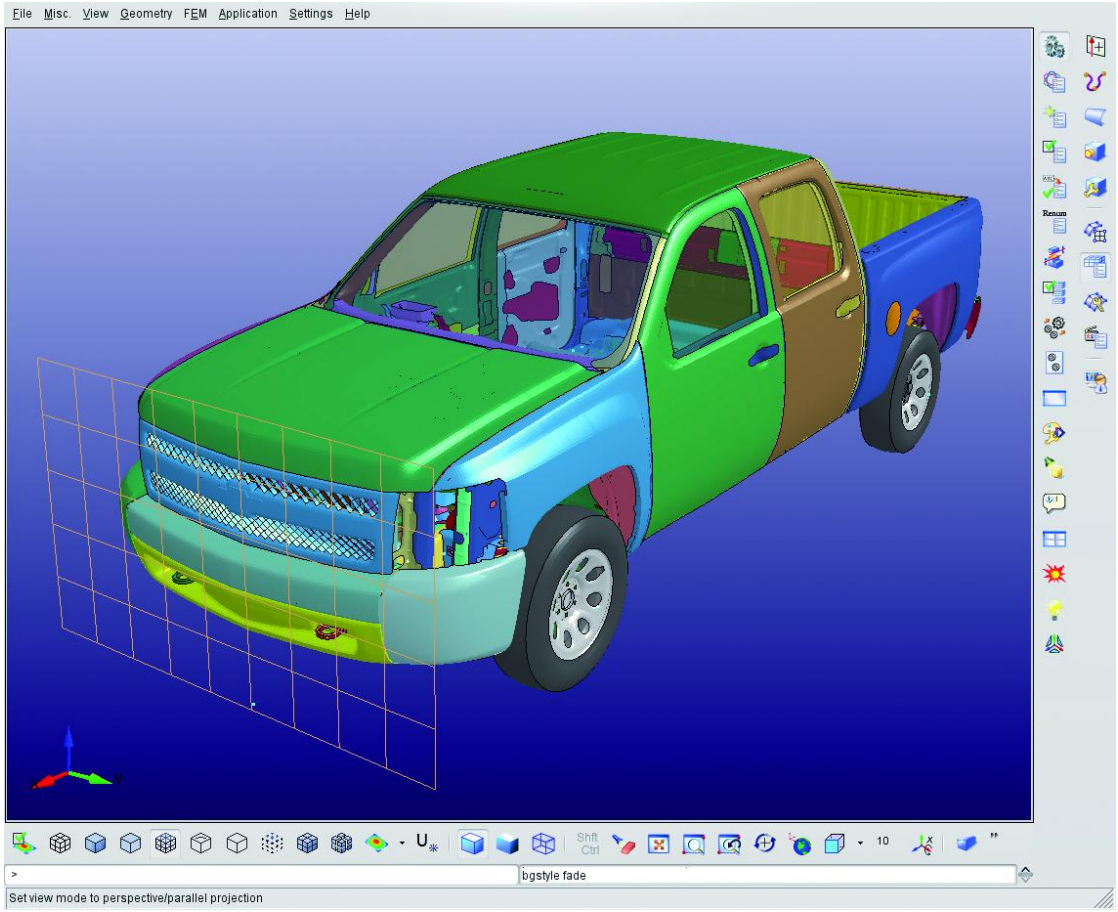
Earthquake



(FSI/ALE)

LS-PrePost – Allgemeiner Pre- und Postprozessor

- An advanced Post-Processor with Pre-Processor Capabilities



DYNAmore Industriekunden (Auszug)

DYNA MORE

DYNAmore Hochschulkunden (Auszug)

- **DLR-Deutsches Zentrum für Luft- und Raumfahrt**
  - Institut für Bauweisen- und Konstruktions-forschung
- **Fachhochschule Aachen**
  - Angewandte Mathematik
  - FB Luft- und Raumfahrttechnik
- **Fachhochschule Aalen**
  - CAD/CAM Zentrum
- **Fachhochschule Amberg-Weiden**
  - FB Wirtschaftsingenieurwesen
- **Fachhochschule Giessen-Friedberg**
  - FB Energie- u. Wärmetechnik
- **Fachhochschule Ingolstadt**
  - FB Elektro- und Informationstechnik
- **Fachhochschule Lausitz**
  - FB Bauingenieurwesen
- **Fachhochschule Reutlingen**
- **Faserinstitut Bremen e.V. (FIBRE)**
  - Faserverbund Struktur- u. Verfahrensentwicklung
- **Fachhochschule für Technik und Wirtschaft Esslingen**
  - Labor Karosserie - Entwicklung & Versuch
  - FB Maschinenbau
- **Forschungsgesellschaft Kraftfahrwesen mbH Aachen**
- **Forschungszentrum Jülich**
  - Zentralinstitut für angewandte Mathematik
- **Fraunhofer Institut**
  - Ernst-Mach-Institut, Freiburg
  - Institut für Werkstoffmechanik, Freiburg
  - SCAI, St. Augustin
  - Werkzeugmaschinen und Umformt., Chemnitz
- **Hochschule für Angewandte Wissenschaften Hamburg**
  - FB Fahrzeugtechnik und Flugzeugbau
- **Montan Universität Leoben**
  - Institut für Werkstoffkunde
- **Technische Universität Berlin**
  - FG Kraftfahrzeuge
  - FG Schienenfahrzeuge
  - Institut für Luft- und Raumfahrt
- **Technische Universität Dresden**
  - Institut für Luft- und Raumfahrt
  - Lehrstuhl für Statik
  - Rechenzentrum
- **Technische Universität Graz**
  - Institut für Mechanik und Getriebelehre
- **Technische Universität Hamburg Harburg**
  - Schiffstechn. Konstruktion u. Berechnung
  - Rechenzentrum
  - FB Baustatik und Stahlbau
- **Universität Karlsruhe**
  - Institut für Mechanik
- **Universität der Bundeswehr Hamburg**
  - FB Maschinenbau
  - Institut für Mechanik
  - Institut für Werkstofftechnik
- **Universität des Saarlandes**
  - Lehrstuhl für Technische Mechanik
- **Universität Erlangen-Nürnberg**
  - Institut für Mechanik
- **Universität Hannover**
  - Institut für Baumechanik und Numerische Mechanik
- **RWTH Aachen**
  - Institut für Leichtbau
- **Technische Fachhochschule Berlin**
  - FB Verfahrens- und Umwelttechnik
- **Universität Kassel**
  - FB Maschinenbau
- **Institut für thermische Energietechnik**
  - Institut für Mechanik

Agenda

Kurzportrait

Übersicht Optimierungslösungen

LS-OPT

FuE-Projekte

Introduction Optimization

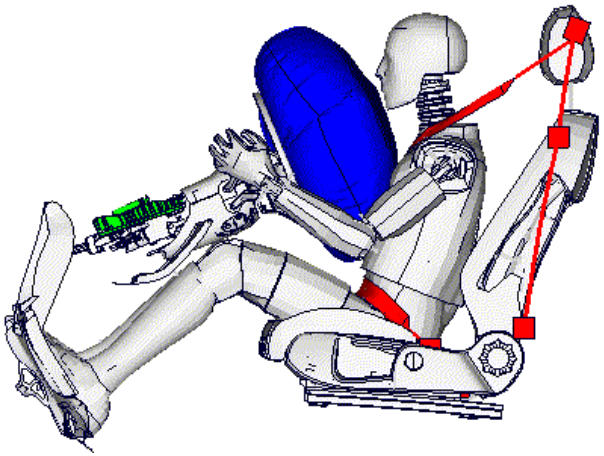
Non-Linear Optimization

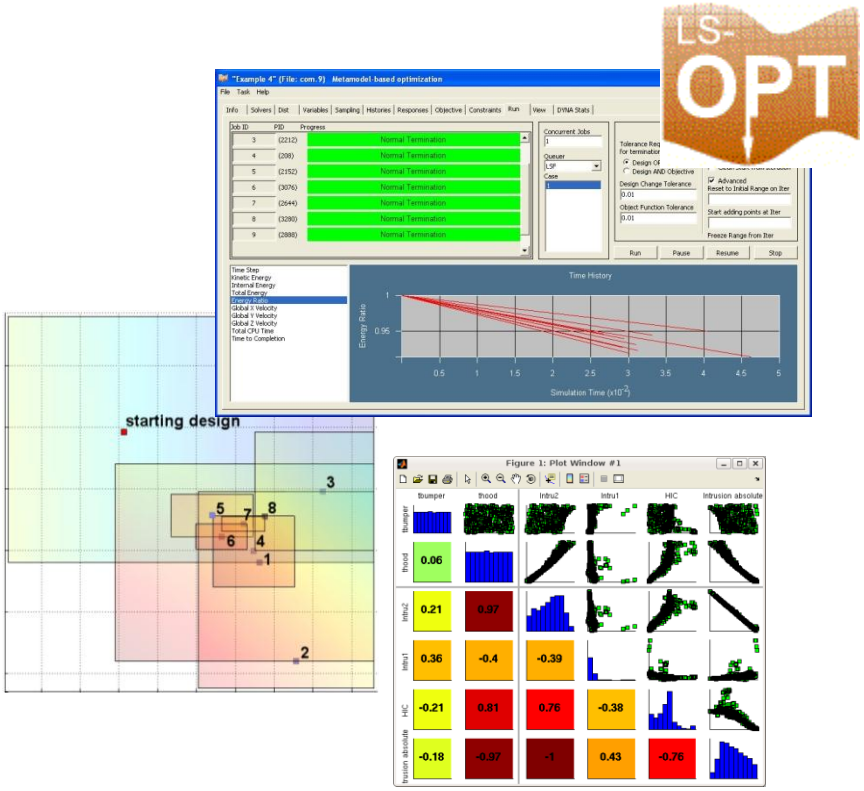
LS-OPT

Non-linear / Parametric

- Parameterization of input files
- Shape/Sizing Optimization
- Possible for general nonlinear

applications: Crash, Fluid Dynamics, Nonlinear Static/Dynamic

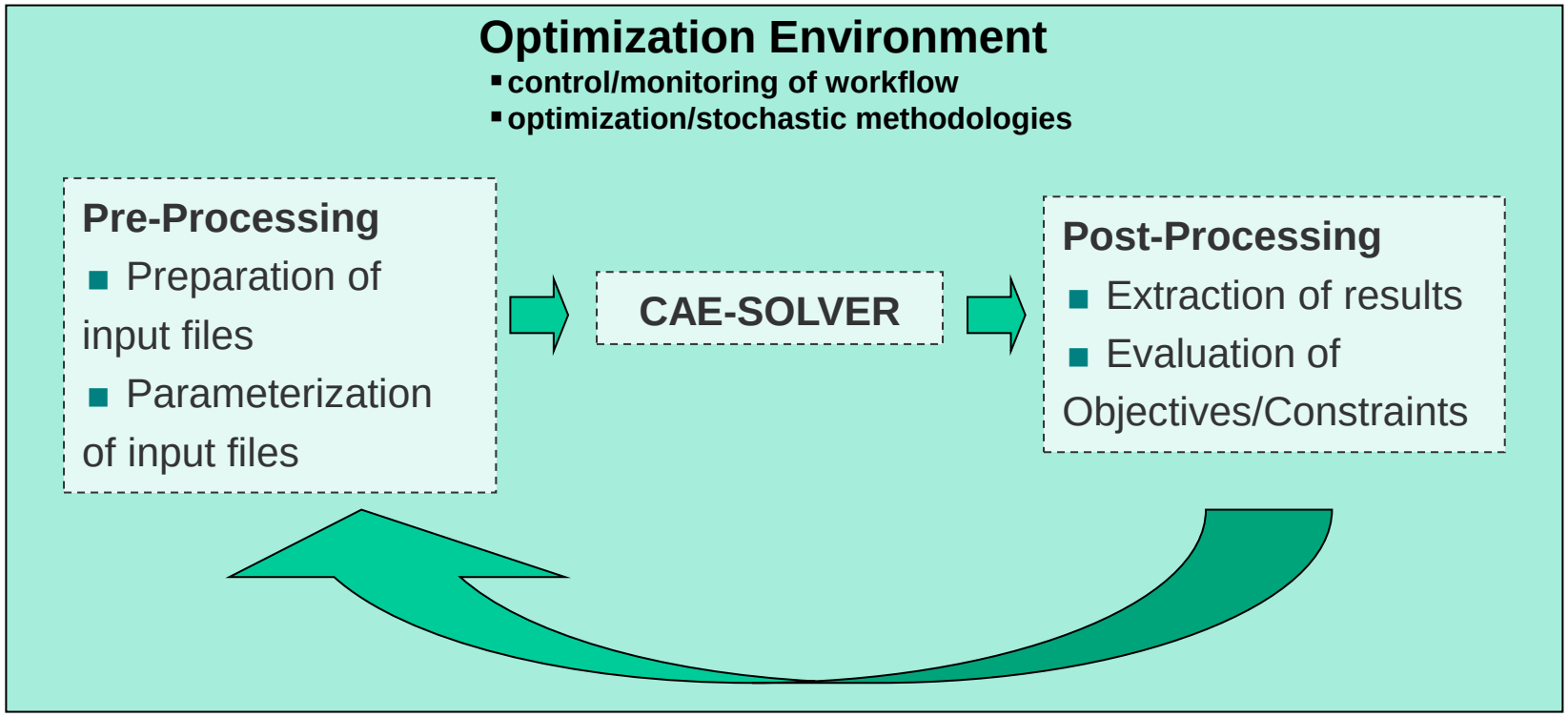




Introduction Optimization

Non-Linear Optimization

- Process Flow for Parametric Optimization - Simplified Representation



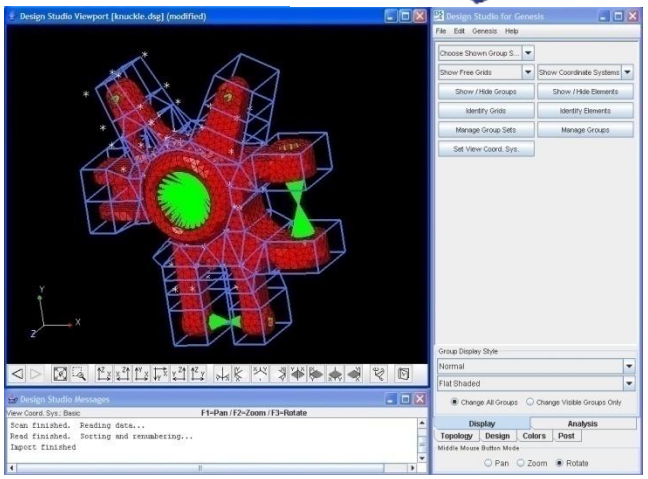
Introduction Optimization

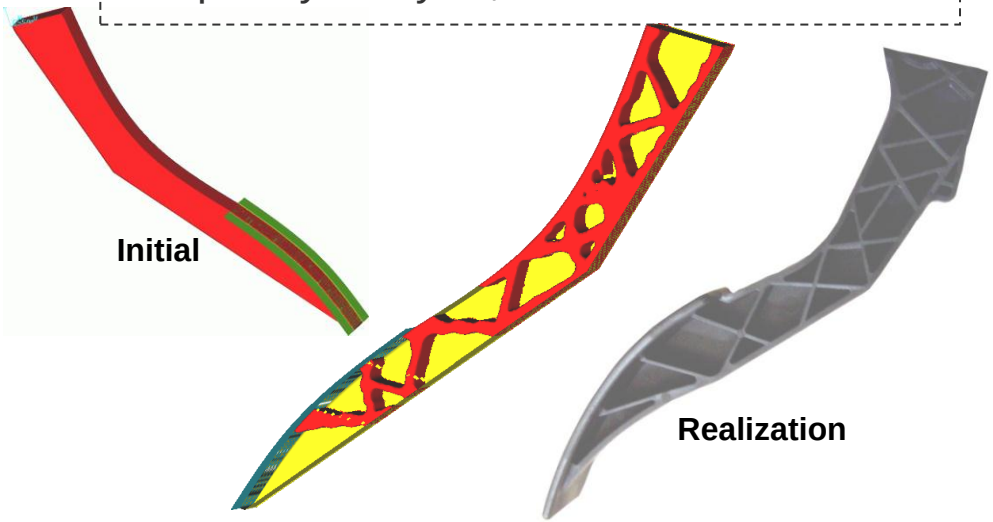
Linear Optimization

- Available Software Products: **Genesis,** Optistruct, Tosca…

Non-Parametric

- Topology / Topometry Optimization
- Usually Linear FE-Problems
- Gradient based solvers – many design variables > 1000000
- CAE-Applications: Static Loads, Frequency Analysis, NVH

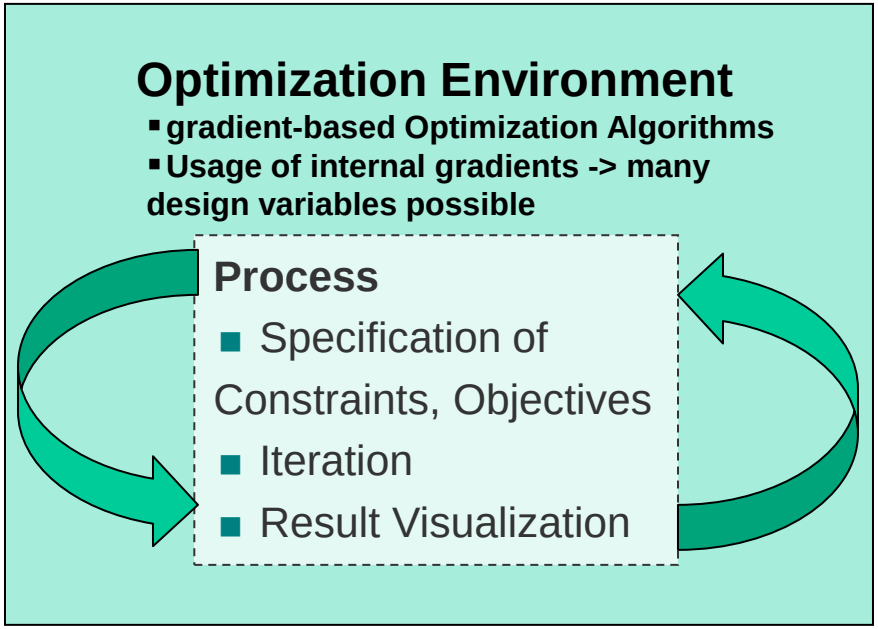


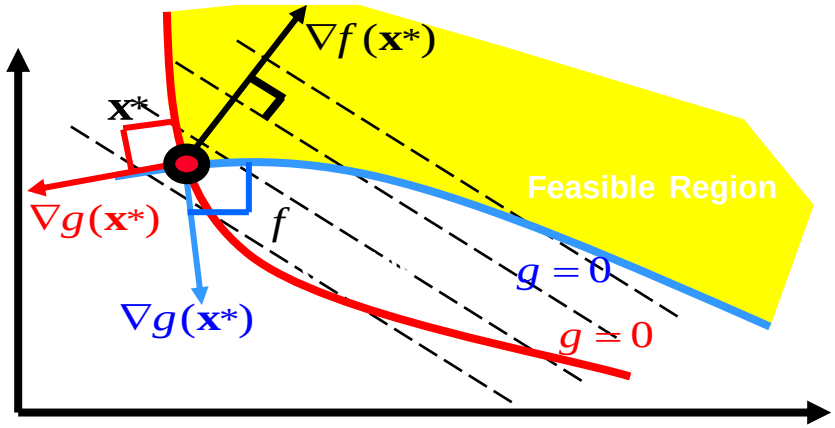


Introduction Optimization

Linear Optimization

- Usually Integrated FE-Solver

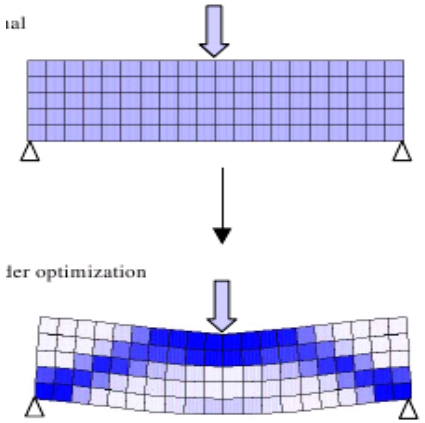




Introduction

Topology Optimization for Crash

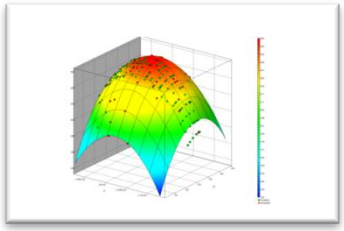
- For topology optimization each element is a design variable - can be switched on/off → many variables
  - *Can not be solved with LS-OPT (too many variables)*
  - *Can not be solved for crash with gradient based topology solvers like e.g. Genesis (strong non-linearities)*
- Two considerable approaches
  - *Equivalent Static Loads Method - ESLM Genesis / LS-DYNA*
  - *Hybrid Cellular Automata - HCA LS-TaSC*



Agenda

Kurzportrait

Übersicht Optimierungslösungen



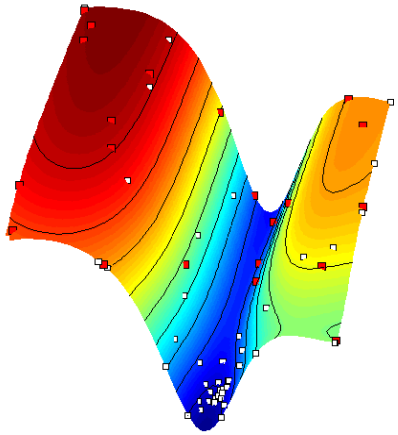
LS-OPT

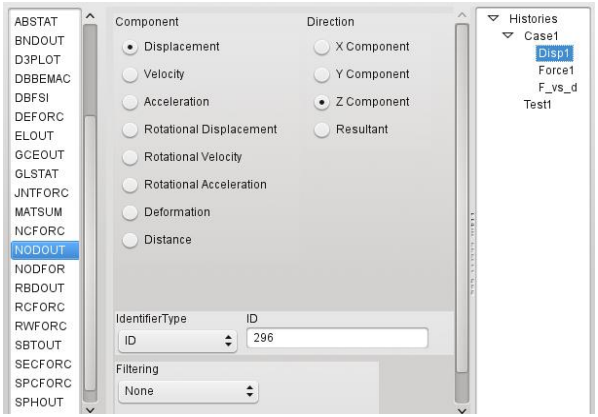
FuE-Projekte

LS-OPT – State of the Art Optimization Software

About LS-OPT

- LS-OPT can be linked to any simulation code – stand alone optimization software, but perfect suitable with LS-DYNA
- LS-OPT is available for Windows and Linux
- Current production version is LS-OPT 4.2 – Release of Version 5.0 is planned for middle of 2012
- 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
  - Mode Tracking LS-DYNA/Implicit
  - …

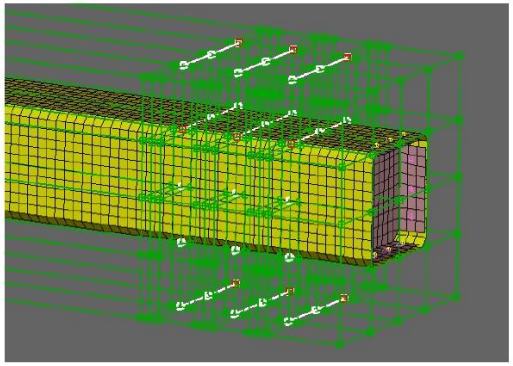


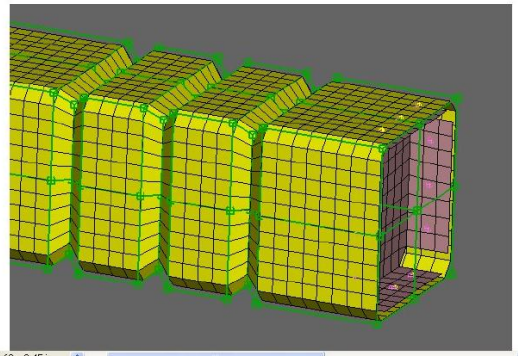


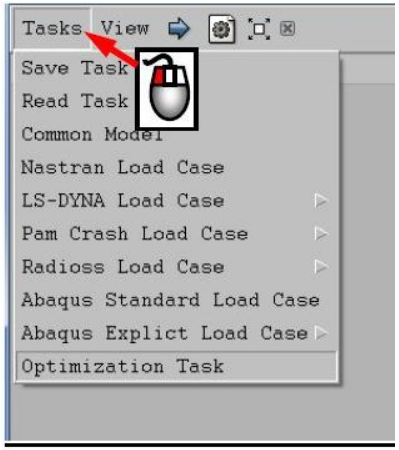
LS-OPT – State of the Art Optimization Software

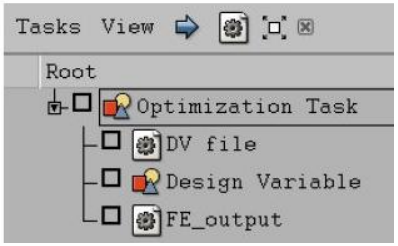
About LS-OPT

- Job Distribution - Interface to Queuing Systems
  - PBS, LSF, LoadLeveler, SLURM, AQS, etc.
- 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)





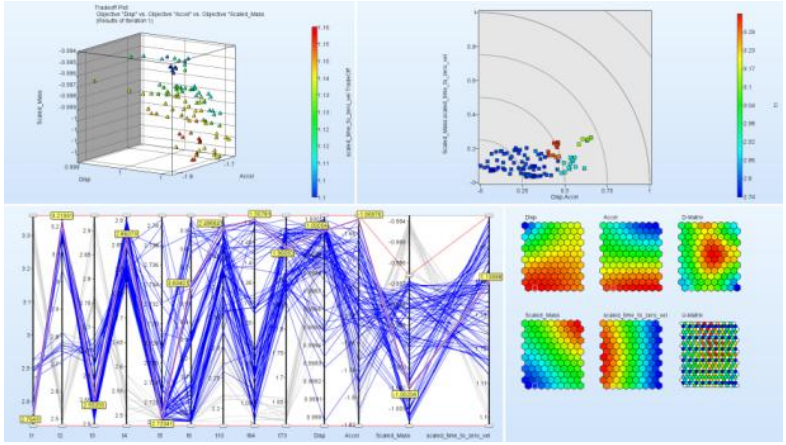


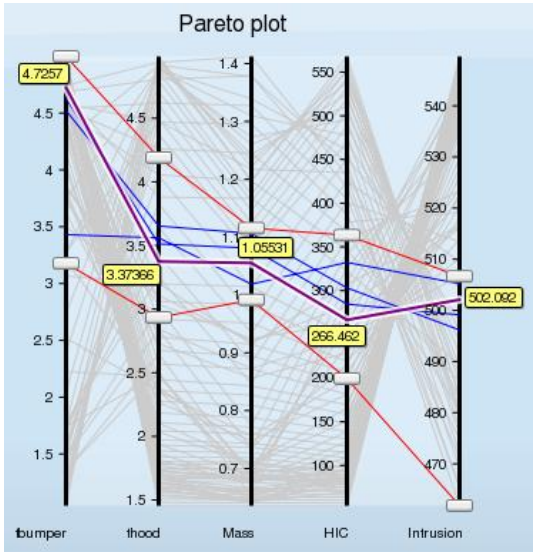


LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

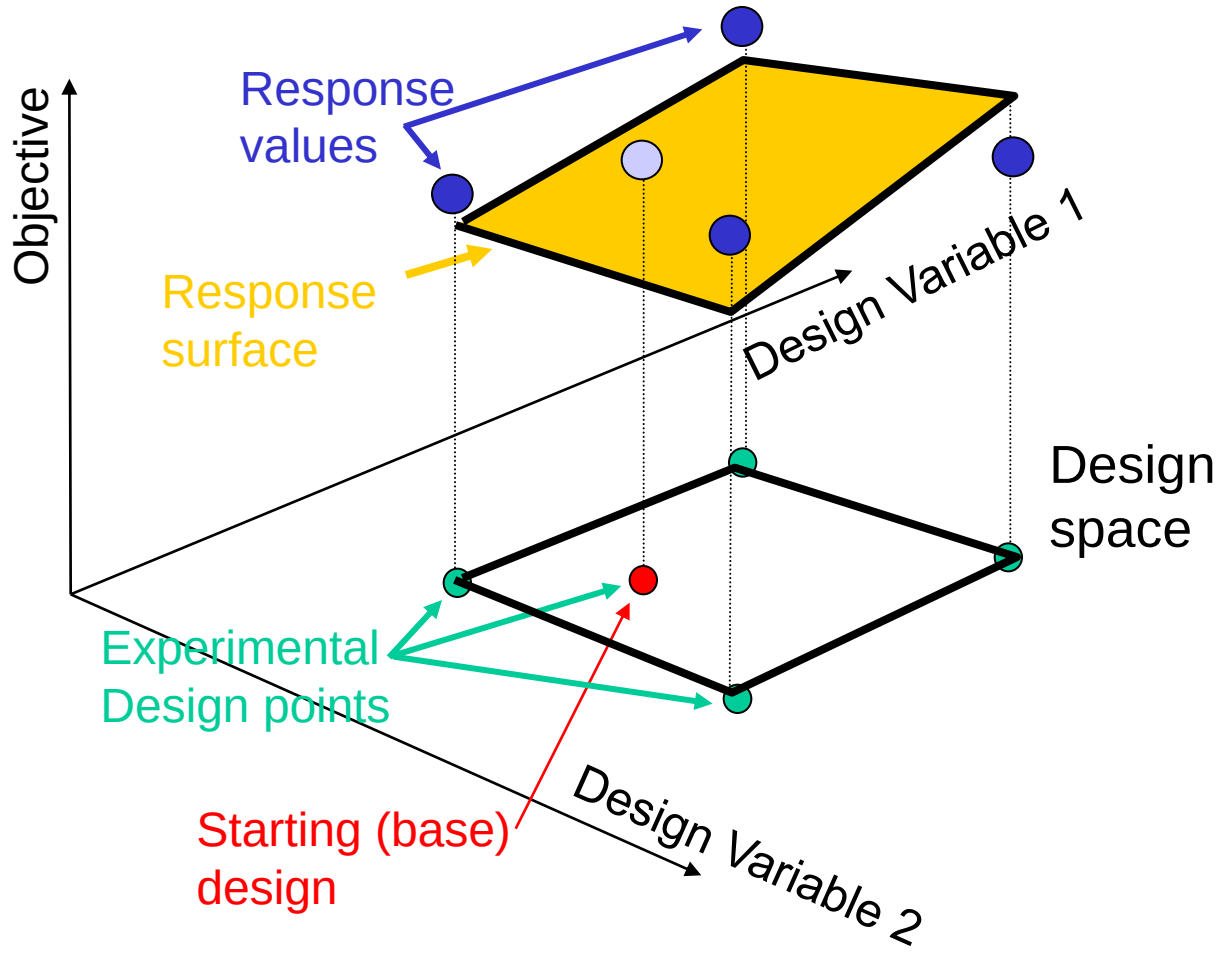
- Optimization
  - Size-/Shape optimization
  - Constraints
  - Mixed continuous/discrete variables
  - Multiple load cases (MDO)
  - Multi-Objective optimization (Pareto Frontier)
  - Reliability based design optimization
  - Methodologies
    - Meta-model based approaches
    - Genetic Algorithms





LS-OPT – State of the Art Optimization Software

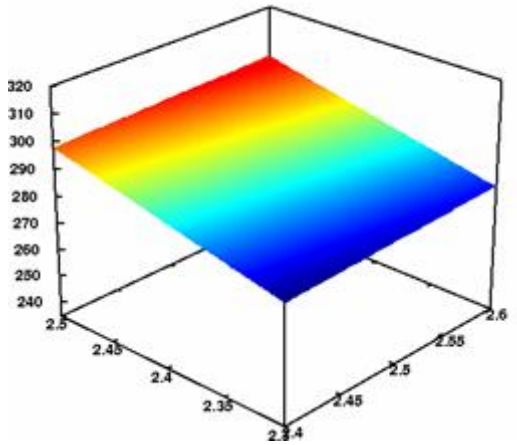
- What is a Meta-Model ?
  (Synonyms: Approximation, Response Surface, Surrogate model,…)



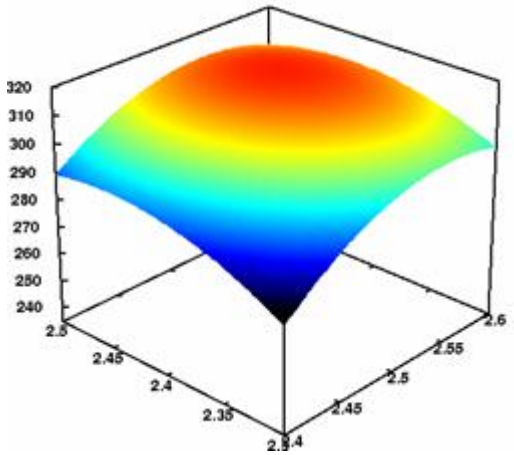
LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

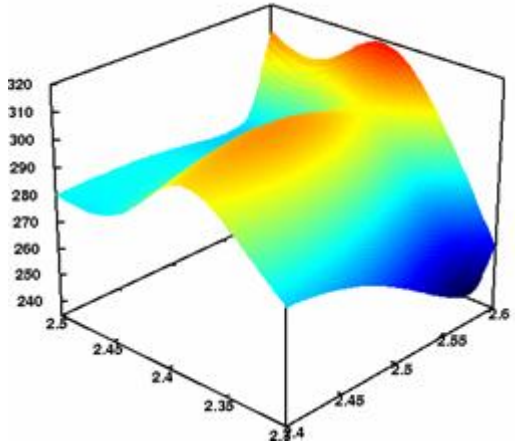
- DOE-Studies, Design Exploration
  - Samplings: Factorial, Latin Hypercube, Space Filling, …
  - Meta-models: Polynomials, Radial Basis Functions, Neural Nets (FFNN),…



linear polynomial



quadratic polynomial

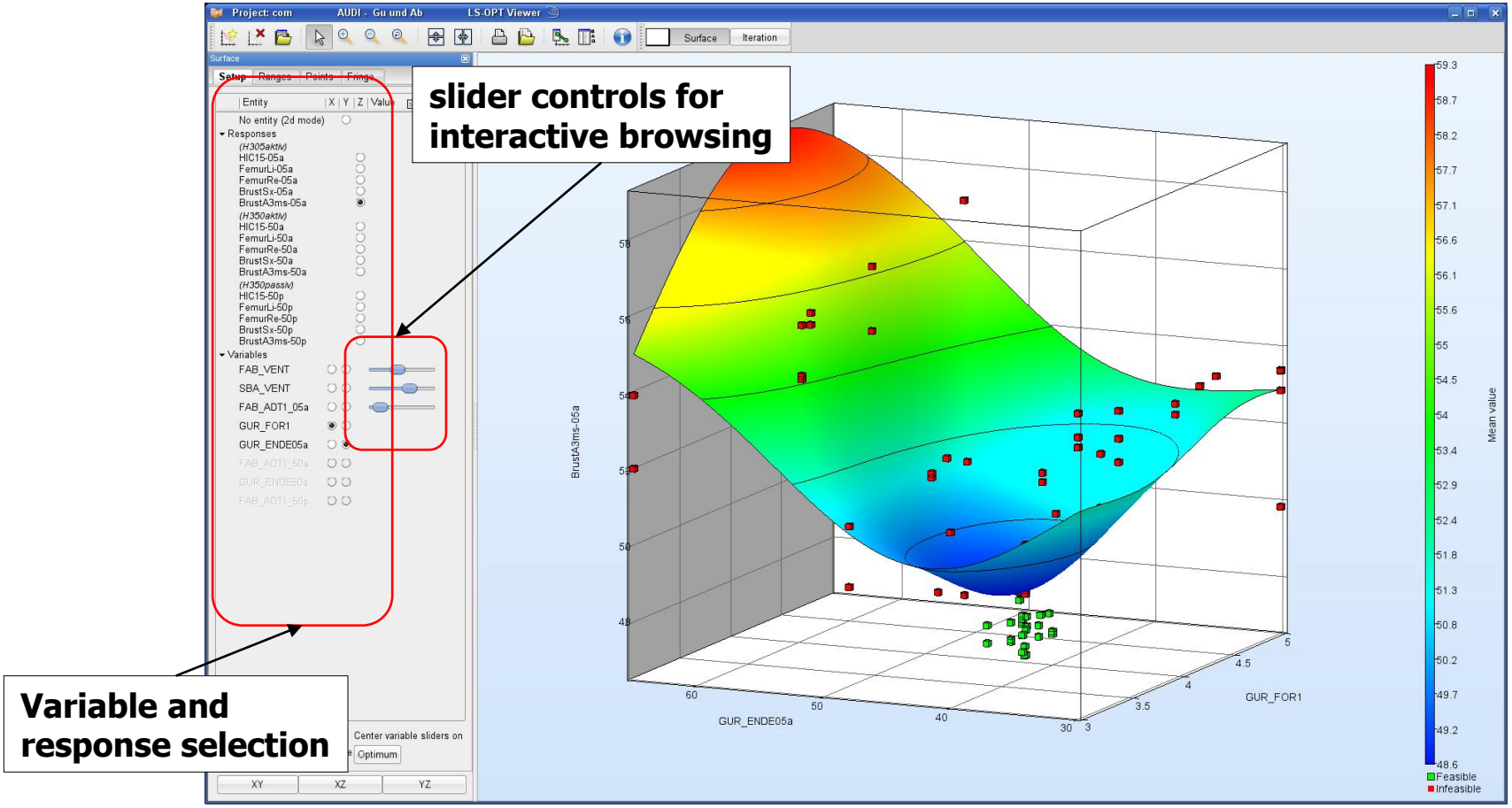


neural network

LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

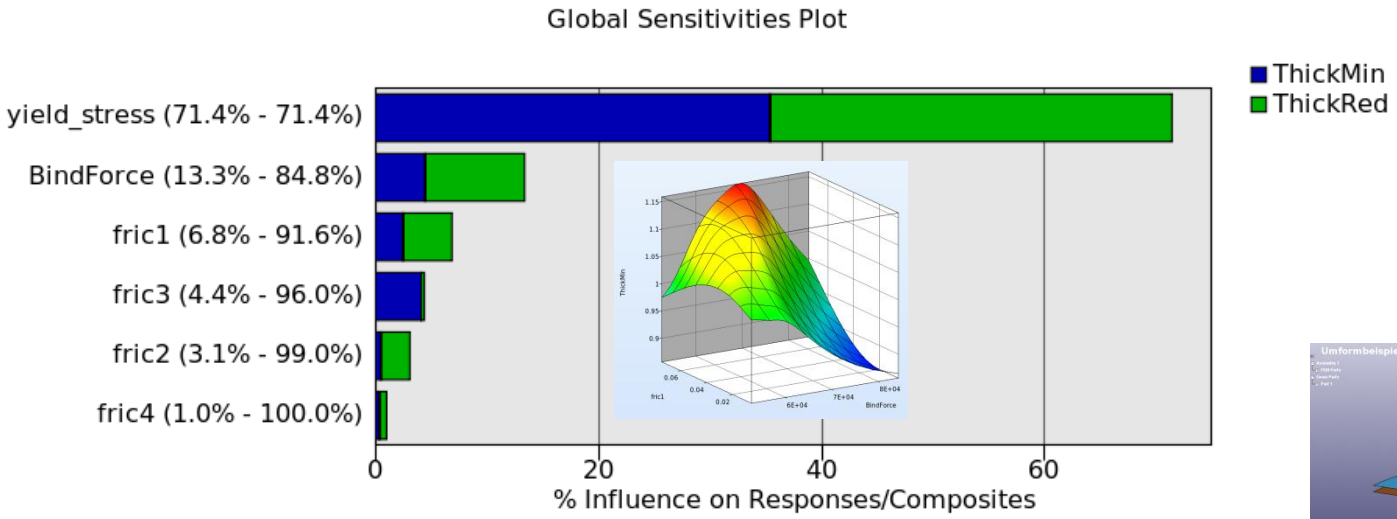
- DOE-Studies, Design Exploration
  - Visualization: 2D/3D sections of the surfaces, 1 or 2 selected variables vs. any response

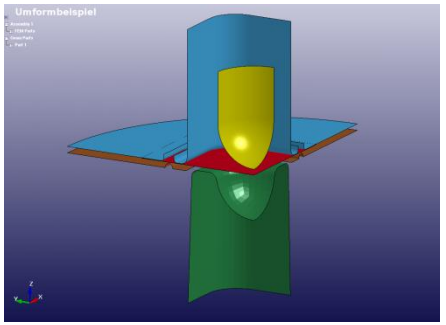


LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

- Sensitivity Studies
  - Contribution of variables to system performance
  - Identification of significant and insignificant variables
  - Ranking of importance





LS-OPT – State of the Art Optimization Software

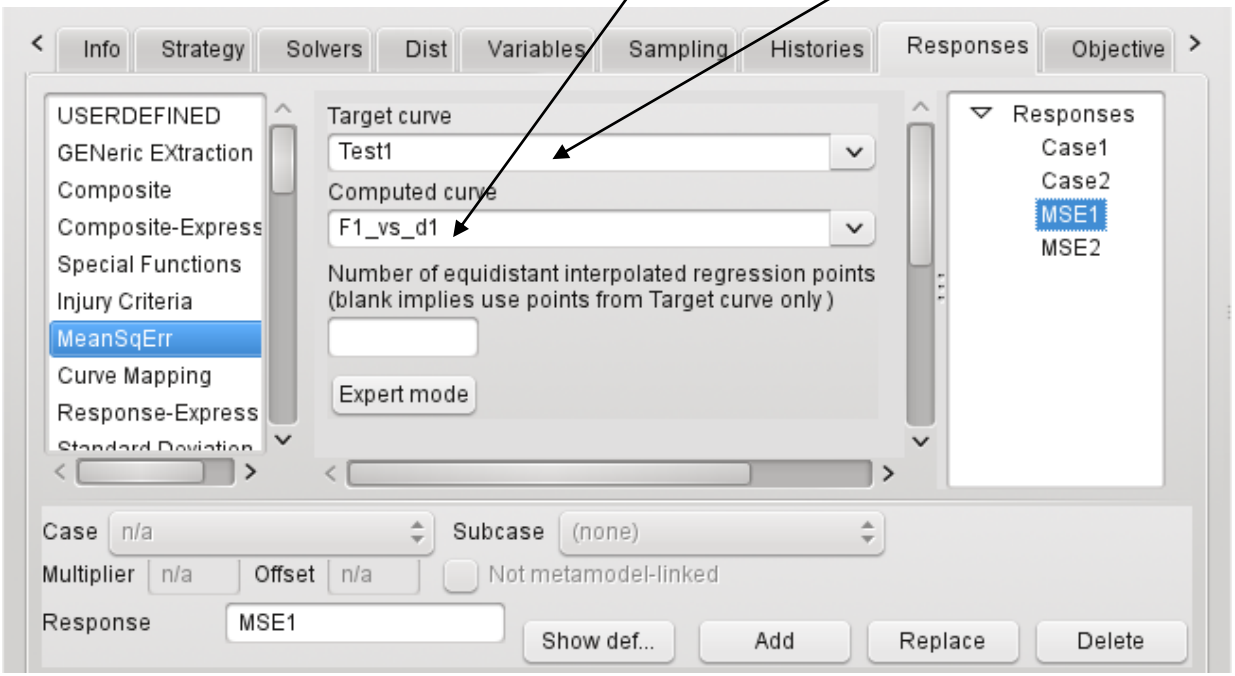
Applications of LS-OPT

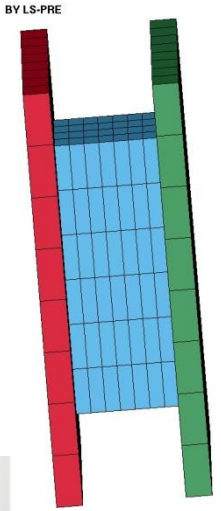
- Parameter Identification

$$MSE(\mathbf{x}) = \frac{1}{P}\sum_{i=1}^{P} W_i \left(\frac{F_i(\mathbf{x}) - G_i}{s_i} \right)^2 \rightarrow \min$$

Test curve

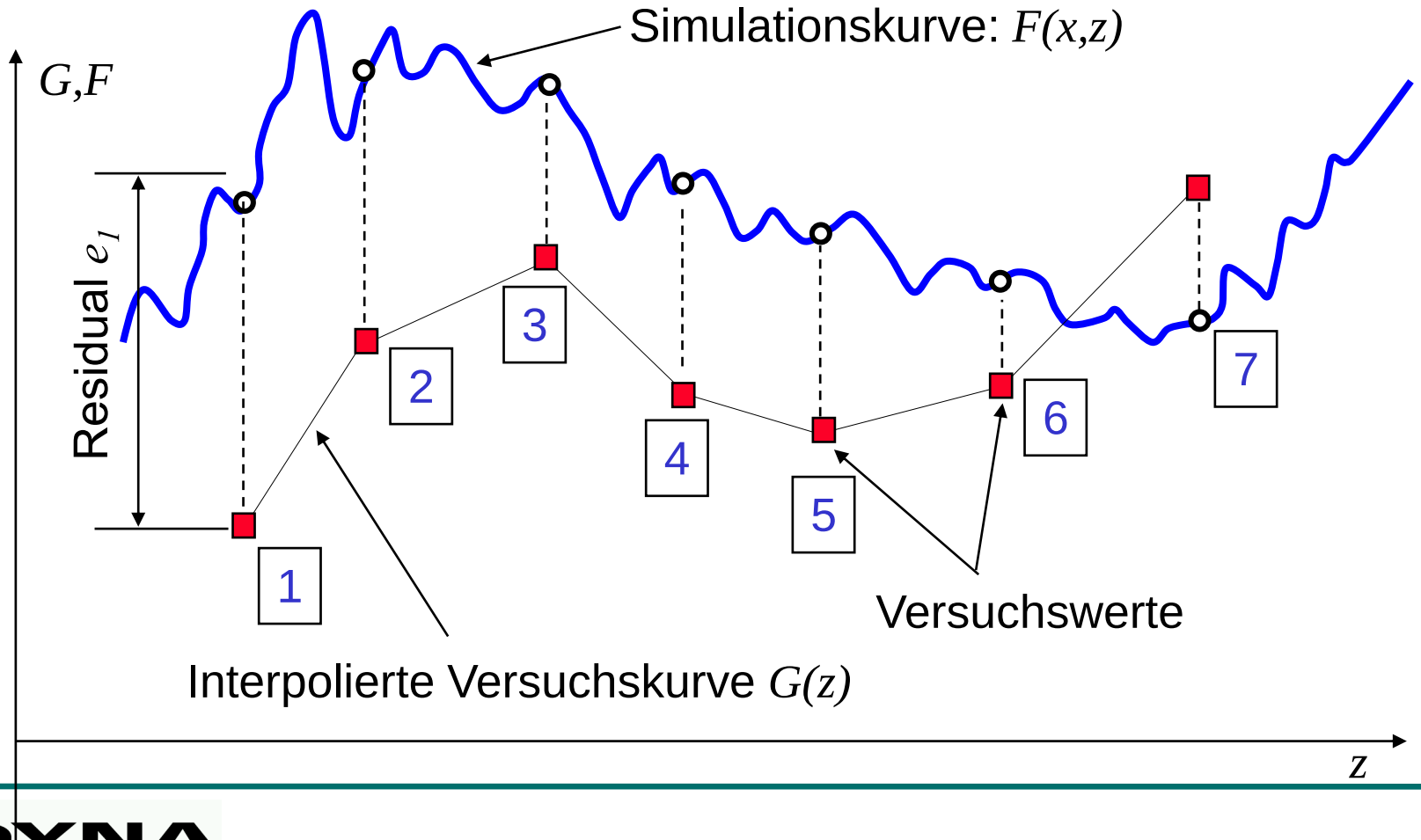
Simulation curve





Applications of LS-OPT

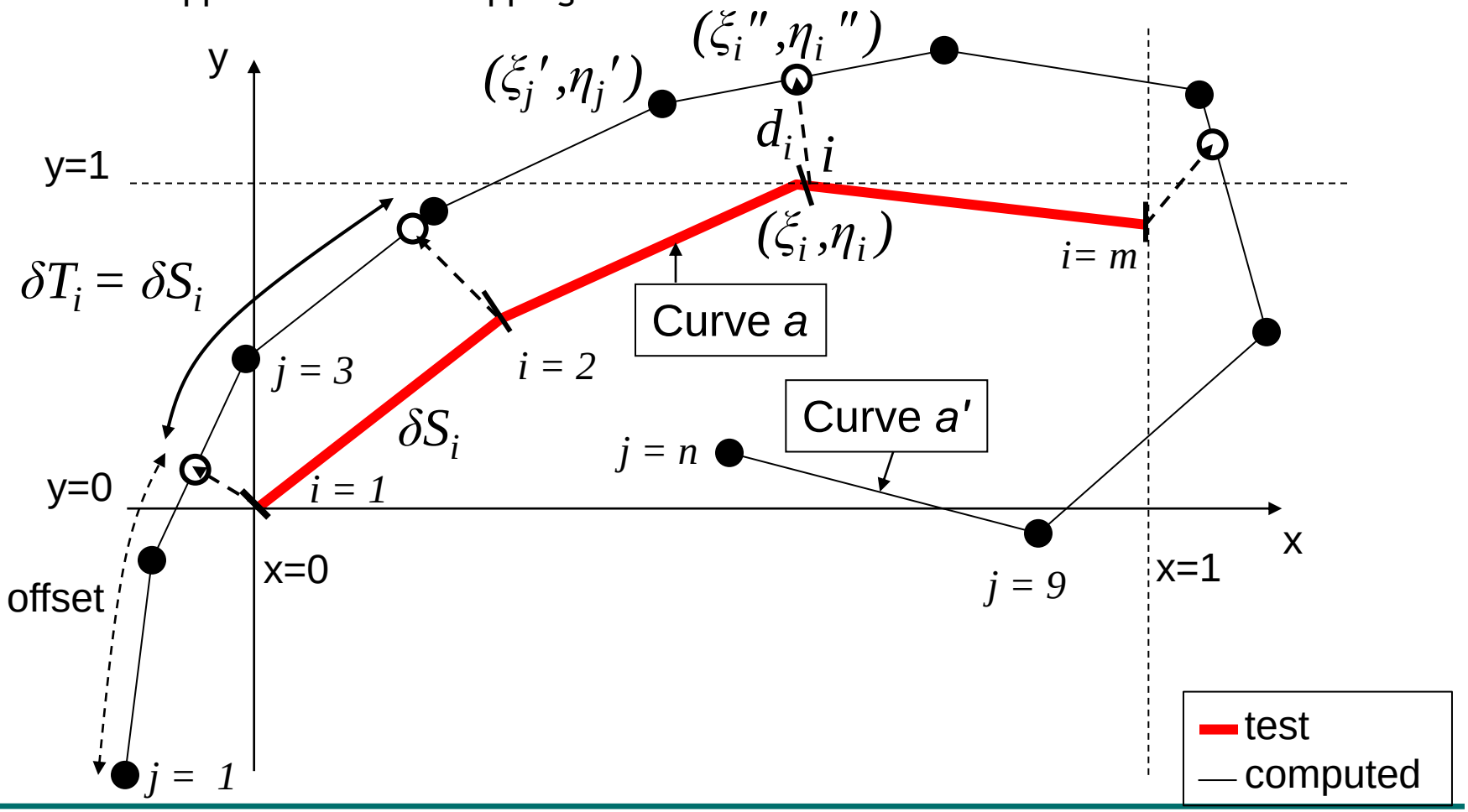
- Parameter Identification
  - Ordinate based mean square error function (MSE)



LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

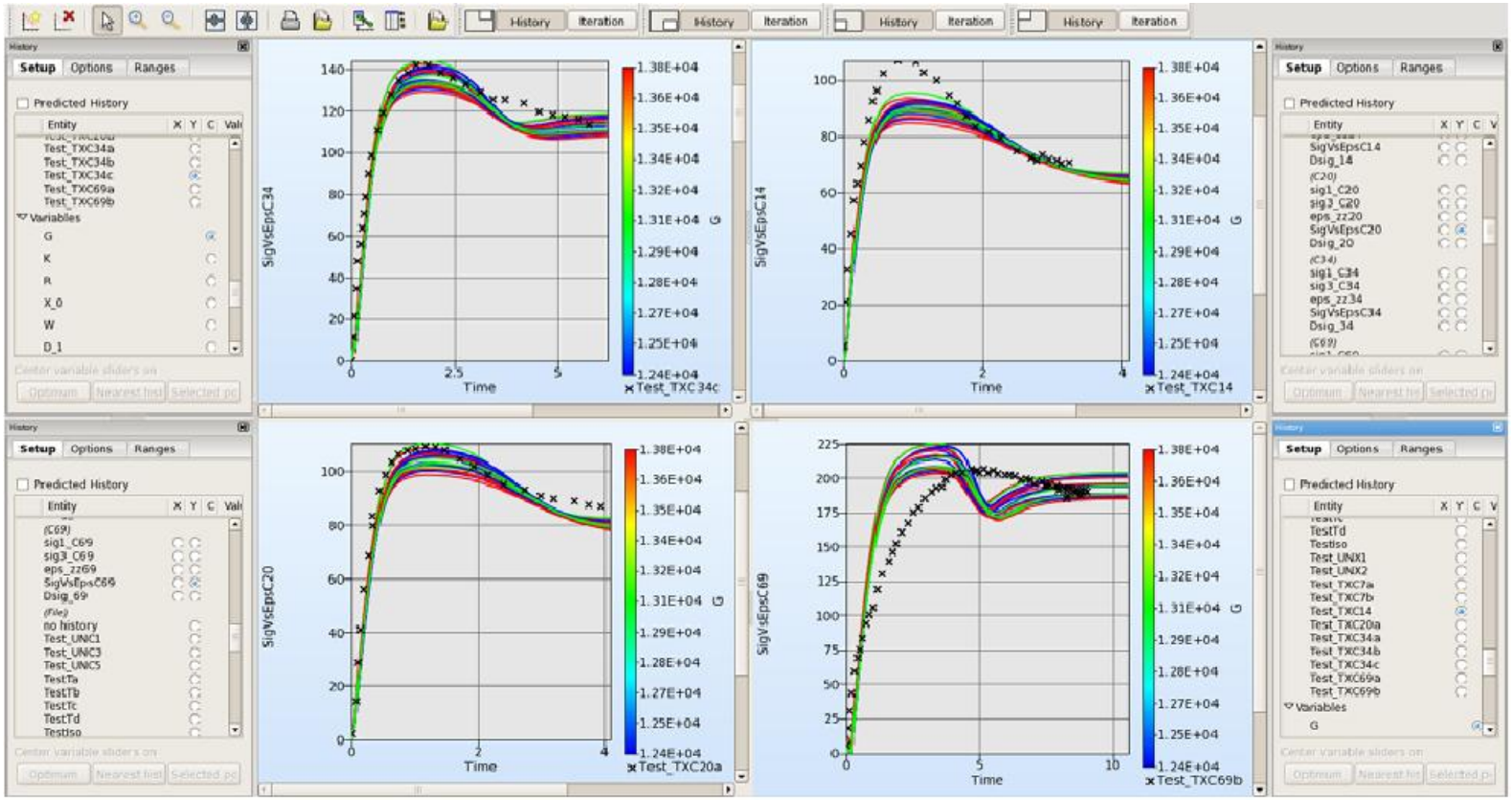
- Parameter Identification
  - New Approach: Curve mapping



Introduction / Features

Applications of LS-OPT

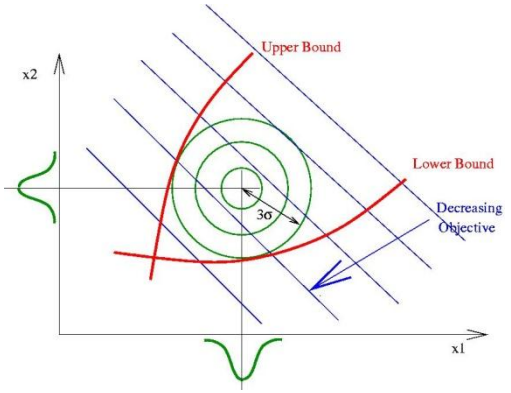
- Parameter Identification

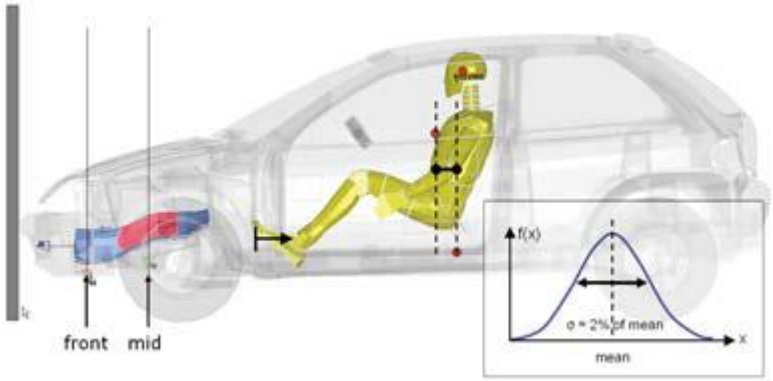


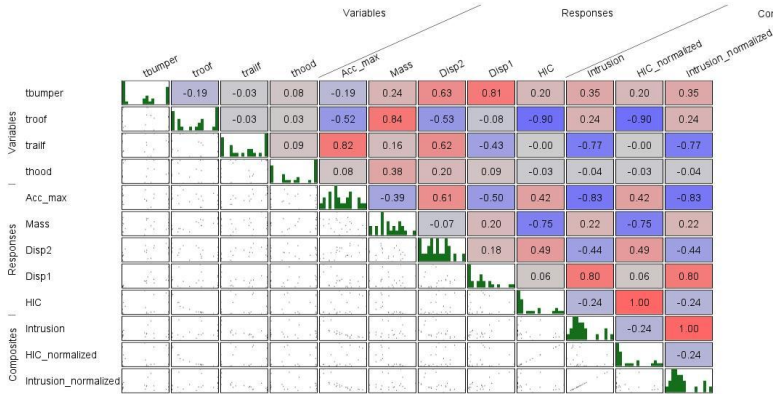
LS-OPT – State of the Art Optimization Software

Applications of LS-OPT

- Robustness / Reliability Analysis
  - Consideration of uncertainties
  - Evaluation of reliability (probability of failure)
  - Statistics
  - Correlation Analysis
  - Outlier Analysis







LS-OPT – State of the Art Optimization Software

Stochastic Analysis - Goals

- **Statistical Quantities of Output (Response) due to Variation of Input (Parameter)**
  - Mean
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- **Reliability Issues**
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- **Visualization of statistical quantities on FE-model**
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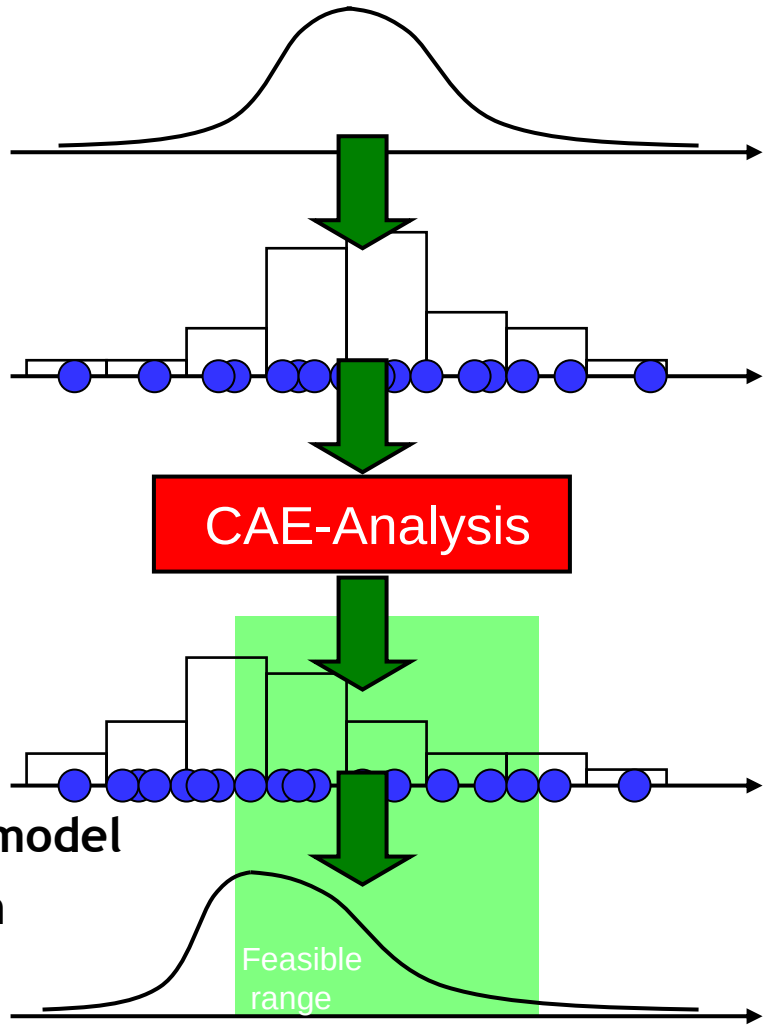
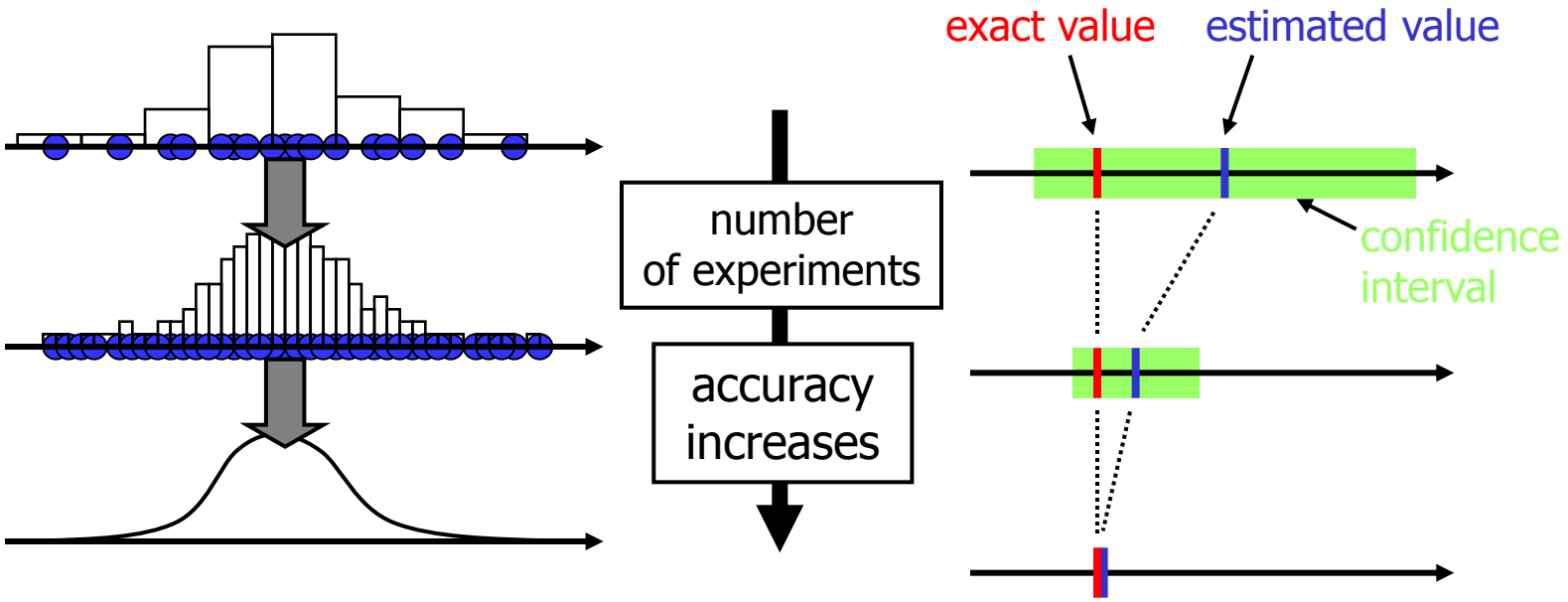


Statistical Quantities of Output due to Variation of Input

Direct Monte Carlo Sampling

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

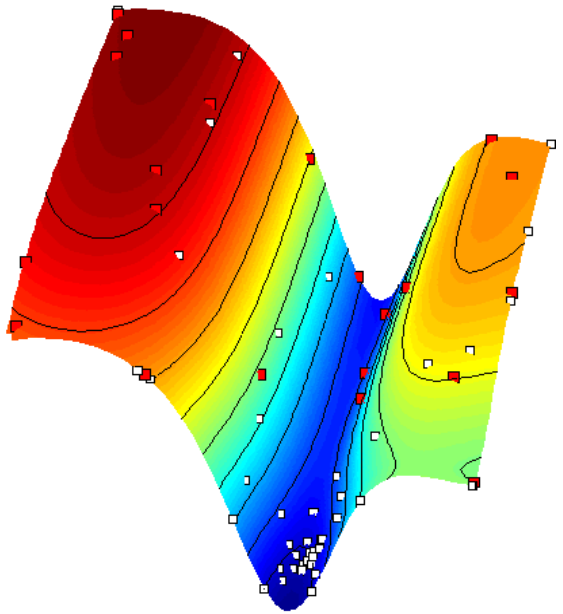


LS-OPT – State of the Art Optimization Software

Statistical Quantities of Output due to Variation of Input

Monte Carlo using Meta-Models

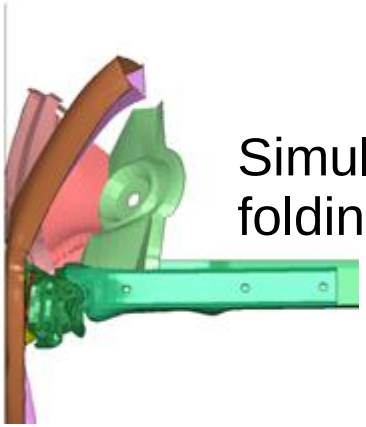
- Response Surface / Neural Network
- Medium number of FE runs
- Number of runs depend on the dimension of the problem (number of variables) and the type of Meta-Model
- Identify design variable contributions clearly
- Exploration of parameter space



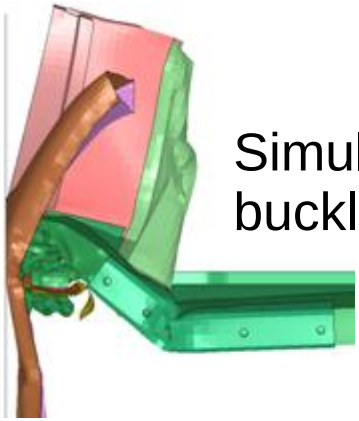
Outlier Analysis

Tradeoff Plot

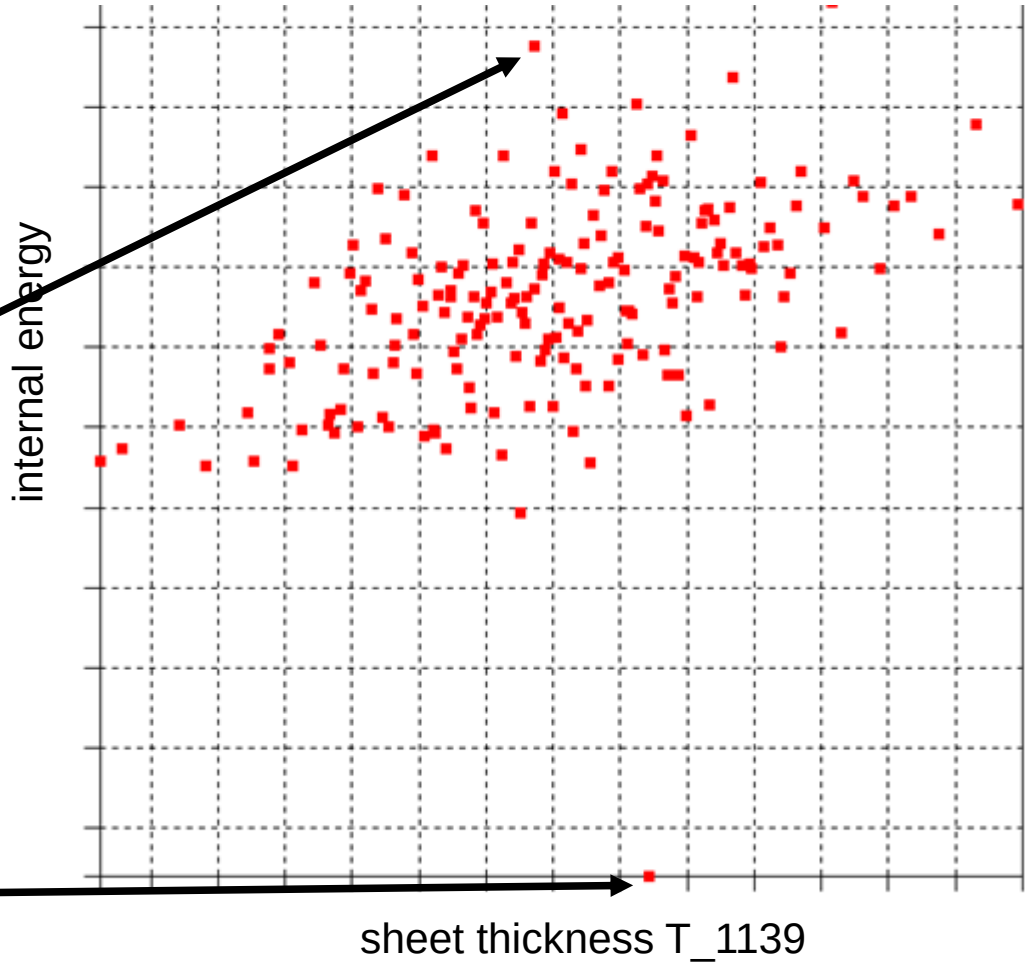
- Monte Carlo Simulation
- Identification of Clustering



Simulation 185
folding



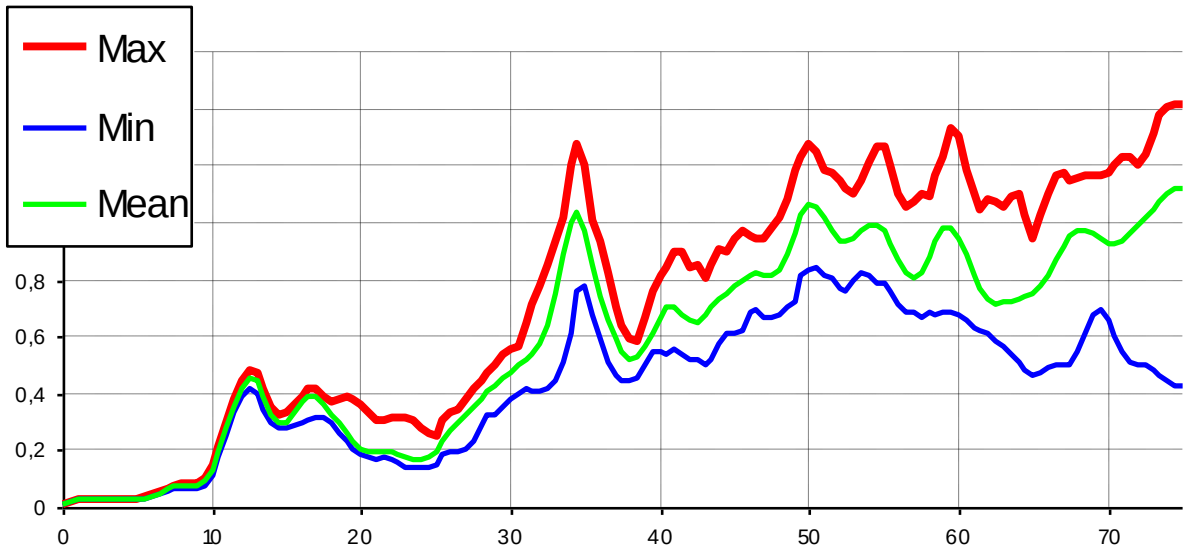
Simulation 47
buckling



Statistics for Time History Curves

Scatter Band of Curves due to Variation of Input

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



LS-OPT – State of the Art Optimization Software

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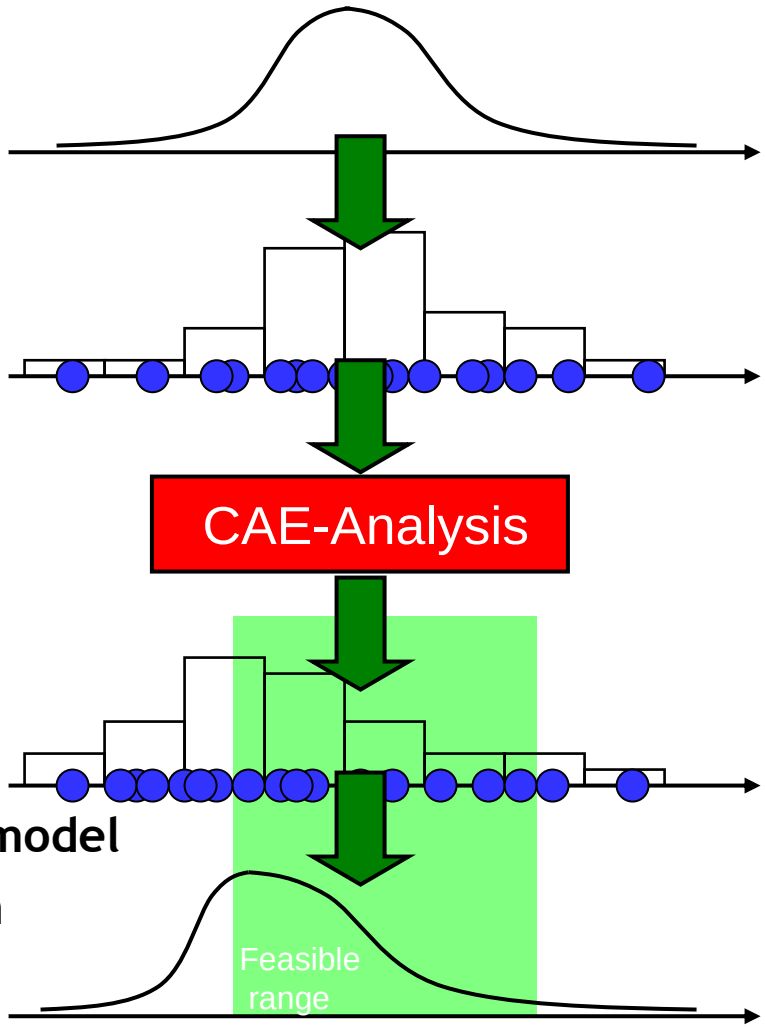
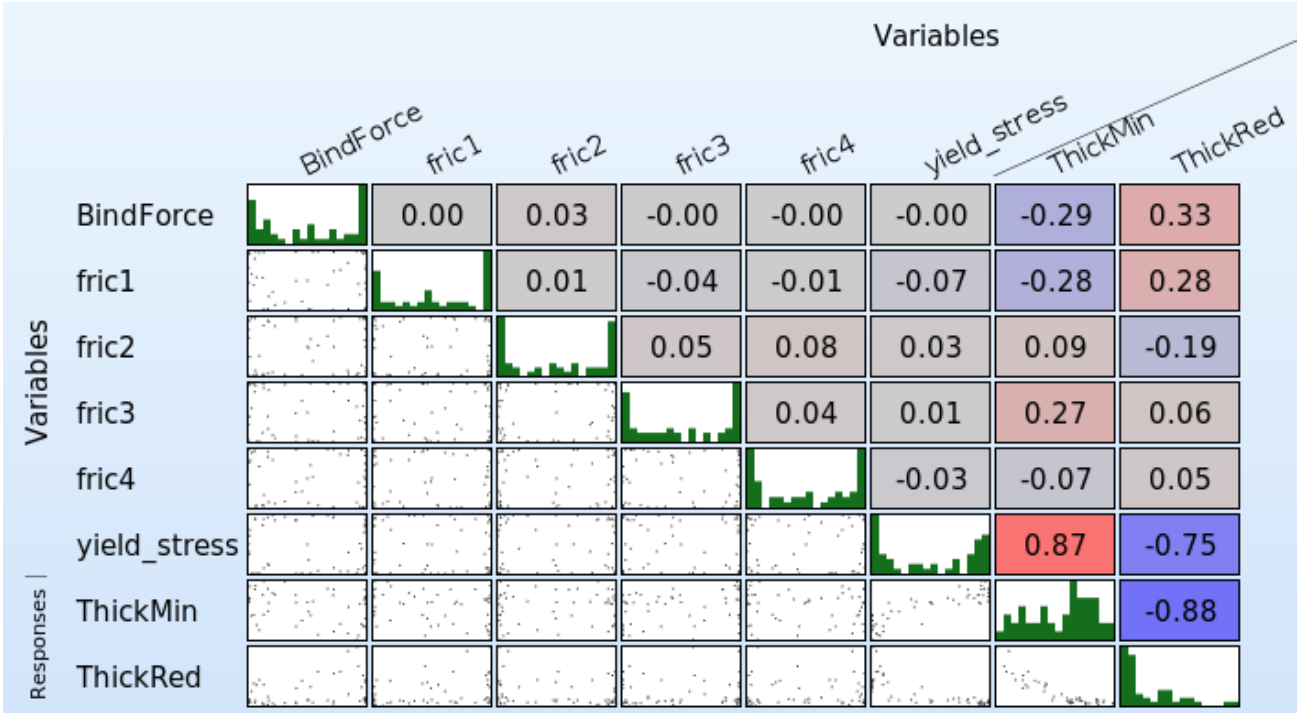


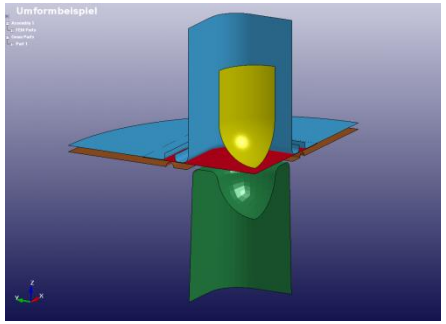
LS-OPT – State of the Art Optimization Software

Significance of Parameter with respect to Responses

Correlation Analysis

- Display of correlation matrix in LS-OPT

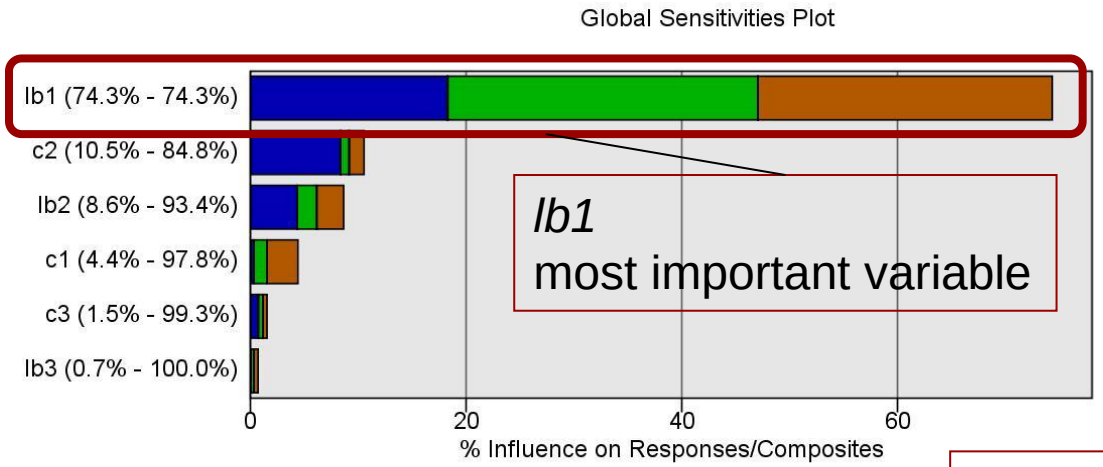




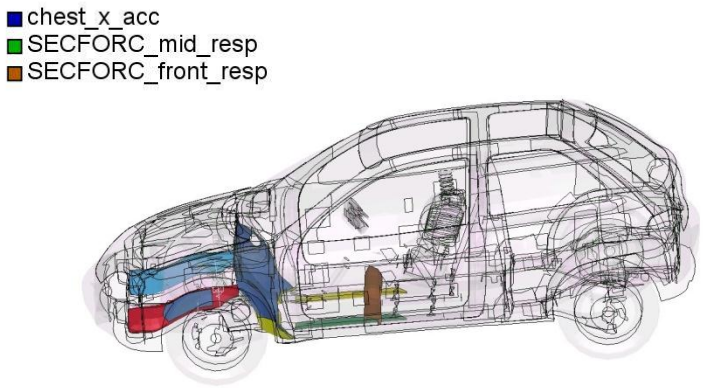
LS-OPT – State of the Art Optimization Software

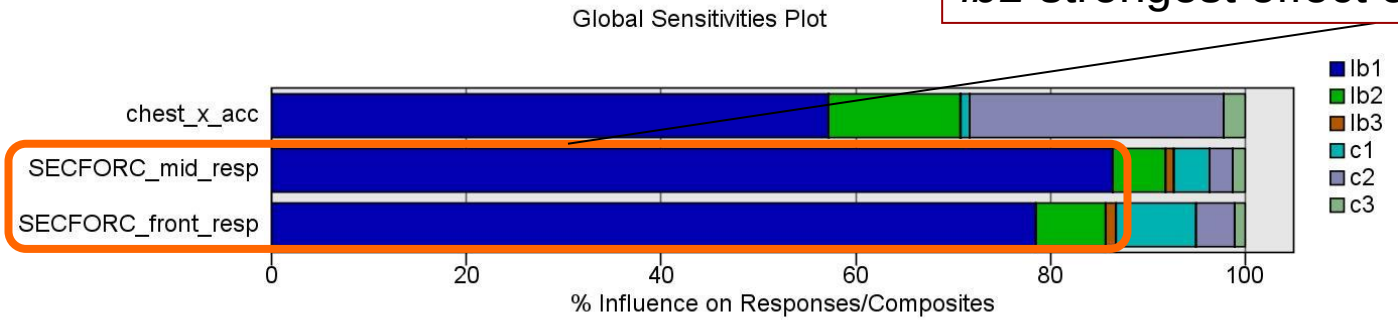
Sobol Analysis

- Generally applicable non-linear sensitivity measure [Sobol, 1993]
- Determination computational expensive, many sampling points required
  → application of meta models (radial basis functions, neural networks,…)



lb1
most important variable





lb1 strongest effect on section forces

LS-OPT – State of the Art Optimization Software

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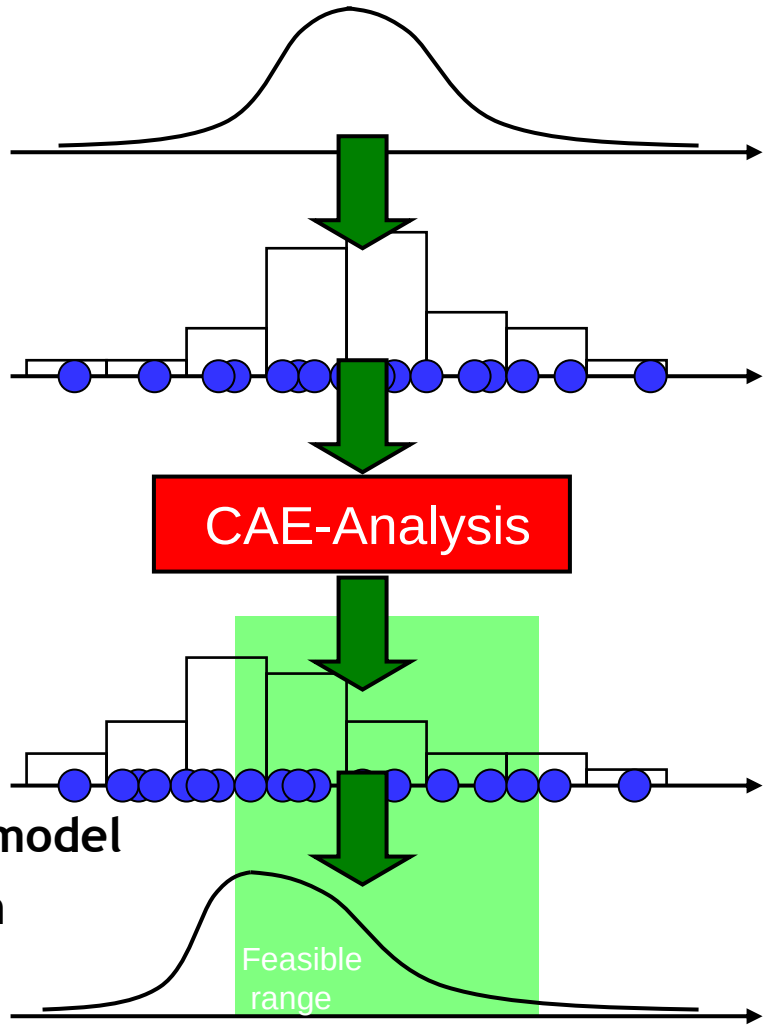
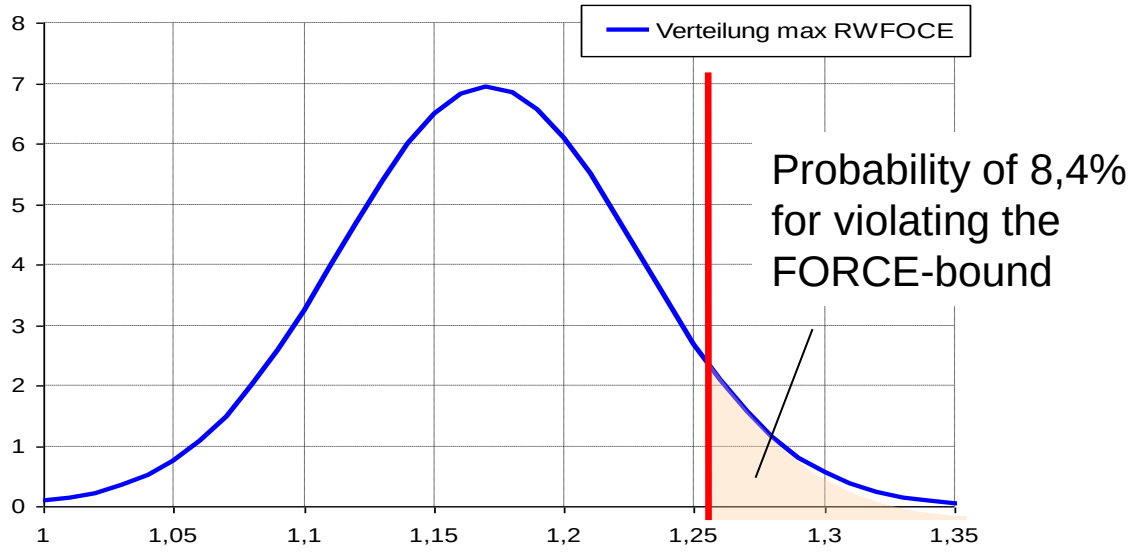


Reliability Analysis

- 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)*



LS-OPT – State of the Art Optimization Software

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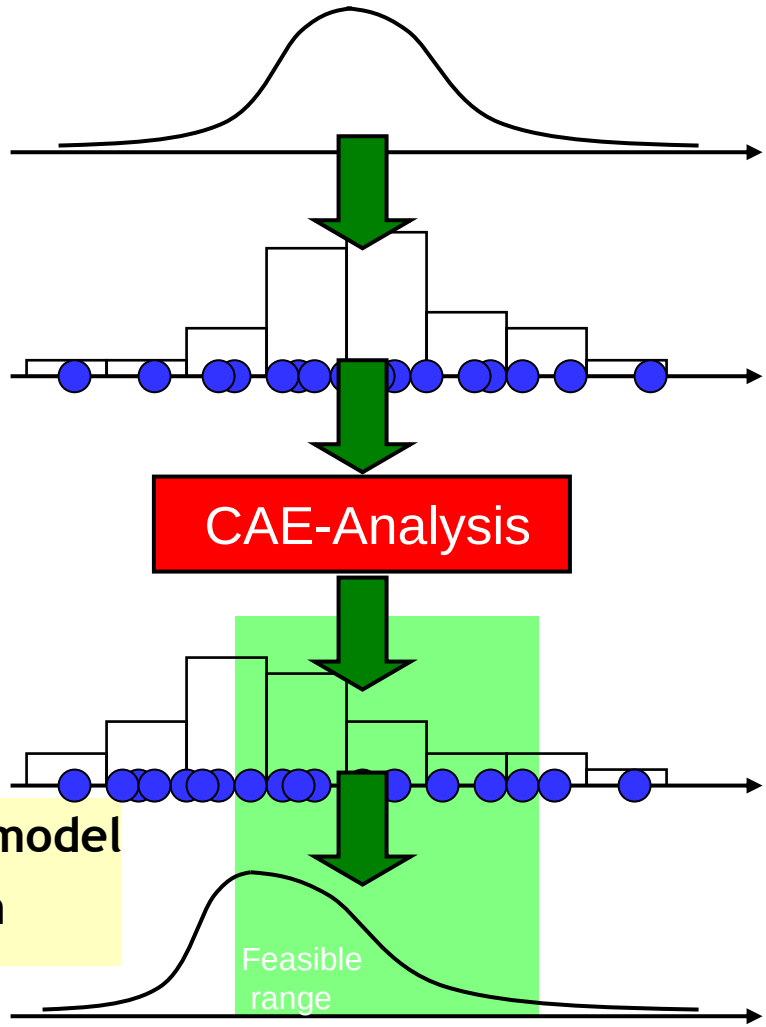
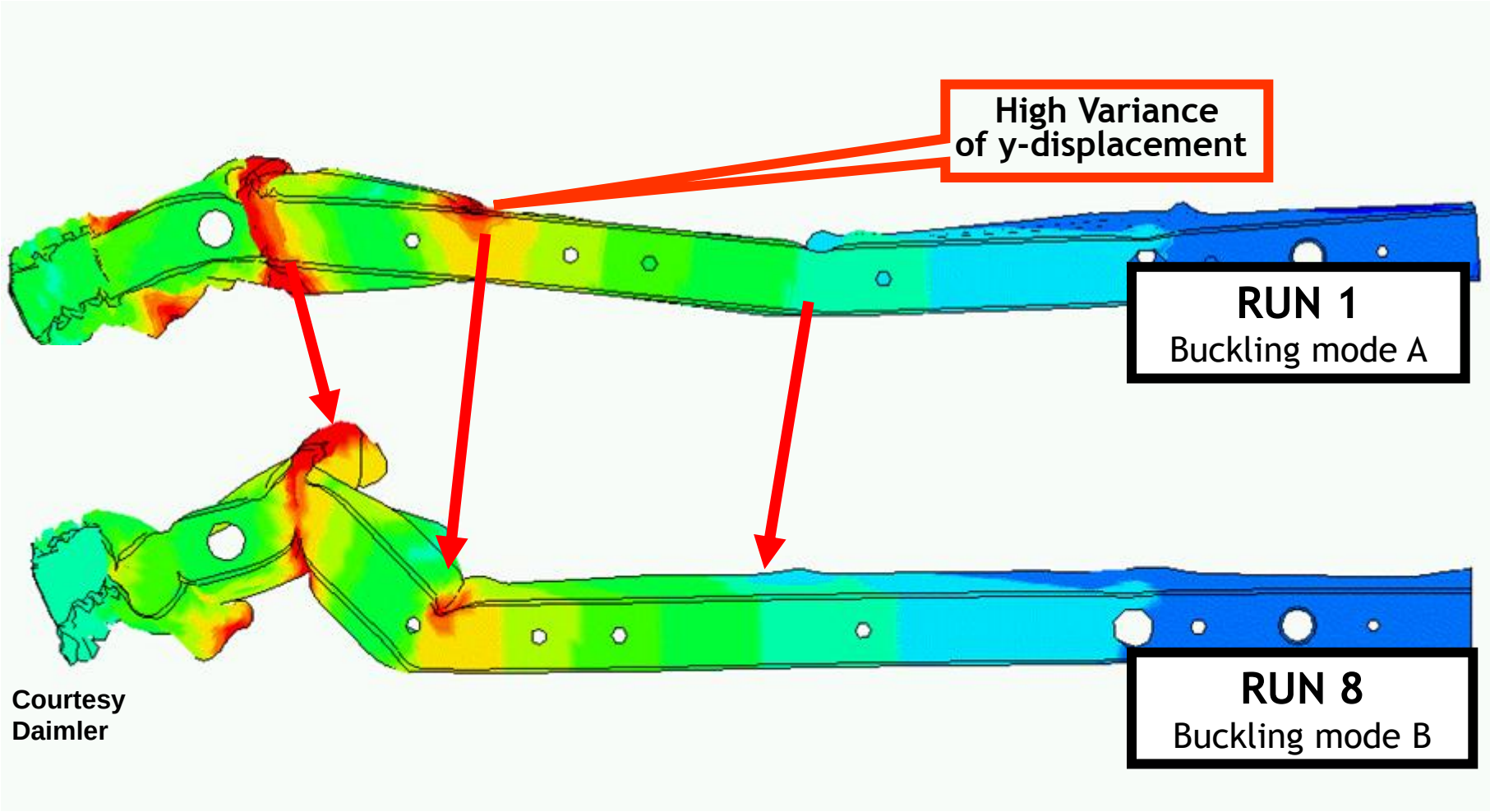


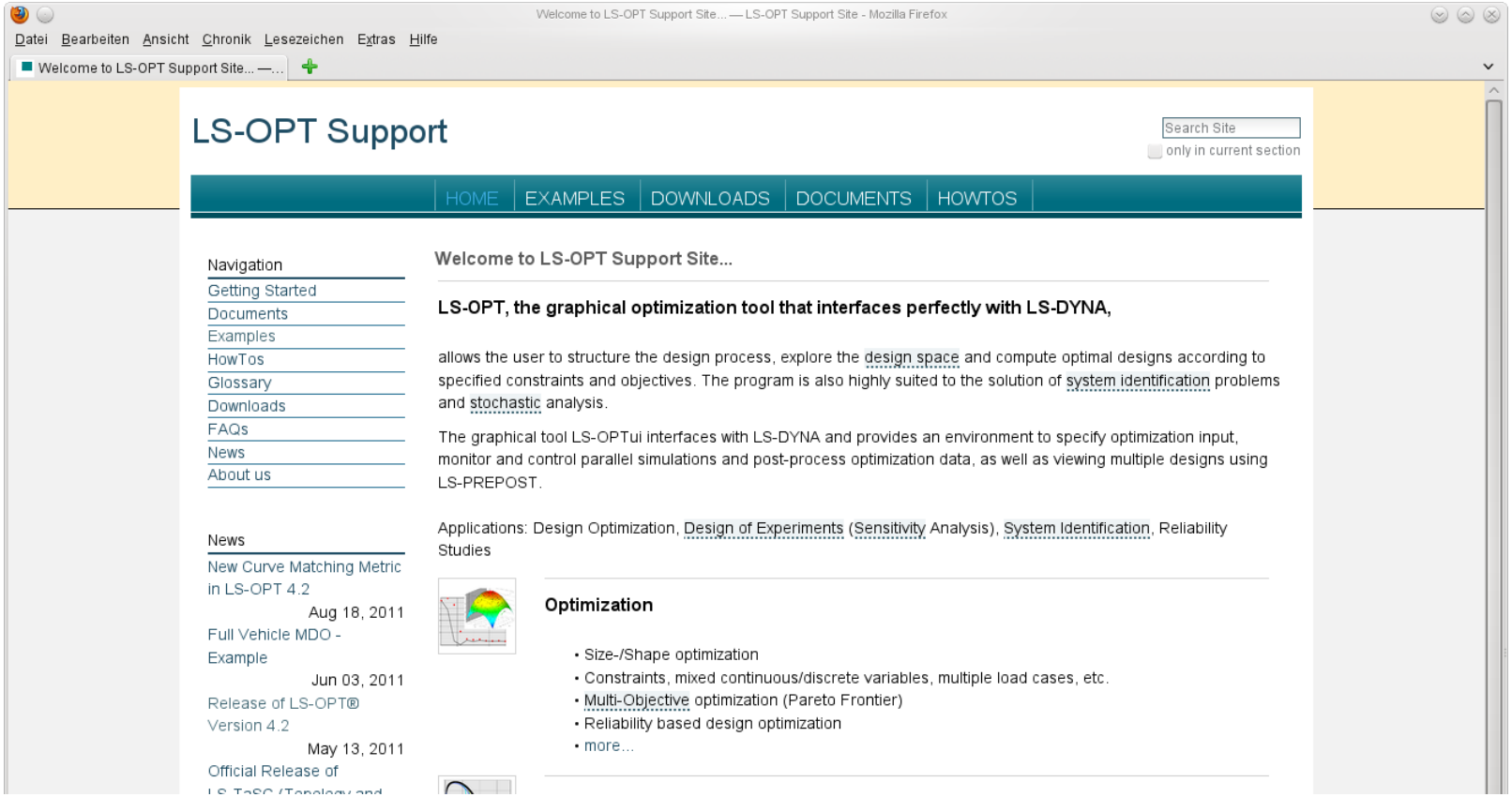
Visualization of Statistical Quantities on FE-model

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



LS-OPT – State of the Art Optimization Software

- LS-OPT Support-Webpage -> www.lsoptsupport.com
  - Many examples, tutorials, FAQs, HowTos…



Licensing of LS-DYNA, LS-OPT, LS-PrePost

- **LS-DYNA Solver**
  - classic explicit solver
  - implicit features
  - SPH and EFG
  - Euler, ALE-Method and FSI
  - corpuscular method
  - CFD solver
  - SMP and MPP platforms
  - network and node locked license
  - all features includes

- **LS-PREPOST**
  - supports all LS-DYNA features
  - unlimited number of license

- **LS-OPT**
  - optimization, stochastic analysis
  - advanced methodologies
  - no additional fee

- **Support by DYNAmore**
  - experienced staff give support
  - telephone or e-mail support included
  - direct access to staff of DYNAmore
  - full supports for all three products
  - info support mails

- **DYNA*more* Toolbox**
  - many tools for daily work
  - no additional fee

Agenda

Kurzportrait

Übersicht Optimierungslösungen

LS-OPT

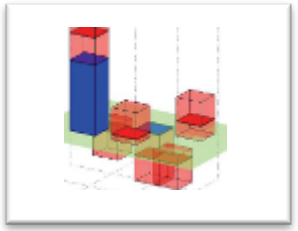
FuE-Projekte

FuE-Projekte / Hochschulkooperationen

Prozessmanagement in der Crashsimulation

- Laufzeit 2008-2010
- Kooperation mit FH Kempten, Fakultät Informatik
- Projektträger: Freistaat Bayern

Entwicklung von Methoden zur effizienten globalen Sensitivitätsanalyse



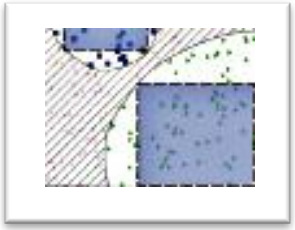
- Verbundprojekt mit TU Dresden (Fakultätsrechenzentrum)
- Laufzeit 2010-2013
- Projektträger: Freistaat Sachsen und EU

FuE-Projekte / Hochschulkooperationen

Topologieoptimierung für Crash

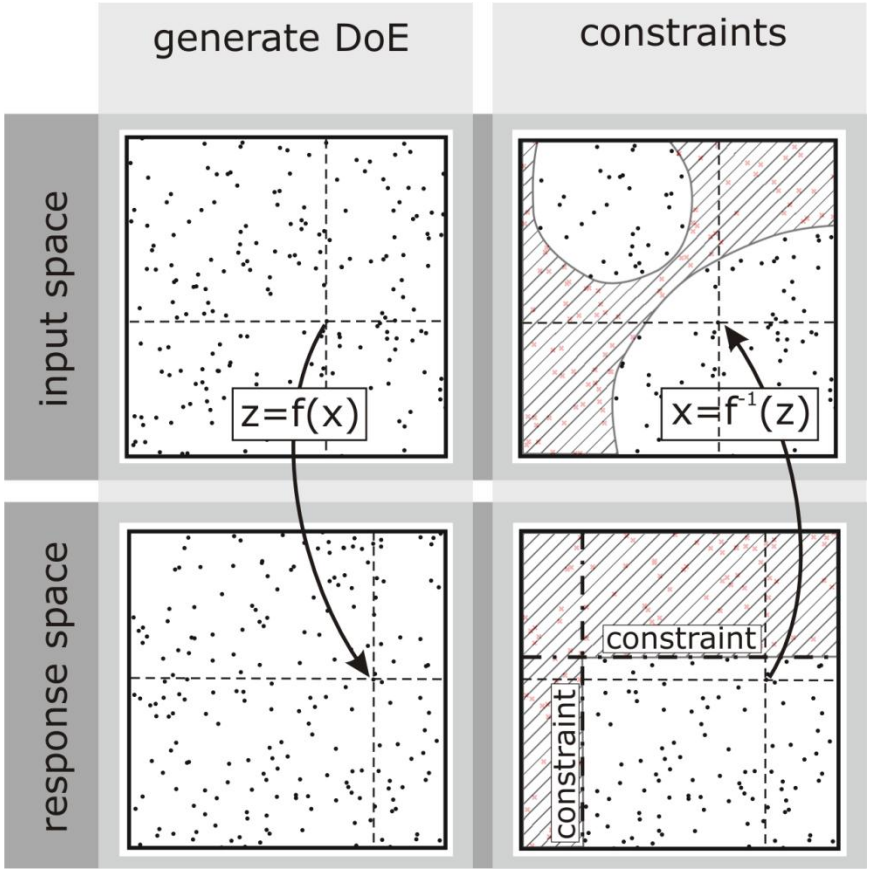
- Laufzeit 2010-2012
- Hochschulpartner:
  - HAW Hamburg (Prof. A. Schumacher)
  - TU München (Prof. F. Duddeck)
- BMBF-Förderung für Forschungsvorhaben

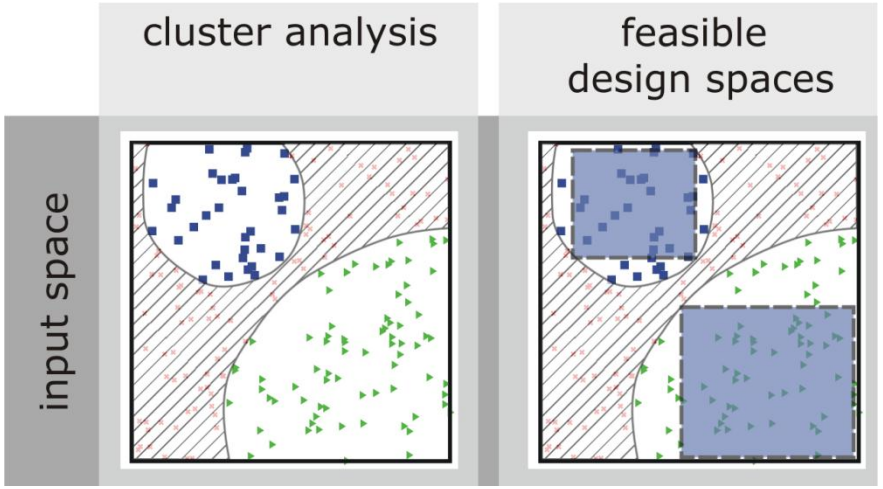
Ermittlung zulässiger Bereiche



- Laufzeit 2012-2014
- Kooperation mit TU Dresden,
  Institut für Statik und Dynamik (Prof. M. Kaliske)
- ZIM Kooperationsprojekt

Alternative Entwurfsstrategien – Zulässige Parameterbereiche

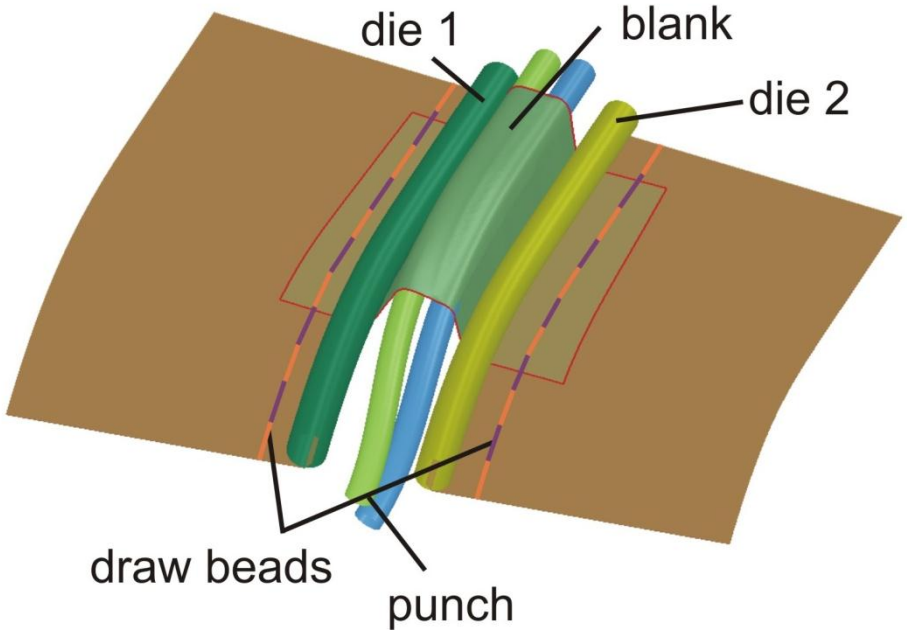




Alternative Entwurfsstrategien - Zulässige Parameterbereiche

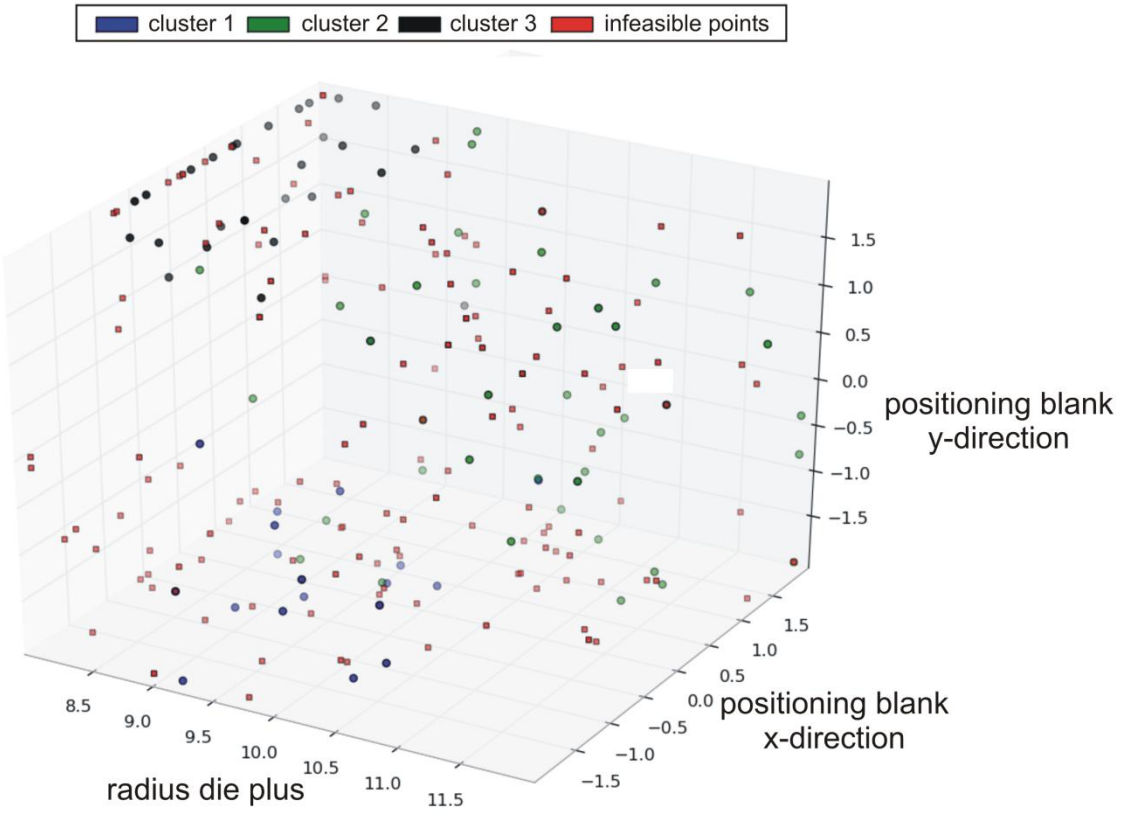
- Considered input parameters for the metal forming application
- In total 28 parameters

input parameter	ranges
radius die 1	8 . . . 12
radius die 2	8 . . . 12
draw bead force 1	0 . . . 300
⋮	⋮
draw bead force 22	0 . . . 300
shell thickness	0.45 . . . 0.5
binder force	100 . . . 300
positioning blank x-direction	−2 . . . 2
positioning blank y-direction	−2 . . . 2



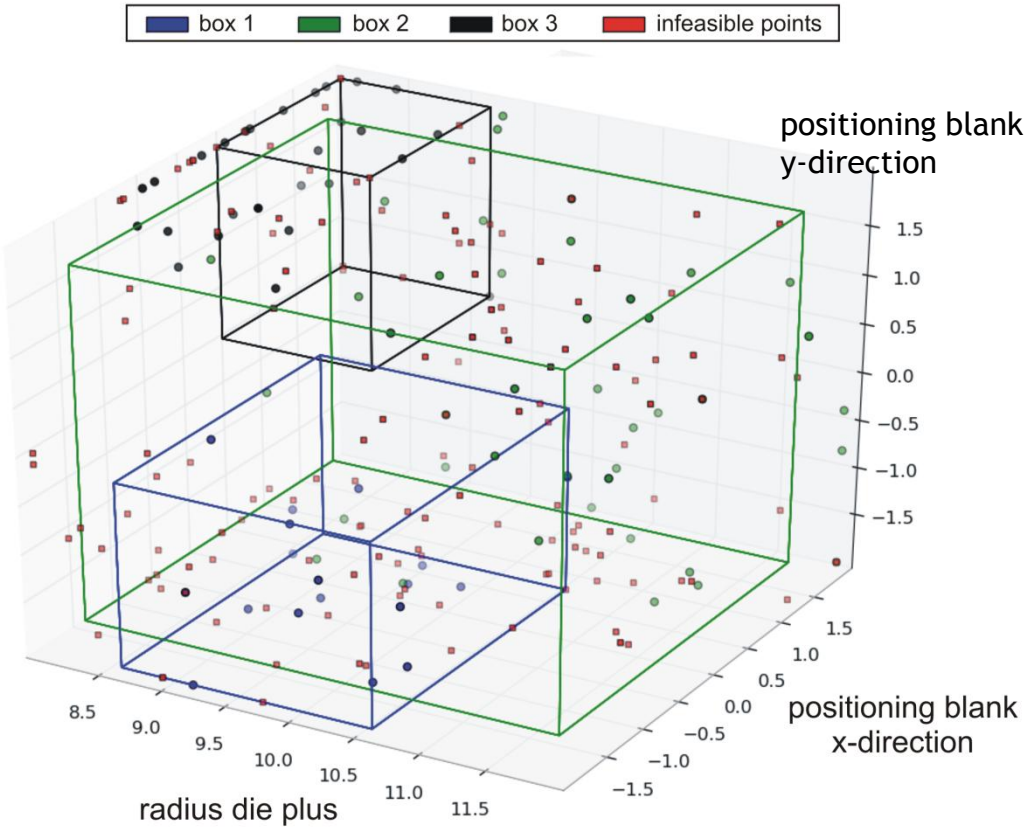
Alternative Entwurfsstrategien – Zulässige Parameterbereiche

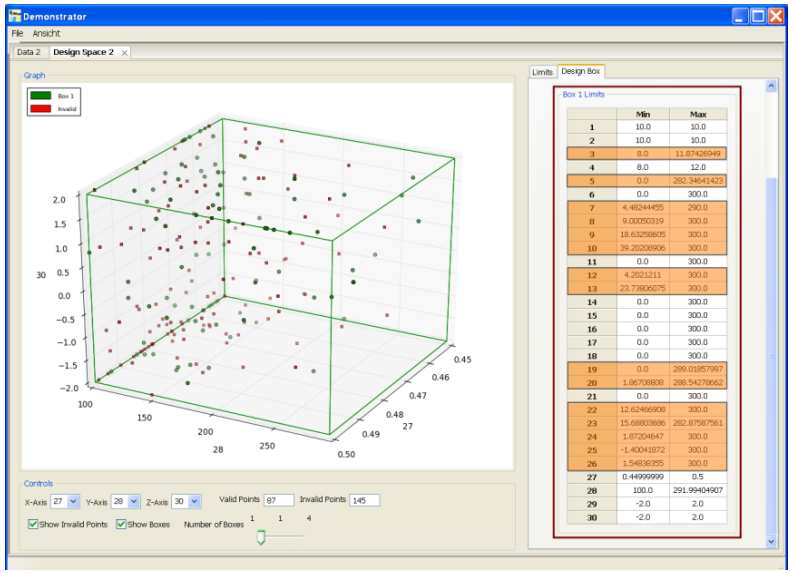
- Introduction of constraints
  - No violation of FLC criteria
  - No violation of cracking criteria
  - Edge of blank not to pass draw beads
  - criterion for blank geometry after springback by comparing actual geometry with target geometry



Alternative Entwurfsstrategien - Zulässige Parameterbereiche

- Adapted hyper rectangles as borderlines for feasible parameter regions





Vielen Dank
für Ihre Aufmerksamkeit!