

Workshop - Parameter Study of a Twenty-Five Bar Truss

AN MSC NASTRAN SOL 200 TUTORIAL

Before Starting

This example is a continuation of a previous example titled: Workshop - Optimizing for Buckling - Twenty-Five Bar Truss

This example requires MSC Nastran 2018 or newer.

Optimization Problem Statement

Design Variables

$y_1 \rightarrow A_1 = \frac{\pi y_1^2}{10}$ of PROD 1

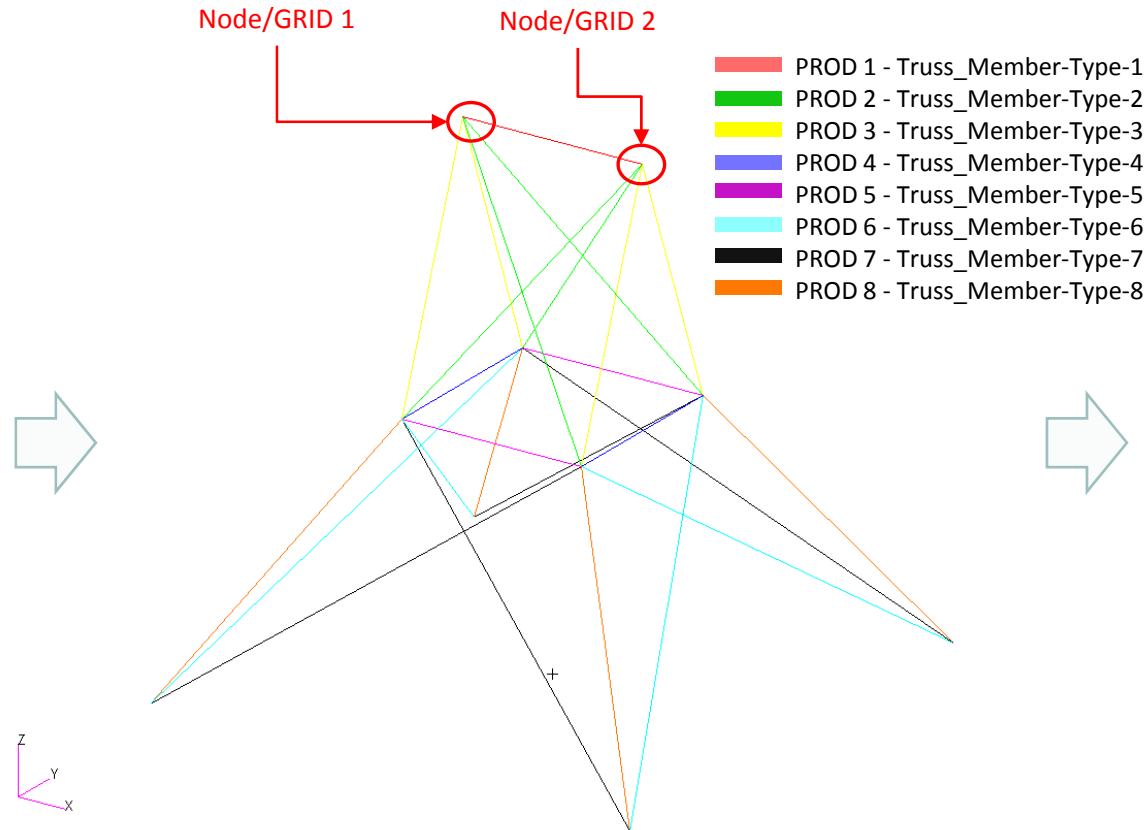
....

$y_8 \rightarrow A_8 = \frac{\pi y_8^2}{10}$ of PROD 8

$y_{i_initial} = 2.52$

$1.0 < y_i < 8.$

Allowed values for design variables: .1, .5, 1.0, 2.0, ... 100.



Design Objective

r0: Minimize weight

Design Constraints

r1: Axial stress of elements related to PROD 1

...

r8: Axial stress of elements related to PROD 8

$$-40,000 < r_1, \dots, r_8 < 40,000$$

r9: x, y component of displacement at nodes 1 and 2

$$-.35 < r_9 < .35$$

Design Constraints, Equation

$$R_i = F_s \frac{-7.69 \cdot r_i \cdot L_i^2}{\pi^2 \cdot 1.0E7 \cdot y_i^2} < 1.0$$

Number	Label	L	Variable
1	r1	75.	y1
2	r2	130.5	y2
3	r3	106.8	y3
4	r4	75.	y4
5	r5	75.	y5
6	r6	181.14	y6
7	r7	181.14	y7
8	r8	133.46	y8

Contact me

- Nastran SOL 200 training
- Nastran SOL 200 questions
- Structural or mechanical optimization questions
- Access to the SOL 200 Web App

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Tutorial

Tutorial Overview

1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
 - Configure Parameter Study
 - Perform parameter study with Nastran SOL 200

SOL 200 Web App Capabilities

The Post-processor Web App and HDF5 Explorer are free to MSC Nastran users.

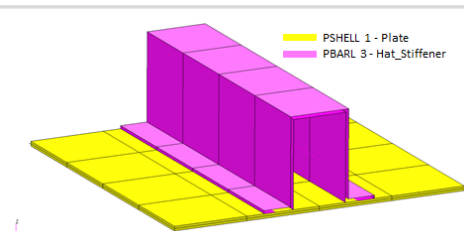
Compatibility

- Google Chrome, Mozilla Firefox or Microsoft Edge
- Windows and Red Hat Linux
- Installable on a company laptop, workstation or server. All data remains within your company.

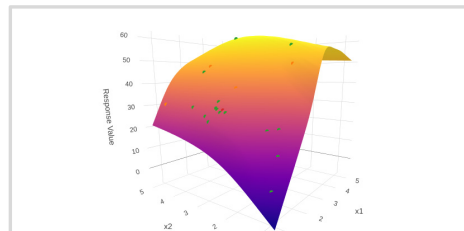
Benefits

- REAL TIME error detection. 200+ error validations.
- REAL TIME creation of bulk data entries.
- Web browser accessible
- Free Post-processor web apps
- +80 tutorials

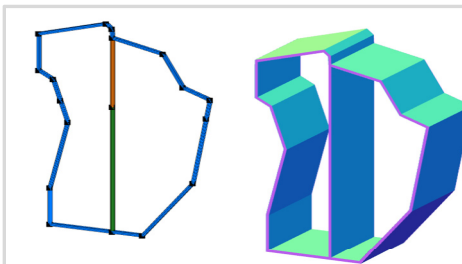
Web Apps



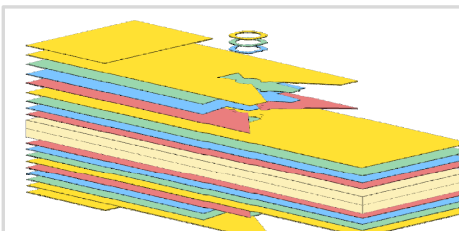
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200.
Support for size, topology, topometry, topography, multi-model optimization.



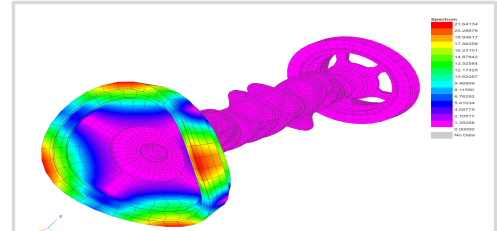
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



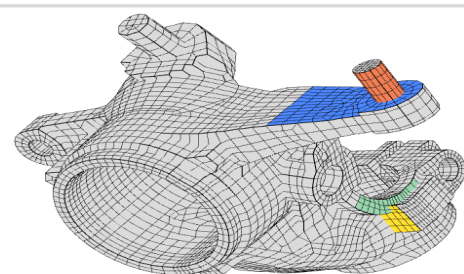
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



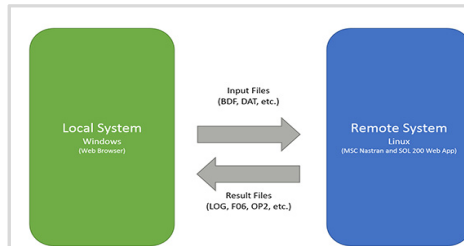
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



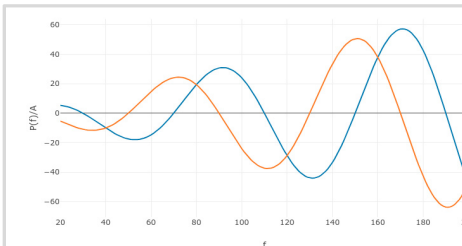
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



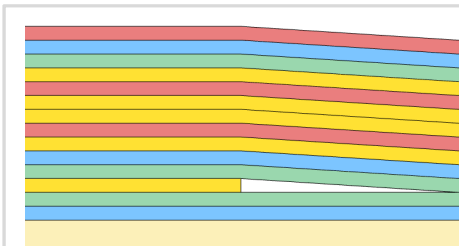
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



Dynamic Loads Web App
Generate RLOAD1, RLOAD2 and DLOAD entries graphically



Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies

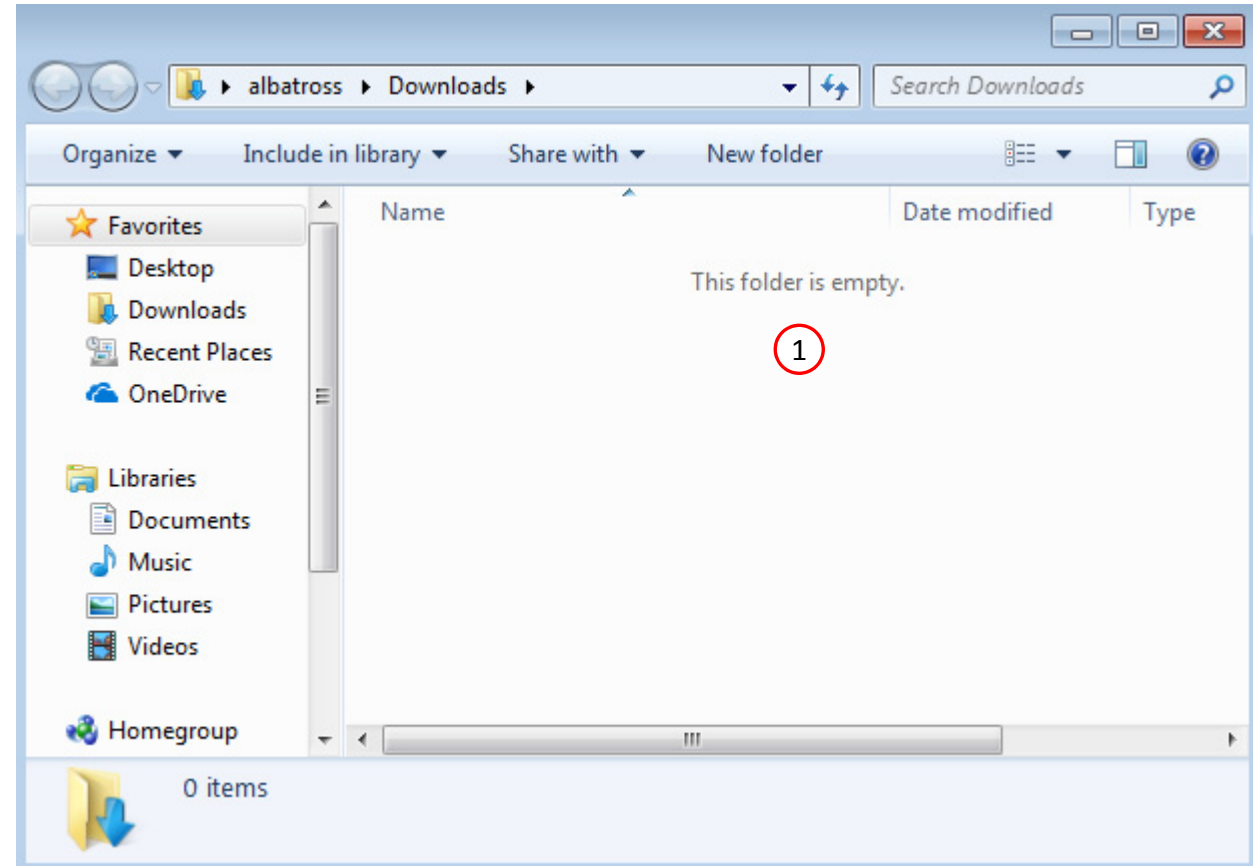


HDF5 Explorer Web App
Create graphs (XY plots) using data from the H5 file

Before Starting

1. Ensure the Downloads directory is empty in order to prevent confusion with other files

- Throughout this workshop, you will be working with multiple file types and directories such as:
 - .bdf/.dat
 - nastran_working_directory
 - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.



Go to the User's Guide

1. Click on the indicated link

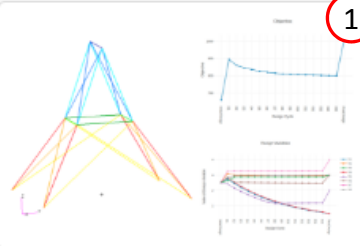
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.



Obtain Starting Files

1. Find the indicated example
2. Click Link
3. The starting file has been downloaded

- When starting the procedure, all the necessary BDF files must be collected together.



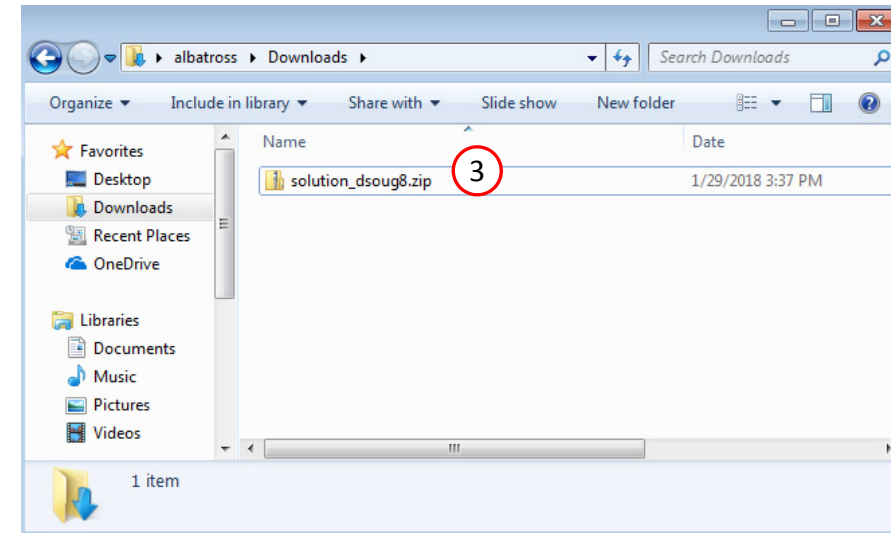
1 Parameter Study

This tutorial details the use of MSC Nastran SOL 200 to perform a "parameter study."

What is a parameter study?

A common engineering technique is to try different structural configurations, for example, changing structural dimensions, and review the impact on structural responses such as displacements and stresses. Dozens, possibly hundreds of structural configurations would ideally be evaluated. This is termed "parameter study." MSC Nastran SOL 200 includes a capability to automatically generate multiple structural configurations and perform static or dynamic analyses. The outcome are results from multiple structural configurations that can be compared.

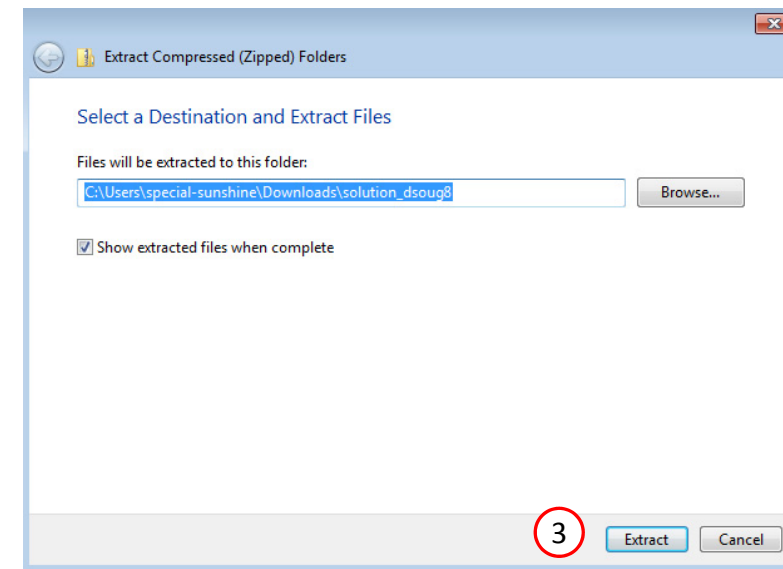
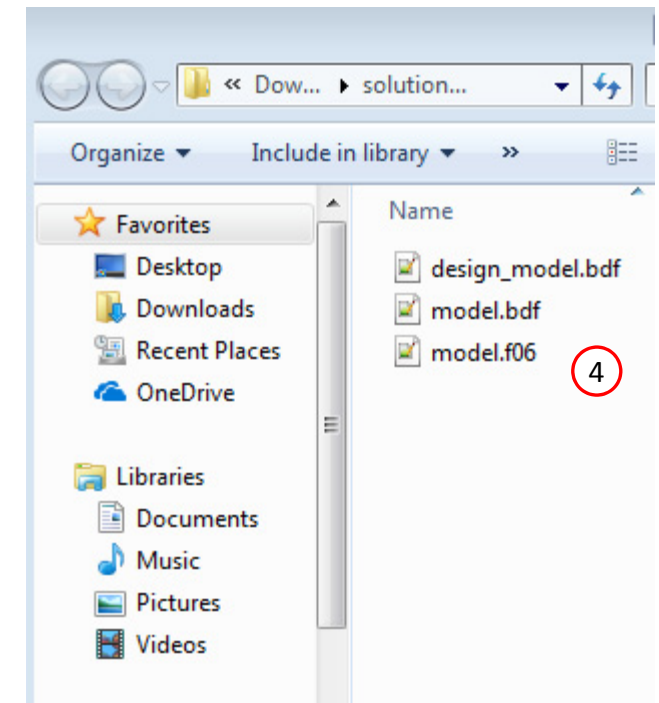
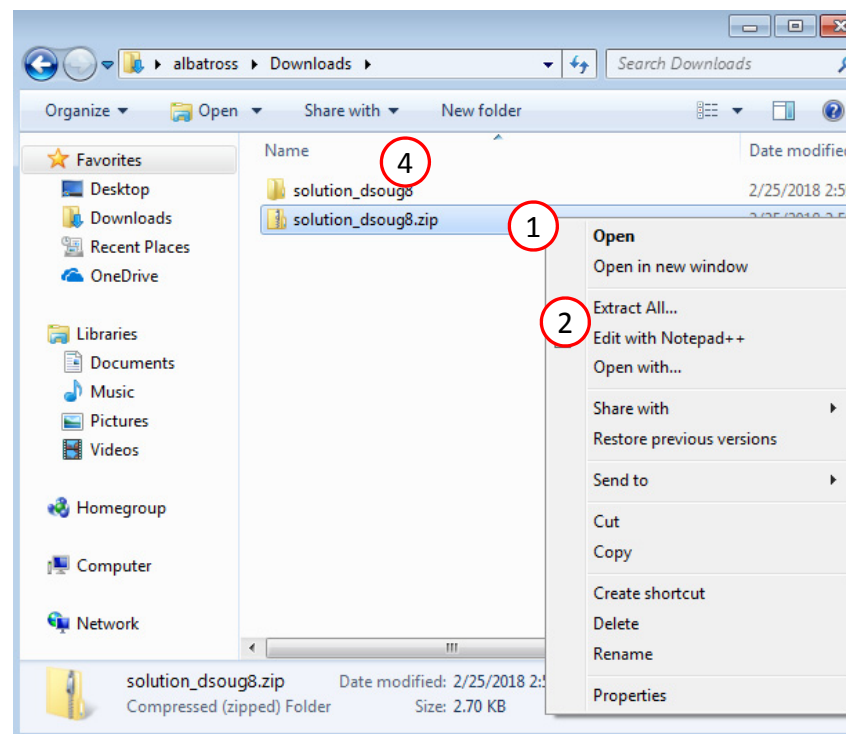
Starting BDF Files: [Link](#)
Solution BDF Files: [Link](#) 2



Obtain Starting Files

1. Right click on the zip file
2. Select Extract All...
3. Click Extract
4. The starting files are now available in a folder

- This example is using a previously created design model. The design model is a model that has been converted to SOL 200 and contains bulk data entries describing the optimization problem statement, e.g. variables, objective and constraints.



Open the Correct Page

1. Click on the indicated link

- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
 - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
 - Multi Model Optimization
 - Machine Learning
- The web app also features the HDF5 Explorer, a web application to extract results from the H5 file type.



Upload BDF Files

1. Click 1. Select Files and select model.bdf and design_model.bdf
2. Click Upload Files

- The process starts by uploading all the necessary BDF files. The BDF files can be files of your own or files found in the Tutorials section of the User's Guide.

Step 1 - Upload .BDF Files

The screenshot shows a two-step process for uploading files. Step 1, '1. Select files', is highlighted with a blue bar and indicates '2 files selected'. Below it is a green progress bar labeled 'Inspecting: 100%'. Step 2, '2. Upload files', is highlighted with a green bar and indicates 'Uploading: 100 %'. Below the progress bars is a checkbox labeled 'List of Selected Files'.

1. Select files 2 files selected

Inspecting: 100%

2. Upload files

Uploading: 100 %

☐ List of Selected Files

Configure Settings

1. Click Settings
2. Mark the checkbox for “Perform Parameter Study”

- Global Optimization involves 3 steps:
 - Create multiple Samples. Each sample has different initial values for design variables.
 - A local optimization is performed for each sample.
 - The global optimum is the best out of all the local optimizations.
- Parameter Study involves 2 steps:
 - Create multiple Samples. Each sample has different initial values for design variables.
 - An analysis is performed for each sample. The goal is to just determine the objective and constraints. A local optimization is not performed.

1

Optimization Settings

Parameter	Description	Configure
APRCOD	Approximation method to be used	<input type="checkbox"/> 2 - Mixed Method
CONV1	Relative criterion to detect convergence	<input type="checkbox"/> Enter a positive real number
CONV2	Absolute criterion to detect convergence	<input type="checkbox"/> Enter a positive real number
DELX	Fractional change allowed in each design variable during any optimization cycle	<input type="checkbox"/> Enter a positive real number
DESMAX	Maximum number of design cycles to be performed	<input checked="" type="checkbox"/> 1
DISBEG	Design cycle number for discrete variable processing initiation	<input type="checkbox"/> Enter a positive integer
GMAX	Maximum constraint violation allowed at the converged optimum	<input type="checkbox"/> Enter a positive real number
P1	Print items, e.g. objective, design variables, at every n-th design cycle to the .f06 file	<input checked="" type="checkbox"/> 1
P2	Items to be printed to the .f06 file	<input checked="" type="checkbox"/> 15 - Print objective, design variab
TCHECK	Topology Checkerboarding	<input type="checkbox"/> -1 - Automatic selection (Default)
TDMIN	Minimum diameter of members in topology optimization	<input type="checkbox"/> Enter a positive real number
TREGION	Trust Region	<input type="checkbox"/> 1 - Trust Region On

5 10 20 30 40 50

Optimization Type

- ☐ Perform Local Optimization
- ☐ Perform Sensitivity Analysis
- ☐ Perform Global Optimization
- ☐ Perform Global Optimization Type 2
- ☒ Perform Parameter Study

2

Optimization Type

- ☐ Perform Local Optimization
- ☐ Perform Sensitivity Analysis
- ☐ Perform Global Optimization
- ☐ Perform Global Optimization Type 2
- ☒ Perform Parameter Study

2

BDF Output - Design Model

```
$
$
$      optimization Control Settings
$-----
$
$
$
DOPTPRN DESMAX 1    P1    1    P2    15
```

Developed by The Engineering Lab

Update Design Variables

1. Go to the *Variables* section
2. Scroll to section *Step 4 - Adjust Variables*
3. Click 10 on the bar to show 10 rows
4. Set the lower bound to 1.0. Set the upper bound to 8.0

- The bounds on the design variables must be updated. When performing a Parameter Study, it is best to specify bounds that are close to the initial values. For example, before, the bounds were $.01 < y1 < 100$. The new bounds are $1.0 < y1 < 8.0$.

2 Step 4 - Adjust design variables

+ Options

+ Create Variable

	Label ▾	Status ▾	Initial Value	Lower Bound	Upper Bound	Allowed Discrete Values
	<input type="text" value="Search"/>	<input type="text" value="Search"/>				
	y1		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y2		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y3		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y4		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y5		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y6		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y7		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>
	y8		<input type="text" value="2.52"/>	<input type="text" value="1.0"/>	<input type="text" value="8."/>	<input type="text" value=".1, .5, 1.0, THRU, 100., BY, 1.0"/>

4

5 10 20 30 40 50

3

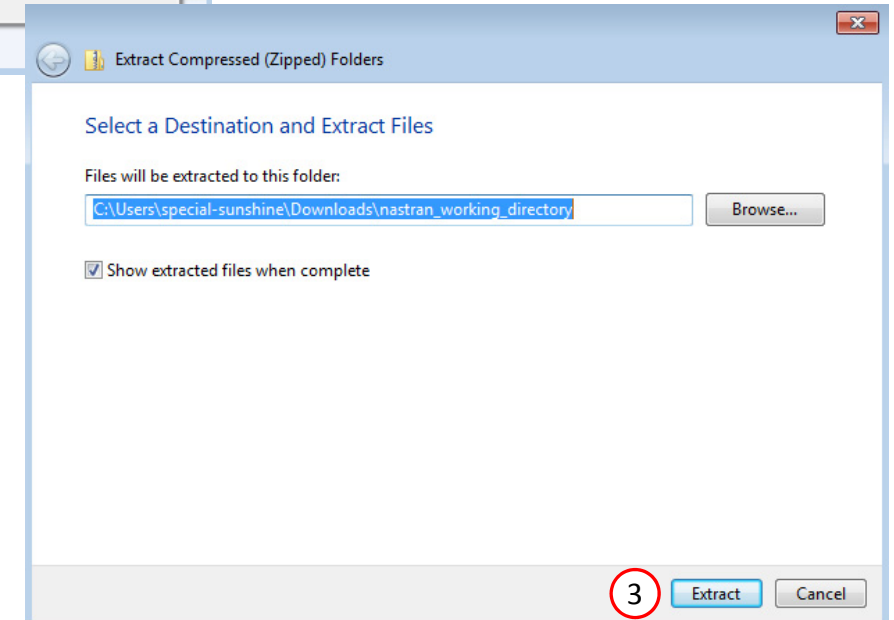
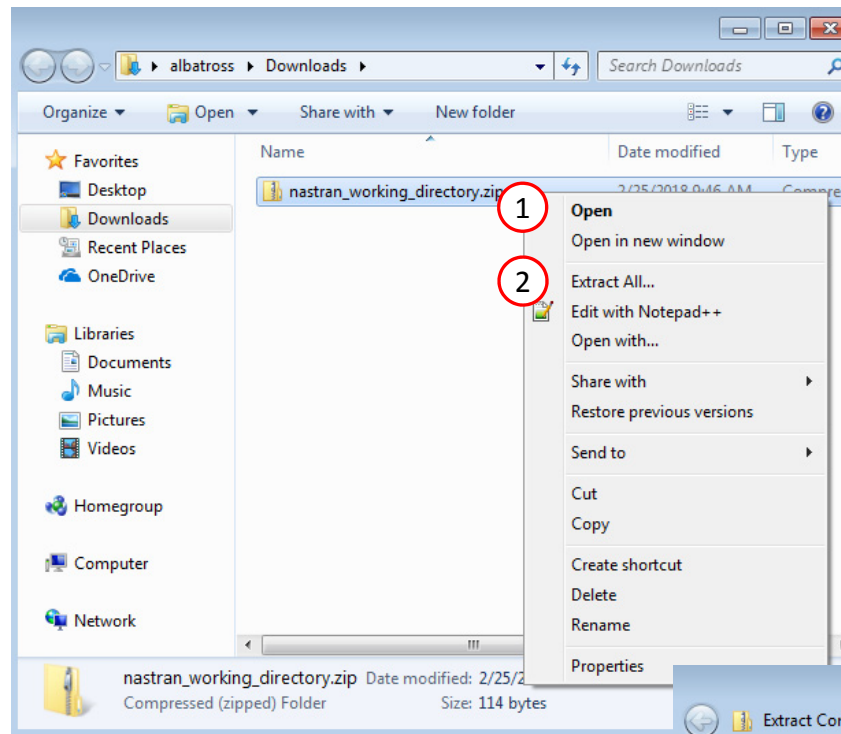
1. Click on Exporter
2. Click on Download BDF Files

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Perform the Optimization with Nastran SOL 200

1. A new .zip file has been downloaded
2. Right click on the file
3. Click Extract All
4. Click Extract on the following window

- Always extract the contents of the ZIP file to a new, empty folder.



Perform the Optimization with Nastran SOL 200

1. Inside of the new folder, double click on Start MSC Nastran
2. Click Open, Run or Allow Access on any subsequent windows
3. MSC Nastran will now start

- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
 - 1) Copy the BDF files and the INCLUDE files to a remote machine.
 - 2) Run the MSC Nastran job on the remote machine.
 - 3) After completion, copy the BDF, F06, LOG, H5 files to the local machine.
 - 4) Click "Start MSC Nastran" to display the results.

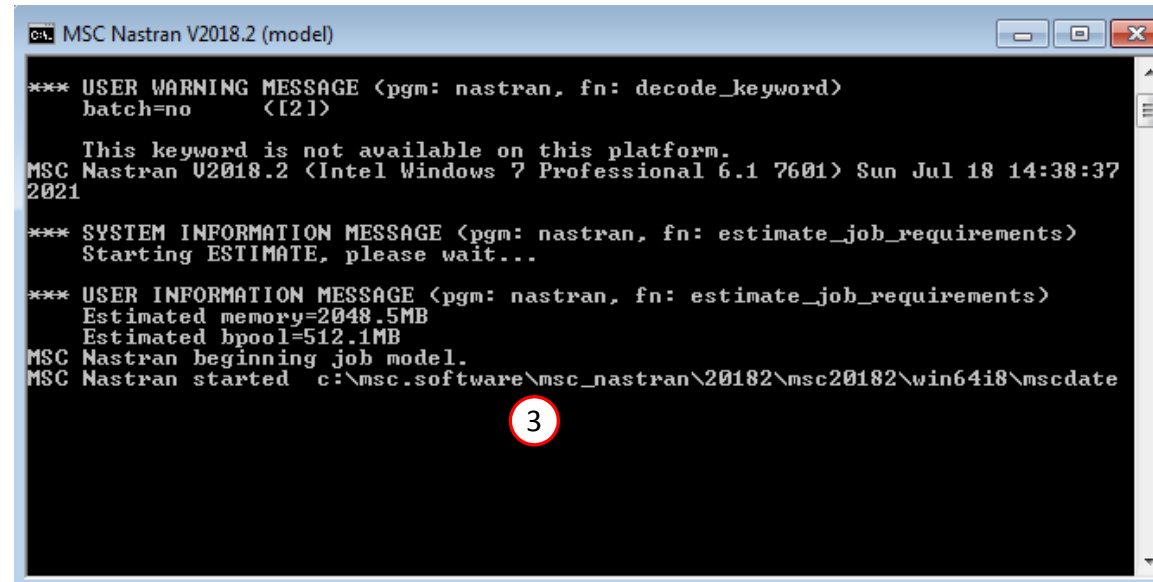
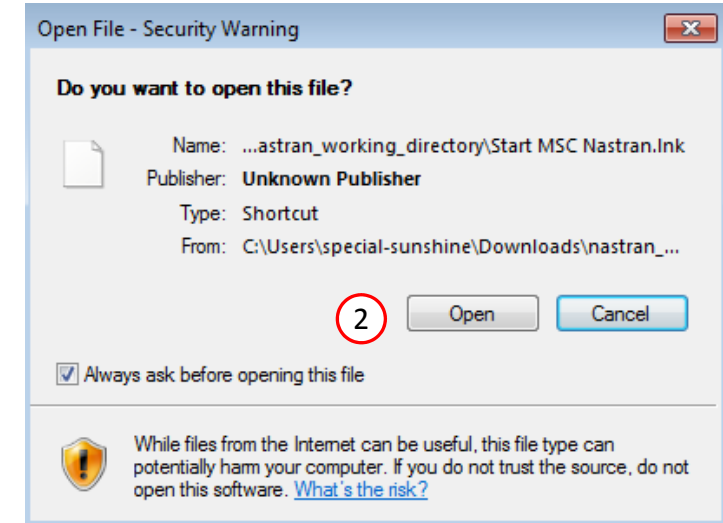
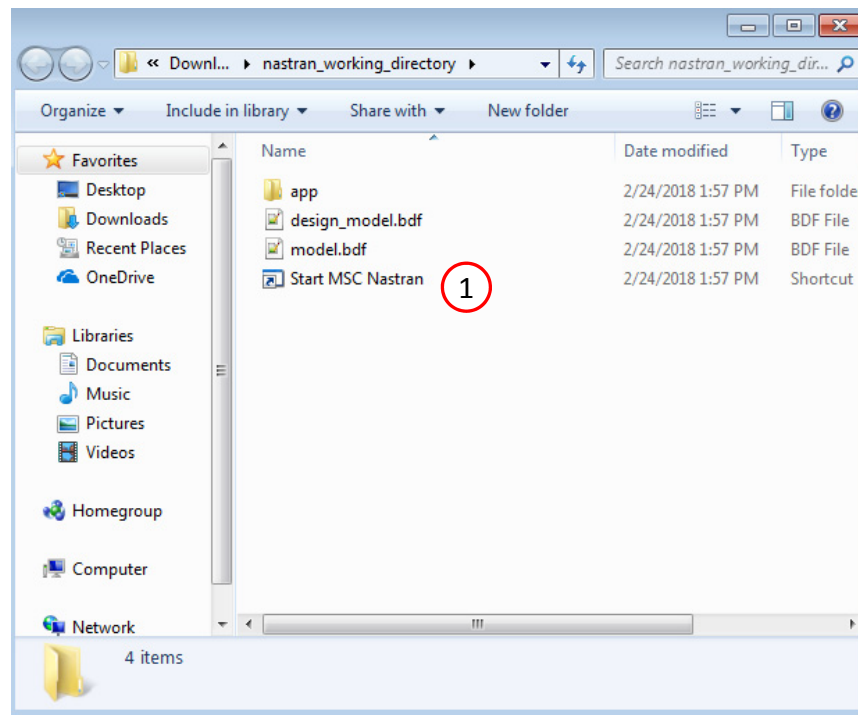
Using Linux?

Follow these instructions:

- 1) Open Terminal
- 2) Navigate to the nastran_working_directory
`cd ./nastran_working_directory`
- 3) Use this command to start the process
`./Start_MSC_Nastran.sh`

In some instances, execute permission must be granted to the directory. Use this command. This command assumes you are one folder level up.

```
sudo chmod -R u+x ./nastran_working_directory
```



Status

- 1. While MSC Nastran is running, a status page will show the current state of MSC Nastran

- The status of the MSC Nastran job is reported on the Status page. Note that Windows 7 users will experience a delay in the status updates. All other users of Windows 10 and Red Hat Linux will see immediate status updates.

SOL 200 Web App - Status

 Python  MSC Nastran

Status

Name	Status of Job	Design Cycle	RUN TERMINATED DUE TO
model.bdf	Running	None	

Review Optimization Results

After MSC Nastran is successfully complete, the results will be automatically uploaded.

For each sample the objective, normalized constraints, and design variables are displayed in a bar chart and table.

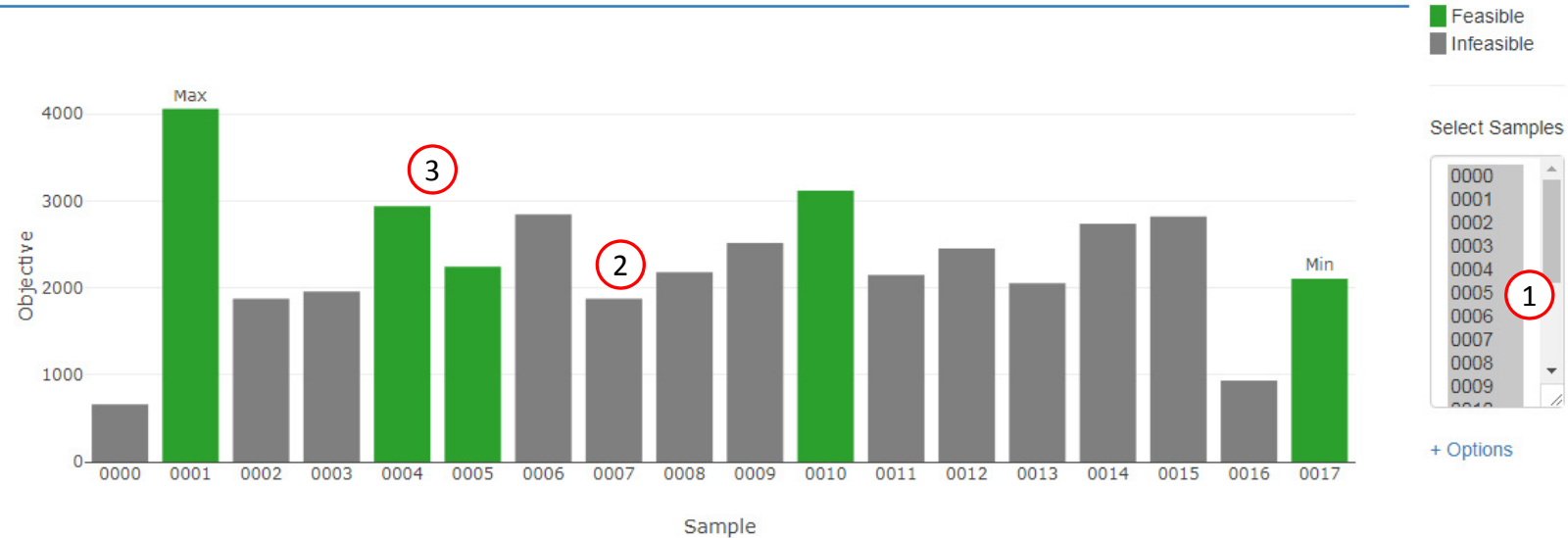
1. The select box can be used to display specific samples.
2. Bars that are colored gray indicate the design is infeasible (Not all design constraints are satisfied)
3. Bars that are green indicate the design is feasible (All design constraints are satisfied)

- Recall Parameter Study involves 2 steps:
 - Create multiple Samples. Each sample has different initial values of values.
 - An analysis is performed for each sample. The goal is to just determine the objective and constraints. A local optimization is not performed.
- Some of the samples yield designs with satisfied constraints (green bars) and other designs with violated constraints (gray bars).

SOL 200 Web App - Parameter Study Results

Home

Objective for Each Sample



Data for Each Sample

Item	Sample 0000	Sample 0001	Sample 0002	Sample 0003	Sample 0004	Sample 0005	Sample 0006	Sample 0007	Sample 0008
Extrema (Max/Min)		Max							
Objective	6.594656E+02	4.056496E+03	1.872572E+03	1.958464E+03	2.937953E+03	2.240882E+03	2.843099E+03	1.872921E+03	2.178409E+03
Normalized Constraint	1.827233E+00	N/A	9.494511E-01	1.126303E+00	-1.867295E-02	9.359214E-04	2.847197E-01	9.261696E-01	3.244243E-01
Y1	2.5200E+00	6.2500E+00	2.7500E+00	6.2500E+00	2.7500E+00	6.2500E+00	2.7500E+00	6.2500E+00	2.7500E+00
Y2	2.5200E+00	6.2500E+00	6.2500E+00	2.7500E+00	2.7500E+00	6.2500E+00	6.2500E+00	2.7500E+00	2.7500E+00
Y3	2.5200E+00	6.2500E+00	6.2500E+00	6.2500E+00	6.2500E+00	2.7500E+00	2.7500E+00	2.7500E+00	2.7500E+00

End of Tutorial