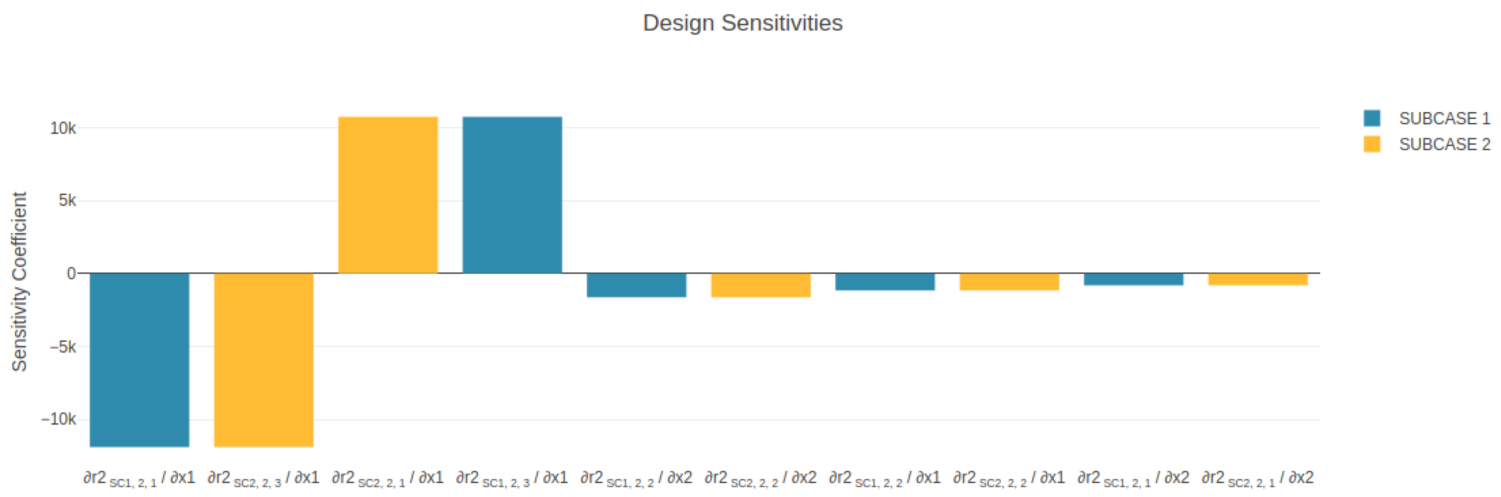
Workshop - Structural Optimization of a 3 Bar Truss, Sensitivity Analysis

AN MSC NASTRAN SOL 200 TUTORIAL

Goal: Perform a Sensitivity Analysis

Sensitivities



Select a response

r0
r1
r2

Select a design variable

x1
x2

Select a SUBCASE

All Subcases
SUBCASE 1
SUBCASE 2

Details of the Structural Model

Three-Bar Truss

A common task in design optimization is to reduce the mass of a structure subjected to several load conditions. Figure 8-1 shows a simple three-bar truss that must be built to withstand two separate loading conditions. Note that these two loads subject the outer truss members to both compressive as well as tensile loads. Due to the loading symmetry, we expect the design to be symmetric as well. As an exercise, we'll show how to enforce this symmetry using design variable linking.

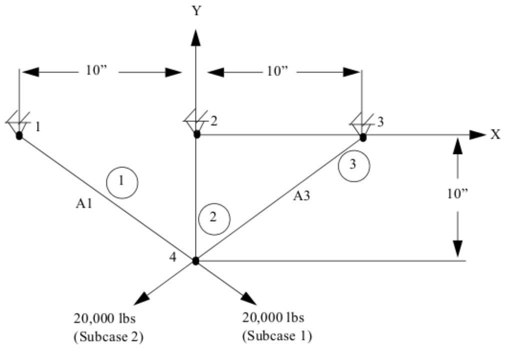
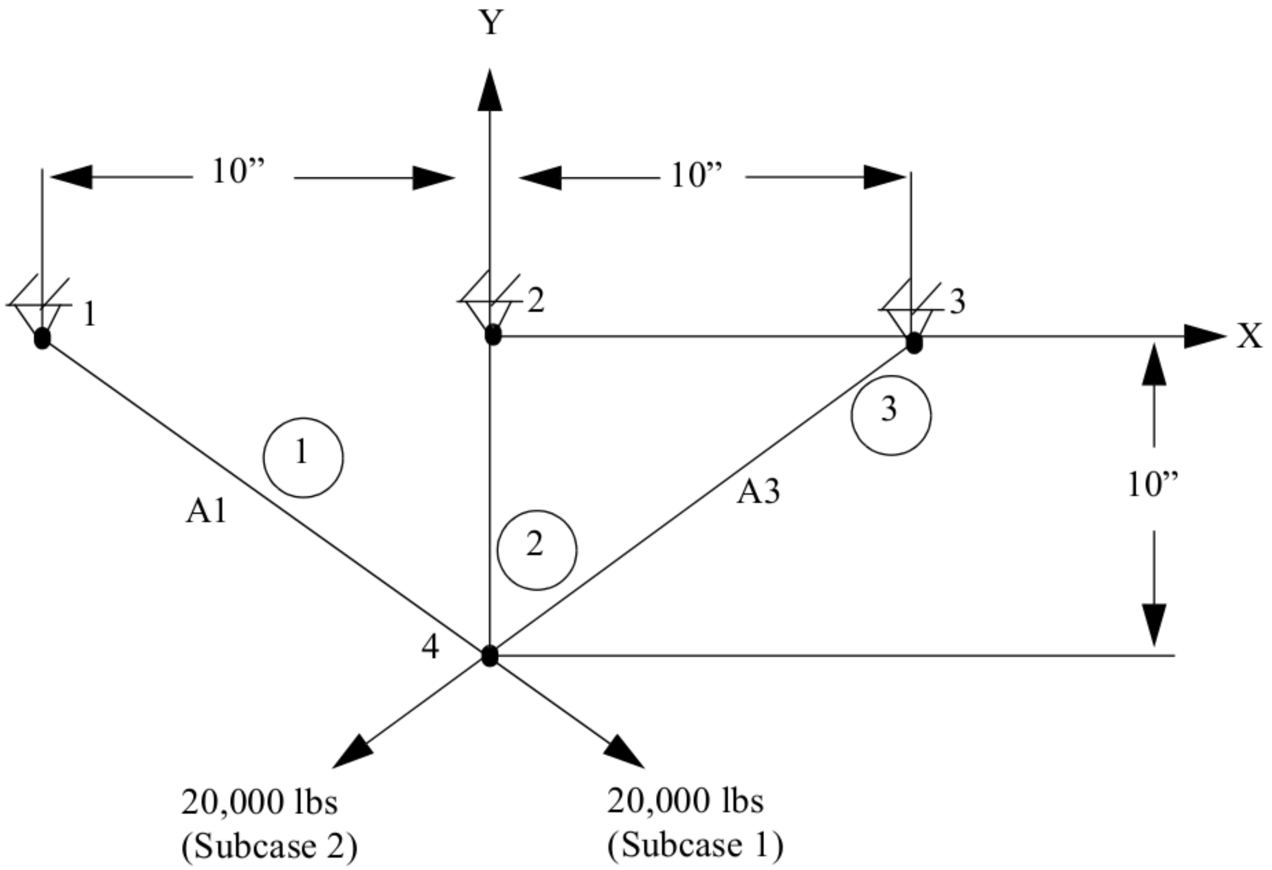


Figure 8-1 Three-Bar Truss

An important, but often overlooked consideration is that the optimization capability in MSC Nastran is multidisciplinary. That is, the final optimal design is the result of a simultaneous consideration of all analysis disciplines across all subcases. In this case, the optimal three-bar truss design will satisfy the load requirements for both statics subcases, which is to be expected. (If, for example, a normal modes or buckling subcase were to be added, the resultant design would have to not only satisfy the static strength requirements, but also constraints on eigenvalues. As an exercise you may wish to try adding an eigenvalue constraint.)

MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Three Bar Truss



Optimization Problem Statement

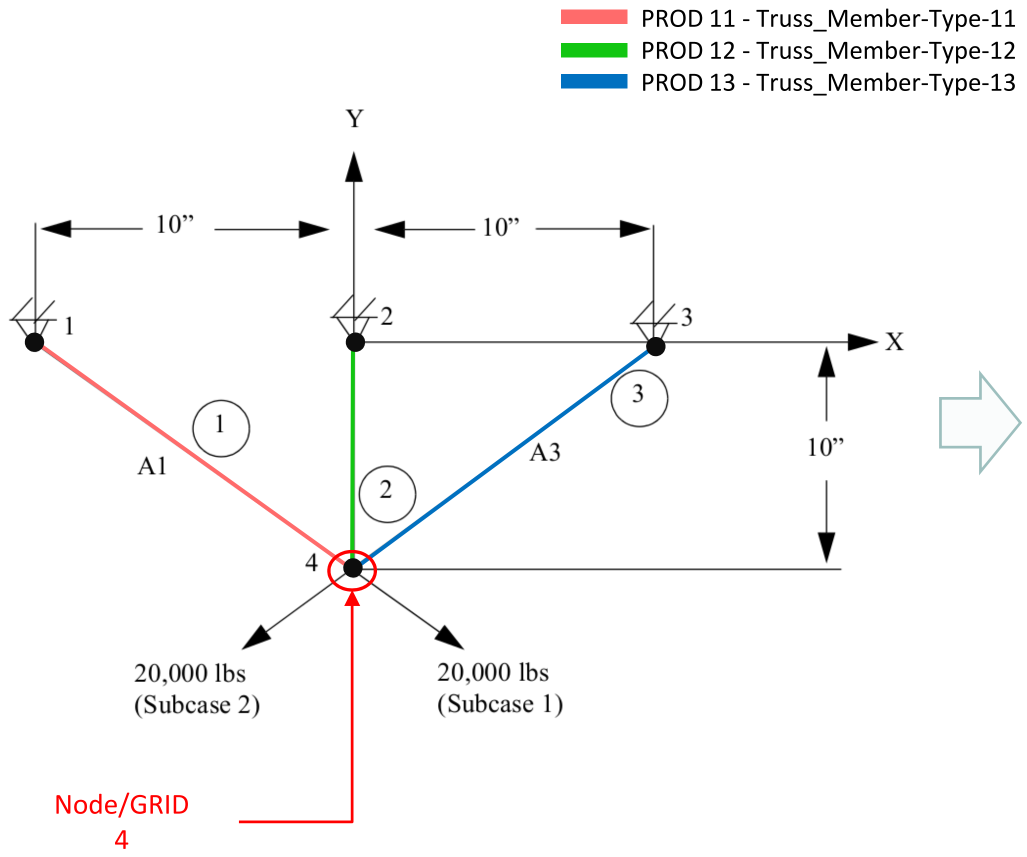
Design Variables

x1: A of PROD 11
x2: A of PROD 12
x3: A of PROD 13

.1 < x1, x2, x3 < 100.

Variable Link

x3 = x1



Design Objective

r0: Minimize weight

Design Constraints

r1: Axial stress of elements related to PROD 11, 12, 13

-15000 < r1 < 20000

r2: x and y component of displacement for node 4

-.2 < r2 < .2

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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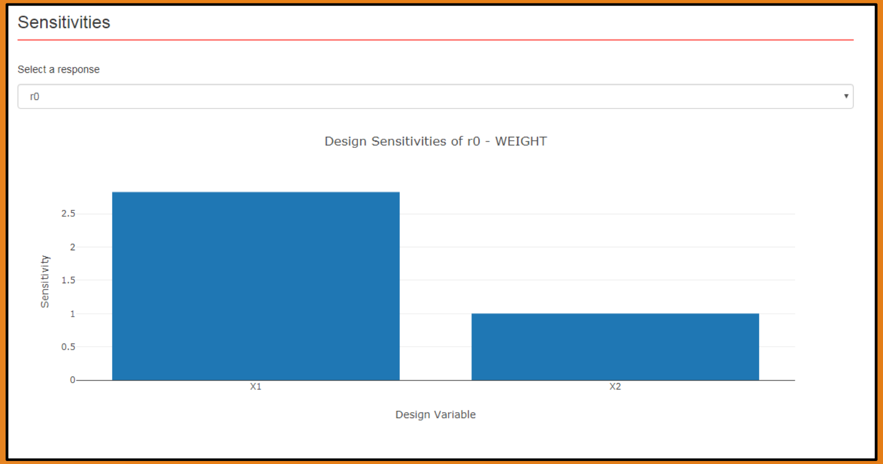
Tutorial

Tutorial Overview

1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Import a previously created SOL 200 BDF files
   - Set the web app to perform a sensitivity analysis
   - Perform sensitivity analysis with Nastran SOL 200
3. Plot the Sensitivities

Special Topics Covered

Automatic Plots - After a sensitivity analysis is complete and result files are created, the sensitivities may be automatically plotted by the Nastran Web App. This tutorial describes how to create these plots.



SOL 200 Web App Capabilities

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

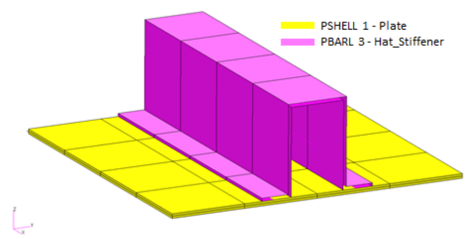
Compatibility

- 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.

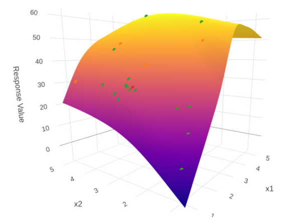
Benefits

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

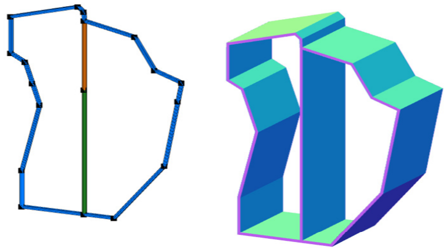
Web Apps



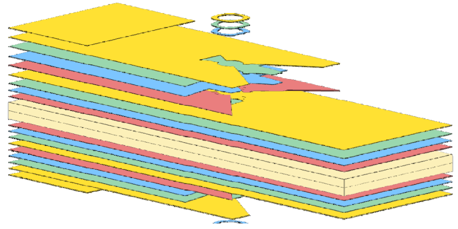
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



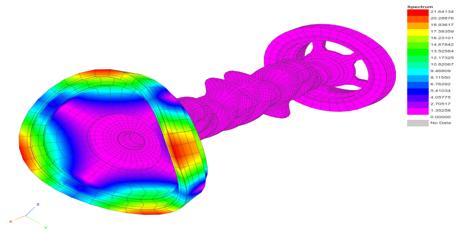
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



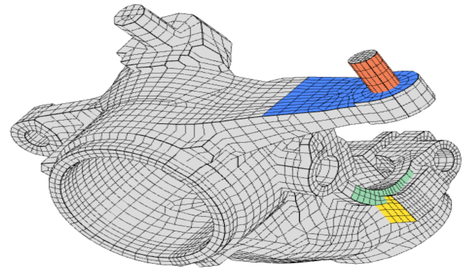
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



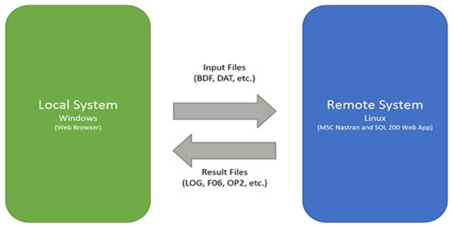
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



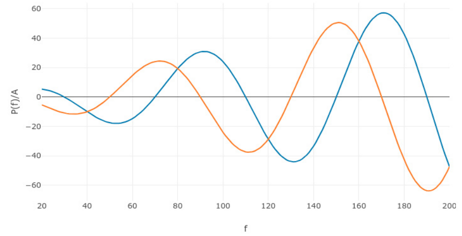
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



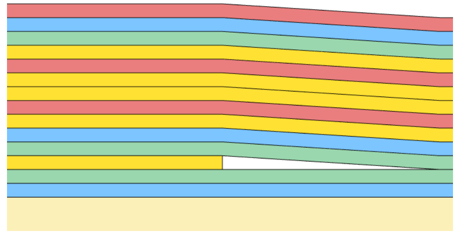
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



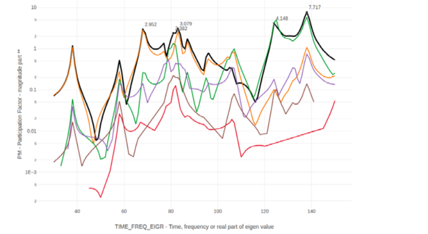
Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



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



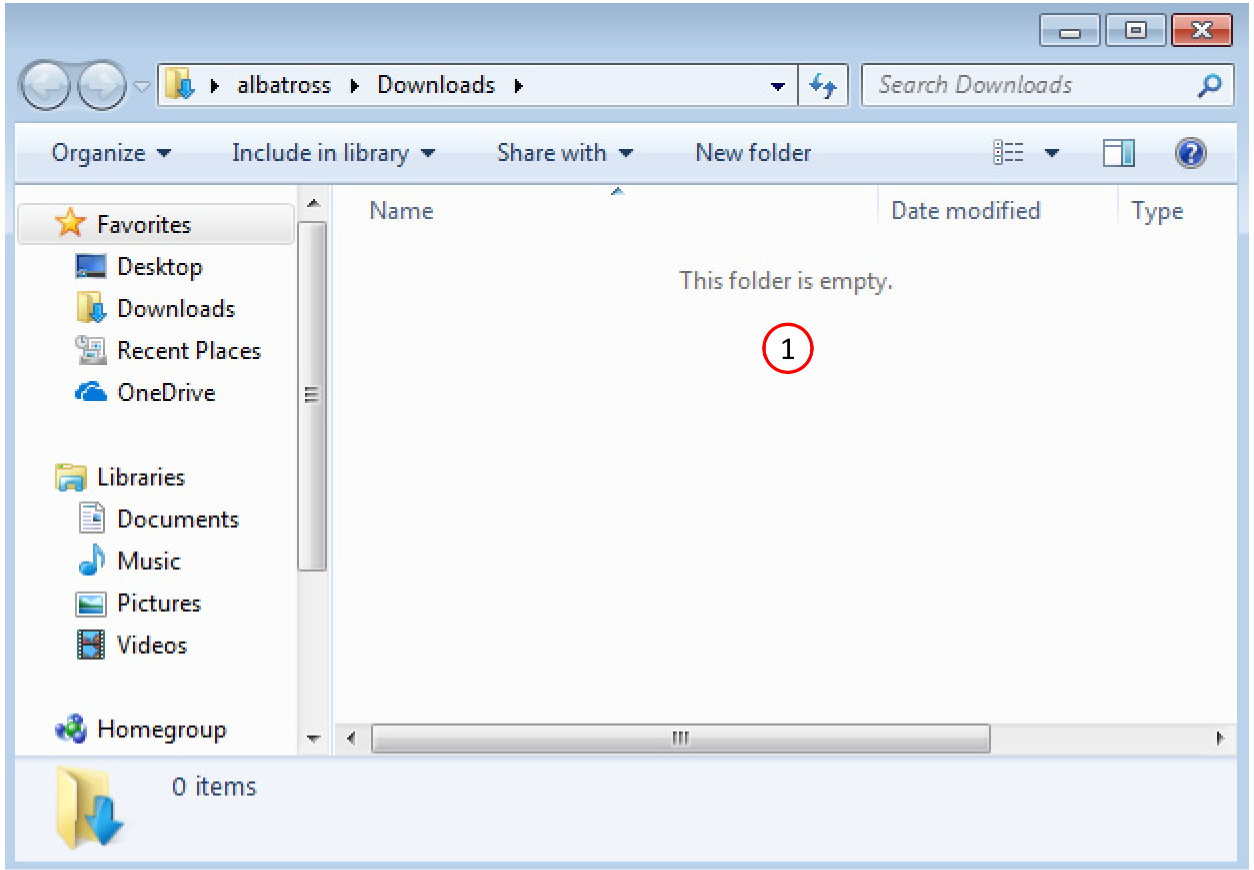
Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies



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

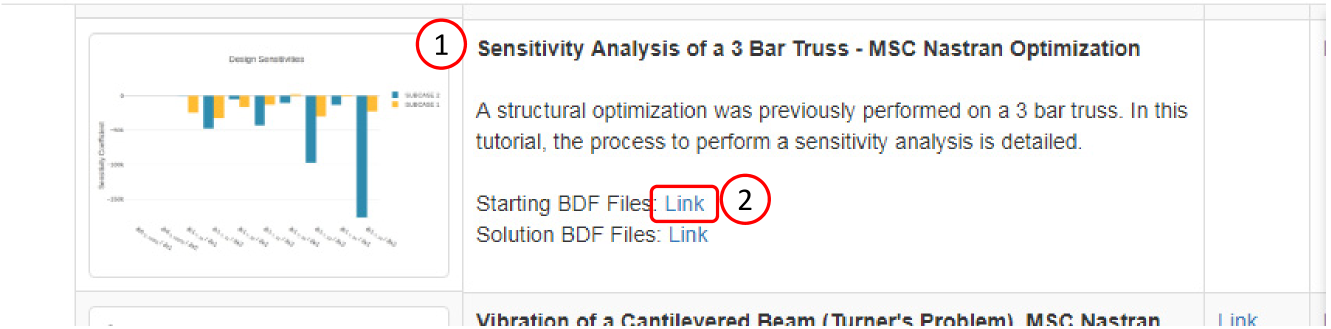
1. Click on the indicated link

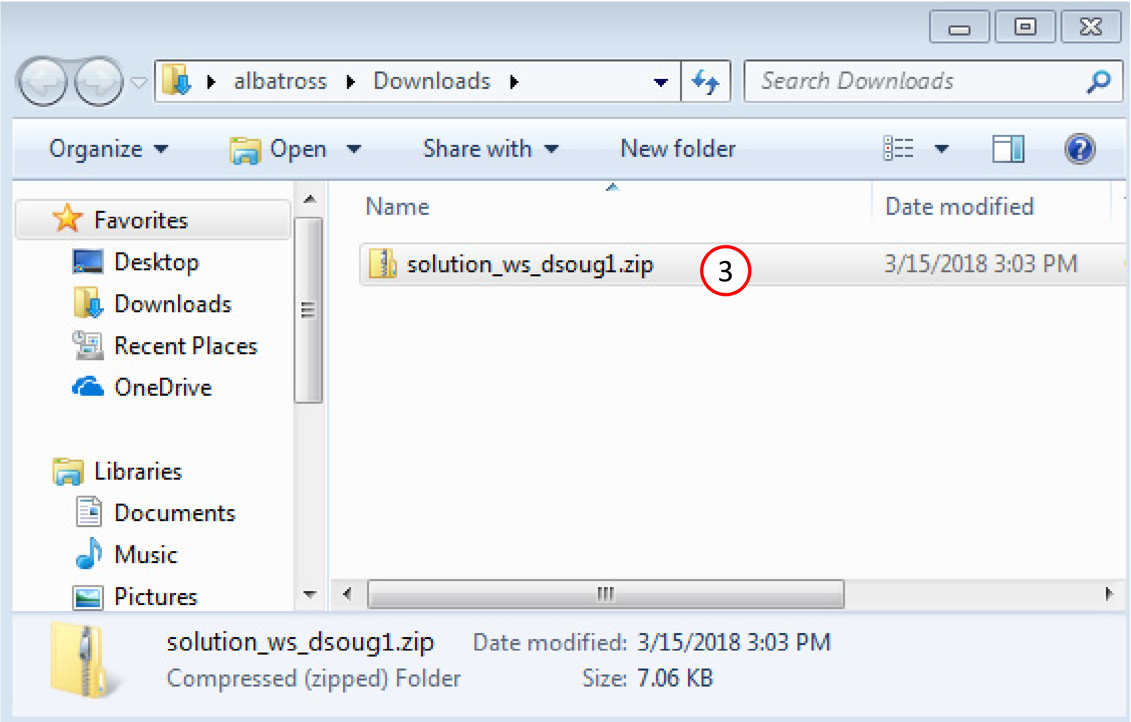
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

The Engineering Lab

Obtain Starting Files

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



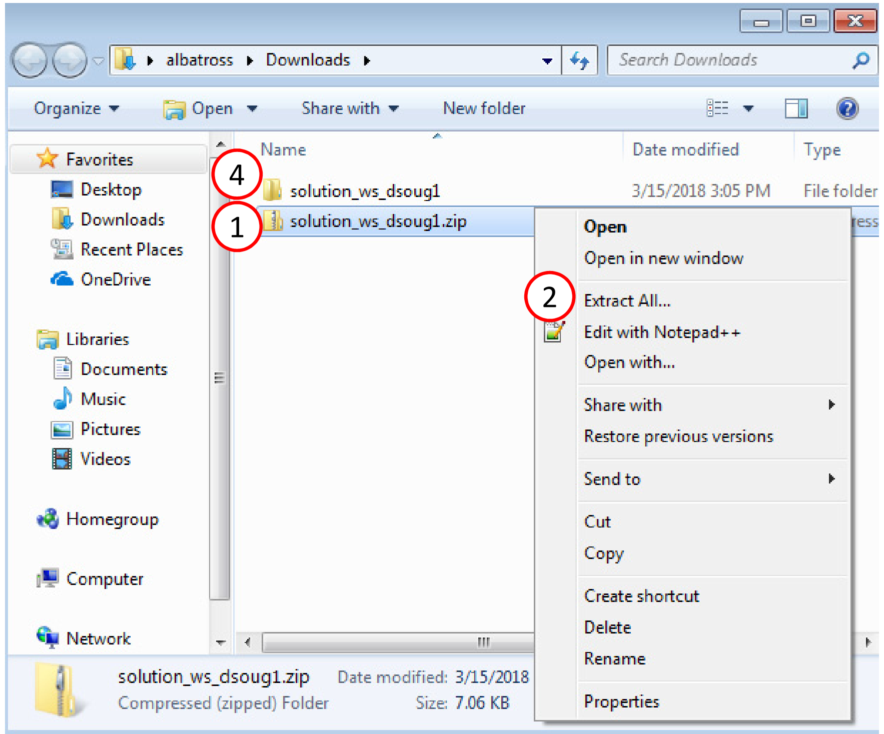


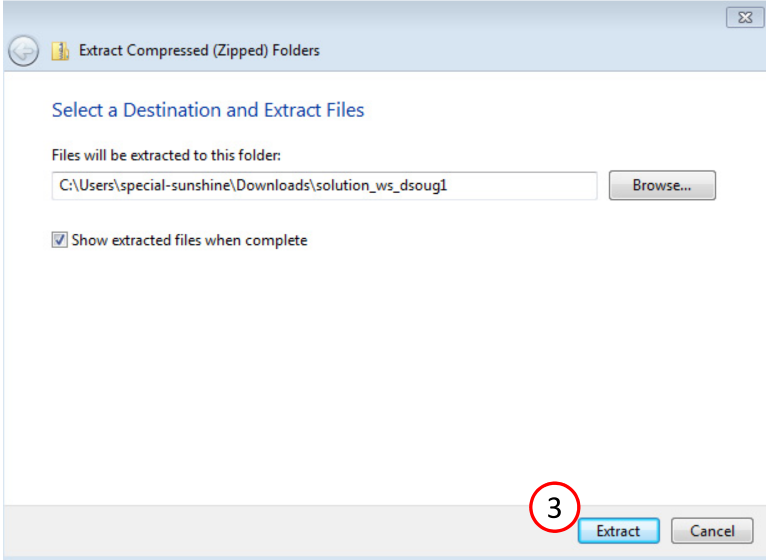
- When starting the procedure, all the necessary BDF files must be collected together.

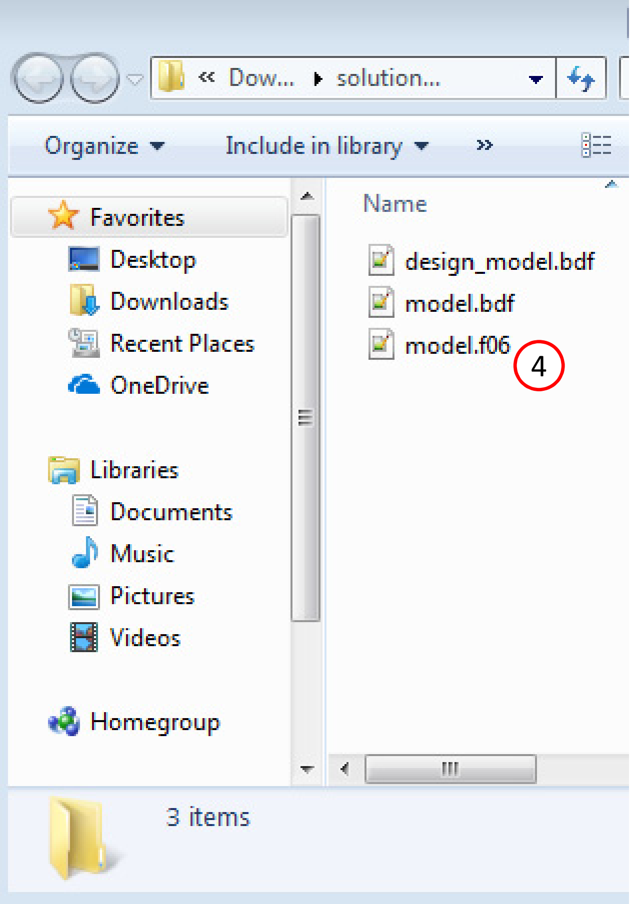
Obtain Starting Files

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.



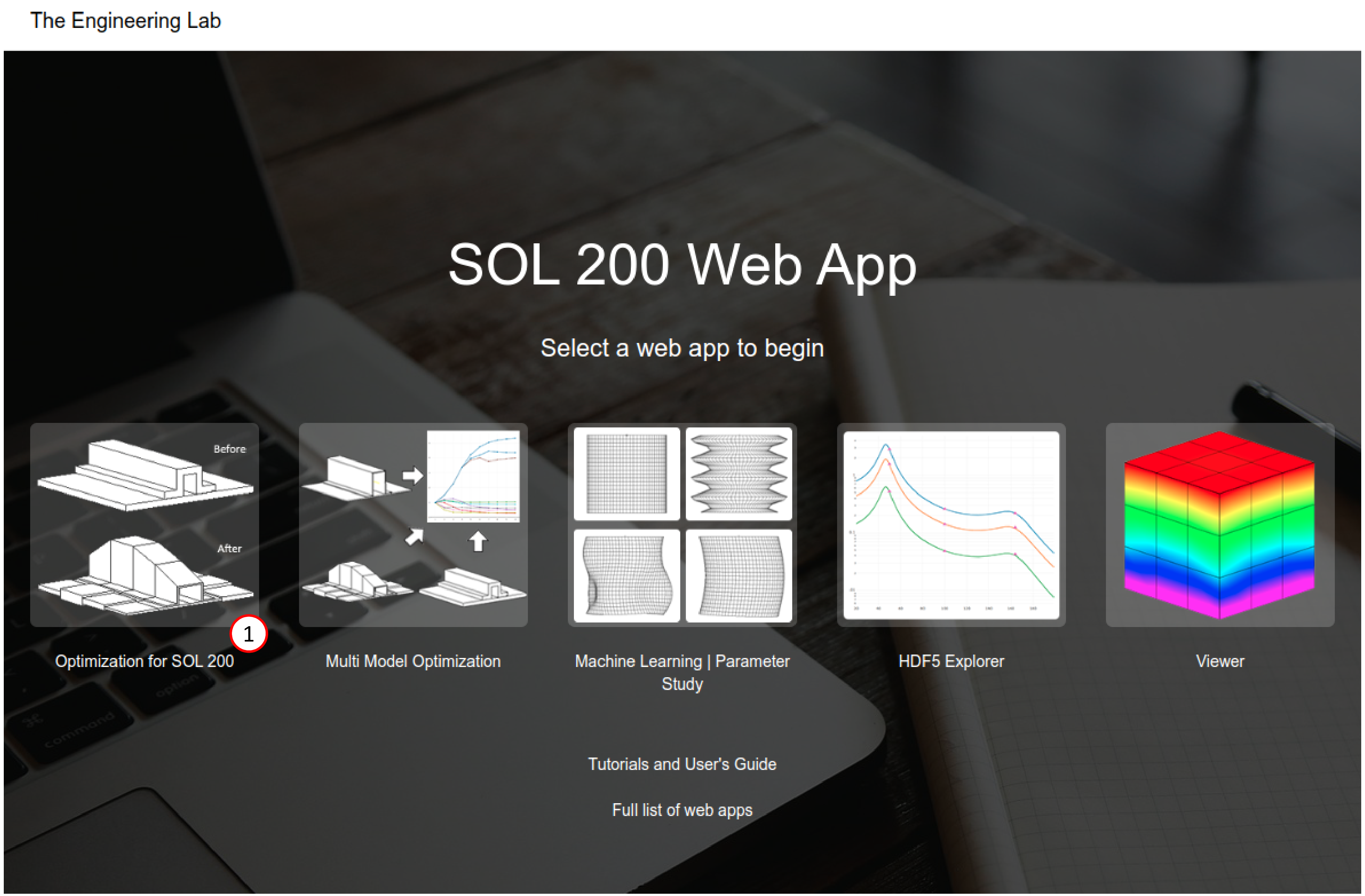




Open the Correct Page

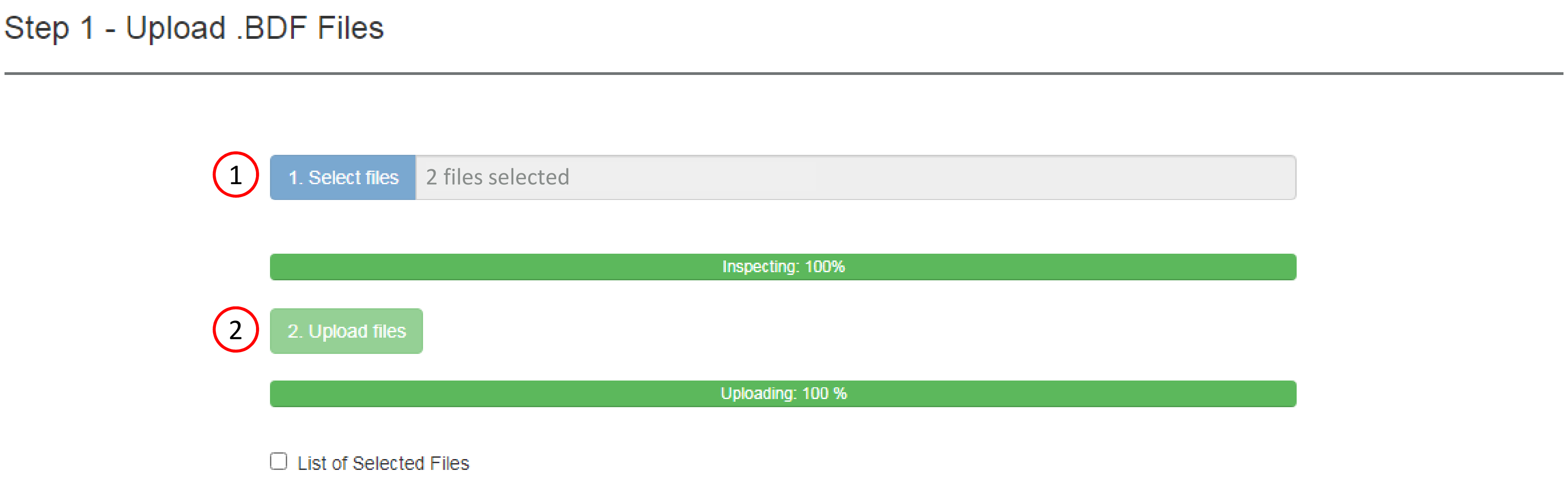
1. Click on the indicated link

- 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

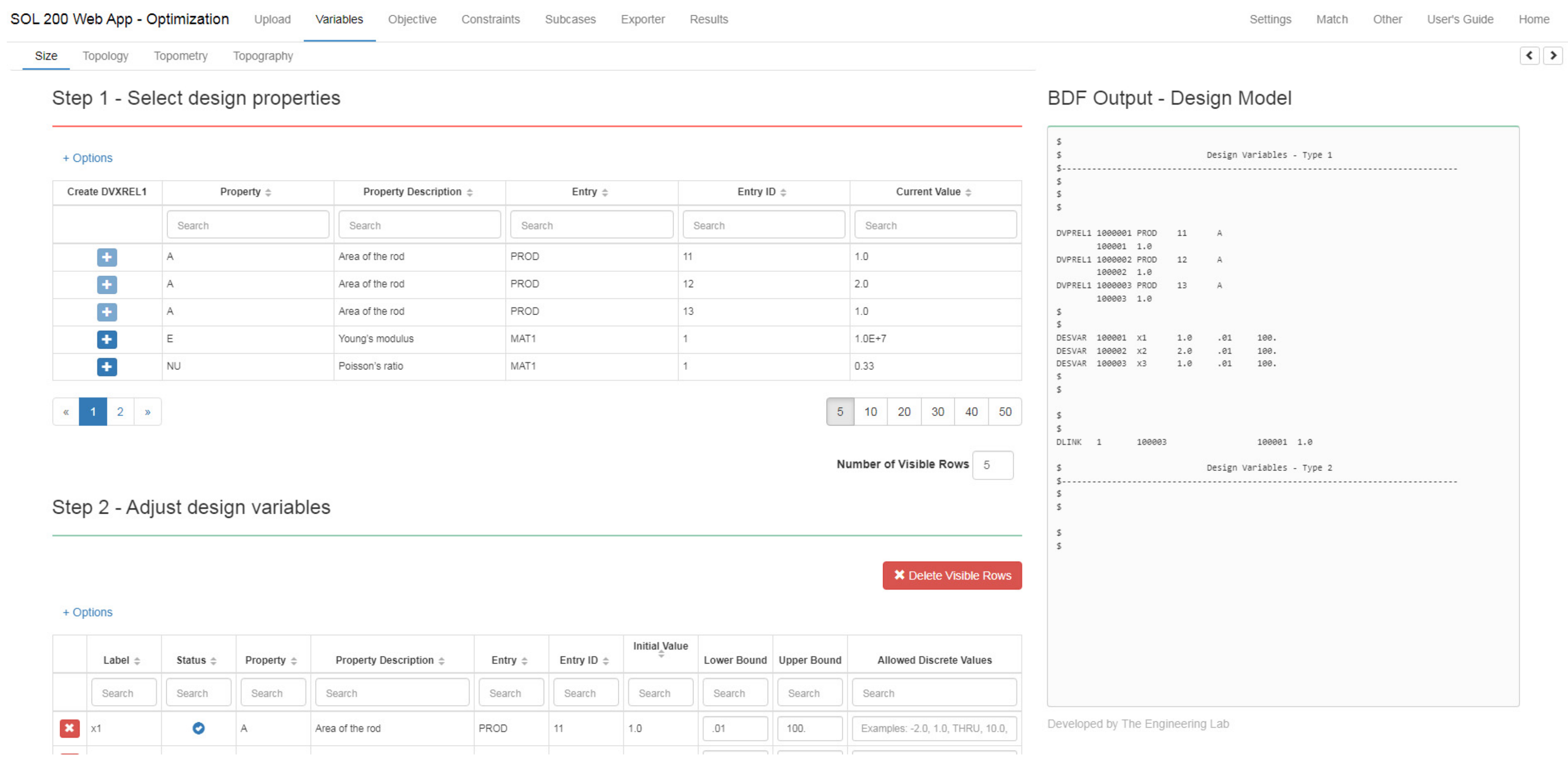
1. Click 1. Select Files and select model.bdf and design_model.bdf
2. Click Upload Files



- 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.

Model Has Been Imported

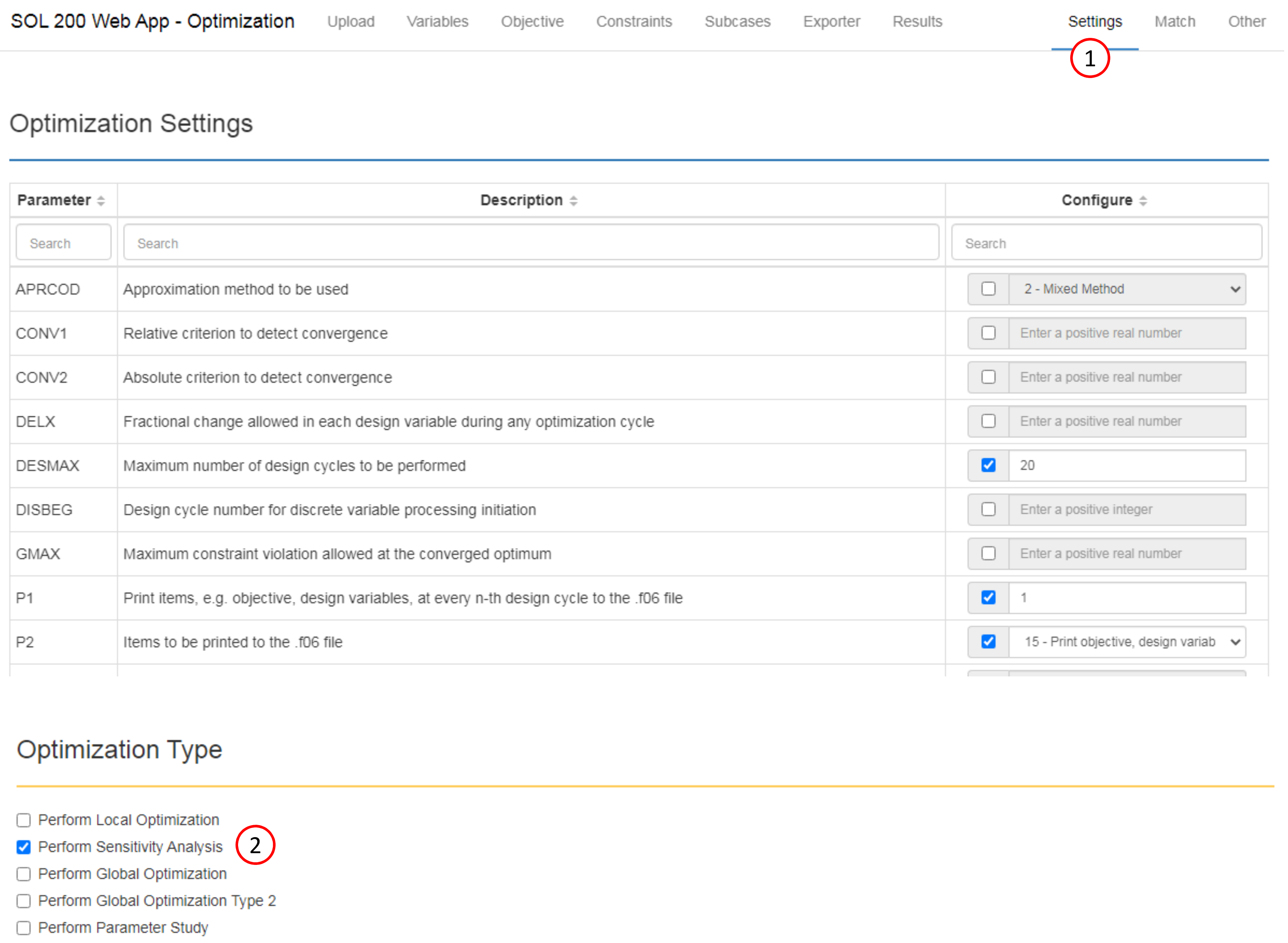
1. Previously created SOL 200 BDF files have been imported to the web app and may be modified.



- 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.

Configure Settings

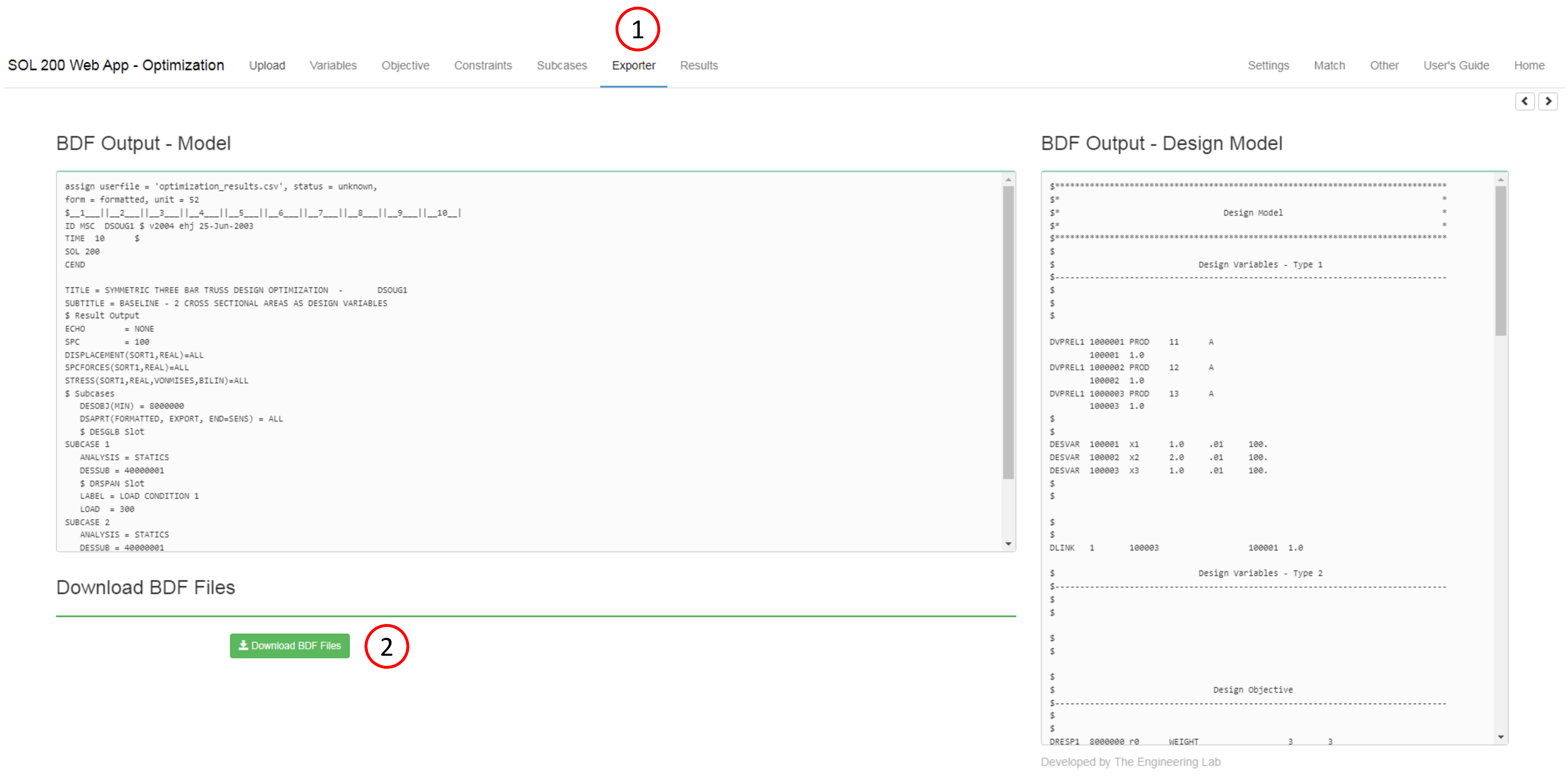
1. At the top right hand corner, click on Settings
2. Mark the checkbox labeled Perform Sensitivity Analysis



- Sensitivity analysis computes the gradients or partial derivatives of responses with respect to design variables. For example, if the sensitivity of weight with respect to x1 is -200., then a change of 1.0 in x1 yields a change of -200 in the weight.

Export New BDF Files

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

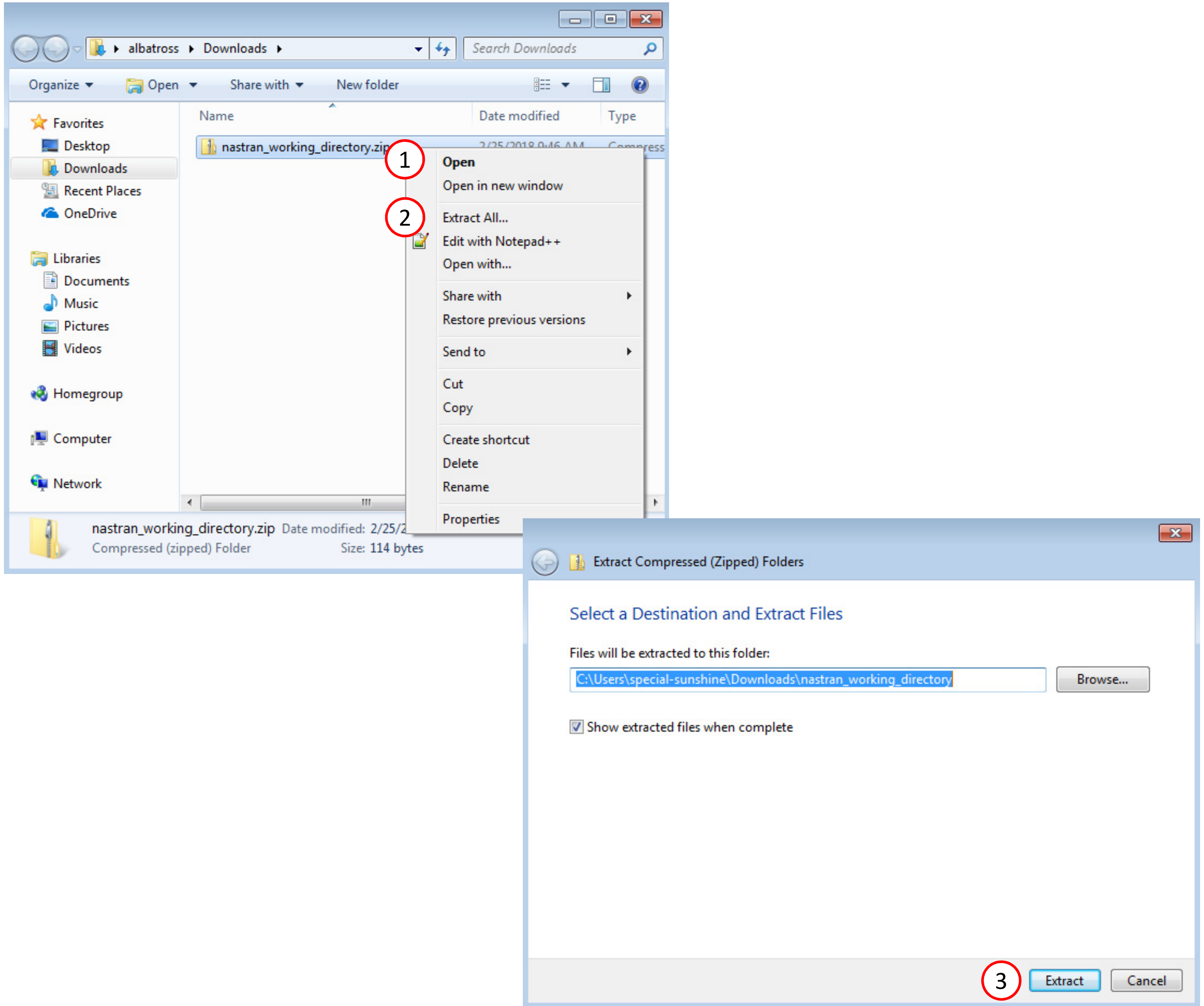


- When the download button is clicked a new file named "nastran_working_directory" is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. "nastran_working_directory (1).zip"

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

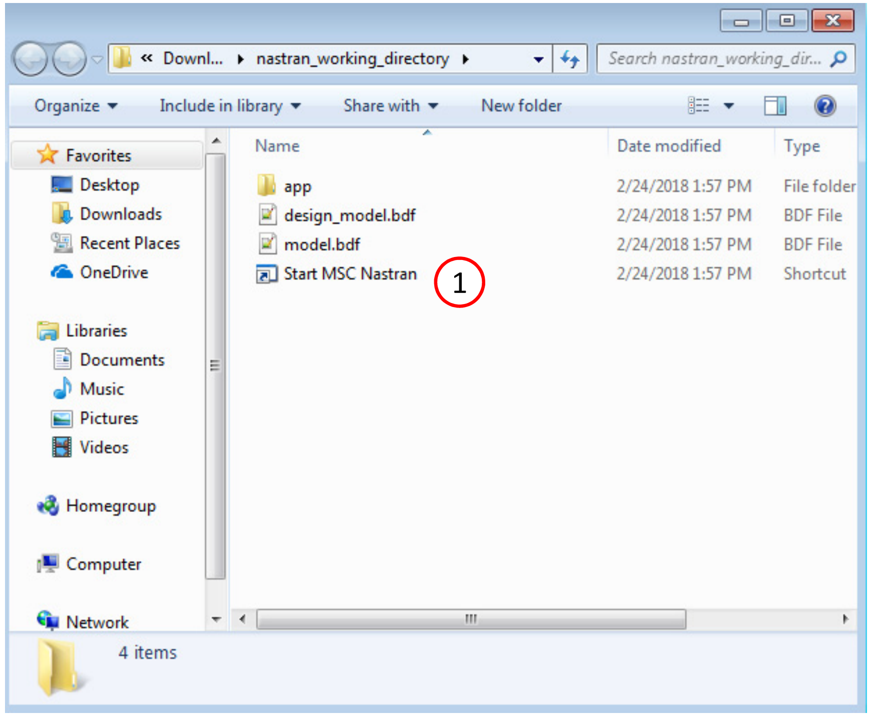
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

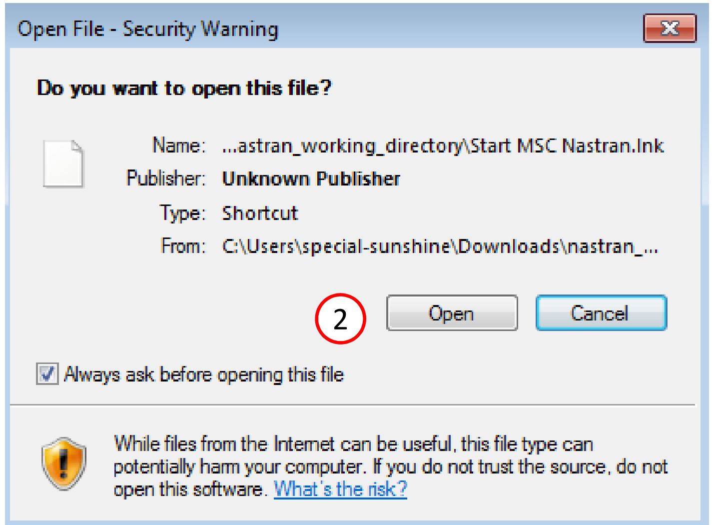
Using Linux?

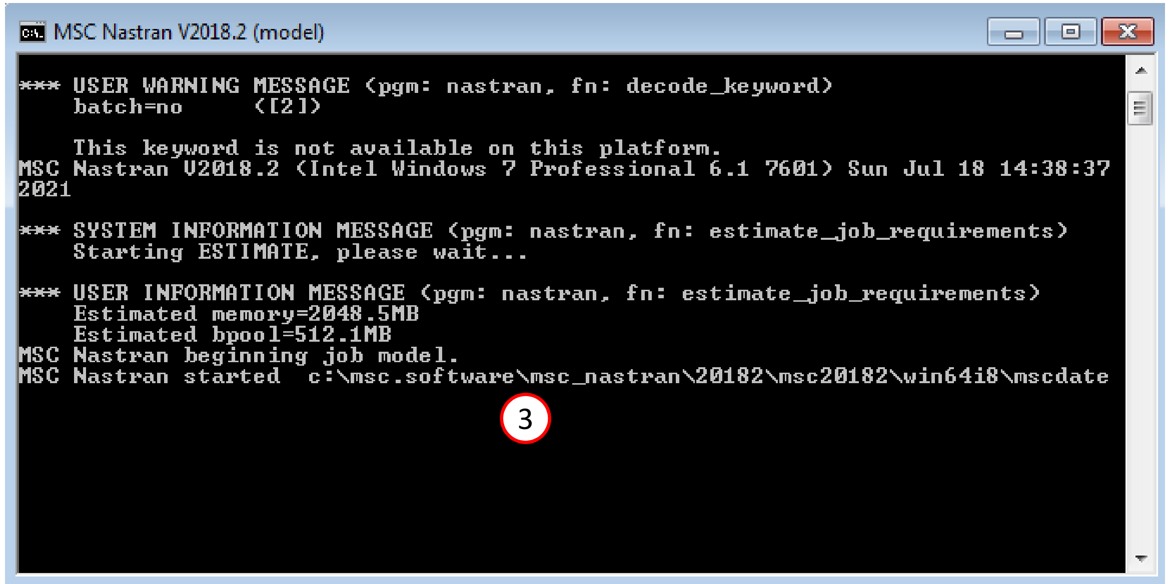
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

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.

1. Select any of the options to dynamically plot different sensitivities

- The sensitivities are labeled in the following form:
  $\partial r2_{SC1,\,2,\,1} / \partial x1$
- This is read as the sensitivity of r2 with respect to x1, for subcase 1, component 2 (axial stress) of element 1.
- This sensitivity is negative, so a unit change in x1 will produce a -11893 change in $r2_{SC1,\,2,\,1}$.

Review Optimization Results

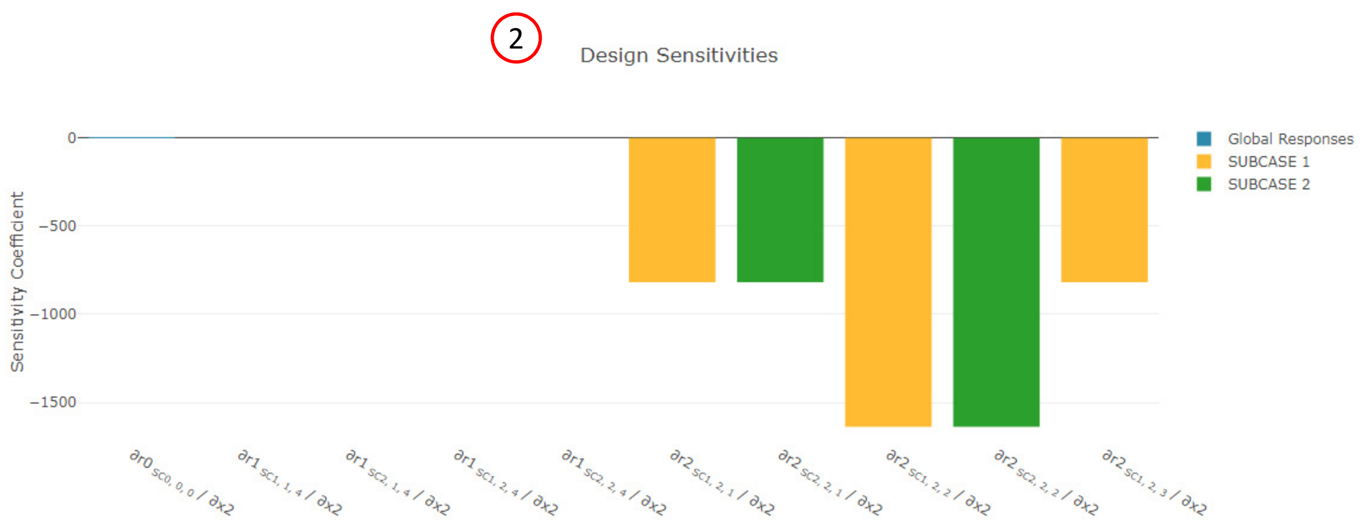
1. Click the column headers to sort the table
2. Note the sensitivities are immediately updated automatically

- The data displayed in the table is immediately plotted in the Bar Charts. This example has 22 sensitivity values. The table shows only 10 sensitivities, so the Bar Chart displays only 10 sensitivities.

SOL 200 Web App - Sensitivities

Home

Sensitivities



Sensitivity Table

Response	Response Type	Variable	Component ID	Element/Grid ID	Subcase	Response Value	Frequency / Time	Sensitivity	Sensitivity Coefficient	Absolute Value of Sensitivity Coefficient
r0	WEIGHT	x2	0	0	0	4.8284E+00	0.0000E+00	$\partial r0_{SC0,0,0} / \partial x2$	1	1
r1	DISP	x2	1	4	1	2.2627E-02	0.0000E+00	$\partial r1_{SC1,1,4} / \partial x2$	0	0
r1	DISP	x2	1	4	2	-2.2627E-02	0.0000E+00	$\partial r1_{SC2,1,4} / \partial x2$	0	0
r1	DISP	x2	2	4	1	-4.4328E-03	0.0000E+00	$\partial r1_{SC1,2,4} / \partial x2$	0.0016375	0.0016375
r1	DISP	x2	2	4	2	-4.4328E-03	0.0000E+00	$\partial r1_{SC2,2,4} / \partial x2$	0.0016375	0.0016375
r2	STRESS	x2	2	1	1	1.3530E+04	0.0000E+00	$\partial r2_{SC1,2,1} / \partial x2$	-818.73	818.73
r2	STRESS	x2	2	1	2	-9.0973E+03	0.0000E+00	$\partial r2_{SC2,2,1} / \partial x2$	-818.73	818.73
r2	STRESS	x2	2	2	1	4.4328E+03	0.0000E+00	$\partial r2_{SC1,2,2} / \partial x2$	-1637.5	1637.5
r2	STRESS	x2	2	2	2	4.4328E+03	0.0000E+00	$\partial r2_{SC2,2,2} / \partial x2$	-1637.5	1637.5
r2	STRESS	x2	2	3	1	-9.0973E+03	0.0000E+00	$\partial r2_{SC1,2,3} / \partial x2$	-818.73	818.73

End of Tutorial