



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

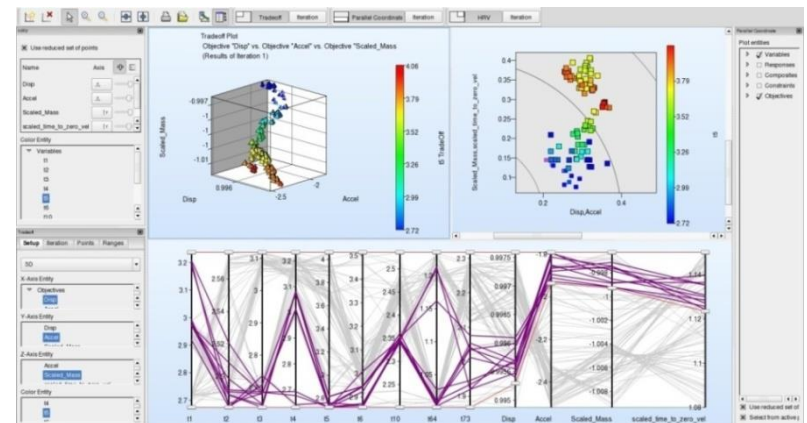
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Outline

- 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*

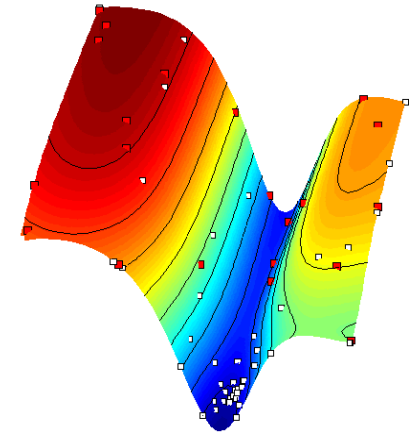


■ Outlook

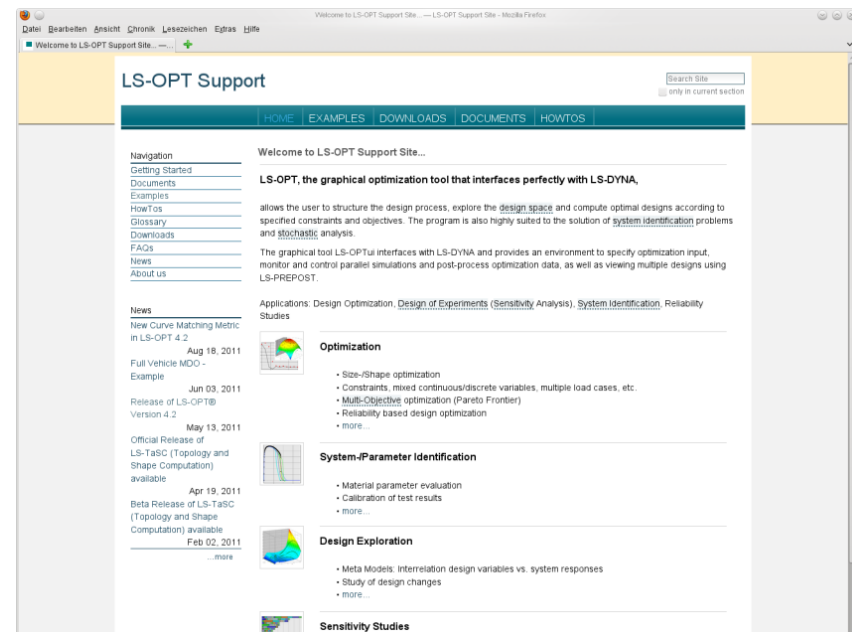
Introduction

→ 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.*

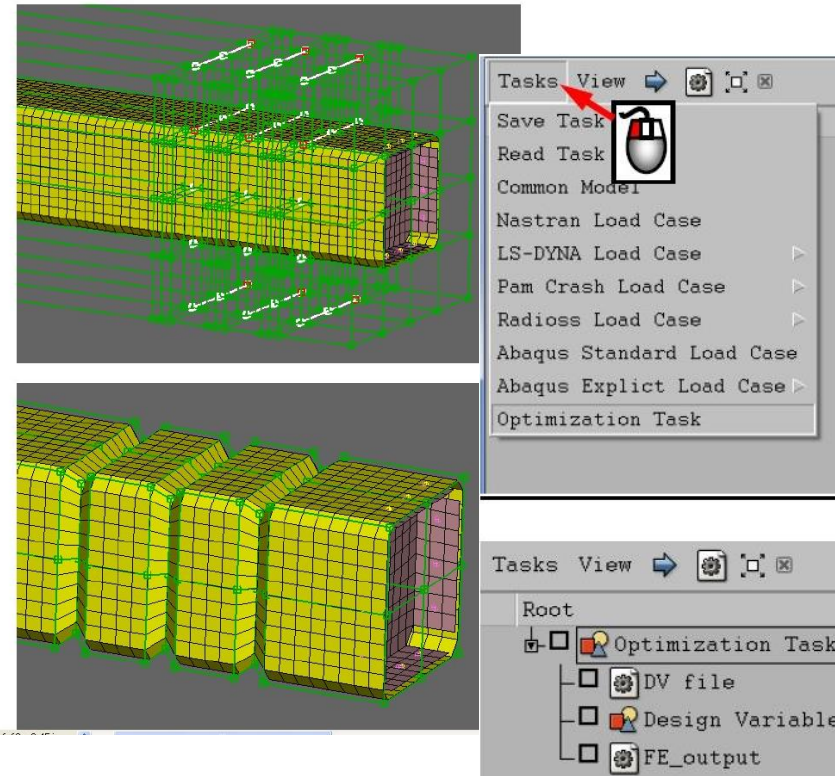
■ LS-OPT might be used as a “Process Manager”

■ Interfaces to Preprocessors (→ Shape Optimization)

- *LS-PrePost, ANSA, HyperMorph, ...*
- *User-defined interface*

■ Interfaces to Postprocessors

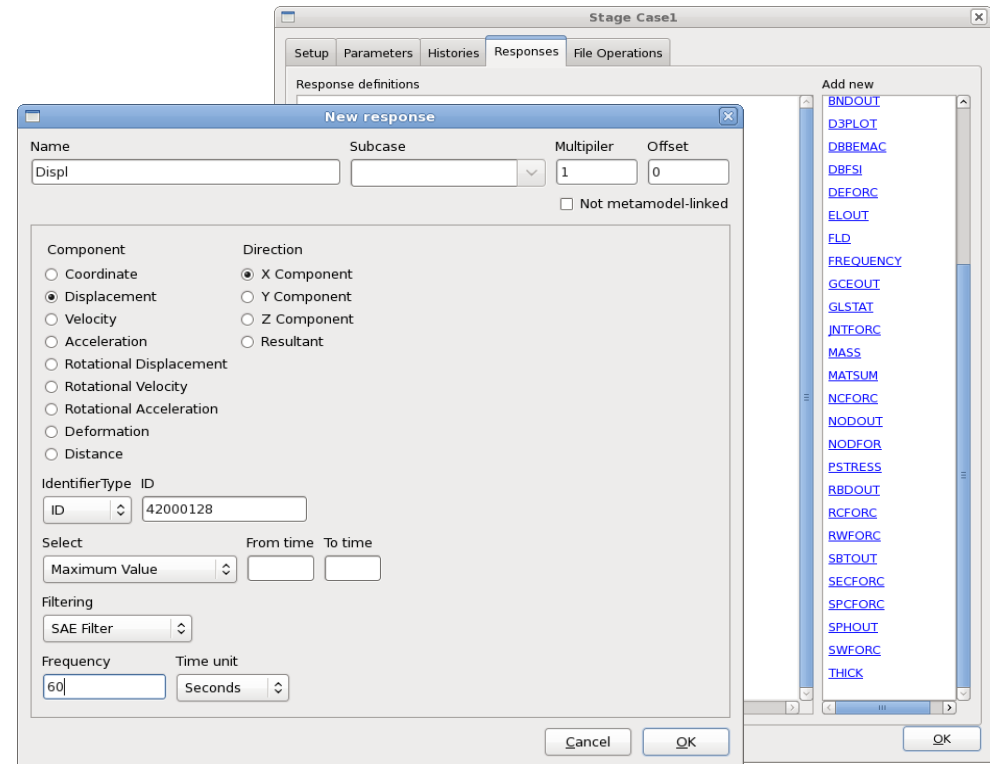
- *META Post: Allows extraction of results from any package (Abaqus, NASTRAN, ...) supported by META Post (ANSA package)*
- *User-defined interface*



➔ 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)

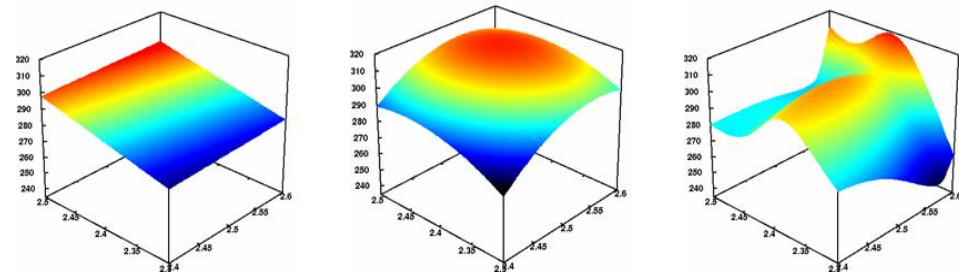
■ *Sequential Response Surface Method (SRSM)*

→ Metamodels

■ *Polynomials*

■ *Radial Basis Functions*

■ *Feedforward Neural Networks ...*



■ Genetic Algorithm (MOGA->NSGA-II)

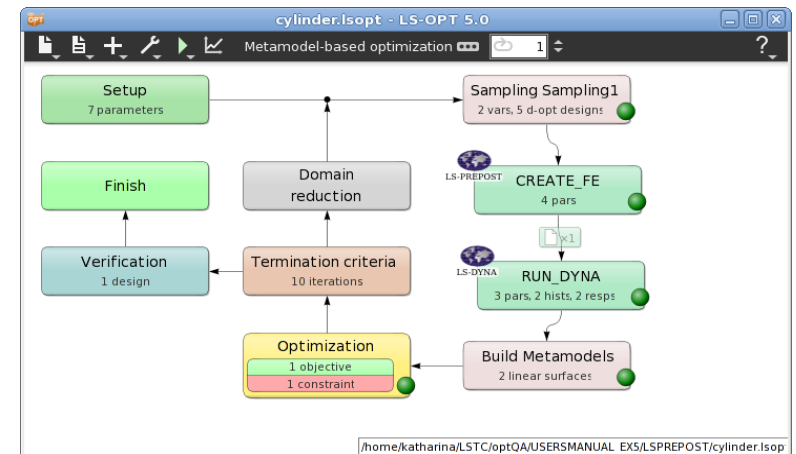
■ *Direct*

■ Metamodel-based

■ Monte Carlo Analysis

■ *Direct*

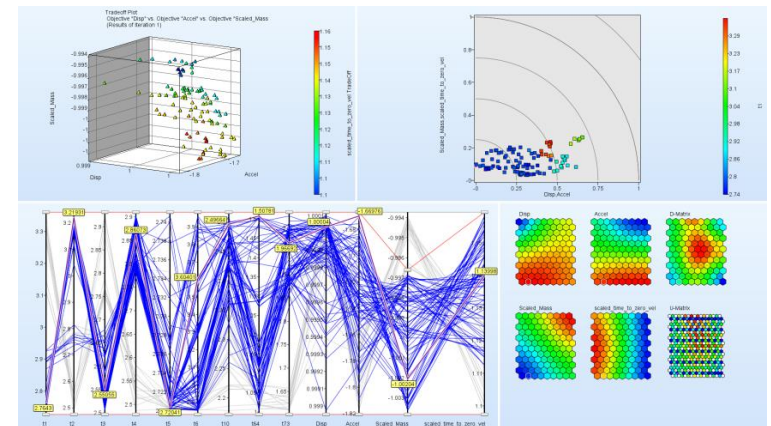
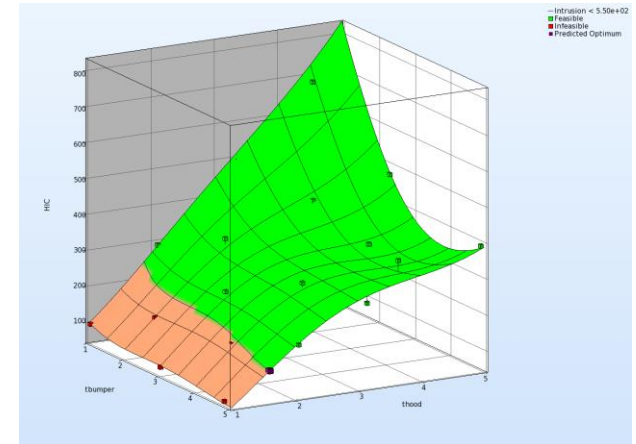
■ Metamodel-based



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

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



History matching composite

Name:

Algorithm:

- Mean Square Error (difference in curve Y values)
- Curve Mapping (size of area between curves)

Target curve: add new file history

Computed curve:

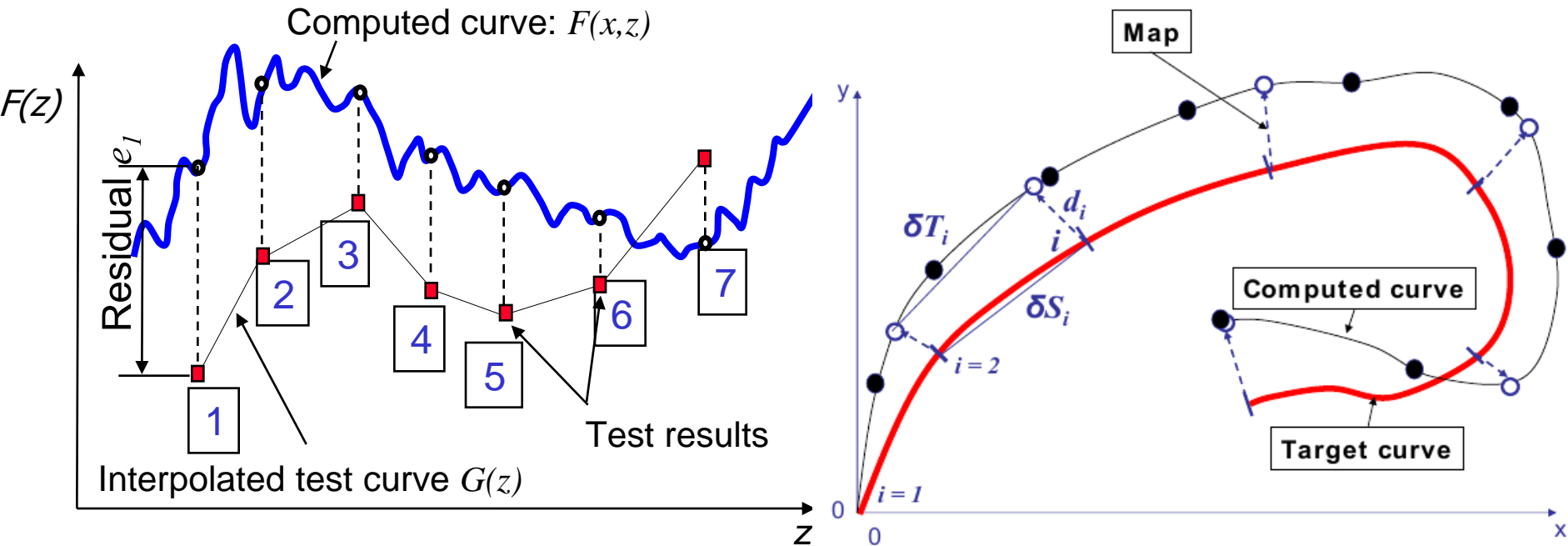
Regression points

- From target curve
- Fixed number (equidistant, interpolated)

You can [convert this composite to an expression](#) for further fine-tuning.

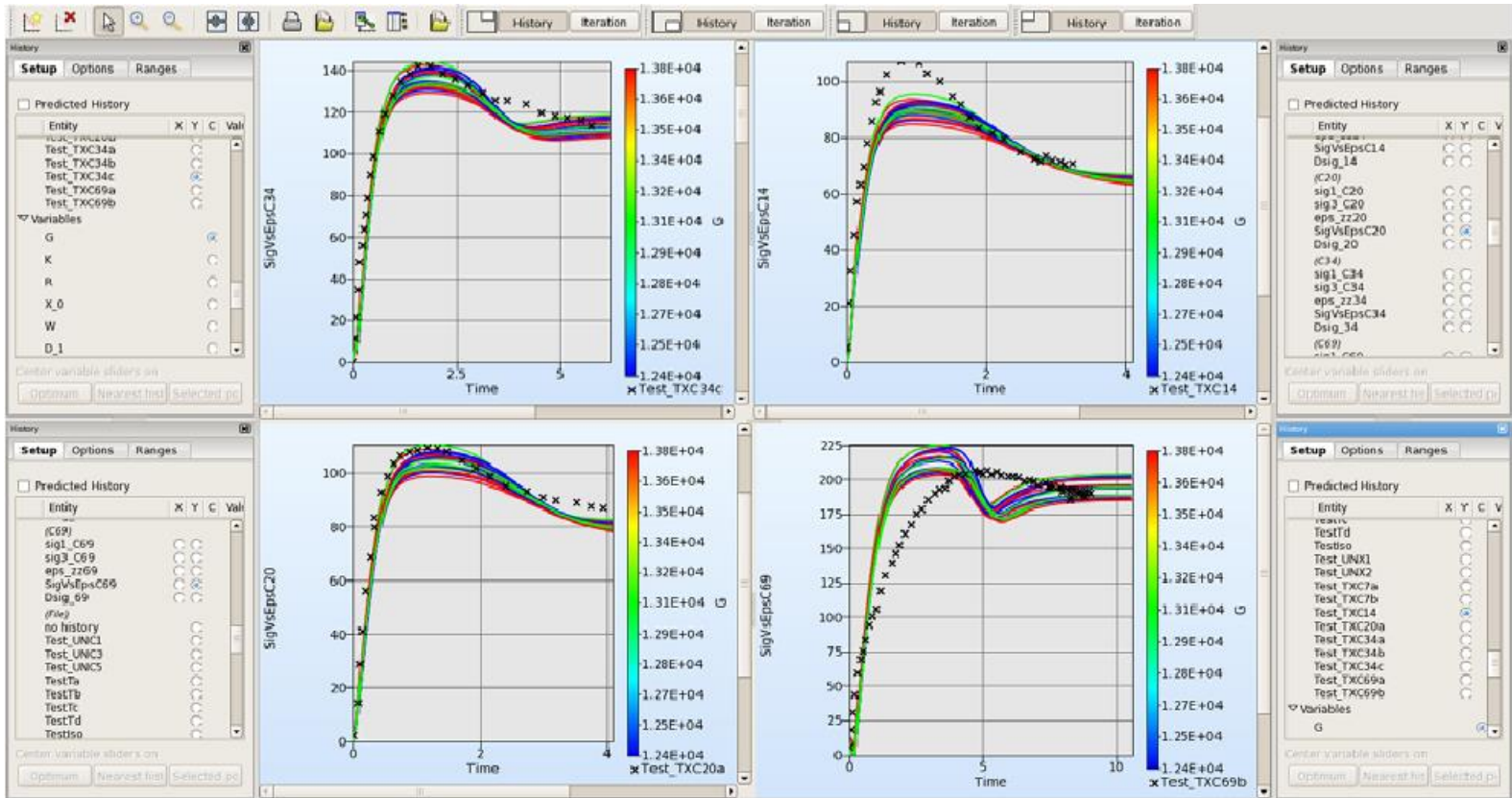
Applications of LS-OPT

Parameter Identification with Test Curves



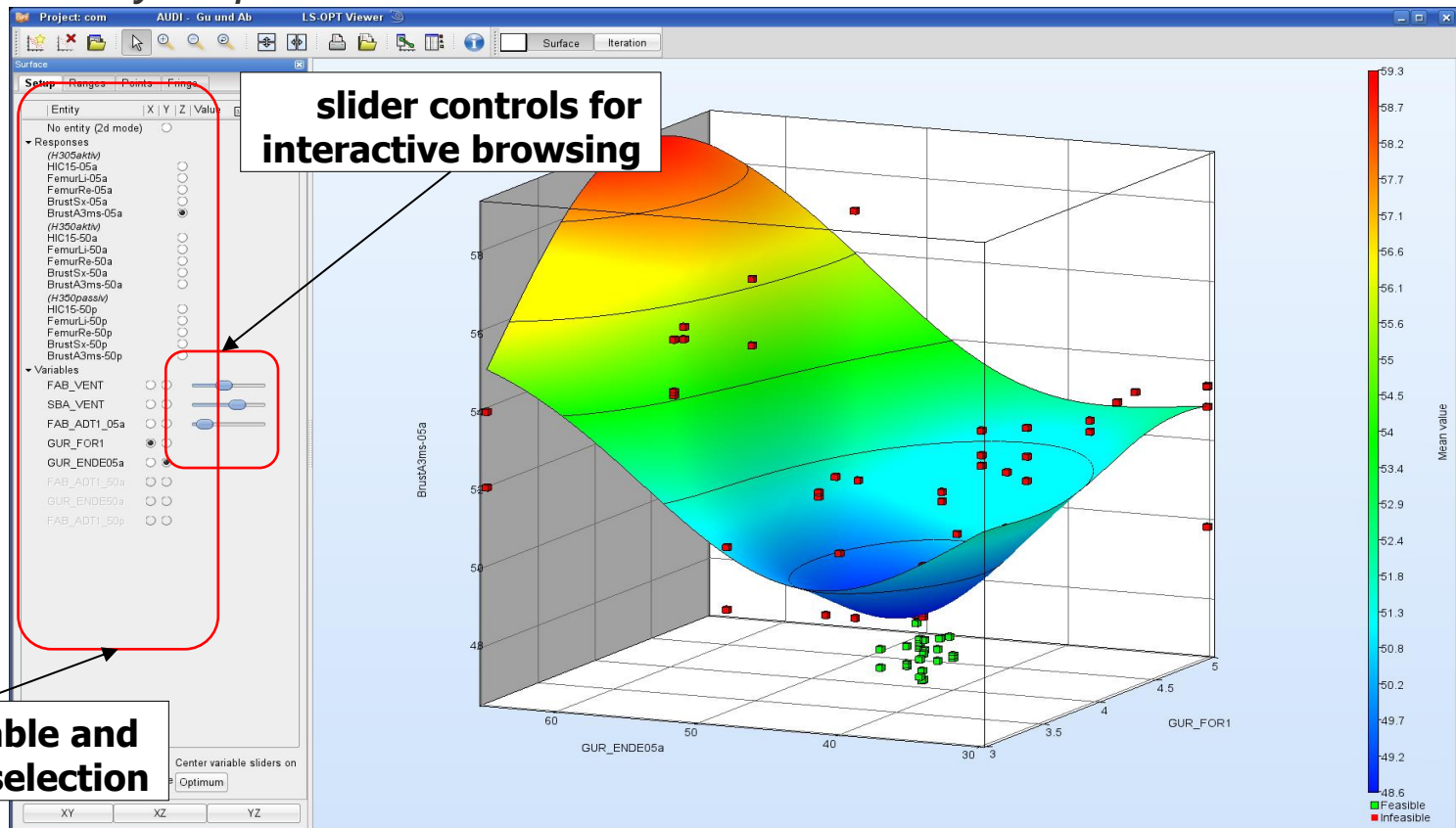
Applications of LS-OPT

■ Computed history curves vs. Target curves



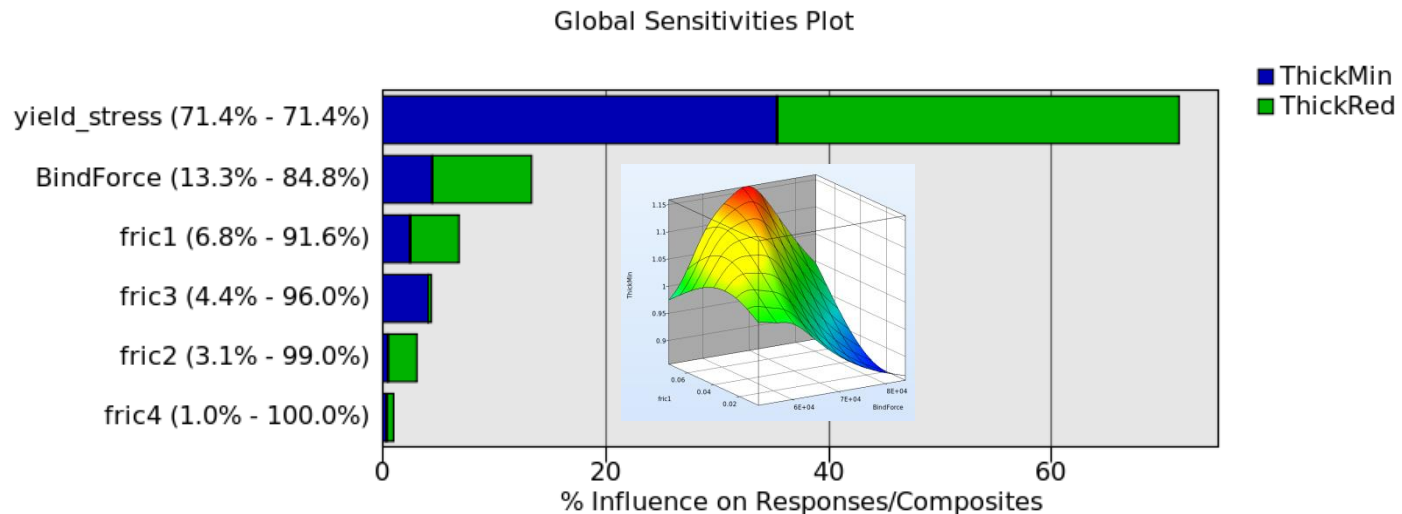
Applications of LS-OPT

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



Applications of LS-OPT

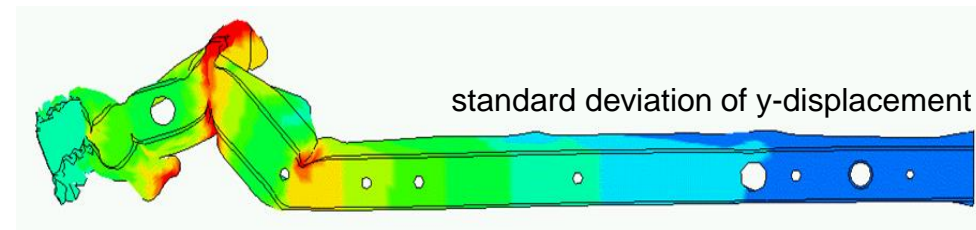
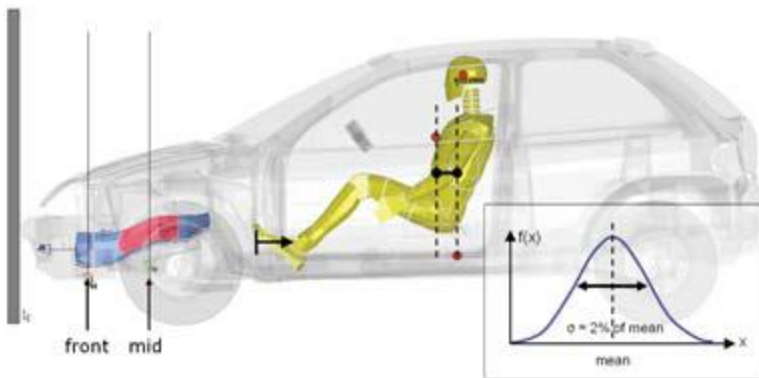
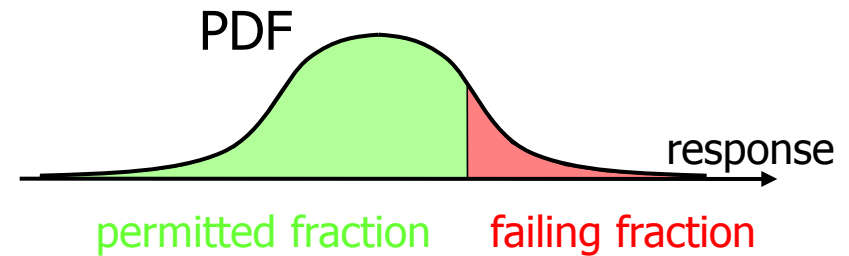
- Sensitivity Studies (ANOVA, Sobol)
 - *Contribution of variables to system performance*
 - *Identification of significant and insignificant variables*
 - *Ranking of importance*



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*



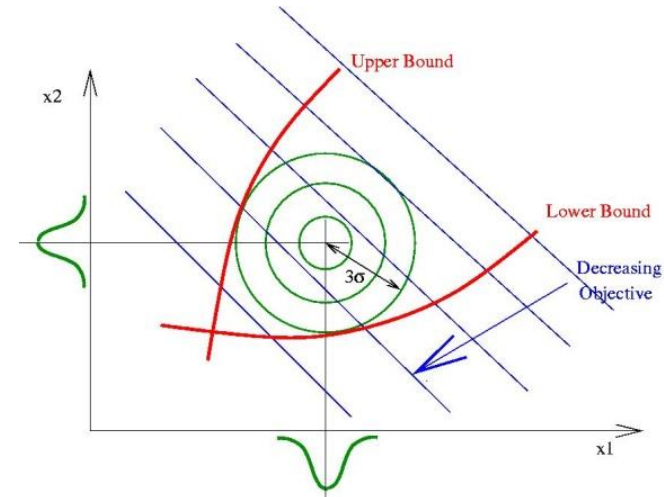
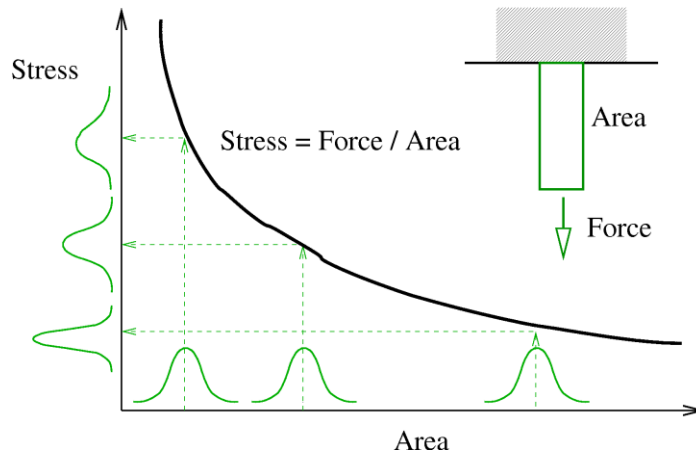
Applications of LS-OPT

■ Robust Parameter Design (RDO)

- *Improve/Maximize the robustness of the optimum*

■ Reliability Based Design Optimization (RBDO)

- *Improve failure probability of optimum*

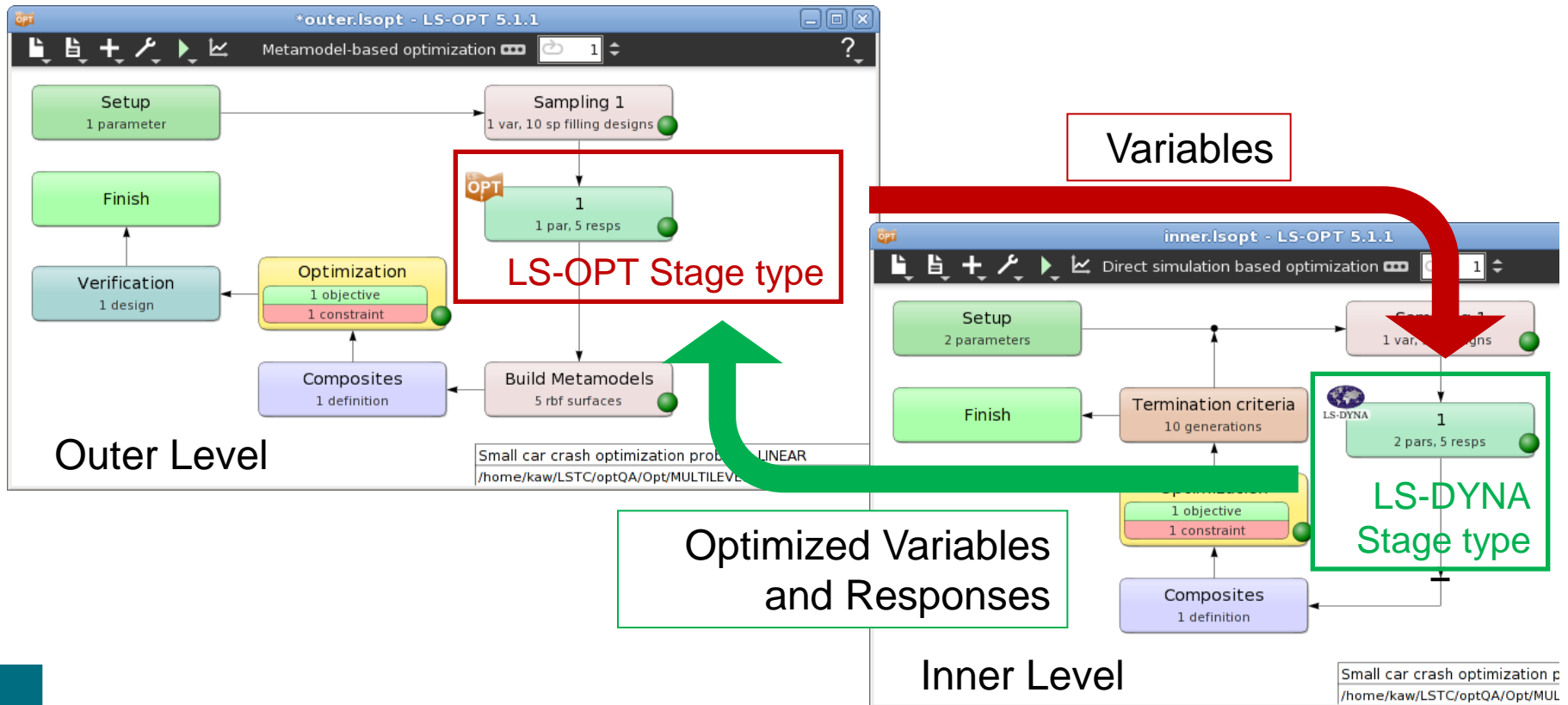




New developments in V 5.1

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*

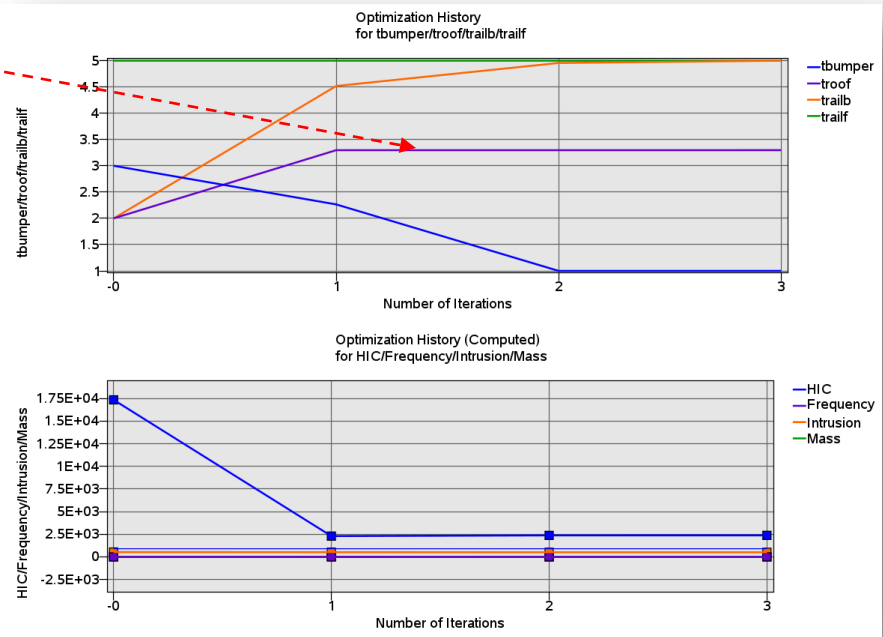
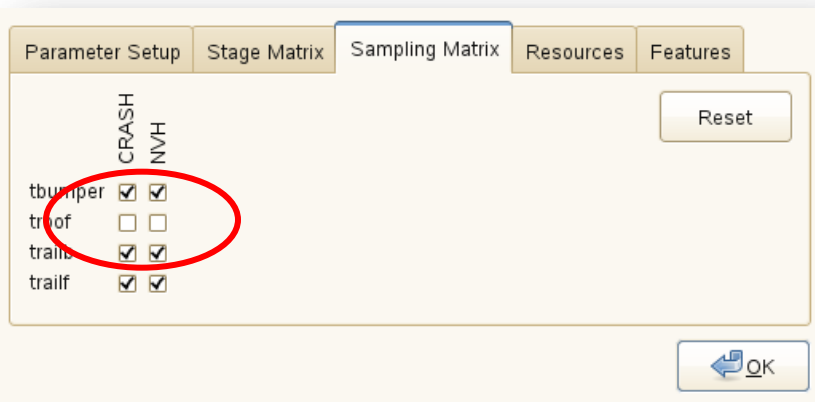
(Basudhar, A. and Stander, N. Tolerance Optimization using LS-OPT, Proceedings of the LS-DYNA Forum, Bamberg, October, 2014)

- *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)

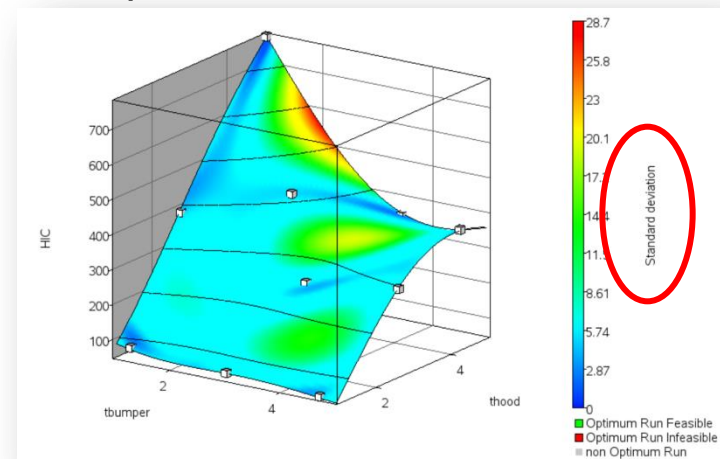
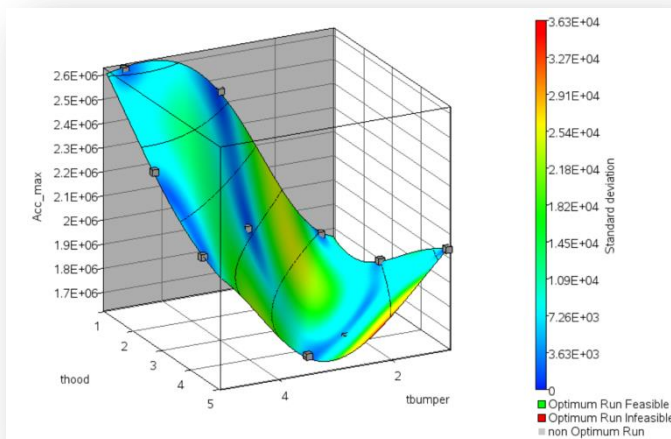
Variable deactivation (iterative methods)

- 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

Sampling & Metamodel Settings | Active Variables | Features | Constraints | Execution

Execution options for FFNN calculation

Resources

| Resource | Units per job | Global limit | Delete |
|-----------|---------------|--------------|--------|
| FFBUILDER | 1 | 120 | x |

[Create new resource](#)

Use Queuing
SLURM

Use LSTCVM proxy

Command: [Browse](#)

[OK](#)

Dialog

Show status for: Metamodel Sampling1

| Job ID/PID | Component | Iter | RespID | Nodes | Status |
|------------|-----------|------|--------|-------|--------------------|
| 30195 | Sampling1 | 1 | 3 | 1 | Normal Termination |
| 30198 | Sampling1 | 1 | 3 | 2 | Normal Termination |
| 30225 | Sampling1 | 1 | 3 | 3 | Normal Termination |
| 30228 | Sampling1 | 1 | 3 | 4 | Normal Termination |
| 30231 | Sampling1 | 1 | 3 | 5 | Running... |
| 30235 | Sampling1 | 1 | 4 | 1 | Normal Termination |
| 30239 | Sampling1 | 1 | 4 | 2 | Normal Termination |
| 30260 | Sampling1 | 1 | 4 | 3 | Normal Termination |
| 30283 | Sampling1 | 1 | 4 | 4 | Running... |
| 30287 | Sampling1 | 1 | 4 | 5 | Running... |
| 30291 | Sampling1 | 1 | 5 | 1 | Normal Termination |
| 30294 | Sampling1 | 1 | 5 | 2 | Running... |
| 30297 | Sampling1 | 1 | 5 | 3 | Running... |
| 30303 | Sampling1 | 1 | 5 | 4 | Running... |
| 30307 | Sampling1 | 1 | 5 | 5 | Running... |
| 0 | Sampling1 | 1 | 6 | 1 | Waiting... |
| 0 | Sampling1 | 1 | 6 | 2 | Waiting... |
| 0 | Samolind1 | 1 | 6 | 3 | Waiting... |

Tools: View log, Open folder, LS-PREPOST, Kill, Accelerated kill

Progress

```
[STDOUT] 2-2 discarded nets
[STDOUT] Averaging type: Mean using 5 remaining nets
[STDOUT] Found input data file: S_AnalysisResults
[STDOUT] Response # 3
[STDOUT] Training primal net # 1 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 2 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 3 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 4 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 5 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 6 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 7 (3 layers, Neurons: 2 -> 2 -> 1 )
[STDOUT] Training primal net # 8 (3 layers, Neurons: 2 -> 2 -> 1 )
```

Log

Excel Interface (Substitution)

Inputs from LS-OPT
to Excel fields

Stage Stage1

History definitions

- xacel_432
- NODOUT: x displacement of node 432

Stage Stage1

Response definitions

- NODOUT1: Last registered X-component of Displacement of node with ID 432
- NODOUT2: Last registered X-component of Coordinate of node with ID 167

Stage Stage2

General

Package Name: Excel

Excel File: data.xlsx

Input definitions

| Sheet | Cell | Type | Value | Fill direction | Delete |
|--------|-----------|-----------|-----------|----------------|--------|
| Sheet1 | A3 | Parameter | x1 | Vertical | |
| Sheet1 | Param2 | Parameter | x2 | Vertical | |
| Sheet2 | nodout1 | Response | NODOUT1 | Vertical | |
| Sheet2 | nodout2 | Response | NODOUT2 | Vertical | |
| Sheet2 | xacel_432 | History | xacel_432 | Vertical | |

Execution

Resources

| Resource | Units per job | Global limit | Delete |
|----------|---------------|--------------|--------|
| EXCEL | 1 | 1 | |

Design variables

Histories/
Responses
of previous
stages

Excel Screenshot 1: Stage 2 Design variables

| | x1 | x2 |
|---|----|----|
| 1 | | |
| 2 | | |
| 3 | 2 | 4 |
| 4 | | |

Excel Screenshot 2: Stage1_Isopt_output => Stage2_excel_input

| | nodout1 | nodout2 | xacel_432 | |
|----|----------|----------|-----------|----------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | -736.719 | -26.1055 | 0 | 0 |
| 7 | | | 0.009999 | -155.516 |
| 8 | | | 0.019992 | -305.94 |
| 9 | | | 0.029999 | -452.651 |
| 10 | | | 0.039994 | -595.531 |
| 11 | | | 0.049999 | -736.719 |
| 12 | | | | |

Excel interface (extraction)

| | A | B | C | D | E |
|----|---|---------------------|---|---|----------------|
| 13 | | | | | |
| 14 | | Stage2_Isopt_output | | | |
| 15 | | | | | |
| 16 | | | | | |
| 17 | | intrusion | | | xaccel_432_mod |
| 18 | | | | | |
| 19 | | -710.614 | | | 1 0 |
| 20 | | | | | 2 -53.4974 |
| 21 | | | | | 3 -105.243 |
| 22 | | | | | 4 -155.712 |
| 23 | | | | | 5 -204.863 |
| 24 | | | | | 6 -253.431 |
| 25 | | | | | |

Excel fields as LS-OPT histories/responses

Edit history

Name: xaccel_432_mod Subcase: [dropdown]

File: data.xlsx [Browse]

Worksheet: Sheet2 [Refresh]

X/time range: [dropdown] Y/value range: xaccel_432_mod [dropdown]

Auto increment

[OK] [Cancel]

Edit response

Name: intrusion_dist Subcase: [dropdown] Multiplier: n/a Offset: n/a

Not metamodel-linked

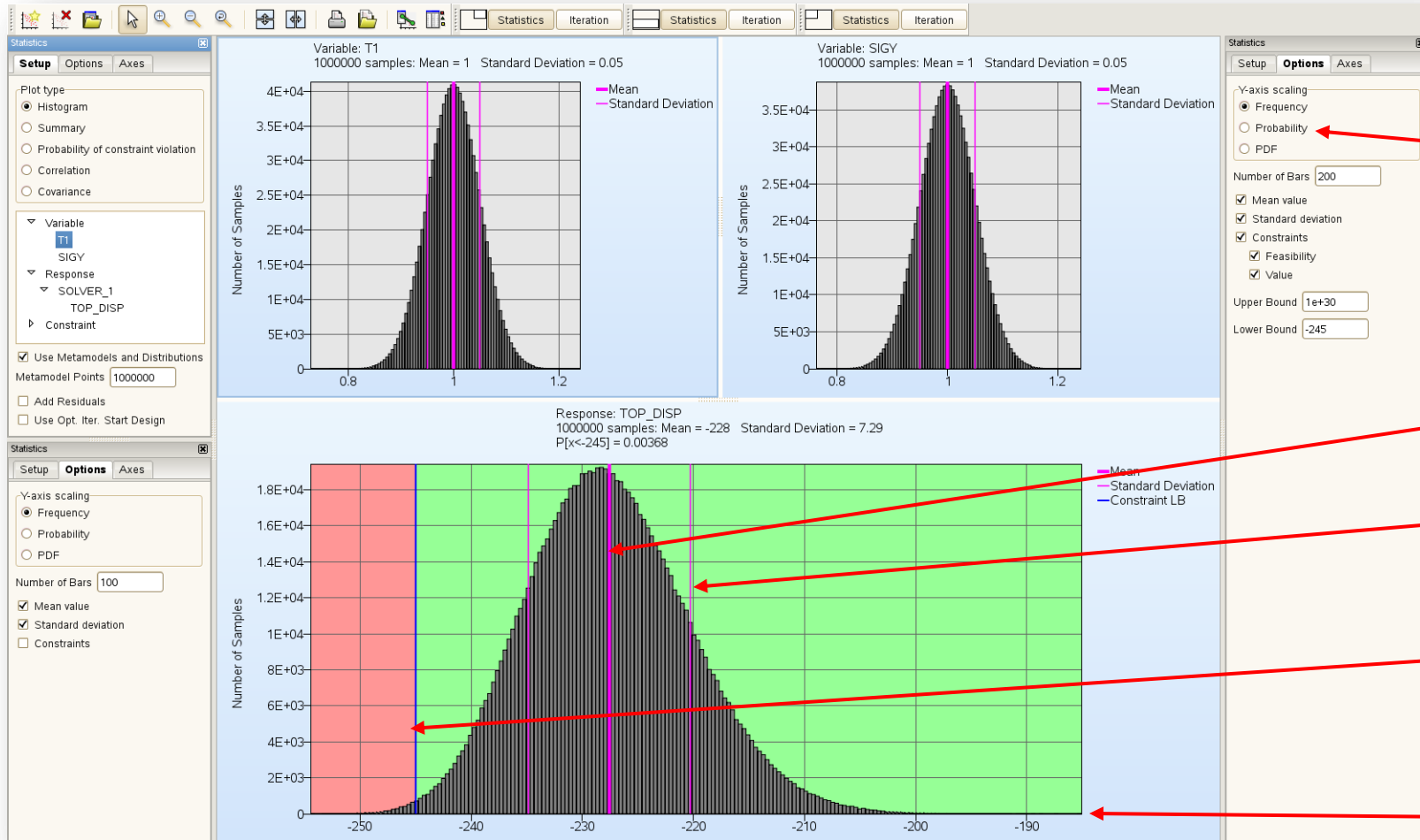
File: data.xlsx [Browse]

Worksheet: Sheet2 [Refresh]

Value cell: intrusion_dist [dropdown]

[OK] [Cancel]

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

Number of Points for Integration
10000 (default)

Overwrite global computations

Subregion definitions Define subregions

| Name | Active | Overwrite | Delete |
|------------|-------------------------------------|-------------------------------------|--------|
| Subregion1 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Edit × |
| subregion2 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Edit × |

Add...

All active All overwrite

OK

Name
Subregion1

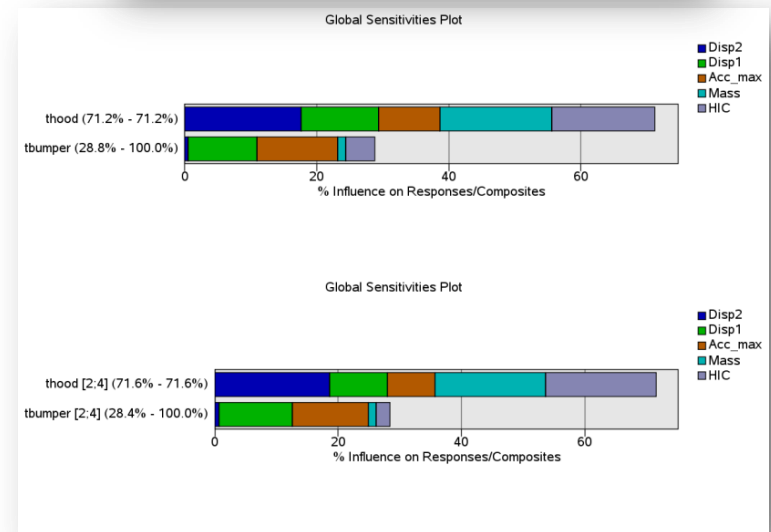
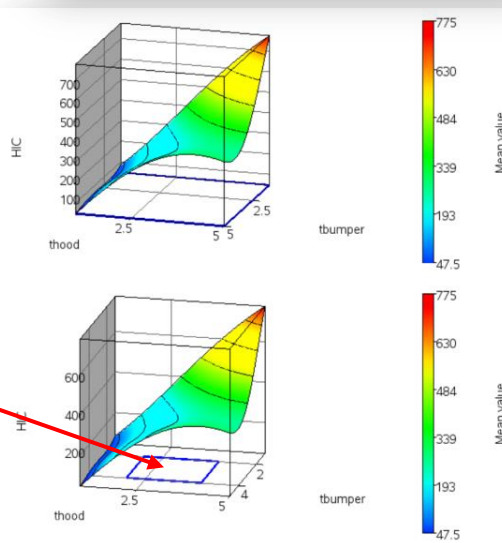
Active
 Overwrite

Bounds - Global bounds used for variable if not specified below

| Variable | Lower bounds | Upper bounds | Delete |
|----------|--------------|--------------|--------|
| tbumper | 2 | 4 | × |
| thood | 2 | 4 | × |

Add...

OK



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*