

**RAMDO**  
**HyperStudy & OptiStruct**  
**Example**



# Contents

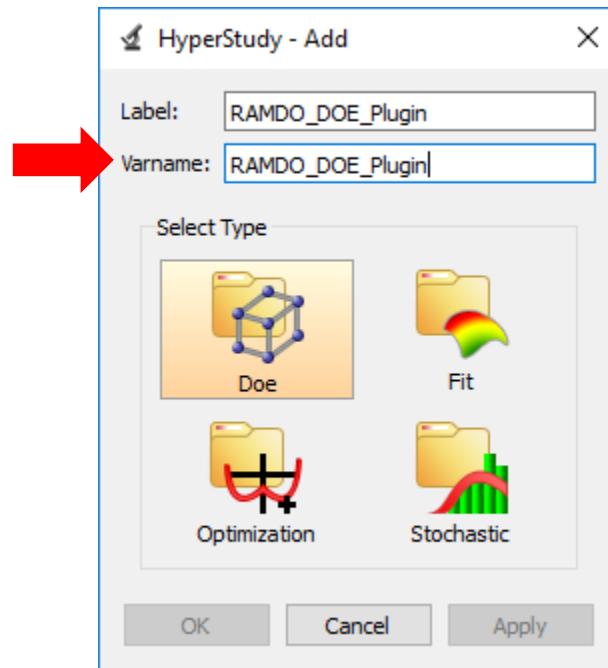
HyperStudy Model Setup.....	3
Instructions.....	3
HyperStudy & OptiStruct Plate Example .....	7
Problem Formulation .....	7
Problem Definition .....	8
Instructions.....	9
Methods and Options .....	10
Simulation Solvers.....	13
Statistical Information.....	16
Performance Measures.....	19
Analysis Settings.....	23
Review and Execute .....	29
Results .....	32
Navigation Table Tree.....	33
Result Frames .....	34
The Results.....	35

# HyperStudy Model Setup

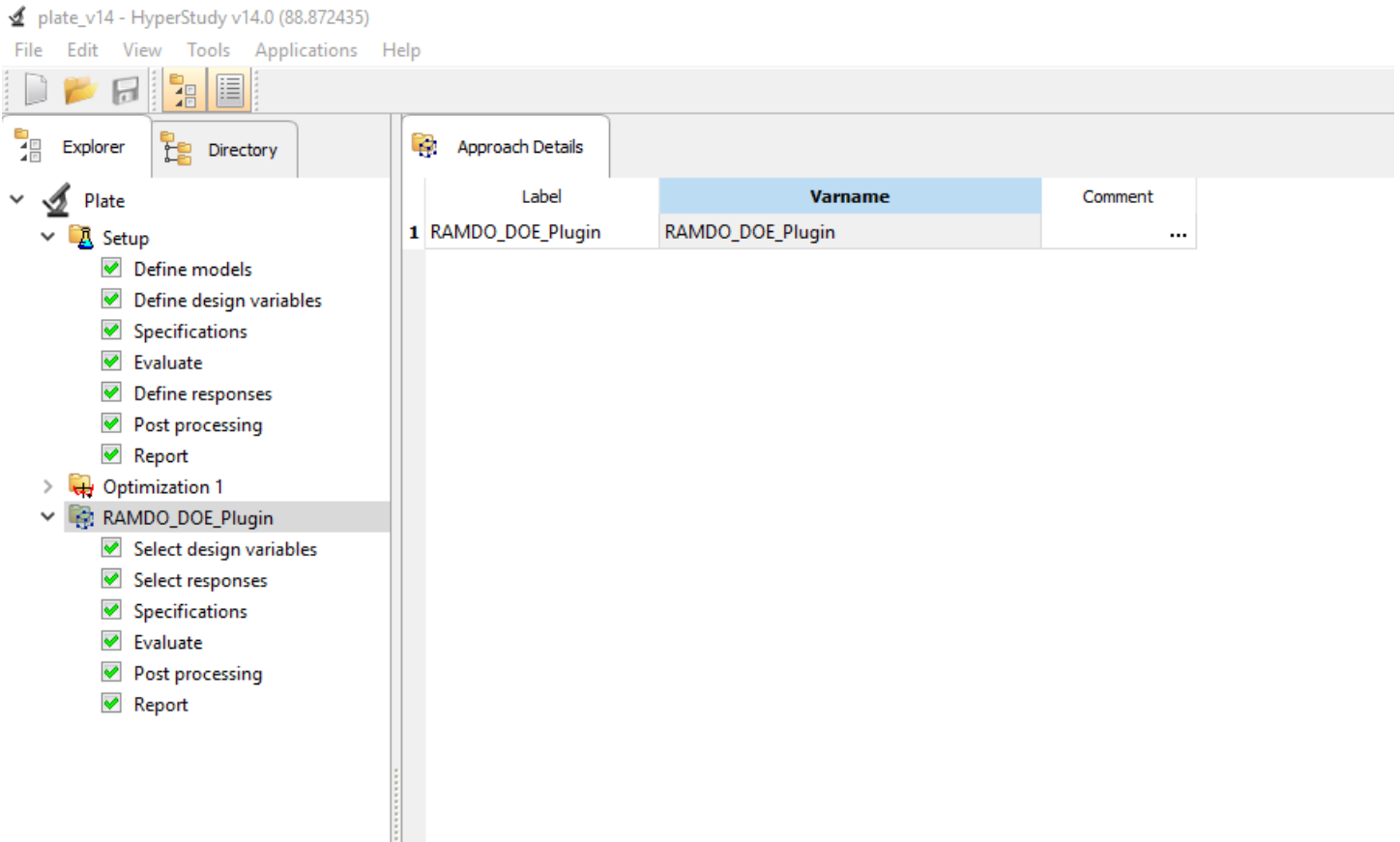
The first step to using HyperStudy with RAMDO is to setup the HyperStudy model to use a DOE Approach to connect to RAMDO. It is assumed that the user is familiar with how to setup a HyperStudy model. This example only provides the details specific for using HyperStudy with RAMDO.

## Instructions

1. Following the typical process, create a HyperStudy model that links to the OptiStruct model.
2. Add a DOE Approach to the HyperStudy model.
  - a. The Varname for the approach needs to be named RAMDO\_DOE\_Plugin
    - i. This is DOE approach is how RAMDO is linked to HyperStudy. Thus, setting the variable name correctly is critical.



3. Note that in RAMDO all variables defined in the HyperStudy model are used, even if defined as in active in HyperStudy. Thus, the HyperStudy model should only include the variables that are to be used in RAMDO. In a future release the active state of the variable will imported into RAMDO.
4. The HyperStudy DOE approach should show the Varname as in the figure below.



5. The Specifications node in the RAMDO\_DOE\_Plugin (DOE approach) needs to be configured as a Run Matrix as shown in the figure below.

The screenshot shows the HyperStudy v14.0 interface. On the left, the 'Plate' tree is expanded to 'RAMDO\_DOE\_Plugin', where 'Specifications' is checked. The main window displays the 'Specifications' table with 10 rows. The 'Run Matrix' row (row 9) is selected, indicated by a radio button.

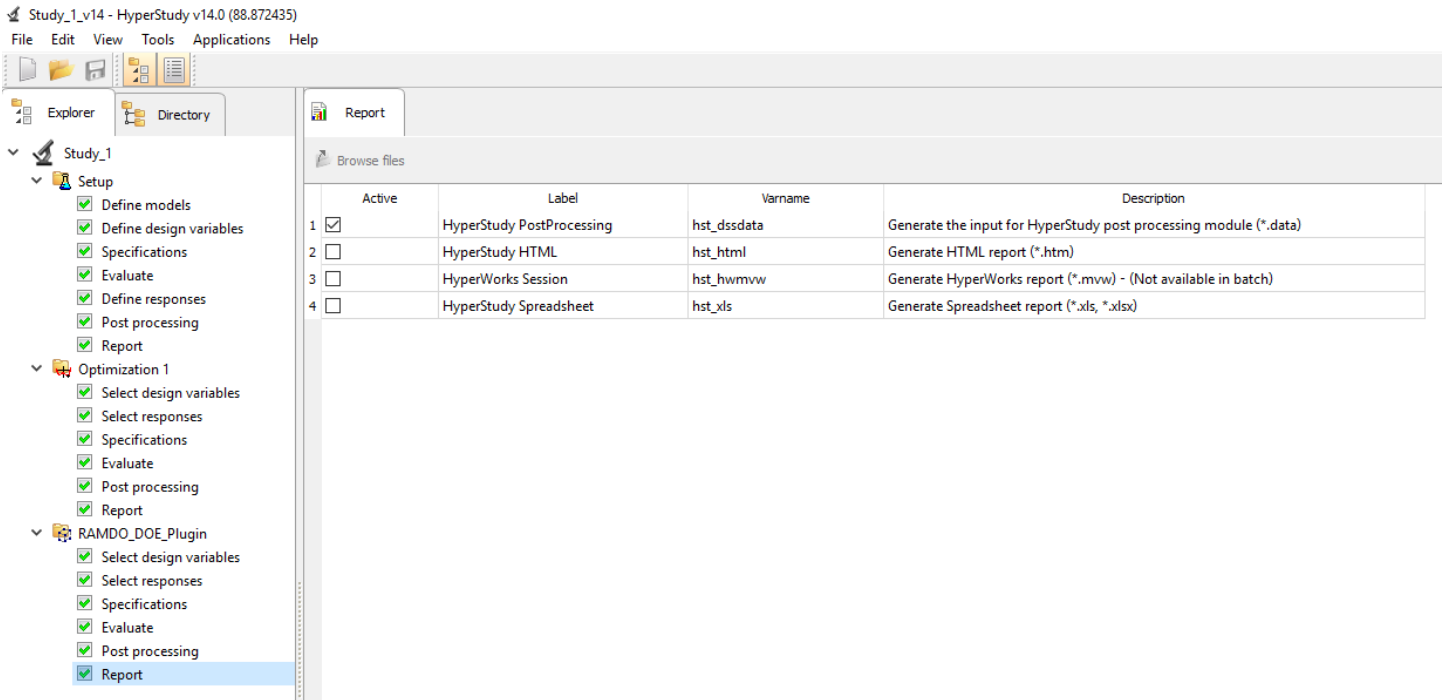
	Mode	Label	Varname	Details
1	<input type="radio"/>	Full Factorial	FullFact	
2	<input type="radio"/>	Fractional Factor...	FracFact	
3	<input type="radio"/>	Plackett Burman	PlackBurm	
4	<input type="radio"/>	Central Composite	Ccd	
5	<input type="radio"/>	Box Behnken	Box	
6	<input type="radio"/>	Latin HyperCube	LatinHyperCube	
7	<input type="radio"/>	Hammersley	Hammersley	
8	<input type="radio"/>	User Defined	User	
9	<input checked="" type="radio"/>	Run Matrix	RunMatrix	
10	<input type="radio"/>	None	None	

6. The Perturb File Value for the Run Matrix can be set to any CSV in any location.
  - a. RAMDO will use the same name for the CSV file when it runs HyperStudy. It will not modify the original CSV. RAMDO creates a new CSV file in a new location when running HyperStudy.

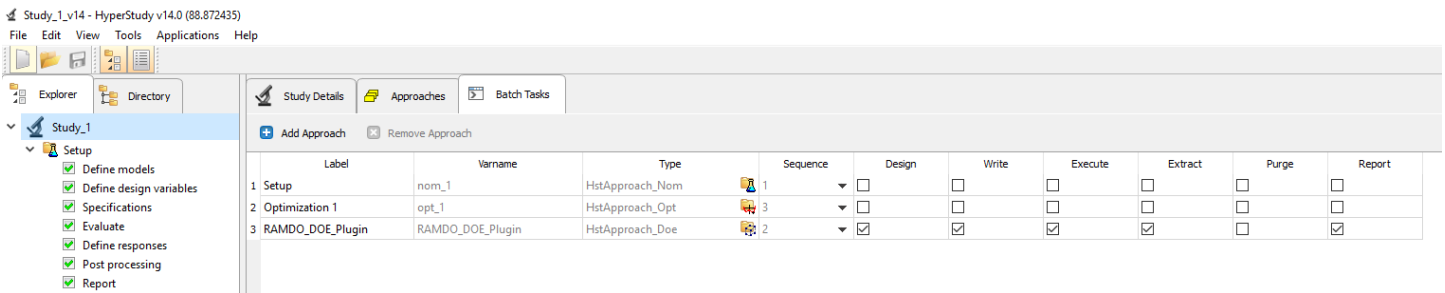
The screenshot shows a small dialog box with an 'Edit' button. The 'Value' field is highlighted in blue and contains the text './DOE\_Points.csv' next to a folder icon.

	Value
Perturb File	./DOE_Points.csv

7. On the Report node of the RAMDO\_DOE\_Plugin make sure the HyperStudy PostProcessing is checked as shown in the figure below.



8. The final step is going to select the Study in the tree and go to the Batch Tasks tab.
  - a. For each listed approach in the list, uncheck all the checkboxes that are not required. Note that this is required, because when RAMDO runs HyperStudy in batch mode to evaluate the DOE, it will run every step for every approach that is checked. Thus, if an Optimization approach is checked, HyperStudy will run the full optimization approach in addition to the RAMDO\_DOE\_Plugin approach.
    - i. Note, this does allow for linking multiple approaches together. Therefore, if multiple approaches need to run, in order, to evaluate the RAMDO\_DOE\_Plugin approach, then the HyperStudy model can be setup accordingly.
9. Save the HyperStudy model.
  - a. Make a note of where the HyperStudy file is saved, so that in RAMDO you can browse to the HyperStudy file and find the HyperStudy XML file.
10. After setting up the HyperStudy model, proceed to start RAMDO and follow the example below.

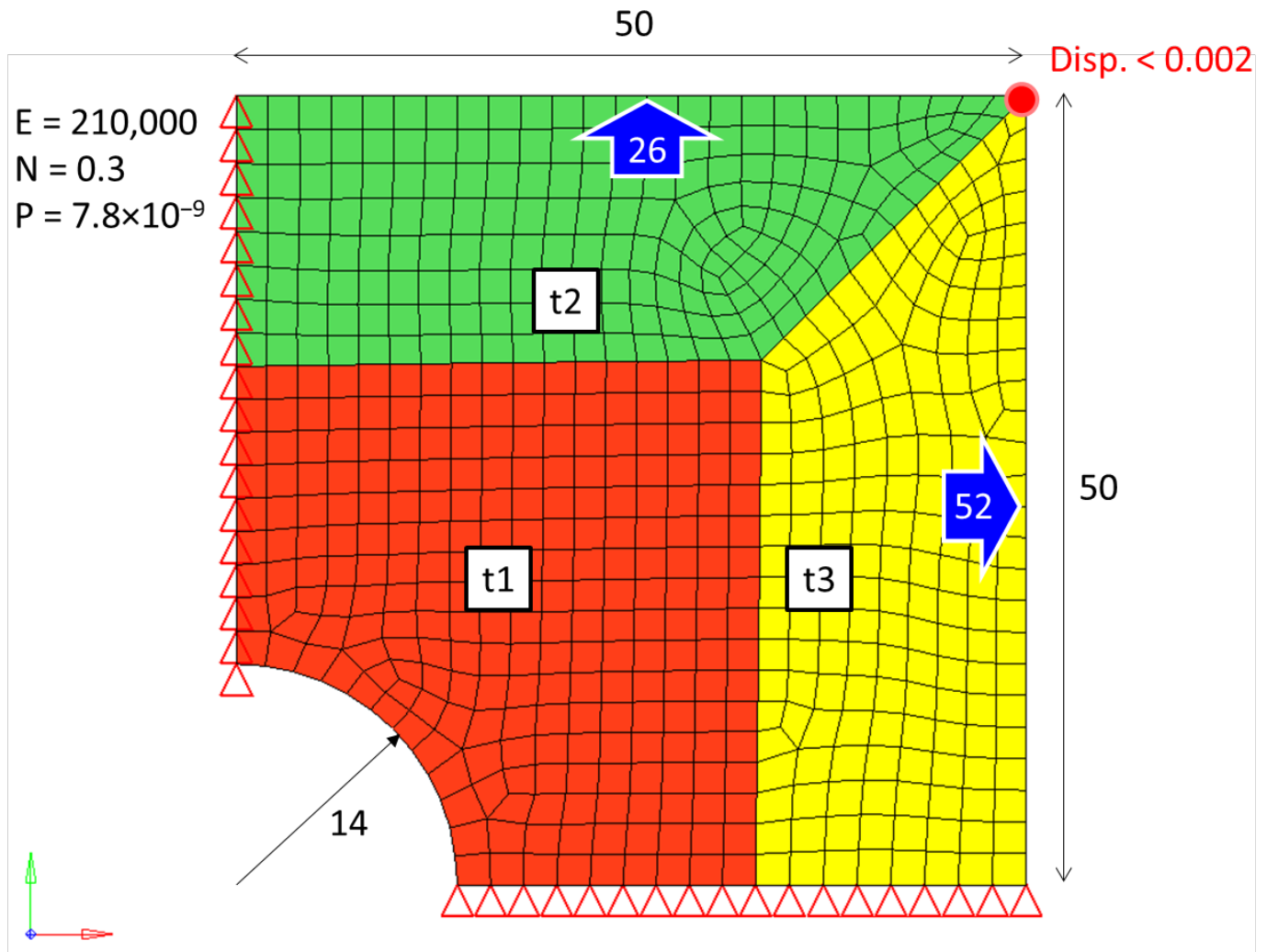


## Note

The HyperStudy model can be setup to connect to any simulation solver.

# HyperStudy & OptiStruct Plate Example

## Problem Formulation



$Cost(\mathbf{d}) = \text{mass of plate}$

$G_1(\mathbf{X}) = \text{Displacement of top right corner} \leq 0.002$

Lower Bounds of Design  $\mathbf{d} = [0.05, 0.05, 0.05]$

Upper Bounds of Design  $\mathbf{d} = [0.15, 0.15, 0.15]$

Initial Design  $\mathbf{d}_{initial} = [0.096, 0.15, 0.082]$

Target Reliability = 95%

Random Variable	Marginal Distribution	Mean	Variance	Type
$t_1$	Normal	$d_1$	$0.3^2$	Design Variable
$t_2$	Normal	$d_2$	$0.3^2$	Design Variable
$t_3$	Normal	$d_2$	$0.3^2$	Design Variable

## Problem Definition

The plate example is a simple FE model that uses HyperStudy and OptiStruct in connection with RAMDO. There are three thickness variables. The objective is to minimize the mass of the plate and the constraint is the top right corner of the plate should have a displacement less than 0.002.



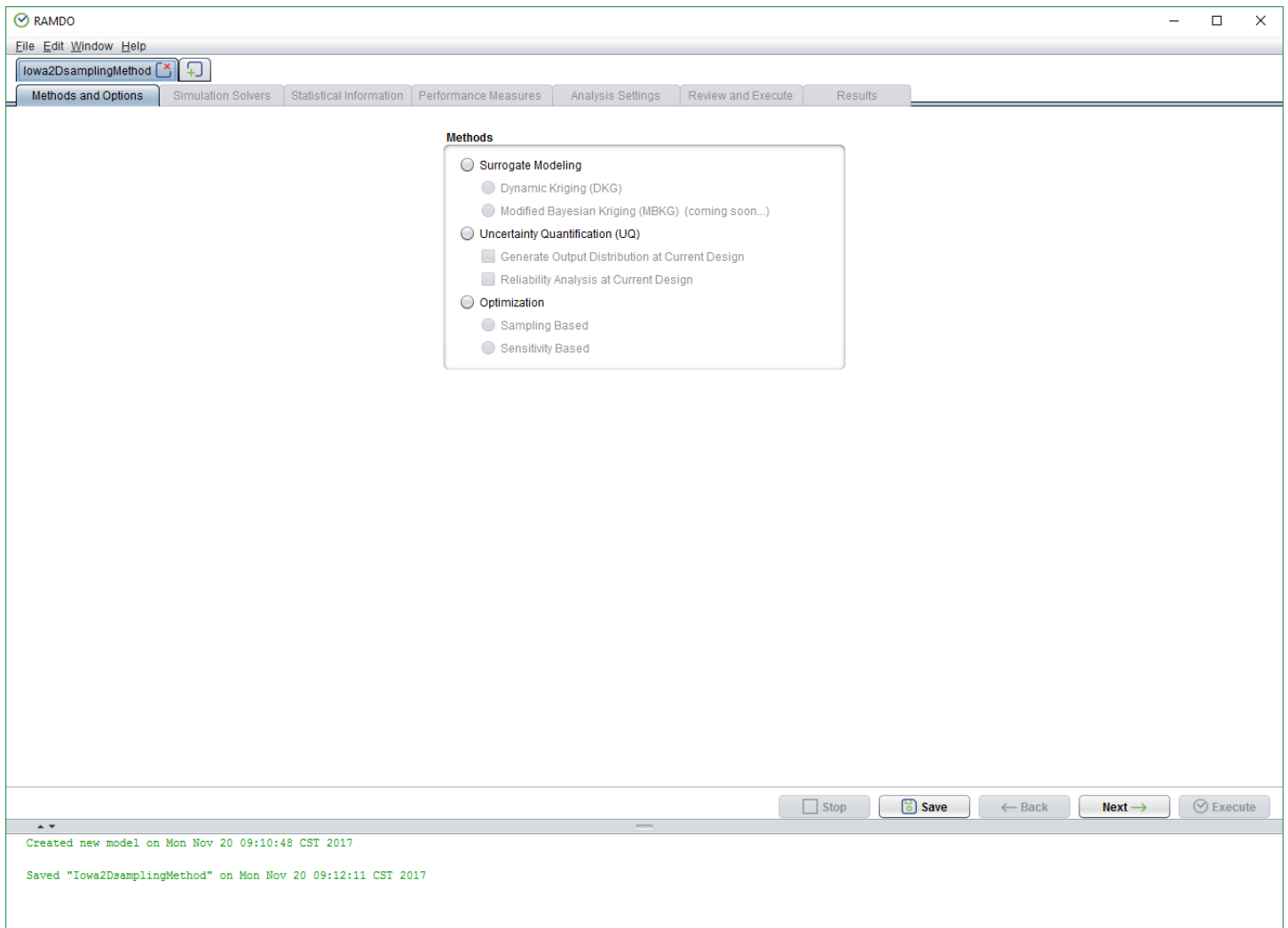
# Instructions

Follow the following steps to set up and run the HyperStudy & OptiStruct Plate Example tutorial. This example will show to use HyperStudy and an existing HyperStudy model as the Simulation Solver in RAMDO. In this example OptiStruct is used as the FEA solver.

The basic process follow is RAMDO, launches HyperStudy, which in turn runs the OptiStruct simulations. HyperStudy then extracts the results from the OptiStruct simulations.

# Methods and Options

Filling out the Methods and Options page.



To fill out the Methods and Options form do the following:

1. Under the Method section select the **Optimization** and **Sampling-Based** methods.
2. Under the Sampling Based Options section select the **Reliability-Based Design Optimization (RBDO) from Current Design** option.

#### Methods

Surrogate Modeling

- Dynamic Kriging (DKG)
- Modified Bayesian Kriging (MBKG) (coming soon...)

Uncertainty Quantification (UQ)

- Generate Output Distribution at Current Design
- Reliability Analysis at Current Design

Optimization

- Sampling-Based
- Sensitivity-Based (coming soon...)

#### Sampling-Based Options

Deterministic Design Optimization (DDO)

- Generate Output Distribution at DDO Design (coming soon...)
- Reliability Analysis at DDO Design (coming soon...)

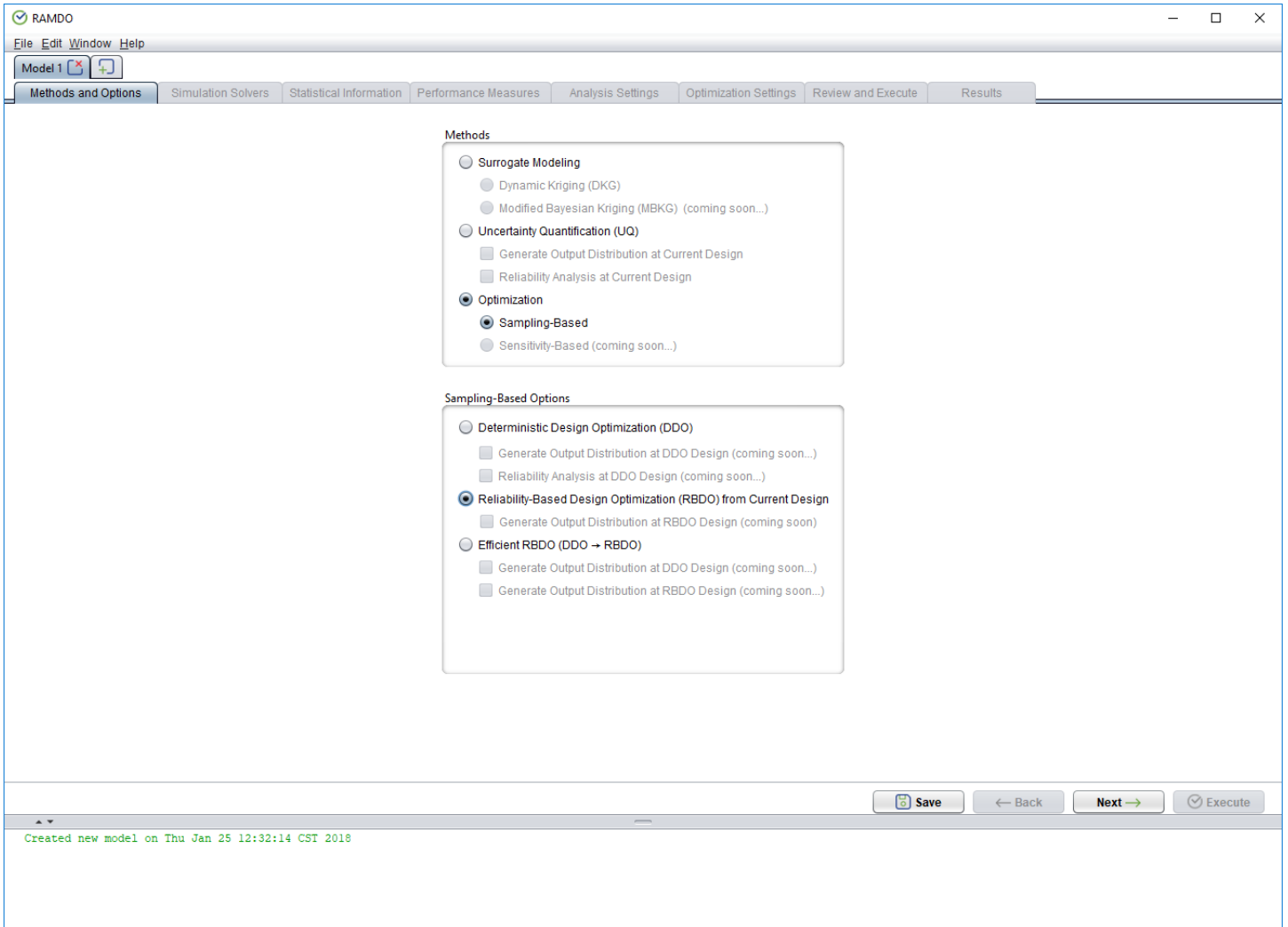
Reliability-Based Design Optimization (RBDO) from Current Design

- Generate Output Distribution at RBDO Design (coming soon)

Efficient RBDO (DDO → RBDO)

- Generate Output Distribution at DDO Design (coming soon...)
- Generate Output Distribution at RBDO Design (coming soon...)

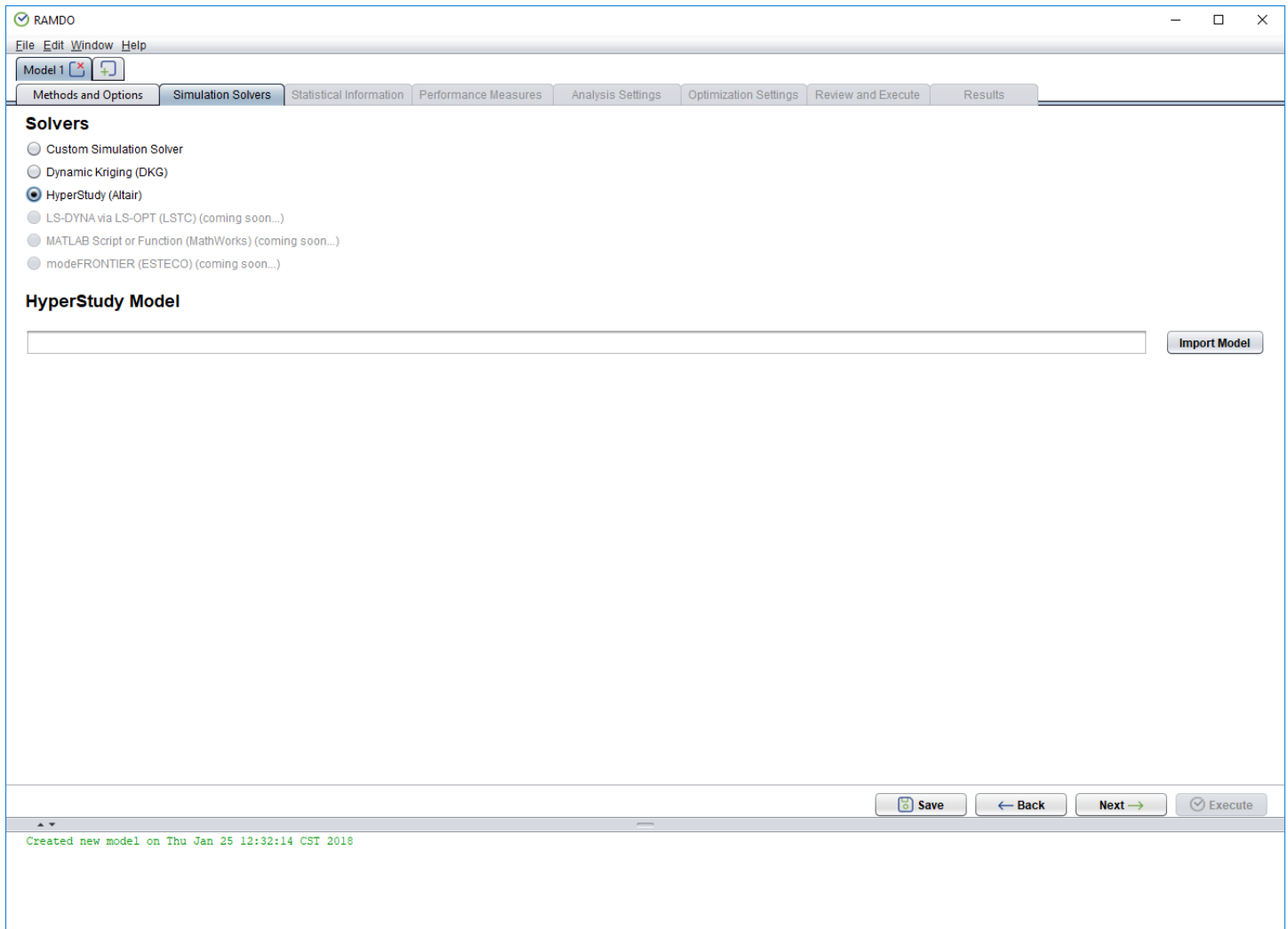
3. You should see the following in the figure below.



4. Click the **Next** button to continue to the next page.

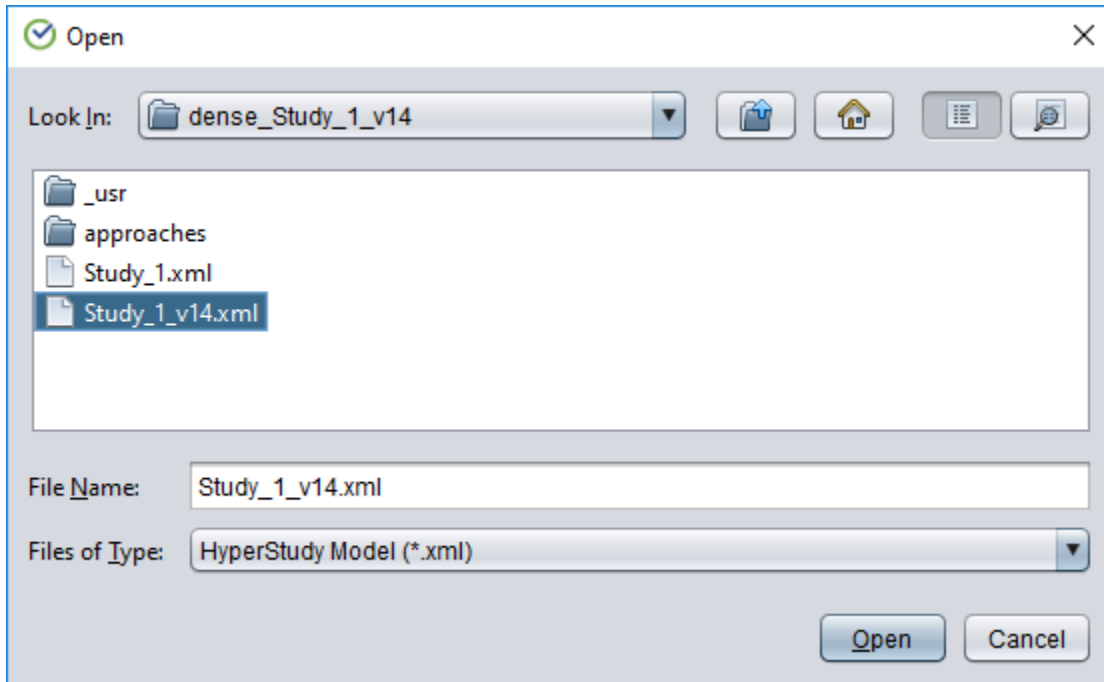
# Simulation Solvers

Filling out the Simulation Solvers page.

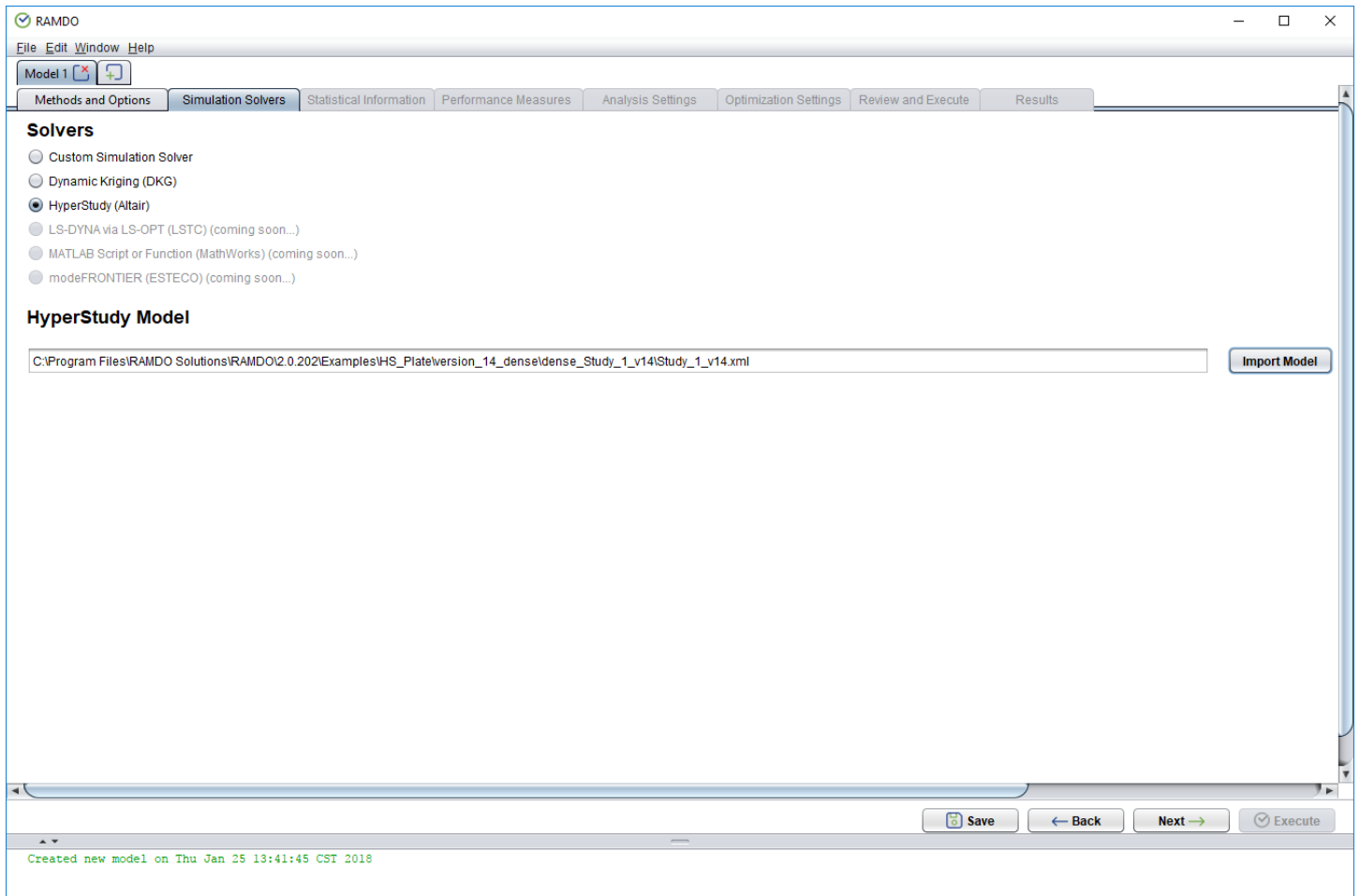


To fill out Simulation Solvers form do the following:

1. Select the **HyperStudy (Altair)** option.
2. Upload the solver:
  - a) Click the **Import Model** button to choose the solver file.
  - b) Browse to the installation location of RAMDO and find the '**plate\_v14.xml**' HyperStudy file in the '**dense\_Study\_1\_v14**' folder in the '**Examples**' folder in the RAMDO program folder.
  - c) Click the **Open** button to import the HyperStudy model.



3. You should see the following in the figure below.



4. Click the **Next** button to continue to the next page.

# Statistical Information

Importing the HyperStudy model adds the variables defined in the HyperStudy model to Random Design Variables (RDV) table in RAMDO. The HyperStudy variable name is shown in the last column of the table to provide a reference back to the variable as defined in HyperStudy.

**Random Design Variables (RDV)**

ID	Name	Distribution Type	Mean	Standard Deviation	Lower Bound	Upper Bound	Attach Data File	Data File Name	Description	HyperStudy Varname
1	t1	Normal	0.096 ...	0.003 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_1
2	t2	Normal	0.150 ...	0.005 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_2
3	t3	Normal	0.082 ...	0.002 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_3

**Random Parameters (RP)**

ID	Name	Distribution Type	Mean	Standard Deviation	Attach Data File	Data File Name	Description	HyperStudy Varname

**Correlated Pairs**

Correlated Pair	1st Variable/Parameter	2nd Variable/Parameter	Copula Type	Kendall's Tau

**Kendall's Tau Range**

Copulas	Lower	Upper
Clayton	0	$< \tau < 0.95$
Frank	-0.95	$< \tau < 0.95$
FGM	-0.222	$< \tau < 0.222$
Gaussian	-0.95	$< \tau < 0.95$
AMH	-0.181	$< \tau < 0.333$
Gumbel	0	$< \tau < 0.95$
A12	0.333	$< \tau < 0.95$
A14	0.333	$< \tau < 0.95$

**Distribution Support**

Distributions	Lower	Upper
Normal	$-\infty$	$< X < \infty$
Log Normal	0	$< X < \infty$
Weibull	0	$< X < \infty$
Gumbel	$-\infty$	$< X < \infty$
Gamma	0	$< X < \infty$
Extreme	$-\infty$	$< X < \infty$
Extreme II	0	$< X < \infty$

Created new model on Thu Jan 25 12:32:14 CST 2018  
HyperStudy Version 14.0 will be used.



Review the Statistical Information:

## Random Design Variable Table

The table should look like the table in the figure below.

**Random Design Variables (RDV)**

ID	Name	Distribution Type	Mean	Standard Deviation	Lower Bound	Upper Bound	Attach Data File	Data File Name	Description	HyperStudy Varname
1	t1	Normal	0.096 ...	0.003 ...	0.050 ...	0.150 ...	<input type="button" value="Browse..."/>			m_1_varname_1
2	t2	Normal	0.150 ...	0.005 ...	0.050 ...	0.150 ...	<input type="button" value="Browse..."/>			m_1_varname_2
3	t3	Normal	0.082 ...	0.002 ...	0.050 ...	0.150 ...	<input type="button" value="Browse..."/>			m_1_varname_3

### Note (Random Design Variable Description)

The Description column is for user convenience. The user can enter any description of the random design variable they want. This is so that when a model is opened later the user can remember what are the random design variables in the problem.

1. The RAMDO window should now look like the window in the figure below.

The screenshot shows the RAMDO software interface with the 'Statistical Information' tab selected. The window contains the following components:

- Random Design Variables (RDV) Table:**

ID	Name	Distribution Type	Mean	Standard Deviation	Lower Bound	Upper Bound	Attach Data File	Data File Name	Description	HyperStudy Varname
1	t1	Normal	0.096 ...	0.003 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_1
2	t2	Normal	0.150 ...	0.005 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_2
3	t3	Normal	0.082 ...	0.002 ...	0.050 ...	0.150 ...	Browse...			m_1_varname_3
- Random Parameters (RP) Table:** (Empty table with columns: ID, Name, Distribution Type, Mean, Standard Deviation, Attach Data File, Data File Name, Description, HyperStudy Varname)
- Correlated Pairs Table:** (Empty table with columns: Correlated Pair, 1st Variable/Parameter, 2nd Variable/Parameter, Copula Type, Kendall's Tau)
- Kendall's Tau Range Table:**

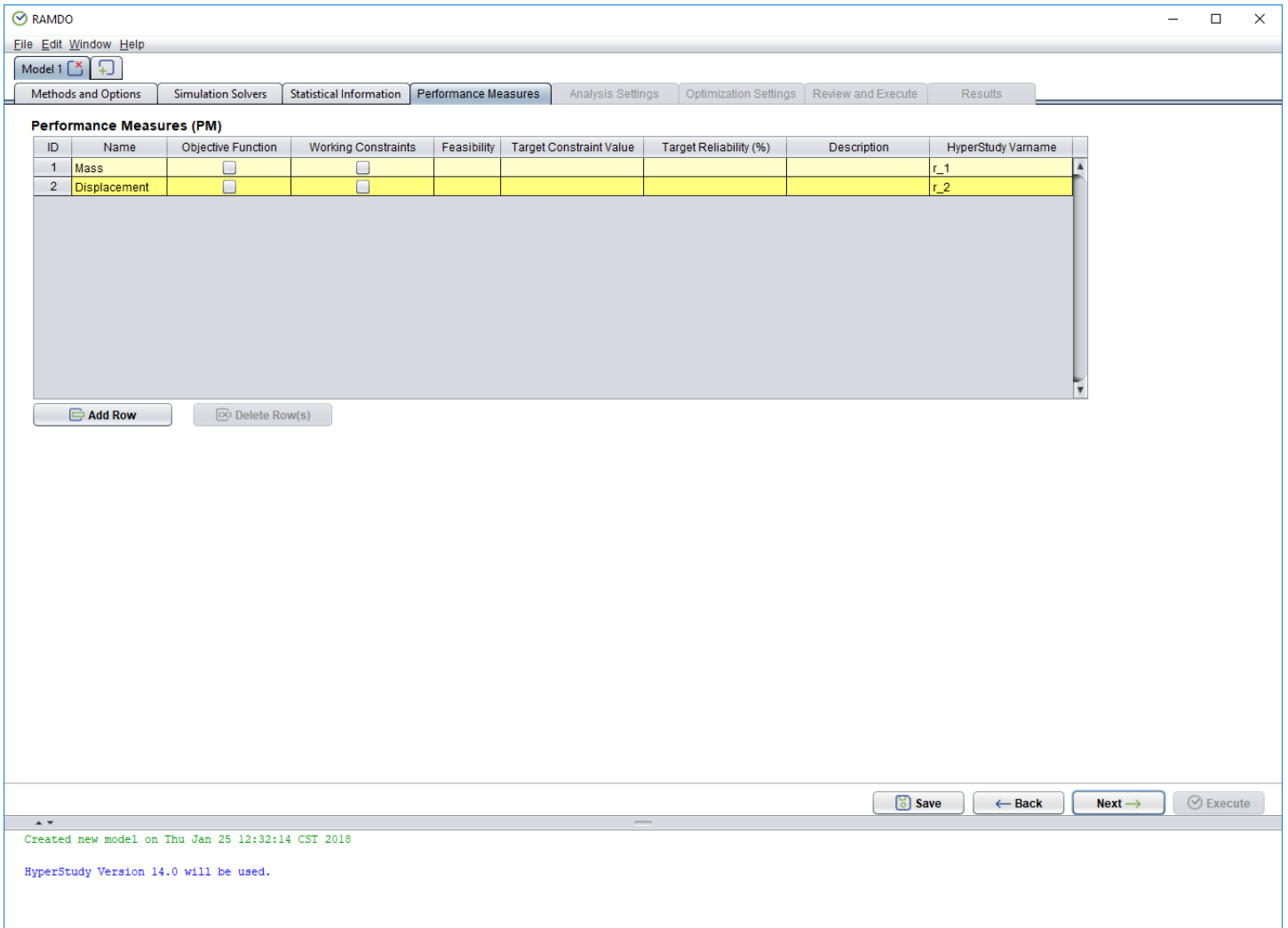
Copulas	Lower	Upper
Clayton	0	$< \tau < 0.95$
Frank	-0.95	$< \tau < 0.95$
FGM	-0.222	$< \tau < 0.222$
Gaussian	-0.95	$< \tau < 0.95$
AMH	-0.181	$< \tau < 0.333$
Gumbel	0	$< \tau < 0.95$
A12	0.333	$< \tau < 0.95$
A14	0.333	$< \tau < 0.95$
- Distribution Support Table:**

Distributions	Lower	Upper
Normal	$-\infty$	$< X < \infty$
Log Normal	0	$< X < \infty$
Weibull	0	$< X < \infty$
Gumbel	$-\infty$	$< X < \infty$
Gamma	0	$< X < \infty$
Extreme	$-\infty$	$< X < \infty$
Extreme II	0	$< X < \infty$
- Status Bar:**
  - Created new model on Thu Jan 25 12:32:14 CST 2018
  - HyperStudy Version 14.0 will be used.
  - Buttons: Save, Back, Next (highlighted), Execute

2. Click the **Next** button to continue to the next page.

# Performance Measures

Filling out the Performance Measures page.



RAMDO

File Edit Window Help

Model 1

Methods and Options Simulation Solvers Statistical Information **Performance Measures** Analysis Settings Optimization Settings Review and Execute Results

**Performance Measures (PM)**

ID	Name	Objective Function	Working Constraints	Feasibility	Target Constraint Value	Target Reliability (%)	Description	HyperStudy Varname
1	Mass	<input type="checkbox"/>	<input type="checkbox"/>					r_1
2	Displacement	<input type="checkbox"/>	<input type="checkbox"/>					r_2

Add Row Delete Row(s)

Save Back Next Execute

Created new model on Thu Jan 25 12:32:14 CST 2018

HyperStudy Version 14.0 will be used.

To fill out the Performance Measures page do the following:

1. Responses defined in the HyperStudy model are imported into the Performance Measure Information table. The last column of the table shows the HyperStudy name of the response, this is for a reference back to the original HyperStudy model.

**Performance Measures (PM)**

ID	Name	Objective Function	Working Constraints	Feasibility	Target Constraint Value	Target Reliability (%)	Description	HyperStudy Varname
1	Mass	<input type="checkbox"/>	<input type="checkbox"/>					r_1
2	Displacement	<input type="checkbox"/>	<input type="checkbox"/>					r_2

2. Fill out the table with the following.

**Performance Measures Table**

ID	Name	Objective Function	Constraints	Feasibility	Target Constraint Value	Target Reliability	Description
1	Mass	x					Cost Function
2	Displacement		x	≤	0.002	95	Constraint

The table should look like the table in the figure below.

**Performance Measures (PM)**

ID	Name	Objective Function	Working Constraints	Feasibility	Target Constraint Value	Target Reliability (%)	Description	HyperStudy Varname
1	Mass	<input checked="" type="checkbox"/>	<input type="checkbox"/>					r_1
2	Displacement	<input type="checkbox"/>	<input checked="" type="checkbox"/>	≤	0.002 ...	95.000 ...		r_2

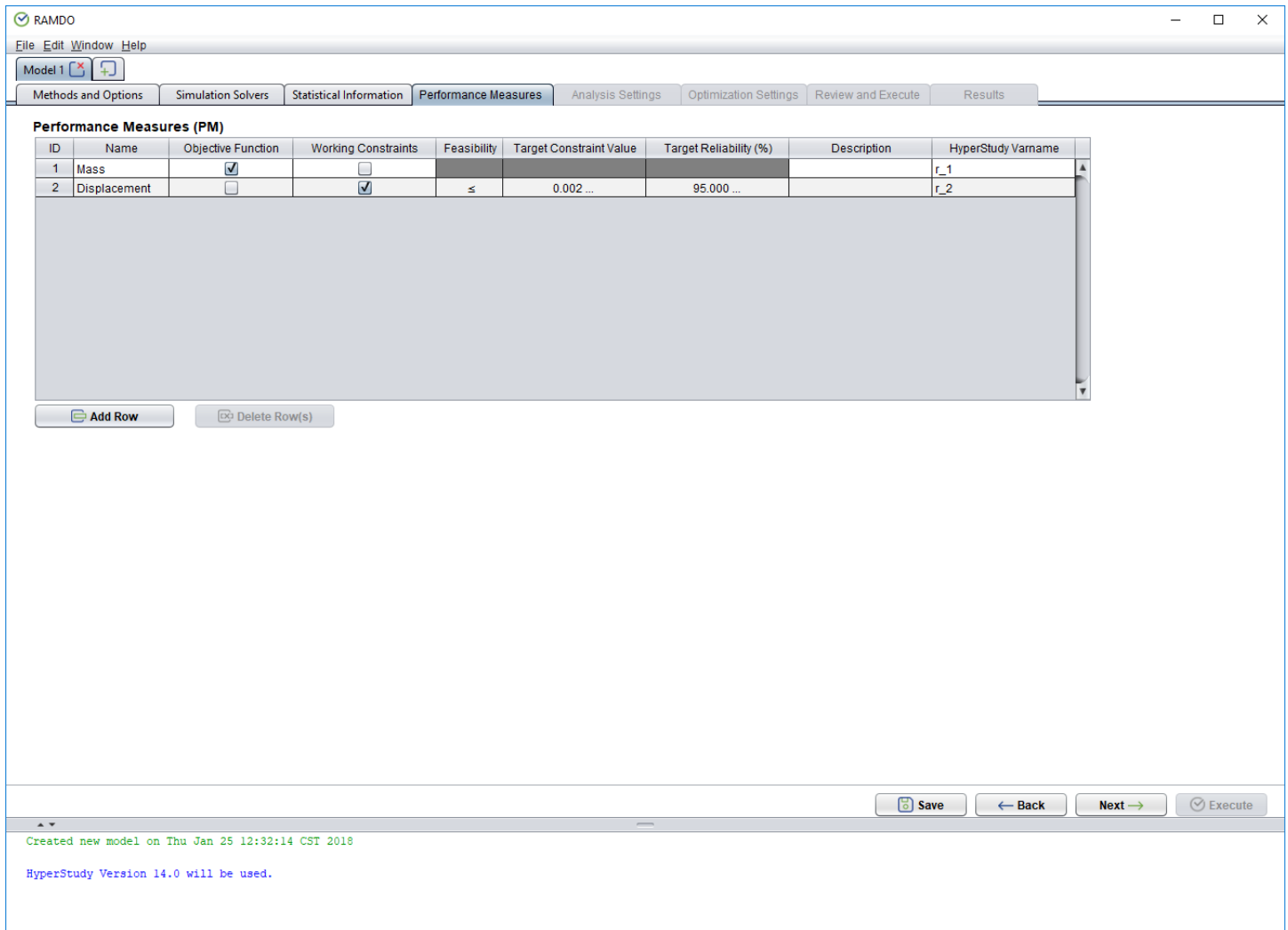
**Note (Inequality Sign)**

The inequality sign defines if the constraint value should be less than or greater than the allowable/target value defined. In the above figure, the inequality sign is  $<$  and the allowable/target value is 0. This means that the constraint would be defined as  $g < 0$ , where  $g$  is the constraint value.

**Note (Performance Measure Description)**

The Description column is for user convenience. The user can enter any description of the performance measure they want. This is so that when a model is opened later the user can remember what the performance measures are for the problem.

3. You should see the following in the figure below.



4. Click the **Next** button to continue to the next page.

# Analysis Settings

Filling out the Analysis Settings page.

RAMDO

File Edit Window Help

Model 1

Methods and Options Simulation Solvers Statistical Information Performance Measures **Analysis Settings** Optimization Settings Review and Execute Results

Sampling Based Analysis Options

Surrogate Modeling Options

Number of Initial Sample Points: 5

MSE for Sequential Sampling: 0.001...

Number of Samples for Each Sequence: 5

Number of Regions in Window: 15

Statistical Analysis Options

Number of MCS-Points: 1,000,000

Calculate Mean and Standard Deviation of Responses

Reset to Default Values

Save Back Next Execute

Created new model on Thu Jan 25 12:32:14 CST 2018

HyperStudy Version 14.0 will be used.

To fill out the Analysis Settings page do the following:

1. The default options can be used for this example.

Sampling Based Analysis Options

Surrogate Modeling Options

Number of Initial Sample Points:	<input type="text" value="5"/>
MSE for Sequential Sampling:	<input type="text" value="0.002 ..."/>
Number of Samples for Each Sequence:	<input type="text" value="5"/>
Number of Regions in Window:	<input type="text" value="15"/>

Statistical Analysis Options

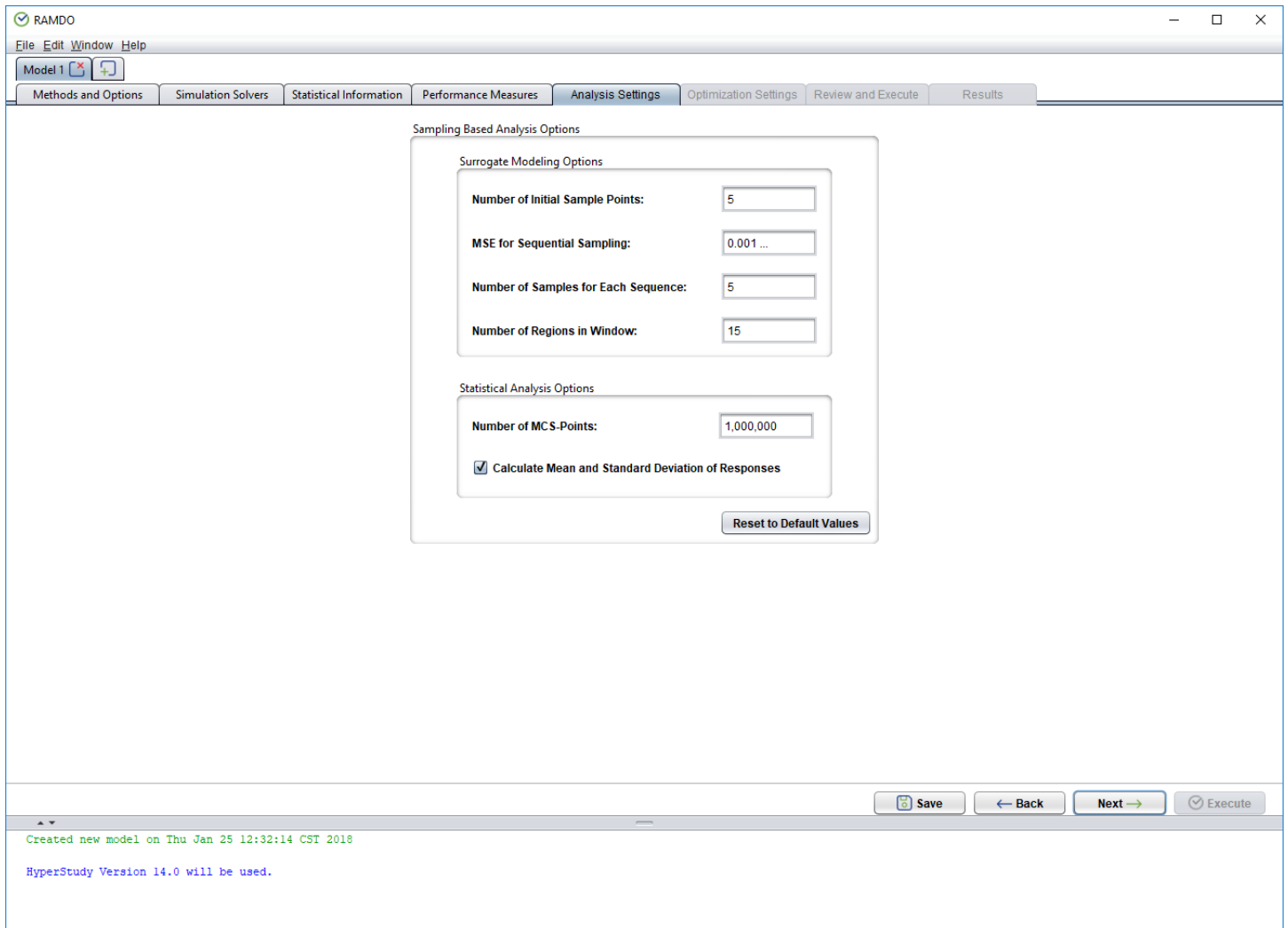
Number of MCS-Points:	<input type="text" value="500,000"/>
<input checked="" type="checkbox"/> Calculate Mean and Standard Deviation of Responses	

**Note**

The Users can set their own values or use the default values.



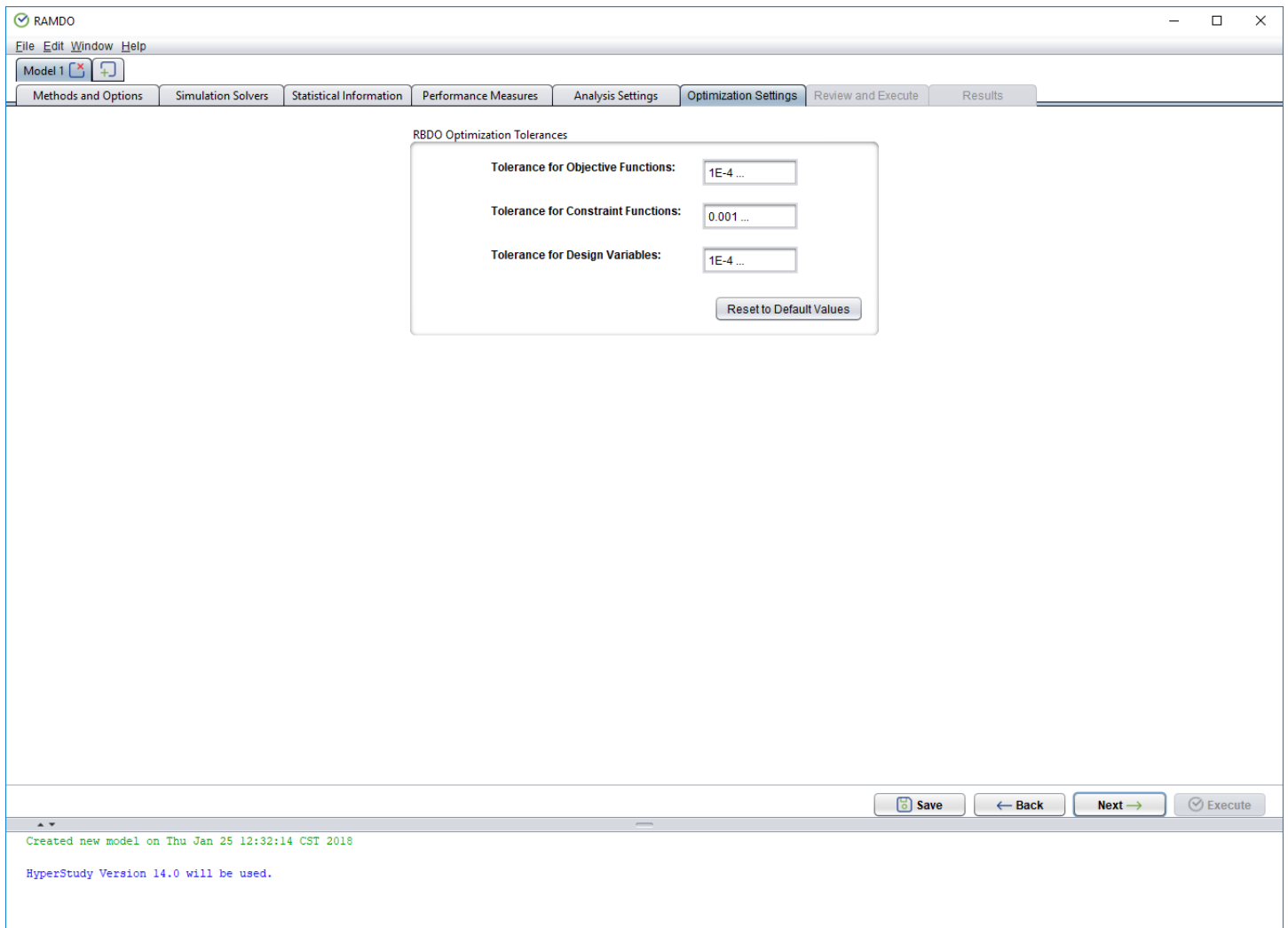
2. You should see the following in the figure below.



3. Click the **Next** button to continue to the next page.

# Optimization Settings

Filling out the Optimization Settings page.



To fill out the Optimization Settings page do the following:

1. The default tolerances can be used for this example.

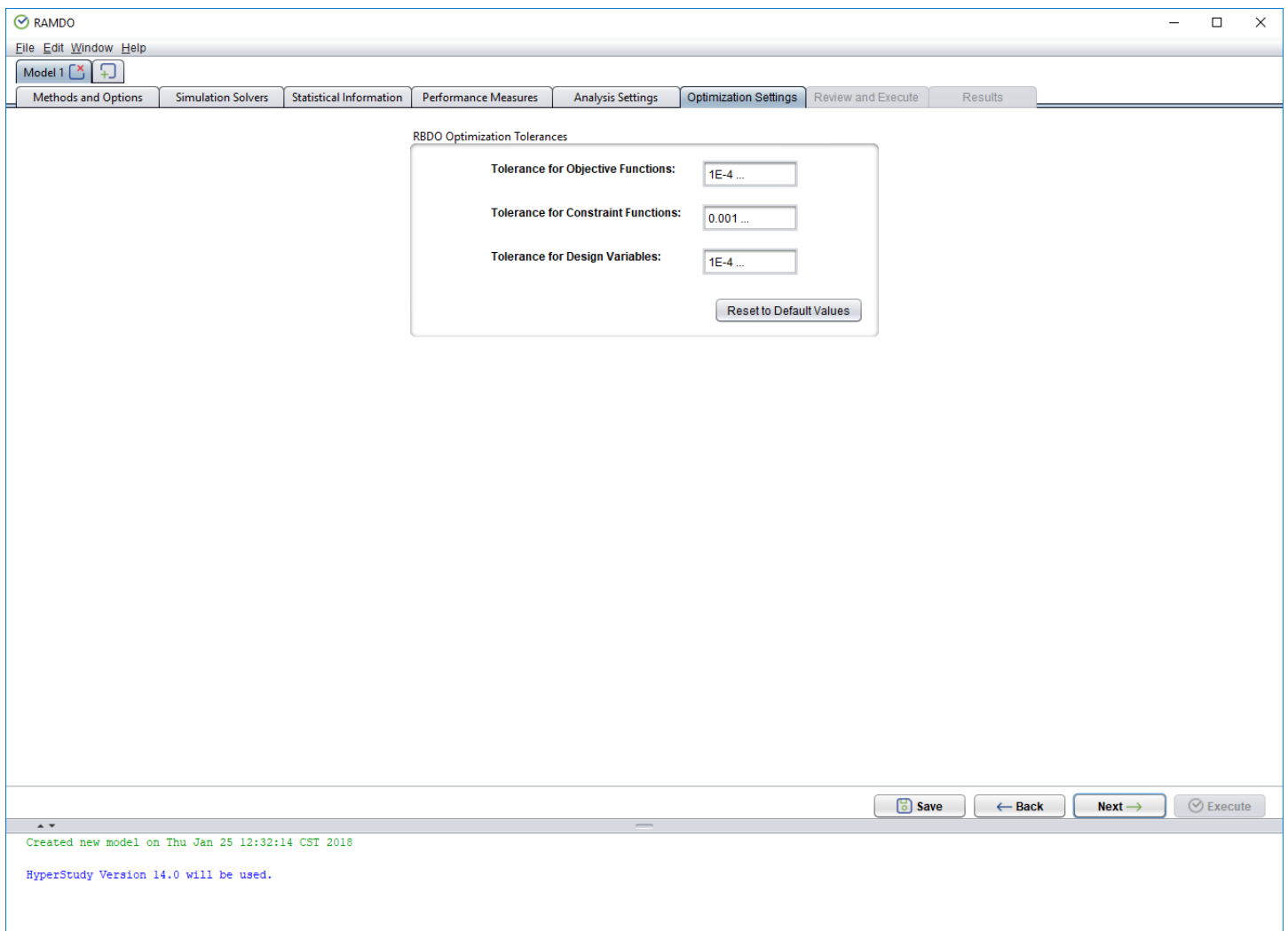
RBDO Optimization Tolerances

Tolerance for Objective Functions:	<input type="text" value="1E-4 ..."/>
Tolerance for Constraint Functions:	<input type="text" value="0.001 ..."/>
Tolerance for Design Variables:	<input type="text" value="1E-4 ..."/>

**Note**

Users can set their own values or use the default values.

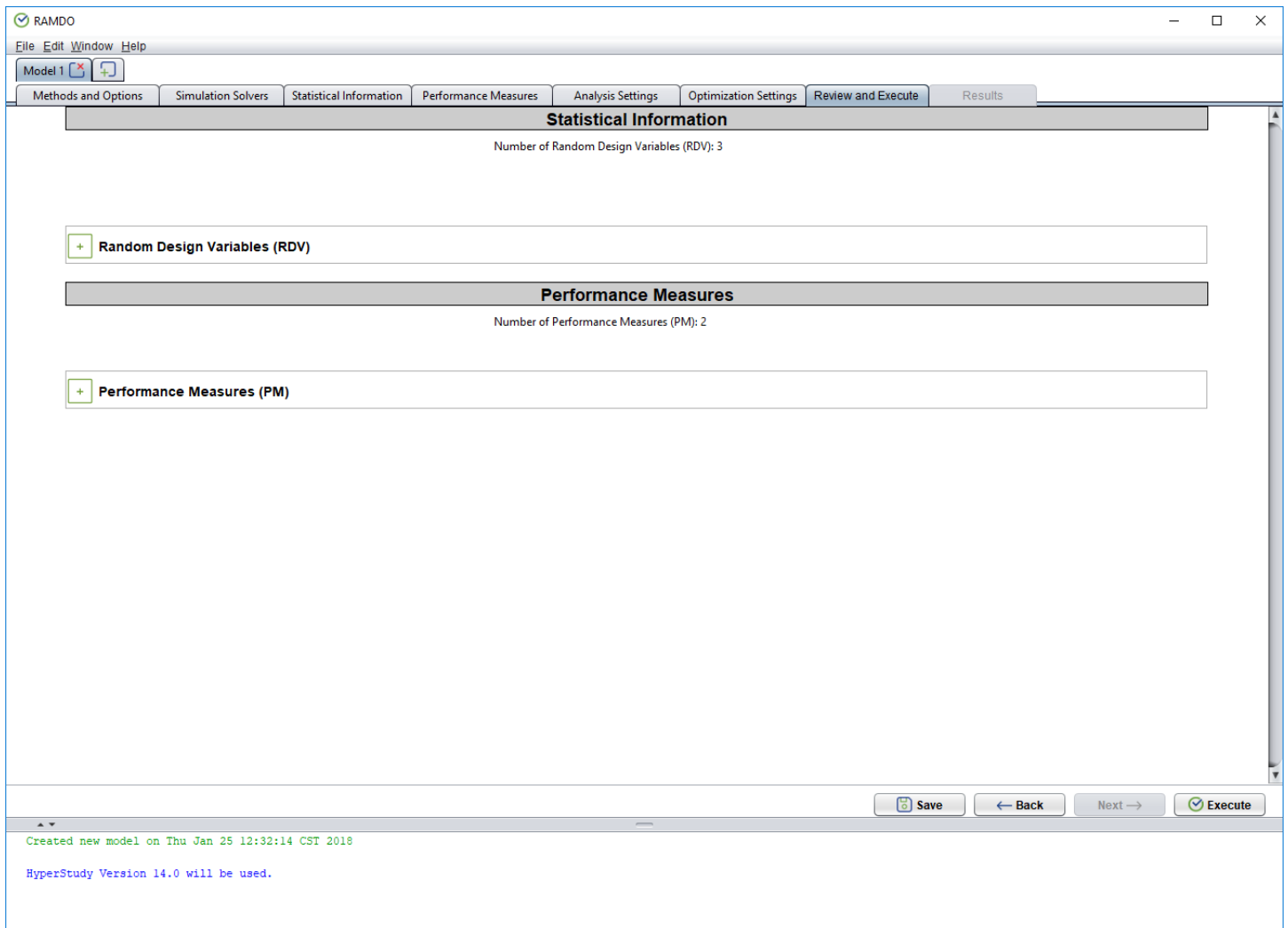
2. You should see the following in the figure below.





3. Click the **Next** button to continue to the next page.

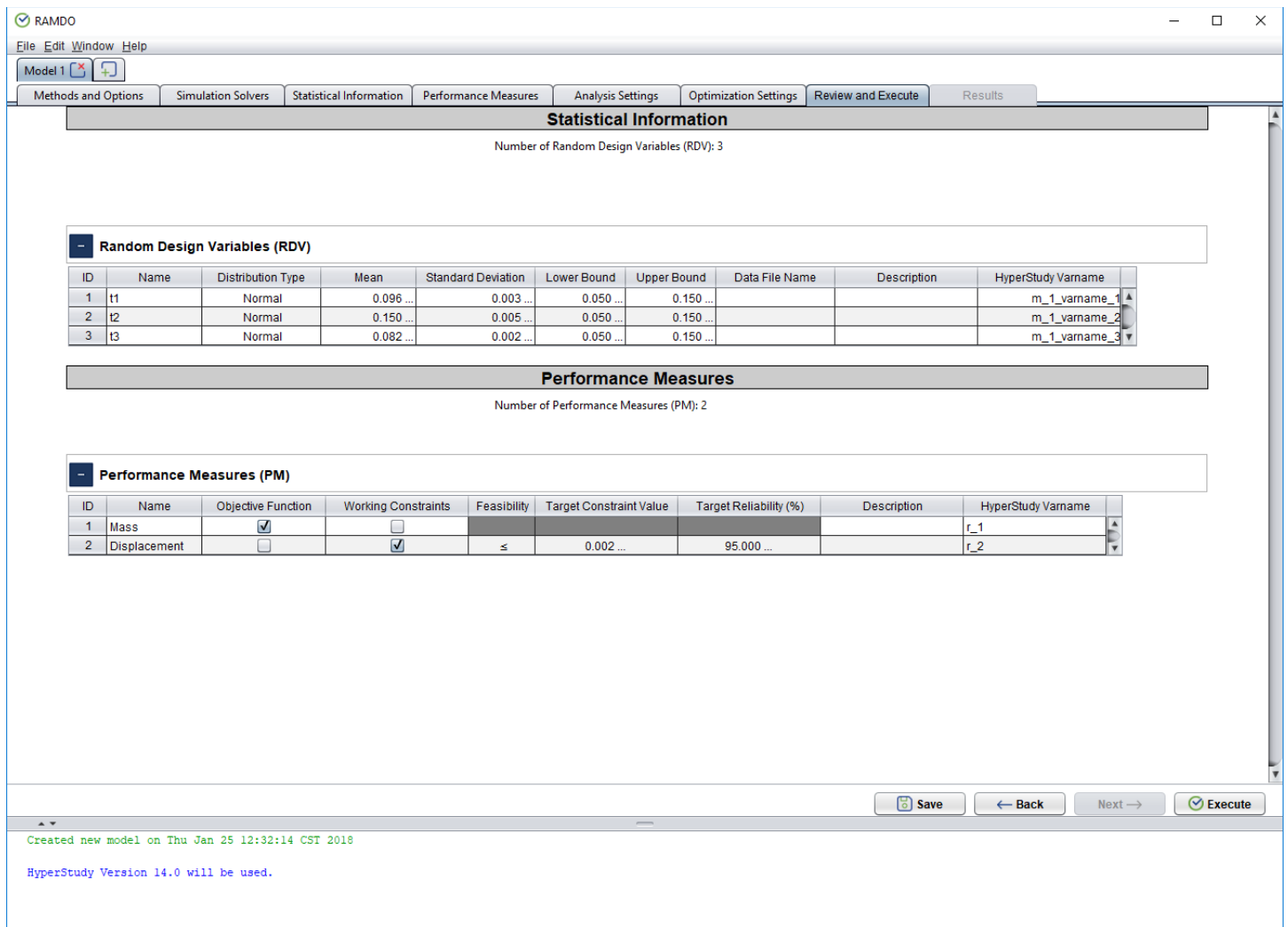
# Review and Execute

Viewing the Review and Execute page.



To use the Review and Execute page you can do the following:

1. Click the  icon to expand the drop-down to display the tables you want to view.
2. Click the  icon to collapse the drop-down.
3. Review the tables to make sure they are correct. Go back and edit them if needed.
4. You should see the following in the figure below if all the drop downs are expanded.
5. Click the **Save** button to save the model.



RAMDO

File Edit Window Help

Model 1

Methods and Options Simulation Solvers Statistical Information Performance Measures Analysis Settings Optimization Settings Review and Execute Results

### Statistical Information

Number of Random Design Variables (RDV): 3

#### Random Design Variables (RDV)

ID	Name	Distribution Type	Mean	Standard Deviation	Lower Bound	Upper Bound	Data File Name	Description	HyperStudy Varname
1	t1	Normal	0.096 ...	0.003 ...	0.050 ...	0.150 ...			m_1_varname_1
2	t2	Normal	0.150 ...	0.005 ...	0.050 ...	0.150 ...			m_1_varname_2
3	t3	Normal	0.082 ...	0.002 ...	0.050 ...	0.150 ...			m_1_varname_3

### Performance Measures

Number of Performance Measures (PM): 2

#### Performance Measures (PM)

ID	Name	Objective Function	Working Constraints	Feasibility	Target Constraint Value	Target Reliability (%)	Description	HyperStudy Varname
1	Mass	<input checked="" type="checkbox"/>	<input type="checkbox"/>					r_1
2	Displacement	<input type="checkbox"/>	<input checked="" type="checkbox"/>	≤	0.002 ...	95.000 ...		r_2

Save Back Next Execute

Created new model on Thu Jan 25 12:32:14 CST 2018

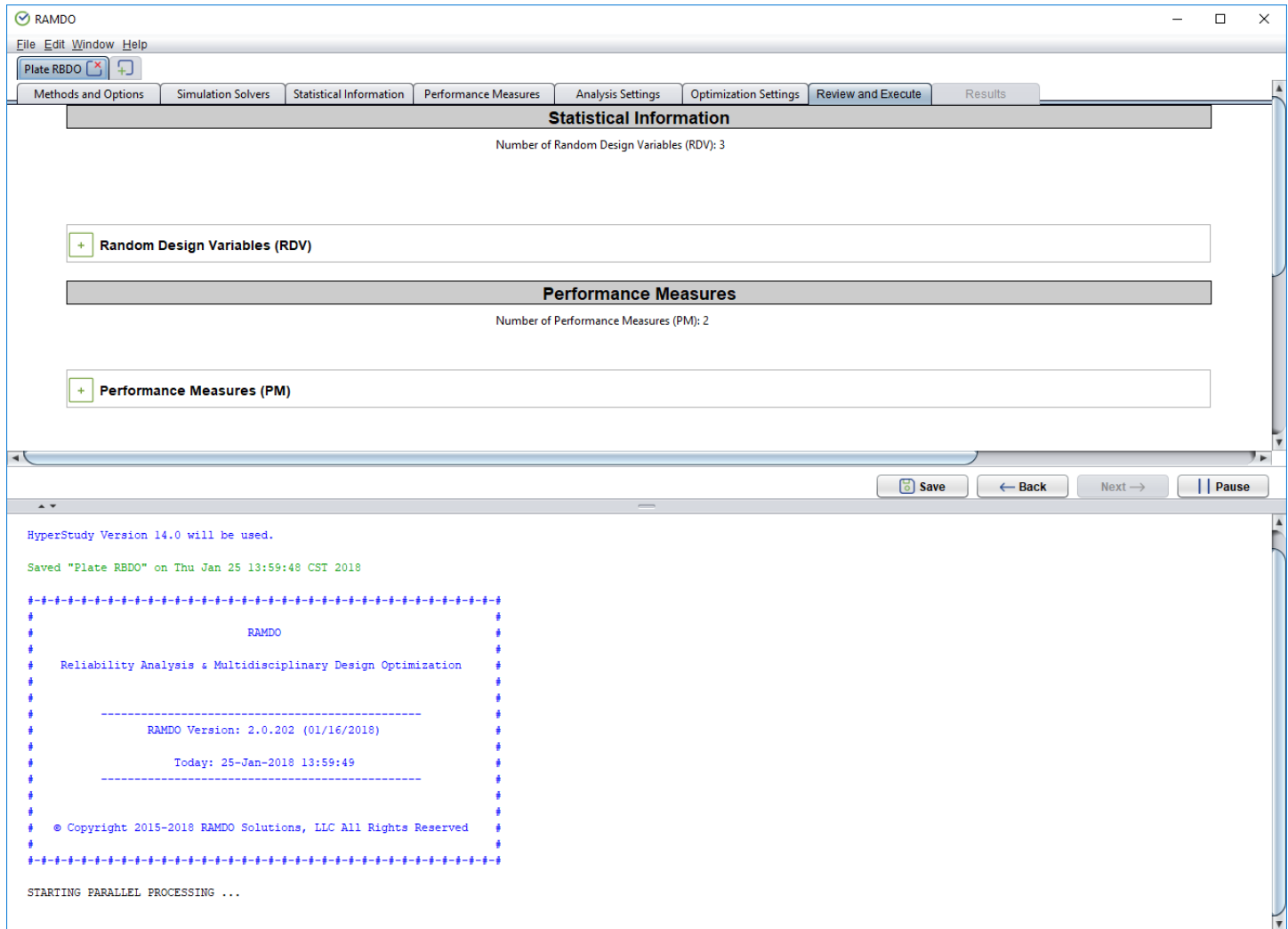
HyperStudy Version 14.0 will be used.

1. Click the **Execute** button to execute the simulation of the model.

## Note

As shown in the log window it will take a few minutes before you will see the RBDO code start and for information to appear in the log window. This normal so please be patient.

2. The output of the simulation will be printed in the output window. Once the model is finished simulating then the Results page will be shown.



# Results

Viewing the Results page.

The screenshot shows the RAMDO software interface. The main window displays a plot titled "RBDO Objective Mass and Reliability History". The plot has "Mass" on the left y-axis (ranging from 1.95 to 2.05) and "Reliability" on the right y-axis (ranging from 0 to 100). The x-axis is "Iterations" (ranging from 0 to 11). Two data series are shown: "Mass" (blue line with circles) and "Displacement" (red line with circles). The Mass series starts at approximately 1.98 and increases to about 2.04. The Displacement series starts at approximately 95 and increases to about 99.5.

Overlaid on the plot is a table titled "RBDO Design Variable Values":



ID	Name	Initial Value	RBDO Value
1	t1	0.096 ...	0.105 ...
2	t2	0.150 ...	0.150 ...
3	t3	0.082 ...	0.082 ...



The interface also shows a sidebar with a tree view of results, including "Results", "Sampling RBDO", "Plots", "Tables", and "RBDO History". The bottom of the window has a status bar with a message: "Saved 'Plate RBDO' on Thu Jan 25 14:50:55 CST 2018".





























## Navigation Table Tree

To use the navigation table tree, make sure it is visible on the page. Change the view of the table tree by dragging right or left the split pane bar or by clicking the right arrow to expand or left arrow to collapse.


To collapse or expand the navigation table tree click the collapse icon  and expand icon  button arrows respectively.


The “Name” column is the name of the results or result types. The “View” column is the current view state of the internal frames of the plots and tables if they are visible or hidden. The visible icon  means the item is visible and the hidden icon  means the item is hidden. To change the viewing state of the plots and tables on the navigation tree table, double-click on the desired item or grouping of items to toggle the view.

Name	View
 Results	
 Sampling RBDO	
 Plots	
 RBDO Objective Function History	
 t1 History	
 t2 History	
 t3 History	
 Displacement History	
 Tables	
 RBDO Objective Function Values	
 RBDO Design Variable Values	
 RBDO Reliability and Constraint Values	
 RBDO History	


## Result Frames

The result windows behave like normal desktop windows. They can be resized and dragged around.

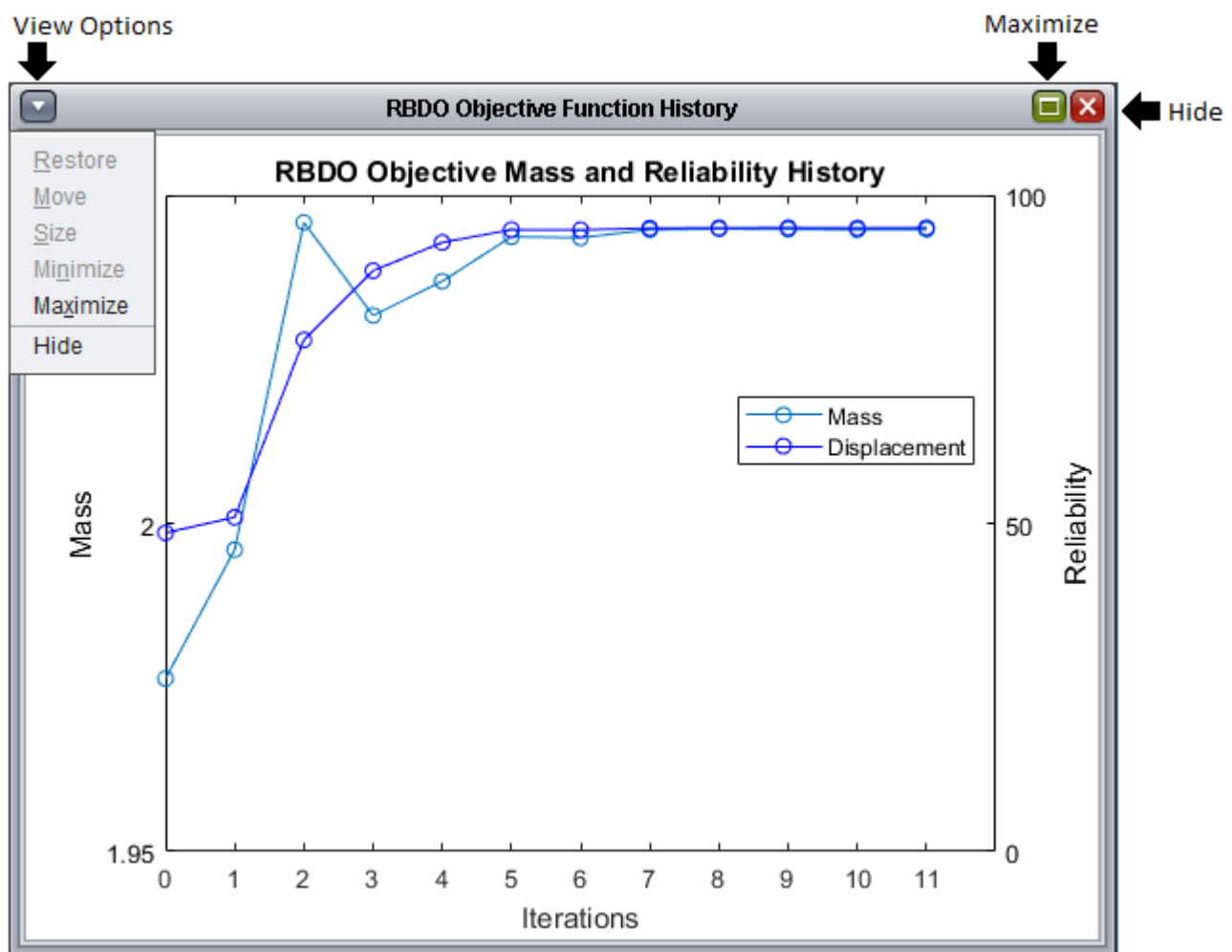
To expand a window to fit the result's desktop, click the Expand button  in the top right-hand corner.

To restore a window to its last size after it has been expanded, click the Restore button  in the top right-hand corner.

To show an individual result window, double-click on the window's corresponding name or single-click on the view icon in the navigation tree table. Or do the same actions on a group of tables, plots, or results to hide or show them all at once.

To hide an individual result window, click the Hide button  in the top right-hand corner.

Click the View Options button  in the top left-hand corner to use all the viewing options.



# The Results

## Note

The results in the table may vary a little from the ones shown in the table below. This is to be expected being a sampling-based RBDO method using surrogate models is used for analysis.

Name	Initial Value	RBDO Value
Mass	1.976 ...	2.045 ...

ID	Name	Initial Value	RBDO Value
1	t1	0.096 ...	0.105 ...
2	t2	0.150 ...	0.150 ...
3	t3	0.082 ...	0.082 ...

ID	Name	Initial Reliability (%)	RBDO Reliability (%)	Initial Nominal Value	RBDO Nominal Value	Initial Mean Value	RBDO Mean Value
1	Displacement	48.544 ...	95.036 ...	-5E-5 ...	-0.030 ...	0.001 ...	-0.029 ...

Iteration	t1	t2	t3	Mass	Displacement Reliabil...	Displacement Nominal	Displacement Mean
0	0.096 ...	0.150 ...	0.082 ...	1.976 ...	48.544 ...	-5E-5 ...	0.001 ...
1	0.084 ...	0.150 ...	0.101 ...	1.996 ...	50.925 ...	-0.001 ...	2.561E-5 ...
2	0.120 ...	0.150 ...	0.063 ...	2.046 ...	77.939 ...	-0.014 ...	-0.013 ...
3	0.096 ...	0.150 ...	0.092 ...	2.032 ...	88.489 ...	-0.023 ...	-0.022 ...
4	0.102 ...	0.150 ...	0.084 ...	2.037 ...	92.800 ...	-0.027 ...	-0.026 ...
5	0.104 ...	0.150 ...	0.084 ...	2.044 ...	94.735 ...	-0.030 ...	-0.029 ...
6	0.104 ...	0.150 ...	0.083 ...	2.044 ...	94.712 ...	-0.030 ...	-0.029 ...
7	0.104 ...	0.150 ...	0.083 ...	2.045 ...	94.968 ...	-0.030 ...	-0.029 ...
8	0.105 ...	0.150 ...	0.083 ...	2.045 ...	95.012 ...	-0.030 ...	-0.029 ...
9	0.105 ...	0.150 ...	0.083 ...	2.045 ...	95.035 ...	-0.030 ...	-0.029 ...
10	0.105 ...	0.150 ...	0.082 ...	2.045 ...	94.989 ...	-0.030 ...	-0.029 ...
11	0.105 ...	0.150 ...	0.082 ...	2.045 ...	95.036 ...	-0.030 ...	-0.029 ...

