



**LSTC**  
Livermore Software  
Technology Corp.

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# LS-OPT<sup>®</sup> Overview and Preview of v4.2

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*LSTC, Livermore, CA*

LS-OPT Infotag  
Ingolstadt, BRD  
October 20, 2010

# Contents

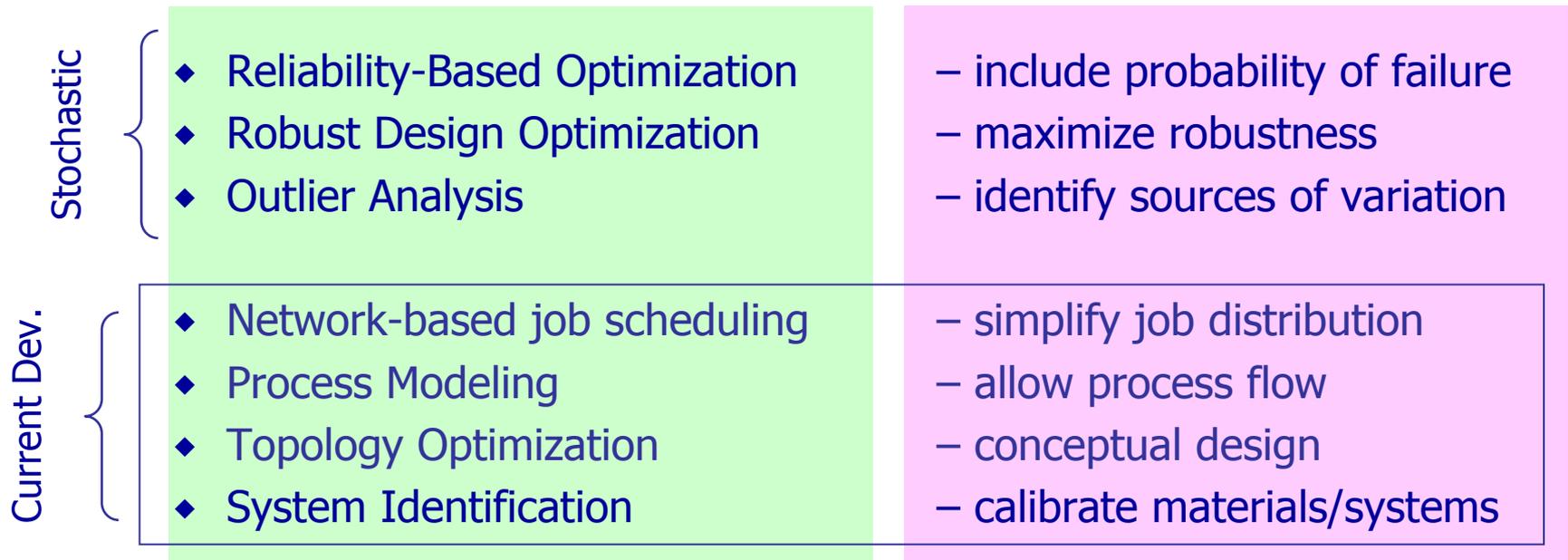
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- ◆ LS-OPT Goals
- ◆ Main features and Methodology
- ◆ Examples
- ◆ Job distribution
- ◆ Preview of Version 4.2

# LS-OPT Goals

- ◆ Provide a design environment for LS-DYNA users with the following capabilities and features:

- ◆ Design Improvement and Optimization



# Summary: Optimization

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## ◆ Metamodel-based Design Optimization

### ◆ Strategies

- *Single Stage*: Fixed computational budget
- *Sequential*: Maximize metamodel accuracy
- *Sequential with Domain Reduction*: Converge to optimal region

## ◆ Direct Optimization

- ◆ Genetic Algorithm (GA)
  - ◆ Particle Swarm Optimization (PSO) (v4.2)
- 

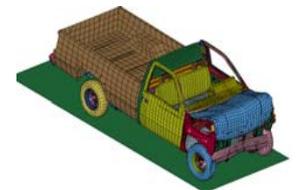
## ◆ Multi-Objective Optimization (Direct or Metamodel)

- ◆ NSGA-II (Non-dominated sorting Genetic Algorithm)
- ◆ SPEA-II (Strength Pareto Evolutionary Algorithm)
- ◆ SMPSO (Speed-Constrained Multi-objective Particle Swarm) (v4.2)

# LS-DYNA Integration

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- Checking of Dyna keyword files (\*DATABASE\_)
- Importation of design parameters from Dyna keyword files (\*PARAMETER\_)
- Monitoring of Dyna progress
- Result extraction of most Dyna response types
- LS-DYNA history plots in Viewer
- D3plot compression (node and part selection)
- Outlier information to FE mesh (LS-PrePost display)
- LS-DYNA \*CASE supported. Responses can be tied to a particular LS-DYNA Case
- \*INCLUDE and \*INCLUDE\_PATH files automatically parsed, copied and/or transmitted to cluster

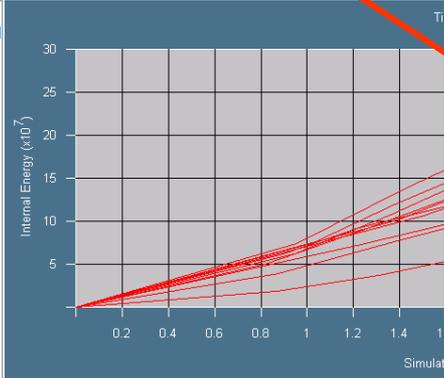


# Job distribution: LSTCVM Secure job proxy server

Job ID	View Log	Progress
1	PID 5948	Normal Termination Iter 1: Case 1, Run 1
2	PID 896	Normal Termination Iter 1: Case 1, Run 2
3	PID 5140	Normal Termination Iter 1: Case 1, Run 3
4	PID 5438	Normal Termination Iter 1: Case 1, Run 4
5	PID 5528	Normal Termination Iter 1: Case 1, Run 5
6	PID 4704	Normal Termination Iter 1: Case 1, Run 6
7	PID 3128	Normal Termination Iter 1: Case 1, Run 7
8	PID 6072	Normal Termination Iter 1: Case 1, Run 8
9	PID 1540	Normal Termination Iter 1: Case 1, Run 9
10	PID 2852	Normal Termination Iter 1: Case 1, Run 10
11	PID 6068	Running Iter 1: Case 1, Run 11
12	PID 4540	Running Iter 1: Case 1, Run 12
13	PID 2144	Running Iter 1: Case 1, Run 13
14	PID 4864	Running Iter 1: Case 1, Run 14

Job progress:  
MS-Win display

LS-DYNA log:  
Linux cluster

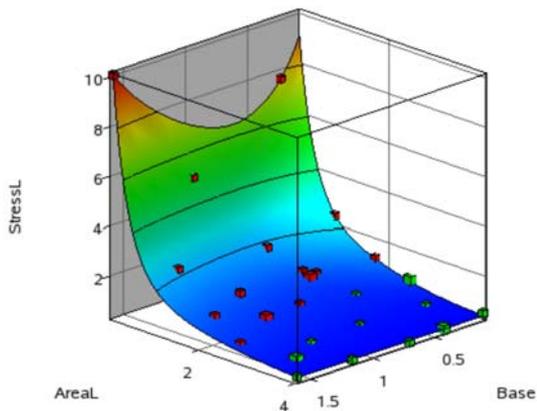


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[STDOUT] | 7374 Las Positas Road
[STDOUT] | Livermore, CA 94551
[STDOUT] | Tel: (925) 449-2500 Fax: (925) 449-2507
[STDOUT] | www.lstc.com
[STDOUT] |
[STDOUT] | LS-DYNA, A Program for Nonlinear Dynamic
[STDOUT] | Analysis of Structures in Three Dimensions
[STDOUT] | Version : ls971s R5.0 Date: 04/10/2010
[STDOUT] | Revision: 59419 Time: 10:11:54
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[STDOUT] | Interactive Graphics
[STDOUT] | ANSYS Database format
[STDOUT] | ANSYS License (ans120)
[STDOUT] | 32 Bit IEEE Binary File
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[STDOUT] | Platform : Xeon64 System
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Ed Helwig (Honda R&D)  
Trent Eggleston

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# Metamodeling



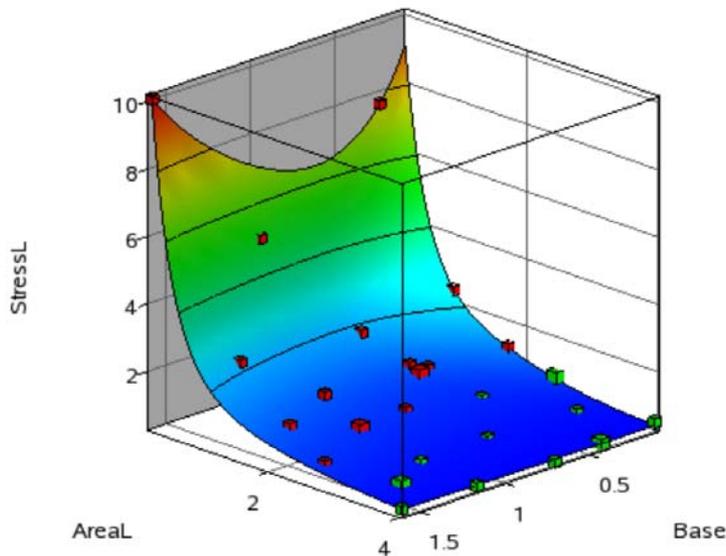
**Metamodel: Approximating the design**

# Metamodeling

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## What is a metamodel ?

An *approximation* to the design response, usually a simple function of the design variables. Is used instead of actual simulations during design exploration hence also called *surrogate*.



# Metamodel Applications

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- ◆ Variable importance
  - ◆ Linear surface fit to produce gradients
  - ◆ Global Sensitivity Analysis using Sobol indices
  
- ◆ Optimization
  - ◆ Sequential metamodel construction/updating
  - ◆ Multiple objectives: Determine *Pareto*-optimal design set
  
- ◆ Reliability and Robustness
  - ◆ Probability of failure: Reliability
  - ◆ Standard deviation of a response: Robustness
  
- ◆ Outlier Analysis
  - ◆ Locate sources of variation and noise

# Metamodel Types in LS-OPT

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- ◆ Response Surface Methodology (RSM)
  - ◆ Polynomial-based
  - ◆ Typically regional approximation (especially linear)
- ◆ Feedforward Neural Networks (FF)
  - ◆ Simulation of a biological network, sigmoid basis function
  - ◆ Global approximation
- ◆ Radial Basis Function Networks (RBF)
  - ◆ Gaussian, Multi-quadric basis functions in a linear system
  - ◆ Global approximation
- ◆ Kriging
- ◆ User-defined
  - ◆ Dynamically linked (.so, .dll)

# Sampling (schemes for point selection)

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## ◆ Space Filling

- ◆ Used with FFNN + RBFN
- ◆ Max. Min. distance between
  - new points
  - new points + fixed points
- ◆ Simulated Annealing

## ◆ $D$ -Optimality

- ◆ Used with polynomials

## ◆ Other types

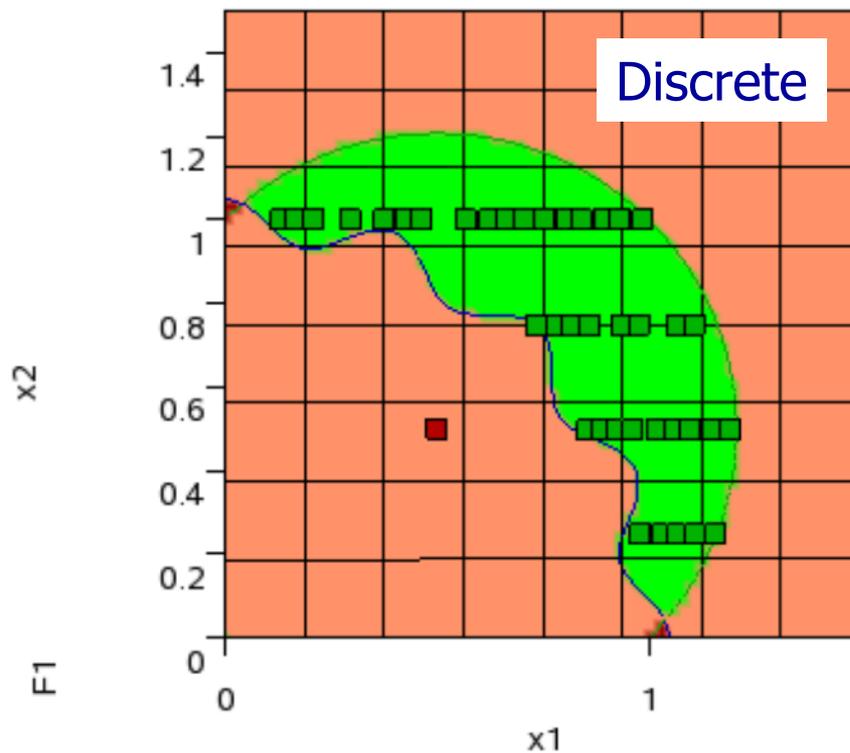
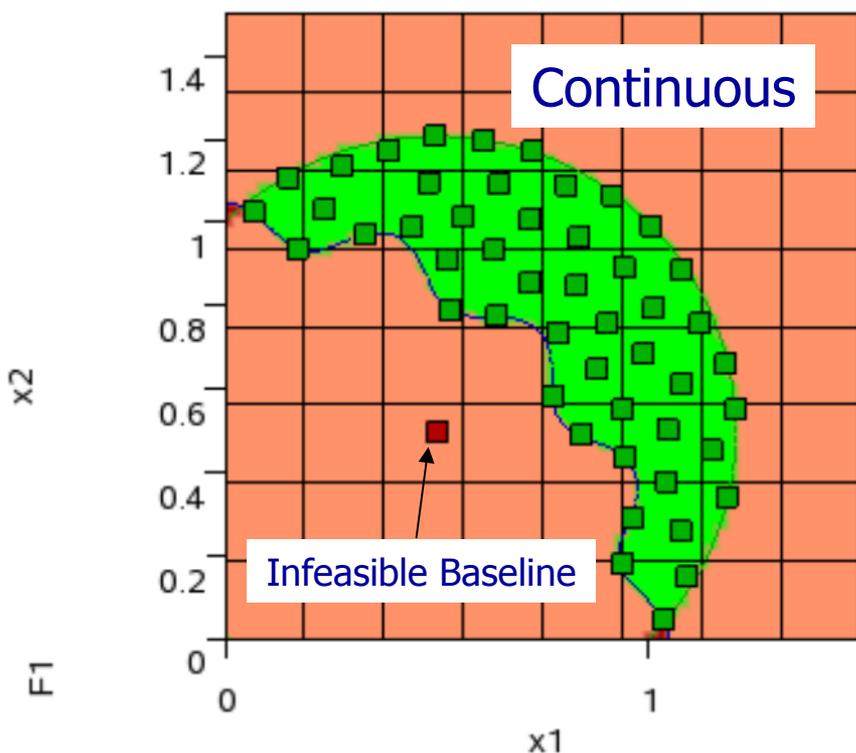
- ◆ Full factorial, Koshal, Central Composite, Latin Hypercube, User

# Sampling in an irregular design space: Constrained Space Filling (v4.2)

$$\text{Max. Min. } \| \mathbf{x}_i - \mathbf{x}_j \| \text{ s.t. } g_j \leq 0; j=1, \dots, m$$

## ◆ TNK Example

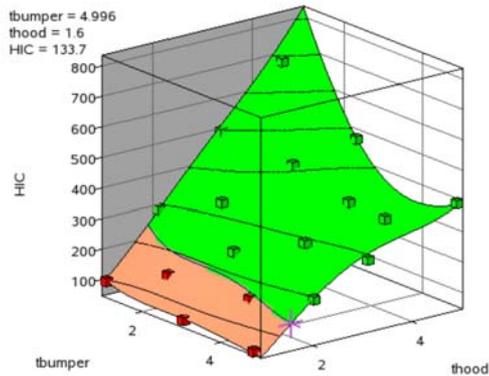
Constraints:  $x_1^2 + x_2^2 - 1 - 0.1 \cos(16 \tan^{-1}(x_1/x_2)) \geq 0$ ;  $(x_1 - 0.5)^2 + (x_2 - 0.5)^2 \leq 0.5$



# Metamodels: Summary

Response Surface Methodology (RSM)	Feedforward Neural Networks (FF)	Radial Basis Function Networks (RBF)
Polynomial basis functions	Simulation of a biological network. Sigmoid basis fns.	Local Gaussian or multi-quadratic basis functions
Regional approximation, requires iterative domain reduction	Global approximation	Global approximation
Linear regression. Accuracy is limited by order of polynomial.	Nonlinear regression. Robustness requires committee (inner loop)	Linear regression within nonlinear loop. Cross-validation for high accuracy
Very fast	Very slow. Responses processed individually	Fast

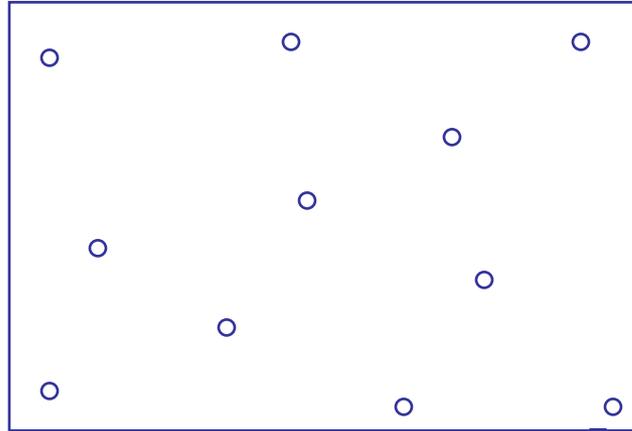
# Metamodel-based Optimization



# Metamodel-based Optimization Strategies

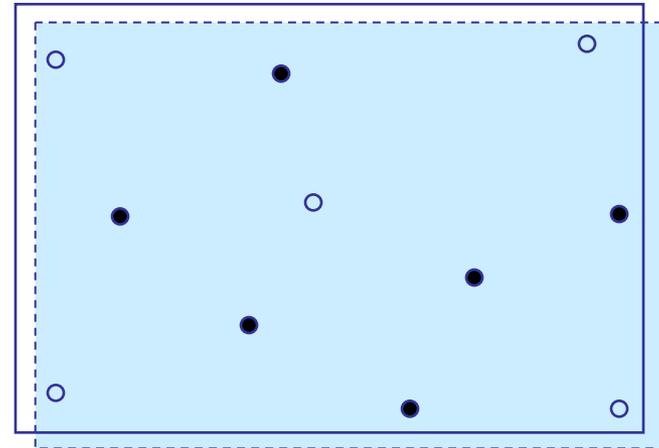
## Space-filling point selection

*I*



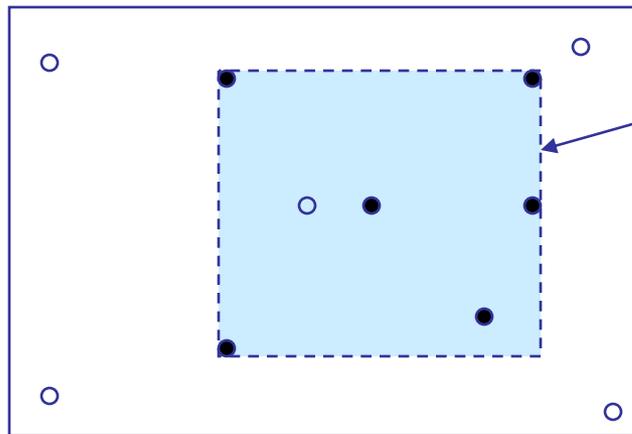
**Single stage**

*II*



**Sequential**

*III*



Design Space

Subregion

Stage 1: open circle, white region  
Stage 2: solid point, blue region

**Sequential with domain reduction**

# Optimization Strategies

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## ◆ Single stage

- ◆ Suitable for a fixed computational budget
- ◆ All the points are determined in one stage, using Space Filling
- ◆ Highly suitable to create a global metamodel

## ◆ Sequential

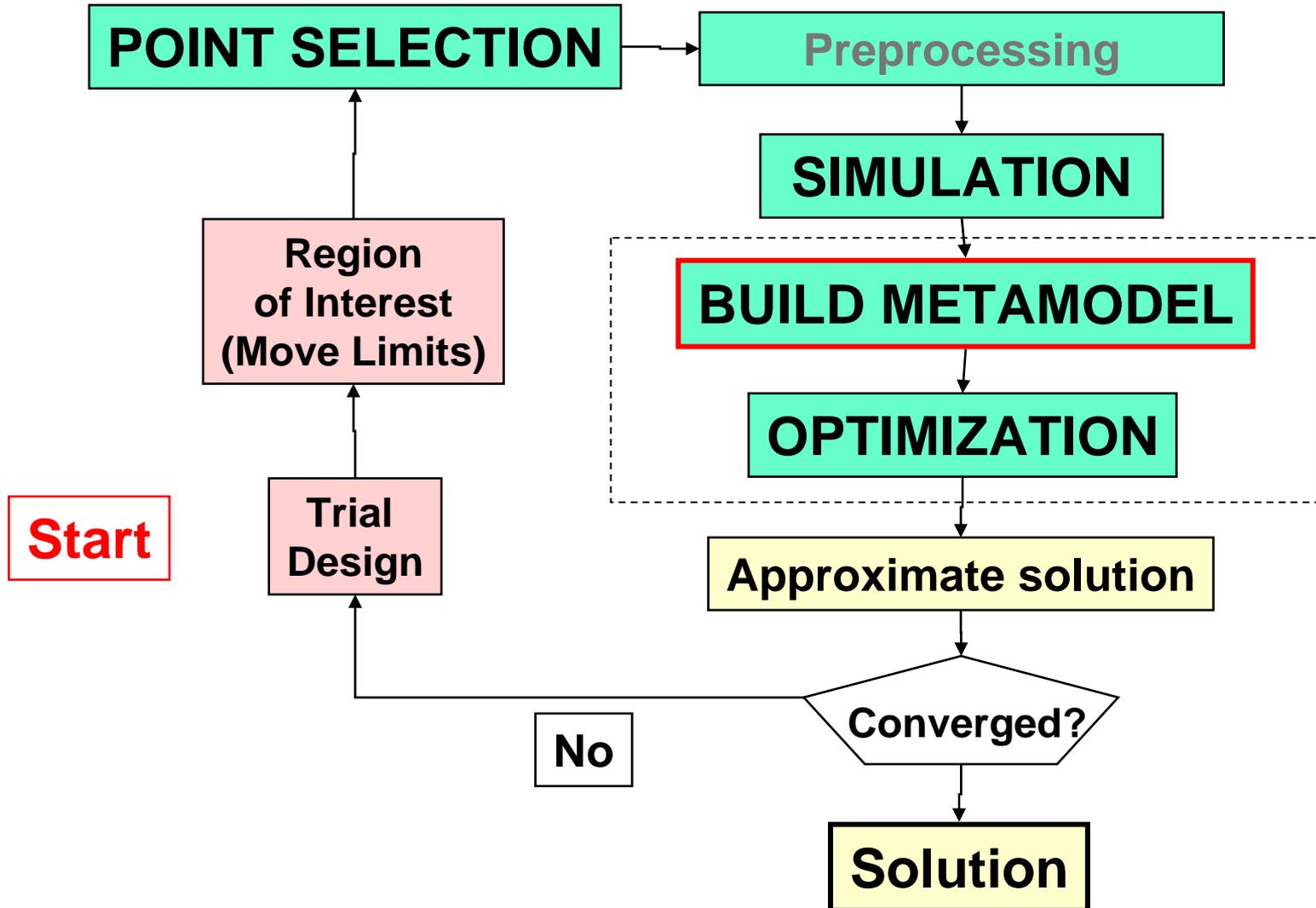
- ◆ Suitable for maximizing metamodel prediction accuracy using a Stopping criterion
- ◆ Add Space Filling points in each iteration

## ◆ Sequential with domain reduction

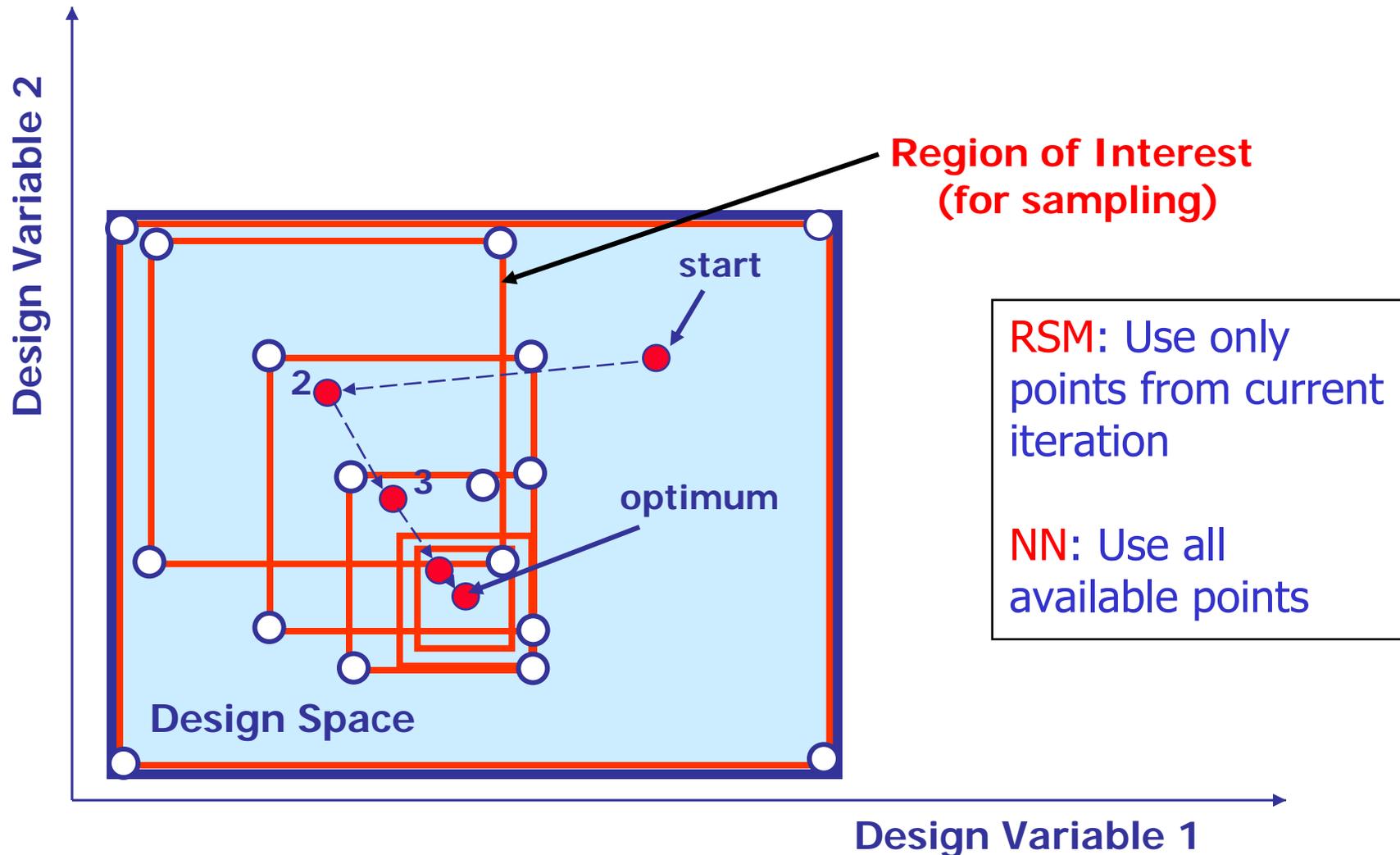
- ◆ Converges to a single optimum point (single objective)
- ◆ Domain reduction in each iteration: all points within a subregion
- ◆ Ideal for system identification

# Design Improvement Cycle

## Simulation-based using Metamodel



# Domain reduction: convergence



# Example (Domain reduction)

## Crash model

30 000 elements

*Intrusion = 552mm*

*Stage1Pulse = 14.34g*

*Stage2Pulse = 17.57g*

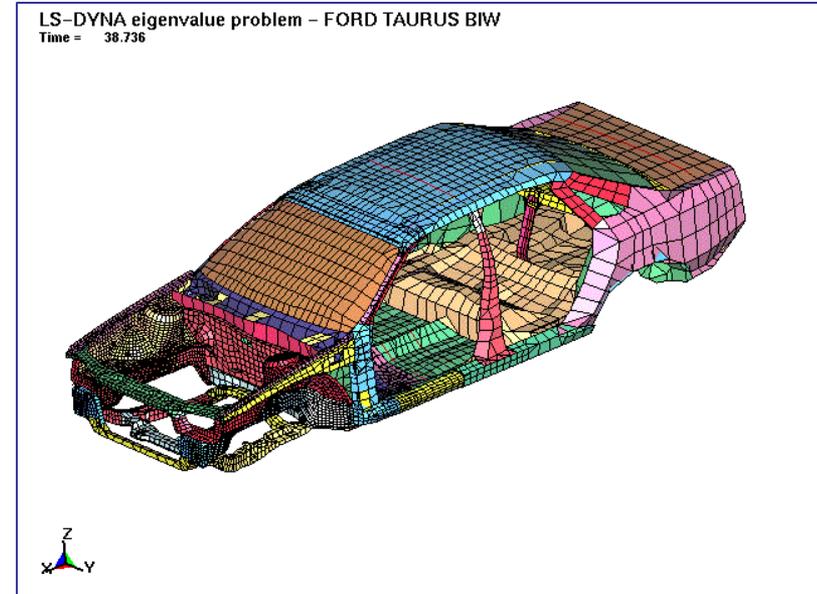
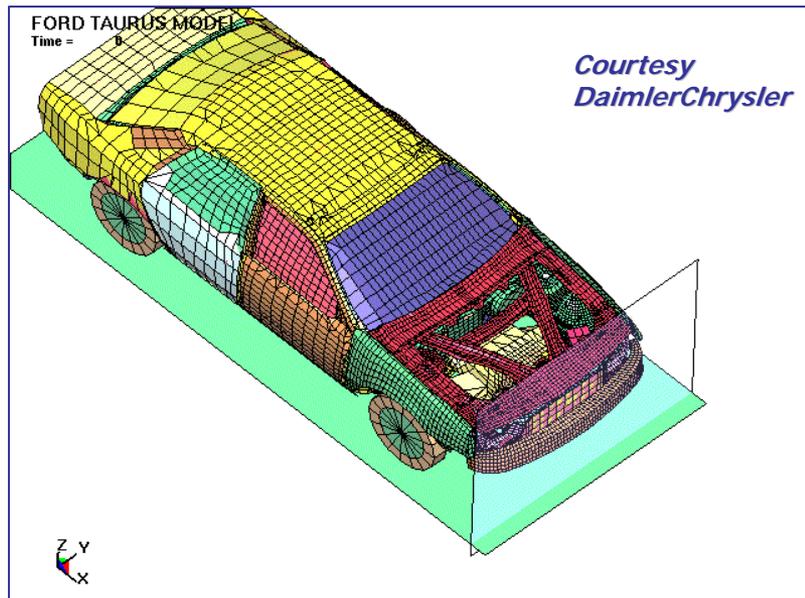
*Stage3Pulse = 20.76g*

## BIW model

18 000 elements

*Torsional mode 1*

*Frequency = 38.7Hz*



# Design Formulation

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## Design Objective:

Minimize (Mass of components)

## Design Constraints:

Intrusion < 552.38mm

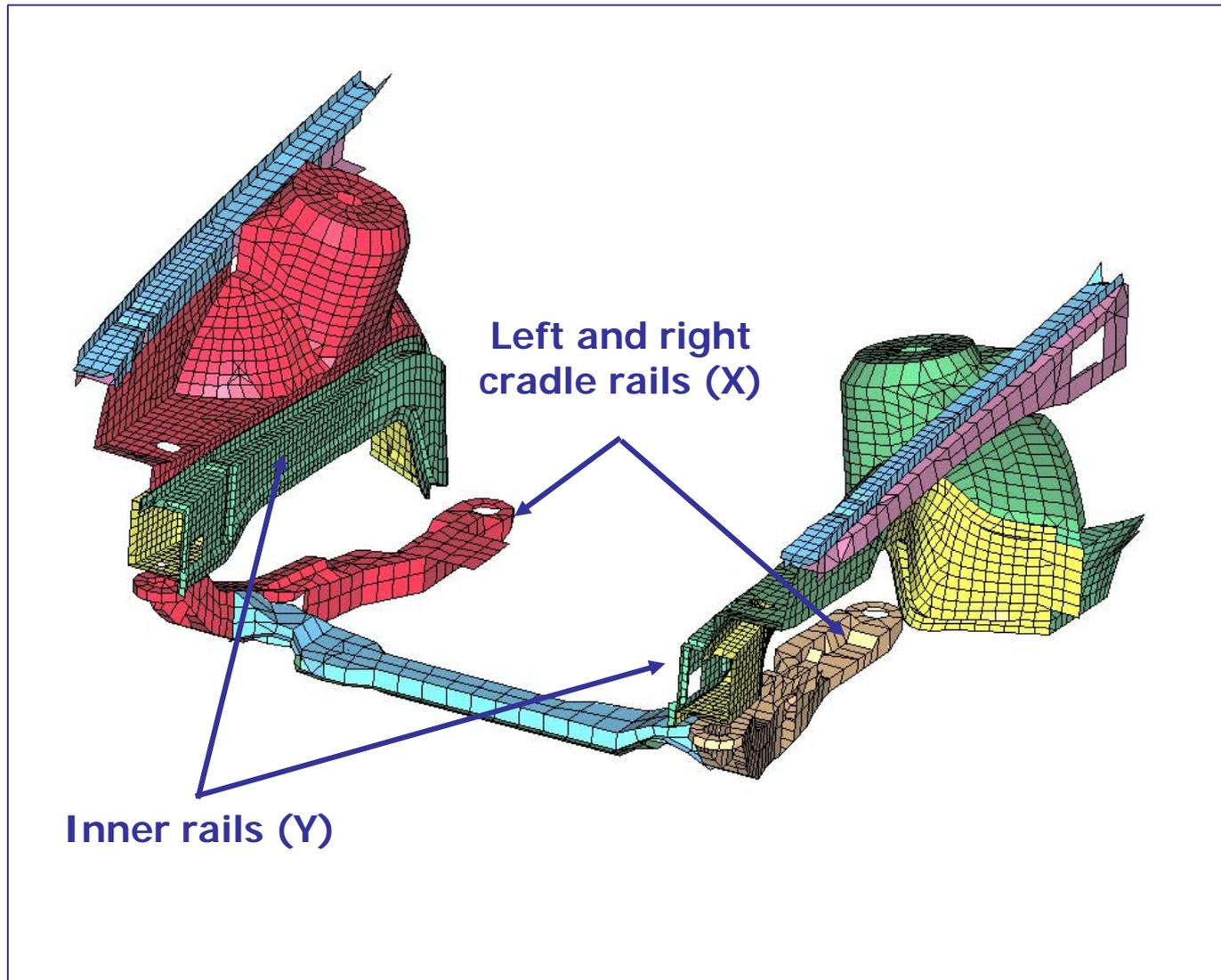
Stage1Pulse > 14.58g

Stage2Pulse > 17.47g

Stage3Pulse > 20.59g

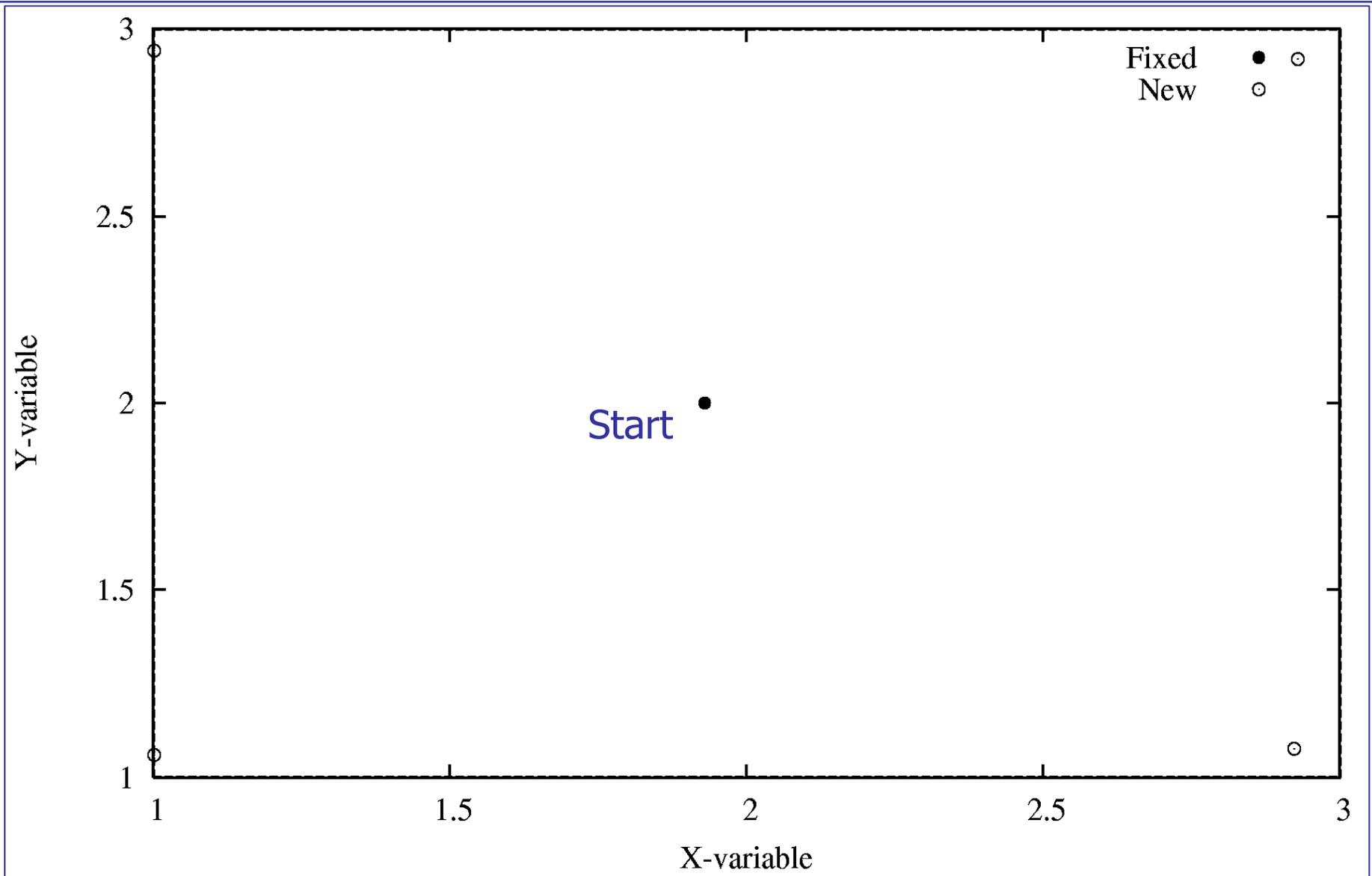
41.38Hz < Torsional mode 1 frequency < 42.38Hz

# Two Design Variables



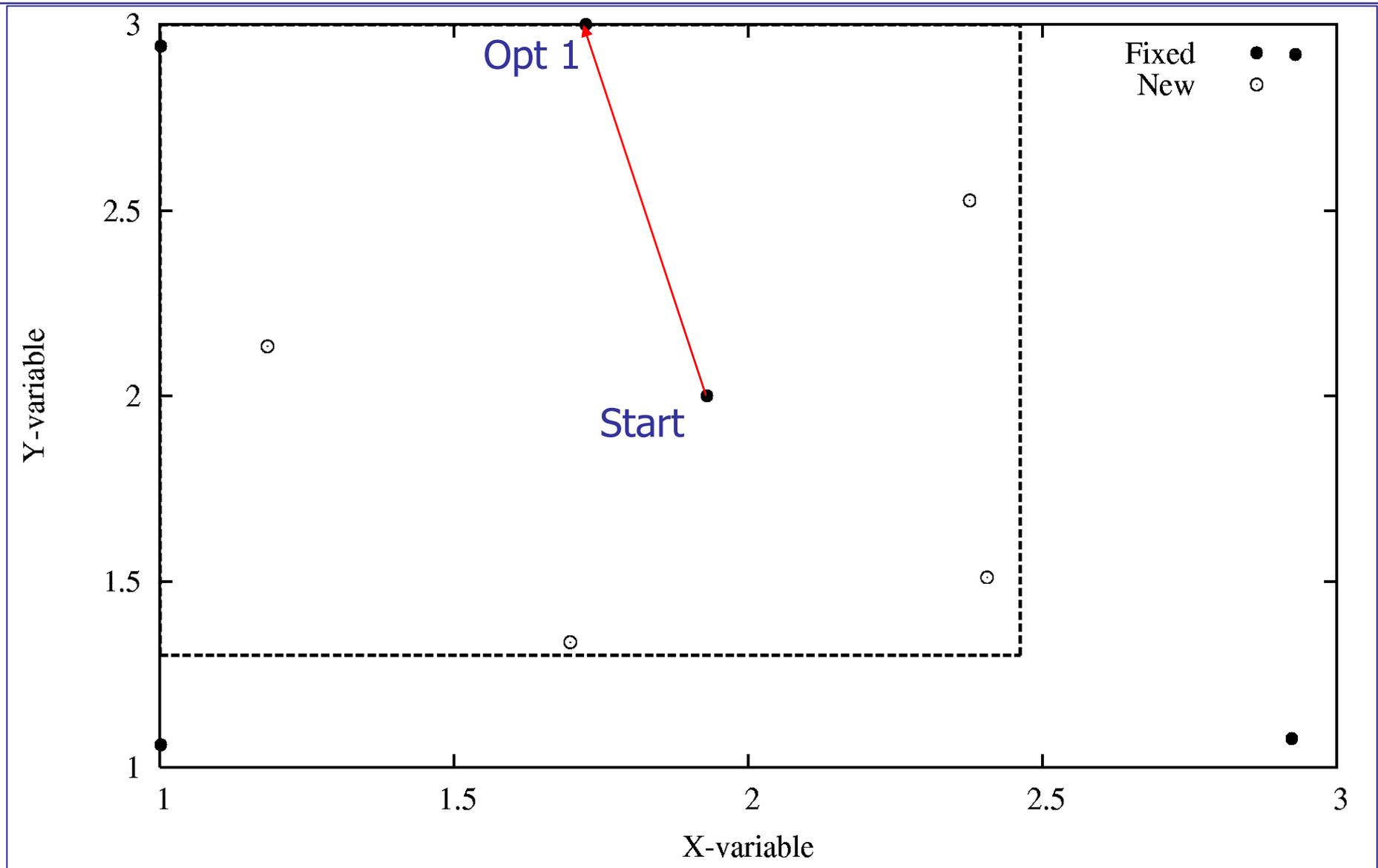
# Sampling: Space Filling Method

## Iteration 1



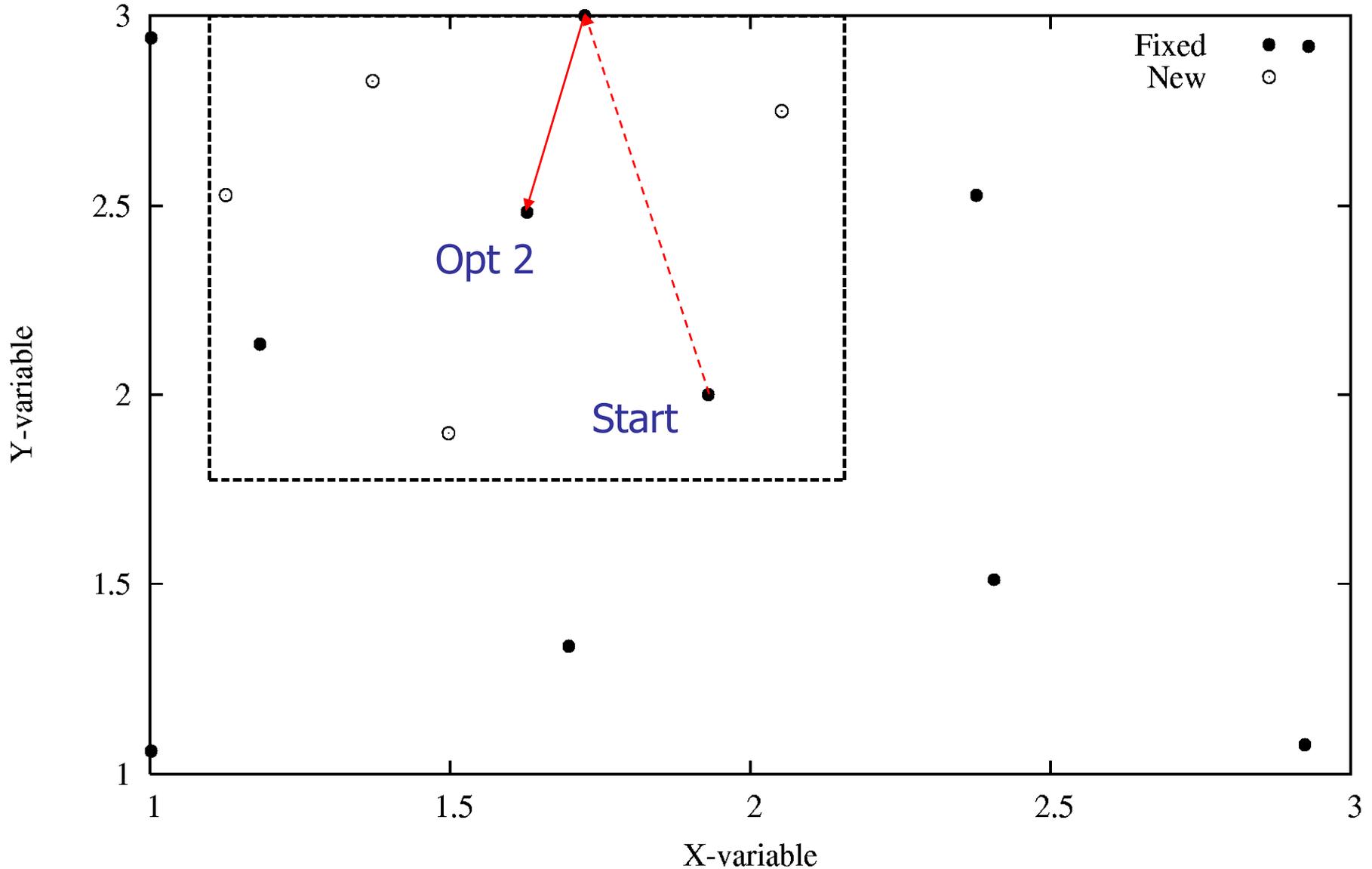
# Sampling: Space Filling Method

## Iteration 2



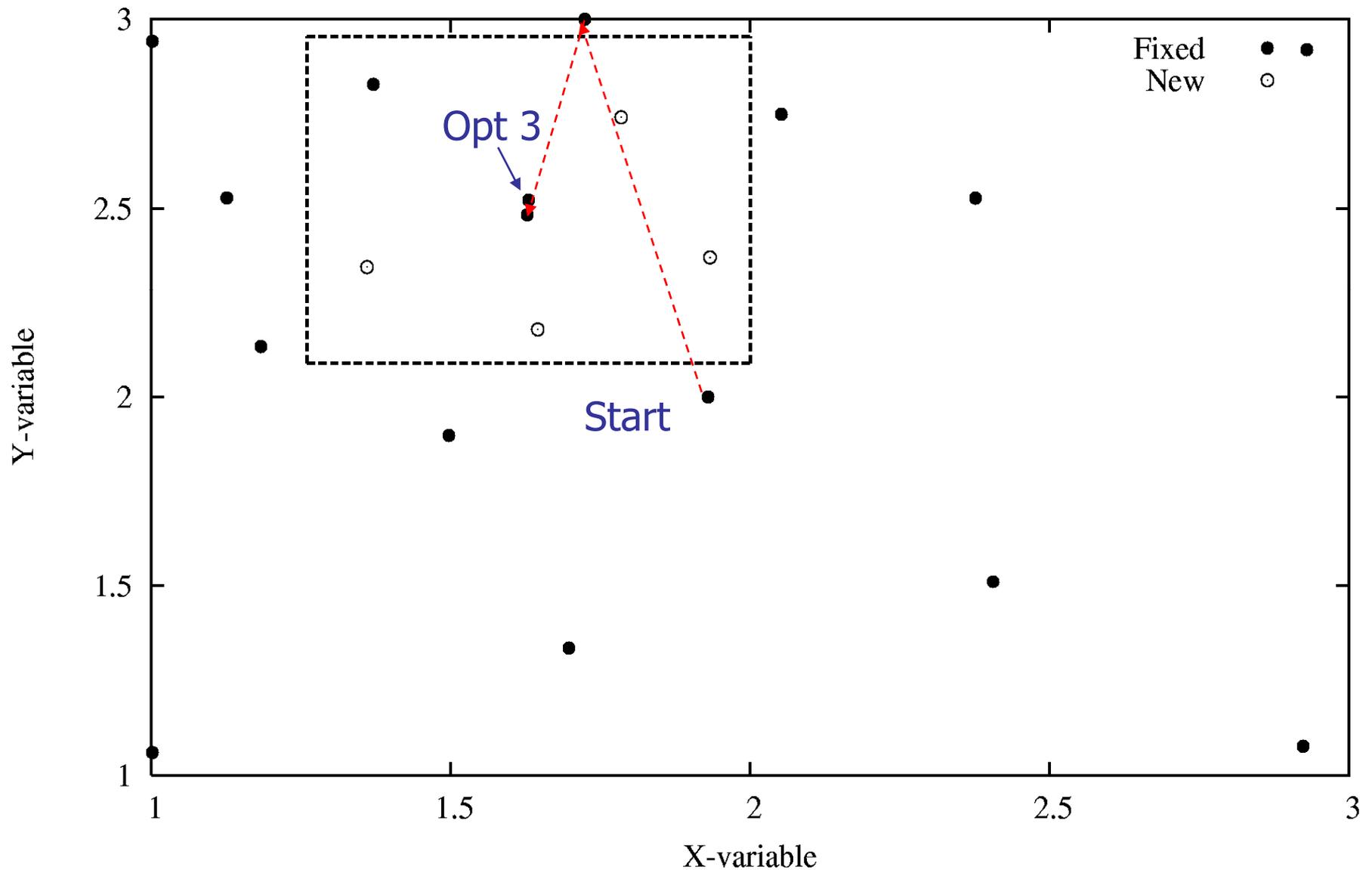
# Sampling: Space Filling Method

## Iteration 3

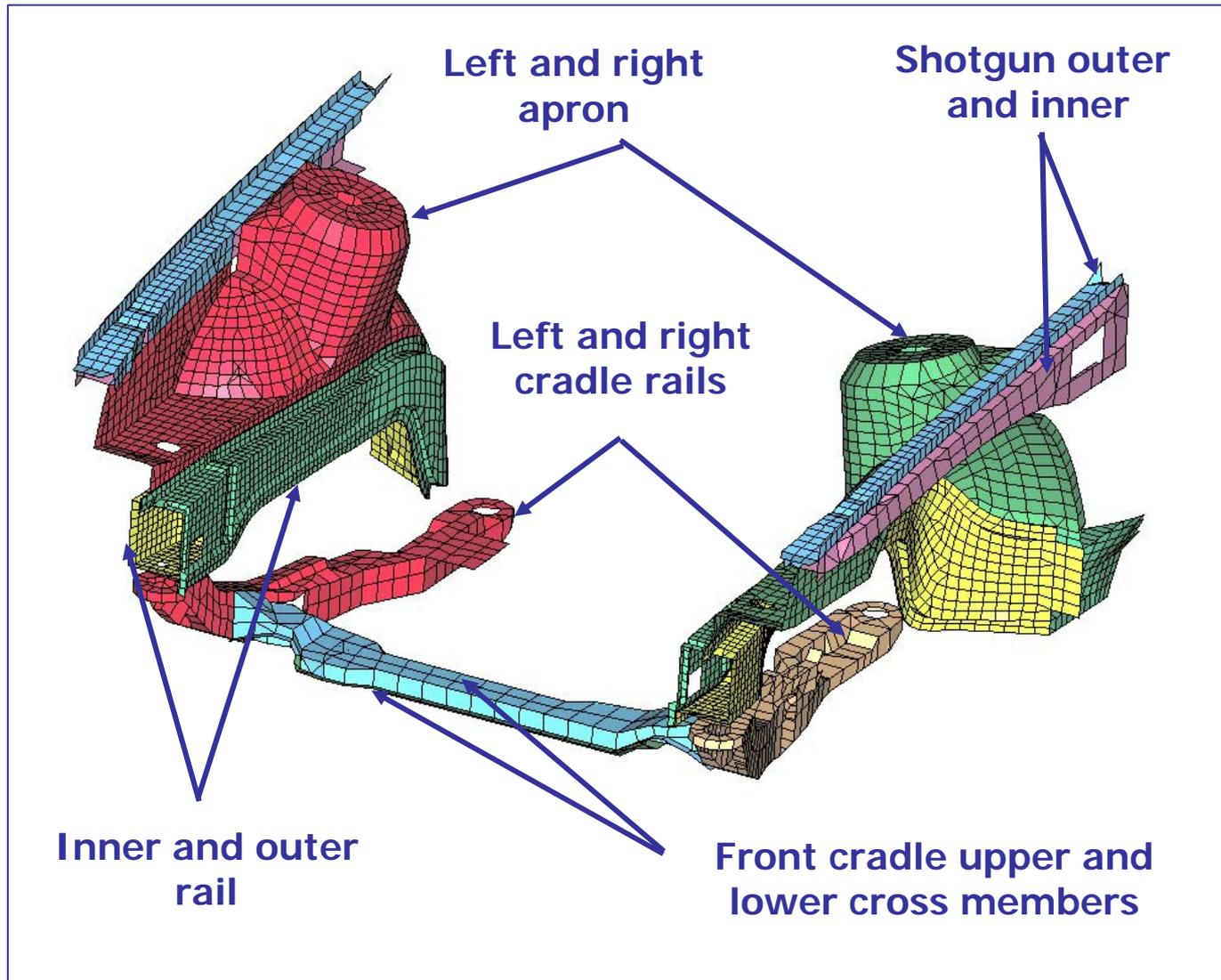


# Sampling: Space Filling Method

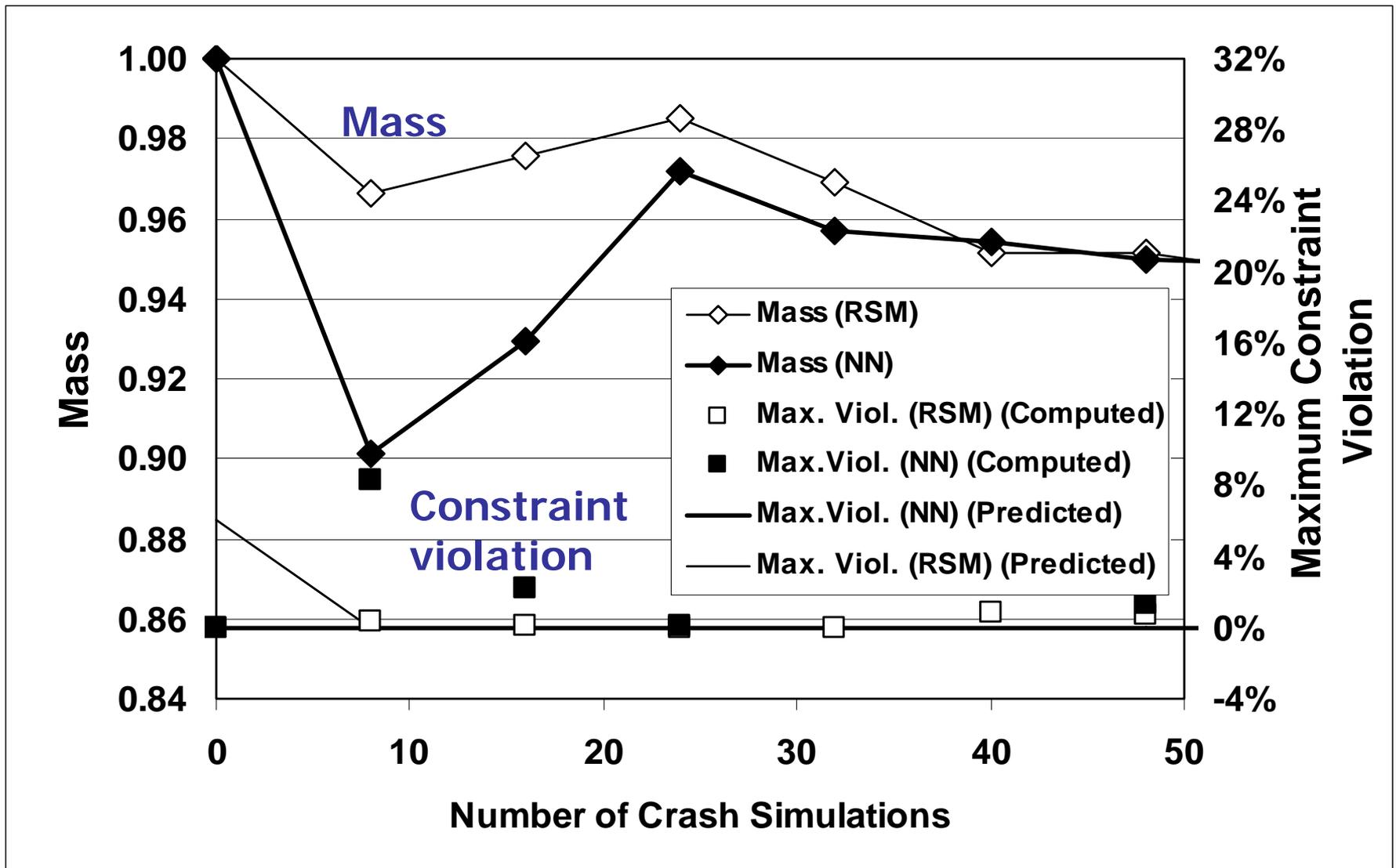
## Iteration 4



# Domain reduction: more variables



# Metamodel Comparison



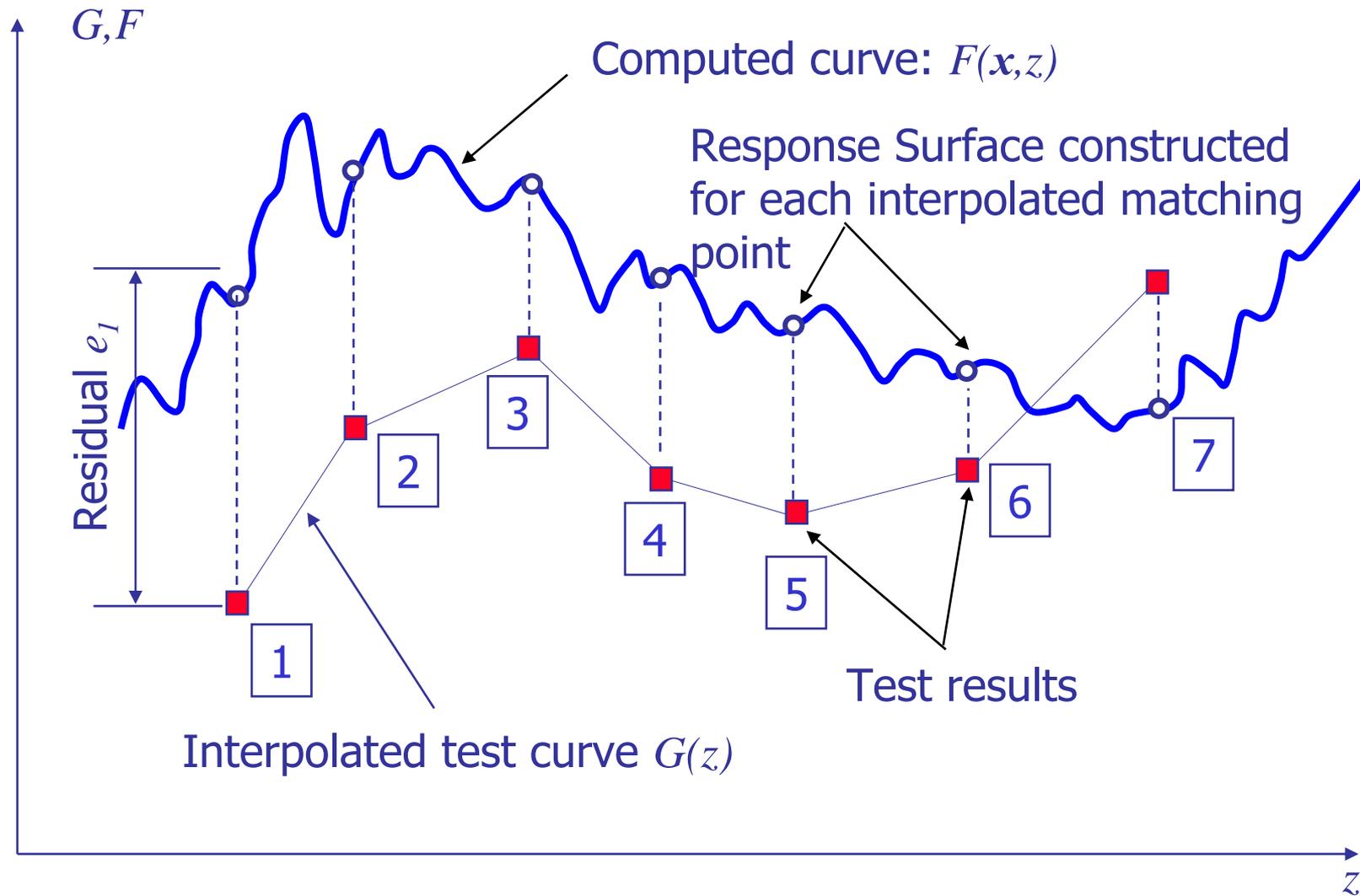
# Parameter Identification

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- ◆ Used for calibrating material or system properties
- ◆ Methodology uses minimization of the differences between test and computed results
- ◆ Strategy
  - ◆ History-based Mean Squared Error
    - The target values can be specified in a history file and imported as a history. A single function computes the MSE

# History-based Parameter Identification

## Test points + Computed curve



# History-based Parameter Identification

## Mean squared error

Weight (Importance of error)

Response Surface Value

Test Value

Residual

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

Number of points

Residual Scale factor  
(Normalization of error)

Variables (material  
or system constants)

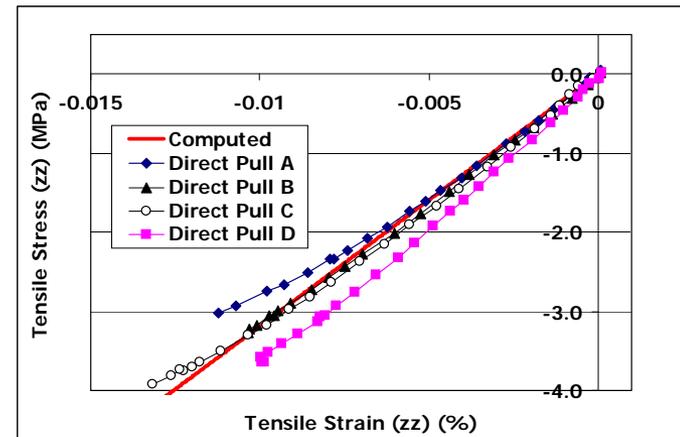
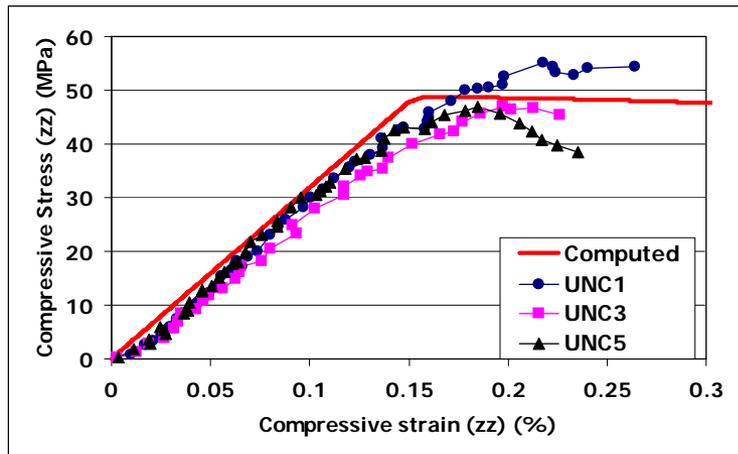
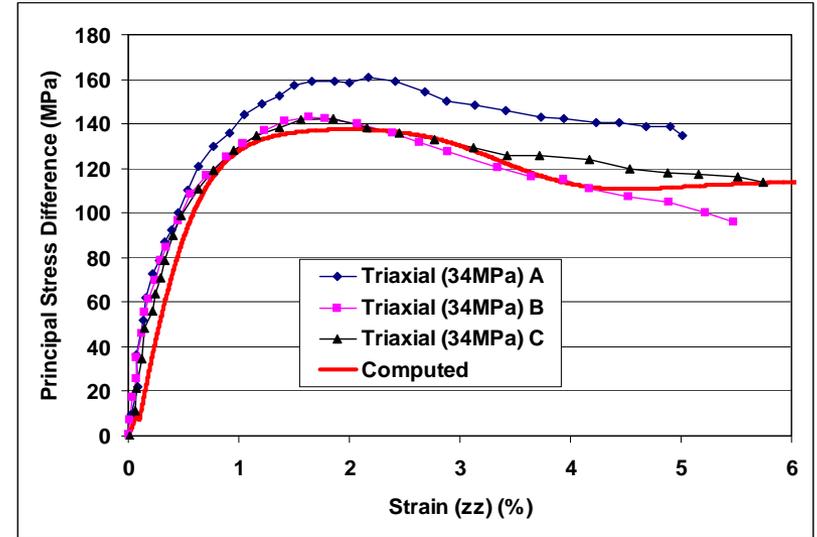
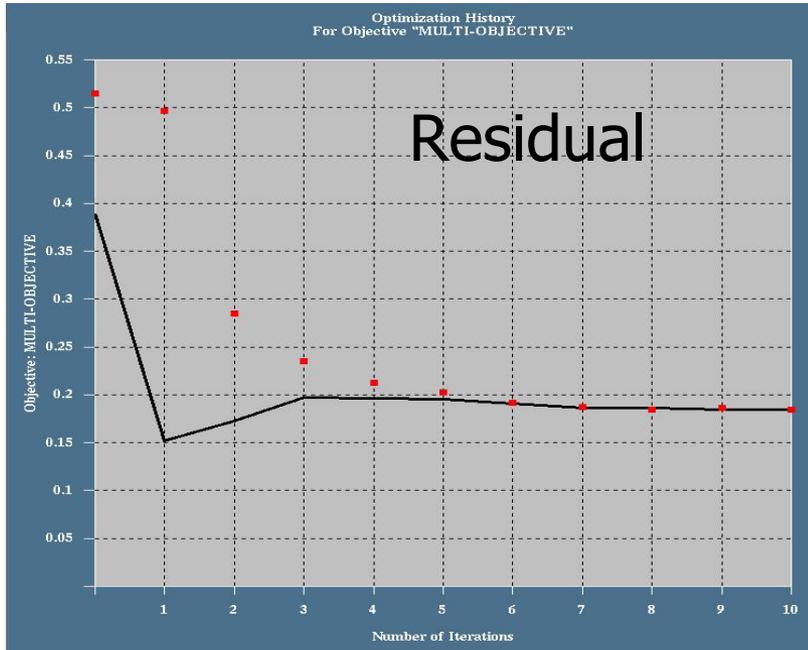
# Material Identification: Concrete Mat 159

## 11 parameters, 9 test types, 20 test sets

Par.	C00 UNC	T00 DP	PRS ISO- comp	UNX UNX	C07 TXC7	C14 TXC14	C20 TXC20	C34 TXC34	C69 TXC69
$G$	•	•	•	•					
$K$	•	•	•	•					
$R$				•	•	•	•	•	•
$X_0$			•						
$W$			•	•					
$D_1$			•						
$D_2$			•						
$\theta$					•	•	•	•	•
$\lambda$					•	•	•	•	•
$\beta$					•	•	•	•	•
$\eta$					•	•	•	•	•

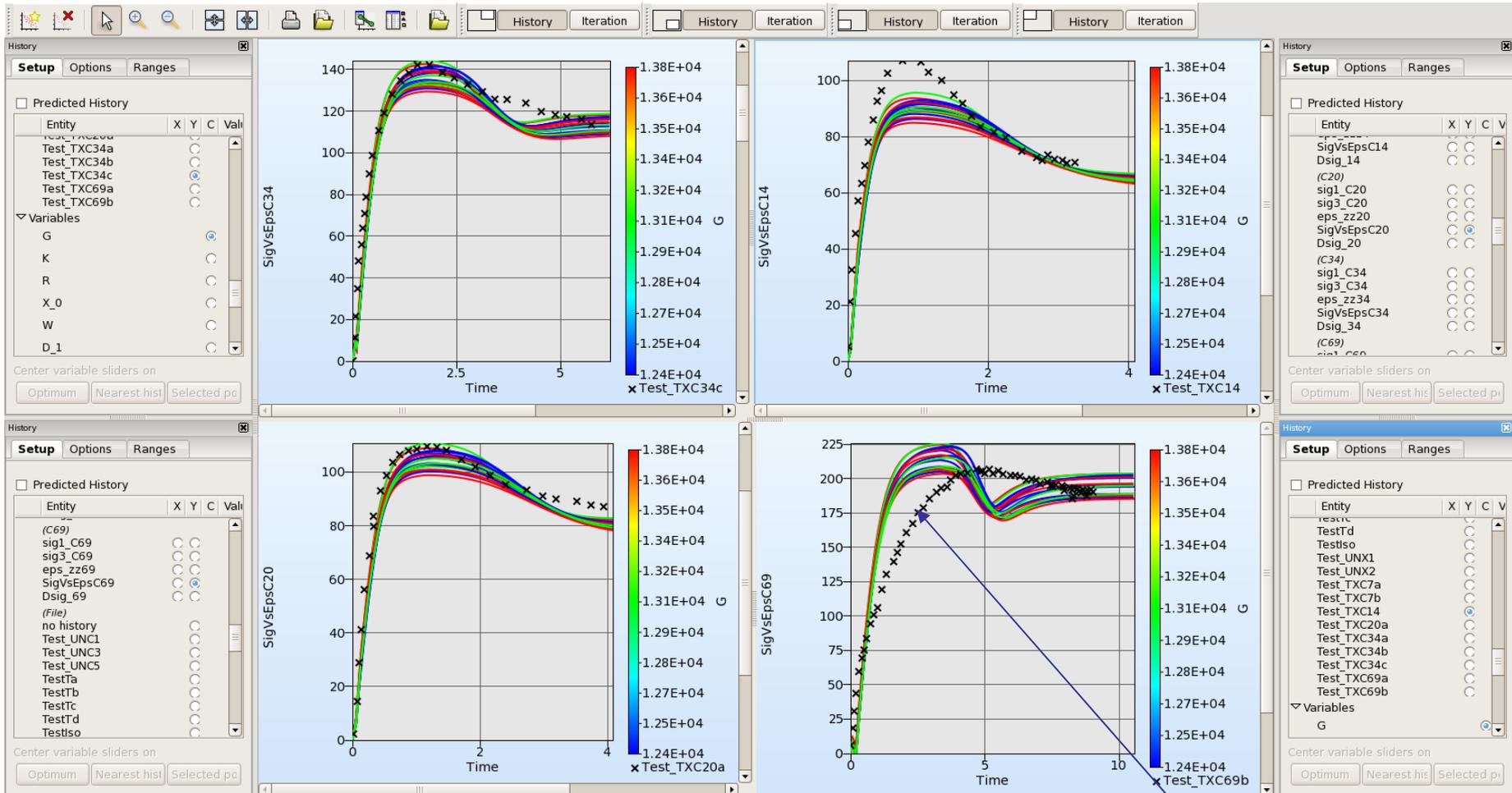
Multiple cases, shared variables

# Material Identification: Optimization (10 iterations): Stress vs. Strain Results



# Viewer: Computed Histories

◆ View comparative histories at all design points



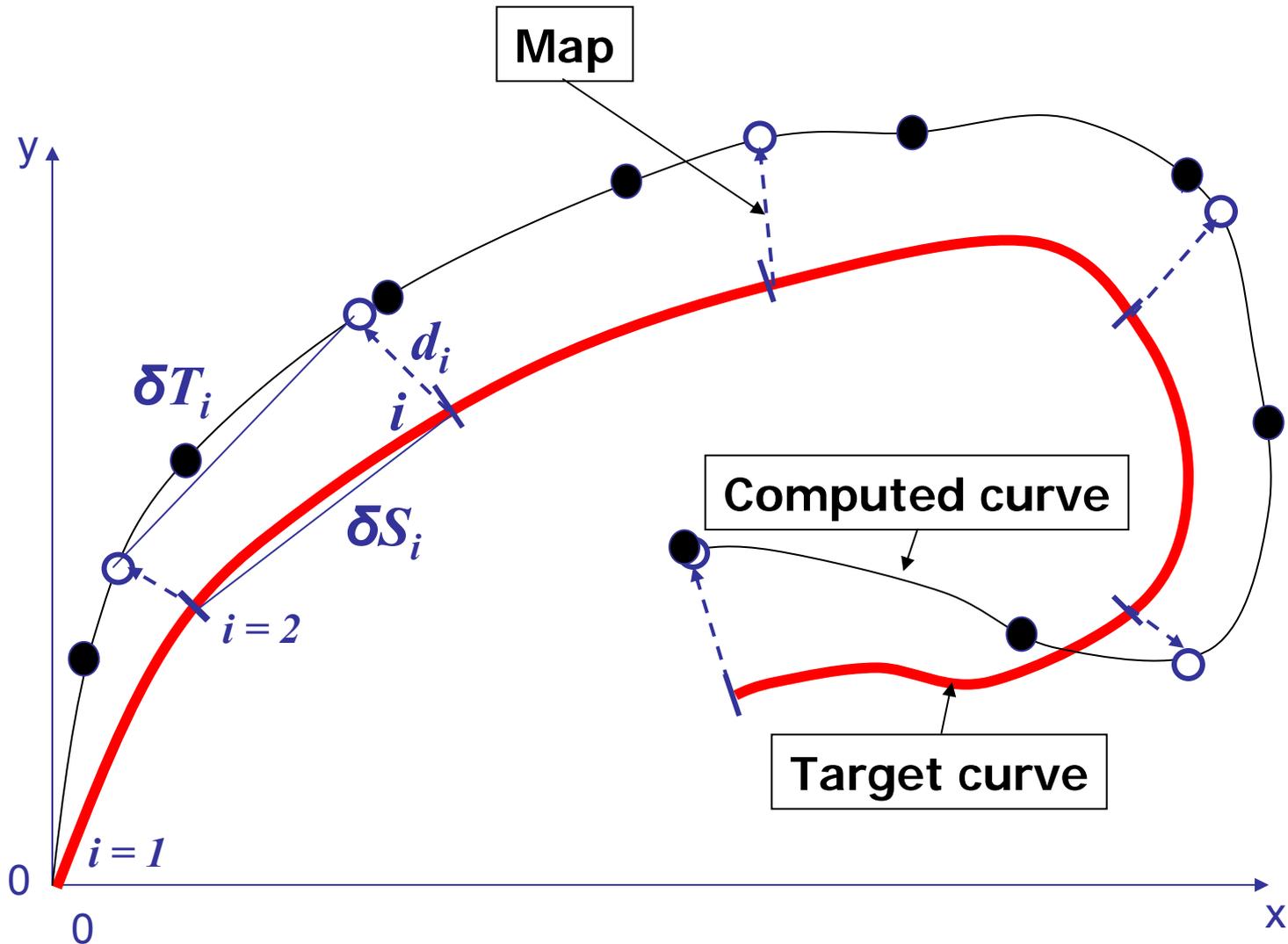
Test data

# Example: Parameter Identification

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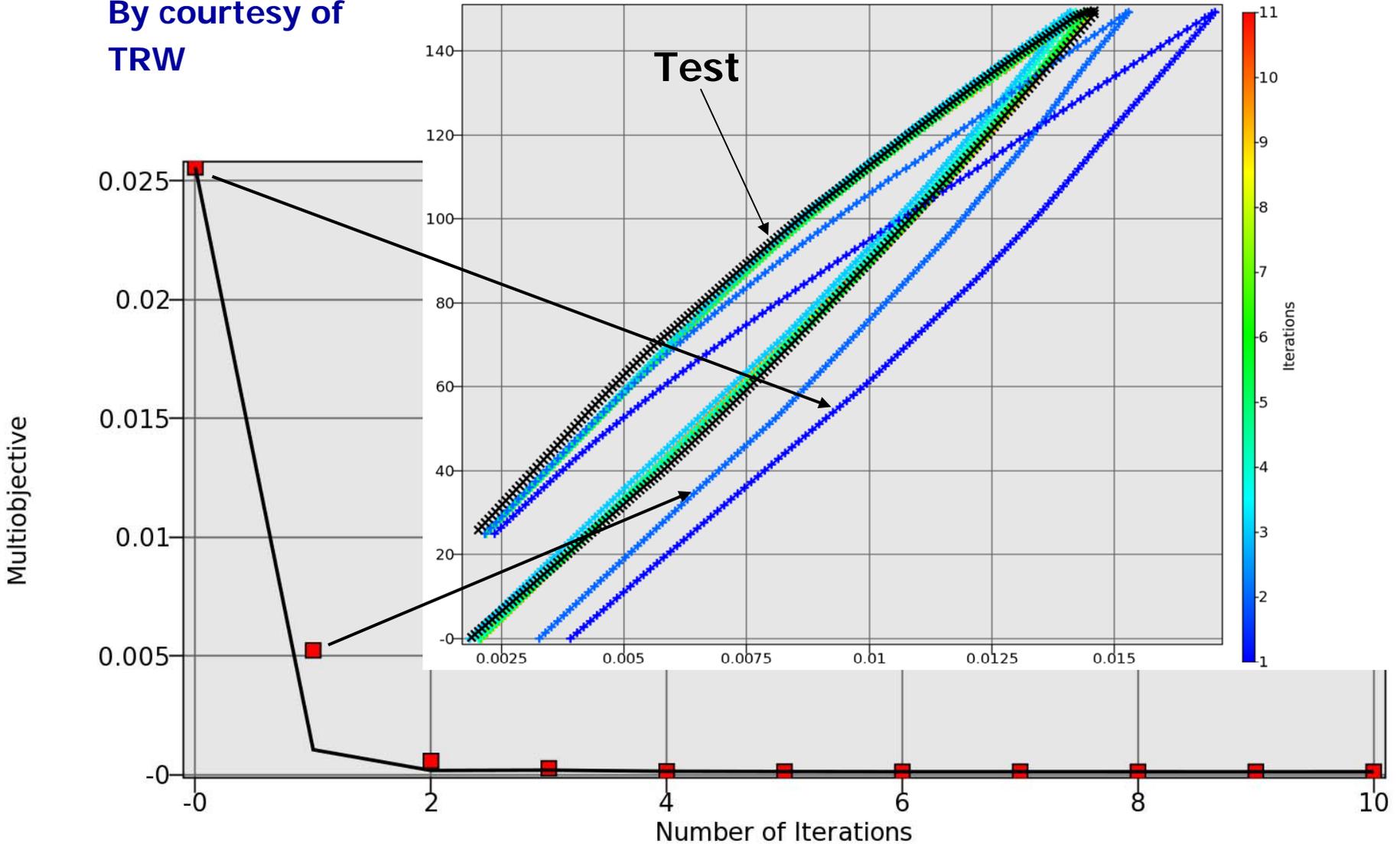
- ◆ Used for calibrating material or system properties
- ◆ *Min.*  
Difference between *test* and *computed* results
- ◆ Use Sequential Response Surface Method (Linear)

# Mapped Curve Matching (v4.2)



# Curve Matching (v4.2)

By courtesy of  
TRW



# Discrete Optimization

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- Discrete variables can have only distinct values, e.g. { 1.0, 2.0, 2.5, 4.5 }
- Discrete and continuous variables can be used together
- Discrete sampling can be combined with discrete optimization

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# Reliability/Robust Design

# Summary: Probabilistic Analysis

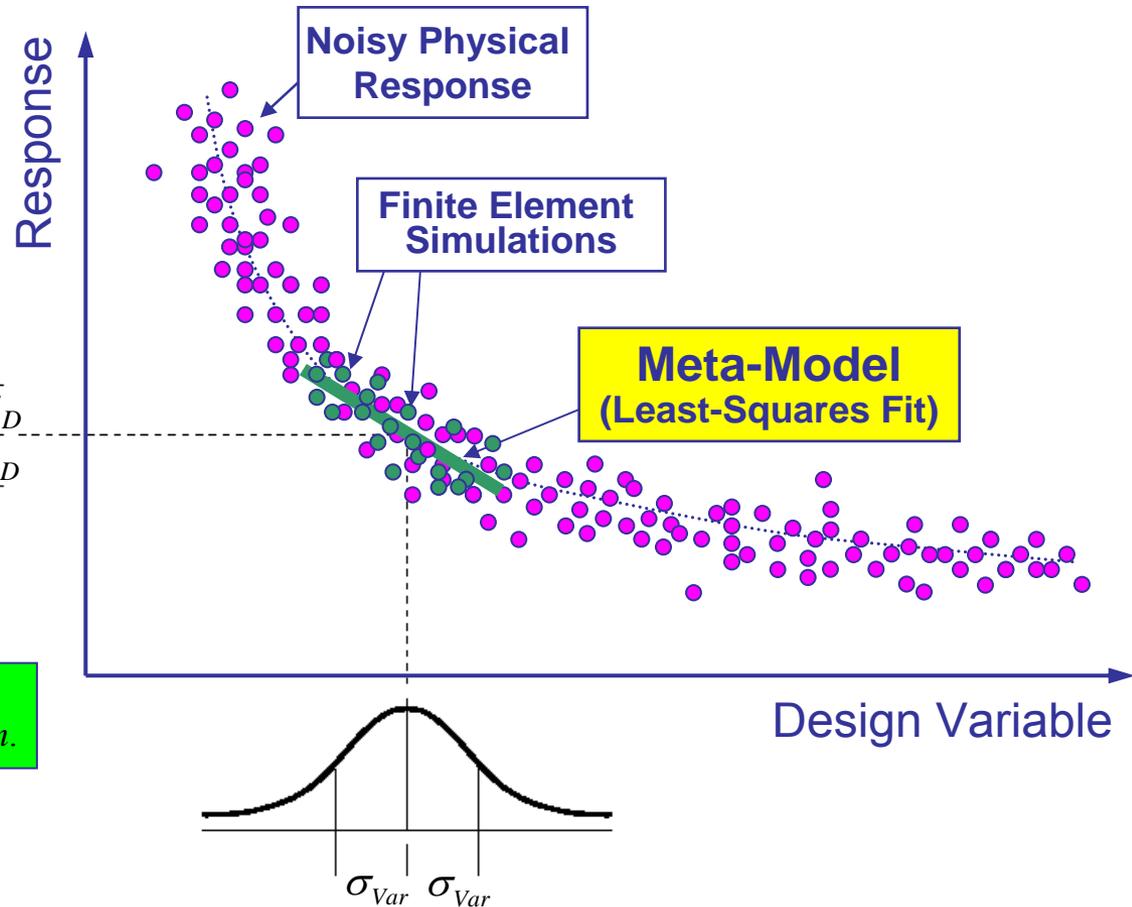
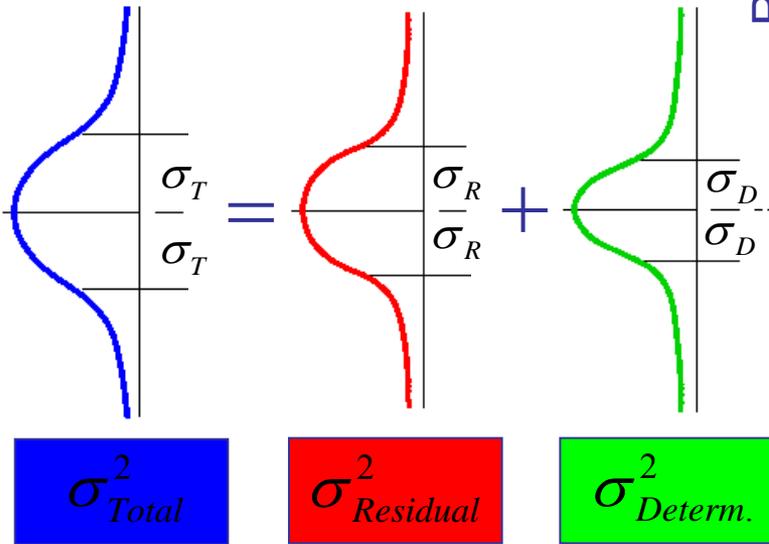
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## ◆ Reliability and Robustness

- ◆ Reliability:
  - Calculate probability of failure
- ◆ Robust Design:
  - Standard Deviation of response
  - Consistent product performance
- ◆ Reliability-based Design Optimization (RBDO)
  - Incorporates Reliability and Robustness into design improvement
- ◆ Identify sources of uncertainty in the FE models: Outlier Analysis

# Meta-Modeling and Stochastic Contributions

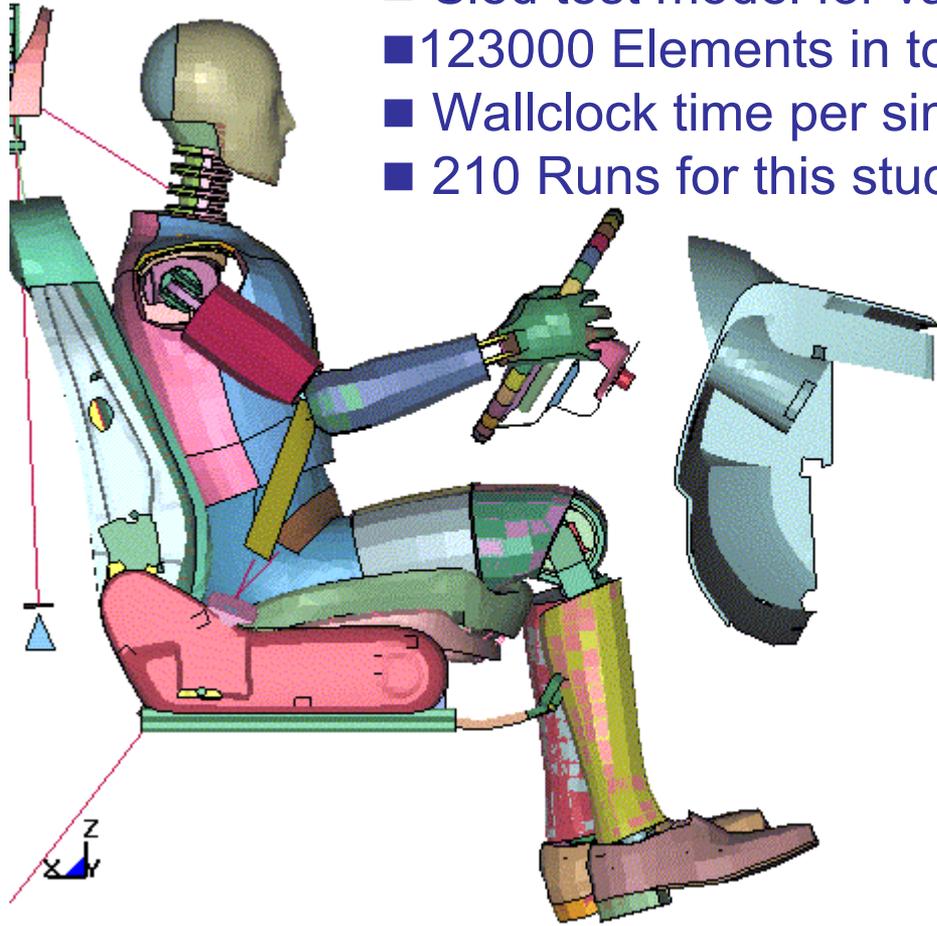
## Stochastic Contributions



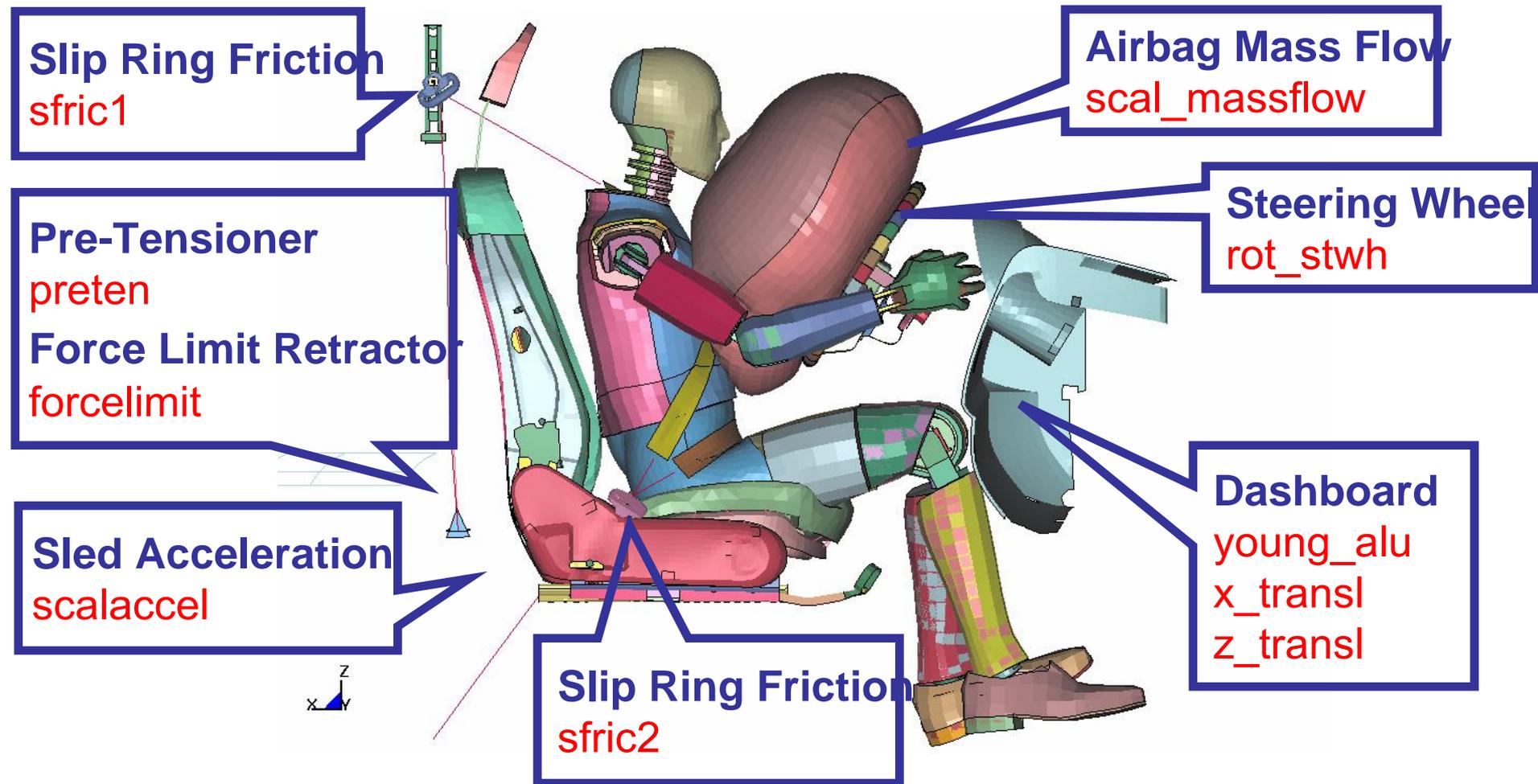
Günther, F., Müllerschön, H., Roux, W.J.  
LS-DYNA International Users  
Conference, 2004

# Occupant Simulation Model

- Sled test model for validation of occupant simulation
- 123000 Elements in total (Beams/Shells/Solids)
- Wallclock time per simulation: 9.5 hours on 16 cpus
- 210 Runs for this study



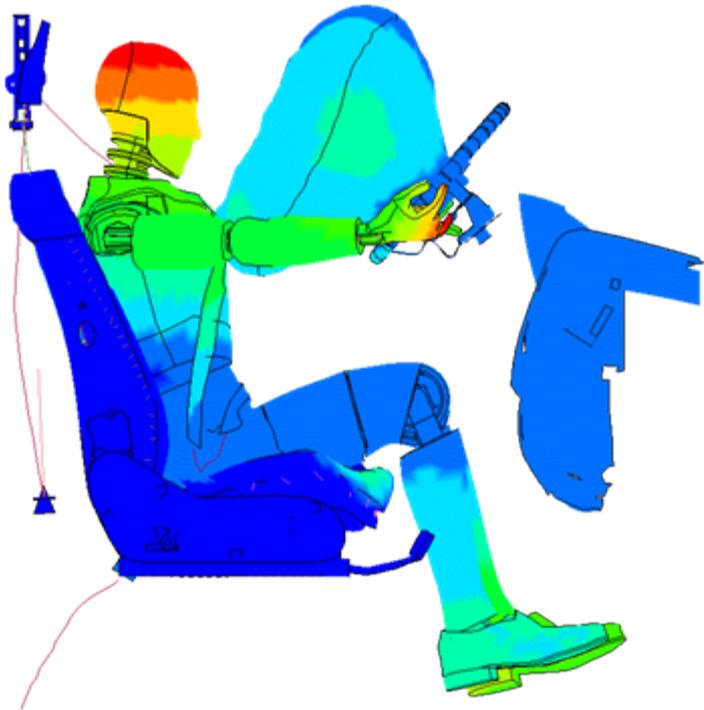
# Uncertainty Design Variables



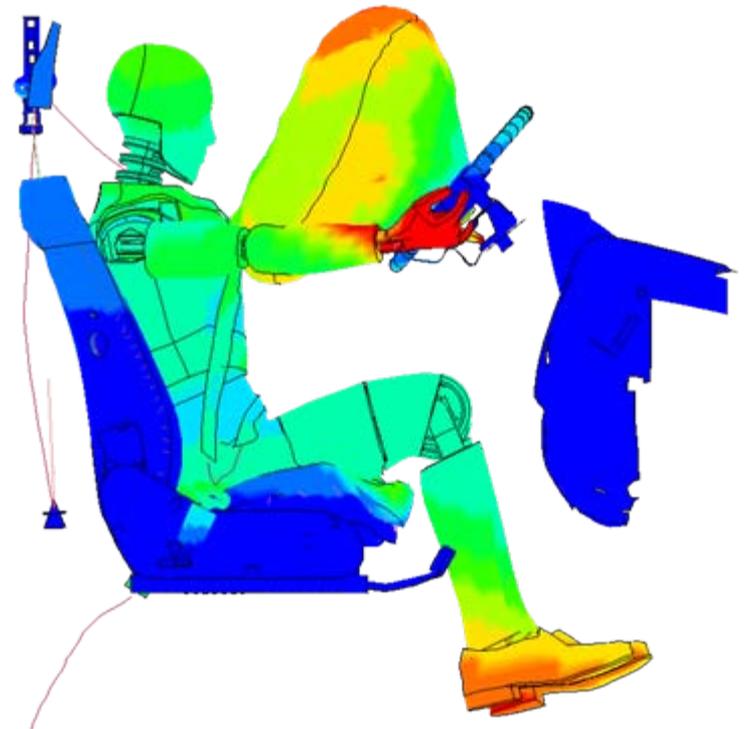
# Displacement Statistics: Metamodel vs. Outliers

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

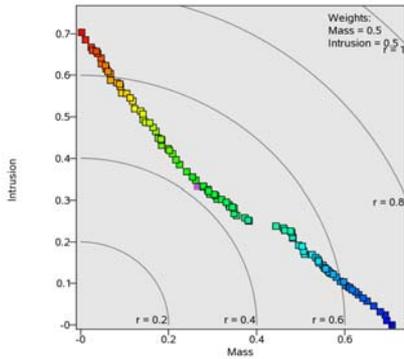
(a) Deterministic (Metamodel)



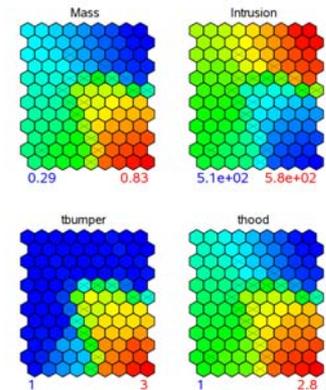
(b) Noise (Outliers)



Günther, F., Müllerschön, H., Roux, W.J.  
LS-DYNA International Users  
Conference, 2004



# Multi-objective Optimization



# Multi-objective Optimization

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- ◆ Most engineering problems deal with multiple objectives e.g., cost, weight, safety, efficiency etc.
- ◆ Often conflicting requirements e.g., weight vs. efficiency
- ◆ **No single optimal solution!**
- ◆ **Strategies**
  - ◆ **Direct Simulation**
    - Higher cost
  - ◆ **Metamodel-based**
    - Accuracy depends on quality of metamodel
    - Can use sequential updating of metamodel to improve accuracy

# Validation of GA Using Benchmarks

## Unconstrained test problems

$$\text{Minimize}_{\vec{X}} \quad f_1(\vec{X}) = x_1; \quad f_2(\vec{X}) = g(\vec{X})h(g(\vec{X}), f_1(\vec{X})),$$

$$\text{ZDT2: } g(\vec{X}) = 1 + 9(N-1)^{-1} \sum_{i=2}^N x_i;$$

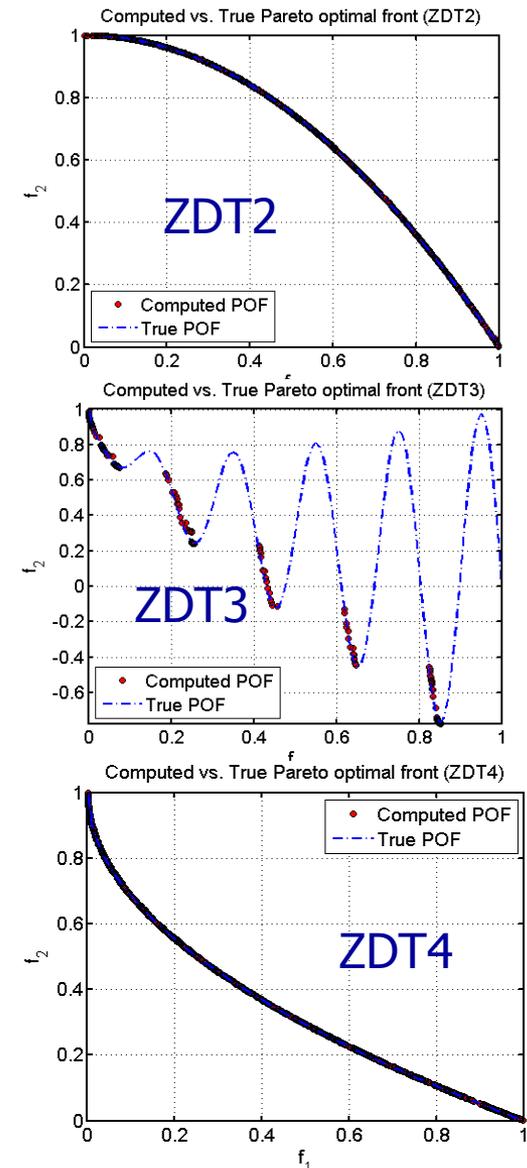
$$h(\vec{X}) = 1 - (f_1/g)^2; x_i \in [0,1].$$

$$\text{ZDT3: } g(\vec{X}) = 1 + 9(N-1)^{-1} \sum_{i=2}^N x_i;$$

$$h(\vec{X}) = 1 - \sqrt{f_1/g} - (f_1/g) \sin(10\pi f_1); x_i \in [0,1].$$

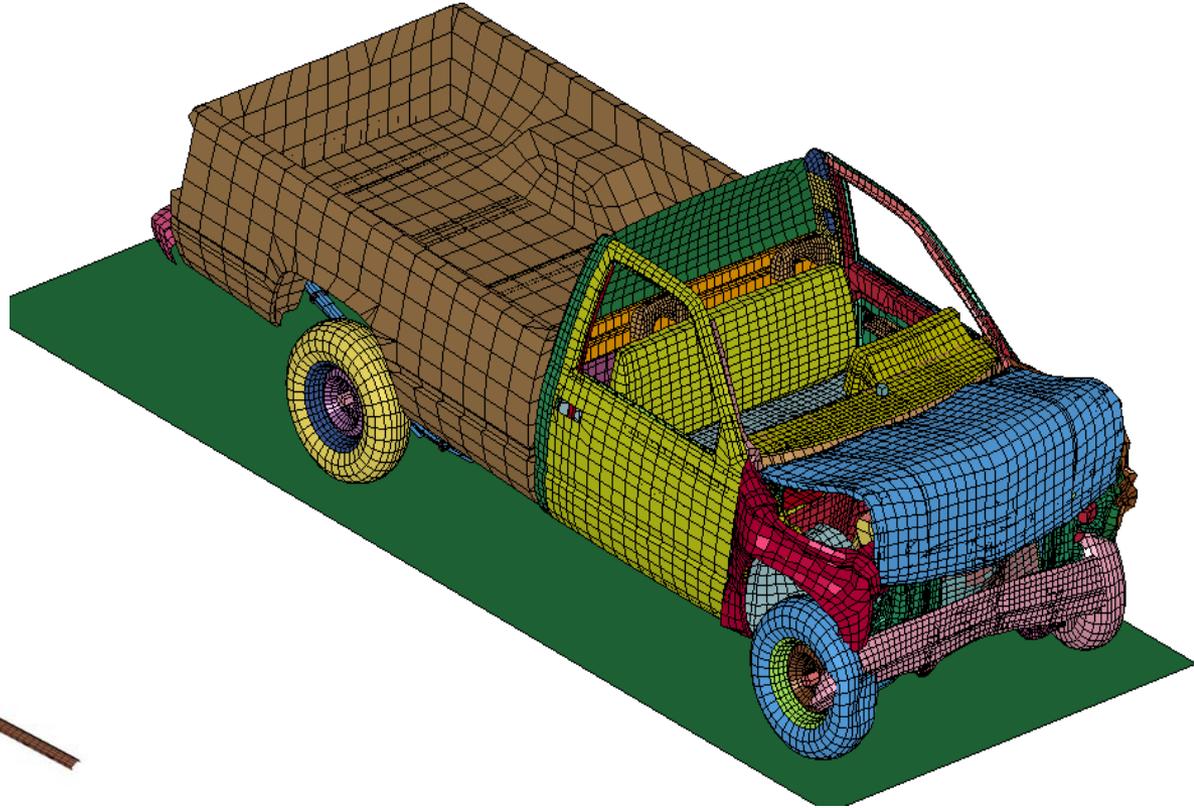
$$\text{ZDT4: } g(\vec{X}) = 1 + 10(N-1) + \sum_{i=2}^N (x_i^2 - 10 \cos(4\pi x_i));$$

$$h(\vec{X}) = 1 - \sqrt{f_1/g}; x_1 \in [0,1]; x_{2,3,\dots,N} \in [-5,5].$$



# Metamodel-based MOO/Robust design

C2500 PICKUP TRUCK MODEL - (NCAC V6)



Thickness design variables

C2500 PICKUP TRUCK MODEL - (NCAC V6)



# Design criteria

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## Minimize

- ◆ Mass
- ◆ Acceleration
- ◆ Standard deviation of the intrusion (robustness)

## Maximize

- ◆ Intrusion
- ◆ Time to zero velocity

9 stochastic thickness variables of main crash members.  
2 discrete + 7 continuous

Intrusion	<	721
Stage 1 pulse	<	7.5g
Stage 2 pulse	<	20.2g
Stage 3 pulse	<	24.5g

**Probability of failure < 0.15**

# Stochastic input

The image shows a software interface with several panels. The top panel is titled 'Statistical Distributions' and has tabs for 'Info', 'Strategy', 'Solvers', 'Dist', 'Variables', 'Sampling', 'Histories', 'Responses', and 'Objective'. The 'Dist' tab is active, showing a list of distributions: 'Uniform' and 'Truncated\_Normal'. A plot shows a uniform distribution with 'Mean = 0' and 'Std Dev = 0.0'. The 'Lower Bound' is 1 and the 'Upper Bound' is 2.

The bottom panel is titled 'Design Variables' and has tabs for 'Info', 'Strategy', 'Solvers', 'Dist', 'Variables', 'Sampling', 'Histories', 'Responses', 'Objective', 'Constraints', 'Algorithms', 'Run', 'Viewer', and 'DYNA Stats'. The 'Variables' tab is active, showing a table of design variables:

Type	Name	Starting	Init. Range	Minimum	Maximum	SamplingType	Distribution
Variable	t1	3.137		2.5	3.765		Uniform
Discrete Va	t2	3.112	Values	2.48 2.6 2.8 3.2 3.4 3.6 3.7		Continuous	Uniform
Discrete Va	t3	2.997	Values	2.4 2.6 2.8 3.2 3.4 3.6		Continuous	Uniform
Variable	t4	3.072		2.4	3.6		Uniform
Variable	t5	3.4		2.72	4.08		Uniform
Variable	t6	3.561		2.85	4.27		Truncated_Normal
Variable	t10	2.7		2.16	3.24		Truncated_Normal
Variable	t64	1.262		1.	1.51		Truncated_Normal
Variable	t73	1.99		1.6	2.4		Truncated_Normal

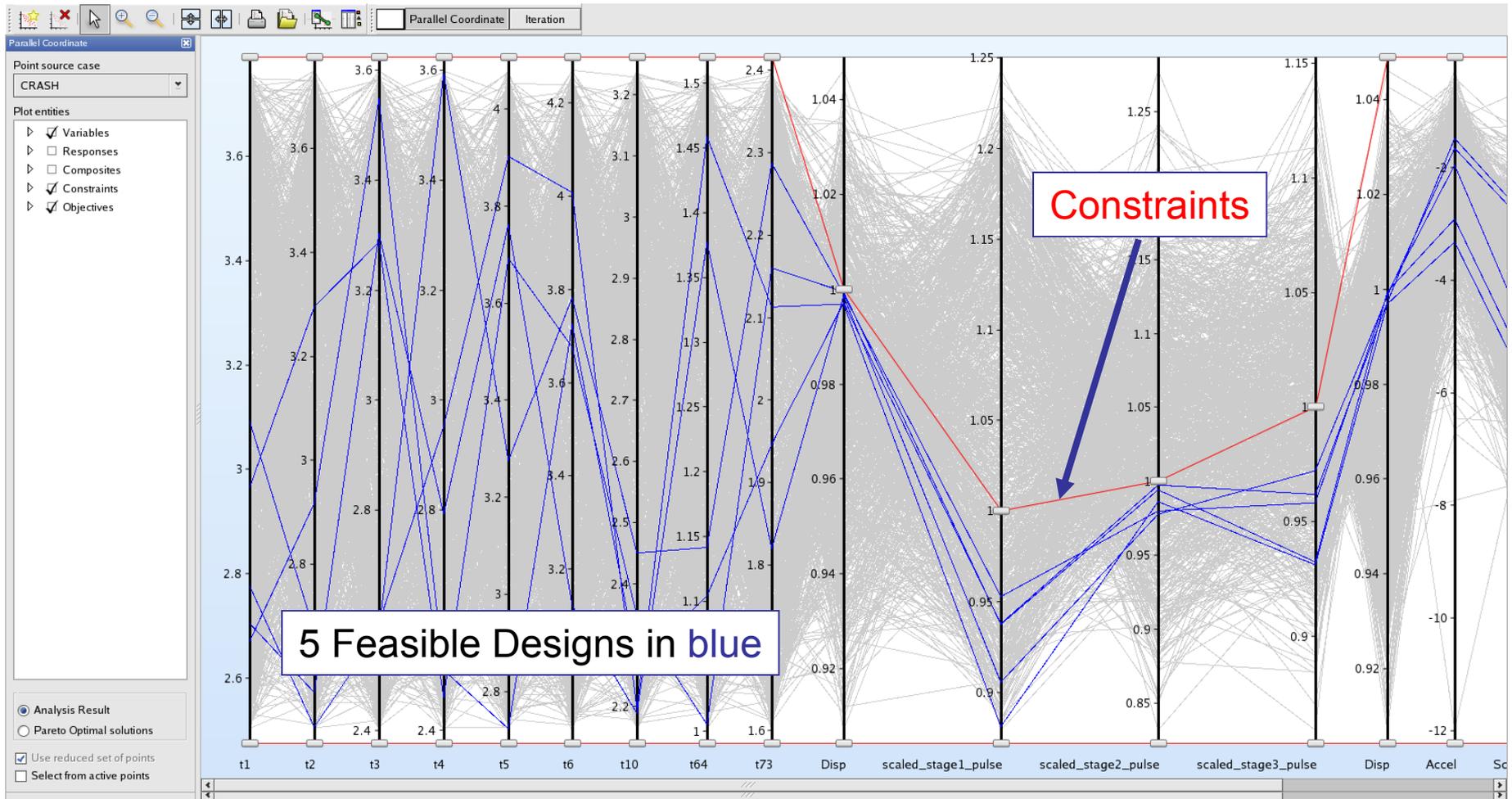
Annotations include 'Truncated normal' pointing to the 'Truncated\_Normal' distribution in the top panel, and 'Discrete' pointing to the 'Discrete Va' rows in the 'Design Variables' table.

# Simulation statistics

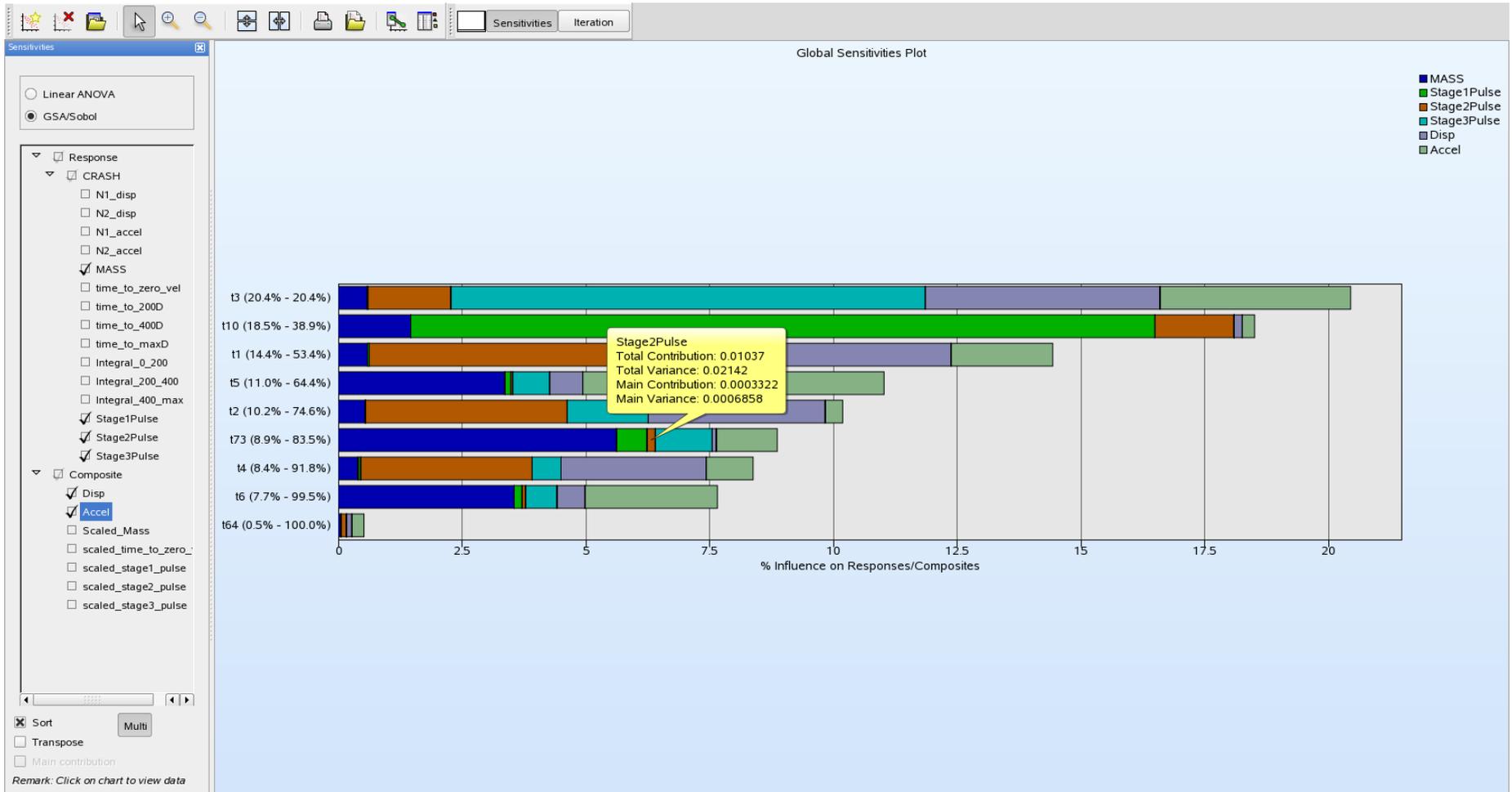
---

- ◆ 640-core HP XC cluster (Intel Xeon 5365 80 nodes of 2 quad-core)\*
  - ◆ Queuing through LSF
  - ◆ Total of **1000** crash runs
  
  - ◆ Strategy: Single stage run
  - ◆ Sampling scheme: *Space Filling* (MinMax distance) using 1000 points
  - ◆ Metamodel: *Radial Basis Function Network*
  - ◆ Optimization solver: *NSGA-II* to find *Pareto Optimal Frontier*
- \* *In collaboration with Yih-Yih Lin Hewlett-Packard Company*

# Parallel Coordinate Plot: 1000 Simulations



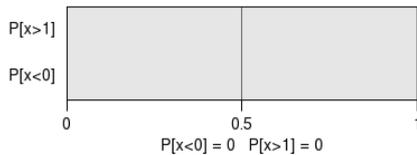
# Global Sensitivity Analysis (Sobol indices)



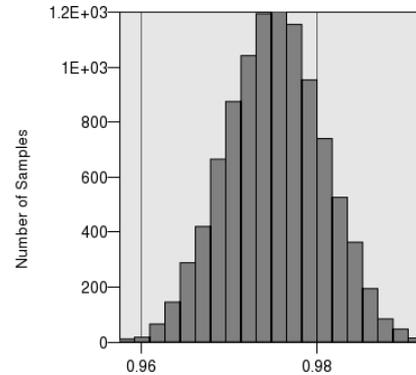
# Probability distributions of constraint values

## Starting Design (infeasible)

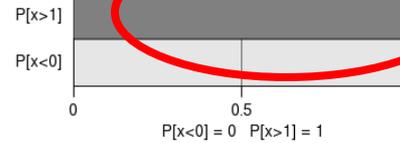
Composite: Disp  
10000 samples: Mean = 0.975 Standard Deviation = 0.00552  
95% confidence interval in red



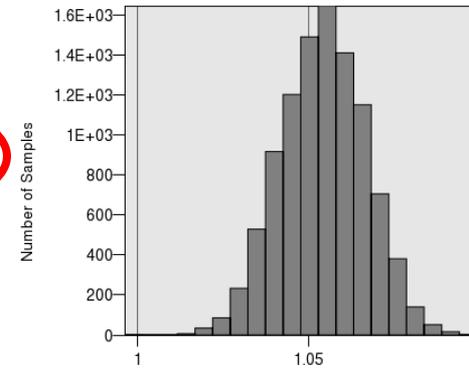
Composite: Disp  
10000 samples: Mean = 0.975 Standard Deviation = 0.00551



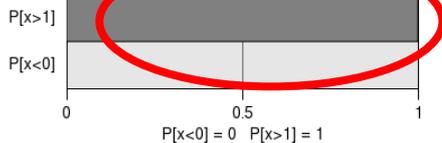
Composite: scaled\_stage2\_pulse  
10000 samples: Mean = 1.05 Standard Deviation = 0.0123  
95% confidence interval in red



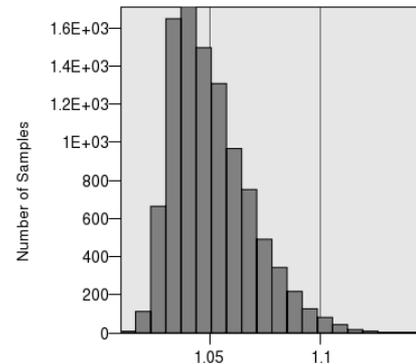
Composite: scaled\_stage2\_pulse  
10000 samples: Mean = 1.05 Standard Deviation = 0.0123



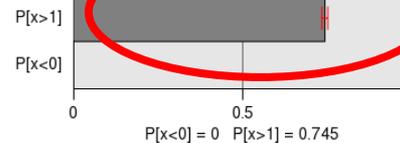
Composite: scaled\_stage1\_pulse  
10000 samples: Mean = 1.05 Standard Deviation = 0.0178  
95% confidence interval in red



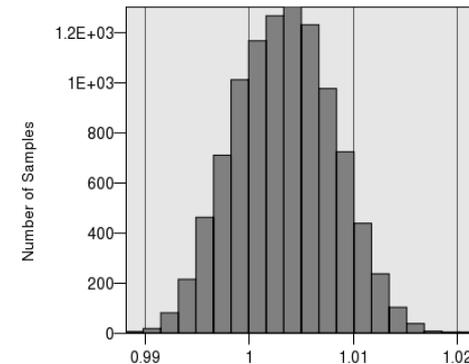
Composite: scaled\_stage1\_pulse  
10000 samples: Mean = 1.05 Standard Deviation = 0.0178



Composite: scaled\_stage3\_pulse  
10000 samples: Mean = 1 Standard Deviation = 0.00476  
95% confidence interval in red



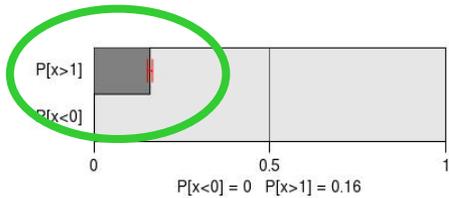
Composite: scaled\_stage3\_pulse  
10000 samples: Mean = 1 Standard Deviation = 0.00475



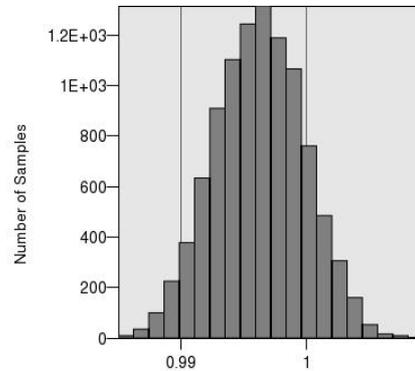
# Probability distributions of constraint values

## Optimal Design (equal weights)

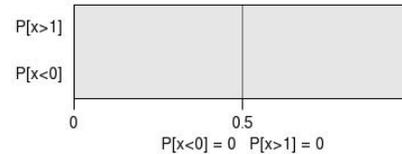
Composite: Disp  
10000 samples: Mean = 0.996 Standard Deviation = 0.00365  
95% confidence interval in red



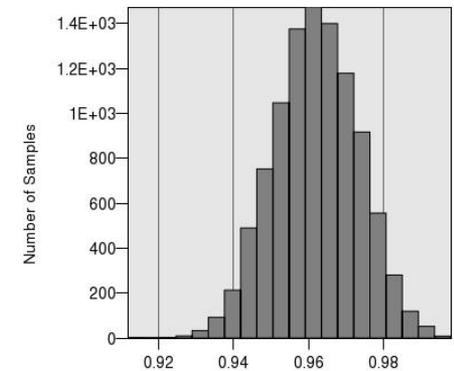
Composite: Disp  
10000 samples: Mean = 0.996 Standard Deviation = 0.00359



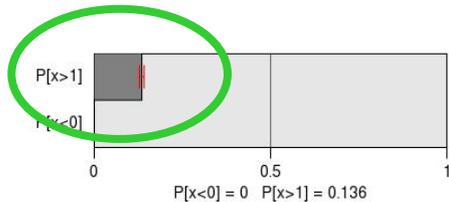
Composite: scaled\_stage2\_pulse  
10000 samples: Mean = 0.962 Standard Deviation = 0.0113  
95% confidence interval in red



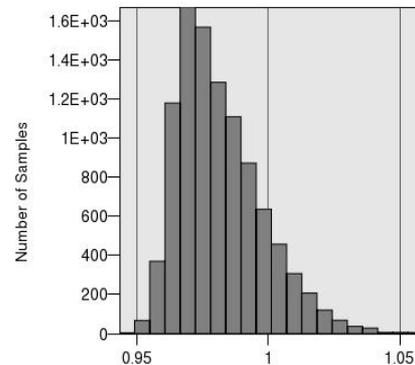
Composite: scaled\_stage2\_pulse  
10000 samples: Mean = 0.962 Standard Deviation = 0.0112



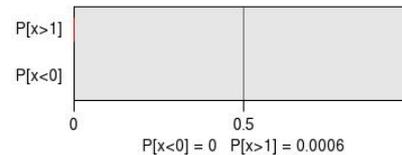
Composite: scaled\_stage1\_pulse  
10000 samples: Mean = 0.982 Standard Deviation = 0.0159  
95% confidence interval in red



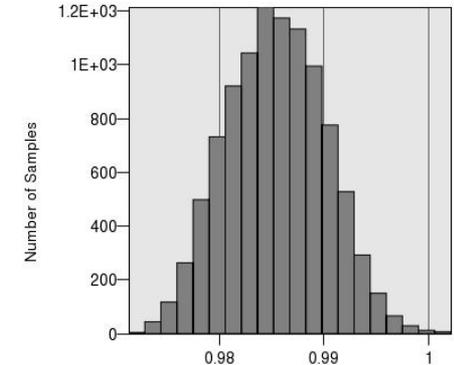
Composite: scaled\_stage1\_pulse  
10000 samples: Mean = 0.982 Standard Deviation = 0.016



Composite: scaled\_stage3\_pulse  
10000 samples: Mean = 0.985 Standard Deviation = 0.00473  
95% confidence interval in red



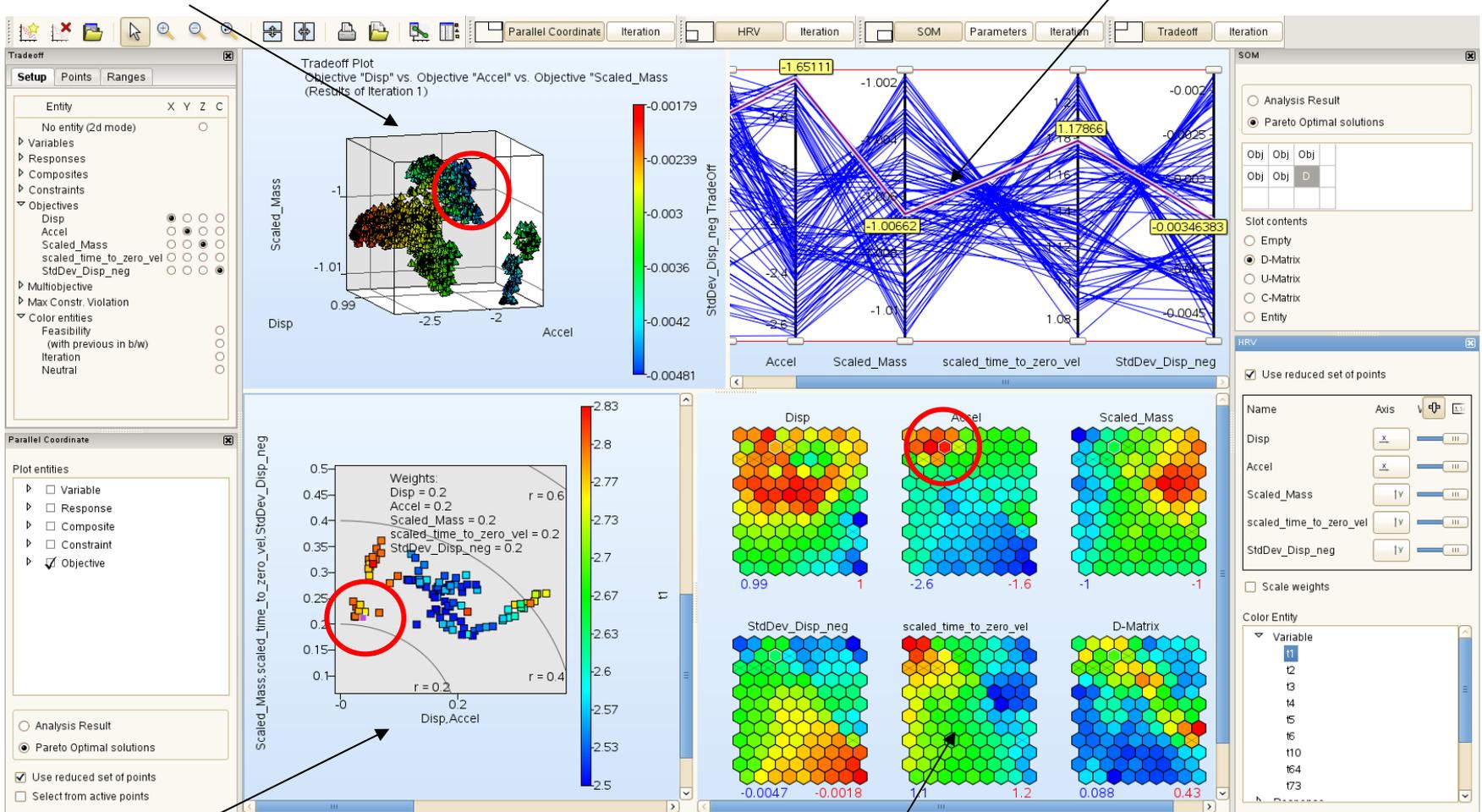
Composite: scaled\_stage3\_pulse  
10000 samples: Mean = 0.985 Standard Deviation = 0.00473



# Integrated Pareto Front Exploration

Scatter plot

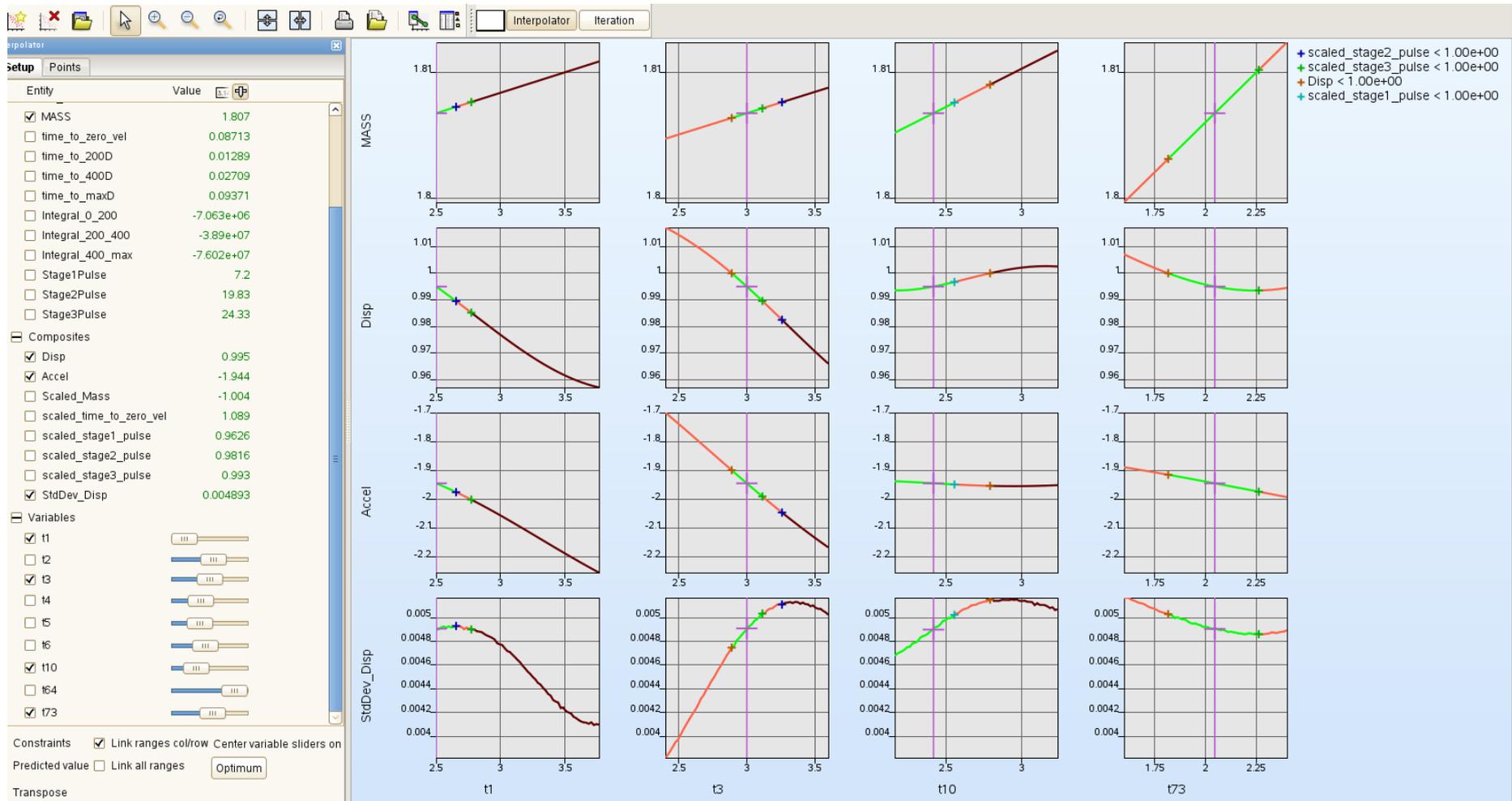
Parallel Coordinate



Hyper-Radial Visualization

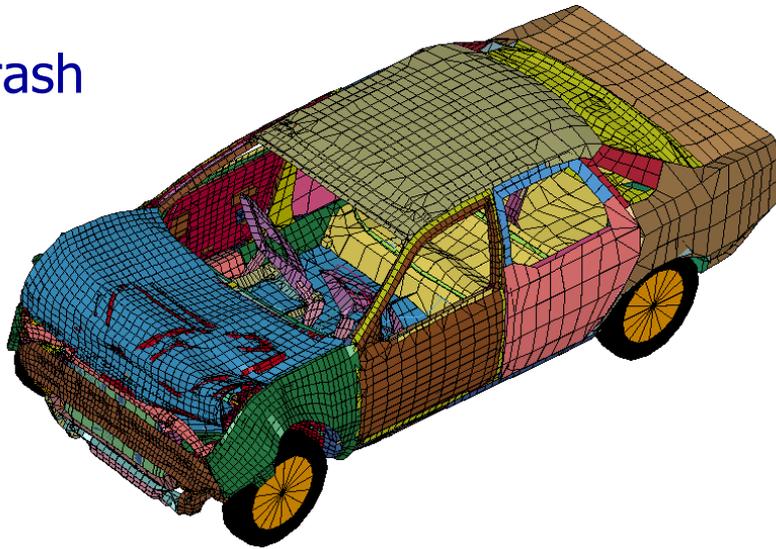
Self-Organizing Maps

# 2D sections of the design response

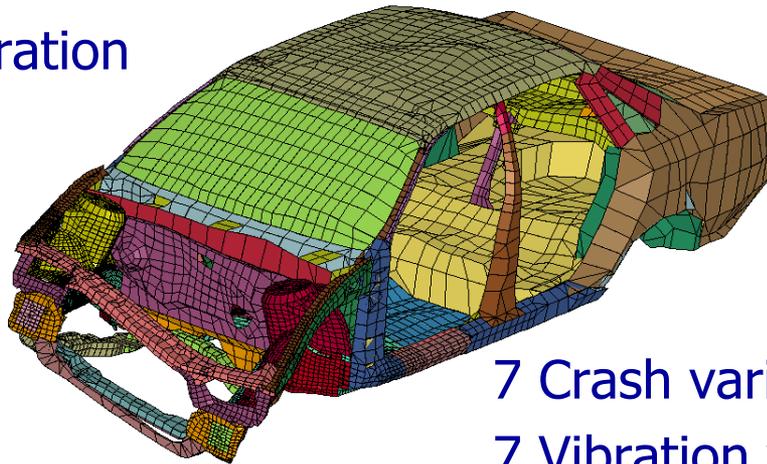


# Example: Direct MDO/MOO

Crash



Vibration



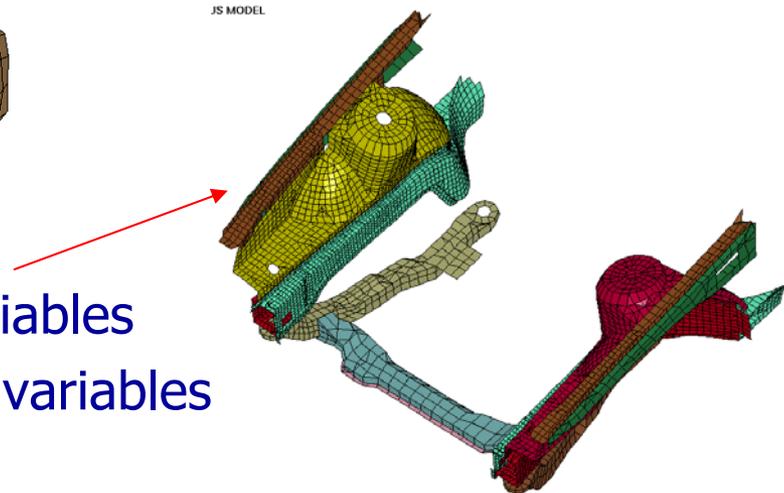
7 Crash variables  
7 Vibration variables  
(2 discrete)

Min. (Mass, Intrusion)

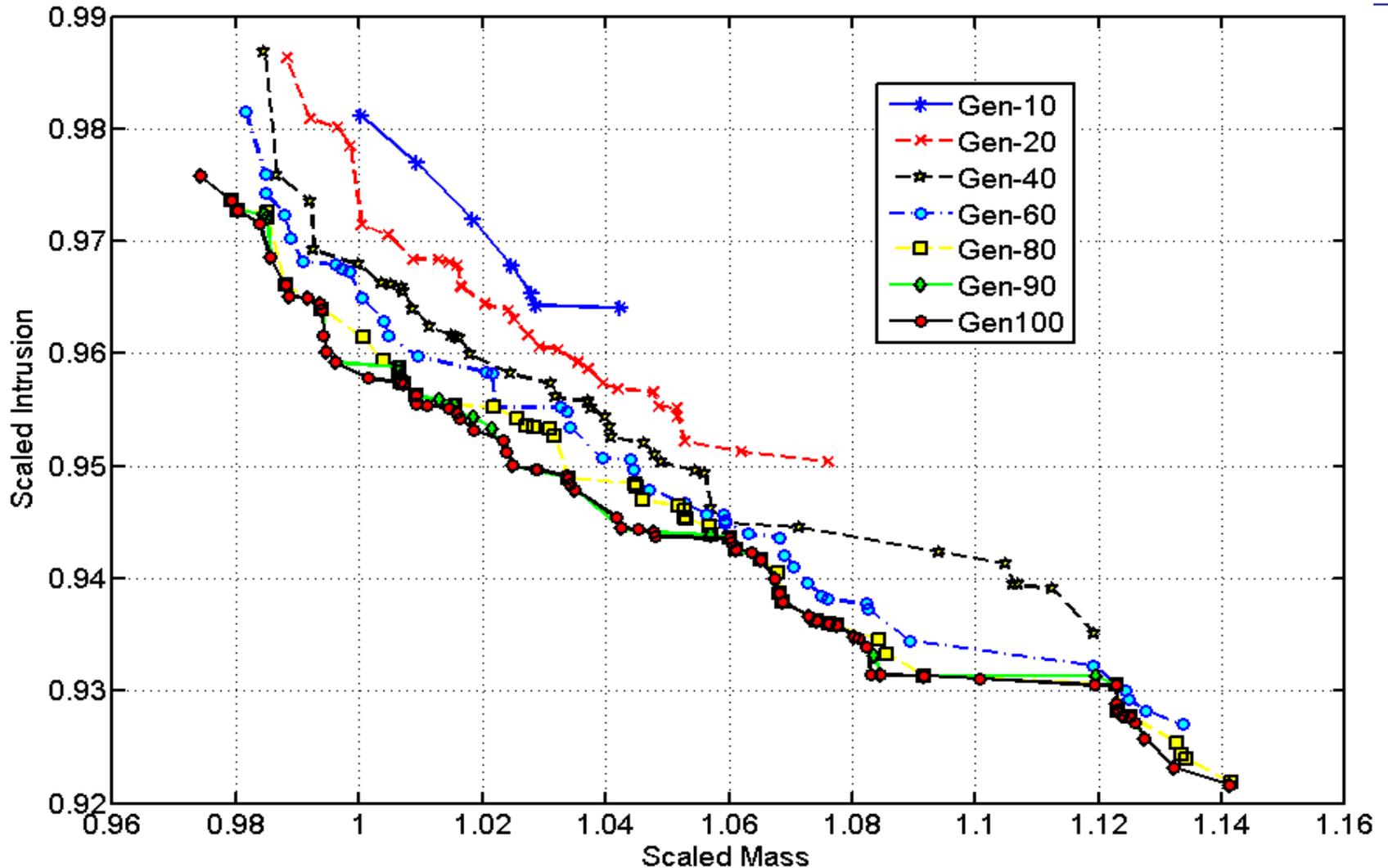
Subject to:

- ◆ Intrusion  $\leq 551\text{mm}$
- ◆ Stage 1 pulse  $> 14.5g$
- ◆ Stage 2 pulse  $> 17.6g$
- ◆ Stage 3 pulse  $> 20.7g$
- ◆  $41.38\text{Hz} \leq \text{freq} \leq 42.38\text{Hz}$

JS MODEL



# Direct MDO/MOO: Pareto Optimal Front History



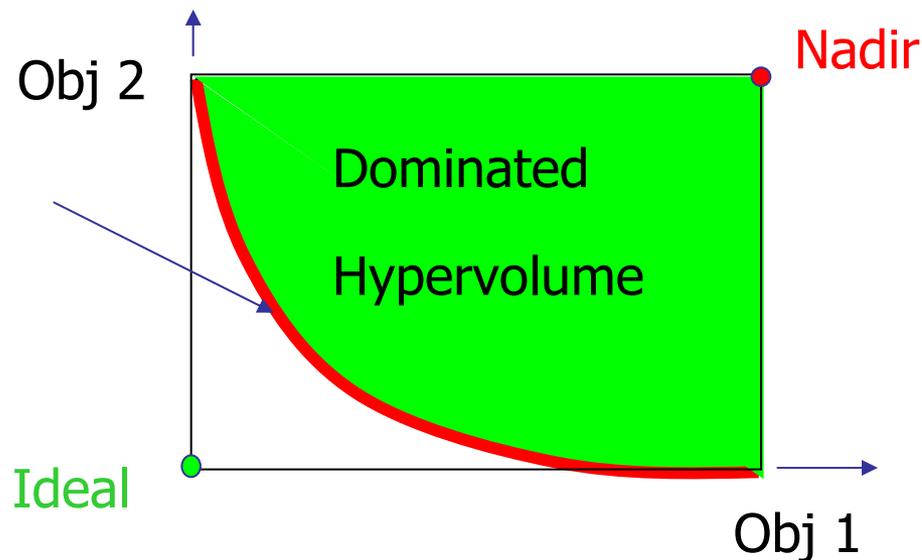
Li G, Goel T, Stander N, Assessing the convergence properties of NSGA-II for direct crashworthiness optimization, 10<sup>th</sup> International LS-Dyna Conference, Jun 8-10, 2008, Detroit, MI.

# Direct MOO Convergence Metrics (v4.2)

## ◆ Dominated Hypervolume

- ◆ Measure the volume of the dominated portion of the objective space with respect to a reference point.
- ◆ In this study use the Nadir vector as reference point
- ◆ Hypercube between Ideal vector and Nadir vector is normalized
- ◆ HSO (Hypervolume by slicing objectives) algorithm used to compute volume efficiently. While *et al* (2005).

Pareto Optimal Front

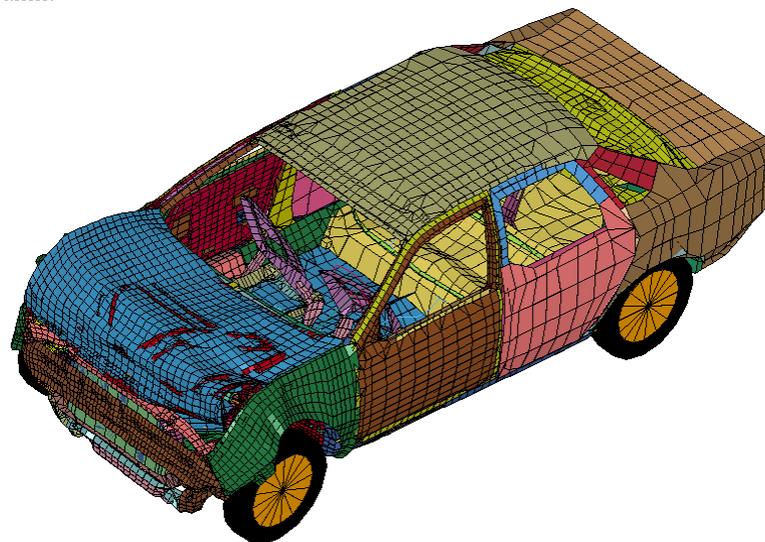


Stander, N., Goel, T. An assessment of geometry-based stopping criteria for multi-objective evolutionary algorithms, Proceedings of the AIAA MAO Conference, Fort Worth, Texas, Sep. 2010

# Direct MOO Convergence: Test Problems

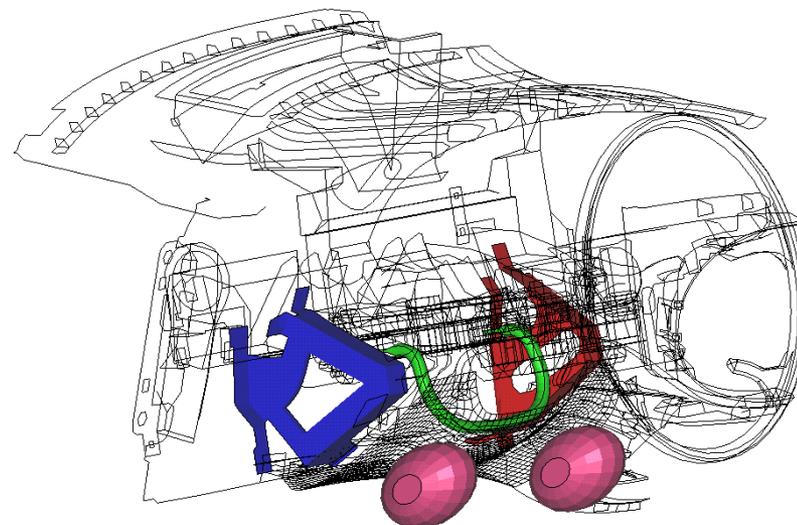
## MDO frontal crash/vibration

Frontal crash of a NHTSA vehicle  
7 variables, 6 responses  
30K+ elements  
18K+ elements for modal analysis  
90ms crash

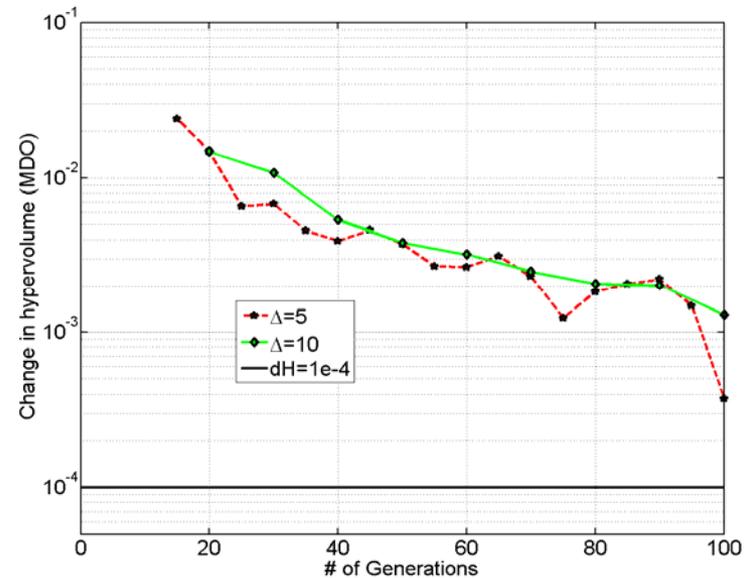
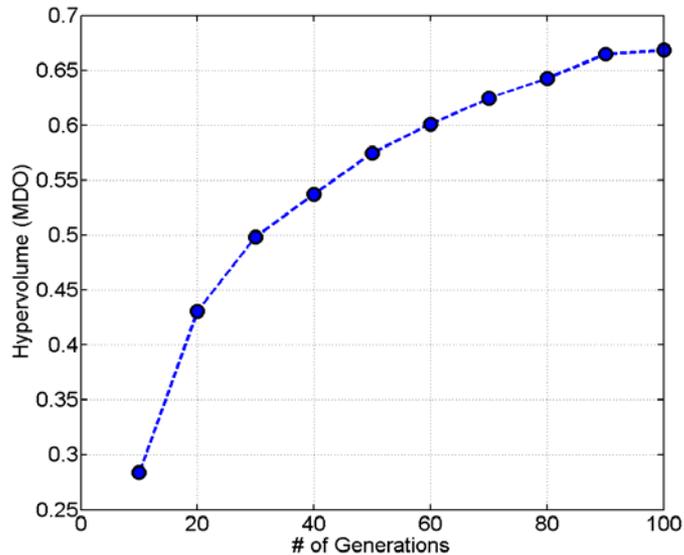
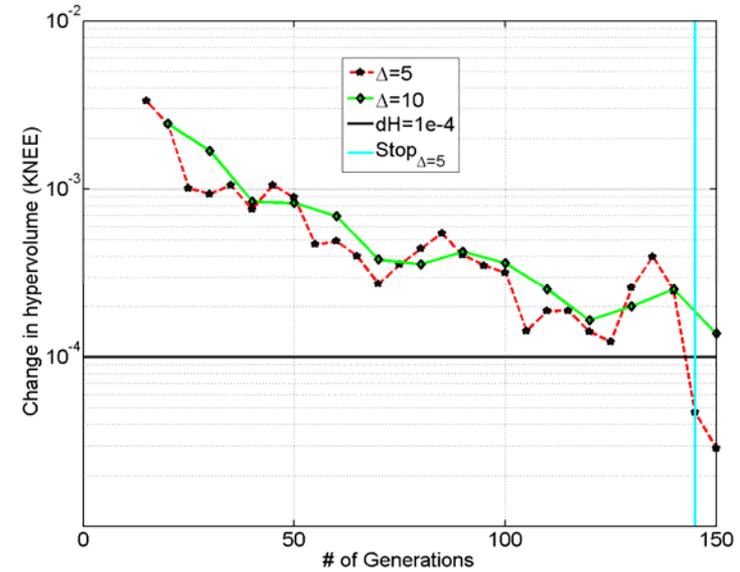
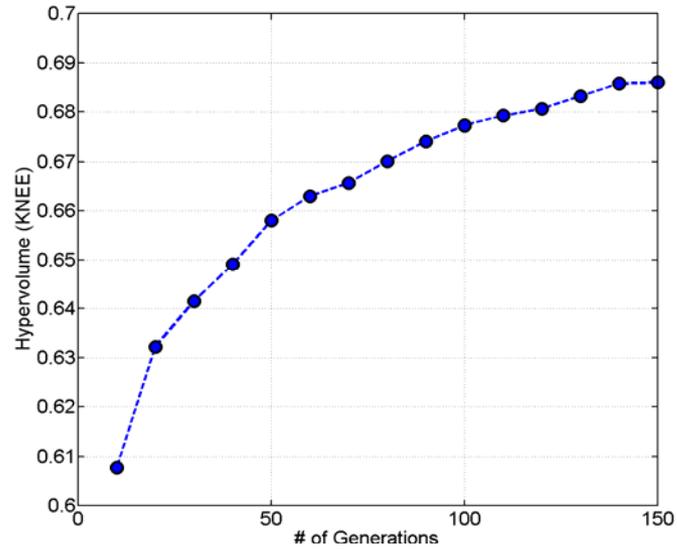


## Knee impact

Automotive panel impact with knee  
11 variables, 7 responses  
25K+ elements  
400 ms crash



# Hypervolume and Change in hypervolume



# Injury Criteria

---

- ◆ HIC (Head Injury Criterion)
- ◆ VC (Viscous Criterion)
- ◆ Chest Compression
- ◆ A3ms (Acceleration level for 3ms)
- ◆ Clip3m
- ◆ Clip3m (3nodes)
- ◆ Deformation/intrusion in local coordinates (to be merged into v4.1)
- ◆ MOC (Total Moment about Occipital Condyle)\*
- ◆ Nij (Normalized Neck Injury Criterion)\*
- ◆ NIC (Neck Injury Criterion)\*
- ◆ Nkm (Neck criteria)\*
- ◆ LNL (Lower Neck Load)\*
- ◆ TTI (Thoracic Trauma Index)\*
- ◆ TI (Tibia Index)\*
- ◆ MTO (Total Moment)\*

\* *Available in Version 4.2*

*Reference: Crash Analysis Criteria Description, Arbeitskreis Meßdatenverarbeitung  
Fahrzeugsicherheit, Mai 2008*

# Frequency/Mode Tracking

---

- ◆ NASTRAN Frequency with Mode tracking
  - ◆ Modal Assurance Criterion (MAC)
    - Use correlation coefficient to match eigenvector
  - ◆ Orthogonality criterion:

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

*r* the reference mode

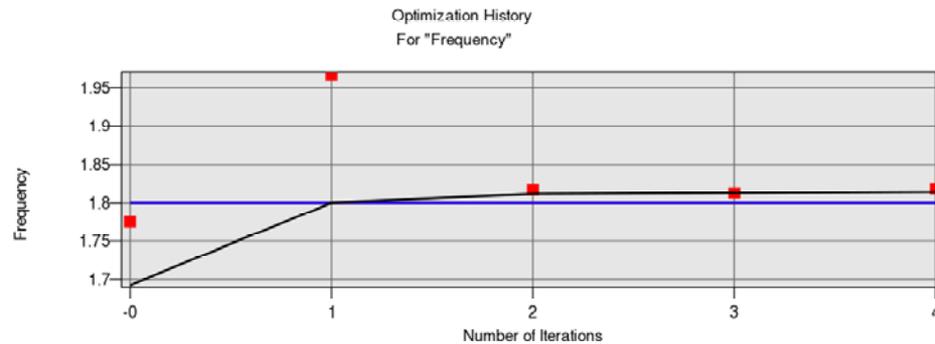
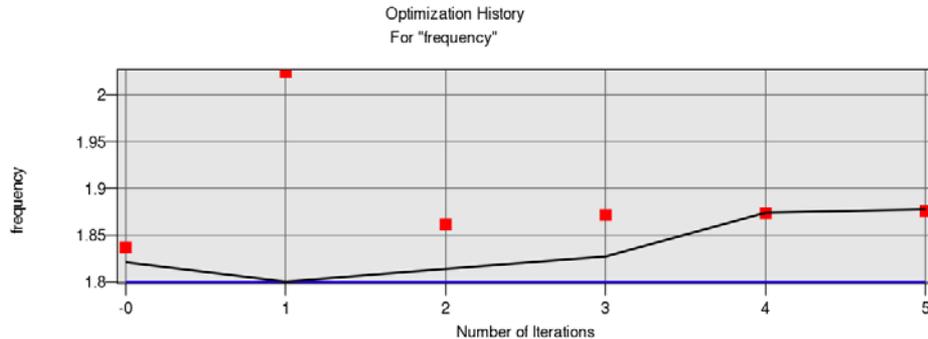
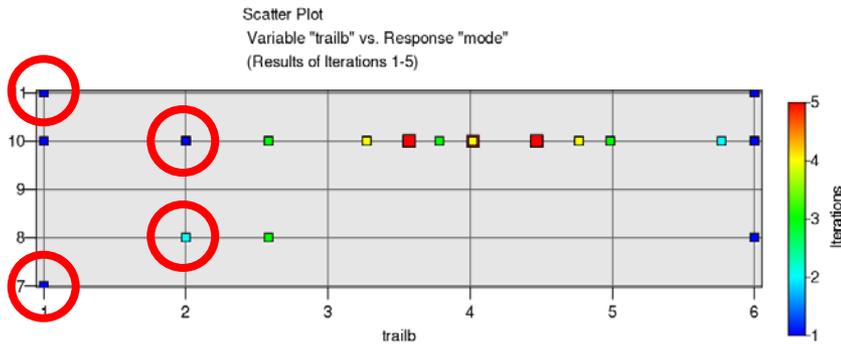
- ◆ Industry tested in a multidisciplinary automotive setting

# Frequency/Mode Tracking

## Modes corresponding to a twisting frequency

### NASTRAN

### LS-DYNA



# Pre/Postprocessors

---

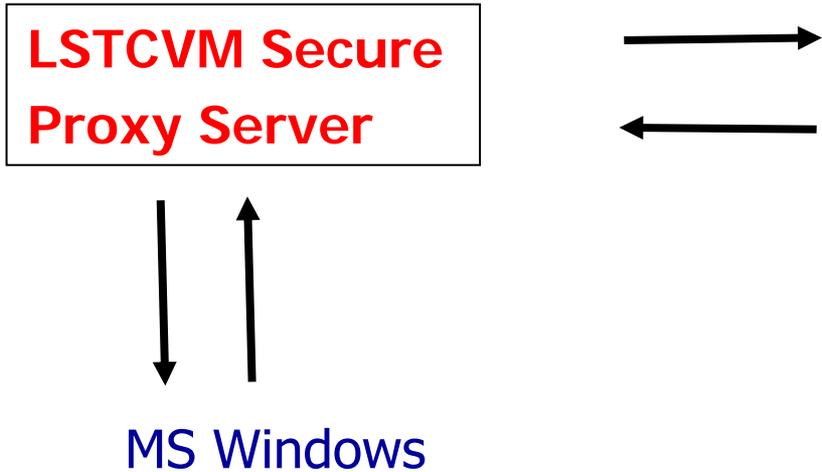
## ◆ Morphing

- ◆ ANSA (BETA CAE Systems SA)
- ◆ DEP Meshworks (v4.2)

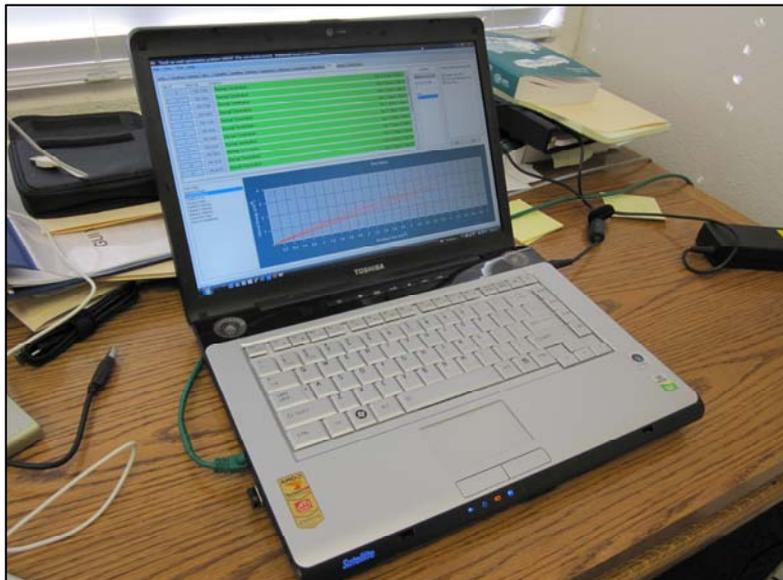
## ◆ Post-processing

- ◆ MetaPOST (BETA CAE Systems SA)
- ◆ GenEx (LS-OPT)
  - Generic Text file result extraction
  - Vector/history extraction (v4.2)

# Simulation job distribution with LSTCVM



Linux



# Secure connection to cluster: LSTCVM Proxy Server

---

- ◆ Popular execution mode: LS-OPT on Windows controlling/monitoring LS-DYNA on a Linux cluster
- ◆ LSTCVM avoids security risks associated with rsh/ssh
  - ◆ Administrator sets up restrictions:
    - allowable commands
    - allowable locations
    - allowable users
    - no interactivity
  - ◆ No login required → no passwords transmitted
- ◆ File system can be shared or not (latter requires LS-OPT/*wrapper* executable for transmission)
- ◆ Interfaces to queuing systems
- ◆ Available with v4.1 (current production version)

Ed Helwig (Honda R&D)  
Trent Eggleston

# LSTCVM: Secure job proxy

The screenshot shows the LSTCVM software interface. At the top, it displays the title "Small car crash optimization problem: LINEAR" and the file path "com.simple.correct". Below the title bar is a menu bar with "File", "View", "Task", and "Help". The main window is divided into several panes. On the left, there is a "Job ID" table with columns for "View Log", "Progress", and "Iteration". The table lists 14 jobs, with jobs 1-10 marked as "Normal Termination" and jobs 11-14 as "Running". A red arrow points from the "Normal Termination" status of job 11 to the "Running" status of job 14. In the center, there is a "Time History" graph showing "Internal Energy (x10<sup>7</sup>)" on the y-axis (ranging from 0 to 30) and "Simulation Time" on the x-axis (ranging from 0 to 1.6). The graph shows several red lines representing different simulation runs, all showing an increasing trend in internal energy over time. On the right, there is a "QUEUING" section with a dropdown menu set to "None" and a "SINGLE STAGE OPTIMIZATION" section with checkboxes for "Baseline Run Only", "Omit Last Verification Run", and "Clean Start".

Job ID	View Log	Progress	Iteration
1	PID 5948	Normal Termination	Iter 1: Case 1, Run 1
2	PID 896	Normal Termination	Iter 1: Case 1, Run 2
3	PID 5140	Normal Termination	Iter 1: Case 1, Run 3
4	PID 5148	Normal Termination	Iter 1: Case 1, Run 4
5	PID 5528	Normal Termination	Iter 1: Case 1, Run 5
6	PID 4704	Normal Termination	Iter 1: Case 1, Run 6
7	PID 3128	Normal Termination	Iter 1: Case 1, Run 7
8	PID 6072	Normal Termination	Iter 1: Case 1, Run 8
9	PID 1540	Normal Termination	Iter 1: Case 1, Run 9
10	PID 2852	Normal Termination	Iter 1: Case 1, Run 10
11	PID 6068	Running	Iter 1: Case 1, Run 11
12	PID 4540	Running	Iter 1: Case 1, Run 12
13	PID 2144	Running	Iter 1: Case 1, Run 13
14	PID 4864	Running	Iter 1: Case 1, Run 14

Job progress:  
MS-Win display

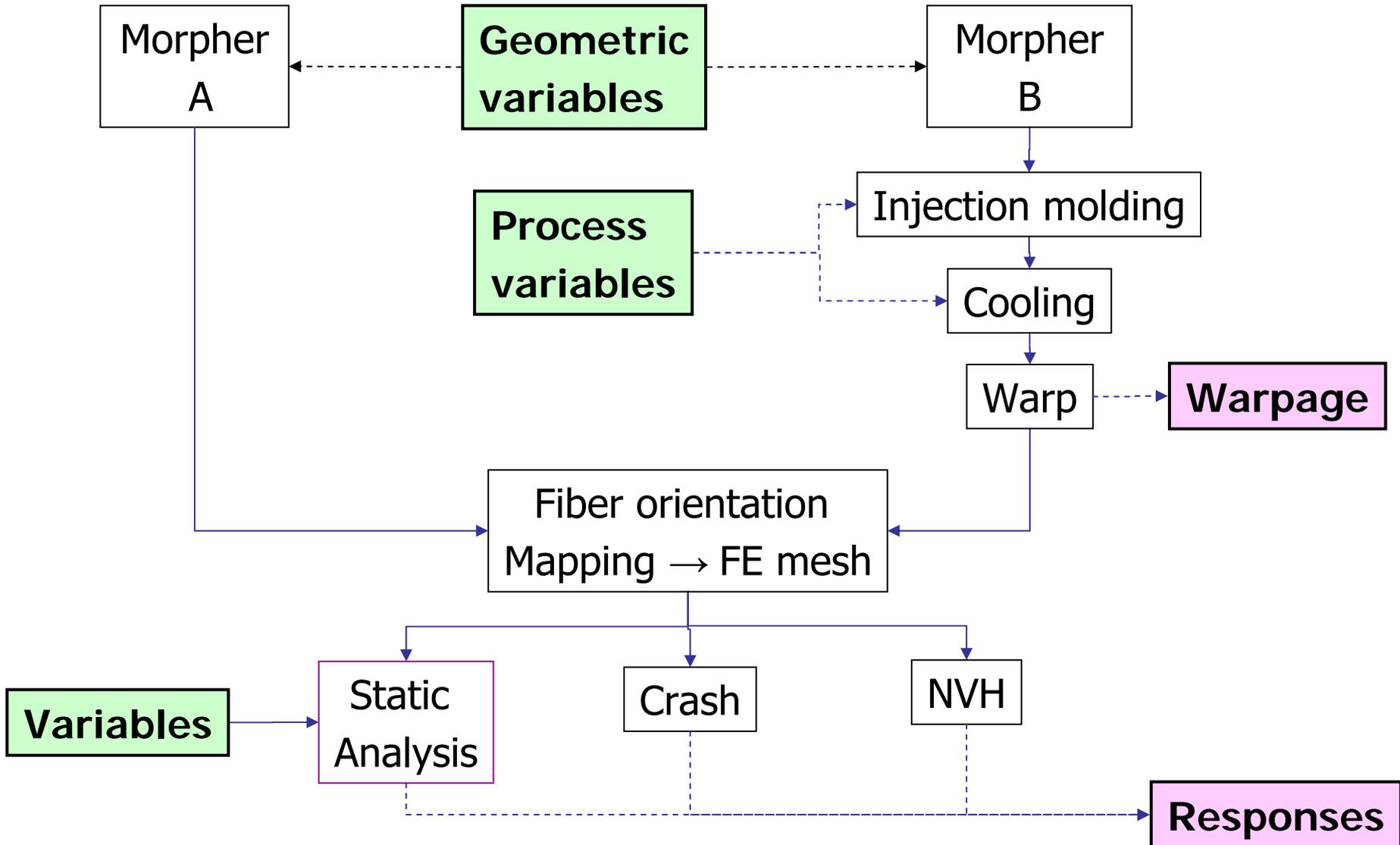
LS-DYNA log:  
Linux cluster

The screenshot shows the LS-DYNA log output window. The window title is "JOB ID=> PID=3328 HOME=/1/3". The log content is as follows:

```
[STDOUT] | 7374 Las Positas Road  
[STDOUT] | Livermore, CA 94551  
[STDOUT] | Tel: (925) 449-2500 Fax: (925) 449-2507  
[STDOUT] | www.lstc.com  
[STDOUT] |  
[STDOUT] | LS-DYNA, A Program for Nonlinear Dynamic  
[STDOUT] | Analysis of Structures in Three Dimensions  
[STDOUT] | Version : ls971s R5.0 Date: 04/10/2010  
[STDOUT] | Revision: 59419 Time: 10:11:54  
[STDOUT] |  
[STDOUT] | Features enabled in this version:  
[STDOUT] | Shared Memory Parallel  
[STDOUT] | Interactive Graphics  
[STDOUT] | ANSYS Database format  
[STDOUT] | ANSYS License (ans120)  
[STDOUT] | 32 Bit IEEE Binary File  
[STDOUT] |  
[STDOUT] | Licensed to: LSTC Redundant Server (sun240a,ham  
[STDOUT] |  
[STDOUT] | Platform : Xeon64 System  
[STDOUT] | OS Level : Linux 2.6.9  
[STDOUT] | Compiler : Intel Fortran Compiler 10.1  
[STDOUT] | Hostname : florida.lstc.com  
[STDOUT] | Precision : Single precision (I4R4)  
[STDOUT] | SVN Version: 59770  
[STDOUT] |  
[STDOUT] | Unauthorized use infringes LSTC copyrights
```

Ed Helwig (Honda R&D)  
Trent Eggleston

# Process Modeling (v4.2, v5.0)



# Outlook: Process modeling features

---

- ◆ File handling
  - ◆ Copying, Moving, Saving, Deleting, Renaming
- ◆ Job scheduling
  - ◆ Load balancing – allow concurrent jobs where possible
- ◆ Enhanced usability
  - ◆ Stepping capability, enhancements to repair feature
- ◆ Backward compatibility

# Process Modeling

---

- ◆ V4.2 : Limited functionality (process definition, load balancing, file handling) based on an extension of the current GUI – Spring 2011
- ◆ V5.0 : Redesigned GUI – Winter 2011

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**Thank you for your attention!**