Introduction to LS-OPT®
and new developments in V 5.1

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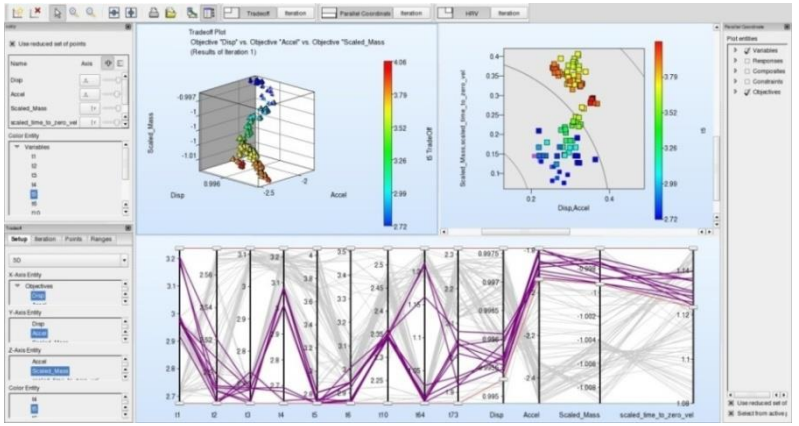
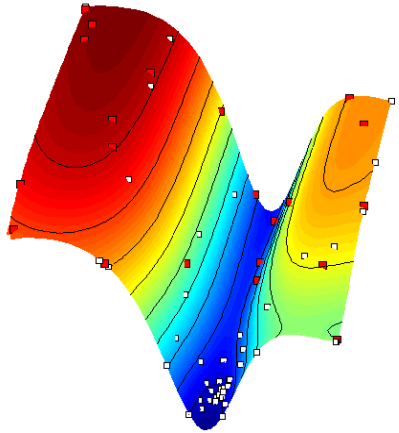
Outline

- Overview of methodologies and applications of LS-OPT
  - *DOE/Sensitivity analysis*
  - *Parameter identification*
  - *Shape optimization*
  - *Robustness analysis*
- New developments in LS-OPT 5.1
  - *Multi-level optimization*
  - *Variable deactivation*
  - *Parallel Neural Networks*
  - *Excel interface*
  - *Viewer enhancements*
  - *GSA in subregions*
- Outlook

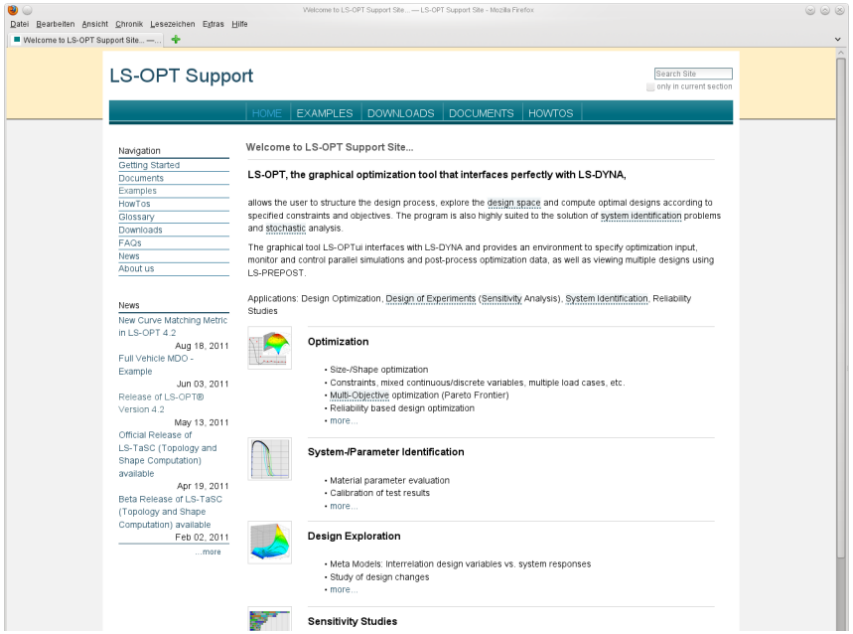


Introduction

→ About LS-OPT

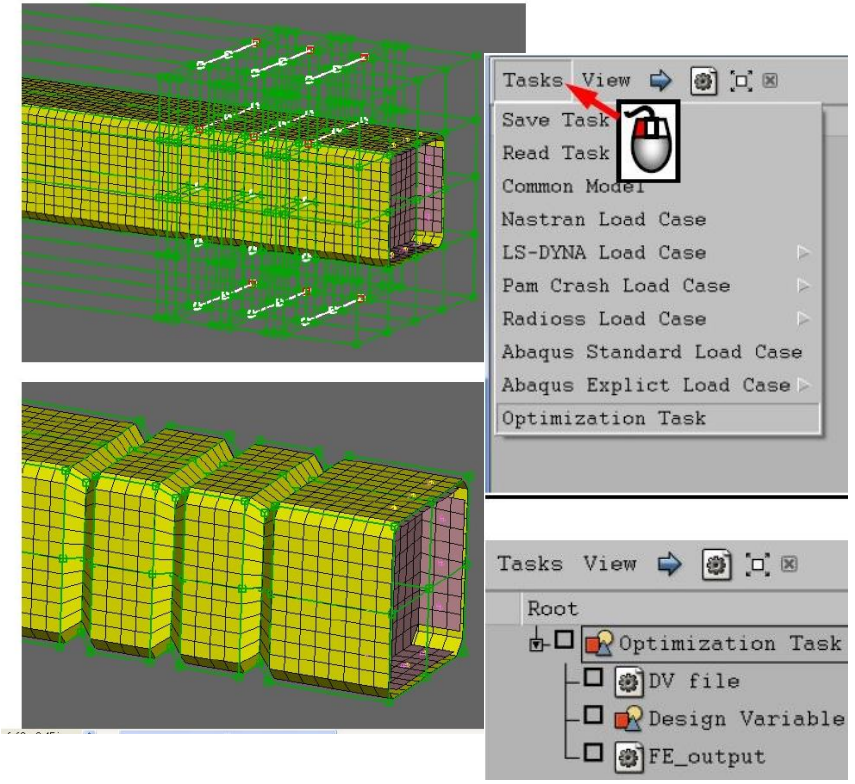


- LS-OPT is a standalone optimization software
  - → can be linked to any simulation code
    - Interface to LS-DYNA, MSC-Nastran, Excel
    - User-defined Interface
- Current production version is LS-OPT 5.1
- LS-OPT Support web page
  - → www.lsoptsupport.com
    - *Download of Executables*
    - *Tutorials*
    - *HowTos / FAQs*
    - *Documents*
    - *….*



→ About LS-OPT – General Aspects

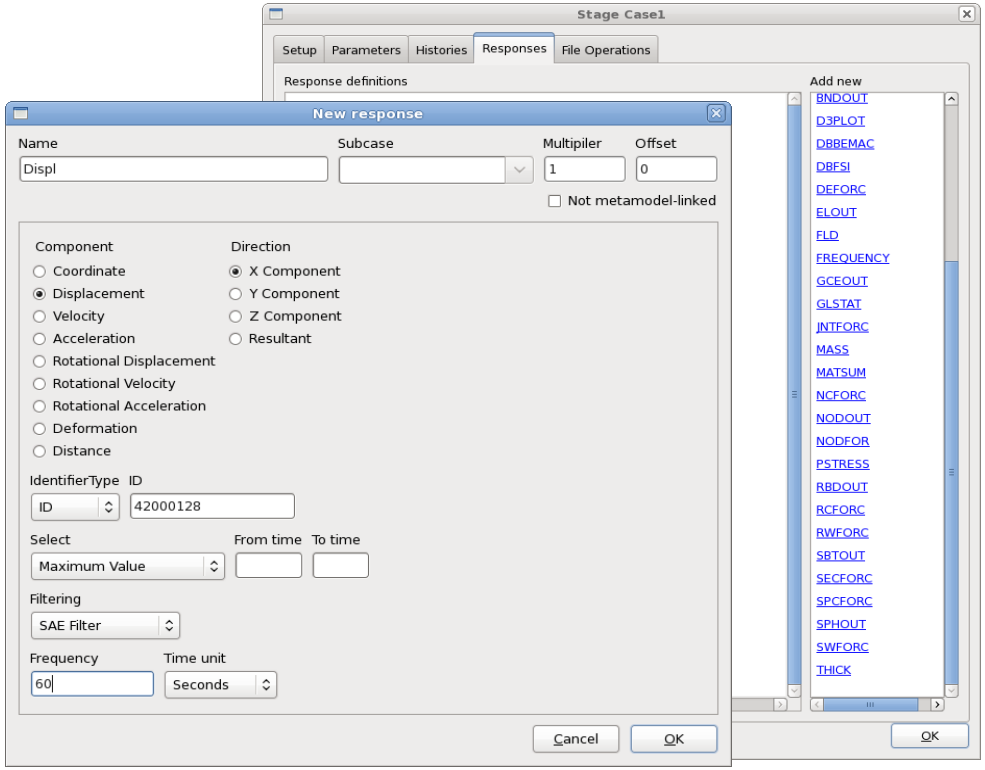
- Job Distribution - Interface to Queuing Systems
  - *PBS, LSF, LoadLeveler, SLURM, AQS, User-defined, etc.*
- LS-OPT might be used as a “Process Manager”
- Interfaces to Preprocessors (→ Shape Optimization)
  - *LS-PrePost, **ANSA**, HyperMorph, …*
  - *User-defined interface*
- Interfaces to Postprocessors
  - *META Post: Allows extraction of results from any package (Abaqus, NASTRAN, …) supported by META Post (ANSA package)*
  - *User-defined interface*



Introduction

About LS-OPT

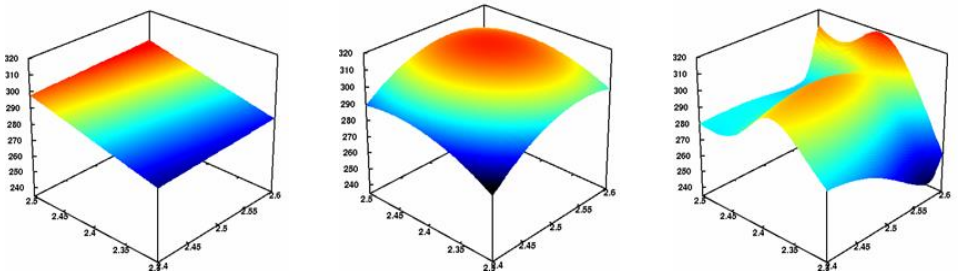
- LS-DYNA Integration
  - *Checking of LS-DYNA keyword files (*DATABASE_)*
  - *Importation of design parameters from LS-DYNA keyword files (*PARAMETER)*
  - *Support of include files (*INCLUDE)*
  - *Monitoring of LS-DYNA progress*
  - *Result extraction of most LS-DYNA response types*
  - *D3plot compression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



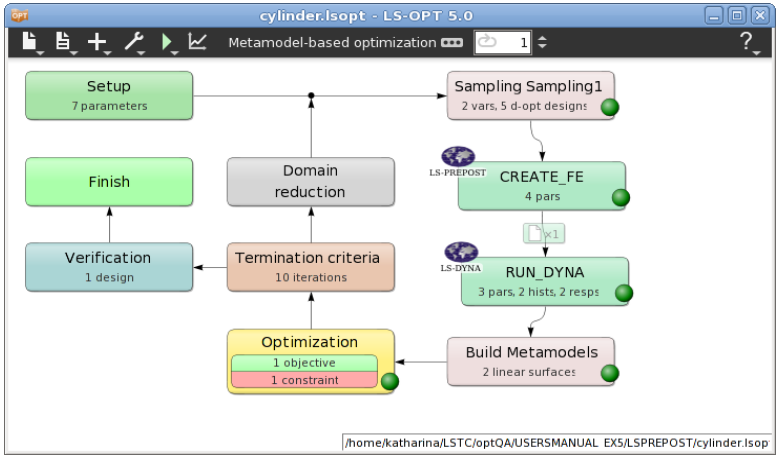
LS-OPT – Overview Methodologies

- Response Surface Method (RSM)
  - *Sequential Response Surface Method (SRSM)*

  → Metamodels
  - *Polynomials*
  - *Radial Basis Functions*
  - *Feedforward Neural Networks …*

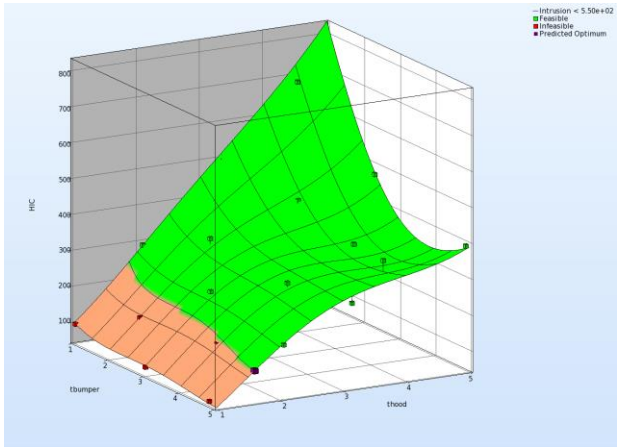


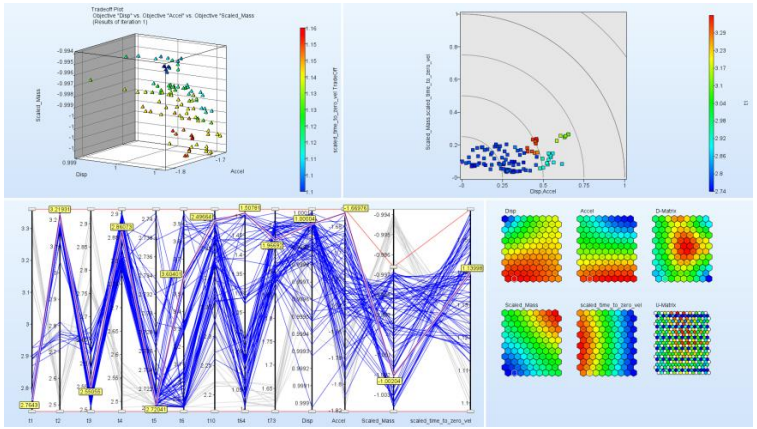
- Genetic Algorithm (MOGA->NSGA-II)
  - *Direct*
  - Metamodel-based
- Monte Carlo Analysis
  - *Direct*
  - Metamodel-based



Applications of LS-OPT

- Optimization
  - *Size-/Shape optimization*
  - *Constraints*
  - *Mixed continuous/discrete variables*
    - *Specify sets of discrete variables (e.g. sheet thicknesses)*
  - *Multiple load cases*
    - *Multi-disciplinary optimization (MDO)*
  - *Multi-objective optimization (Pareto Frontier)*
  - *Reliability based design optimization*
  - *Methodologies*
    - Meta-model based approaches
    - Genetic Algorithms (MOGA->NSGA-II)

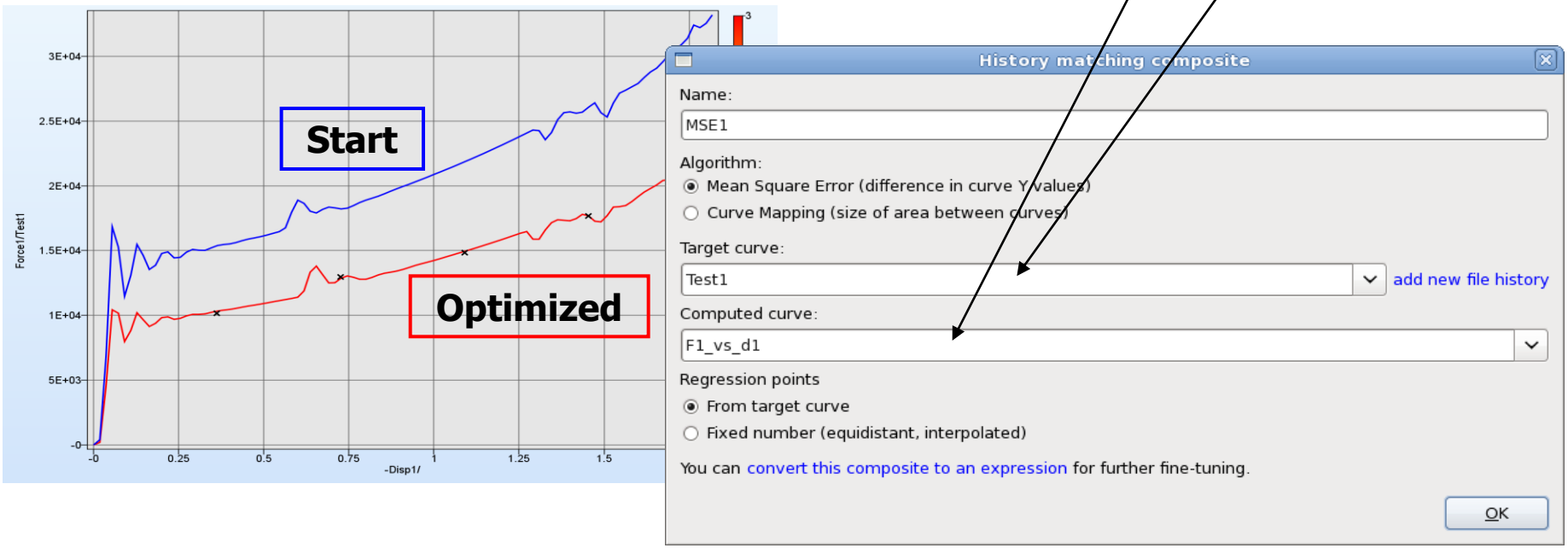




Applications of LS-OPT

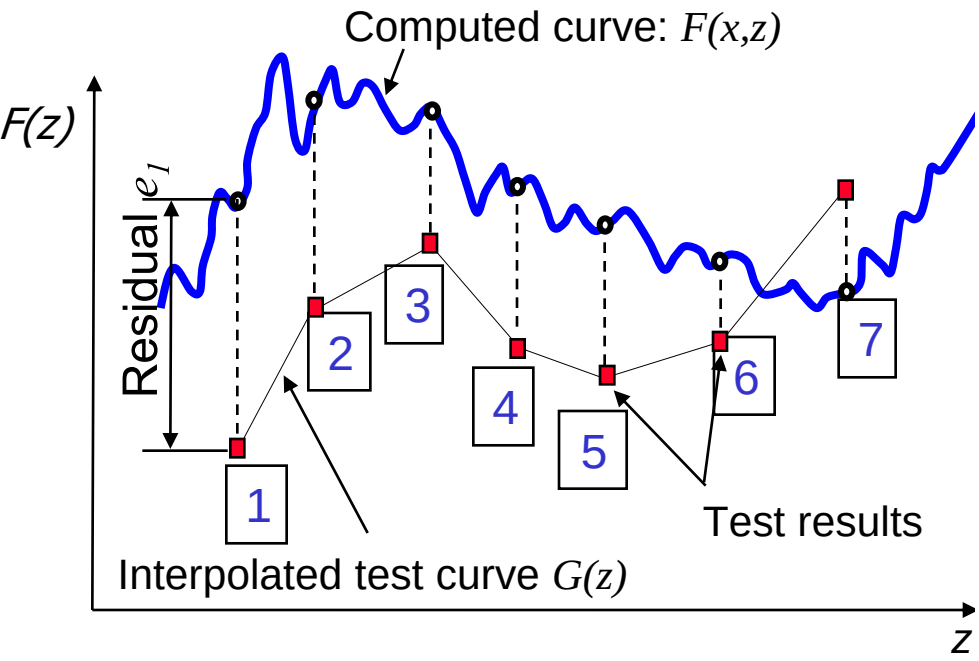
- Parameter/System Identification
  - *Calibration of test and simulation curves or scalar values*
  - *Visualization of test and simulation curve for comparison*

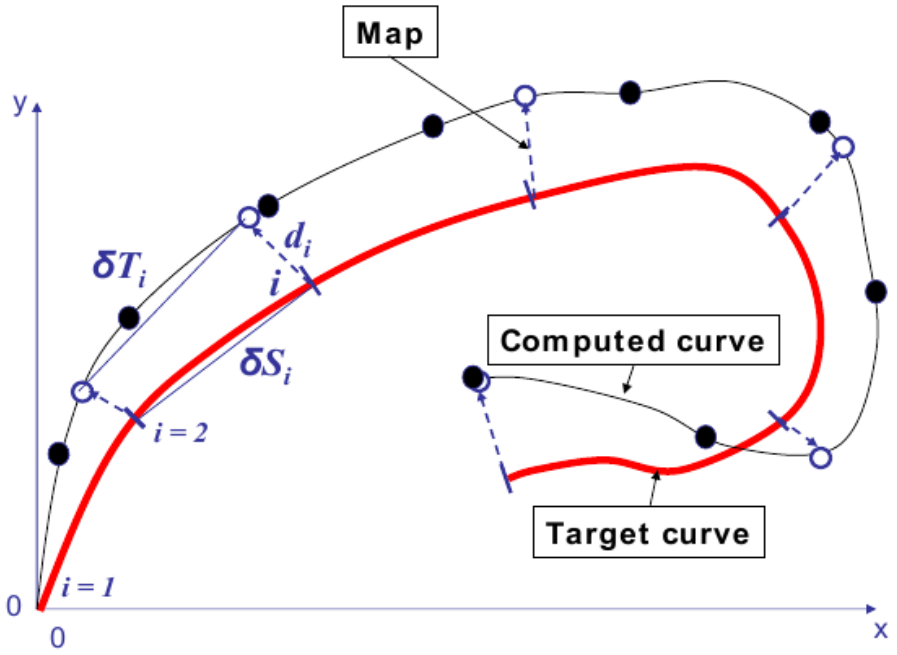
$$\frac{1}{P}\sum_{p=1}^{P} W_i \left(\frac{F_i(\boldsymbol{x}) - G_i}{s_i} \right)^2$$



Applications of LS-OPT

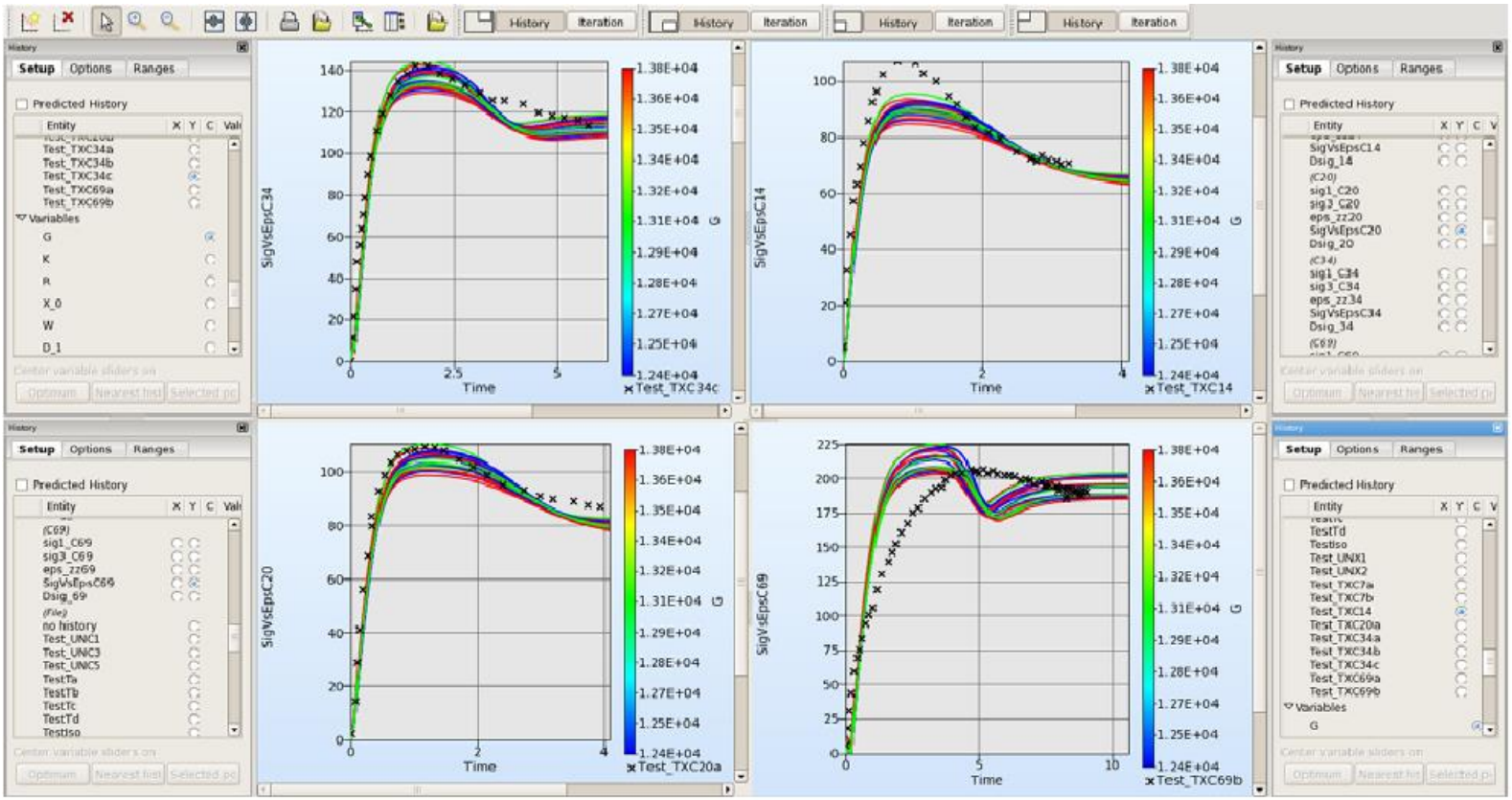
- Parameter Identification with Test Curves





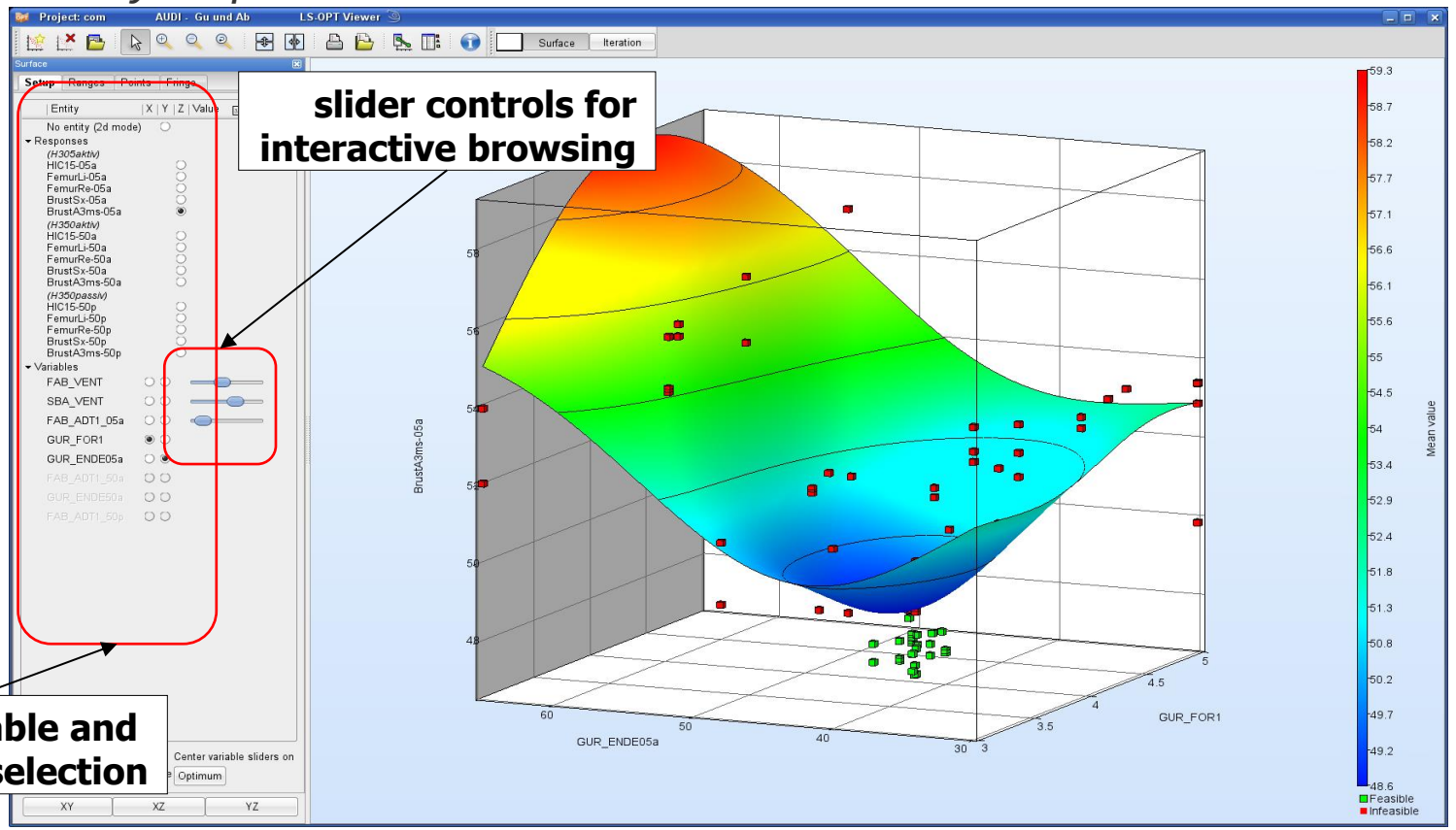
Applications of LS-OPT

- Computed history curves vs. Target curves



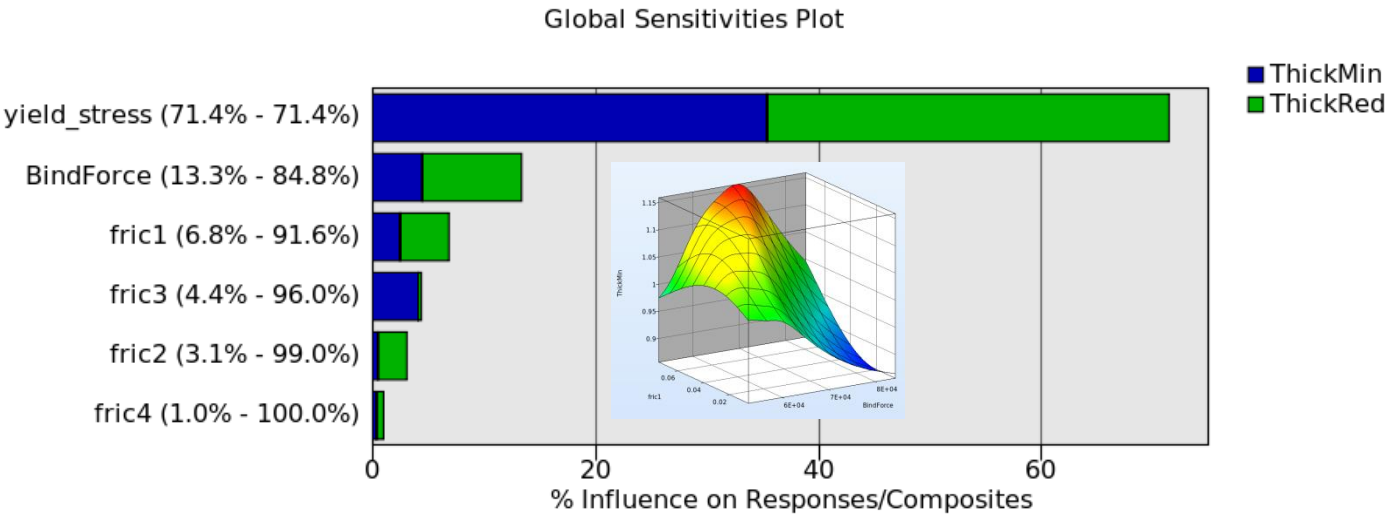
Applications of LS-OPT

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



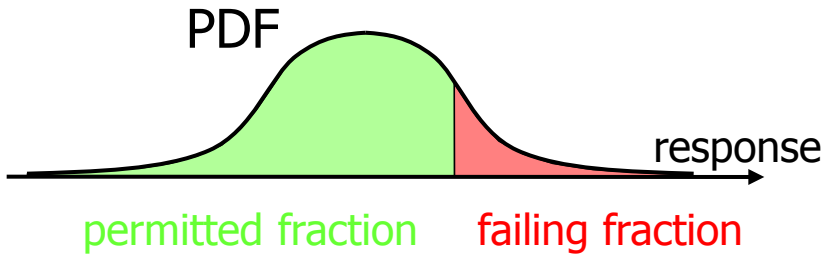
Applications of LS-OPT

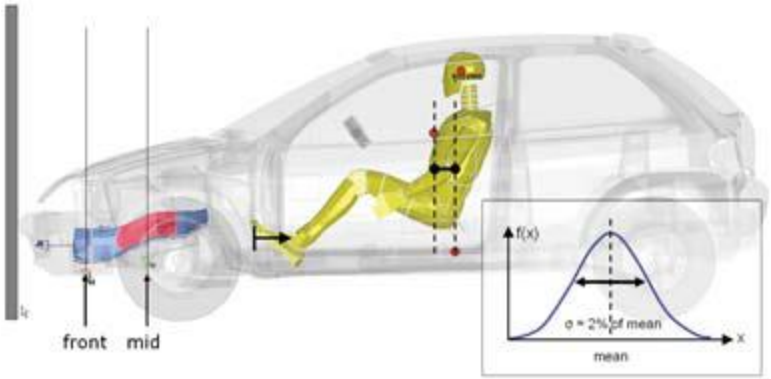
- Sensitivity Studies (ANOVA, Sobol)
  - *Contribution of variables to system performance*
  - *Identification of significant and insignificant variables*
  - *Ranking of importance*

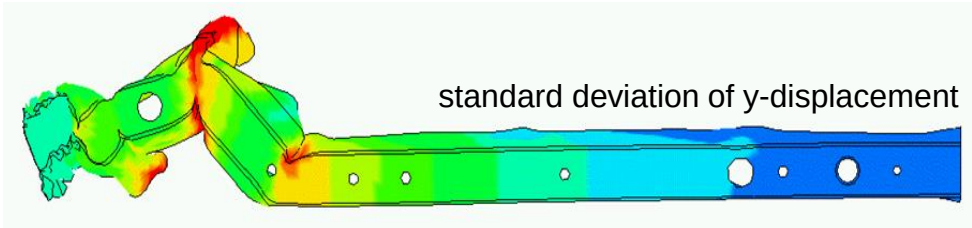


Applications of LS-OPT

- Robustness/Reliability Analysis
  - *Consideration of uncertainties*
  - *Evaluation of reliability (probability of failure)*
  - *Statistics (mean, std, …)*
  - *Correlation analysis*
  - *Confidence intervals*
  - *Outlier analysis*
  - *Fringe statistical results on FE model*

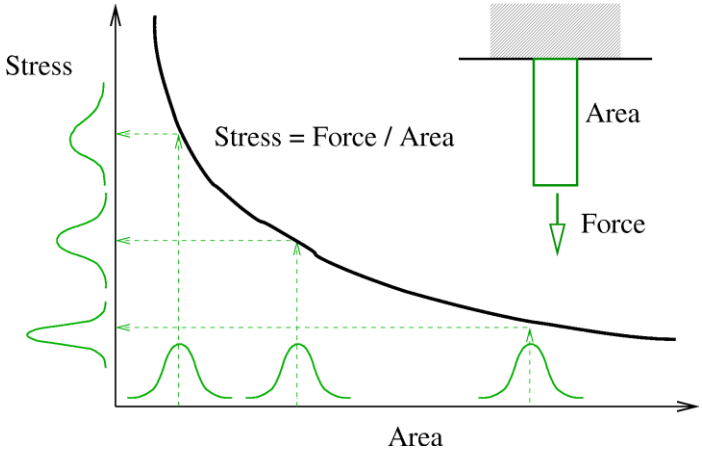


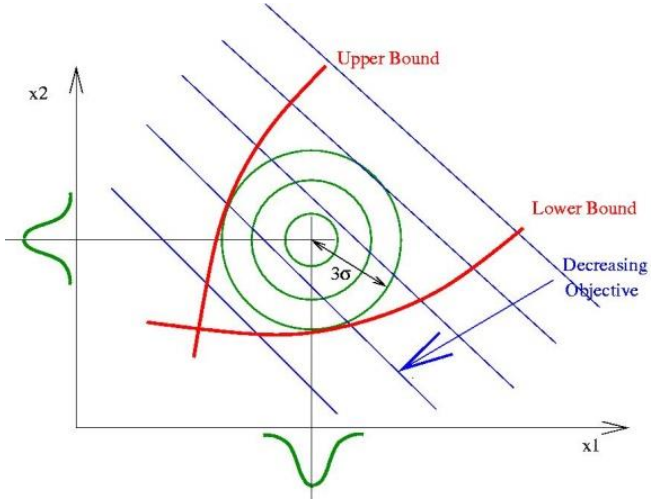




Applications of LS-OPT

- Robust Parameter Design (RDO)
  - *Improve/Maximize the robustness of the optimum*
- Reliability Based Design Optimization (RBDO)
  - *Improve failure probability of optimum*

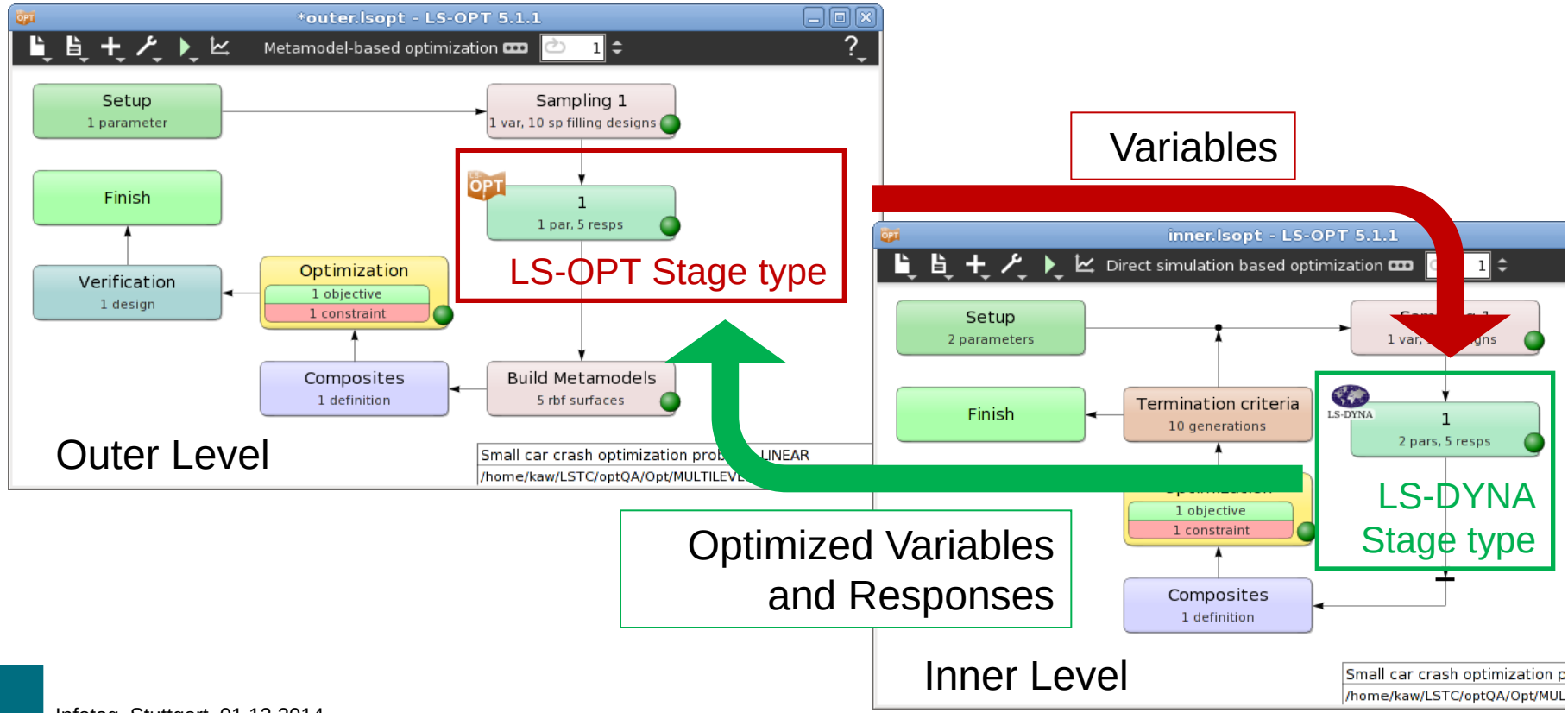




New developments in V 5.1

Multi-level optimization

- Subdivision of problem into levels
- Nesting the optimization problem
- Variables and responses are transferred between levels
- Inner level optimization is done for each outer level sample



Multi-level optimization: Why?

- *Organization*. Easier to organize the problem as a collection of subsystems
- *Efficiency.* Solution algorithm takes advantage of the subproblem type
  - *Can match optimization methods with different variable types, e.g. materials (categorical), sizing/shape (continuous).*
- *Robustness and accuracy.* Smaller sub-problems are typically solved in a relatively low-dimensional space
- Critical framework for rational decomposition methods: *Analytical Target Cascading*
  - *Iterative method which resolves inconsistencies between individual processes with shared variables*

Multi-level optimization: Applications

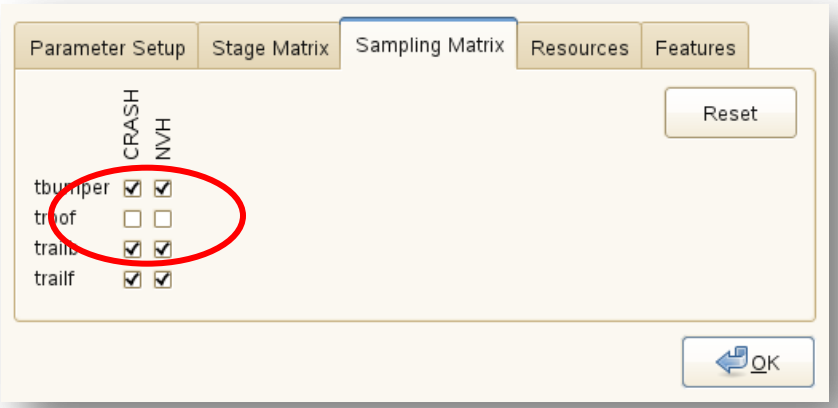
- Applications:
  - *System Optimization (component sublevels)*
  - *Design of Product families*
  - *Tolerance optimization*

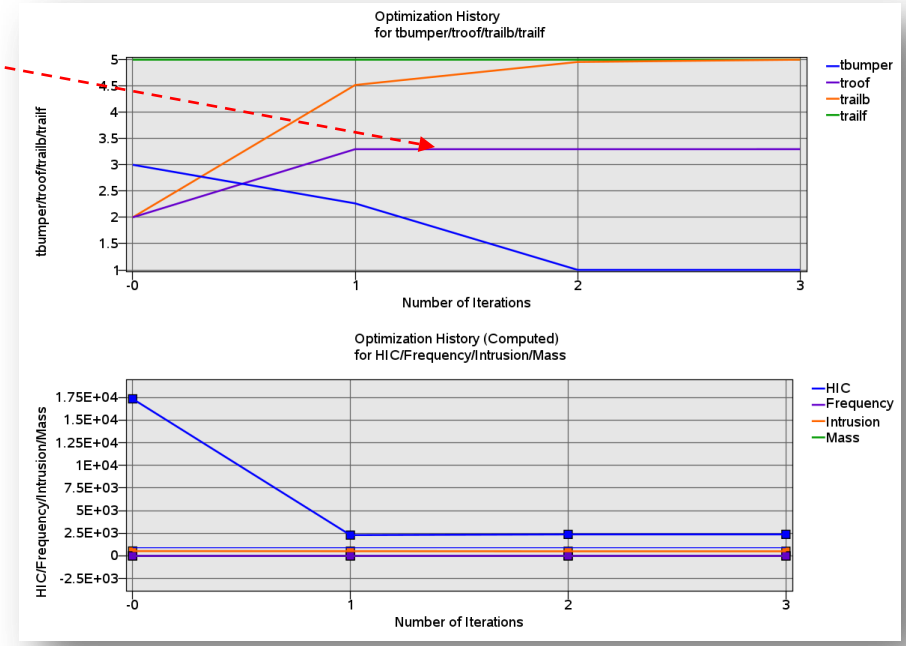
    (Basudhar, A. and Stander, N. Tolerance Optimization using LS-OPT, Proceedings of the LS-DYNA Forum, Bamberg, October, 2014)
  - *Robust design using Random Fields*

    (*Craig, K.-J. and Stander, N. Optimization of shell buckling incorporating Karhune-Loève-based geometrical imperfections, Structural and Multidisciplinary Optimization, 2008, 37:185:194)*

Variable deactivation (iterative methods)

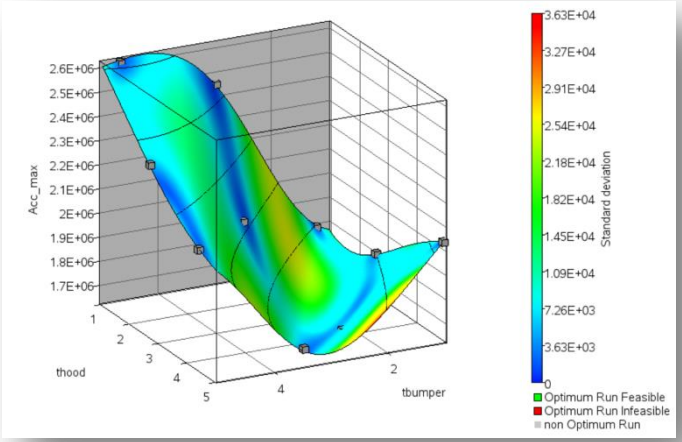
- Optimization: large number of function evaluations, especially in multi-level setup
- Variables can be manually de-activated
  - *Save computational effort (variable screening)*
  - *Variable is frozen*
  - *Seamless restart*

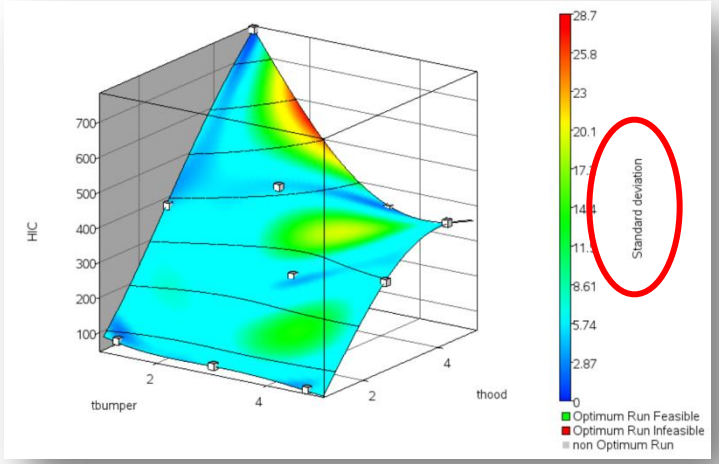




Parallel Neural Networks: Motivation

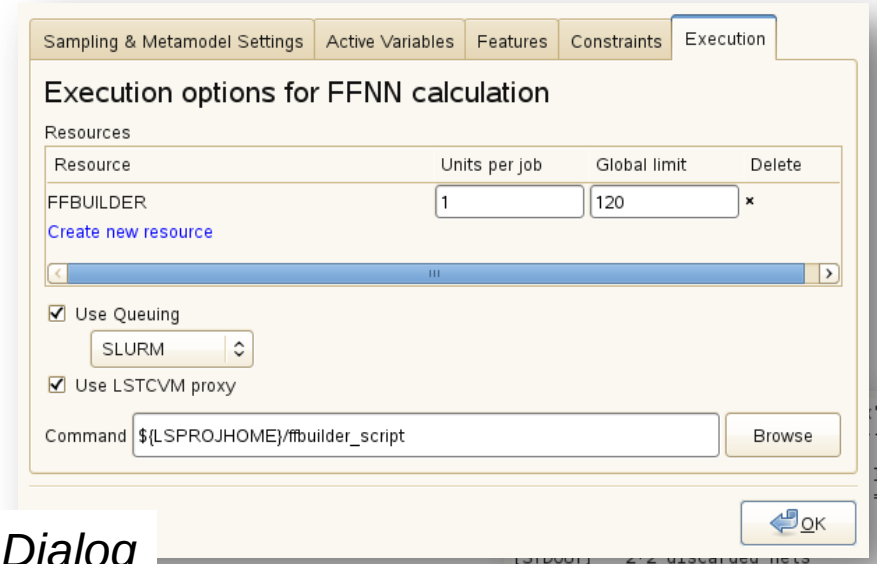
- High metamodel accuracy required. Even with screening, appropriate metamodeling tools needed
- Feedforward Neural Networks
  - *High accuracy global approximation. Good bias-variance compromise. Variance information available (illustrated below)*
  - *Expensive. Vehicle crash often 100+ responses. Solved independently due to nonlinearity. Reduction (as when linear) not possible.*
    - ***Ensembles*** **(sorting through hidden nodes to get the right order)**
      - ***Committees*** **(Monte Carlo method to improve prediction)**
  - *Ensembles and Committees are suitable for parallelization*



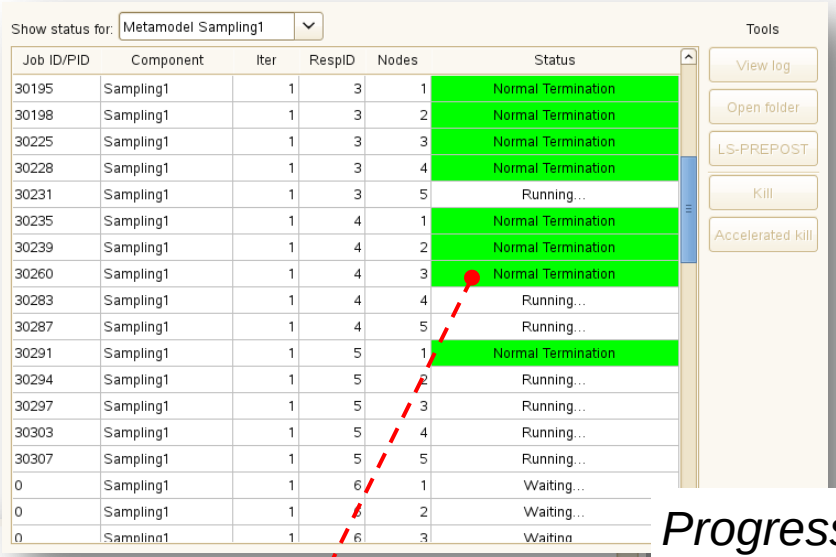


Parallel Neural Networks: Interface

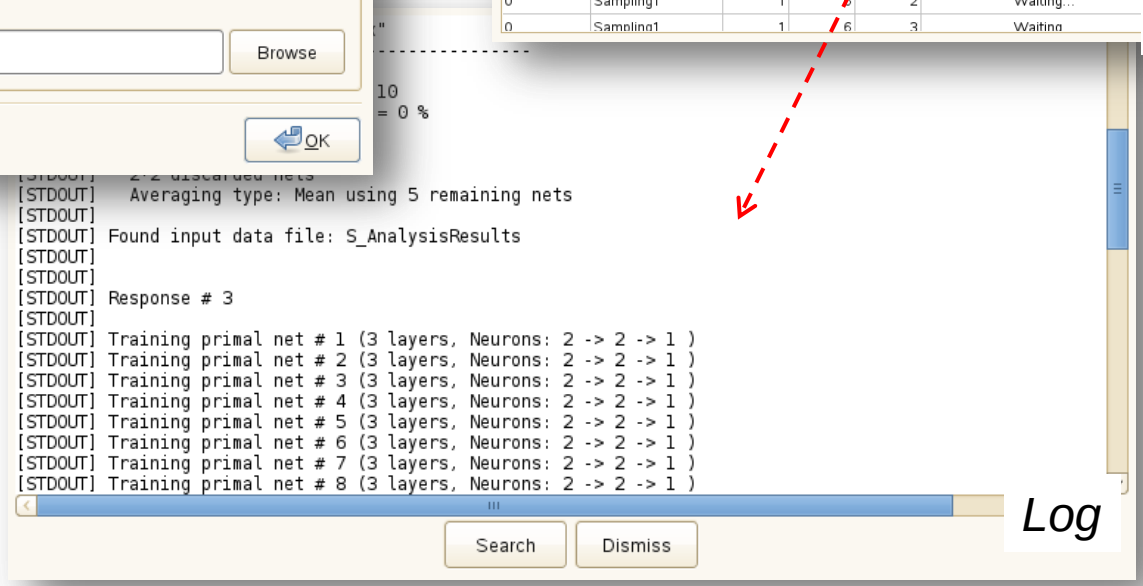
- Functionality similar to solver job monitoring
- Jobs can be distributed



Dialog



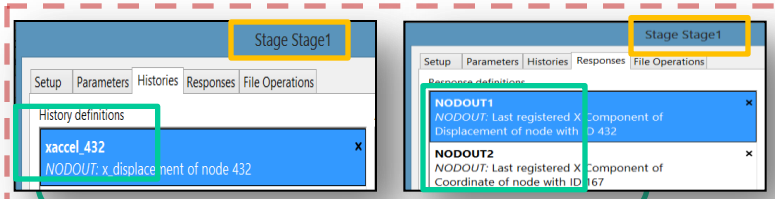
Progress

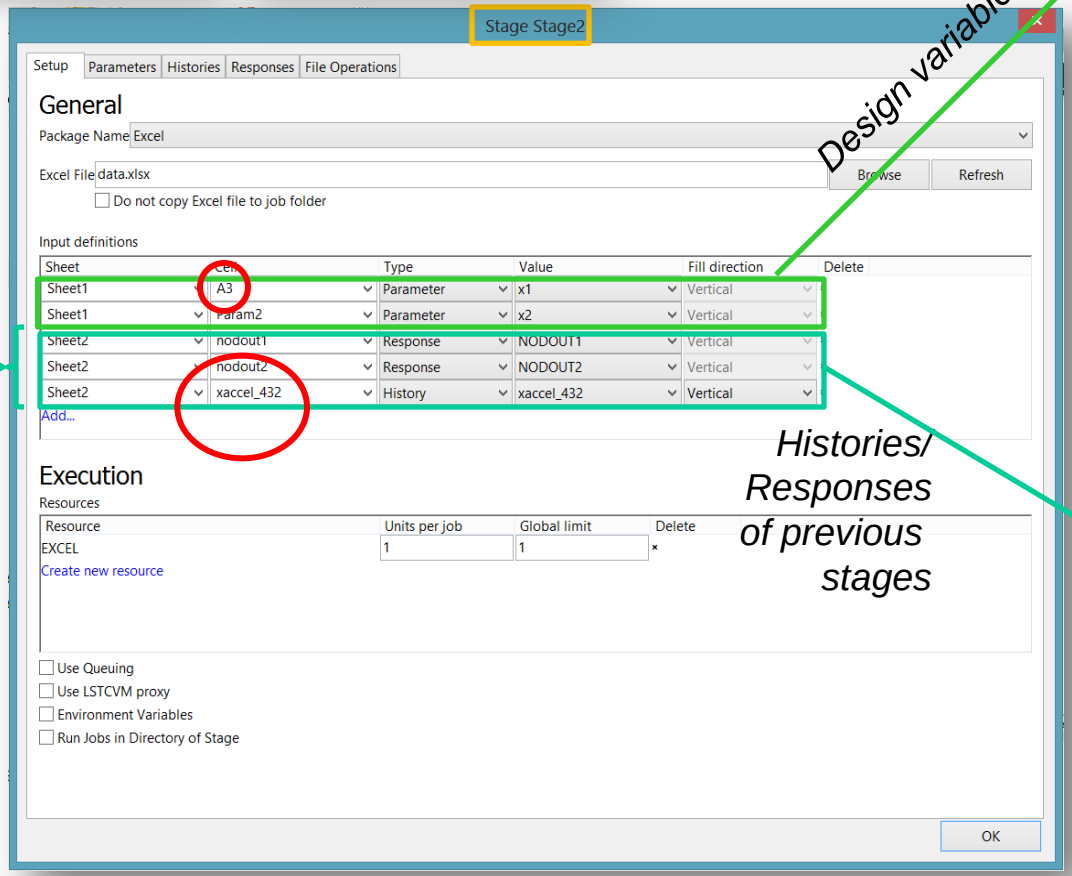


Log

Excel Interface (Substitution)

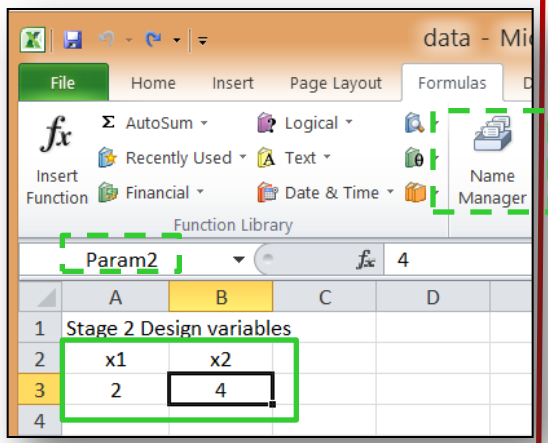
Inputs from LS-OPT to Excel fields

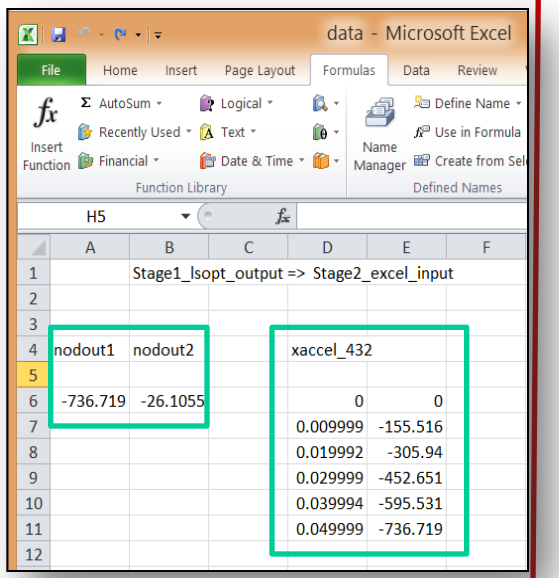




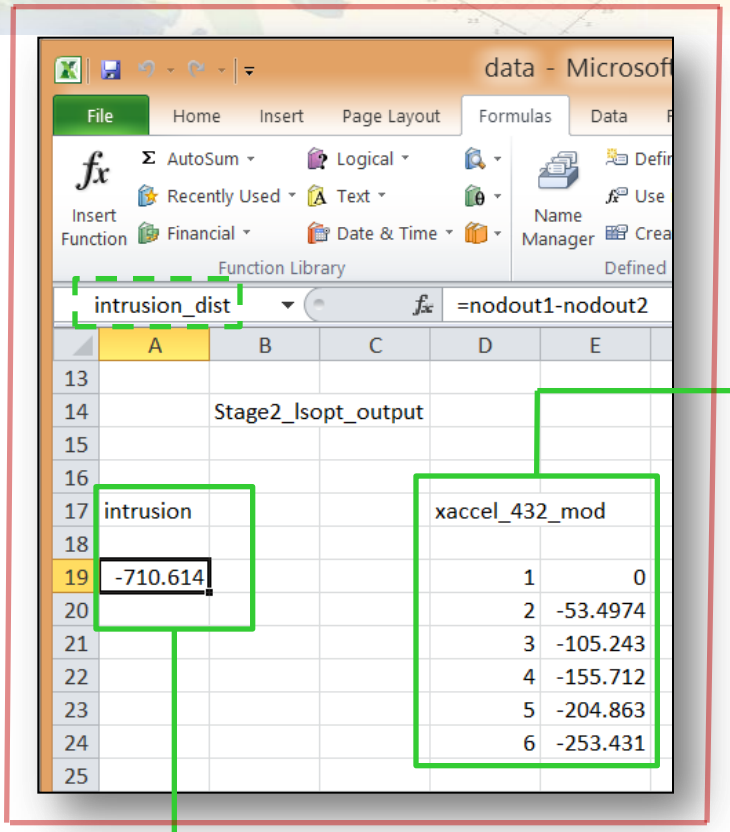
Design variables

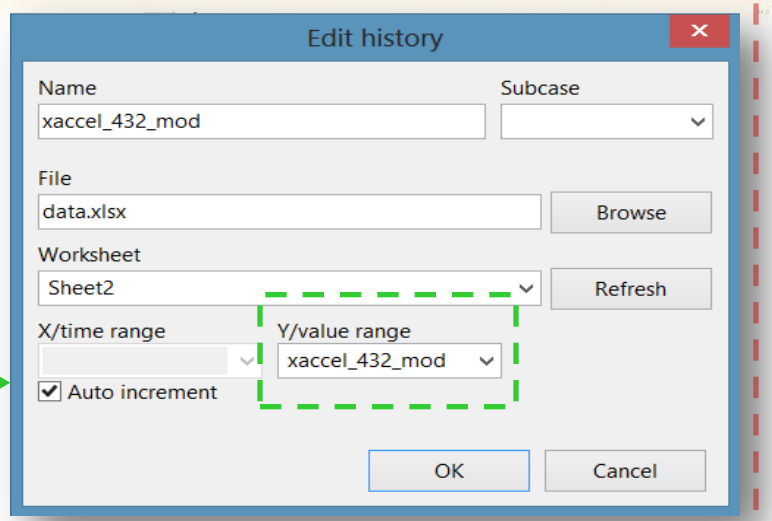
Histories/ Responses of previous stages

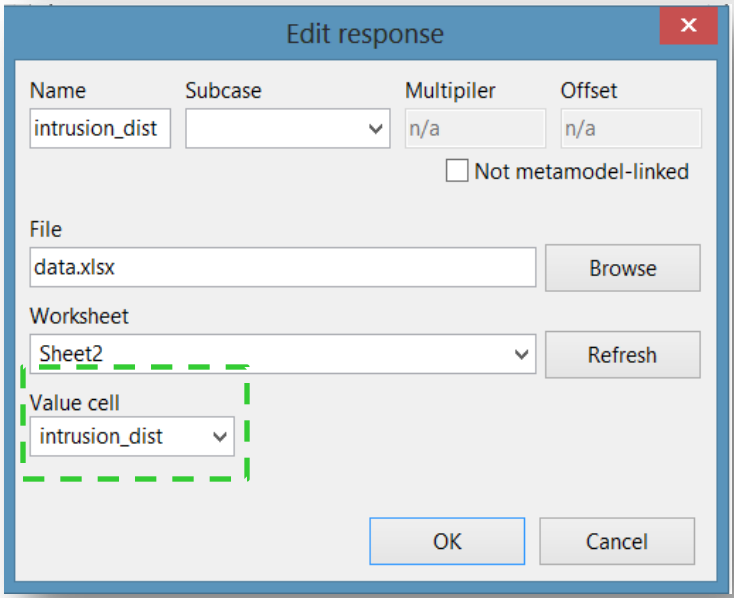




Excel interface (extraction)



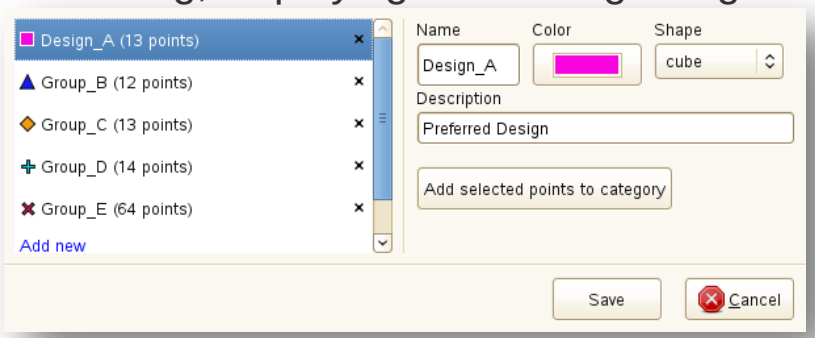




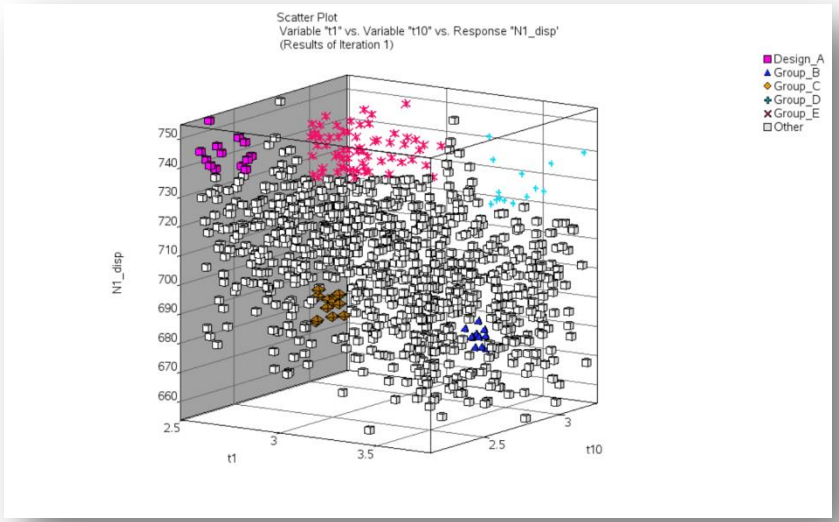
Excel fields as LS-OPT histories/responses

Design Point Categories

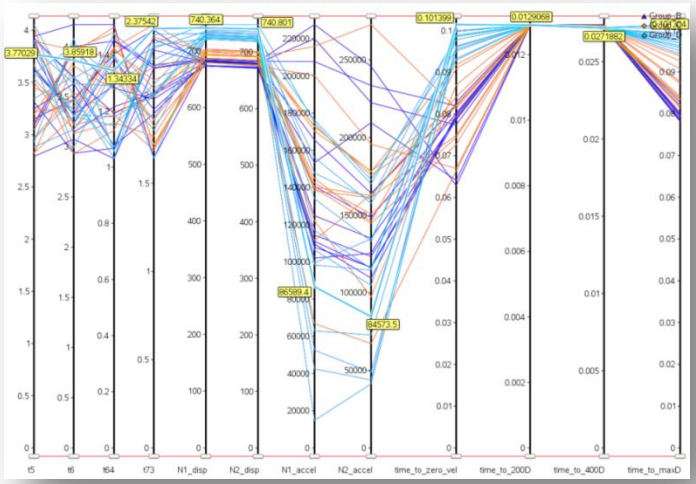
- Picking, displaying and saving designs of interest

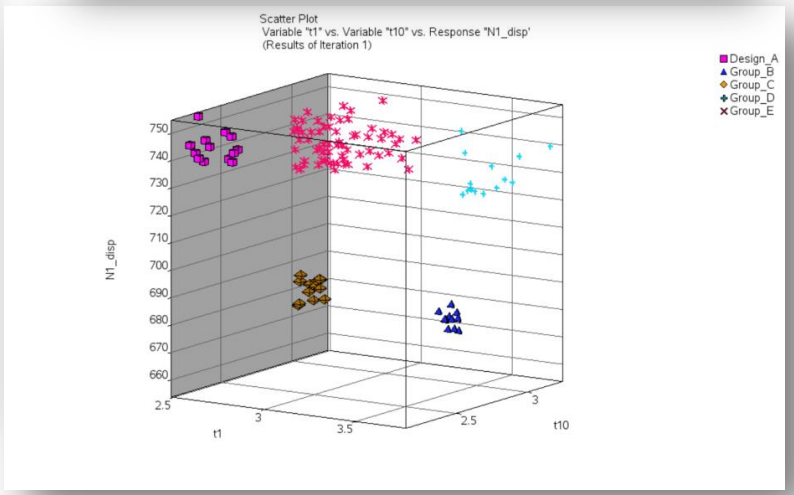


Dialog

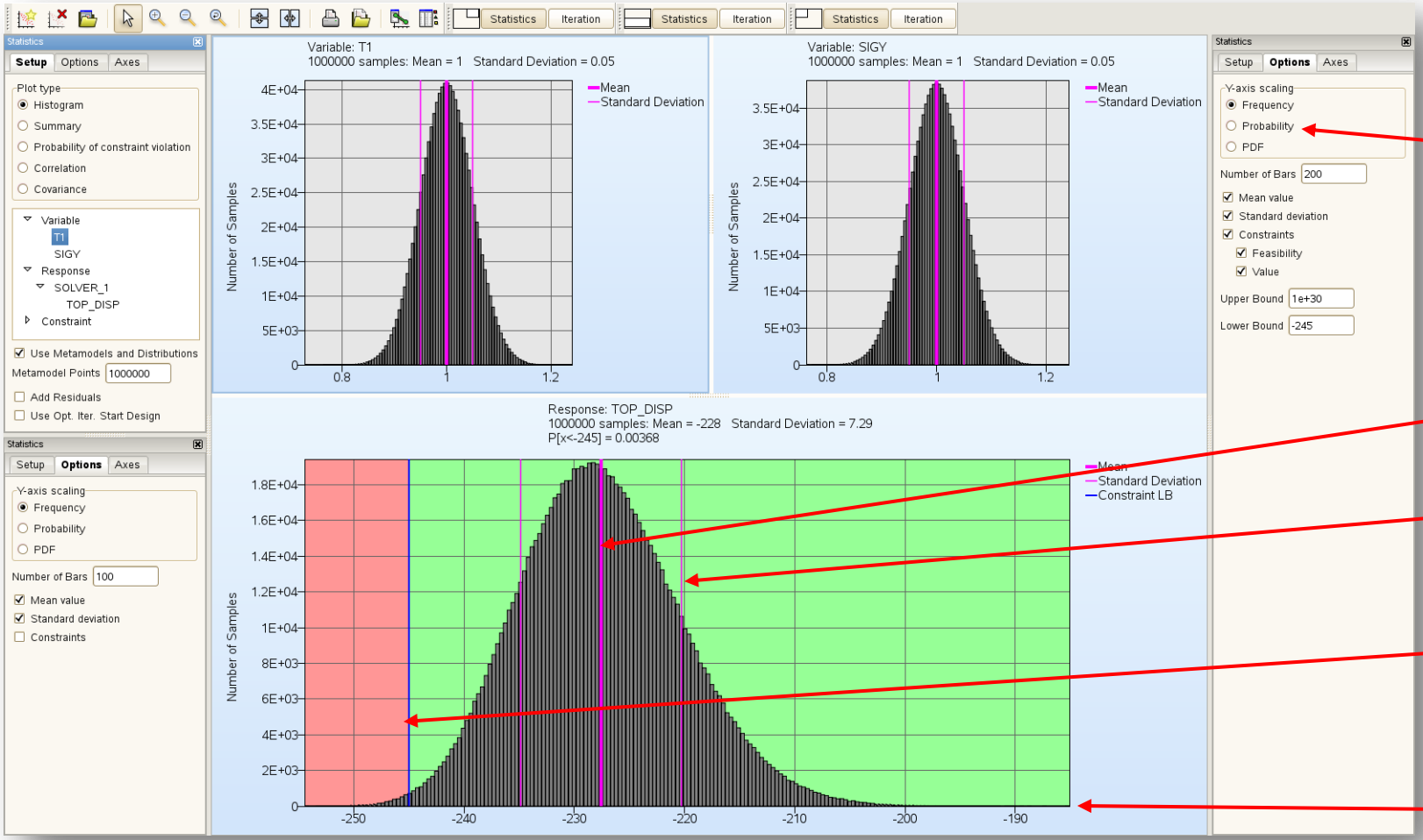


Categories + Other





Histogram Plot: Attributes



Type

Mean

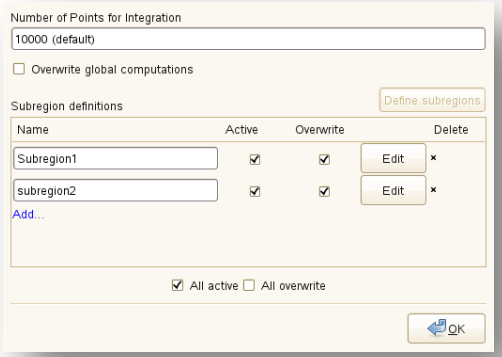
Std Dev

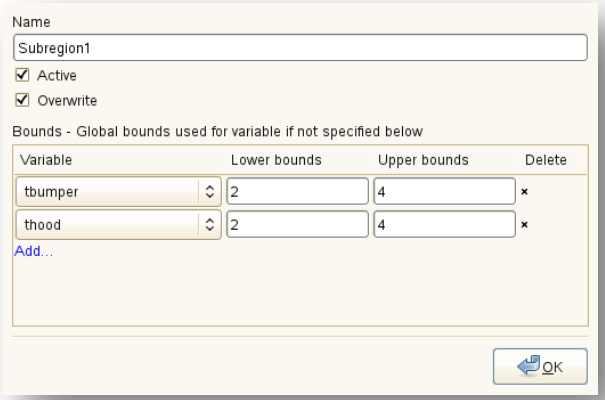
Const. bound

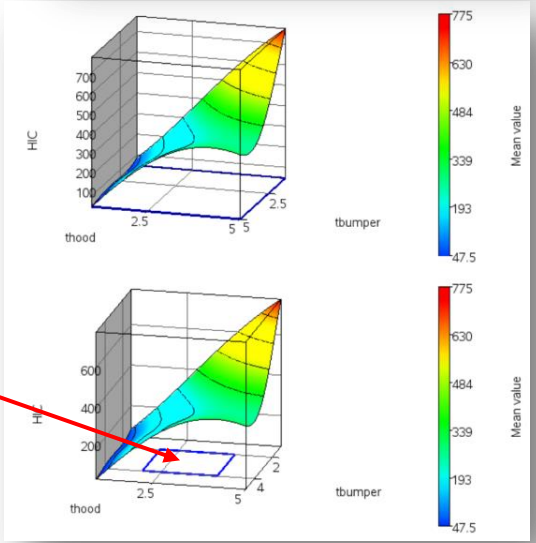
Axis limits

Global Sensitivities: Subregions

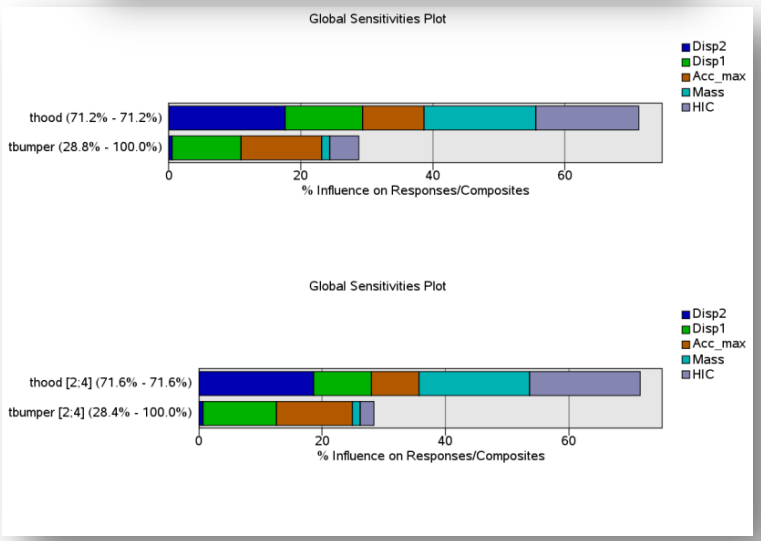
- Sensitivities within specific design *proximity*
- Can set up *multiple* sub-regions interactively







Sub-region



Outlook

- Viewer (post-processing, data mining)
  - *Result table manipulation: integration of categories into tables, etc.*
  - *Speed improvements to Viewer displays*
  - *Predicted design displays: generate cluster of surrogate results*
- Reliability
  - *Probability Density Function approximation from empirical data*
    - **Kernel density approximation**
  - *Sequential reliability analysis*
    - **Convergence of probability of failure value**
    - **Adaptive sampling**
  - *Tolerance-based optimization*
- Metamodels: performance and usability
  - *Multiple metamodel type displays: comparison of metamodels*
- More solver interfaces:
  - *Matlab*
  - *LS-TaSC*