New Developments in LS-OPT Version 4

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LS-OPT Capabilities

- Design of Experiments
  - D-Optimality, Latin Hypercube, Space Filling
- Metamodels
  - Polynomials, Radial Basis Function networks, Feedforward Neural networks, Kriging, User-defined metamodels
  - Used for variable screening, optimization, prediction, reliability and outlier analysis
- Pre/Post-processor interfaces
  - ANSA, META-Post, Truegrid, User-defined
- Job distribution
  - PBS, SLURM, NQE, NQS, LSF, User-defined, Blackbox, Honda, LoadLeveler

LS-OPT Optimization Capabilities

- Optimization solvers
  - NSGA-II (Non-dominated sorting Genetic Algorithm)
    - Multi-Objective global optimization
  - Adaptive simulated annealing
    - Single objective global optimization. Very fast
  - LFOPC
    - Original algorithm, highly accurate for single objective
- Reliability-based Design Optimization
- Topology optimization
  - LS-DYNA explicit and implicit (linear + nonlinear)
  - Multi-case design
  - Large number of elements (1e6 tested)
  - General and extruded geometries
  - Non-cuboidal design domains

LS-OPT development: 4.0

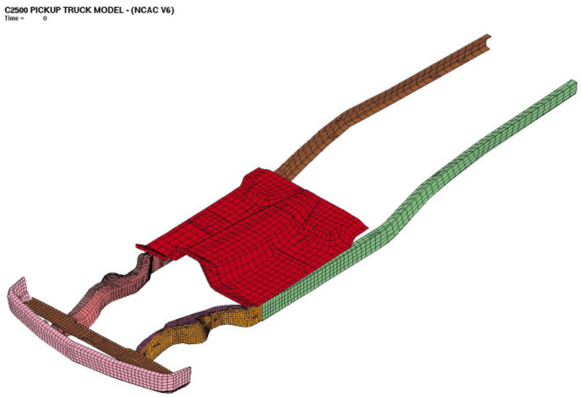
Next Generation Postprocessor (Viewer)

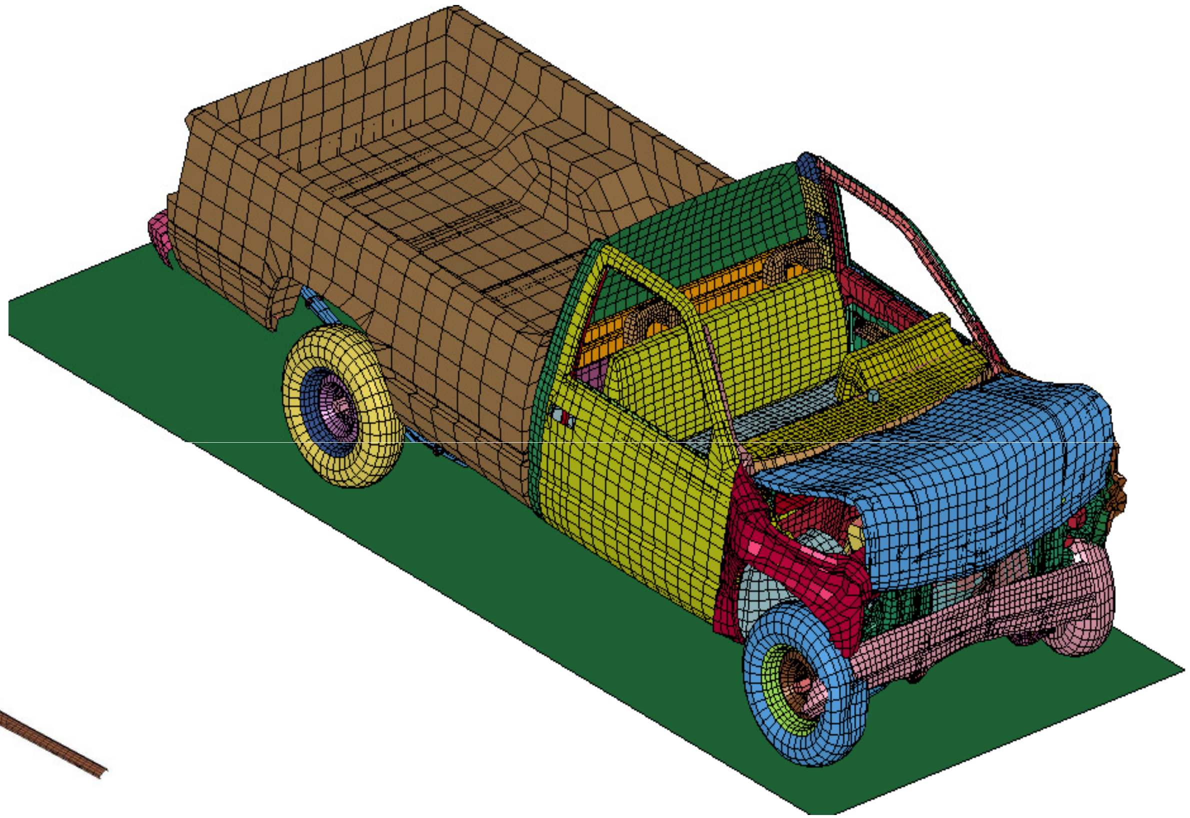
- New architecture
  - Split windows, vertically/horizontally
  - Detachable windows
  - Spreadsheet type point listing
- Correlation Matrix
  - Scatter plots, Histograms and Correlation values
  - Interactive: Display histograms or correlation bars
- Visualization of Pareto Optimal Front
  - 4D plotting (already in Version 3.4)
  - Multi-axis plot for higher dimensions
  - Hyper-Radial Visualization
  - Self Organizing Maps (Version 4.1)
- Virtual histories
  - Plot history at any point in the design space (Version 4.1)

Outlook: LS-OPT development: 4.0

- META Post interface
  - Allows extraction of results from any package (Abaqus, NASTRAN, …) supported by META Post (ANSA package)
- LS-OPT/Topology
  - Nonlinear topology optimization
  - LS-DYNA based
  - Multiple load cases
  - Linear as well as non-linear
  - Design part selection
  - Job distribution (queuing) as in LS-OPT

Multi-Objective Optimization: Example





Thickness design variables

Design criteria

Minimize

- Mass
- Acceleration

Maximize

- Intrusion
- Time to zero velocity

9 thickness variables of main crash members

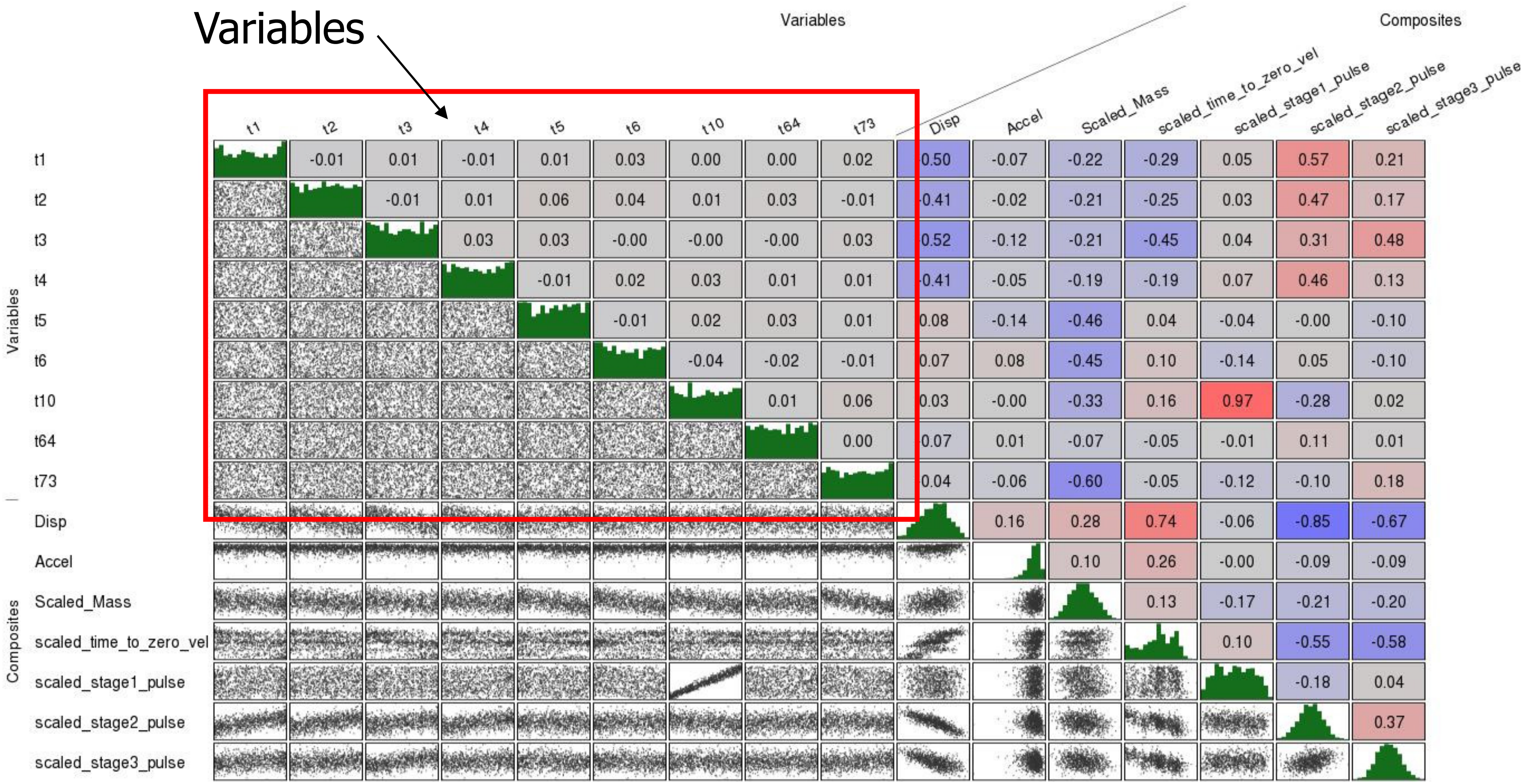
Intrusion	<	721
Stage 1 pulse	<	7.5g
Stage 2 pulse	<	20.2g
Stage 3 pulse	<	24.5g

Simulation statistics

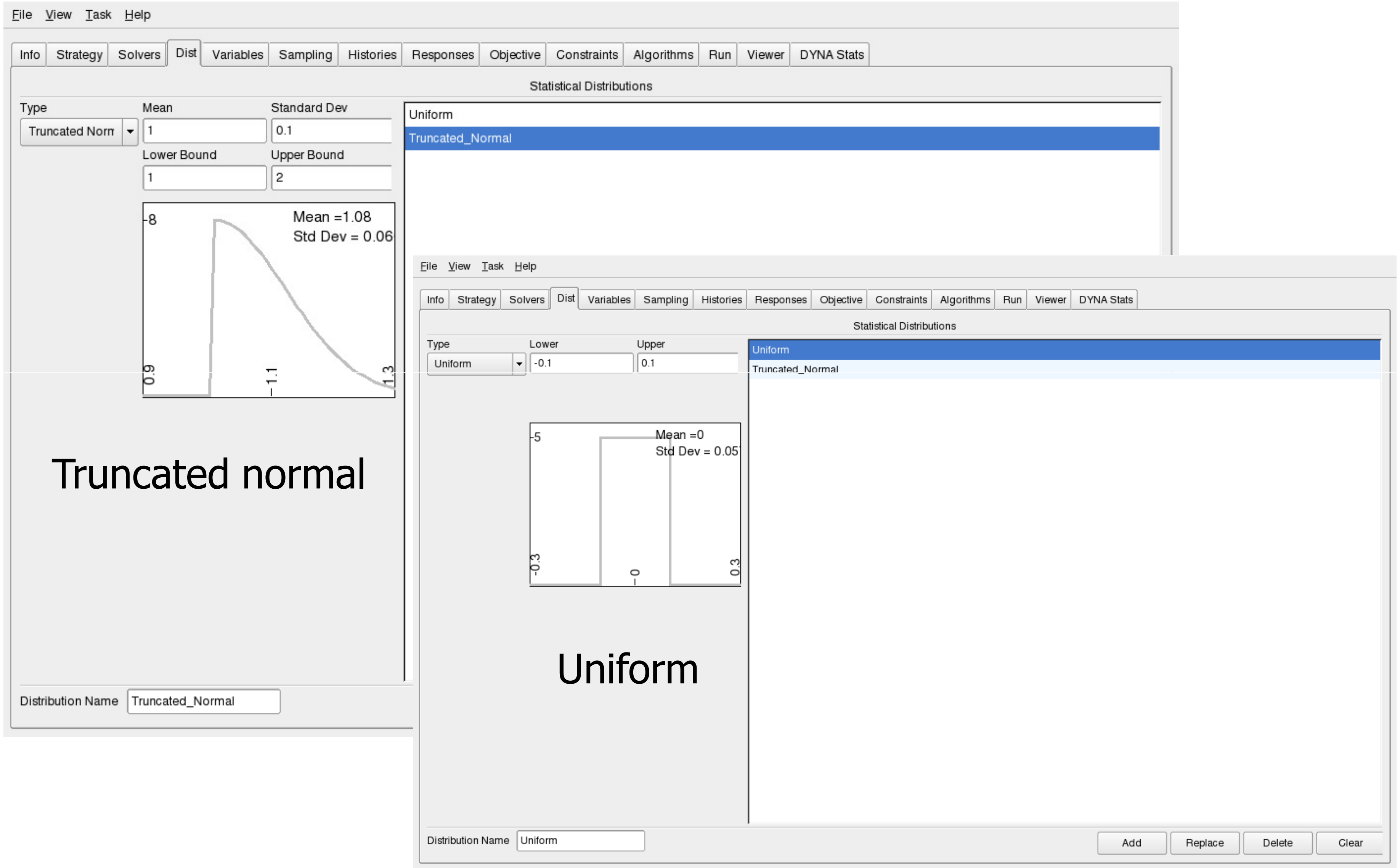
- 640-core HP XC cluster (Intel Xeon 5365 80 nodes of 2 quad-core)
- *Queuing* through LSF
- Elapsed time per generation ~ 6 hours
- Total of 1,000 crash runs

- Strategy: Single stage run
- Sampling scheme: *Space Filling* (MinMax distance) using 1000 points
- Surrogate model: *Radial Basis Function Network*
- Optimization solver: *NSGA-II* to find *Pareto Optimal Frontier*

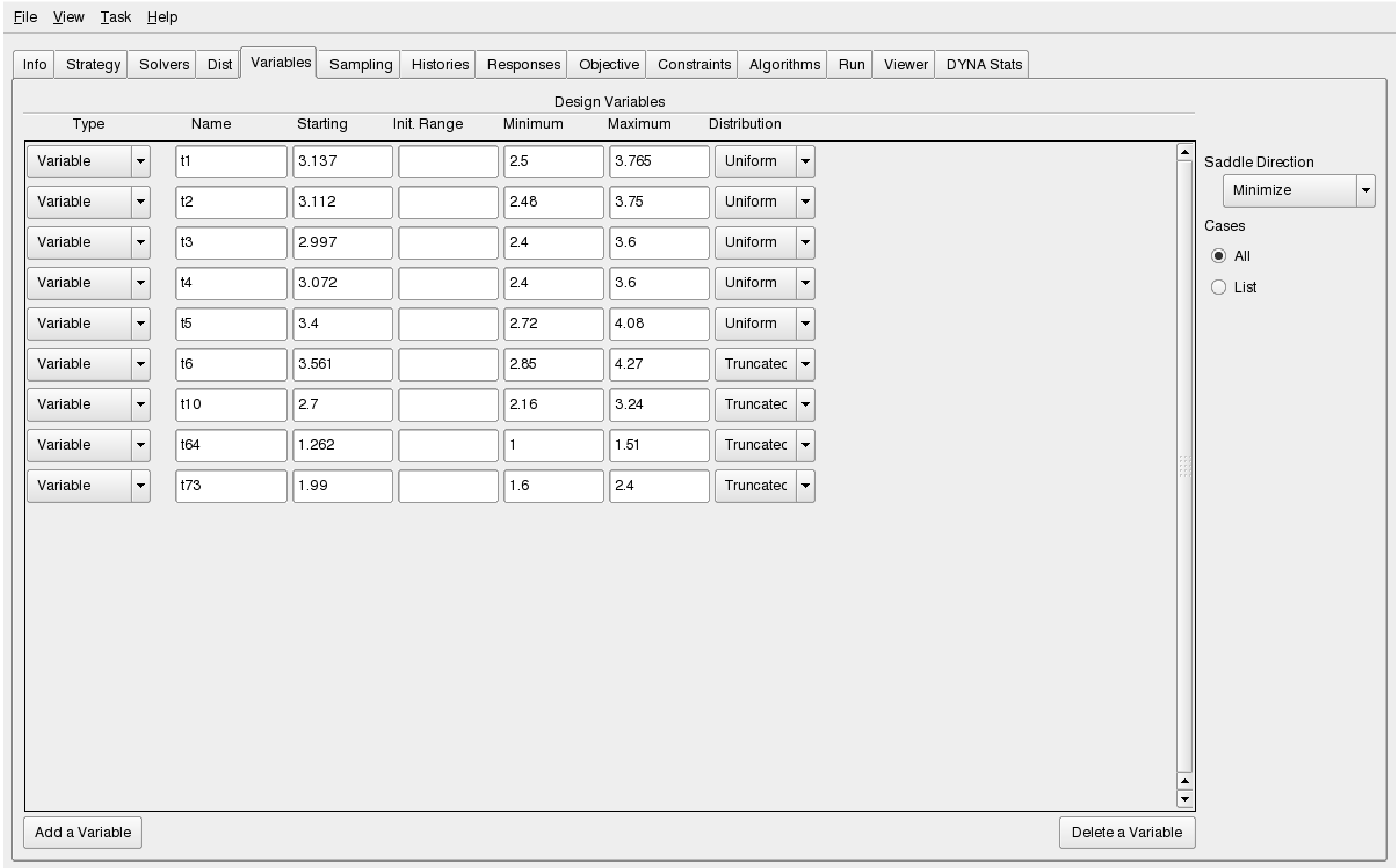
Correlation Matrix of 1000 simulation points



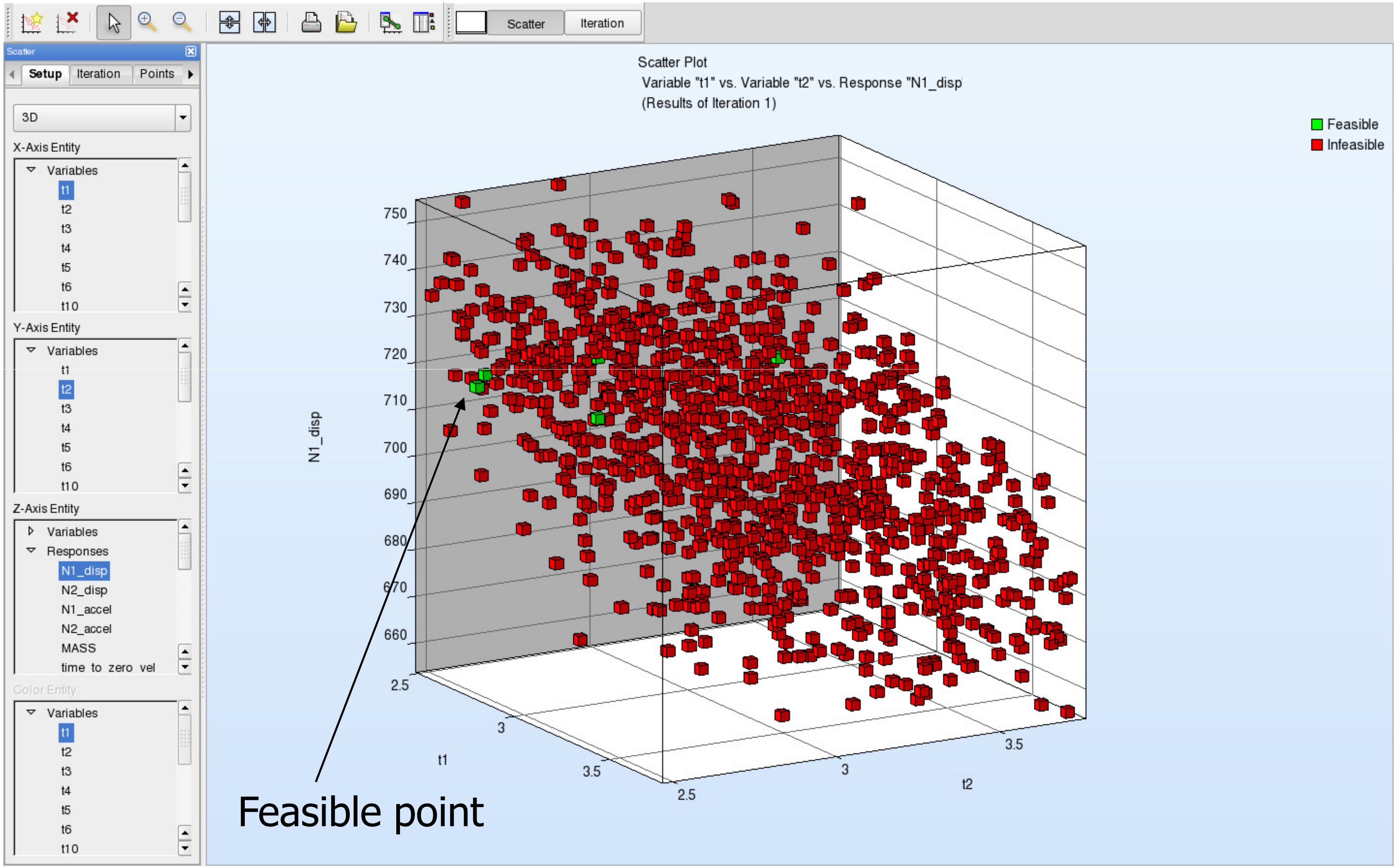
Stochastic input



Variables and distributions



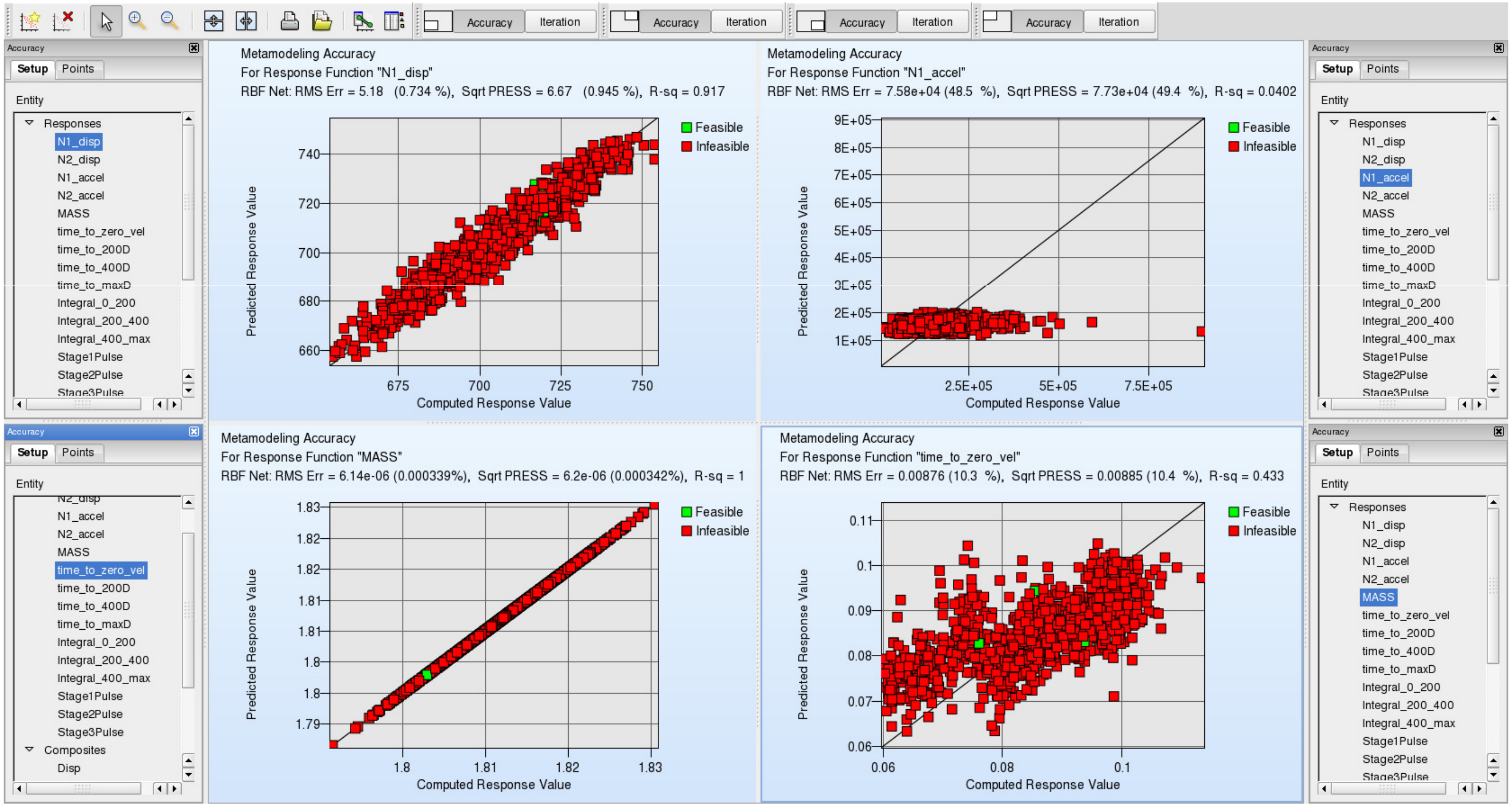
Scatterplot of intrusion: feasibility level



Feasible point

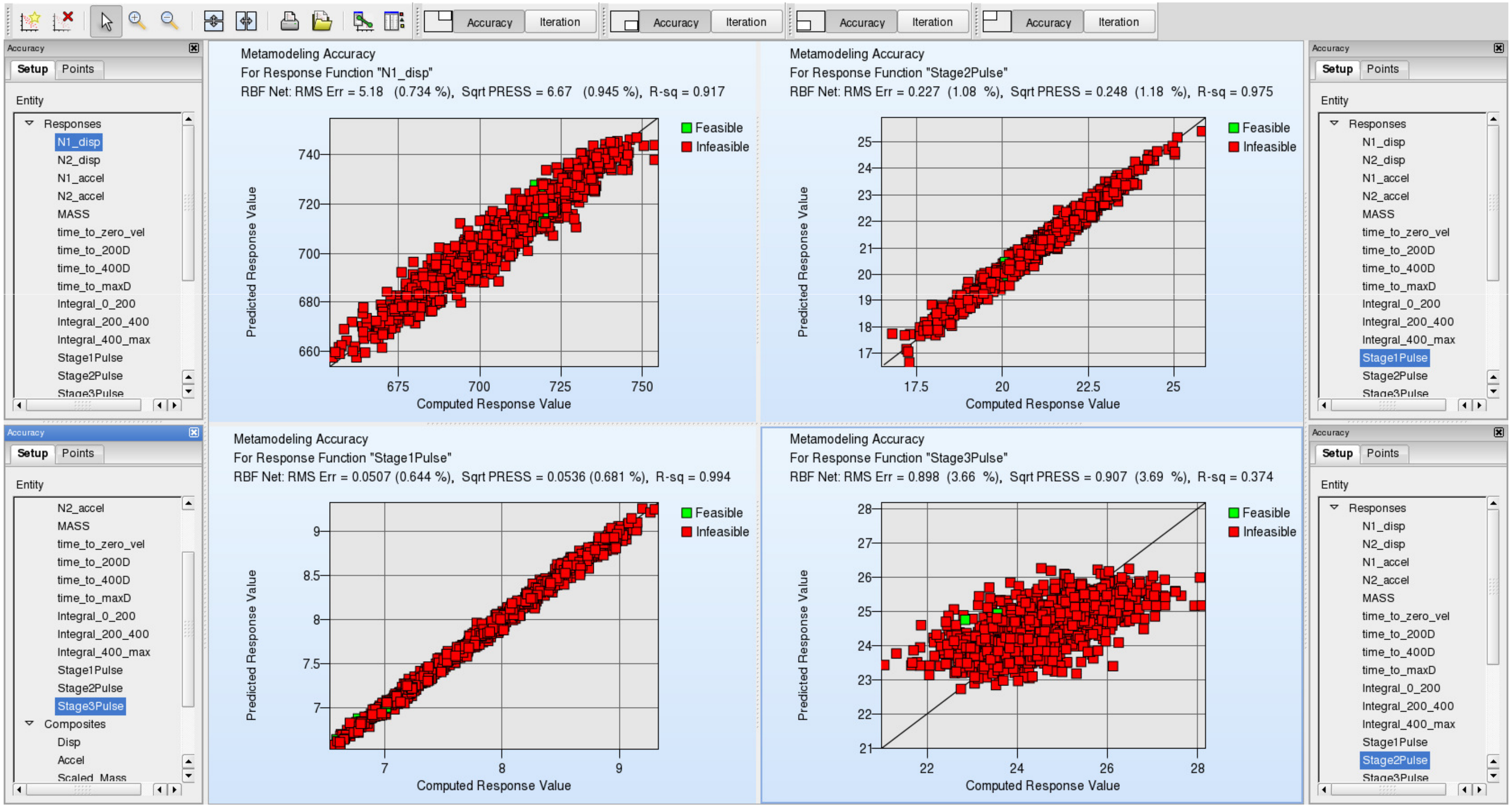
Metamodel Accuracy

Objective Functions

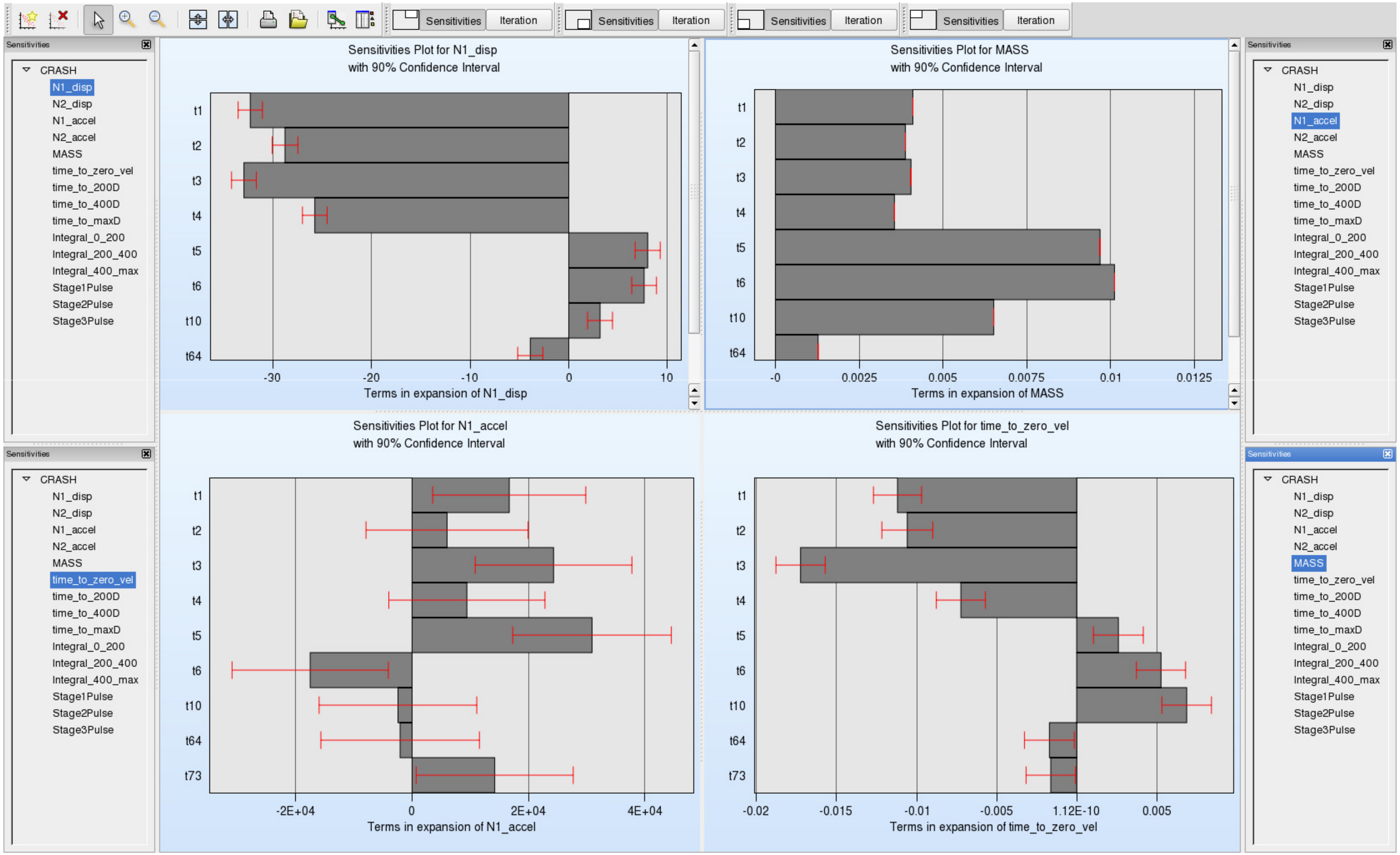


Metamodel Accuracy

Constraint Functions



Sensitivity: Objectives

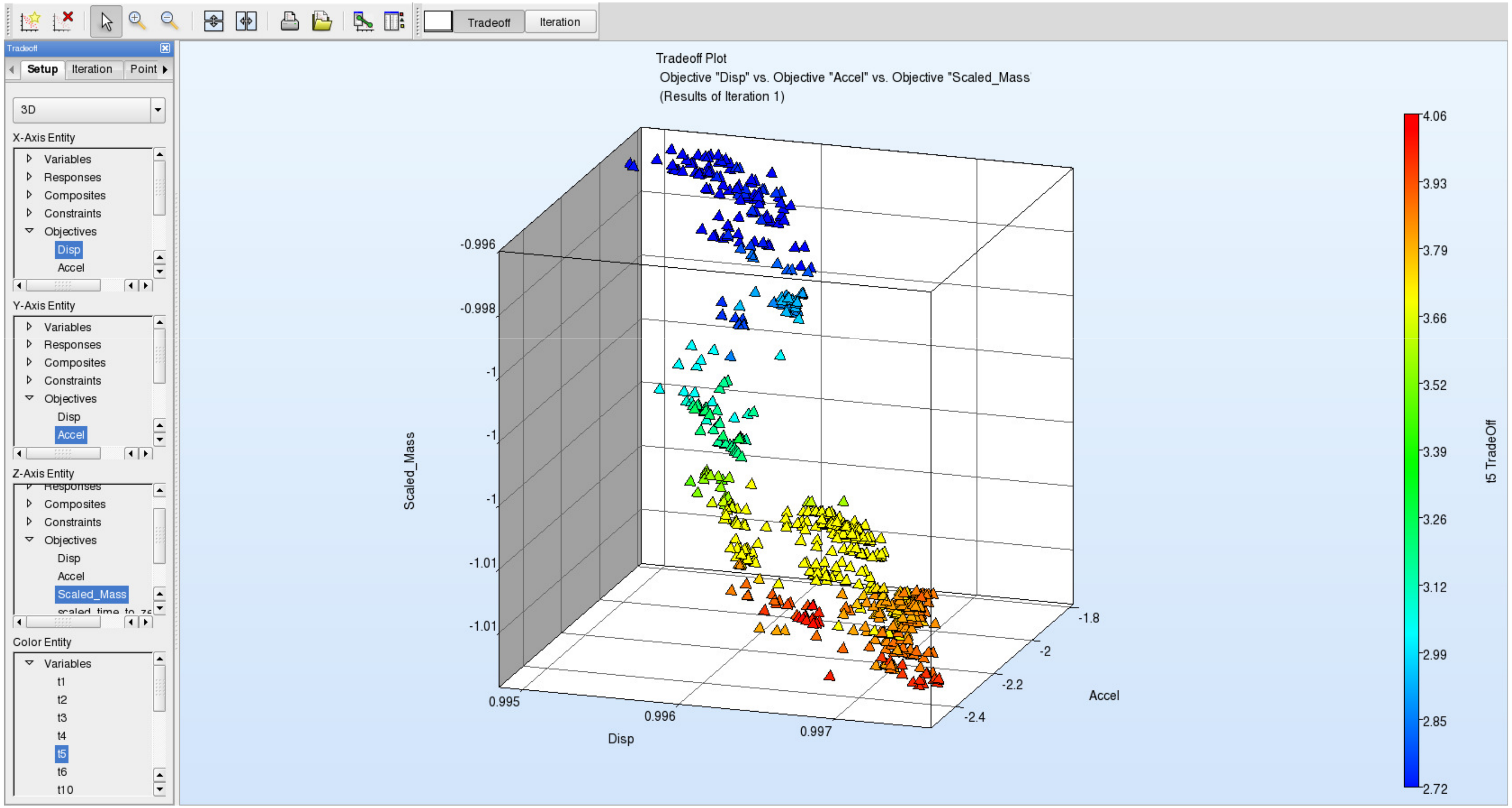


Pareto Optimal Frontier

- A hyper-surface of optimal designs for multiple objectives
- Visualization is complicated, hence 4 tools are provided
  - 4D Spatial plot
    - Traditional
  - Parallel Coordinate plot
    - Pans and zooms in hyperspace
  - Hyper-Radial Visualization
    - Weighting of objectives
  - Self-Organizing Maps (Ver. 4.1)
    - Continuous mapping of objective space
    - "Hole" detection

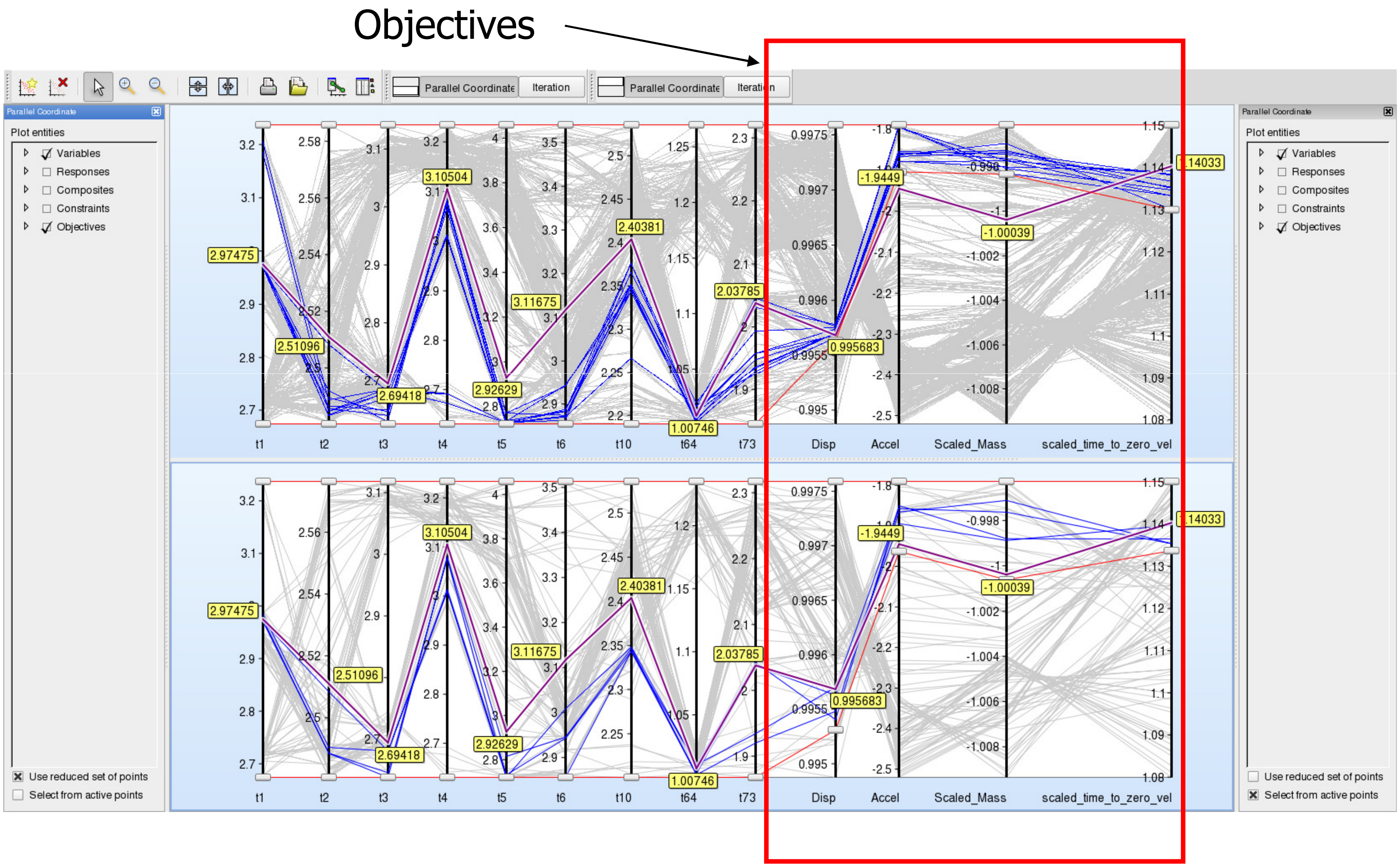
Pareto Optimal Frontier

Spatial plot: t_5 in color



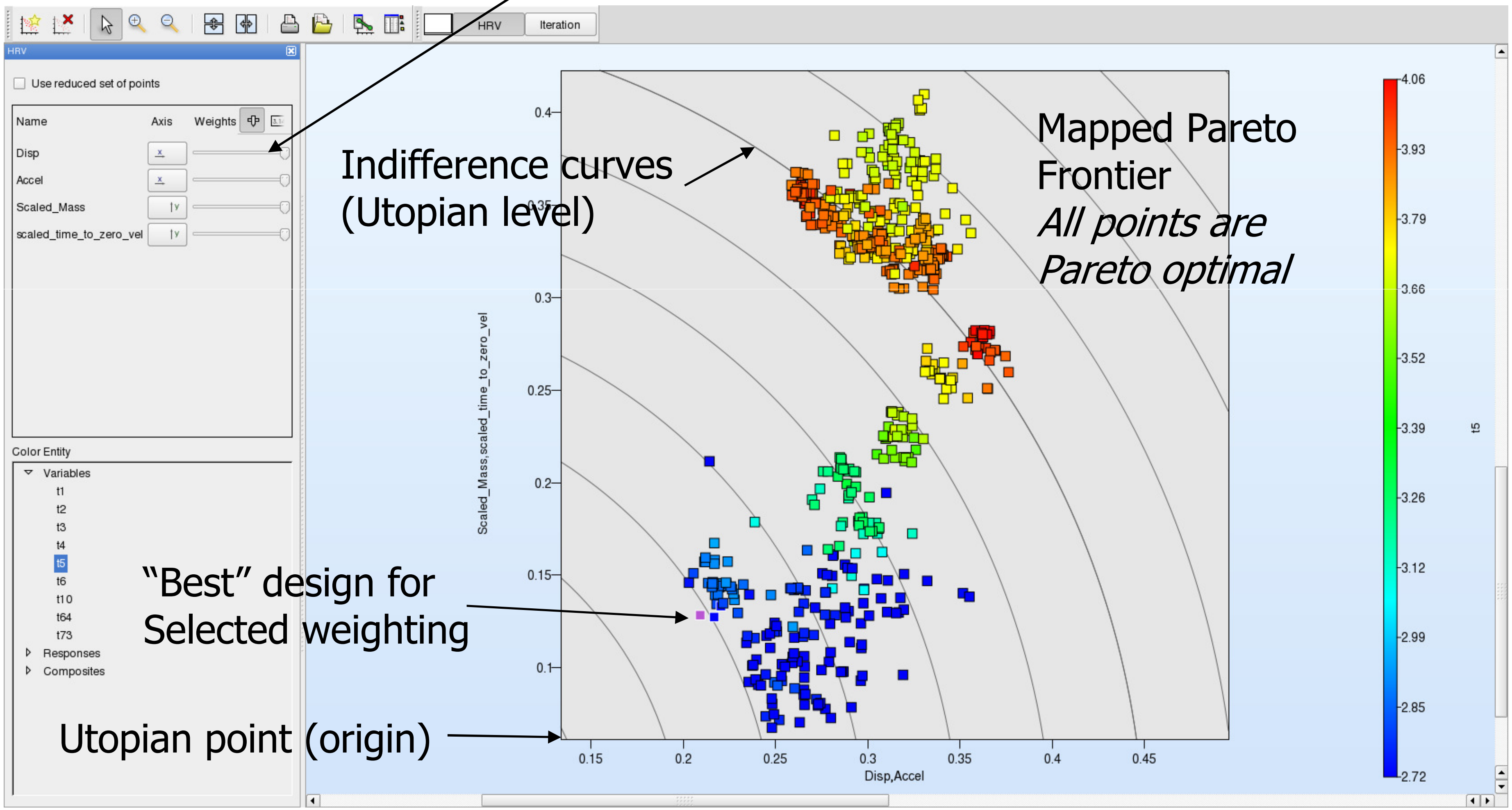
Pareto Optimal Frontier

Parallel Coordinate Plot: Variables and Objectives (Full/Reduced databases)



Pareto Optimal Frontier
Hyper Radial Visualization (variable *t5* in color)

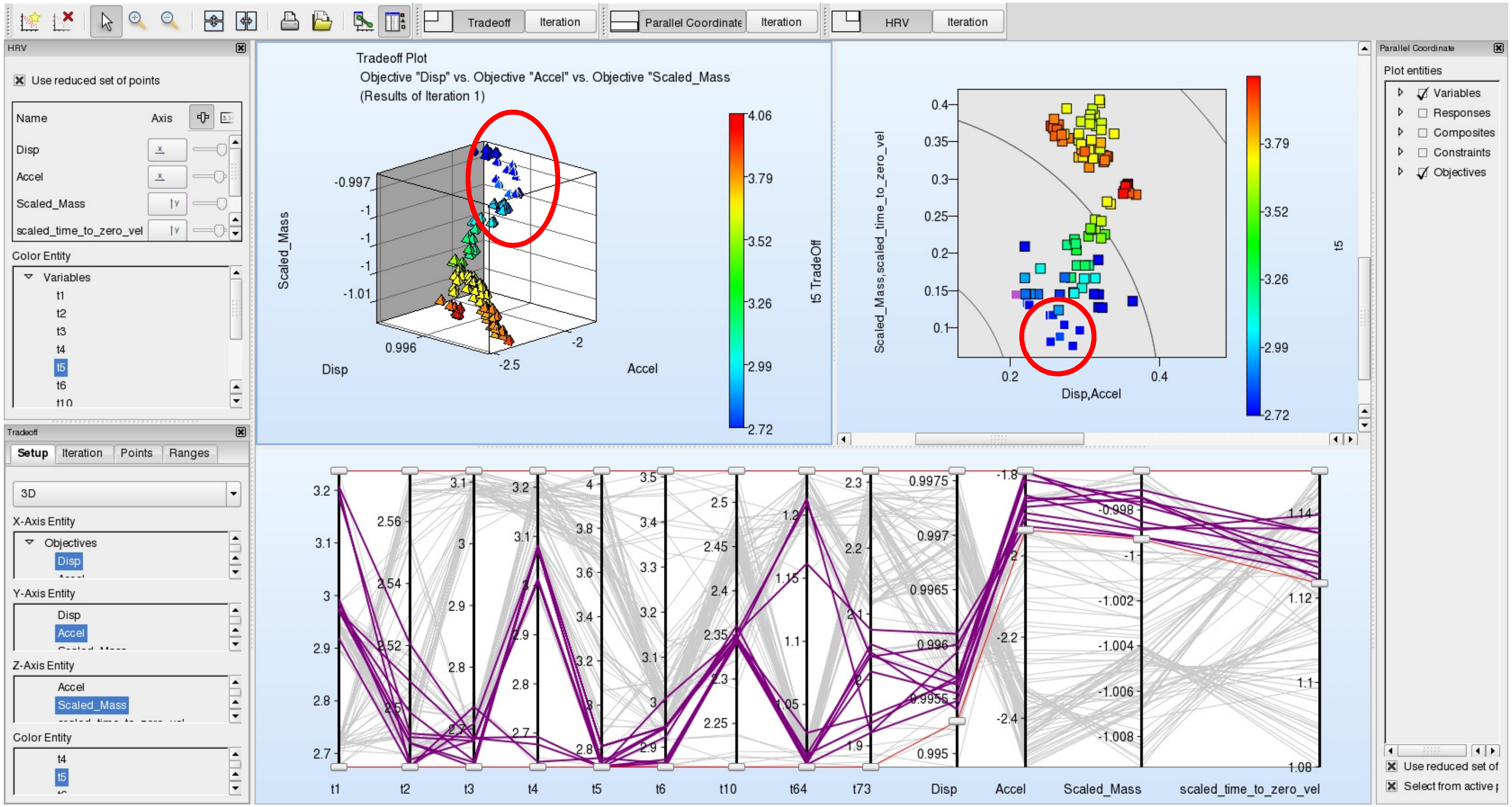
Sliders for adjusting weights



Hyper Radial Visualization

- Hyper Radial Visualization (HRV) maps any number of objectives to 2D
- Objectives are placed in X and Y groups
- Grouping does not matter as “best” point (closest to Utopian point) is always the same
- Points on the same contour have the same “value”
- Objectives can be weighted by moving sliders

Cross-display of selected points



Spreadsheet of selected points

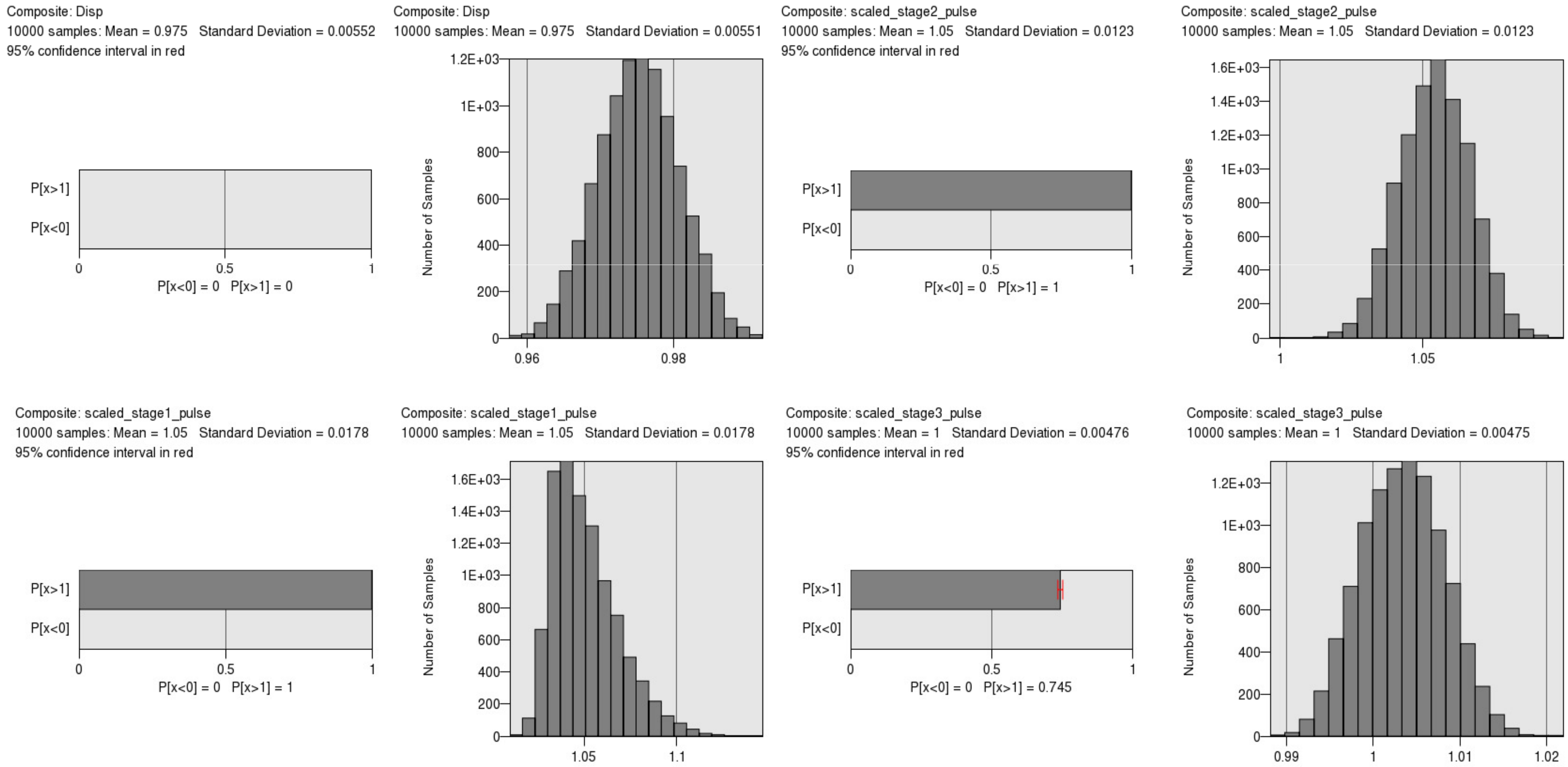
Point selection

t1.61
t1.62
t1.71
t1.78
t1.80
t1.83
t1.99
t1.113
t1.118
t1.128
t1.137
t1.144
t1.151
t1.156
t1.161
t1.172

Point ID	Variables											
	t1	t2	t3	t4	t5	t6	t10	t64	t73	N1_disp	N2_disp	N1_a
t1.61	2.97461	2.48845	2.63813	3.0794	2.81527	2.94545	2.34648	1.00323	2.03686	717.13	718.566	138
t1.314	2.97028	2.50838	2.68088	3.01328	2.73141	2.94295	2.34327	1.01036	1.93423	717.33	718.472	135
t1.339	2.97033	2.48855	2.6456	3.07694	2.72019	2.85593	2.34345	1.00244	1.92001	717.046	718.437	135
t1.360	2.97461	2.49834	2.64825	3.08183	2.81396	2.94505	2.35213	1.20886	2.0356	718.167	718.057	140
t1.381	2.98462	2.4904	2.68054	3.00873	2.72048	3.00838	2.34825	1.01035	2.04238	716.999	718.375	135
t1.388	3.2071	2.52048	2.68494	2.6768	2.72071	2.92279	2.36076	1.00453	2.05429	717.589	718.2	132
t1.395	3.18645	2.49159	2.68559	2.69227	2.72118	2.86564	2.34113	1.00694	2.01281	717.287	718.296	132
t1.510	3.20129	2.48092	2.73607	2.64129	2.76148	2.86426	2.3466	1.02748	1.94592	717.561	718.189	133

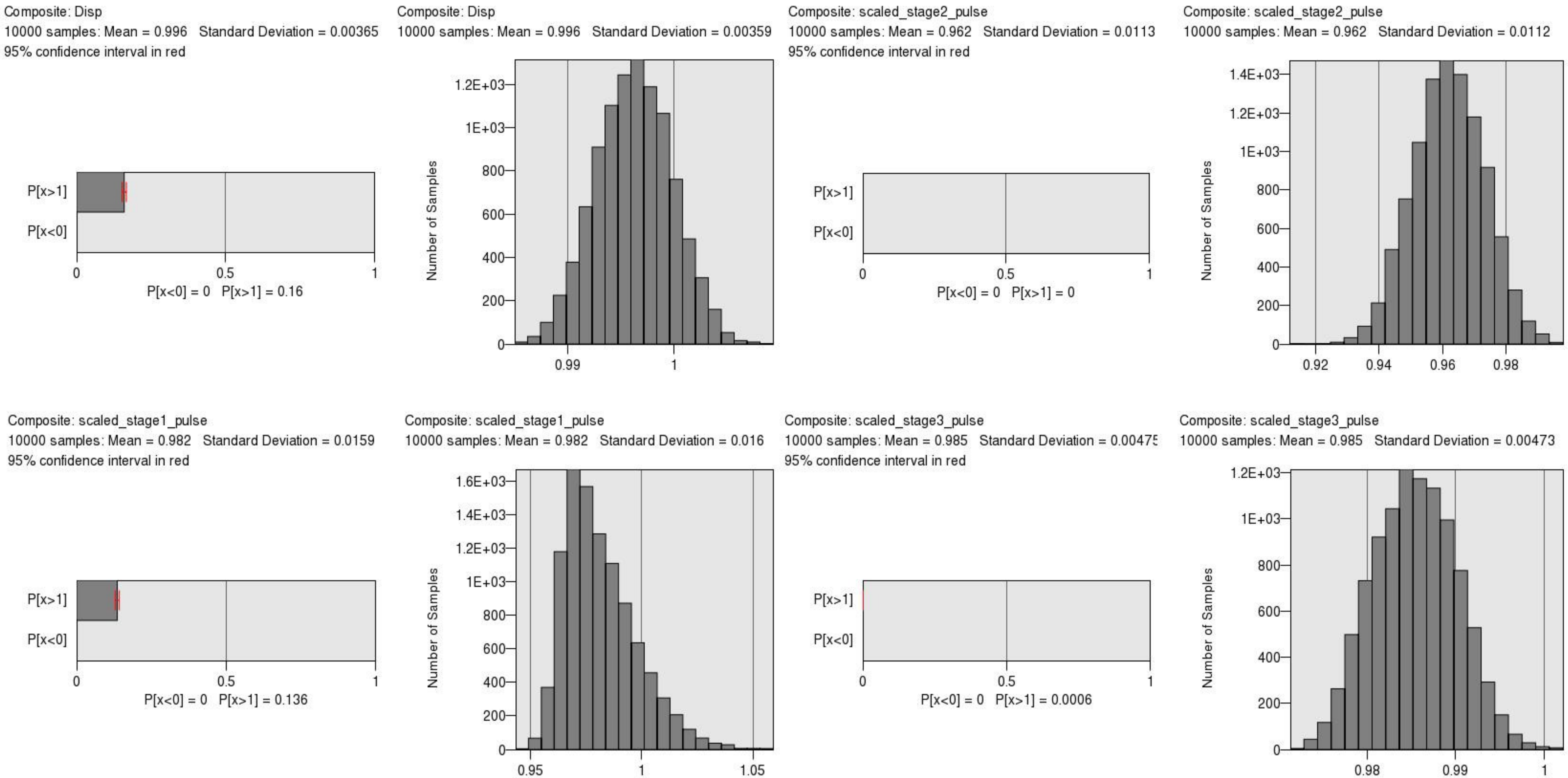
Probability distributions of constraint values

Starting Design

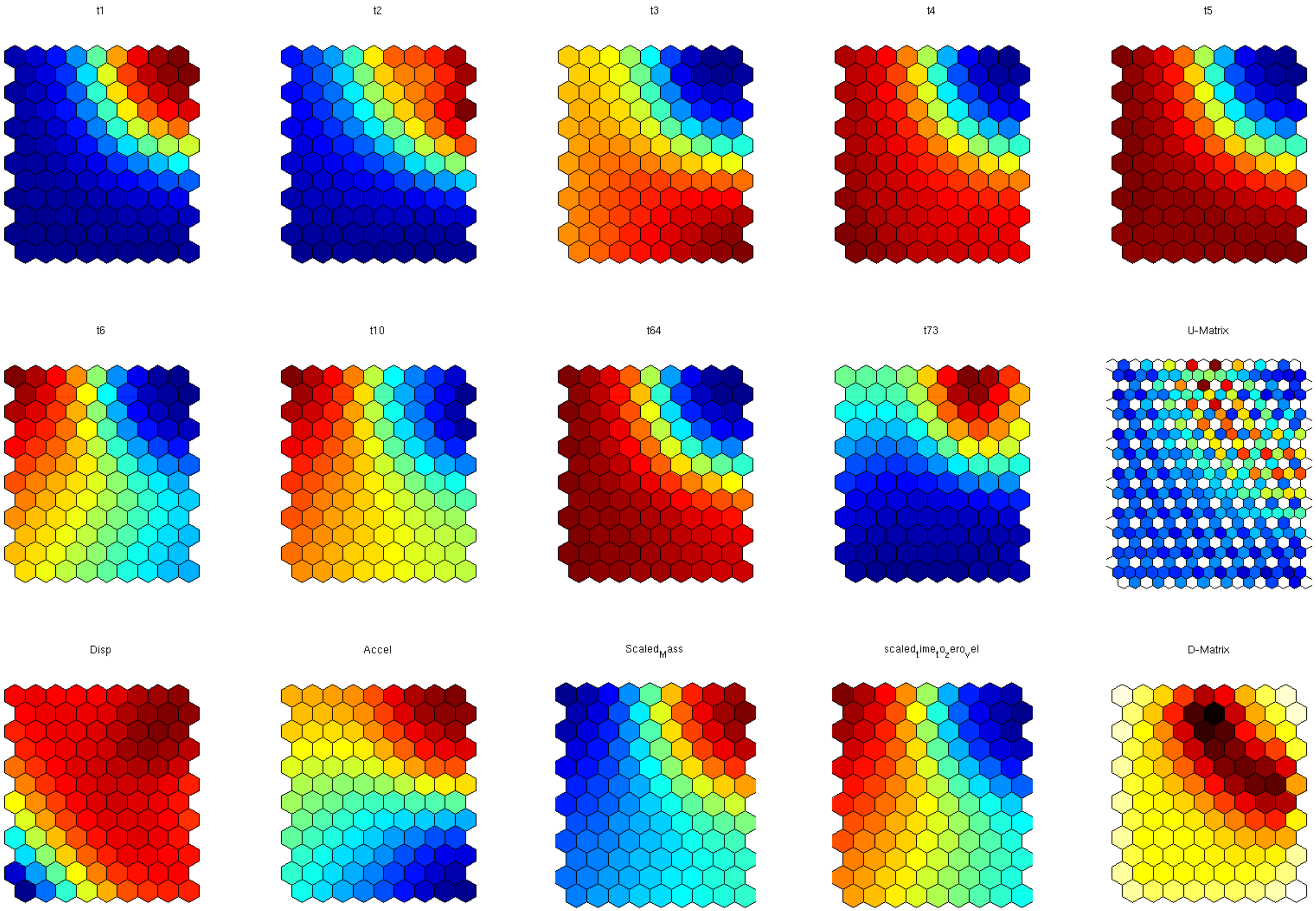


Probability distributions of constraint values

Optimal Design (equal weights)



Self-Organizing Maps



Self-Organizing Maps

- In prototype stage (*D-SPEX* by *DYNAmore* GmbH shown)
- Released in Version 4.1, Fall 2009

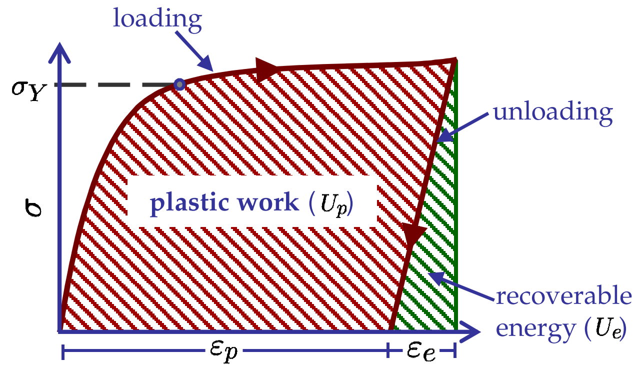
Hybrid Cellular Automata (HCA) algorithm

- In traditional elastic-static problems, material is distributed based on the strain energy (U^e) generated during loading

$$\text{target } (S) \rightarrow \text{strain energy density}$$

- For elastic-plastic problems, every finite element must contribute to absorb internal energy (U) which includes both elastic strain energy and plastic work during loading.

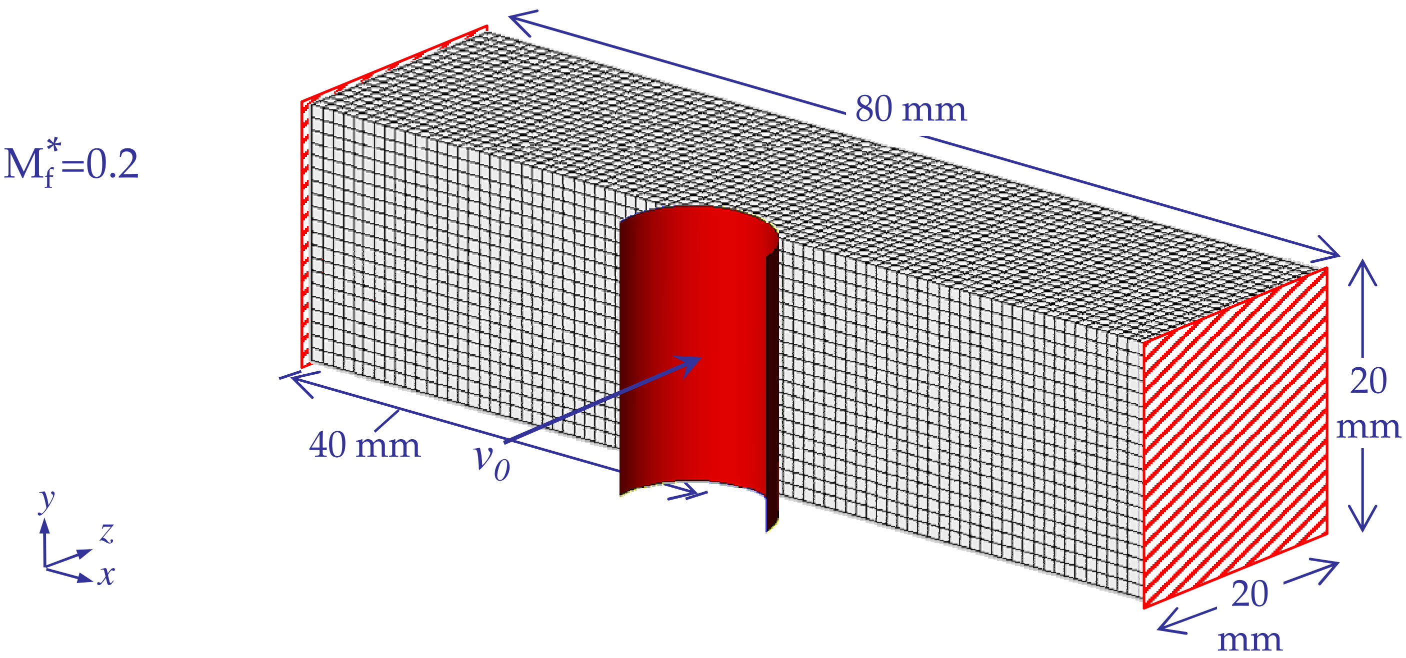
$$\text{target } (S) \rightarrow \text{internal energy density}$$



Example problem: short beam

Courtesy
Neal Patel

$M_f^*=0.2$



v_0**=40 m/s**

80 × 20 × 20 elements*

*~7 minutes/FEA (DYNA) evaluation

Effects of model simplifications

$M_f^*=0.2$

Courtesy
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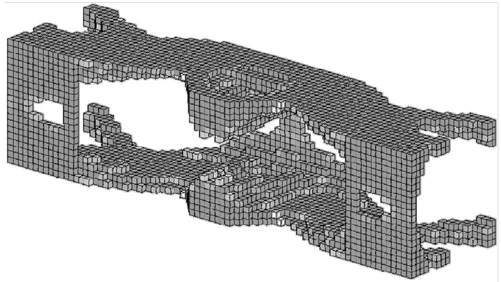
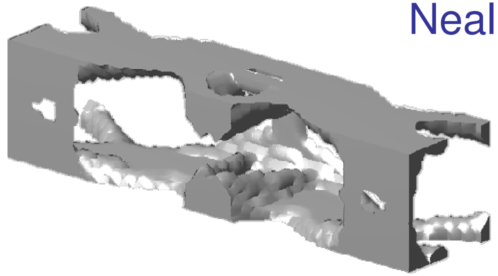
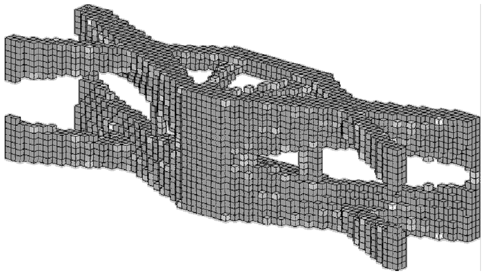
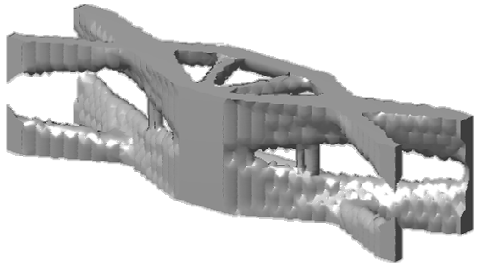
Nonlinear-dynamic



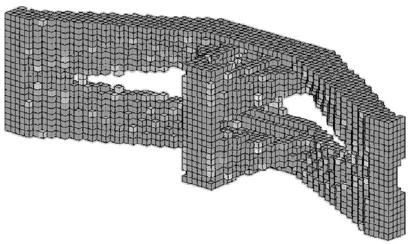


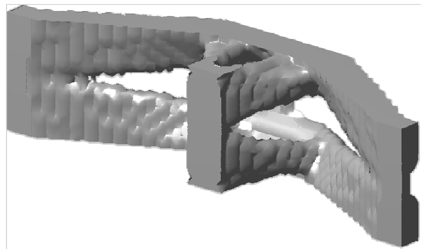
Linear-static

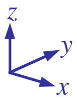




Nonlinear-static







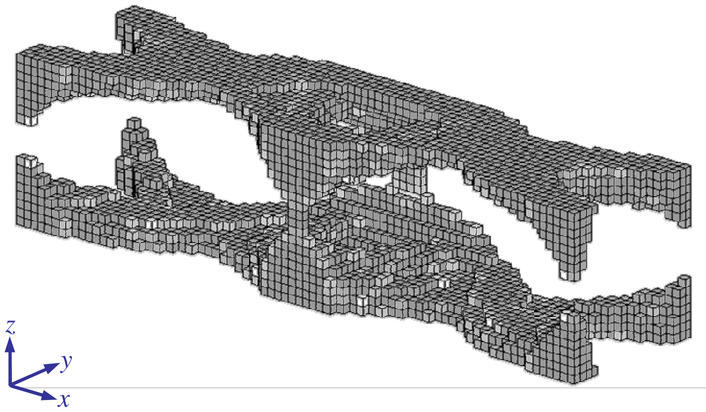
Short beam: extrusion results

Courtesy
Neal Patel

$M_f^*=0.2$

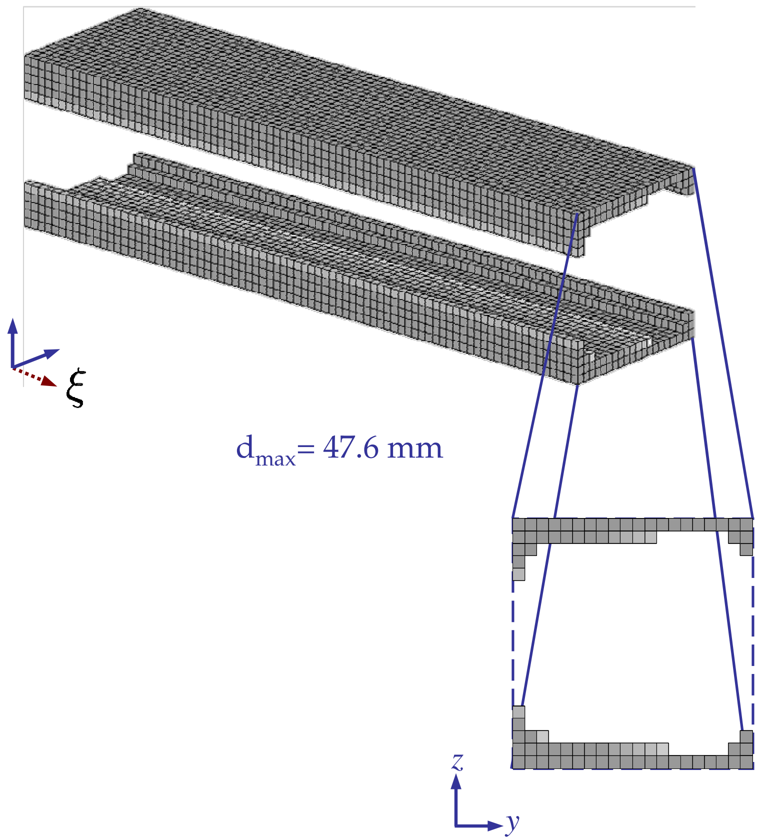
Conventional topology

(no extrusion)

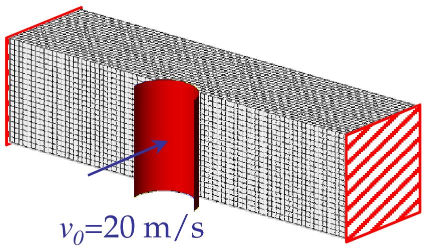


d_{max}= 40.1 mm

Extruded topology

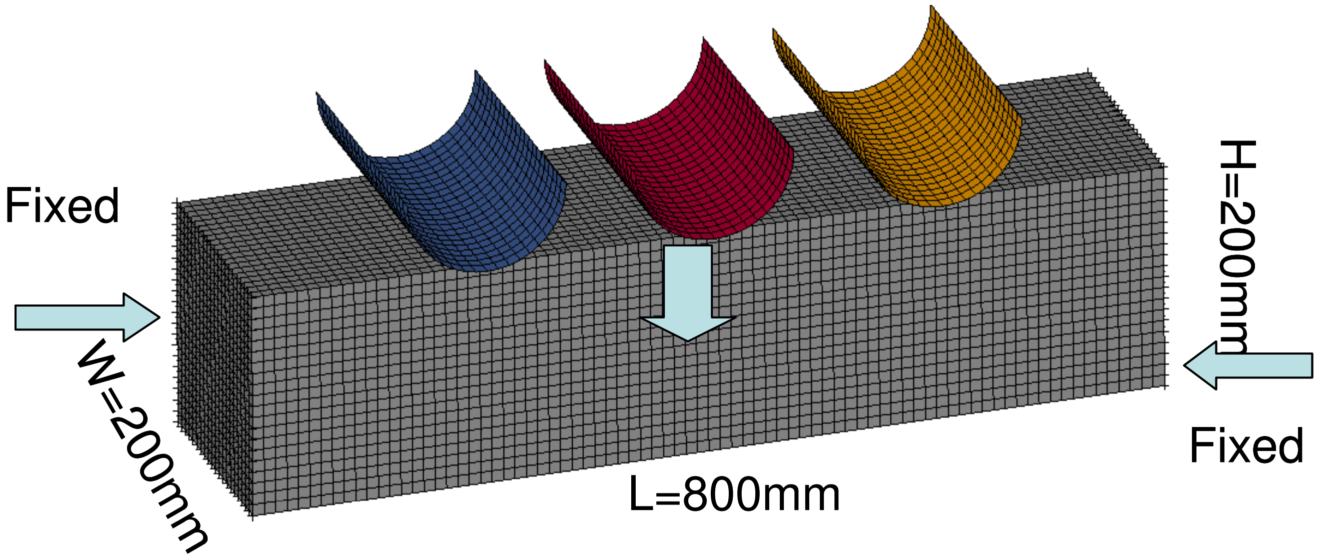


d_{max}= 47.6 mm



v_0=20 m/s

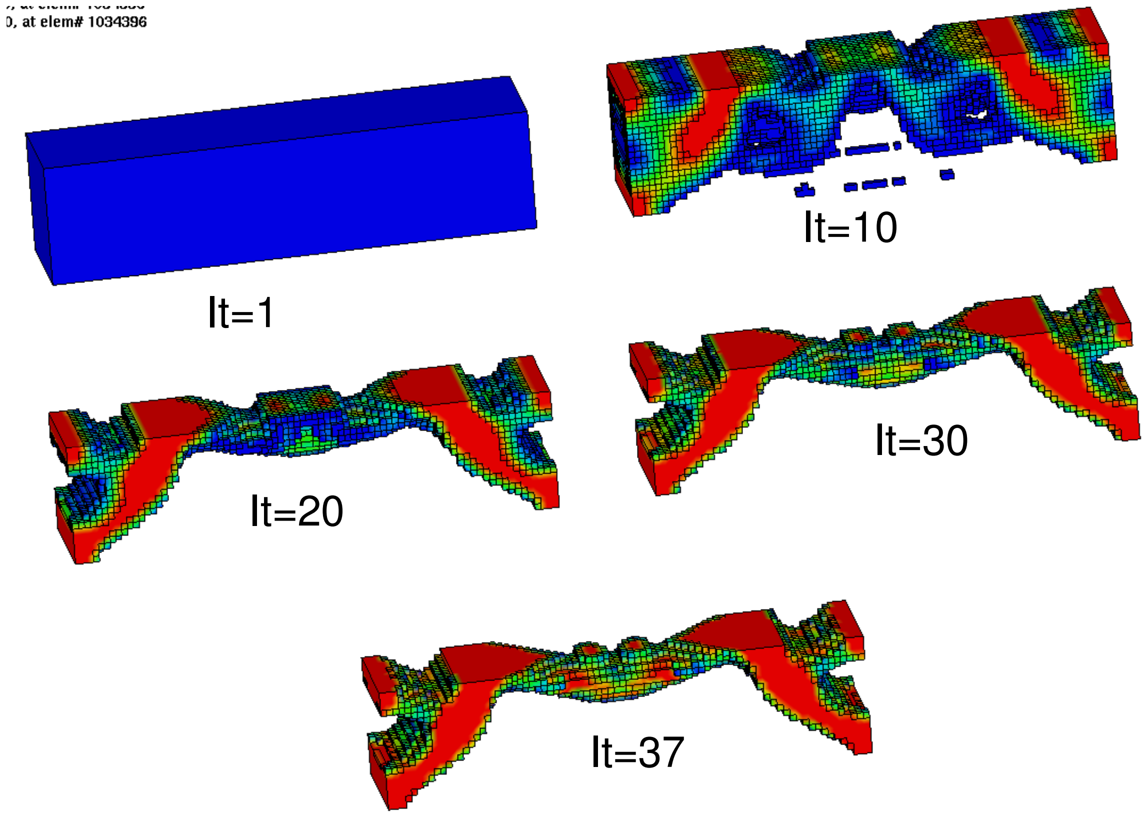
Problem Definition



- Three poles hit the fixed-fixed beam with an initial velocity of 40m/s, one at a time (three load cases)
- Get the optimal structure with 30% mass, equal importance of each load case
- Mesh size – 10mm^3, Material: Bi-linear Aluminum
- MPP LS-DYNA simulations with 8 processors per case

Final Results

- 37 iterations to obtain optimal topology
- The initial shape was evolved within 20 iterations
- Tabular structure with two legs was evolved as optima
- Uniform distribution of material



Estimated beta release

- Version 4.0: April, 2009
- Version 4.1: September, 2009
- Topology Optimization, April, 2009