

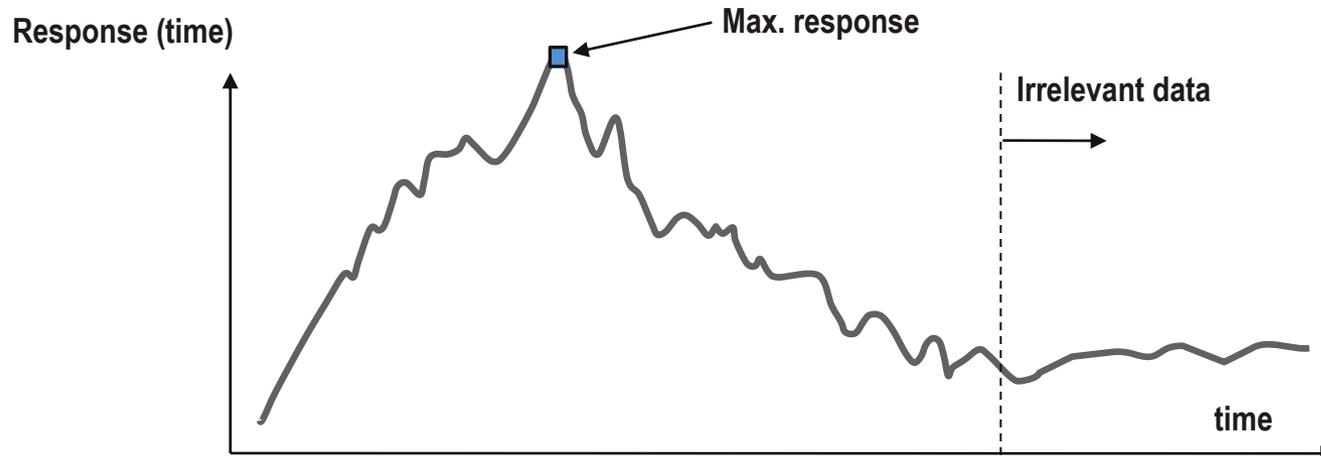
# Introductory Course: Using LS-OPT<sup>®</sup> on the TRACC Cluster

## 1.6b - Design Optimization; Frontal Impact

By: Cezary Bojanowski, PhD

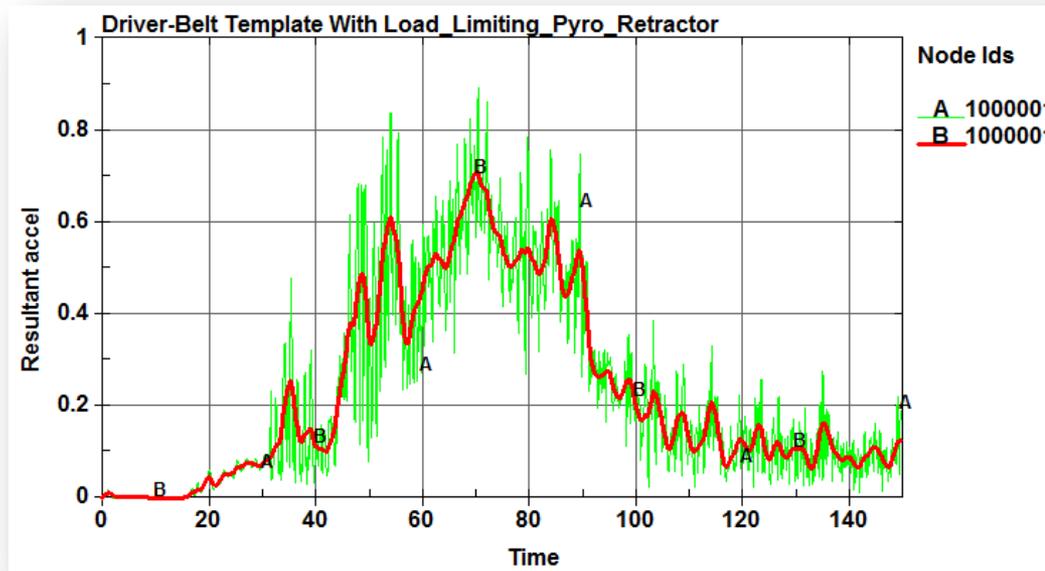
# Design Optimization Process - Model Preparation

- Request only necessary output from LS-DYNA to prevent from storage space depletion – use “clean” script properly: `rm -rf d3plot* elout nodout rcforc`
- Run one simulation and check if the termination time can be decreased.



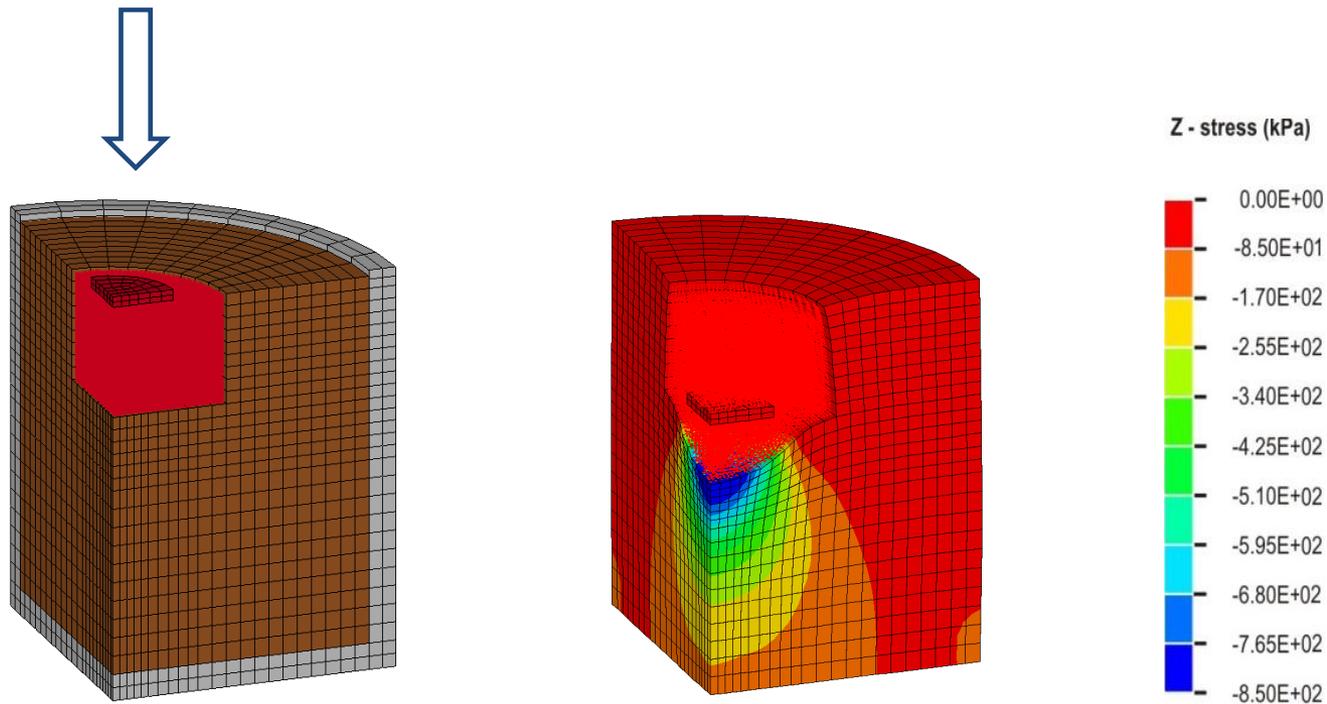
# Model Preparation - Data Filtering and Resolution

- The model used for design should be stable and user should have confidence in its accuracy.
- If you are comparing maximal values of responses, make sure that you filter them to have reasonable values



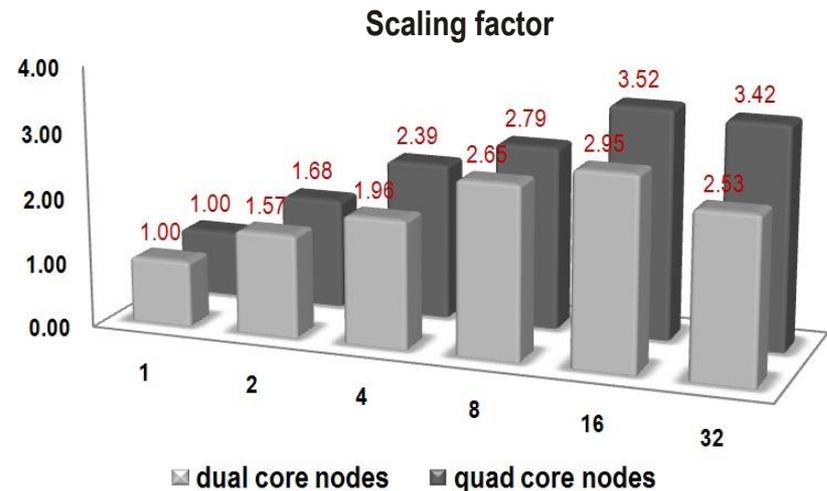
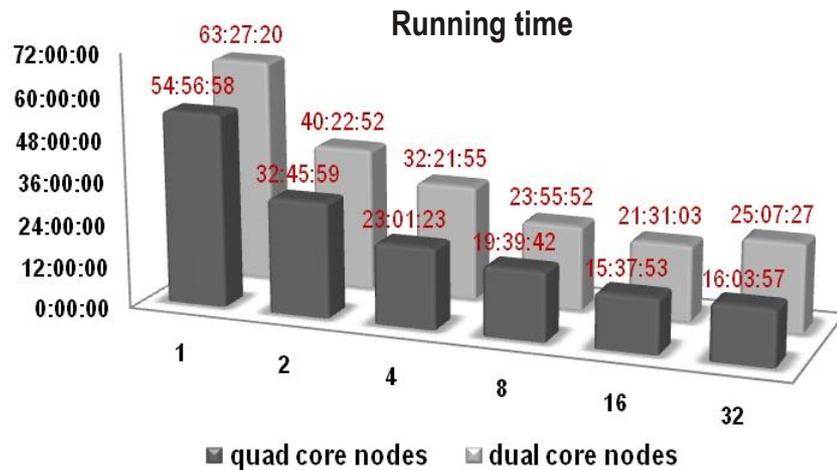
# Model Preparation - Number of Cores

- Problem description:
  - A rigid pad is pressed down into the soil with the rate of 1 in/sec
  - Model is built of 20,256 solid elements + 104,512 SPH particles
  - Simulation lasts 20 sec what corresponds to 20 in of penetration



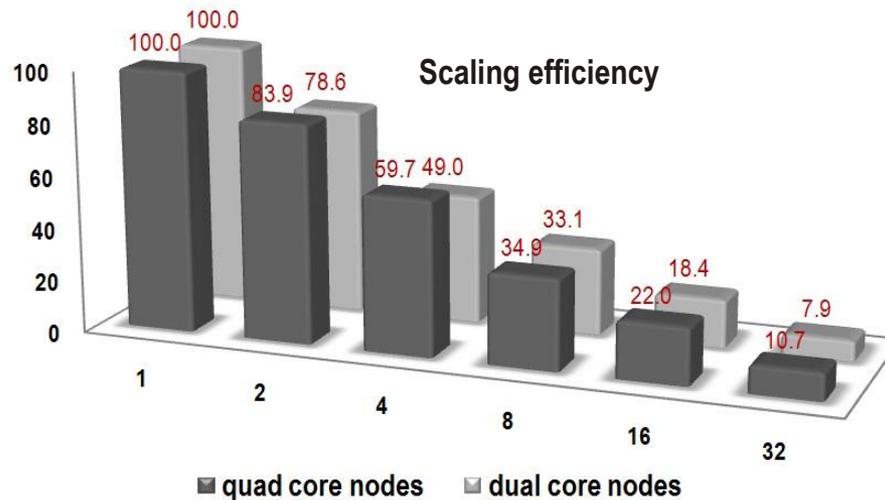
# Model Preparation - Number of Cores

- Requesting more nodes for your job doesn't always mean that you will get your results faster
- Your job is scalable only up to some point that depends on the number of elements in your model and type of analysis you perform.
- As number of cores increases your waiting time in the queue grows accordingly.



# Model Preparation - Number of Cores

- Scaling efficiency = Actual scaling factor / Ideal scaling factor \* 100%
- In ideal case, linear scaling is expected and 100% of efficiency
- When requesting 8 cores, the run time dropped for this particular job to 36% of the time requested for 1 core.
- However, the efficiency of scaling was only 34.9%.
- If you are planning to submit multiple jobs, always request low number of cores.



# Model Preparation - Decomposition

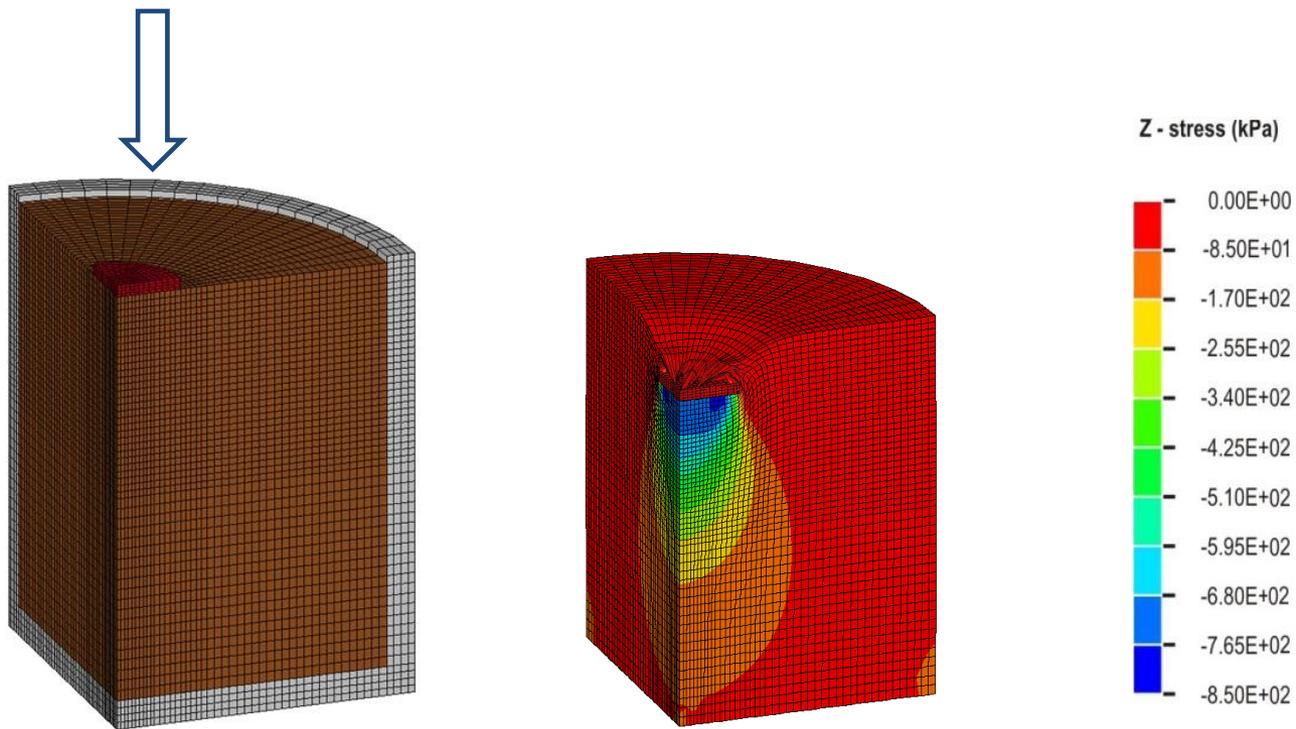
- Check how your model is decomposed. To do it use pfile:

```
decomposition { numproc 8  
                show }
```

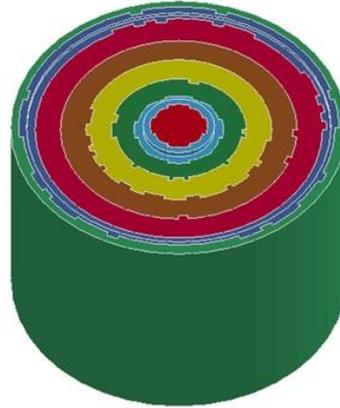
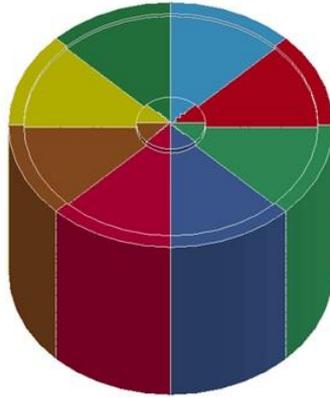
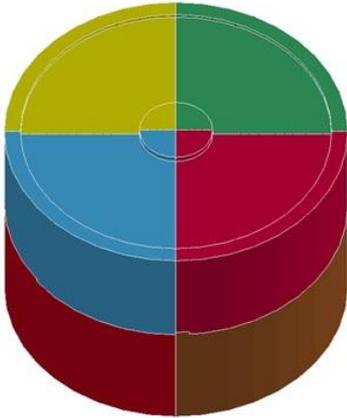
- The default decomposition method in LS-DYNA (Recursive Coordinate Bisection - RCB) works by recursively dividing the model in half, each time slicing the current piece of the model perpendicularly to one of the three coordinate axes.
- The result is that it tends to generate cube shaped domains aligned along the coordinate axes. This is often not the behavior desired.

# Model Preparation - Decomposition

- How to decompose the model? Two things are important:
  - Amount of messages passed between the nodes,
  - What is happening in the elements?



# Model Preparation - Decomposition



decomposition 1 - default

```
decomposition {  
  numproc 8  
  show }
```

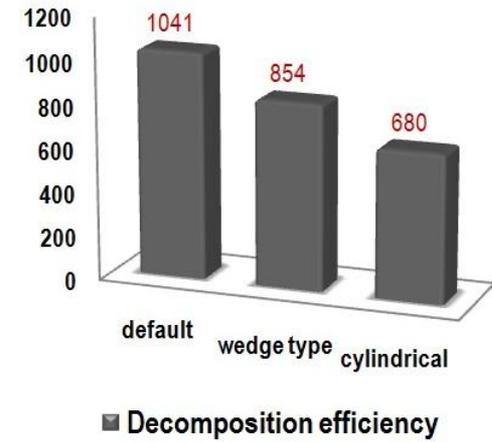
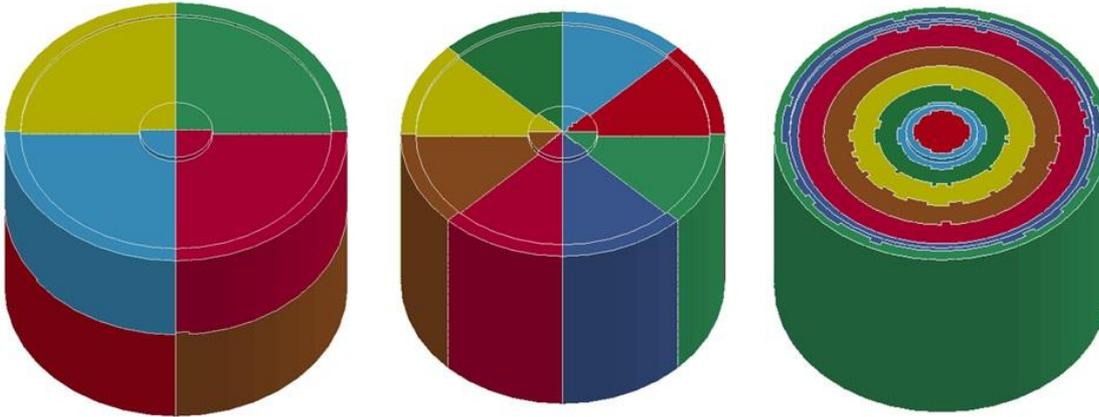
decomposition 2 - wedge type

```
decomposition {  
  numproc 8  
  C2R 0 0 0 0 0 1 1 0 0  
  SY 5000 }
```

decomposition 3 – cylindrical

```
decomposition {  
  numproc 8  
  C2R 0 0 0 0 0 1 1 0 0  
  SX 100 }
```

# Model Preparation - Decomposition



decomposition 1 - default

```
decomposition {
  numproc 8
  show }
```

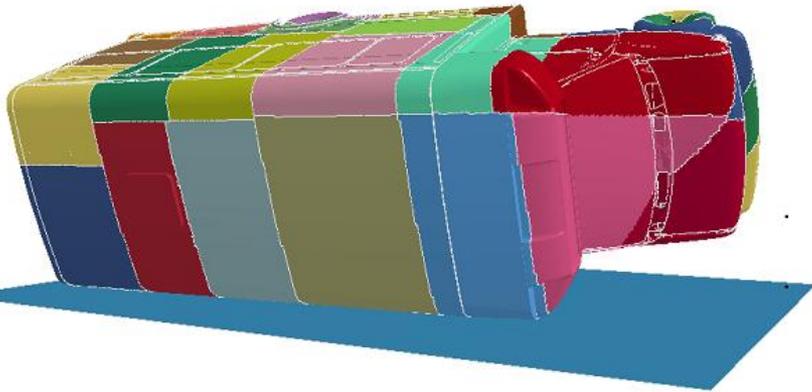
decomposition 2 - wedge type

```
decomposition {
  numproc 8
  C2R 0 0 0 0 0 1 1 0 0
  SY 5000 }
```

decomposition 3 – cylindrical

```
decomposition {
  numproc 8
  C2R 0 0 0 0 0 1 1 0 0
  SX 100 }
```

# Model Preparation - Decomposition



decomposition 1 - default

```
decomposition {  
  numproc 32  
  show }
```

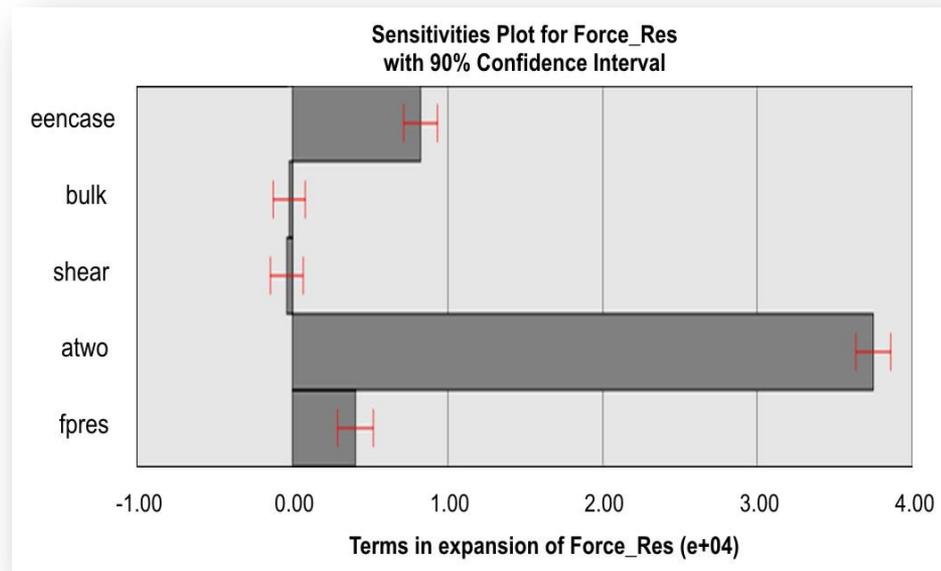


decomposition 2 – slice type

```
decomposition {  
  numproc 32  
  RZ -3.5 SX 200  
  show }
```

# Model Preparation - ANOVA

- Select suitable design parameters. Use many variables at the beginning if you are not sure which of them contribute the most to the changes in response.
- Stop after first iteration and scan for insignificant variables by performing ANOVA.

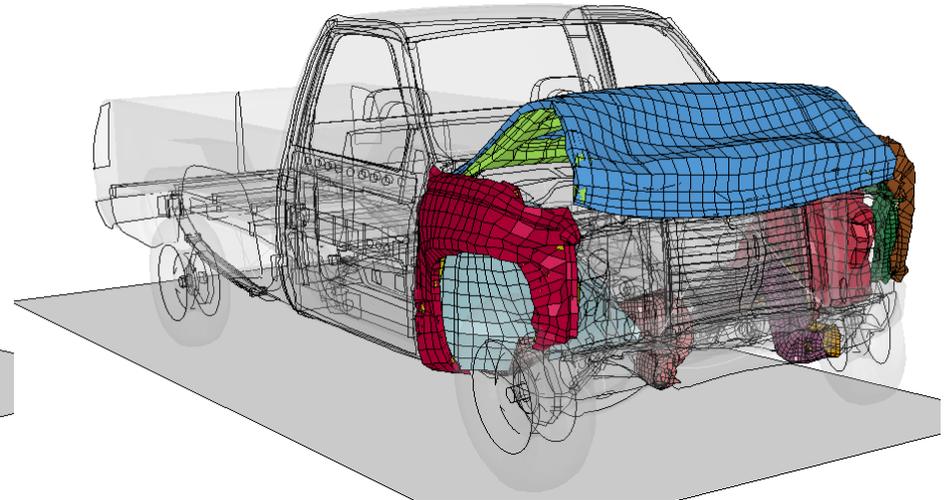
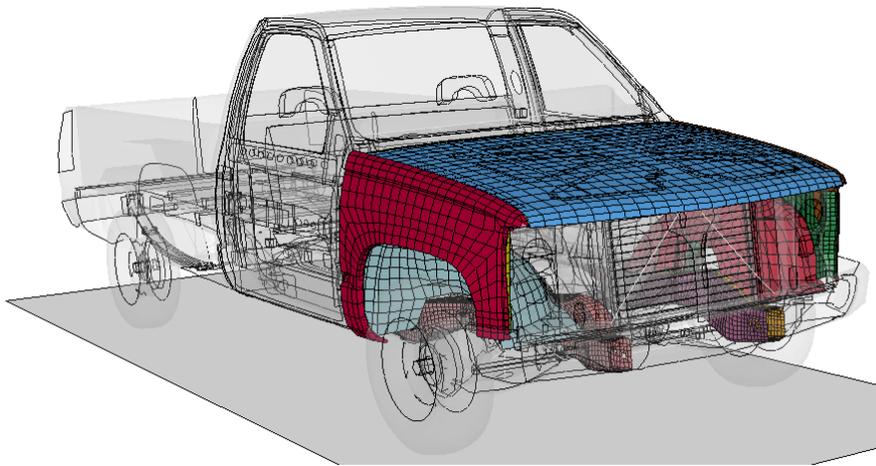


# Design Optimization Process - Model Preparation

- Choose a design space by setting absolute bounds on the design variables. Be sure that the simulation is stable for these values.
- Choose suitable initial range. Too small region may require many iterations to converge to global optimum. Too large region may exhibit large accuracy error.
- Choose appropriate order of design approximation when using polynomial response surfaces.
- In many cases it takes only 2 to 3 iterations to achieve reasonably optimal design. An improvement can be achieved within one iteration.

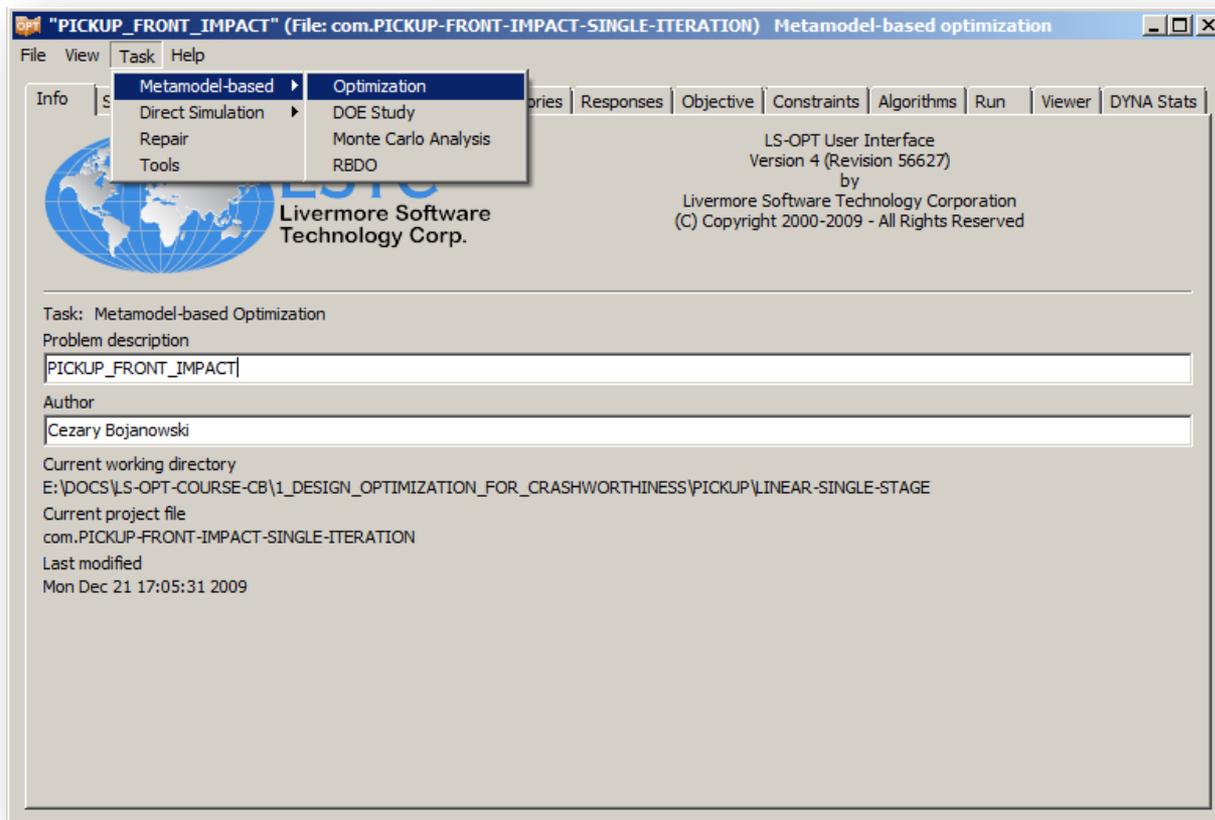
# Problem Description

- Frontal impact of the C2500 Pickup truck (58,354 elements)
- Objective: Maximize the internal energy to mass ratio (for selected 12 parts)
- Variables: thicknesses of 12 parts of the model
- Constraints: bounds on mass



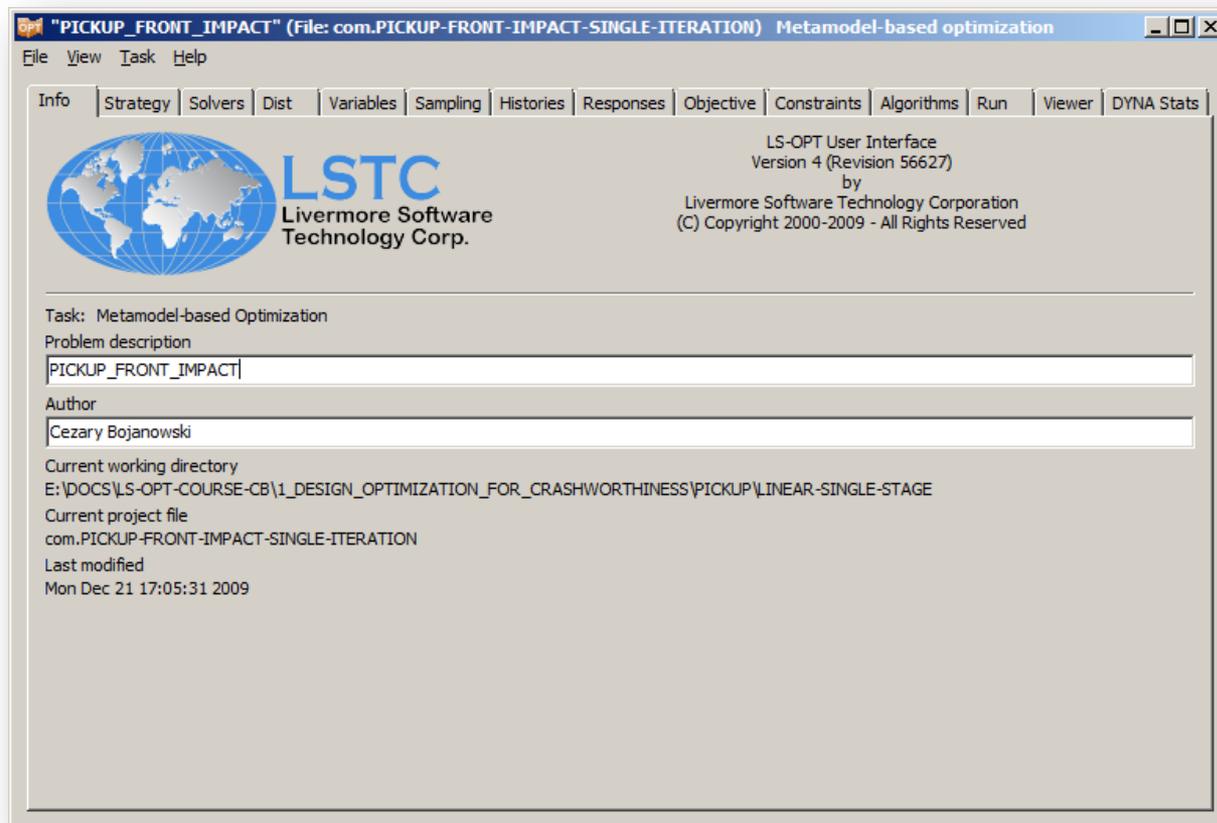
# Task Selection

- Go to Task Tab and
- Select Metamodel – based Optimization



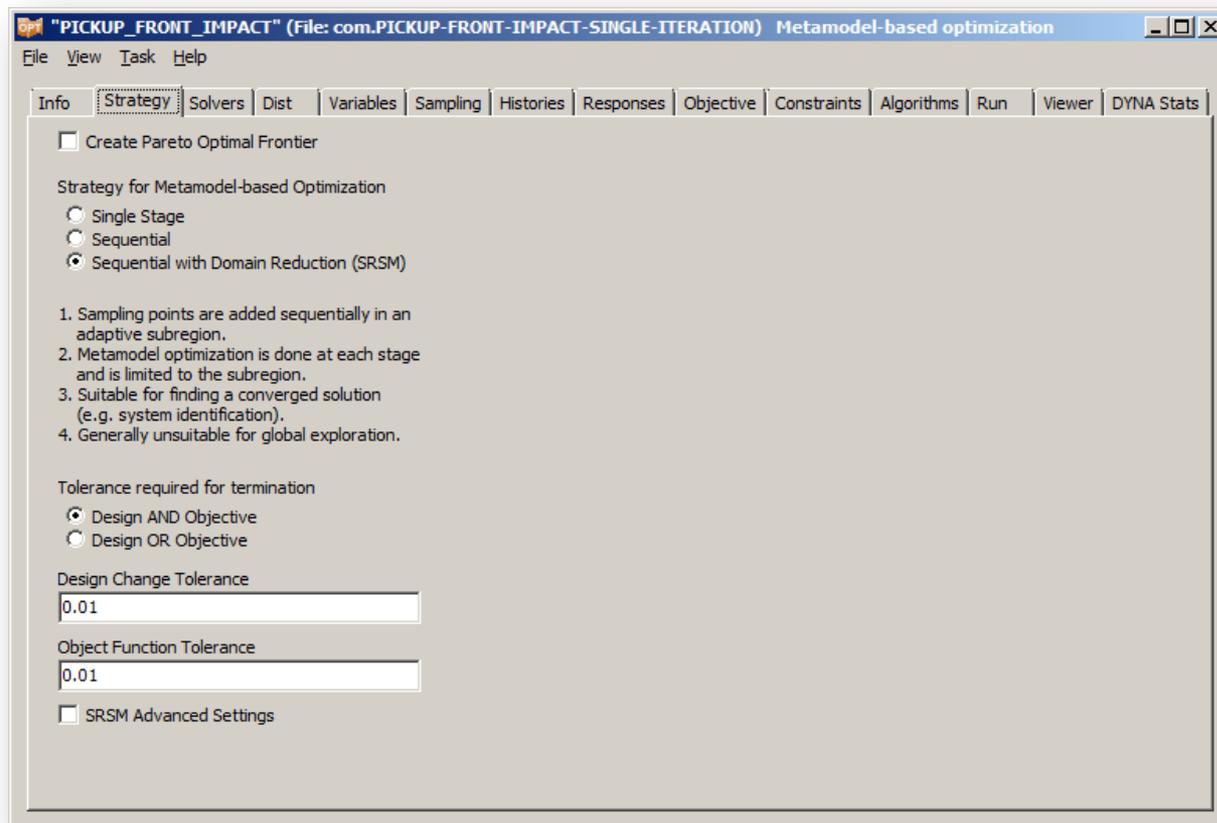
# Info Tab

- Type in the description of the problem and the name of the Author



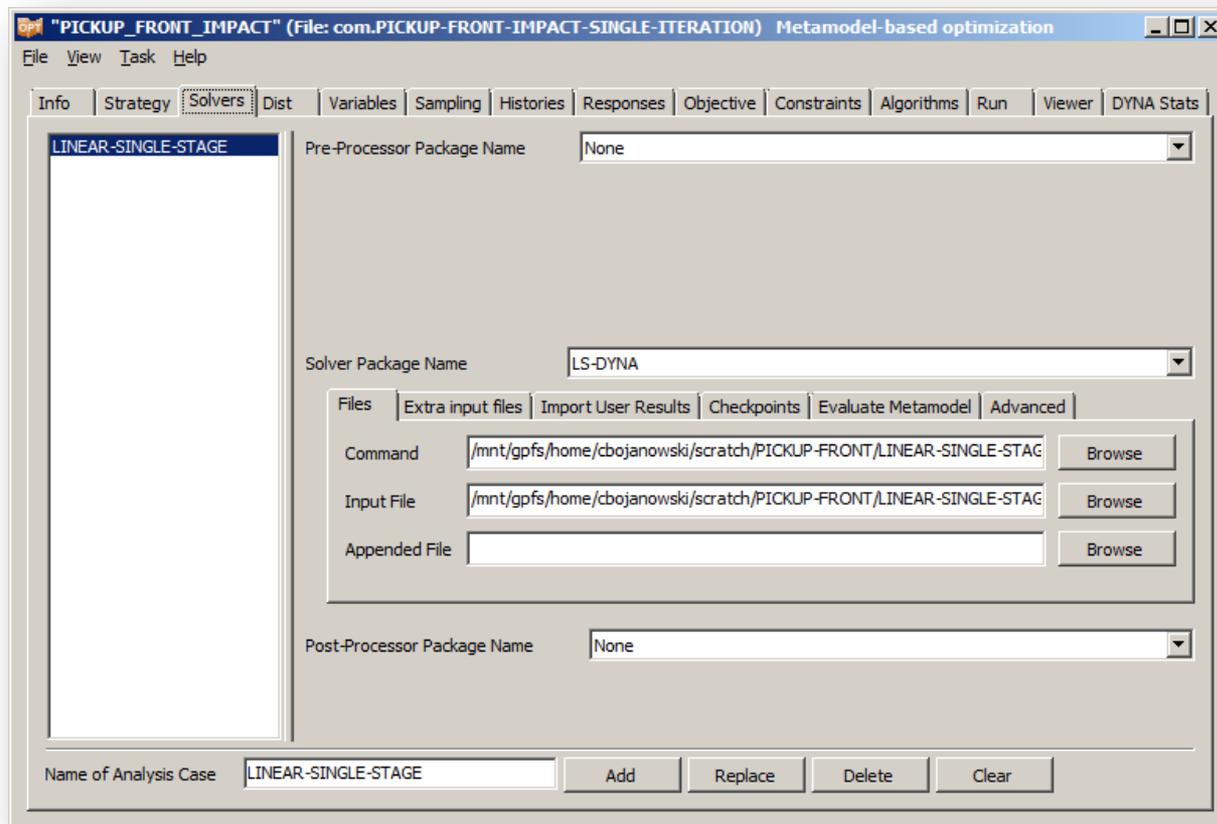
# Strategy Tab

- Go to the Strategy panel
- Choose Sequential with Domain Reduction (SRSM)
- Leave the defaults for the convergence tolerance



# Solvers Tab

- In the Solvers panel browse to your LS-DYNA<sup>®</sup> executables (Windows) or to **Isopscript** (Linux system at TRACC) at Command line
- For the input file find the **Combine.k** file
- Type **LINEAR-SINGLE-STAGE** in the Name of Analysis Case field and hit Add



# Variables Tab

- In the Variables panel Add seven variables:
  - **thic1** with starting value of **3.137** with lower bound **2.8233** and upper bound **3.4507**
  - **thic2** with starting value of **3.112** with lower bound **2.8008** and upper bound **3.4232**
  - **thic40** with starting value of **0.703** with lower bound **0.6327** and upper bound **0.7733**
  - ...

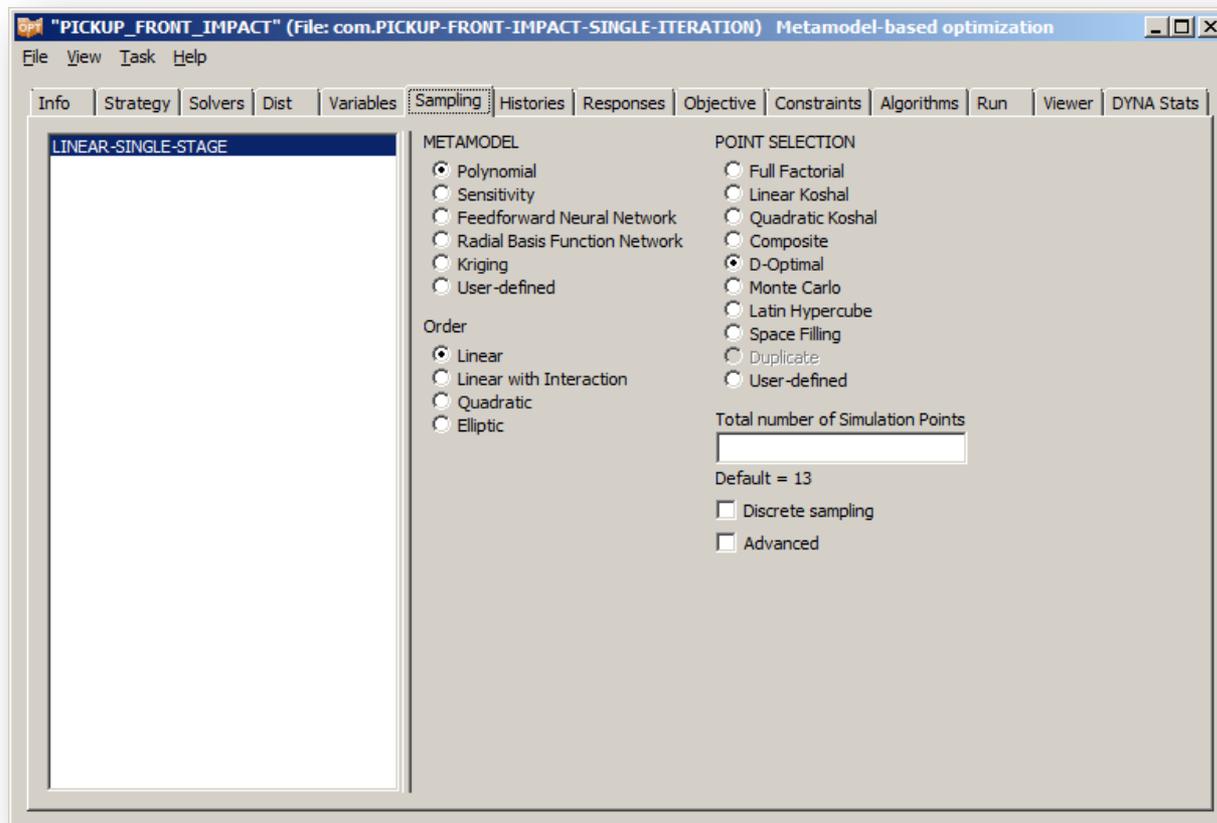
Type	Name	Starting	Init. Range	Minimum	Maximum
Variable	thic1	3.137		2.8233	3.4507
Variable	thic2	3.112		2.8008	3.4232
Variable	thic40	.703		.6327	.7733
Variable	thic41	.78		.702	.858
Variable	thic46	.753		.6777	.8283
Variable	thic48	.804		.7236	.8844
Variable	thic54	.696		.6264	.7656
Dependent	thic3	Definition	thic1		
Dependent	thic4	Definition	thic2		
Dependent	thic47	Definition	thic46		
Dependent	thic49	Definition	thic48		
Dependent	thic55	Definition	thic54		

# Variables Tab

- In the Variables panel Add seven variables:
  - ...
  - `thic41` with starting value of `0.78` with lower bound `0.702` and upper bound `0.858`
  - `thic46` with starting value of `0.753` with lower bound `0.6777` and upper bound `0.8283`
  - `thic48` with starting value of `0.804` with lower bound `0.7236` and upper bound `0.8844`
  - `thic54` with starting value of `0.696` with lower bound `0.6264` and upper bound `0.7656`
- And five Dependent variables:
  - `thic3` defined as `thic1`
  - `thic4` defined as `thic2`
  - `thic47` defined as `thic46`
  - `thic49` defined as `thic48`
  - `thic55` defined as `thic54`

# Sampling Tab

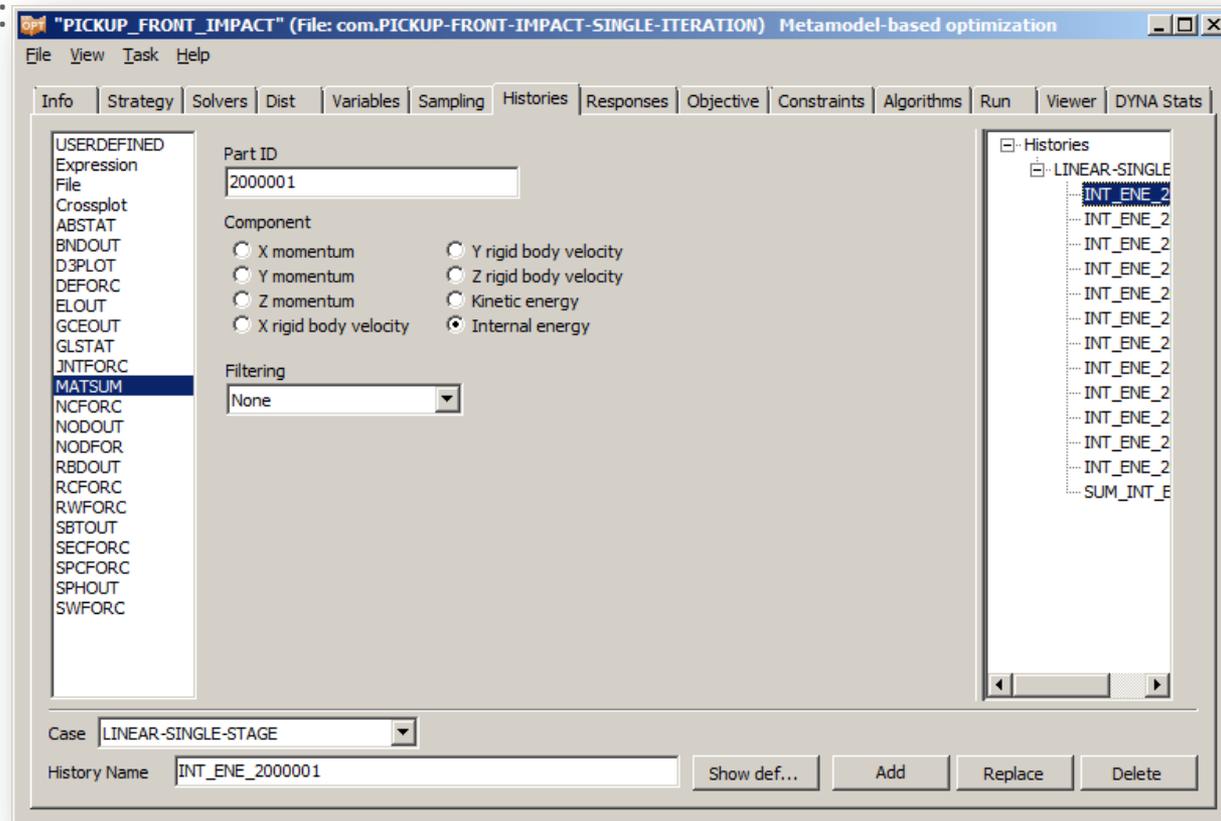
- In the Sampling panel select Polynomial Metamodel with Linear order
- For Point Selection choose D-Optimal criterion
- Leave the default number of Simulation Points



# Histories Tab

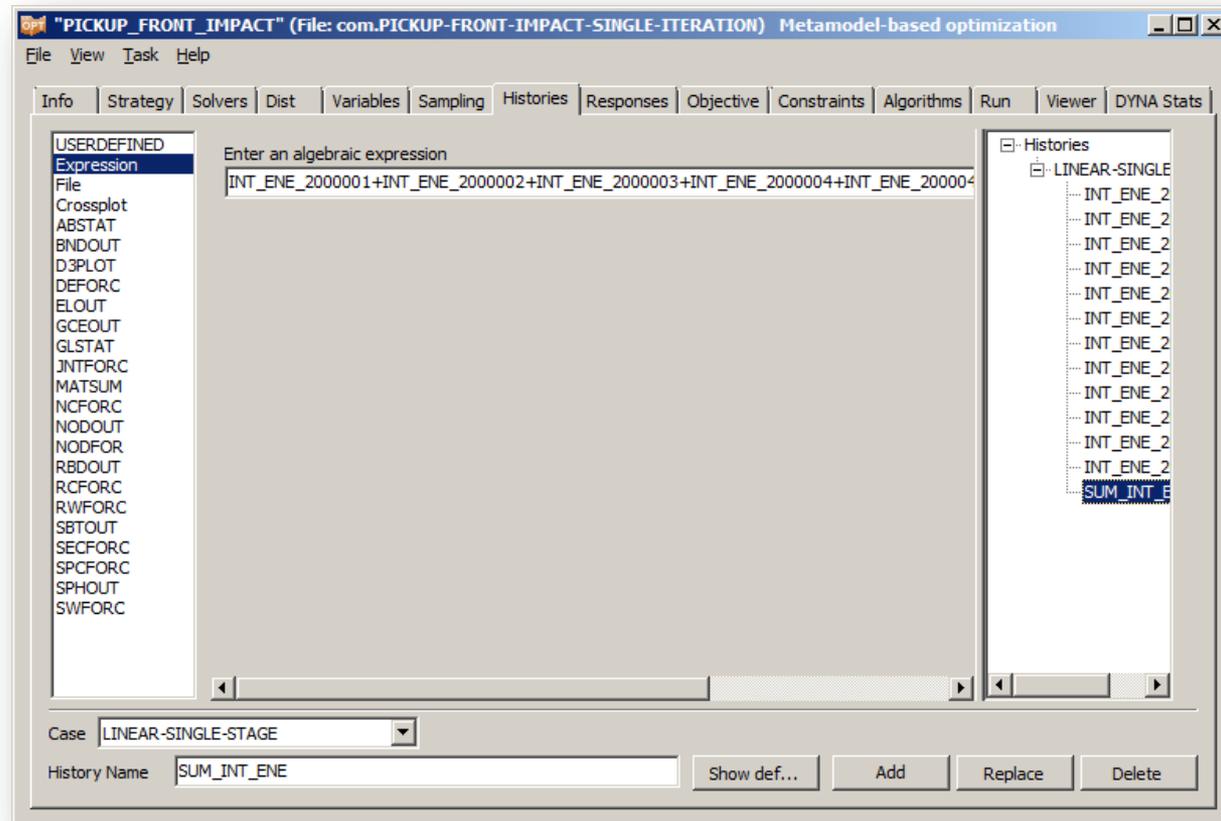
- In the Histories panel from the right window select **MATSUM** file
- For Part ID identifier type **2000001**
- For the component choose Internal Energy
- Name the History as **INT\_ENE\_2000001**
- Repeat the same for parts:

- 2000002
- 2000003
- 2000004
- 2000040
- 2000041
- 2000046
- 2000047
- 2000048
- 2000049
- 2000054
- 2000055



# Histories Definitions

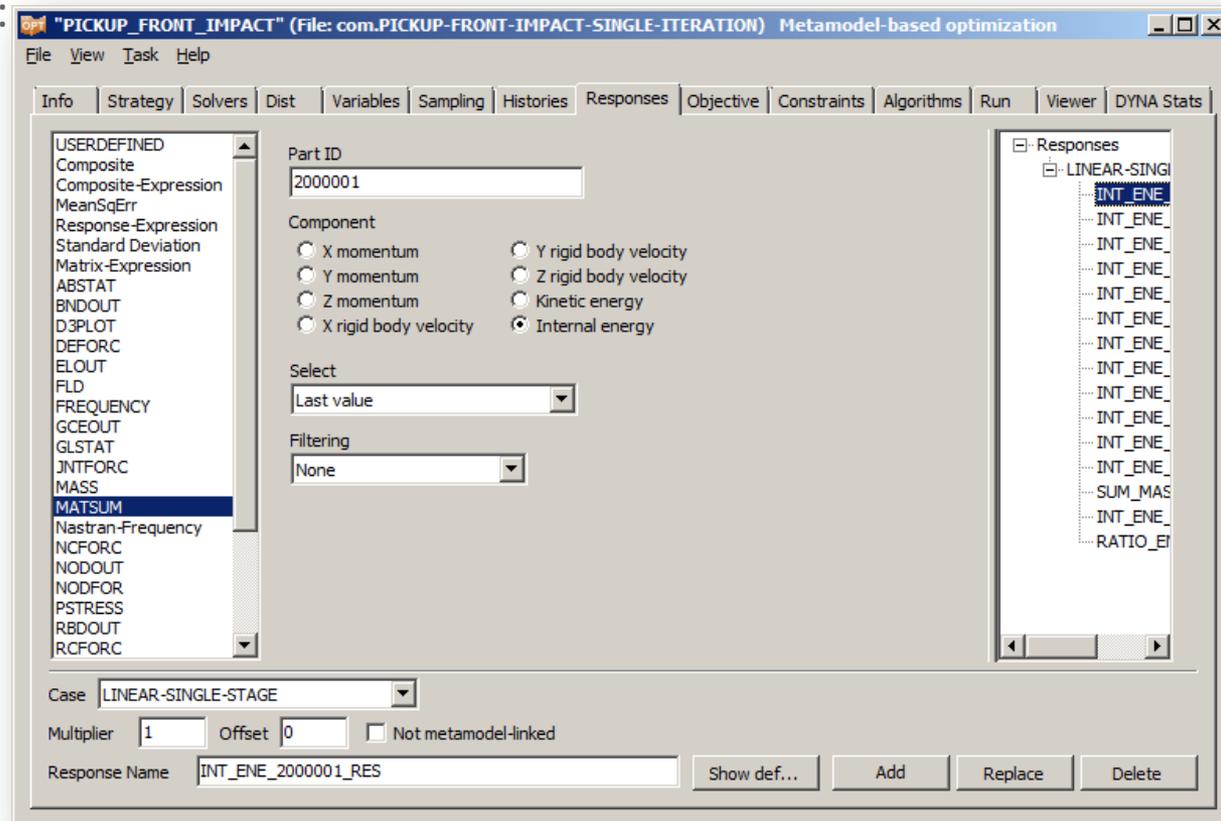
- In the Histories panel from the right window select **Expression**
- For the algebraic expression type  $INT\_ENE\_2000001 + INT\_ENE\_2000002 + INT\_ENE\_2000003 + INT\_ENE\_2000004 + INT\_ENE\_2000040 + INT\_ENE\_2000041 + INT\_ENE\_2000046 + INT\_ENE\_2000047 + INT\_ENE\_2000048 + INT\_ENE\_2000049 + INT\_ENE\_2000054 + INT\_ENE\_2000055$
- Name it as **SUM\_INT\_ENE**
- Press Add



# Responses Definitions

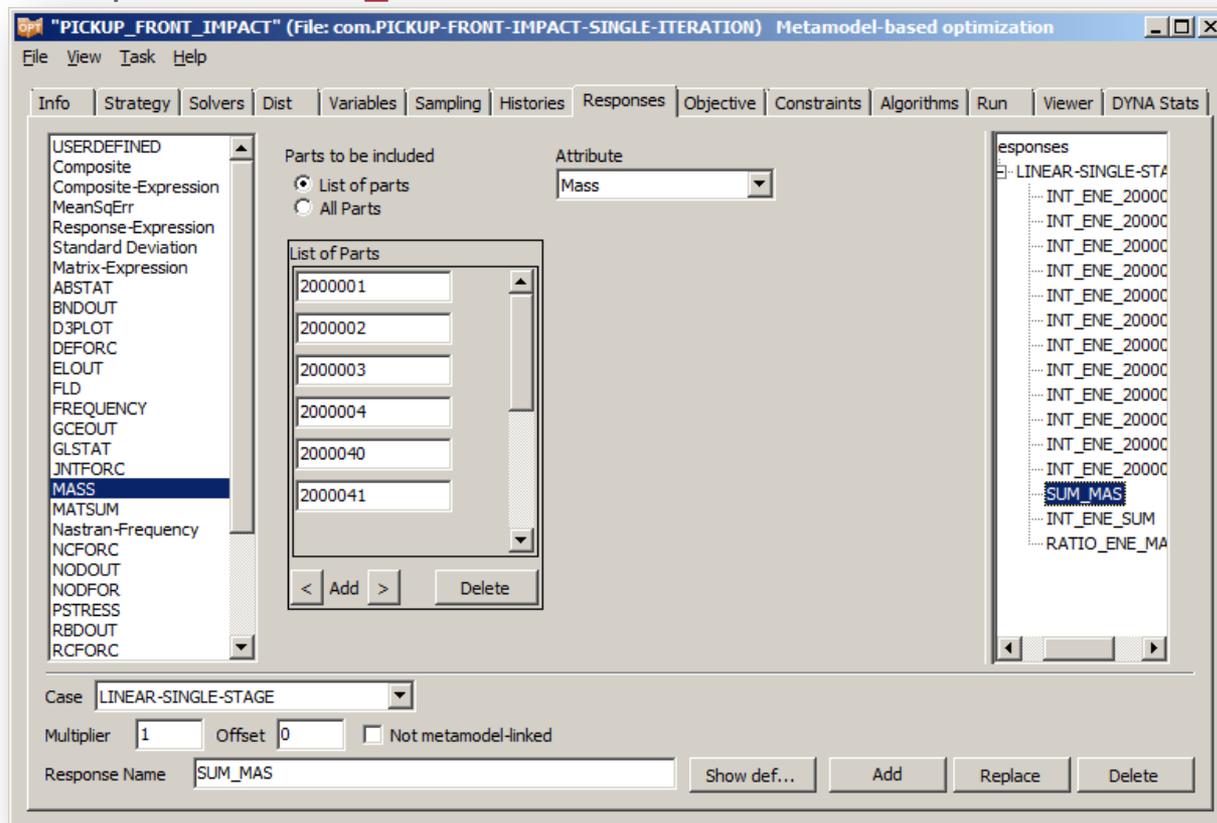
- In the Responses panel from the right window select **MATSUM** file
- For Part ID identifier type **2000001**
- For the component choose Last value of Internal Energy
- Name the Response as **INT\_ENE\_2000001\_RES**
- Repeat the same for parts:

- 2000002
- 2000003
- 2000004
- 2000040
- 2000041
- 2000046
- 2000047
- 2000048
- 2000049
- 2000054
- 2000055



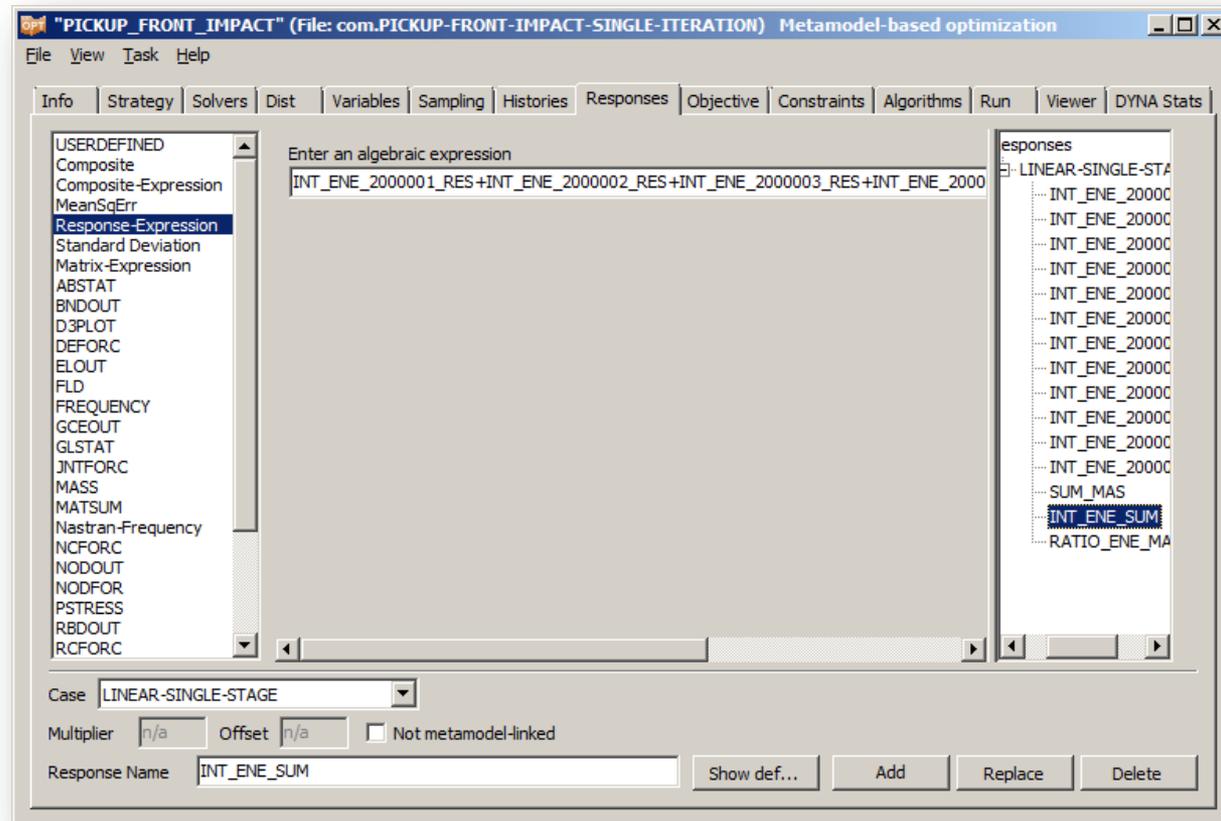
# Responses Definitions

- In the Responses panel from the right window select **MASS** file
- For Parts to be included Add parts: 2000001, 2000002, 2000003, 2000004, 2000040, 2000041, 2000046, 2000047, 2000048, 2000049, 2000054, 2000055
- Name the Response as **SUM\_MAS**



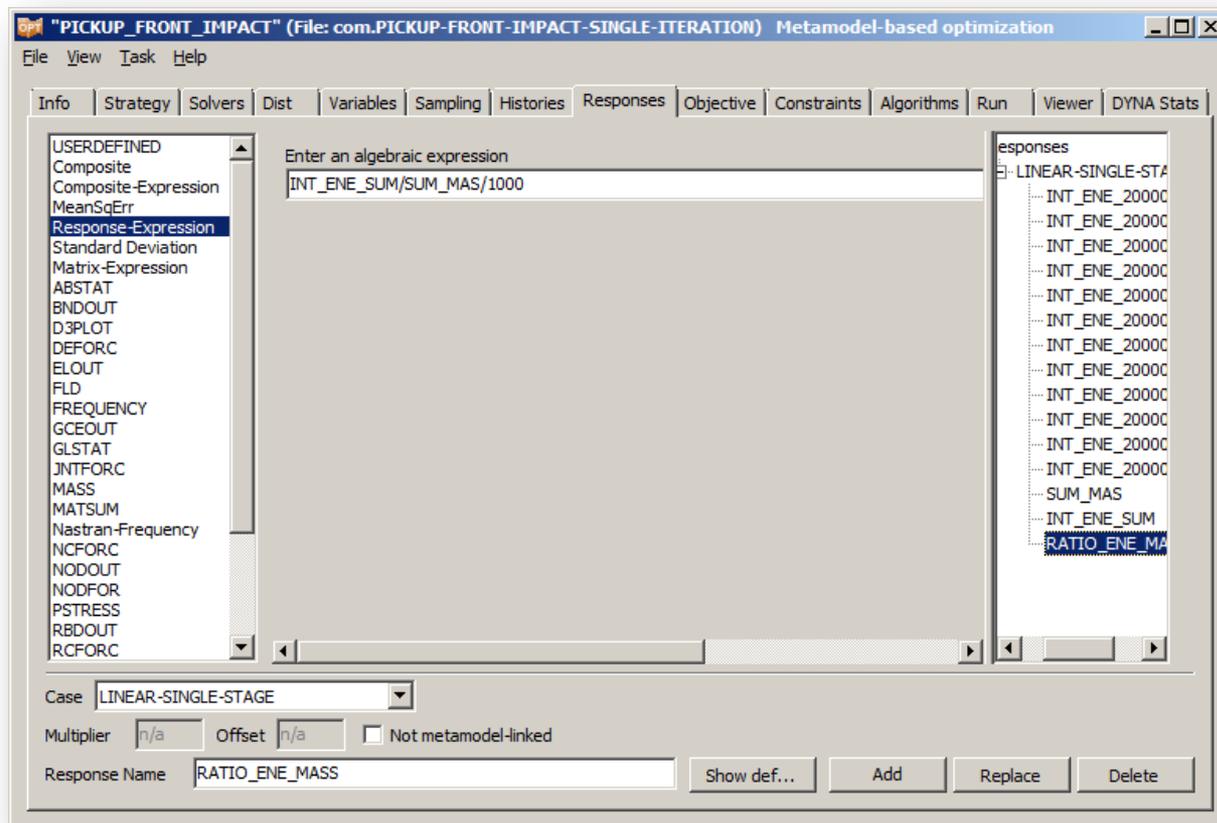
# Responses Definitions

- In the Responses panel from the right window select **Response-Expression**
- For the algebraic expression enter **INT\_ENE\_2000001\_RES + INT\_ENE\_2000002\_RES + INT\_ENE\_2000003\_RES + INT\_ENE\_2000004\_RES + INT\_ENE\_2000040\_RES + INT\_ENE\_2000041\_RES + INT\_ENE\_2000046\_RES + INT\_ENE\_2000047\_RES + INT\_ENE\_2000048\_RES + INT\_ENE\_2000049\_RES + INT\_ENE\_2000054\_RES + INT\_ENE\_2000055\_RES**
- Name it as **INT\_ENE\_SUM**
- Press Add



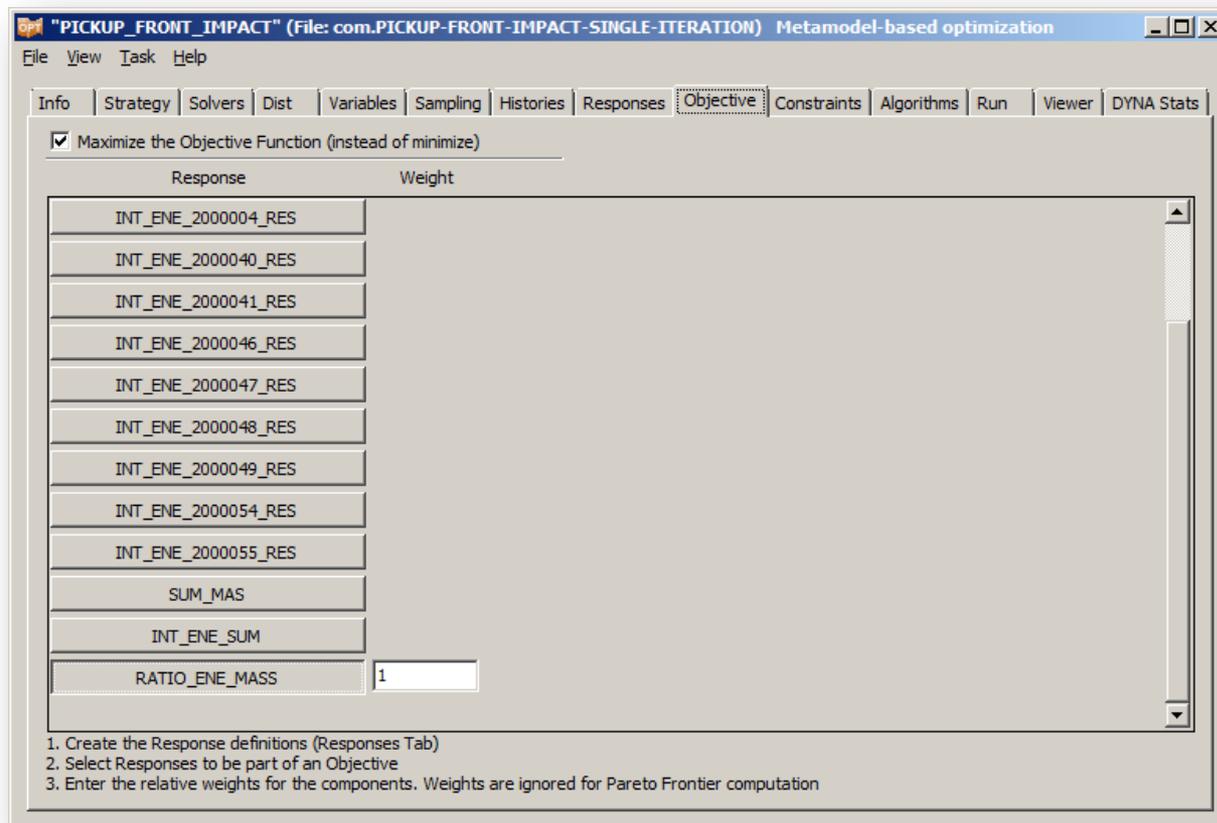
# Responses Definitions

- In the Responses panel from the right window select **Response-Expression**
- For the algebraic expression type **INT\_ENE\_SUM/SUM\_MAS/1000**
- Name it as **RATIO\_ENE\_MASS**
- Press Add



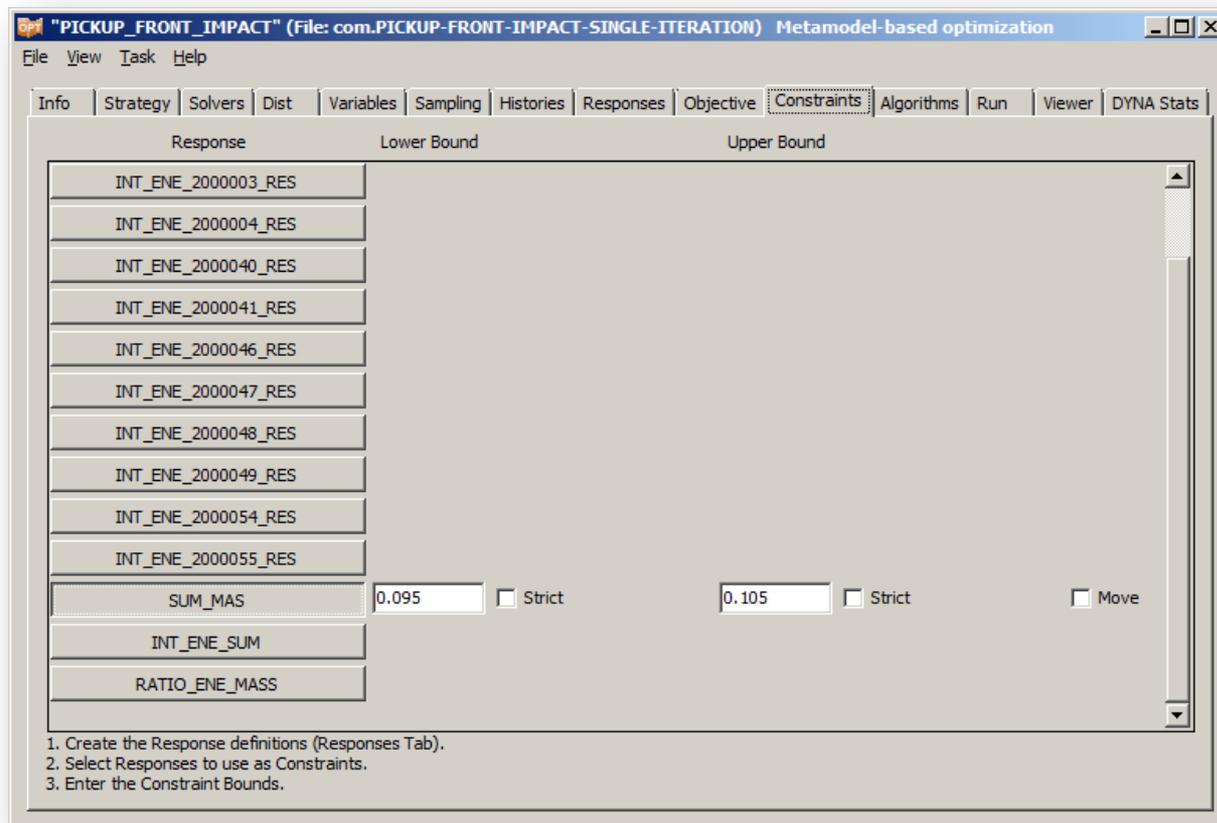
# Objectives Tab

- In Objectives panel select to maximize the **RATIO\_ENE\_MASS** with default weight 1.0



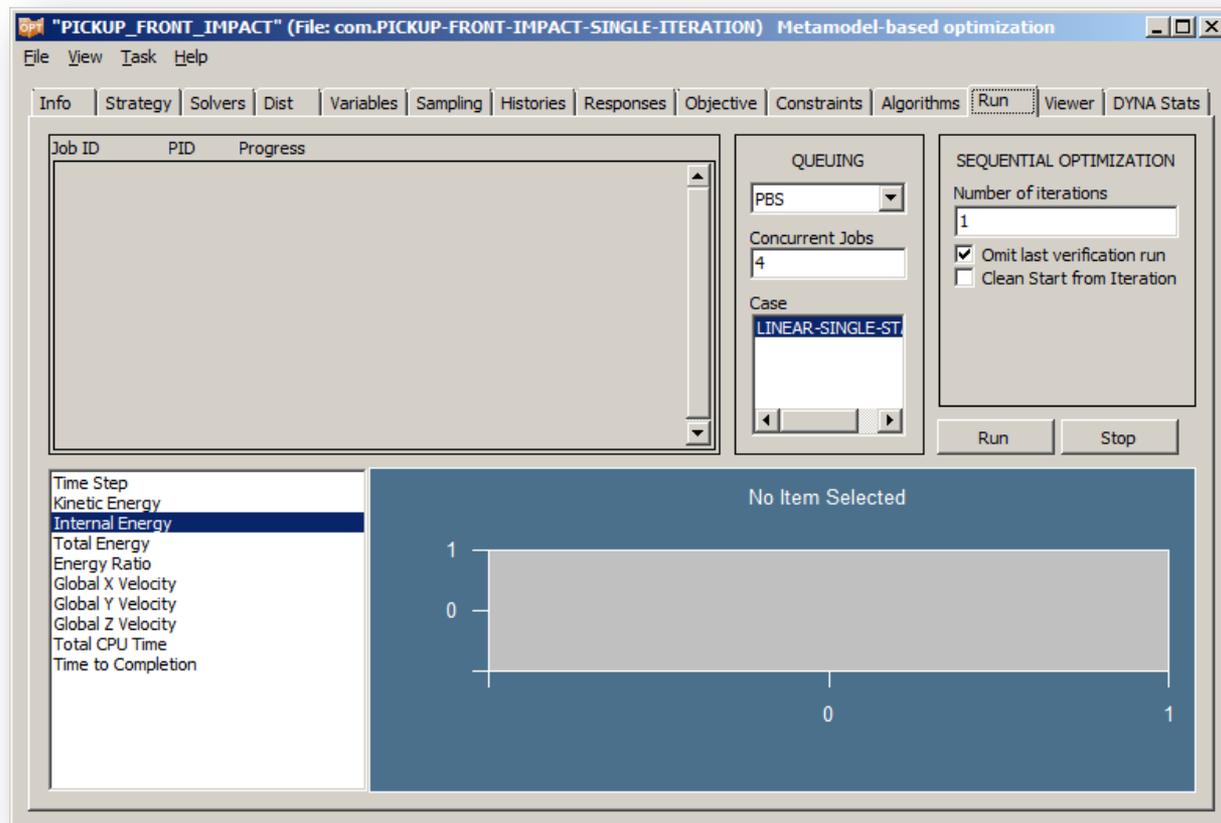
# Constraints Tab

- From Responses select **SUM\_MAS**
- For lower bound type **-0.095** and the Upper bound **+0.105**



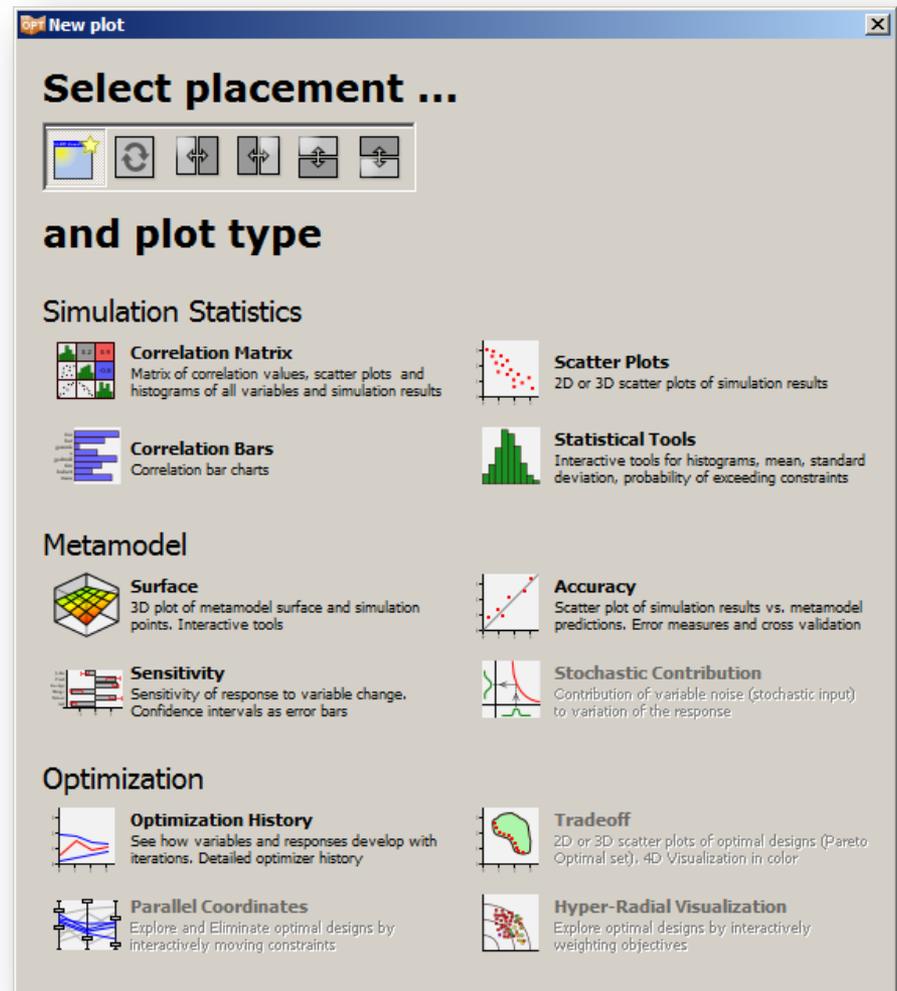
# Run Tab

- Select PBS for QUEUING software (TRACC cluster users)
- For Concurrent Jobs enter 4
- For Number of Iteration enter 1 and
- Check Omit last verification run and Clean Start from iteration 1
- Hit Run to start simulations



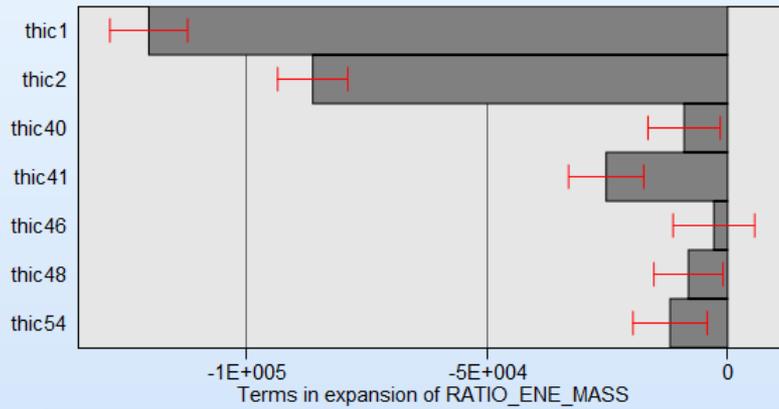
# Viewer

- Go to Viewer panel and the viewer options should pop up automatically
- From Metamodel menu select Sensitivity
- New window should appear
- See the sensitivities of responses:
  - Sum of the mass
  - Sum of the internal energies
  - Ratio of the internal energy to mass (objective)



# Sensitivities

Sensitivities Plot for RATIO\_ENE\_MASS  
with 90% Confidence Interval



Sensitivities for RATIO\_ENE\_MASS  
from Isopt\_output file

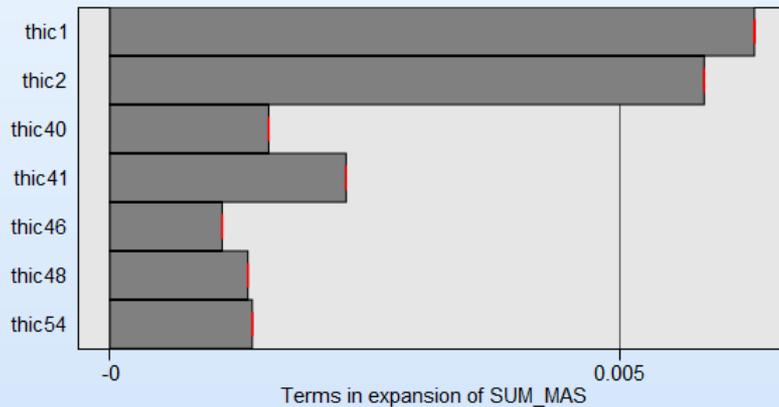
Isopt\_output - Notepad

File Edit Format View Help

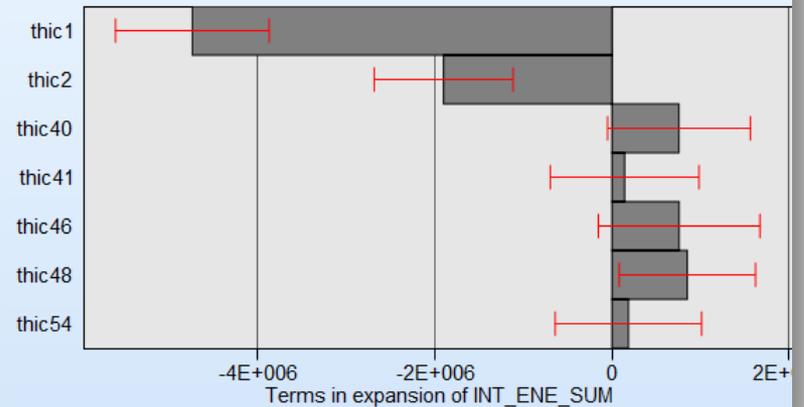
Ranking of terms based on bound of confidence interval

Coeff.	Absolute value (90%)	10-Scale
thic1	1.123e+005	10.0
thic2	7.897e+004	7.0
thic41	1.743e+004	1.6
thic54	4247	0.4
thic40	1517	0.1
thic48	968.7	0.1
thic46	Insignificant	0.0

Sensitivities Plot for SUM\_MAS  
with 90% Confidence Interval

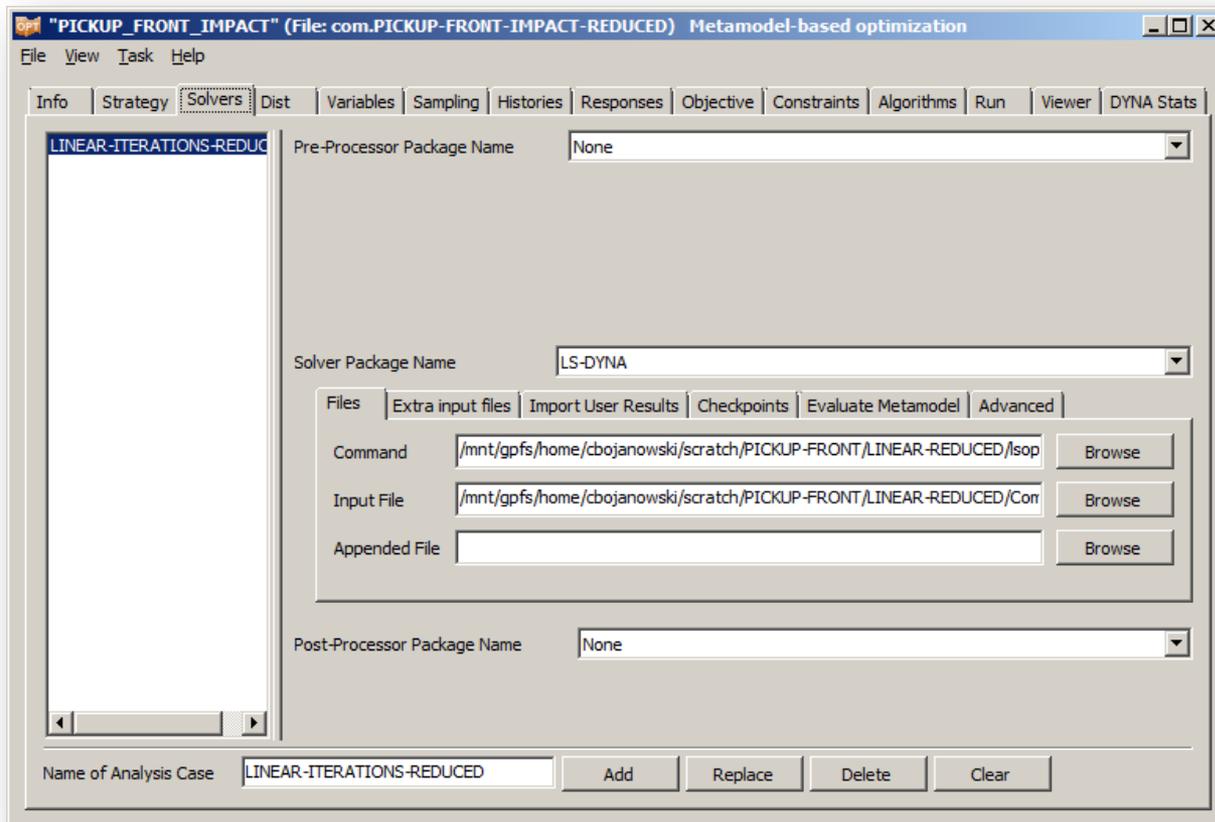


Sensitivities Plot for INT\_ENE\_SUM  
with 90% Confidence Interval



# Solvers Tab

- Copy the input files to another folder
- In the Solvers panel browse to your LS-DYNA® executables (Windows) or to **Isopscript** (Linux system at TRACC) at Command line
- For the input file again locate the **Combine.k** file
- Type **LINEAR-ITERATIONS-REDUCED** in the Name of Analysis Case field and hit Replace



# Variables Tab

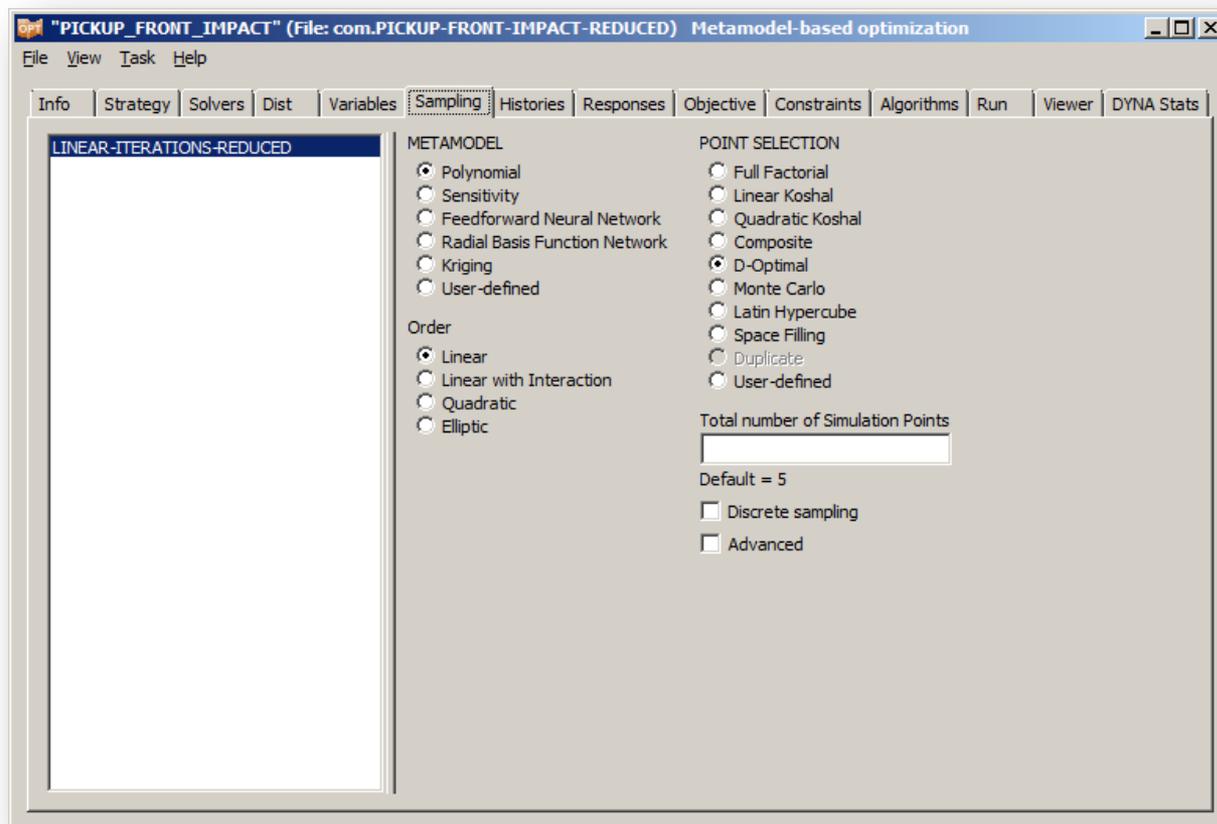
- In the Variables panel change Type of the variables to Constant for:
  - thic40, thic41, thic46, thic48, thic54

The screenshot shows the 'Variables' tab in a software interface for 'PICKUP\_FRONT\_IMPACT' optimization. The interface includes a menu bar (File, View, Task, Help) and a toolbar with tabs: Info, Strategy, Solvers, Dist, Variables (selected), Sampling, Histories, Responses, Objective, Constraints, Algorithms, Run, Viewer, and DYNA Stats. The main area is titled 'Design Variables' and contains a table with columns: Type, Name, Starting, Init. Range, Minimum, and Maximum. The table lists variables thic1 through thic55. Variables thic1, thic2, thic3, thic4, thic47, thic49, and thic55 are of type 'Variable' or 'Dependent'. Variables thic40, thic41, thic46, thic48, and thic54 are of type 'Constant'. The 'Starting' column contains values for thic1 (3.137), thic2 (3.112), thic40 (0.703), thic41 (0.78), thic46 (0.753), thic48 (0.804), and thic54 (0.696). The 'Minimum' and 'Maximum' columns contain values for thic1 (2.8233, 3.4507) and thic2 (2.8008, 3.4232). The 'Init. Range' column is empty for thic1, thic2, thic40, thic41, thic46, thic48, and thic54. The 'Definition' column contains values for thic3 (thic1), thic4 (thic2), thic47 (thic46), thic49 (thic48), and thic55 (thic54). The 'Saddle Direction' dropdown is set to 'Minimize'. The 'Cases' section has radio buttons for 'All' (selected) and 'List'. At the bottom, there are buttons for 'Add a Variable' and 'Delete a Variable'.

Type	Name	Starting	Init. Range	Minimum	Maximum
Variable	thic1	3.137		2.8233	3.4507
Variable	thic2	3.112		2.8008	3.4232
Constant	thic40	0.703			
Constant	thic41	0.78			
Constant	thic46	0.753			
Constant	thic48	0.804			
Constant	thic54	0.696			
Dependent	thic3	Definition	thic1		
Dependent	thic4	Definition	thic2		
Dependent	thic47	Definition	thic46		
Dependent	thic49	Definition	thic48		
Dependent	thic55	Definition	thic54		

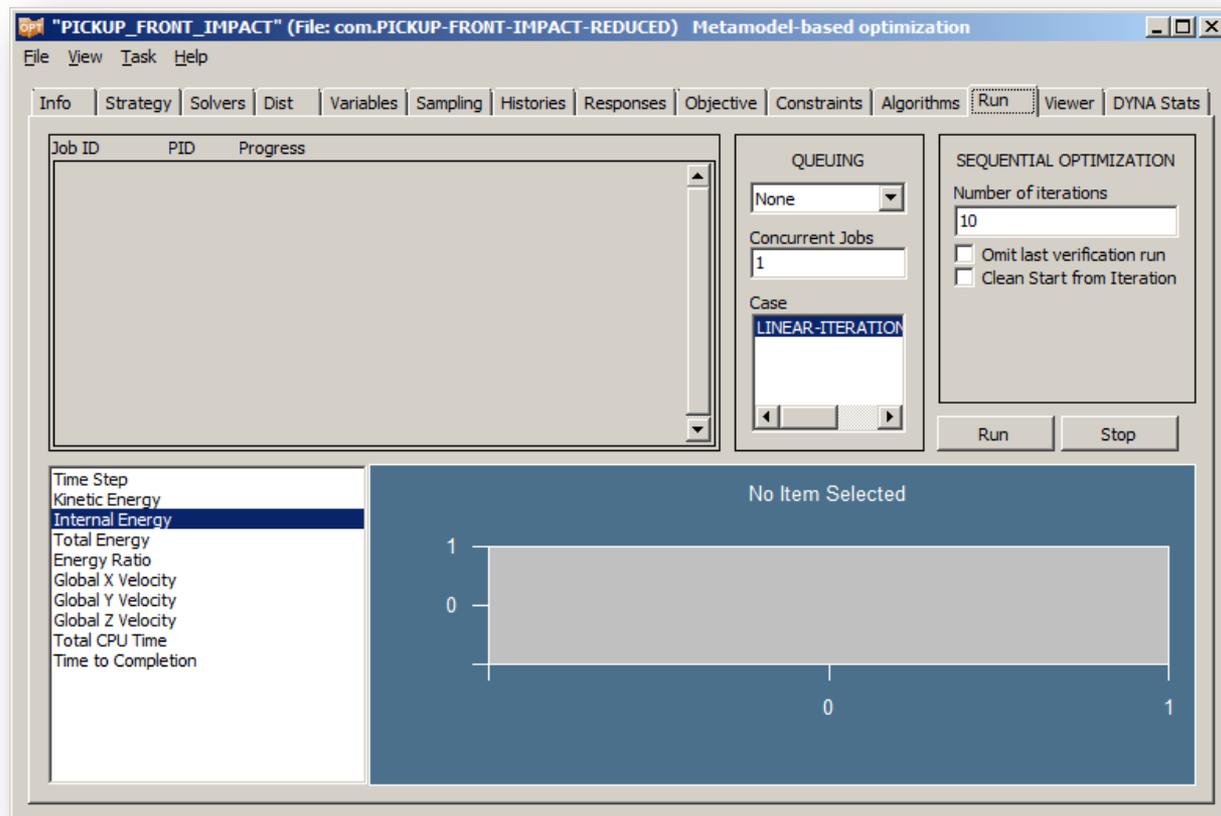
# Sampling Tab

- In the Sampling panel leave Polynomial Metamodel with Linear order
- The default number of simulation points per iteration will drop from 13 to 5



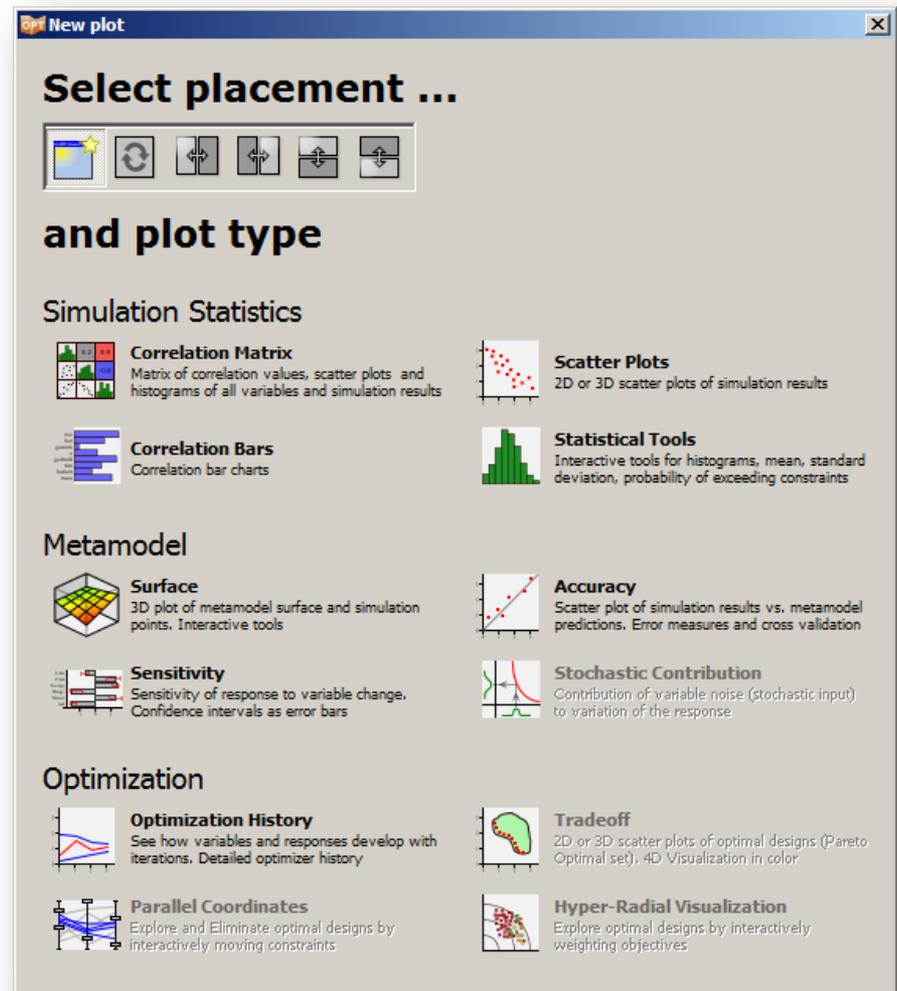
# Run Tab

- Select PBS for QUEUING software (TRACC cluster users)
- For Concurrent Jobs enter 4
- For Number of Iteration enter 10 and
- Check Omit last verification run and Clean Start from iteration 1
- Hit Run to start simulations



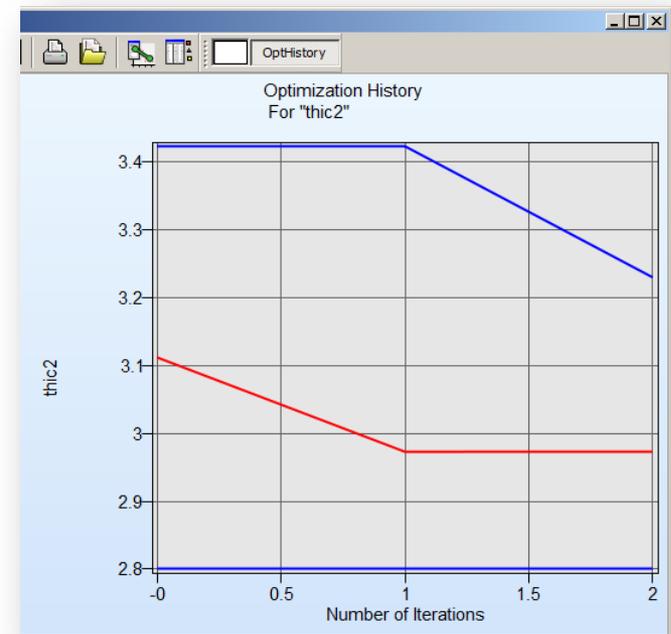
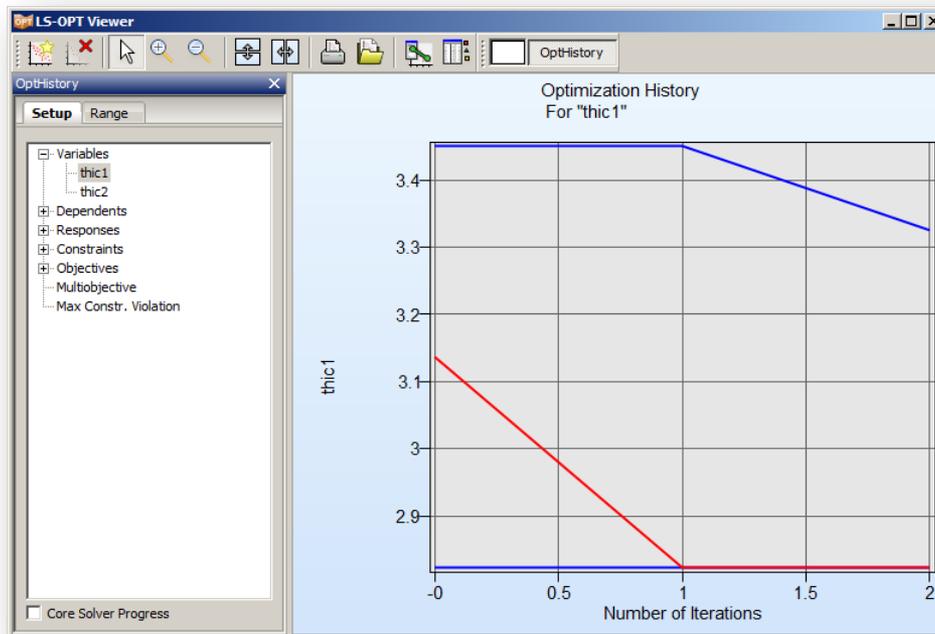
# Viewer

- Go to Viewer panel and the viewer options should pop up automatically
- From Optimization menu select Optimization History
- New window should appear



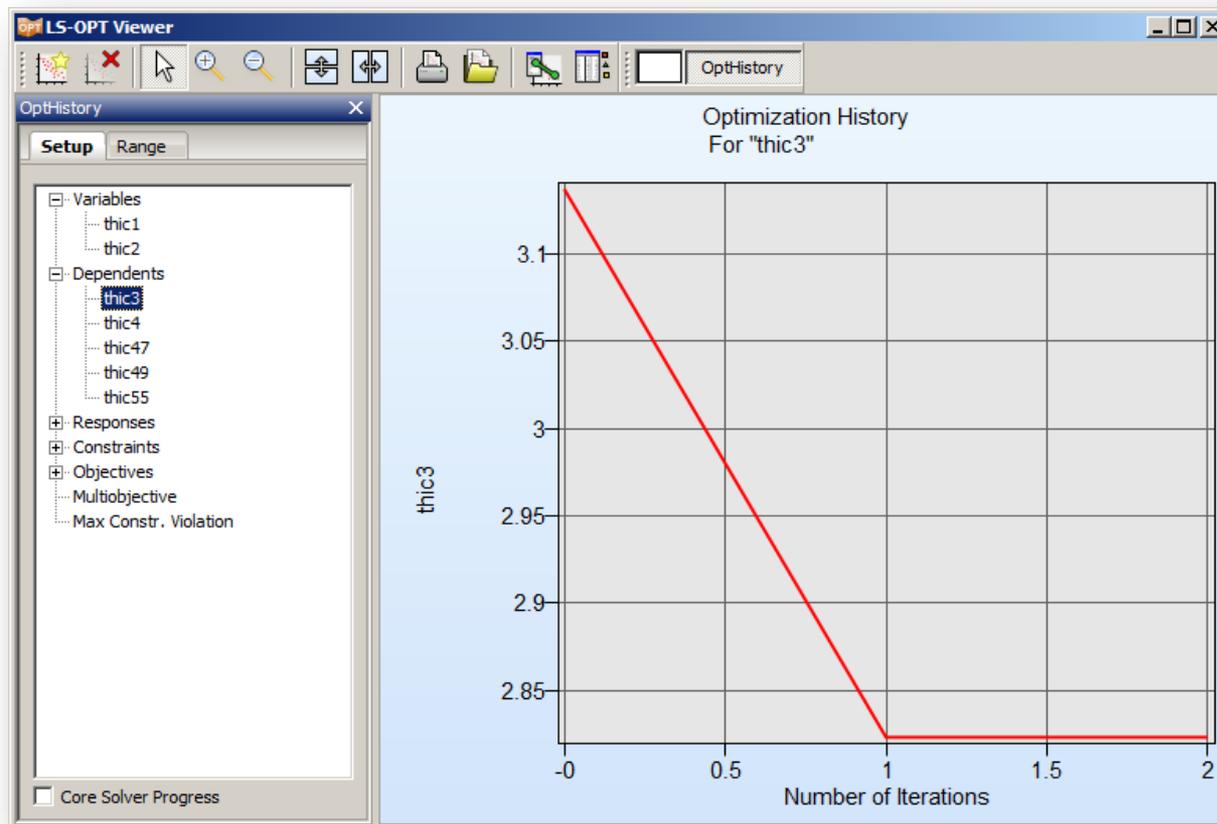
# Optimization History

- Select the variable `thic1` and `thic2`
- The problem became easy and the number of simulations was reduced considerably



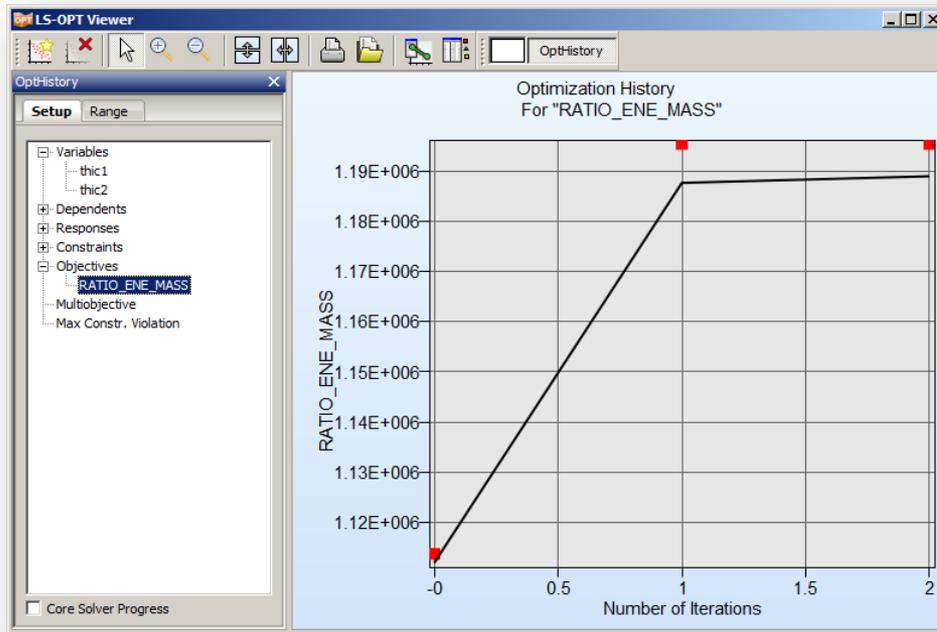
# Optimization History

- The Dependents follow the history of the Independent Design Variables



# Optimization History

- Select **RATIO\_ENE\_MASS** from objectives list to see its optimization history
- Click on the graph to see exact values of the responses



The 'Point selection' dialog shows the 'Entity' list with '1.Opt' selected. The table below displays the values for various entities at this point.

Entity	Computed	Predicted
Point		
Variables		
thic1	3.137	3.137
thic2	3.112	3.112
Dependents		
Responses		
Constraints		
SUM_MAS	0.099362	0.099362
Objectives		
RATIO_ENE_MASS	1.11361e+006	1.11181e+006
Multiobjective	1.11361e+006	1.11181e+006
Max Constraint Violation	0	0

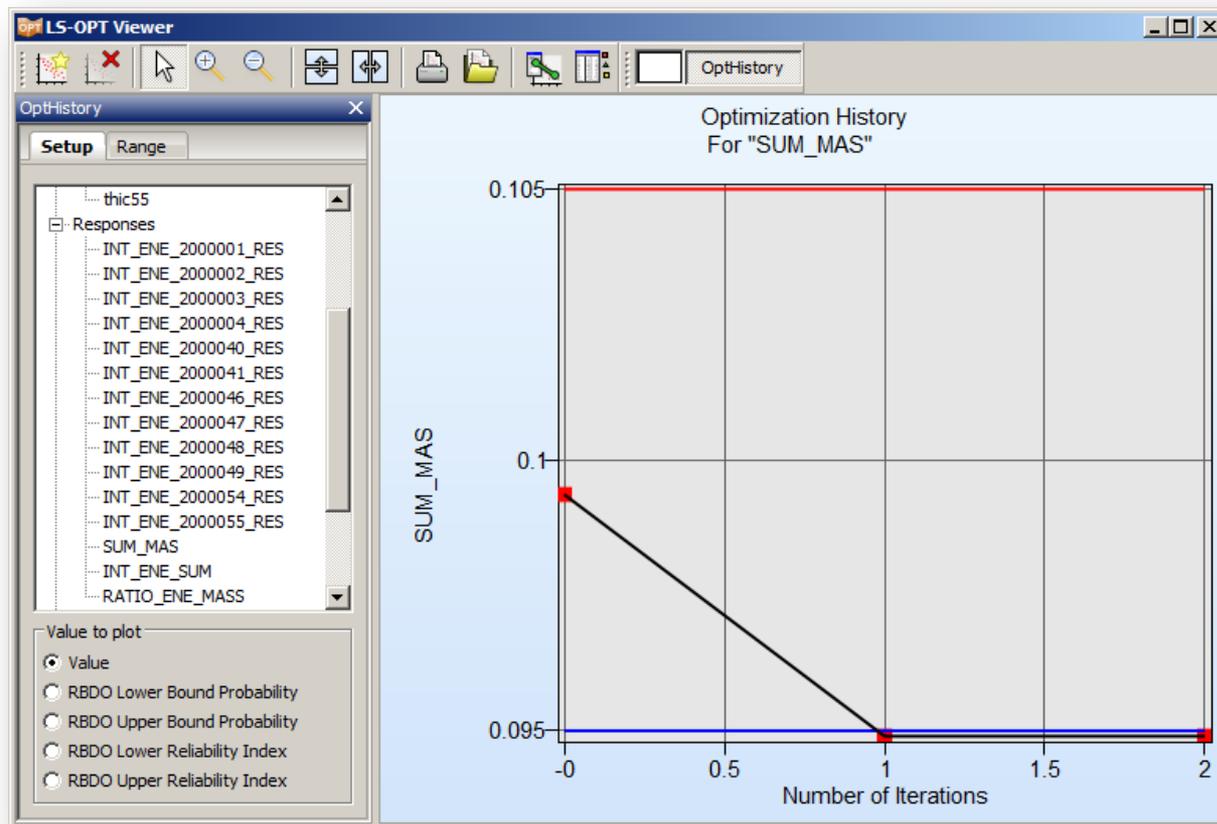
The 'Point selection' dialog shows the 'Entity' list with '2.Opt' selected. The table below displays the values for various entities at this point.

Entity	Computed	Predicted
Point		
Variables		
thic1	2.82331	2.82331
thic2	2.97298	2.97298
Dependents		
Responses		
Constraints		
SUM_MAS	0.094899	0.0949
Objectives		
RATIO_ENE_MASS	1.19555e+006	1.18911e+006
Multiobjective	1.19555e+006	1.18911e+006
Max Constraint Violation	0.000101	0.000100001

- The value of the objective increased **7.36 %** in the optimization process

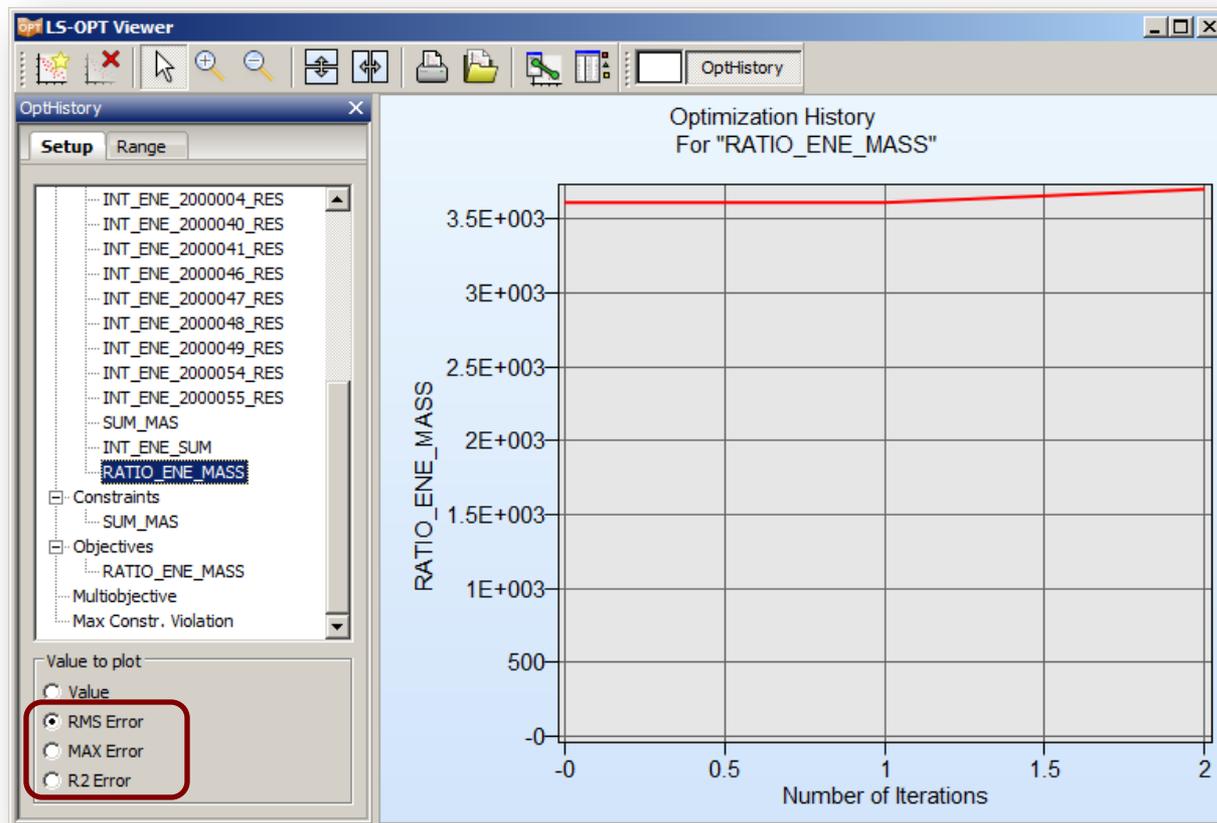
# Optimization History - Modeling Errors

- Select **SUM\_MAS** from objectives list to see its optimization history
- Click on the graph to see exact values of the responses



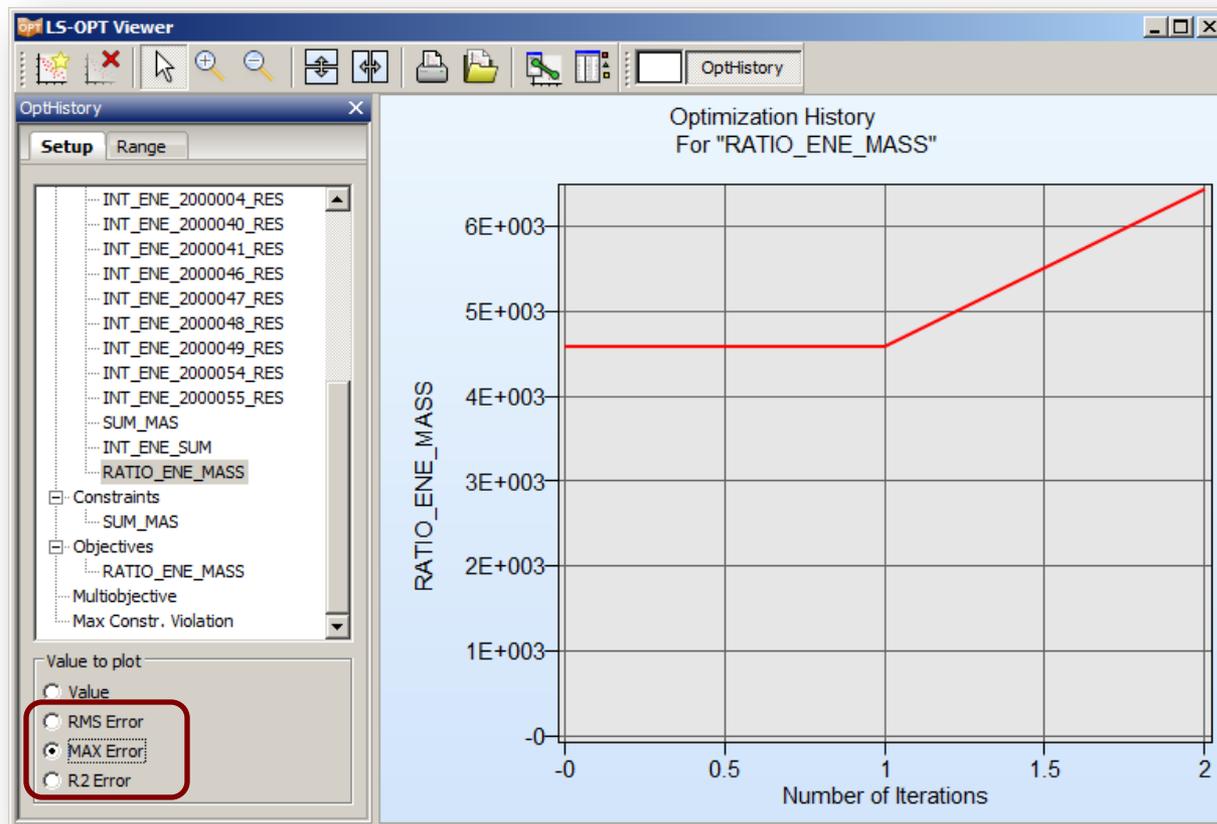
# Optimization History - Modeling Errors

- Select again **RATIO\_ENE\_MASS** from objectives list to see its optimization history
- Select **RMS Error** value to plot
- When the region of interest is shrinking, the modeling errors may increase



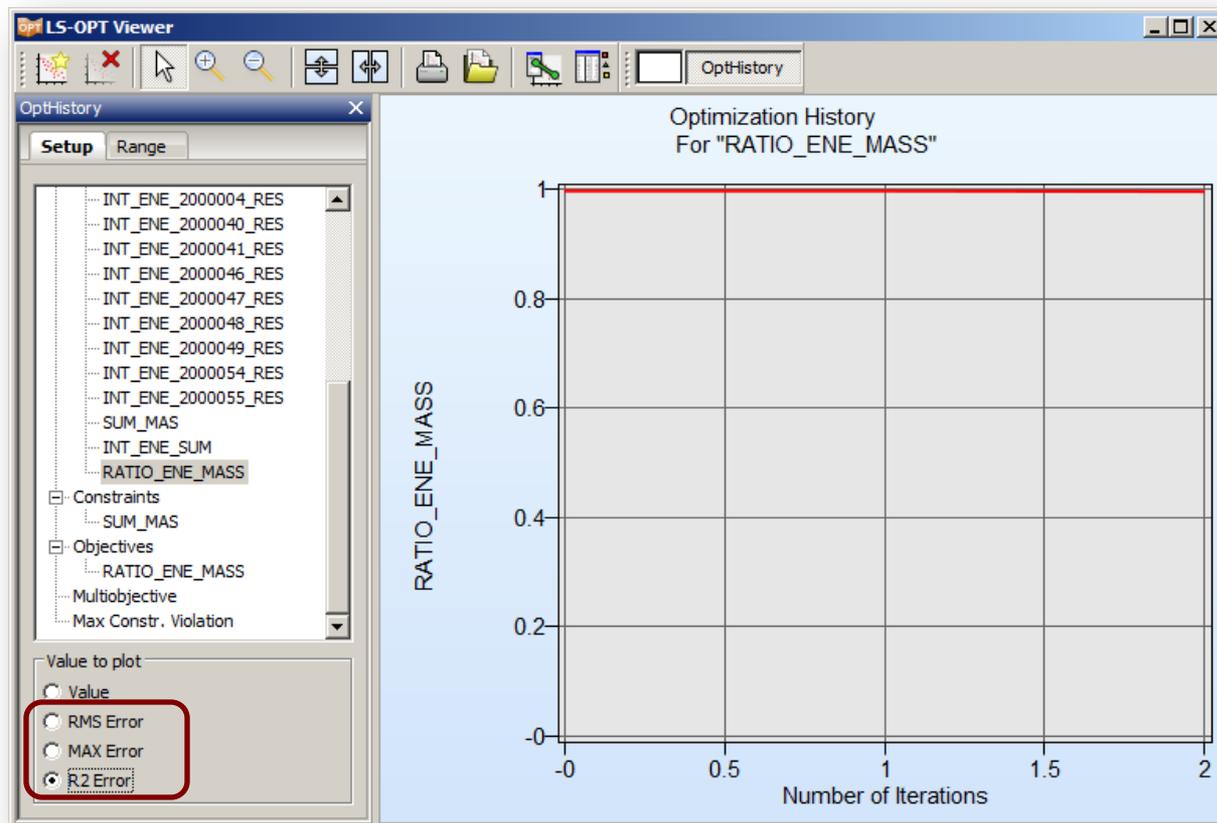
# Optimization History - Modeling Errors

- Select again **RATIO\_ENE\_MASS** from objectives list to see its optimization history
- Select **MAX Error** value to plot



# Optimization History - Modeling Errors

- Select again **RATIO\_ENE\_MASS** from objectives list to see its optimization history
- Select **R2 Error** value to plot
- **R2 Error** represents ability of the model to capture the variability of the real response



# Metamodel Accuracy

- Go to Viewer panel and Restart Viewer
- From Metamodel menu select Accuracy
- Display accuracy of the metamodeling of **RATIO\_ENE\_MASS** response
- Locate the error parameters in the **Isopt\_output.1** file

