

Workshop - Global Optimization of a Composite Laminate

AN MSC NASTRAN SOL 200 TUTORIAL

Global Optimization

This example is a continuation of a previous example titled: Workshop - Automated Optimization of a Composite Laminate

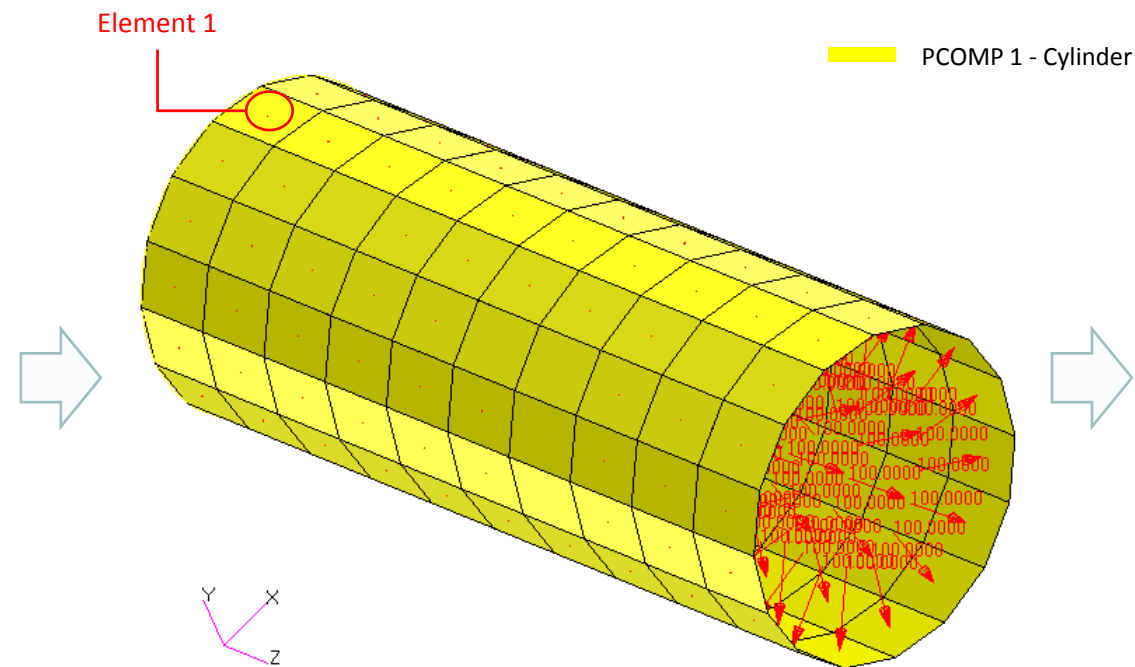
Optimization Problem Statement

Design Variables

x1: T of lamina 1 of PCOMP 1
x2: T of lamina 2
x3: T of lamina 3
x4: T of lamina 4
x5: T of lamina 5
x6: T of lamina 6
x7: T of lamina 7
x8: T of lamina 8
 $.001 < x_i < 10.$
x9: Orientation of lamina 1 of PCOMP 1
x10: Orientation of lamina 2
x11: Orientation of lamina 3
x12: Orientation of lamina 4
x13: Orientation of lamina 5
x14: Orientation of lamina 6
x15: Orientation of lamina 7
x16: Orientation of lamina 8
 $-90. < x_i < 90.$

Variable Linking

x2, x3, ..., x8 = x1
x15 = x9
x10, x16 = -1.0 * x9
x13 = x11
x12, x14 = -1.0 * x11



Design Objective

r0: Minimize weight

Design Constraints

r1: Failure index of lamina 1 of element 1
...
r8: Failure index of lamina 8 of element 1

$$r1, \dots, r8 < .9$$

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

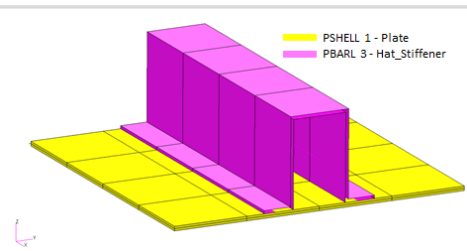
1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
 - Configure Global Optimization
 - Perform optimization with Nastran SOL 200

SOL 200 Web App Capabilities

Benefits

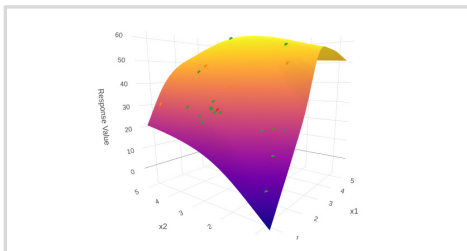
- 200+ error validations (real time)
- Web browser accessible
- Automated creation of entries (real time)
- Automatic post-processing
- 76 tutorials

Capabilities



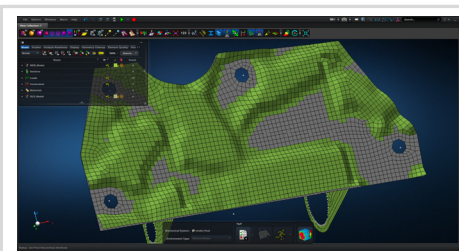
Web Apps for SOL 200

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



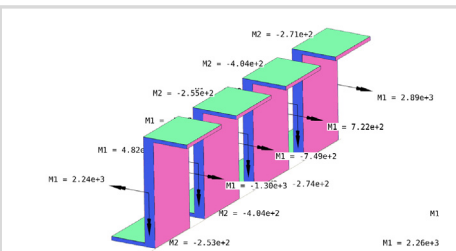
Machine Learning Web App

Bayesian Optimization for nonlinear response optimization (SOL 400)



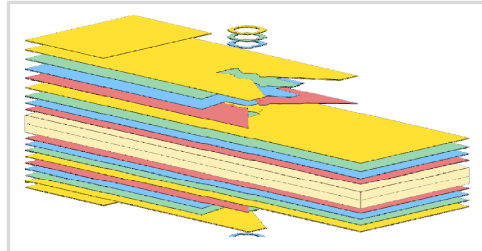
MSC Apex Post Processing Support

View the newly optimized model after an optimization



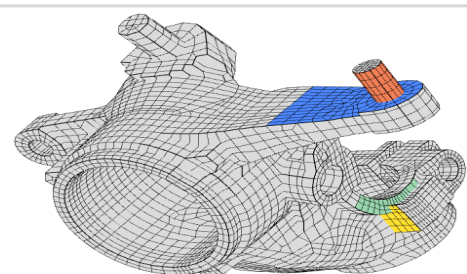
Beams Viewer Web App

Post process 1D element forces, including shear forces, moments, torque and axial forces



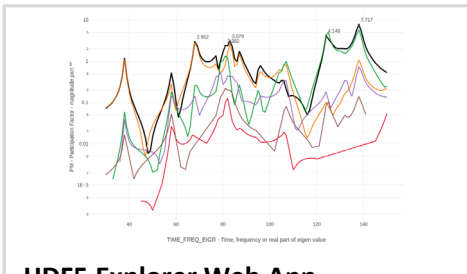
Ply Shape Optimization Web App

Spread plies optimally and generate new PCOMPG entries



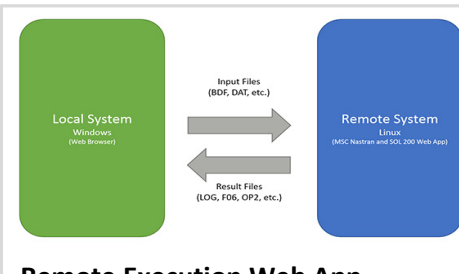
Shape Optimization Web App

Use a web application to configure and perform shape optimization.



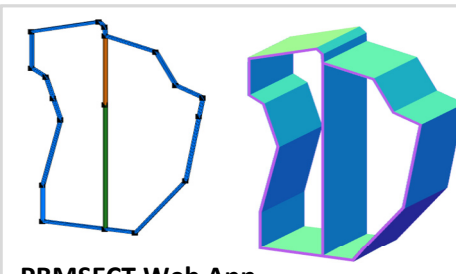
HDF5 Explorer Web App

Create XY plots using data from the H5 file



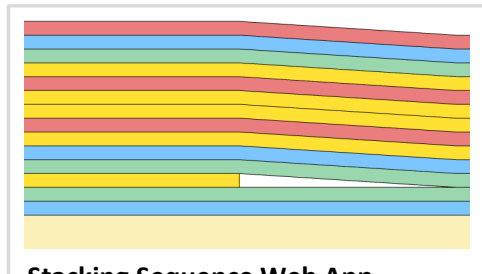
Remote Execution Web App

Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



PBMSECT Web App

Generate PBMSECT and PBRSECT entries graphically



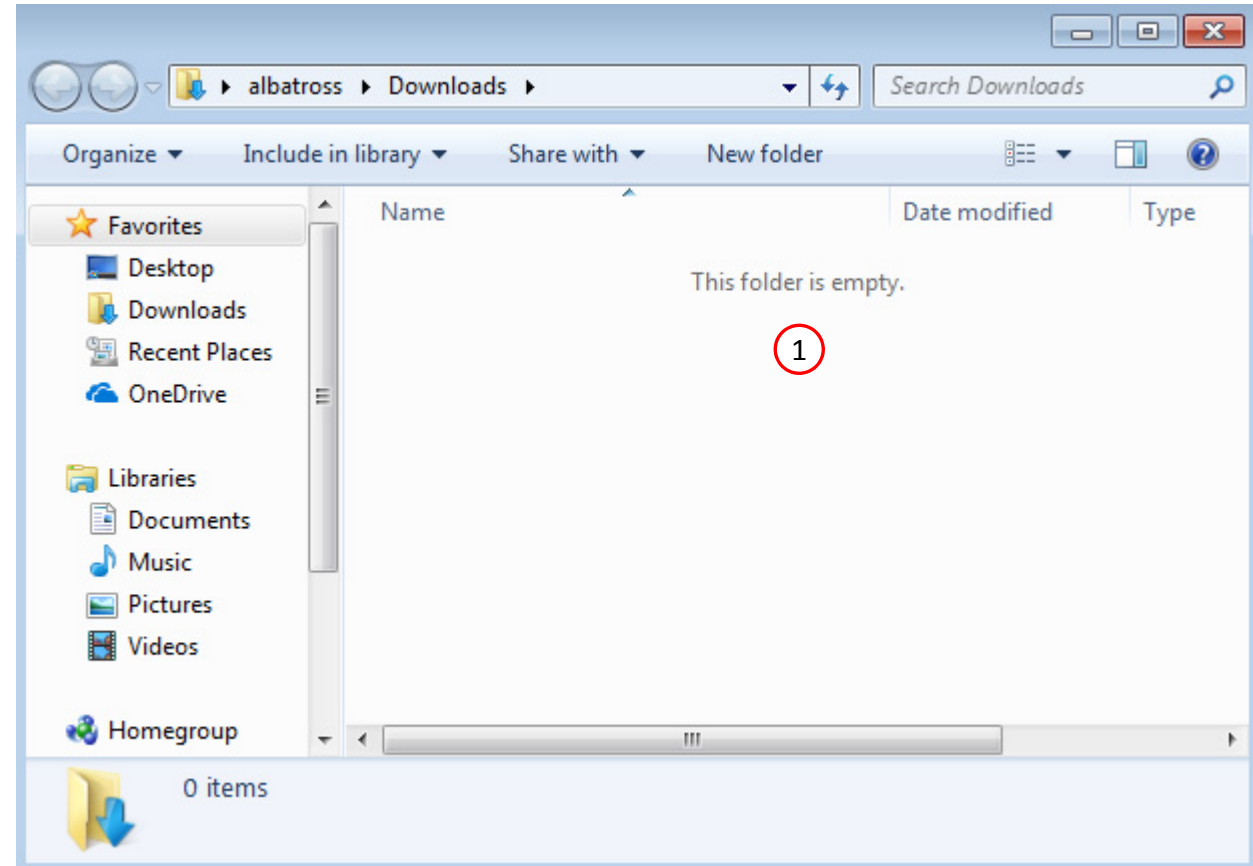
Stacking Sequence Web App

Optimize the stacking sequence of composite laminate plies

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

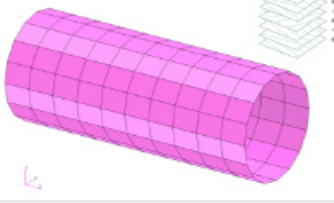
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.



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.



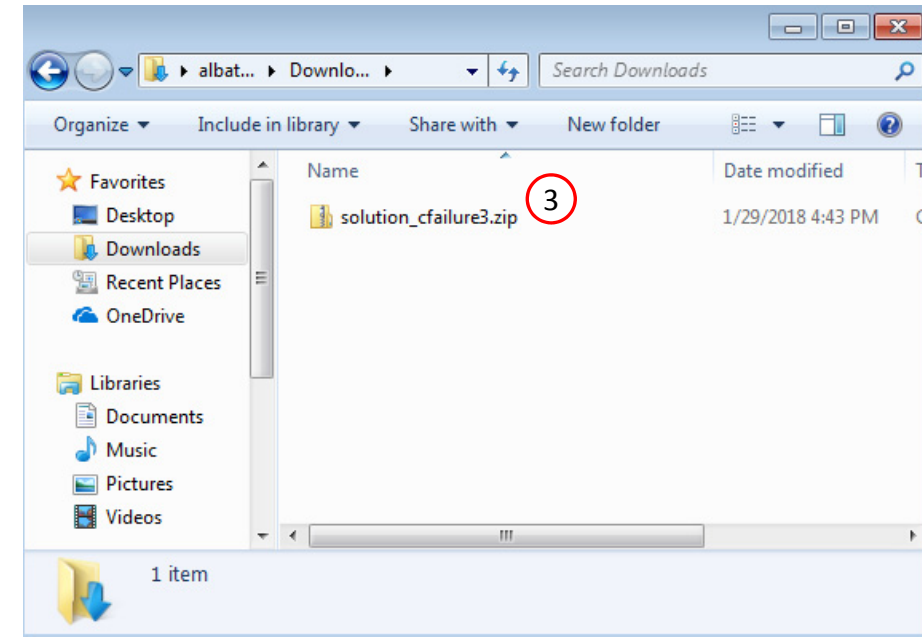
1 Global Optimization

This examples demonstrates the procedure of performing a Global Optimization with MSC Nastran SOL 200.

Often, optimization problems have multiple local minimas, or maximas, when starting from different initial design variables. In order to find the global optimum, multiple local optimizations must be performed, then the best of the local optimizations is taken to be global optimum. This process can be performed with the Global Optimization capability available in MSC Nastran SOL 200.

Starting BDF Files: [Link](#)

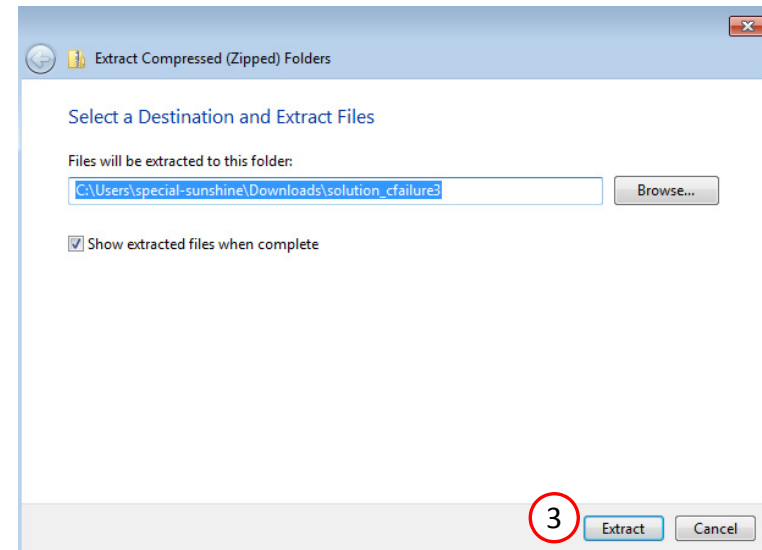
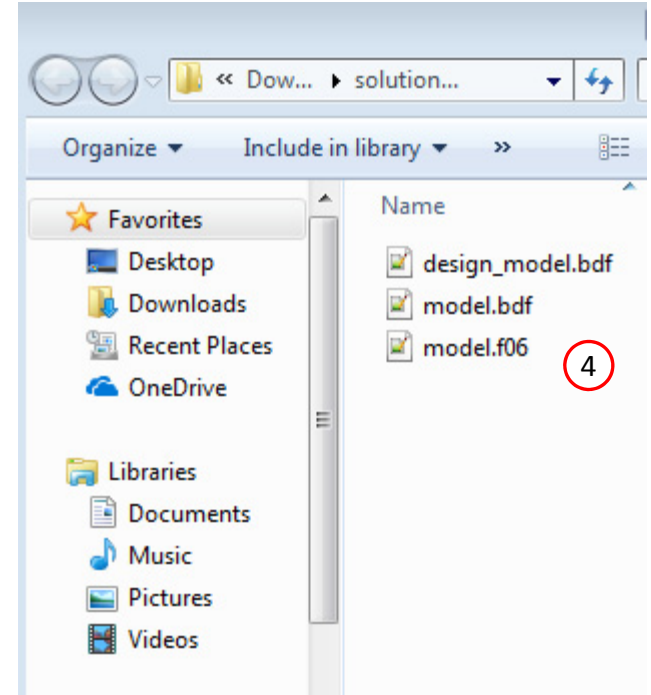
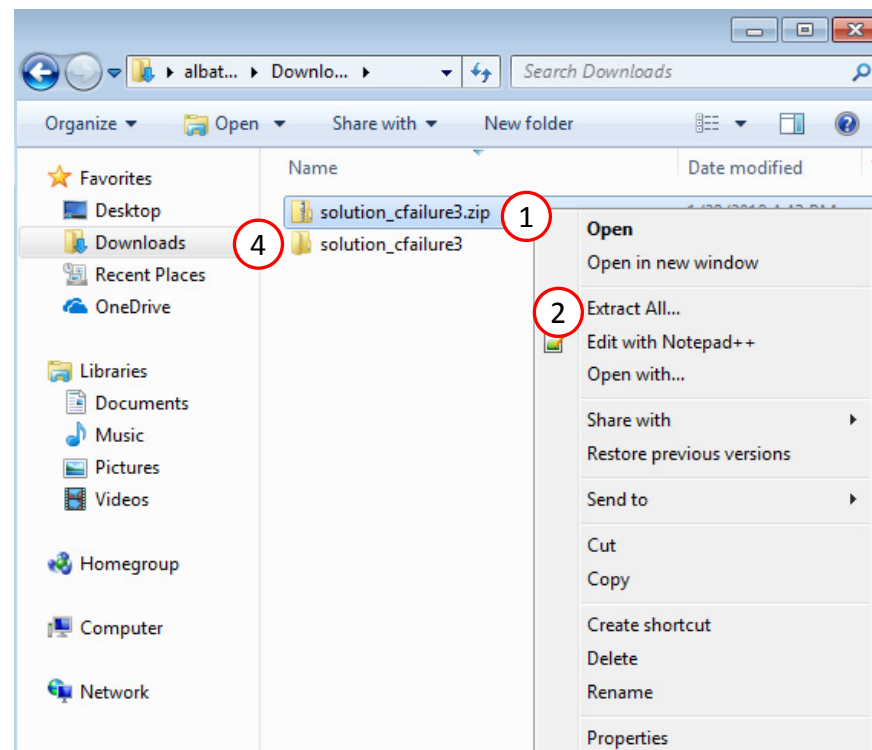
Solution BDF Files: [Link](#)



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.

The screenshot displays the SOL 200 Web App interface. At the top, it says "SOL 200 Web App" and "Select a web app to begin". Below this, there are five main categories of web apps, each with a representative image:

- Optimization for SOL 200**: Shows a 3D model of a mechanical part with "Before" and "After" states. A red circle with the number "1" is placed over this icon.
- Multi Model Optimization**: Shows a 3D model and a line graph.
- Machine Learning | Parameter Study**: Shows four small plots representing different data sets or models.
- HDF5 Explorer**: Shows a line graph with multiple colored curves.
- Remote Execution**: Shows a diagram of data flow between a "Remote System" and a "Local System", with "Input Files" going up and "Results Files" going down.

At the bottom of the interface, there are two links: "Tutorials and User's Guide" and "Full list of web apps".

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 BDF files. Step 1, '1. Select files', is highlighted with a blue bar and shows '2 files selected'. Below it is a green progress bar labeled 'Inspecting: 100%'. Step 2, '2. Upload files', is highlighted with a green bar. Below it is another green progress bar labeled 'Uploading: 100 %'. At the bottom, there is a checkbox labeled 'List of Selected Files' which is currently unchecked.

1. Select files 2 files selected

Inspecting: 100%

2. Upload files

Uploading: 100 %

☐ List of Selected Files

Export New BDF Files

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

- When the download button is clicked a new file named "nastran_working_directory" is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. "nastran_working_directory (1).zip"

SOL 200 Web App - Optimization

UploadVariablesObjectiveConstraintsSubcasesExporterResults

SettingsMatchOtherUser's GuideHome

1

BDF Output - Model

```
$ NASTRAN input file created by the Patran 2013.0.2 input file
$ translator on February 08, 2017 at 15:12:27.
$ Direct Text Input for Nastran System Cell Section
$ Direct Text Input for File Management Section
$ Direct Text Input for Executive Control
$ Linear Static Analysis, Database
SOL 200
CEND

$ Direct Text Input for Global Case Control Data
TITLE = HSC,Nastran job created on 08-Feb-17 at 14:28:39
ECHO = NONE
DESOBJ(MIN) = 8000000
$ DESGLB Slot
$ DSAPRT(FORMATTED, EXPORT, ENH=SENS) = ALL
SUBCASE 1
ANALYSIS = STATICS
DESSUB = 400000001
$ DRSPAN Slot
SUBTITLE=Default
SPC = 2
LOAD = 2
DISPLACEMENT(SORT1,REAL)=ALL
SPCFORCES(SORT1,REAL)=ALL
STRESS(SORT1,REAL,VONMISES,CENTER)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
INCLUDE './design.model.bdf'
```

Download BDF Files

2

BDF Output - Design Model

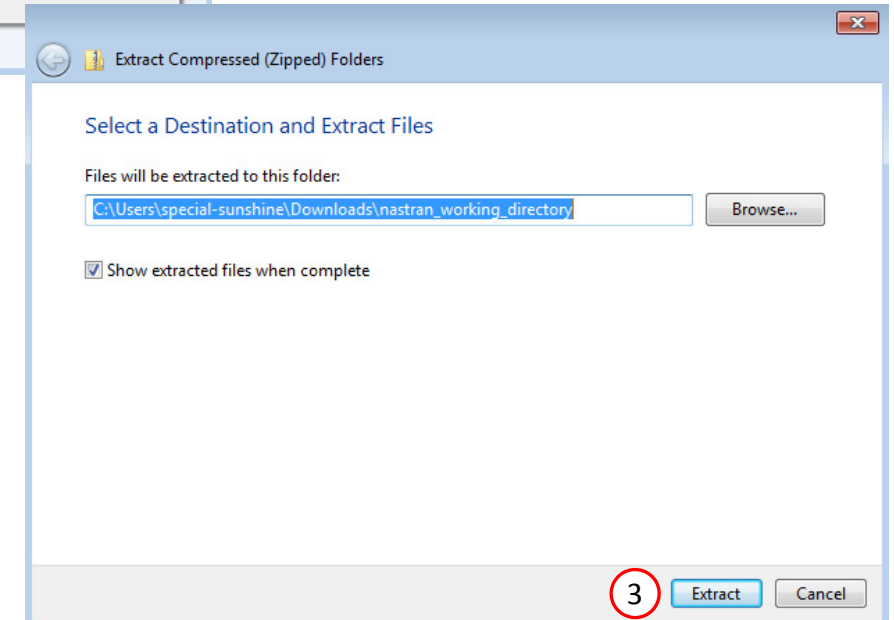
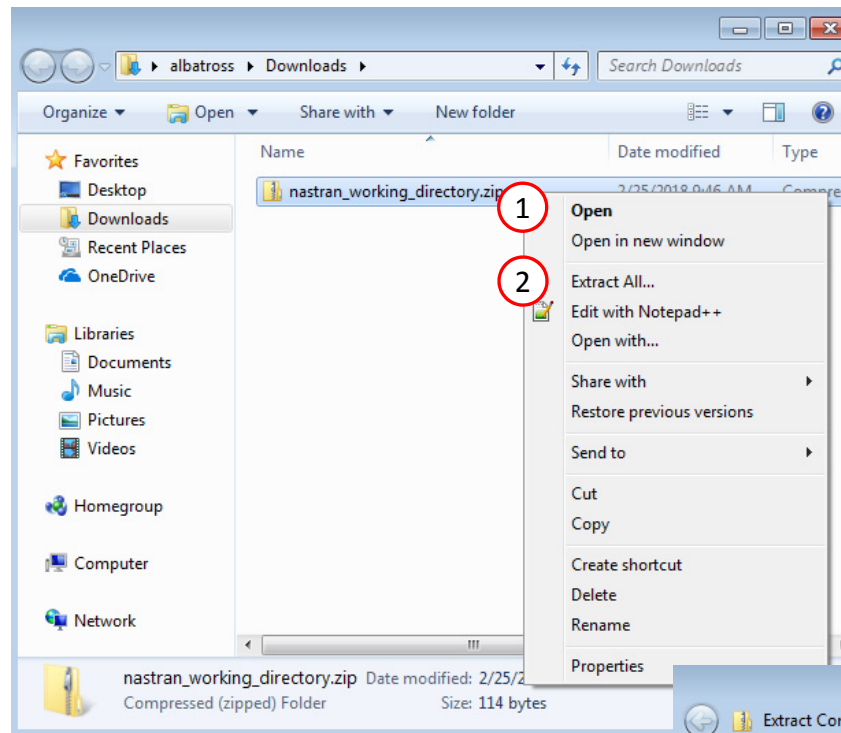
```
$*****
$*
$*                               Design Model
$*
$*****
$
$                               Design Variables - Type 1
$-----
$
$
DVPREL1 1000001 PCOMP 1 T1
100001 1.0
DVPREL1 1000002 PCOMP 1 T2
100002 1.0
DVPREL1 1000003 PCOMP 1 T3
100003 1.0
DVPREL1 1000004 PCOMP 1 T4
100004 1.0
DVPREL1 1000005 PCOMP 1 T5
100005 1.0
DVPREL1 1000006 PCOMP 1 T6
100006 1.0
DVPREL1 1000007 PCOMP 1 T7
100007 1.0
DVPREL1 1000008 PCOMP 1 T8
100008 1.0
DVPREL1 1000009 PCOMP 1 THETA1
100009 1.0
DVPREL1 1000010 PCOMP 1 THETA2
100010 1.0
DVPREL1 1000011 PCOMP 1 THETA3
100011 1.0
DVPREL1 1000012 PCOMP 1 THETA4
100012 1.0
DVPREL1 1000013 PCOMP 1 THETA5
100013 1.0
DVPREL1 1000014 PCOMP 1 THETA6
100014 1.0
DVPREL1 1000015 PCOMP 1 THETA7
100015 1.0
DVPREL1 1000016 PCOMP 1 THETA8
100016 1.0
```

Developed by The Engineering Lab

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.

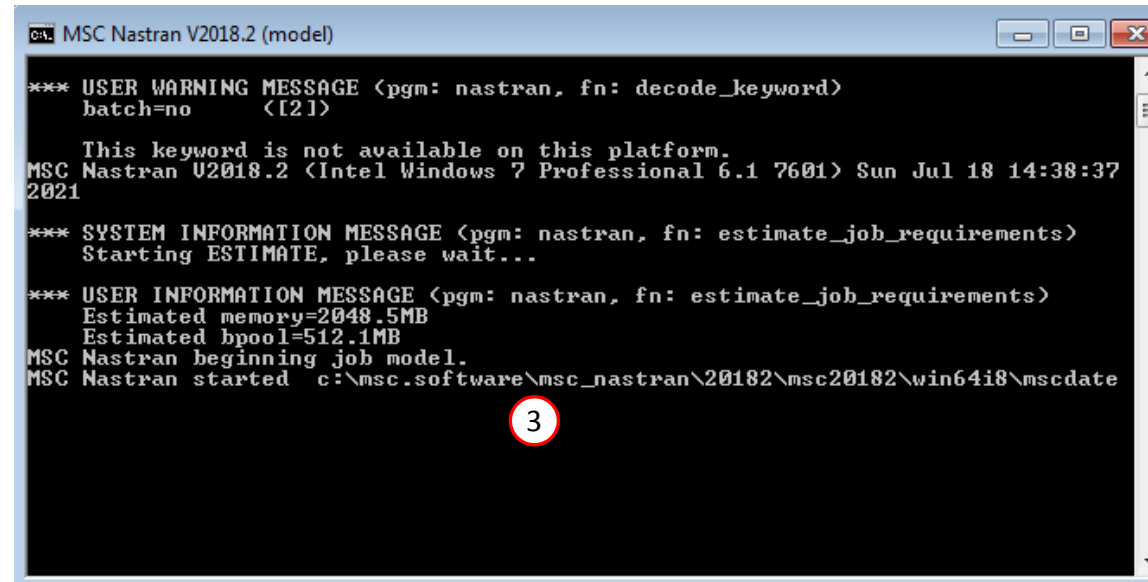
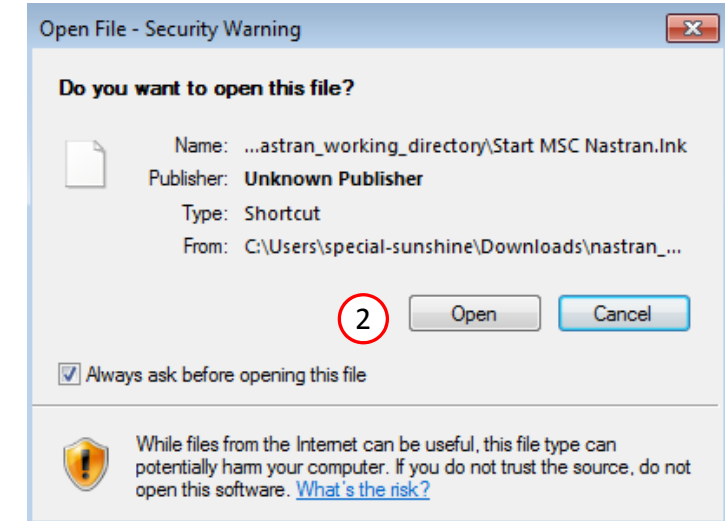
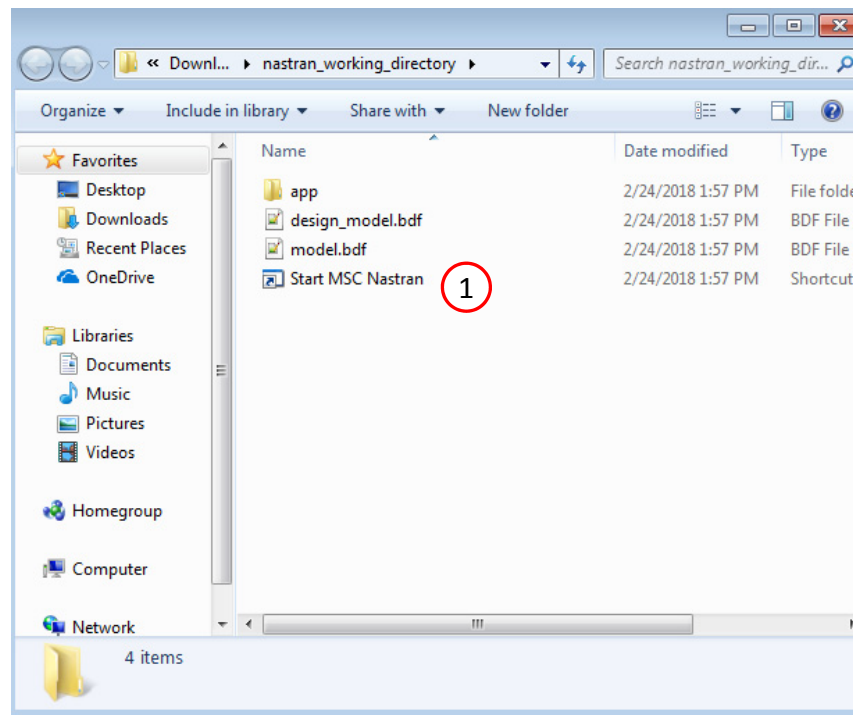
Using Linux?

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. The Final Message found in the multipt.log file provides information regarding the global minimum or maximum

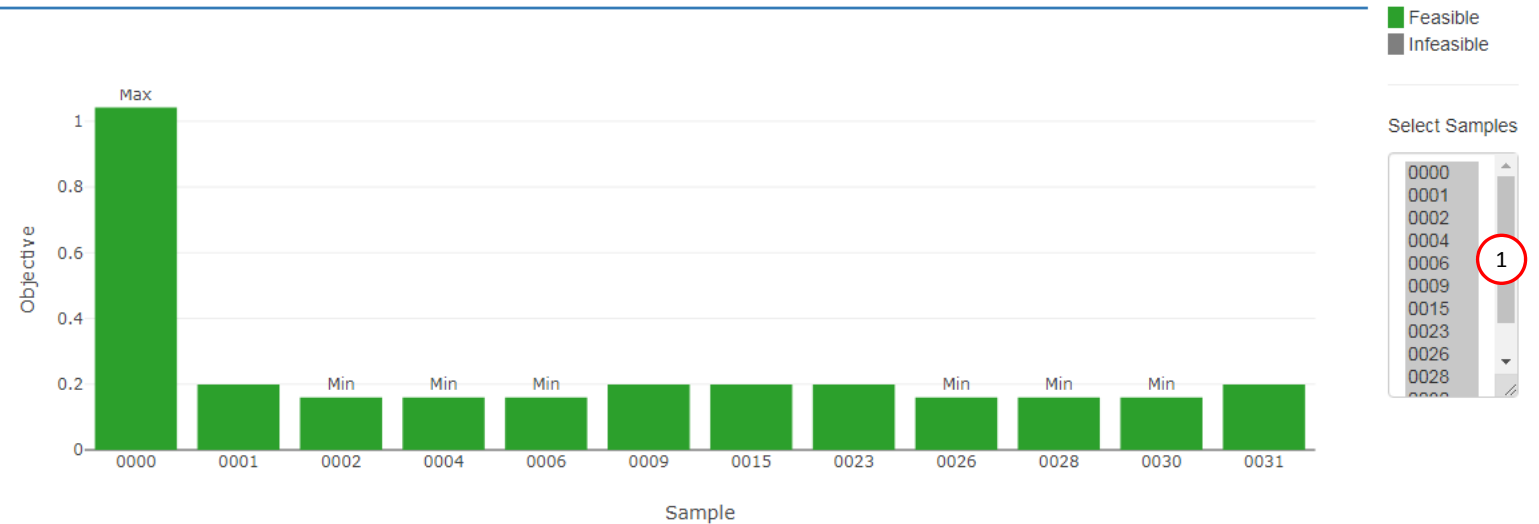
- The Global Optimization has performed multiple local optimizations and are labeled by different Sample numbers. Out of all the local optimizations performed or samples, the global optimum is the better of all. The sample that is the global optimum is reported in the section Final Message in multipt.log. The sample and its respective objective and variables are listed in the bar chart and table.

Final Message in multipt.log

THE GLOBAL SOLUTION IS: LOCAL OPTIMIZATION SAMPLE # 2
OBJECTIVE = 1.5982E-01,
MAXIMUM CONSTRAINT VALUE = -1.2455E-01 (A FEASIBLE SOLUTION).

2

Objective for Each Sample



Data for Each Sample

Item	Sample 0000	Sample 0001	Sample 0002	Sample 0004	Sample 0006	Sample 0009	Sample 0015	Sample 0023	Sample 0026
Extrema (Max/Min)	Max		Min	Min	Min				Min
Objective	1.0421E+00	1.9938E-01	1.5982E-01	1.5982E-01	1.5982E-01	1.9938E-01	1.9938E-01	1.9938E-01	1.5982E-01
Normalized Constraint	-1.8746E-04	-3.6671E-02	-1.2455E-01	-1.2455E-01	-1.2455E-01	-3.6671E-02	-3.5109E-01	-3.5109E-01	-1.2455E-01
X1	6.5204E-03	1.2475E-03	1.0000E-03	1.0000E-03	1.0000E-03	1.2475E-03	1.2476E-03	1.2476E-03	1.0000E-03
X9	9.0000E+01	5.0000E+00	0.0000E+00	0.0000E+00	5.0000E+00	5.0000E+00	-5.0000E+00	-5.0000E+00	0.0000E+00
X11	0.0000E+00	1.0000E+01	5.0000E+00	5.0000E+00	0.0000E+00	1.0000E+01	-5.0000E+00	-5.0000E+00	5.0000E+00

End of Tutorial