

Webinar

## New Features in LS-OPT<sup>®</sup> 7.0

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# Outline

- Overview on LS-OPT
- New Features in LS-OPT 7.0

# About LS-OPT

## ■ LS-OPT is a stand alone optimization software

→ can be linked to **any (simulation) code** –

■ Interface to LS-DYNA, Excel, Matlab

■ Interface to LS-PrePost, PRIMER, ANSA, Hypermorph, ...

→ **shape optimization**

■ Interface to META Post

→ **result extraction**

■ Interface to LS-OPT, LS-TaSC

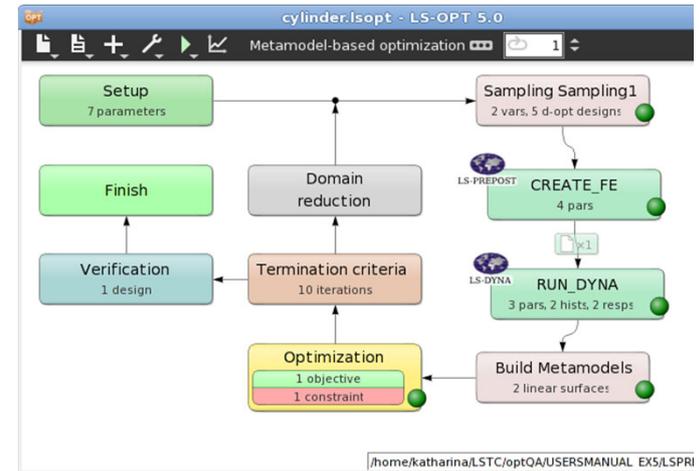
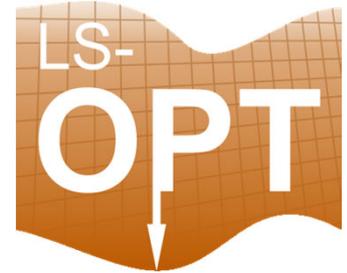
→ **nested optimization**

■ User-defined interface

■ Interface to Queuing Systems

■ PBS, LSF, SLURM, AQS, User-defined, ...

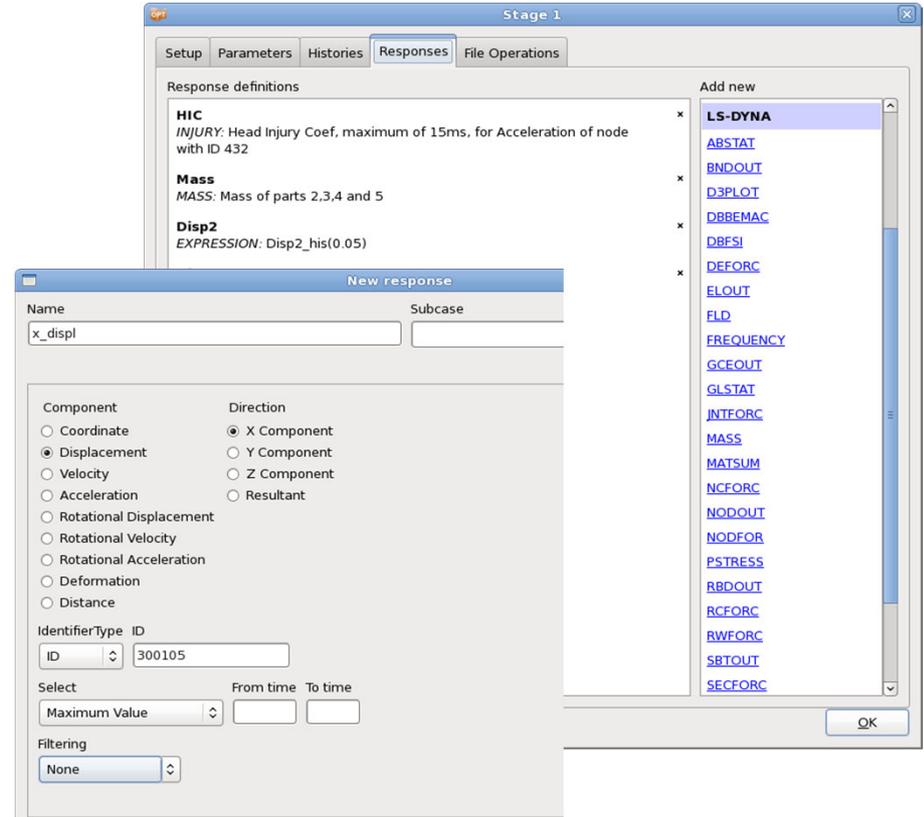
→ **LS-OPT as process manager**



# About LS-OPT

## ■ LS-DYNA integration

- Importation of design parameters from LS-DYNA keyword files (\*PARAMETER)
- Support of include files (\*INCLUDE)
- Result extraction of most LS-DYNA response types
- Checking of LS-DYNA keyword files (\*DATABASE\_)
- Monitoring of LS-DYNA progress



# Methodologies

## ■ (Sequential) Response Surface Method ((S)RSM)

→ Metamodels

- Polynomials
- Radial Basis Functions (RBF)
- Feedforward Neural Networks (FFNN)

## ■ Genetic Algorithm (MOGA-→NSGA-II)

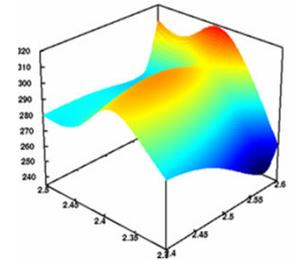
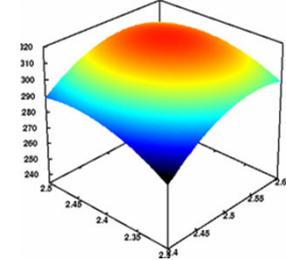
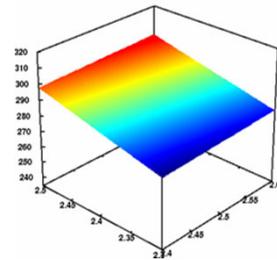
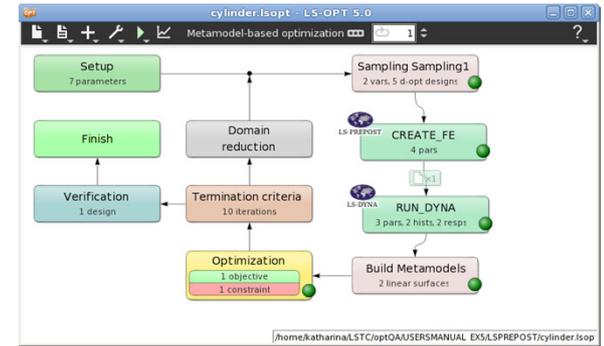
→ Multi-objective Optimization

- Direct and metamodel-based

## ■ Monte Carlo Analysis

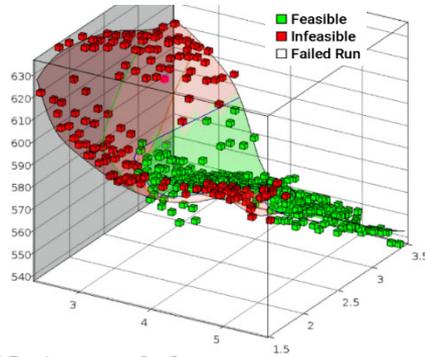
→ Robustness Analysis

- Direct and metamodel-based



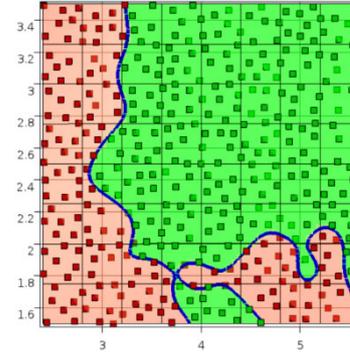
# Methodologies

## ■ Classifiers (Support Vector Classification)



**Metamodel**

Approximation of response

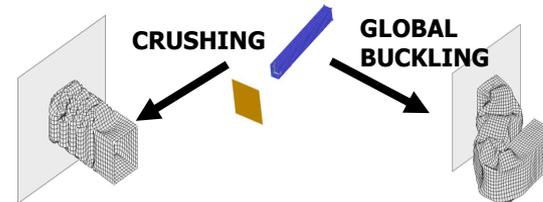


**Classifier**

Approximation of constraint boundary

- Design point (variable values)
- Feasibility of each design

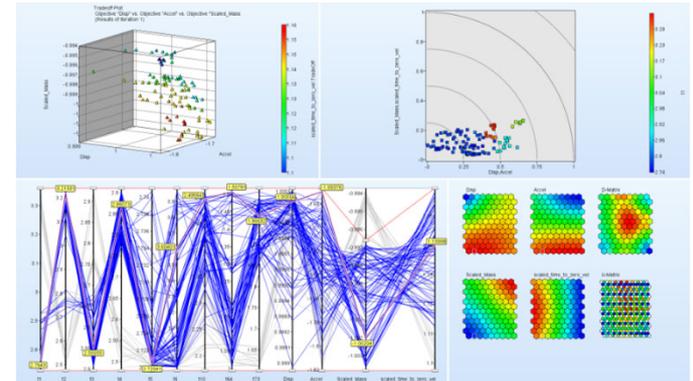
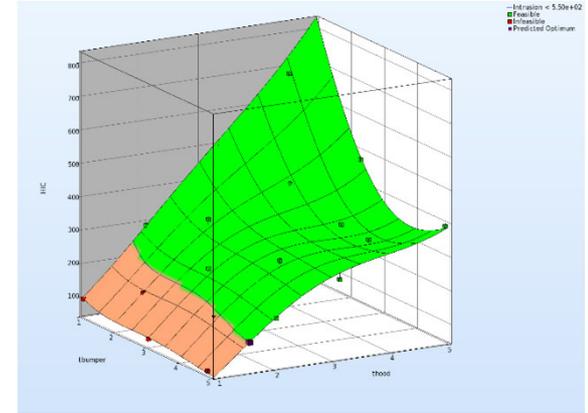
- Discontinuous responses
- Binary responses
- Constraints for optimization or reliability analysis



# Applications of LS-OPT

## ■ Optimization

- Size-/Shape optimization
- Mixed continuous/discrete variables
  - Specify sets of discrete variables (e.g. sheet thicknesses)
- Parameter/System Identification
- Multiple load cases
  - Multi-disciplinary Optimization (MDO)
- Multi-objective optimization (Pareto Frontier)
- Multi-level optimization
- Reliability based design optimization
- Robust parameter design



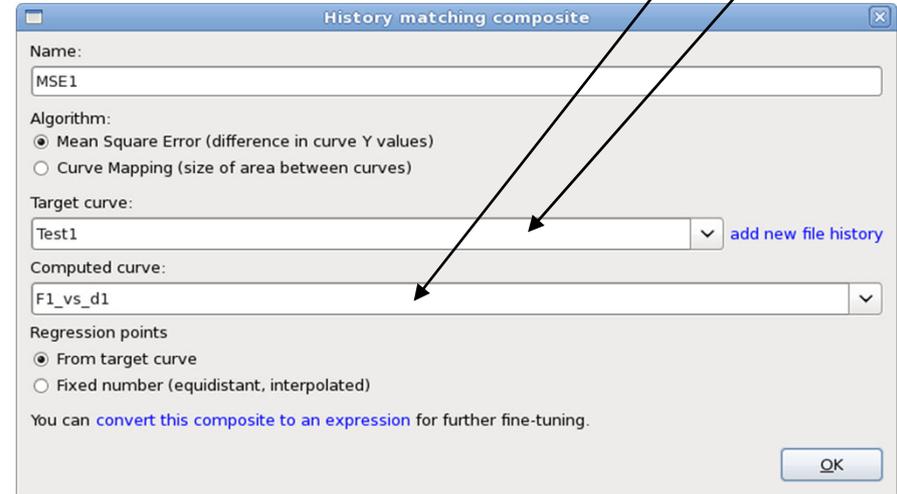
# Applications of LS-OPT

## ■ Optimization

- Parameter/System Identification Module: Calibration of test and simulation curves or scalar values



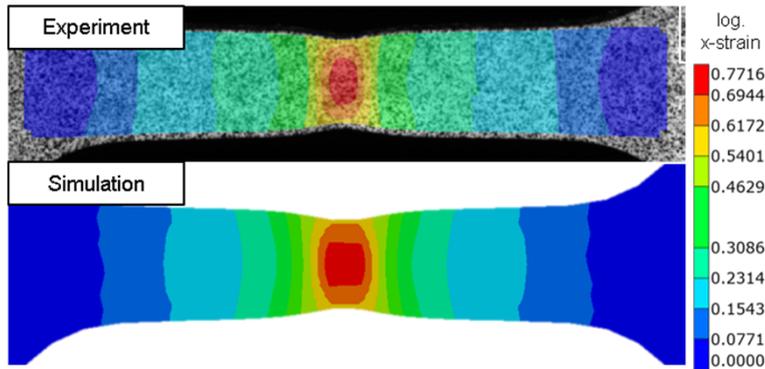
$$\frac{1}{P} \sum_{p=1}^P W_i \left( \frac{F_i(\mathbf{x}) - G_i}{S_i} \right)^2$$



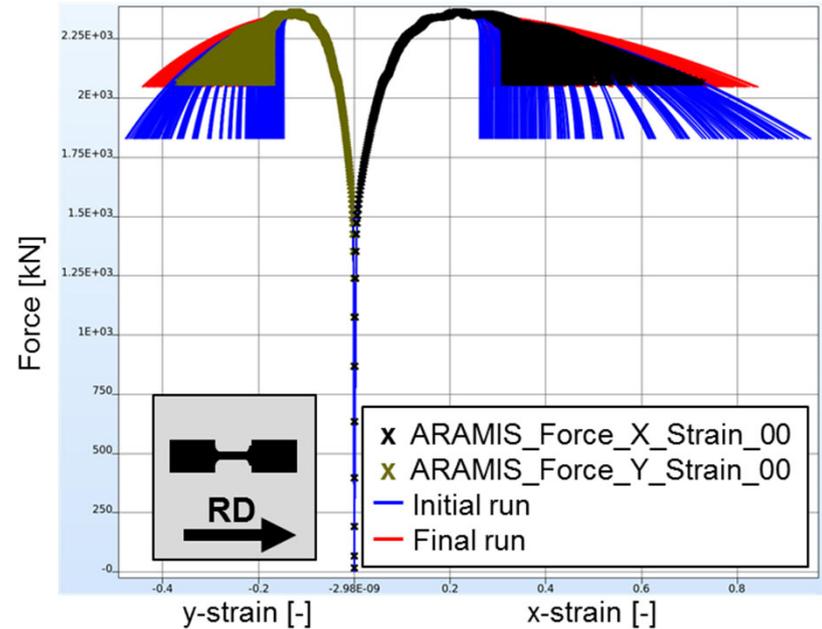
# Applications of LS-OPT

## ■ Optimization

- Full-field calibration
  - parameter identification using DIC data
  - Matching in time and space



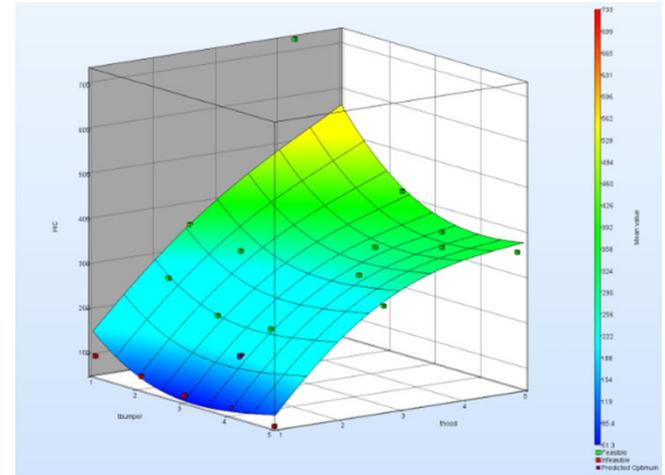
Deformation field of tensile test



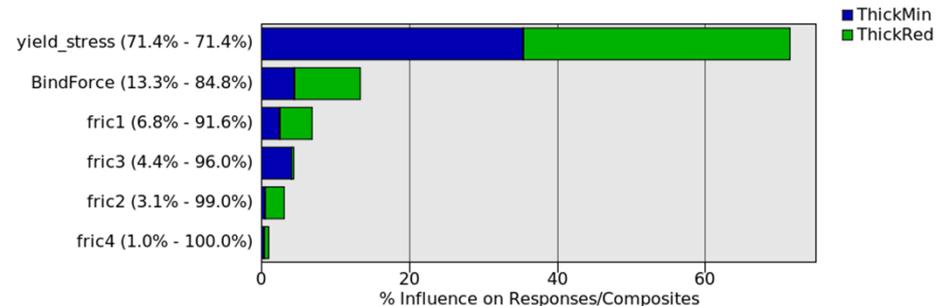
# Applications of LS-OPT

## ■ Sensitivity Analysis

- Design Exploration
- DOE Studies for Variable Screening (ANOVA, Sobol)
  - *Contribution of variables to system performance*
  - *Identification of significant and insignificant variables*
  - *Ranking of importance*
- *Principal Component Analysis (PCA)*



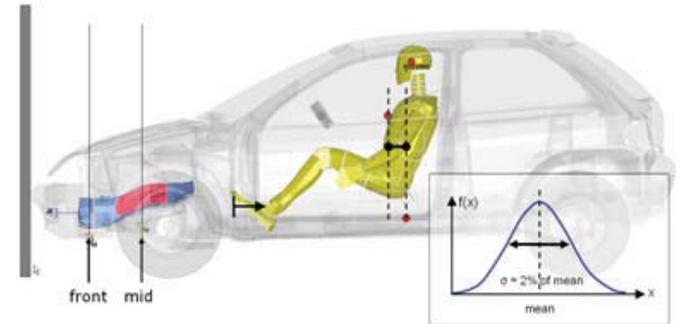
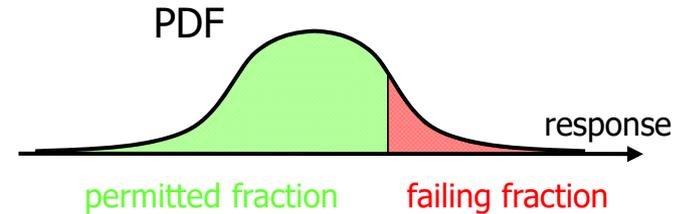
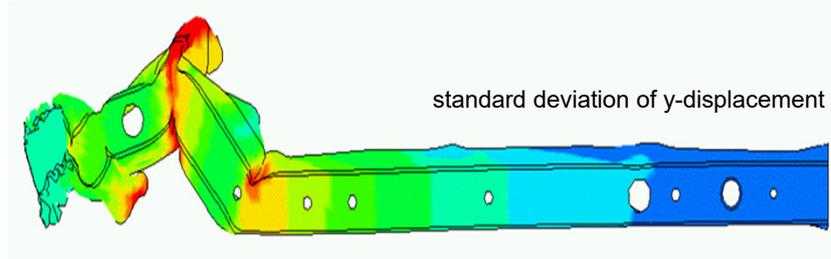
Global Sensitivities Plot



# Applications of LS-OPT

## ■ Stochastic/Probabilistic Analysis: Consideration of uncertainties

- Test of Model Robustness
  - Statistics (mean, standard deviation)
  - Correlation Analysis
- Reliability (Probability of Failure)
- Outlier Detection
- Fringe statistical results on FE model

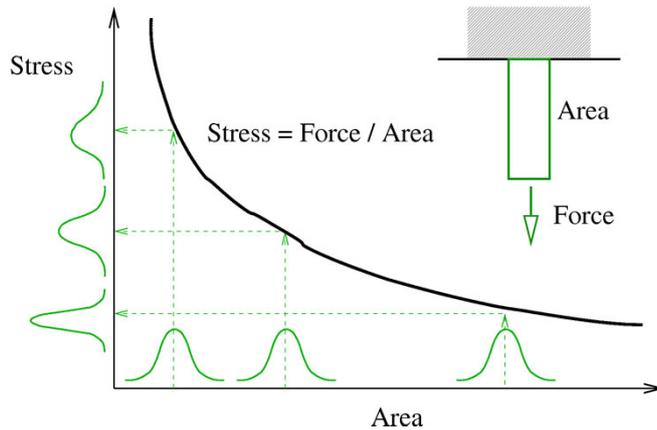


# Applications of LS-OPT

## Optimization incorporating uncertainties

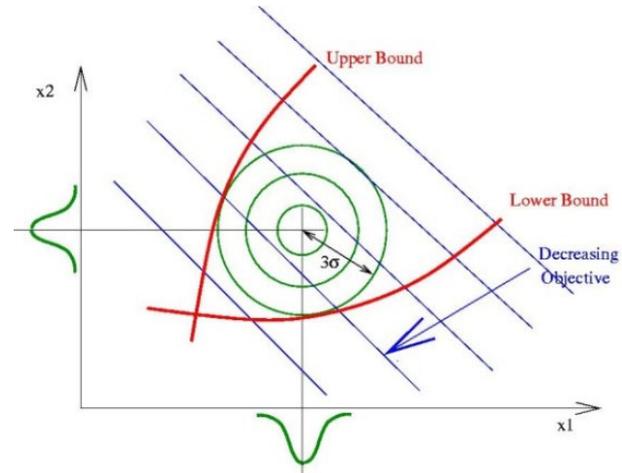
### ■ Robust Parameter Design (RDO)

- Improve/Maximize the robustness of the optimum



### ■ Reliability Based Design Optimization (RBDO)

- Improve failure probability of optimum



# LS-OPT Support webpage

■ [www.isoftware.com](http://www.isoftware.com)

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

The screenshot shows the LS-OPT Support website homepage. The browser address bar displays <https://www.isoftware.com>. The page features a navigation menu with the following items: Home, Getting Started, Downloads, Documents, Examples, Howtos, FAQs, and Videos. A search bar is located in the top right corner, with a "Log in" link and a checkbox for "only in current section".

The main content area is titled "Welcome to LS-OPT Support Site". It includes a "News" sidebar with the following items:

- LS-OPT 6.0 released (Aug 02, 2019)
- European LS-DYNA Conference - Papers online (Jul 09, 2019)
- Official releases of LS-TaSC 4.0 available (Mar 12, 2019)
- German LS-DYNA Forum - Papers online (Dec 11, 2018)
- International LS-DYNA Users Conference - Papers online (Aug 24, 2018)

The main content area contains the following text:

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.

**Optimization**

- Size-/Shape optimization
- Constraints, mixed continuous/discrete variables, multiple load cases, etc.
- Multi-Objective optimization (Pareto Frontier)
- Reliability based design optimization
- more...

**System-/Parameter Identification**

- Material parameter evaluation
- Calibration of test results
- more...

The page also features two visualizations: a 3D surface plot showing a complex optimization landscape and a 2D line graph showing a curve with data points and a fitted line.



# New Features in LS-OPT 7.0

# Principal Component Analysis (PCA)

→ Influence of variables on histories or multipoint responses

## ■ Multivariate statistical technique

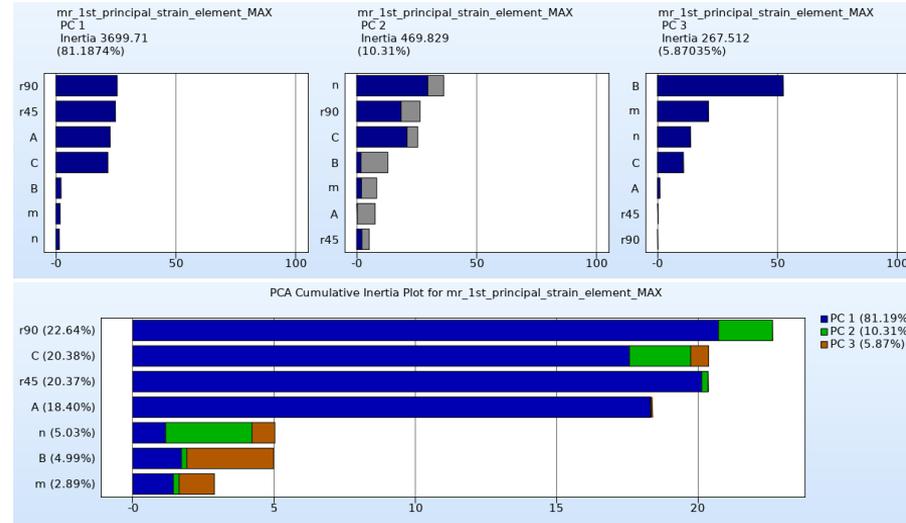
- Reduction of correlated observations (time values/spatial points) without losing information

→ Principal components

## ■ Uses Proper Orthogonal Decomposition (POD) of correlation matrix

## ■ Sensitivities:

Contribution of each principal component and cumulative history/multiresponse sensitivity measure

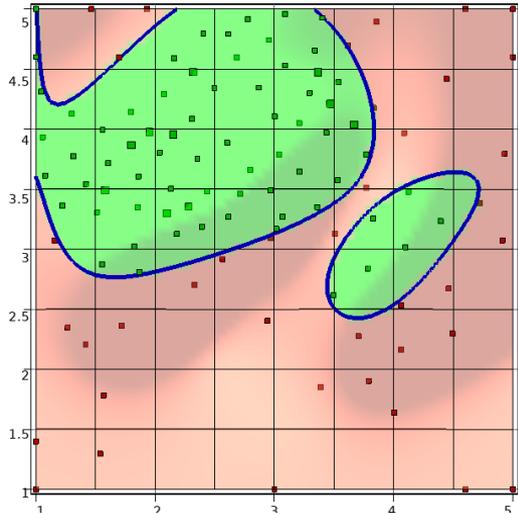


# Adaptive Sampling

- EDSD Sampling Constraints (Explicit Design Space Decomposition)  
→ sampling based on classifier predictions

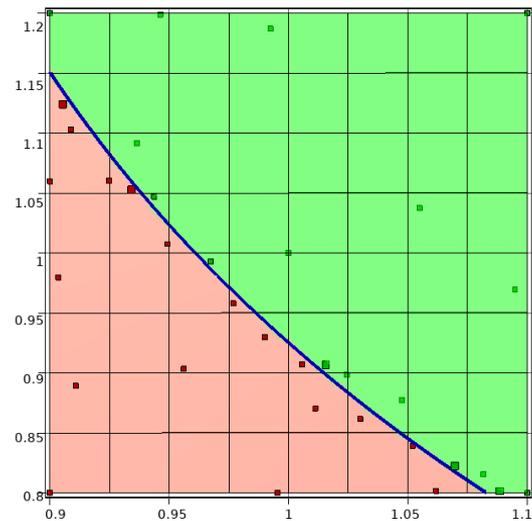
- Optimization

- Sampling in feasible region



- Reliability

- Sampling near the boundary

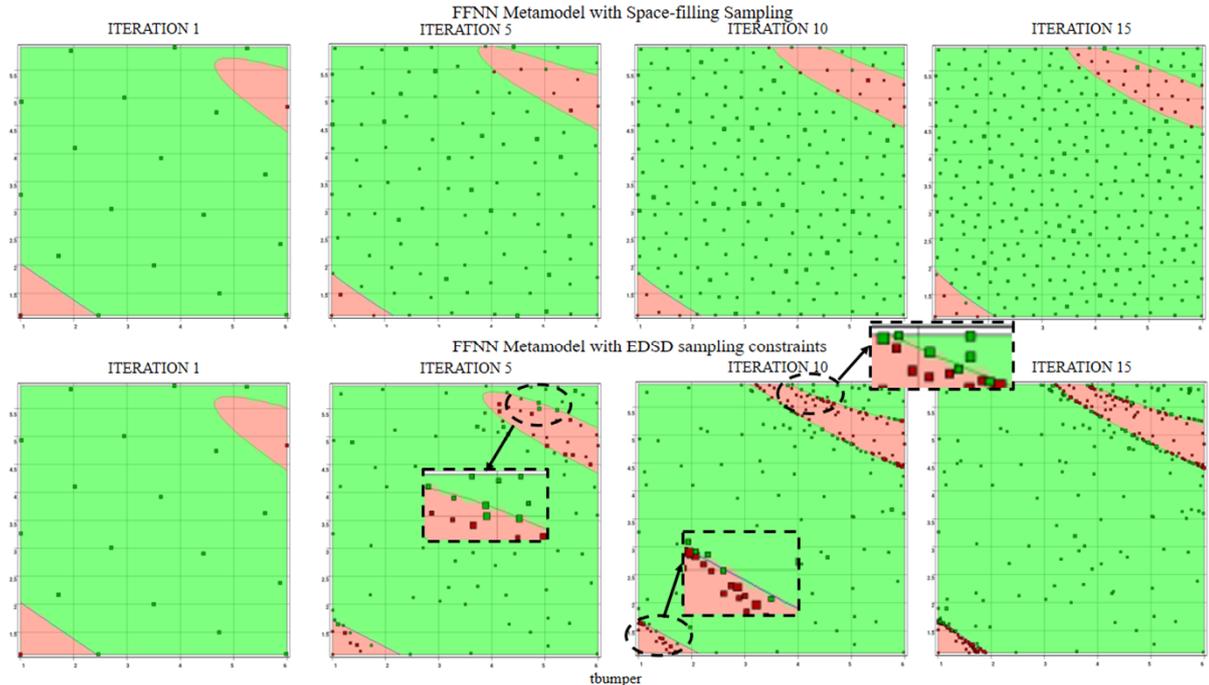
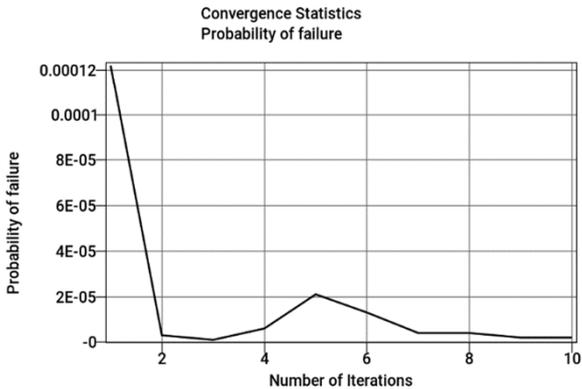


# Sequential Monte Carlo Analysis

- Iteratively add space-filling or adaptively selected samples

- Convergence

- metamodel accuracy
- probability of failure



# Job scheduler

## ■ SSH Support

- *SSH is the default access into UNIX systems*
- Well understood by IT staff  
Maintained and secure
  - Run job directly on remote machine
  - Submit job to cluster via proxy machine
  - Supports OpenSSH or PuTTY binaries (common)
- SSH host configuration saved in user settings as opposed to project file
- GUI settings in lieu of environment variables

## ■ Simplified BLACKBOX queuing system

- No need to implement LsoptJobCheck script
- User-defined termination criteria from GUI
  - Job executable return code
  - Line in stdout (e.g. `N o r m a l`)
  - File existence
  - Line in file

## ■ User-defined port range for runqueueer

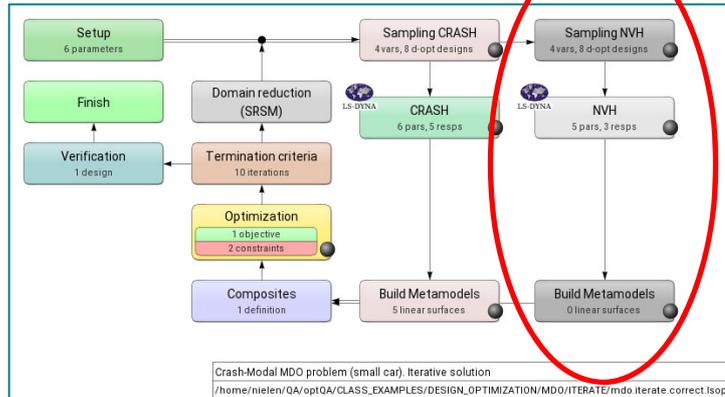
## ■ Parallel limit

- Increase number of simultaneous runs - 300 parallel limit no longer valid

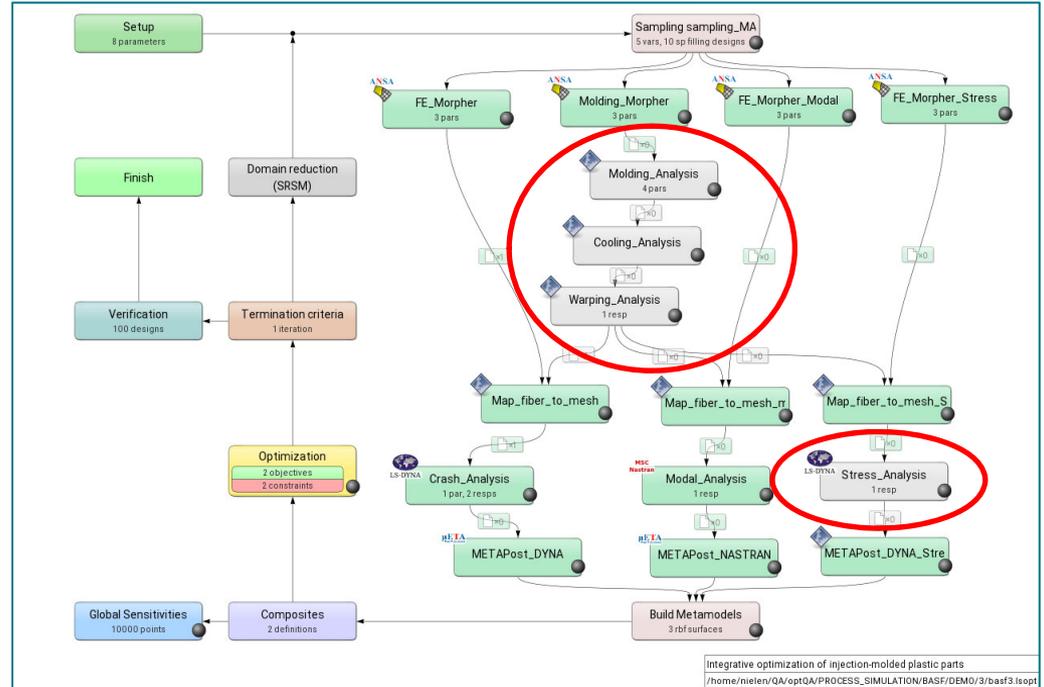
# Process Management: Case and Stage (de)activation

- Deactivate selected MDO samplings or stages
- Automatic (de)activation of dependent composite expressions, classifiers, objectives, constraints, ...

## Case deactivation



## Stage deactivation



# Command line options

- Run LS-OPT in batch mode with command line options
- LS-OPT command line options
  - Archiving
  - Repair
  - Baseline Run
  - Clean

# Interface to Oasys PRIMER

## ■ Shape optimization using PRIMER morphing tool

Stage PRIMER

Setup Parameters Remote Histories Multihistories Responses Multiresponses File Operations

### General

Package Name PRIMER

Command PRIMER

Do not add input file argument

DV File primer\_variable\_def.txt

*copies primer\_variable\_def.txt (0 includes) to PRIMER/it.run/ PRIMEROpt.inp and substitutes parameters*

Extra input files

Solver Input File input\_with\_flow.key

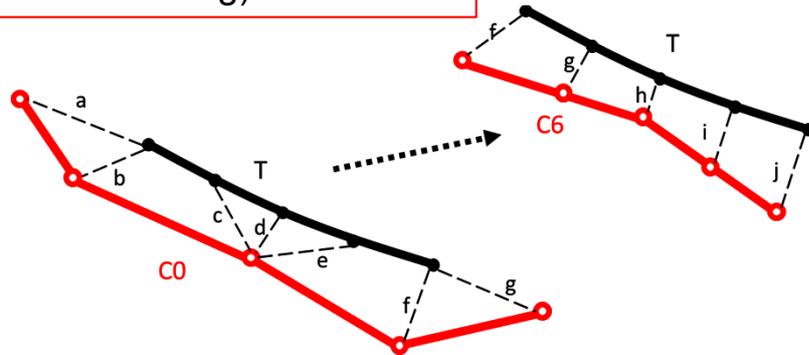
Output File input\_morphed.key

# Material Calibration Using Partial Curves

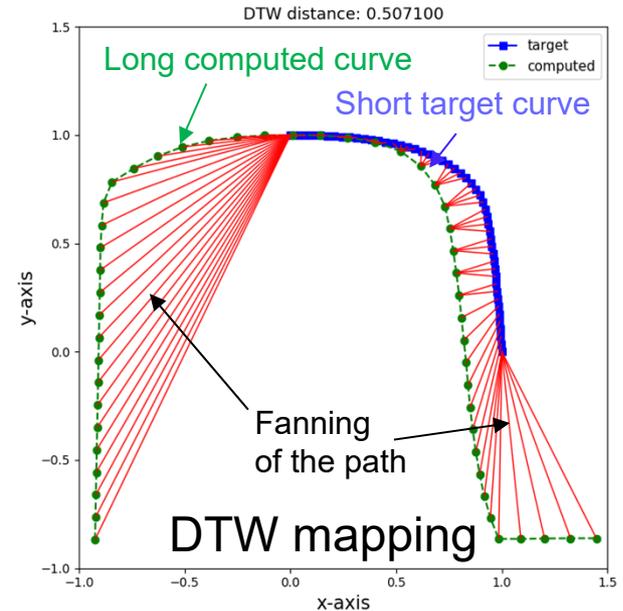
## ■ Modified Dynamic Time Warping

- Partial curves confound the error source (shape vs length mismatch)
- Trimming improves curve compatibility and can reduce optimization complexity

Partial Dynamic Time Warping (DTW with iterative remeshing).



- Suitable for noisy curves
- Suitable for partial mapping

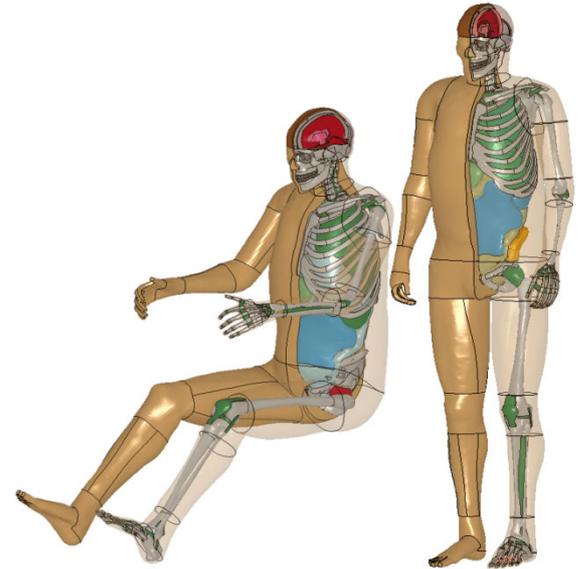


# Comparison of Curve Distance Measures

Distance Metric	Principle	Advantage	Disadvantage
<b>Euclidean Distance (MSE)</b>	<b>Mean Squared Error</b> of the difference in curve ordinates	<ul style="list-style-type: none"> <li>• noise</li> <li>• partial curves</li> </ul>	<ul style="list-style-type: none"> <li>• hysteresis: the curves must be functions</li> </ul>
<b>Partial Curve Mapping (PCM)</b>	<b>Area between curves.</b> Preserves the arc length.	<ul style="list-style-type: none"> <li>• curves of unequal geometric length</li> <li>• hysteresis</li> </ul>	<ul style="list-style-type: none"> <li>• noise (due to arc length preservation)</li> </ul>
<b>Discrete Fréchet (DF)</b>	<b>Minimum of the maximum</b> of all possible edge lengths along a path which connects all given data points, taking into account the location and ordering of the points.	<ul style="list-style-type: none"> <li>• noise</li> <li>• hysteresis</li> </ul>	<ul style="list-style-type: none"> <li>• curves of unequal geometric length</li> </ul>
<b>Dynamic Time Warping (DTW)</b>	Minimizes the sum of path connectors between the curves in a <b>one-to-many mapping</b> end to end.	<ul style="list-style-type: none"> <li>• noise</li> <li>• hysteresis</li> </ul>	<ul style="list-style-type: none"> <li>• curves of unequal geometric length</li> <li>• more expensive to compute</li> </ul>
<b>Modified Dynamic Time Warping (DTW-p)</b>	Recursively <b>trims coincident end connectors</b> of DTW. Simple extension of DTW.	<ul style="list-style-type: none"> <li>• noise</li> <li>• hysteresis</li> <li>• curves of unequal geometric length</li> </ul>	<ul style="list-style-type: none"> <li>• more expensive to compute</li> </ul>

# More Information on the Ansys/LST Product Suite

- Ansys/Livermore Software Technology (Ansys/LST)  
[www.lstc.com](http://www.lstc.com)
- LS-DYNA
  - Support / Tutorials / Examples / FAQ  
[www.dynasupport.com](http://www.dynasupport.com)
  - More Examples  
[www.dynaexamples.com](http://www.dynaexamples.com)
  - Conference Papers  
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