# Workshop - Automated Structural Optimization of a Stiffened Plate

AN MSC NASTRAN SOL 200 TUTORIAL

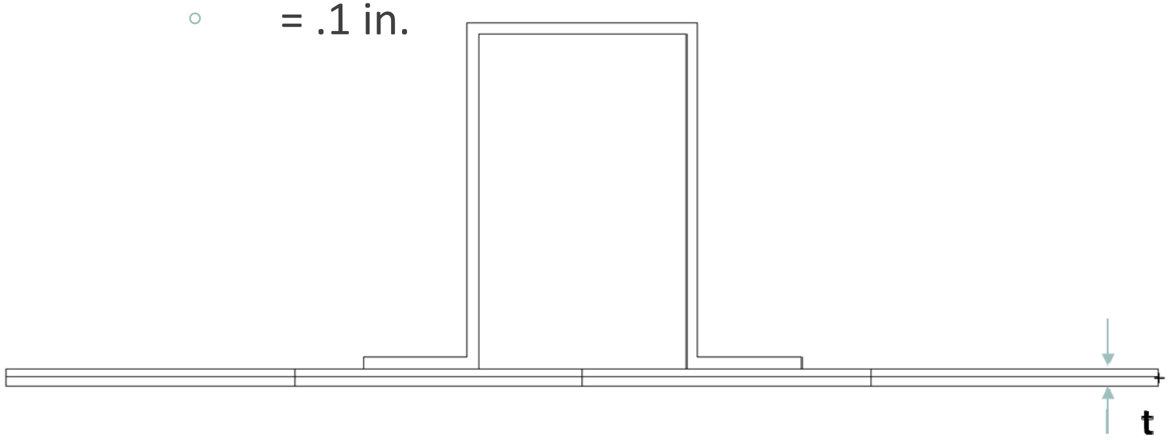
Questions? Email: christian@ the-engineering-lab.com

# Goal: Use Nastran SOL 200 Optimization

Optimize the weight of this structure while constraining stress and displacement

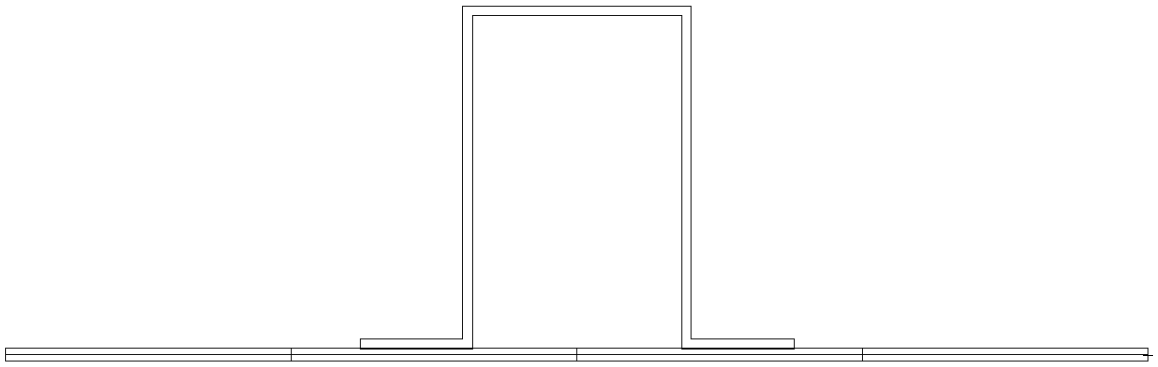
## Before Optimization

- Weight: 6.962
- x1 = T, thickness of shell
- = .15
- x2 = DIM2
- = .1 in.




## After Optimization

- Weight: 5.477
- x1 = T = .113 in.
- x2 = DIM2 = .0839 in.



# Details of the Structural Model

## Stiffened Plate

An effective way to keep the number of independent design variables to a minimum is by grouping designed elements by property type. A smaller set of independent design variables decreases the cost associated with the sensitivity analysis, allows the optimizer to perform more efficiently, and makes interpretation of the final results much easier.

A simple example is shown in Figure 8-20 and includes a plate with a hat stiffener. The design goal is to reduce the weight of the stiffened panel subject to stress and displacement constraints under two separate static load conditions. The thickness of the plate and the thickness of the hat stiffener are allowed to vary. The boundary condition creates a simply supported condition with the plate also restrained in the x direction along x=0.0. The first load case includes both uniaxial tension in the x-direction and a vertical pressure load in the z-direction. The second load case is a concentrated load applied in the +z direction at grid 10203, which is directly under the hat. The example illustrates how the beam library can be utilized to simplify the modeling and design tasks and how the beam offset relations can be adjusted as the structural properties change.

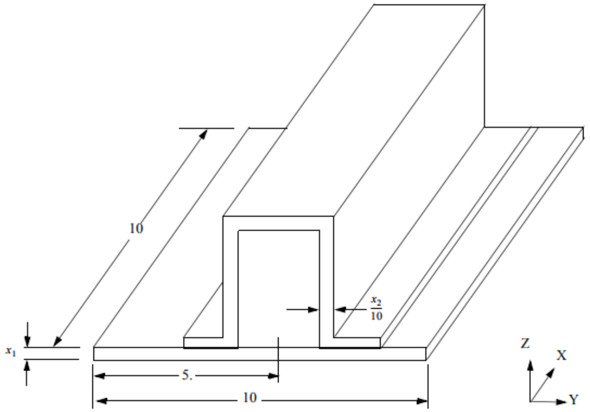
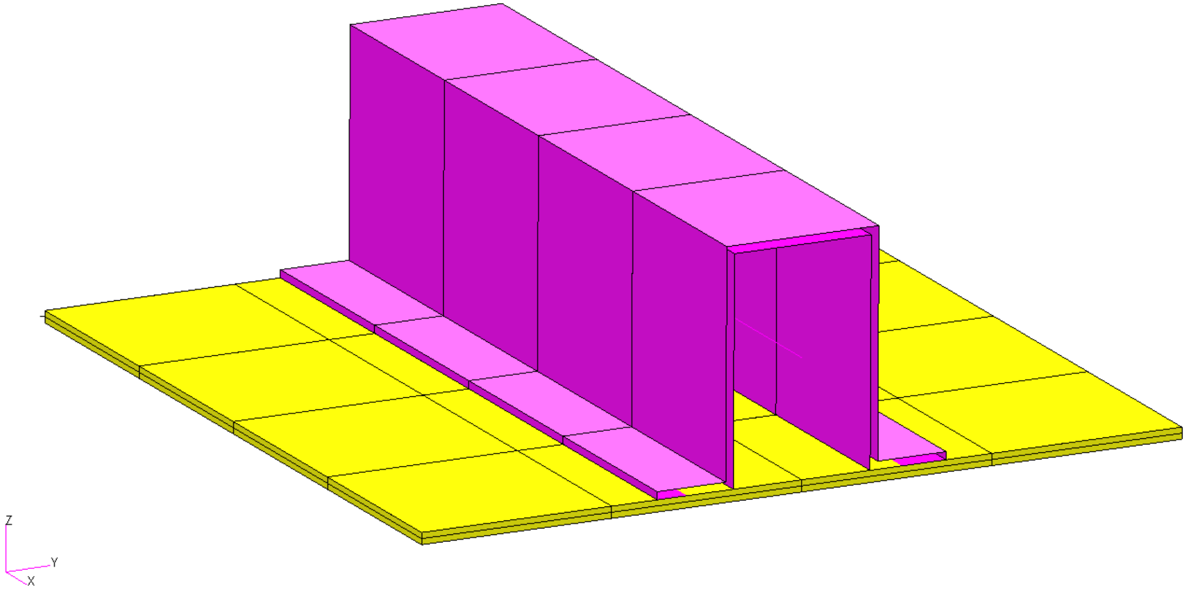



Figure 8-20 Plate with a HAT Stiffener



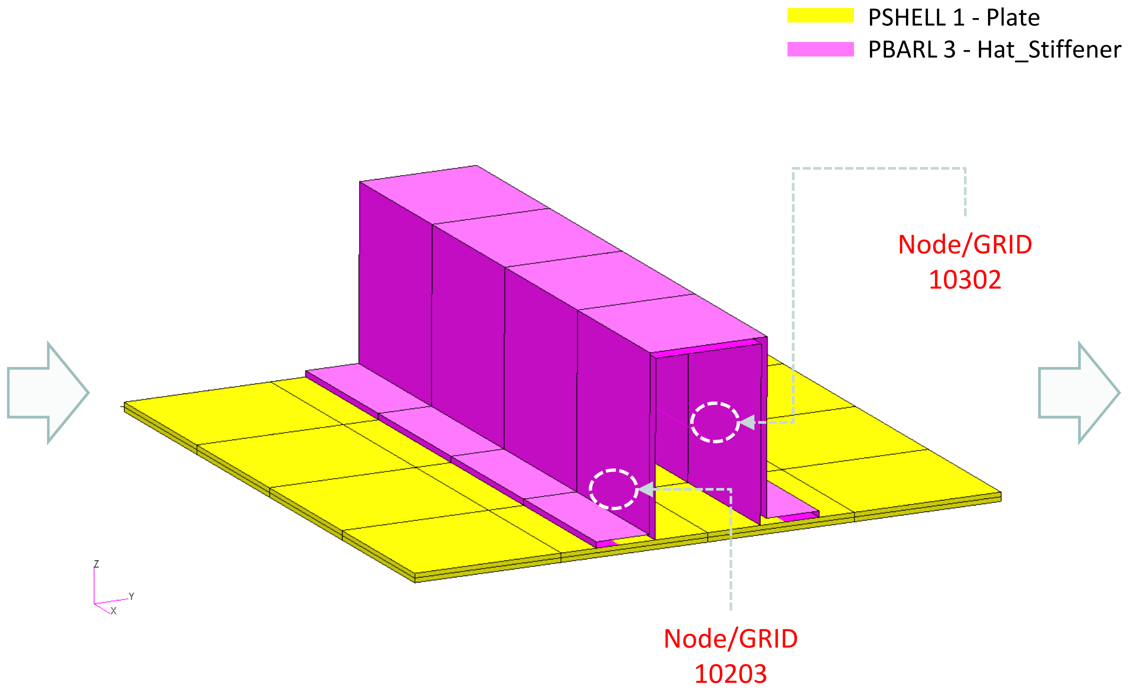

*MSC Nastran Design Sensitivity and Optimization User's Guide*
*Chapter 8 - Example Problems - Stiffened Plate*

# Optimization Problem Statement

## Design Variables

x1: T1   of PSHELL 1 |  .01 < x1 < 1.
x2: DIM2 of PBARL 3   |  .01 < x2 < 1.

W3A,B for each element = 1.5 + x1 / 2.0




## Design Objective

r0: Minimize weight

## Design Constraints

r1: The max stress at end A of elements related to PBARL 3
r2: The max stress at end B of elements related to PBARL 3

-25000 < r1, r2 < 25000

r3: The von Mises stress of elements related to PSHELL 1
r4: The von Mises stress of elements related to PSHELL 1

r3, r4 < 25000

r5: The z component of displacement for node 10302

-.1 < r5 < .1

r6: The z component of displacement for node 10203

-.03 < r6 < .03

# Optimization Problem Statement
# Design Variables

## Design Variables

- $x1$ = T, thickness of shell

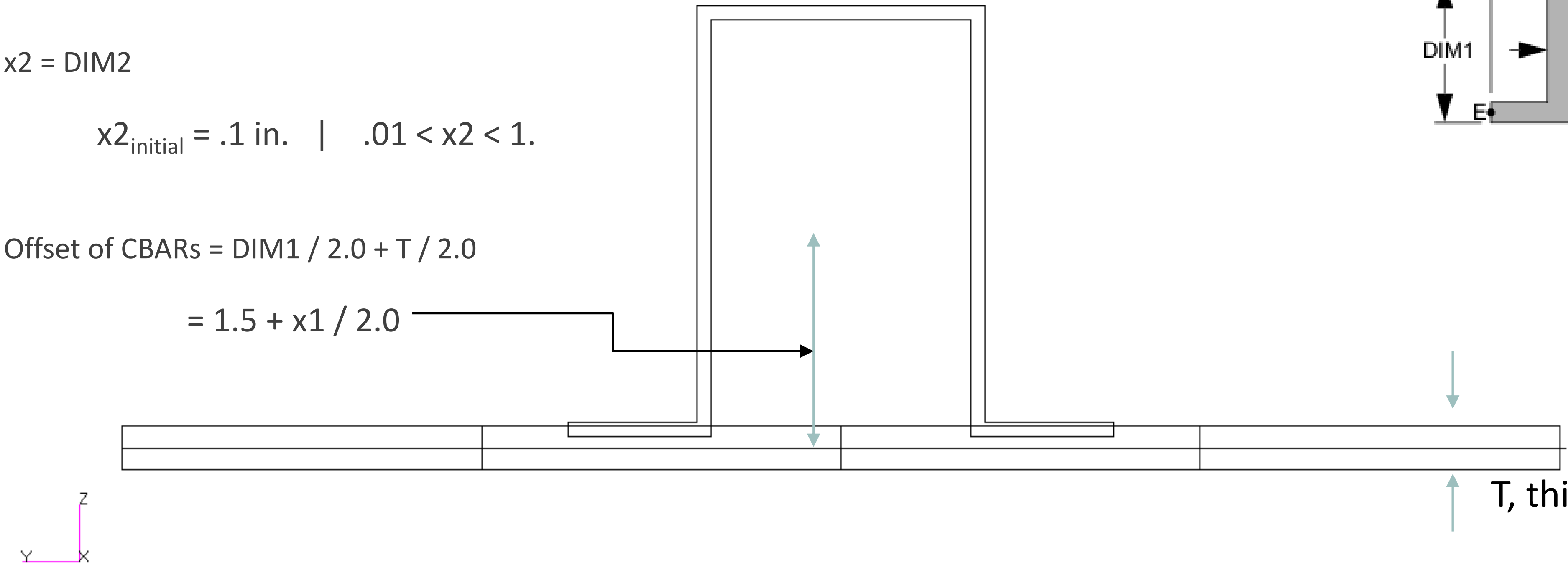
  $x1_{initial} = .15$ in. | $.01 < x1 < 1.$

- $x2$ = DIM2

  $x2_{initial} = .1$ in. | $.01 < x2 < 1.$

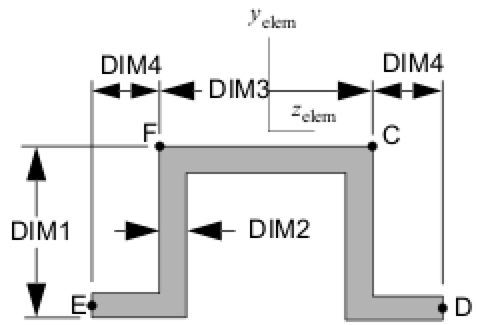
- Offset of CBARs = DIM1 / 2.0 + T / 2.0

  $= 1.5 + x1 / 2.0$




T, thickness of shell

DIM1: 3 in.
DIM2: .1 in
DIM3: 2 in.
DIM4: .9in

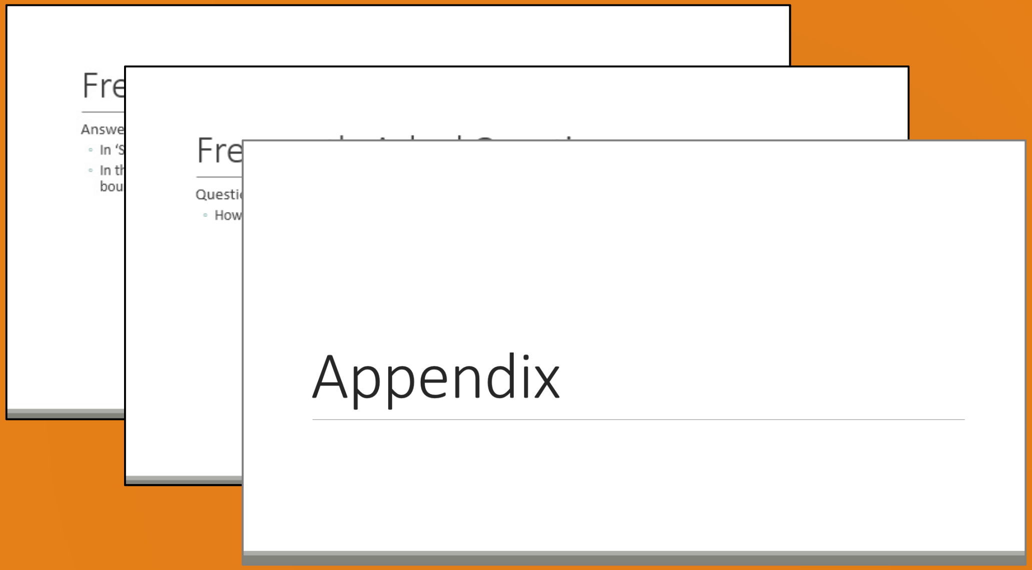



TYPE="HAT"

# More Information Available in the Appendix

The Appendix includes information regarding the following:

- Frequently Asked Questions
  - How do I avoid the scenario where the offset causes the cross section to interfere with the plate?



# 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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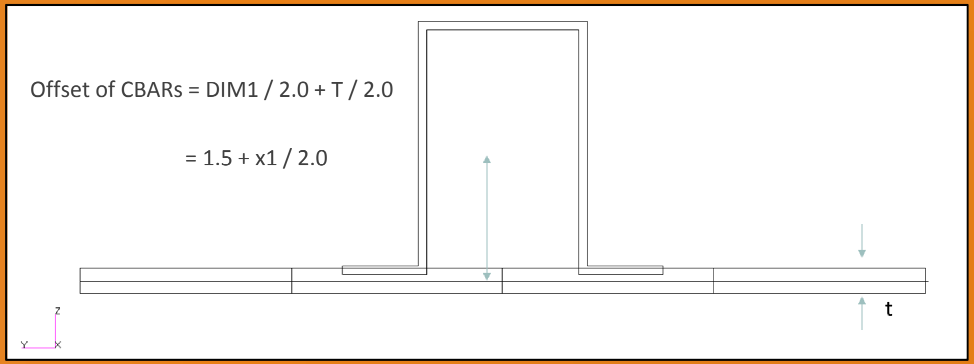
# Tutorial

# Tutorial Overview

1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
     - Design Variables
     - Design Objective
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Plot the Optimization Results
4. Update the original model with optimized parameters

## Special Topics Covered

**Creating Hundreds of Equation Driven Parameters** - Certain parameters of the Finite Element Model may need to be adjusted as certain design variables change. For example, as the thickness of a plate changes, an attached stiffener's offset will depend on the thickness. This tutorials describes the process for automatically generating dozens or hundreds of these equation driven parameters.



# SOL 200 Web App Capabilities

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

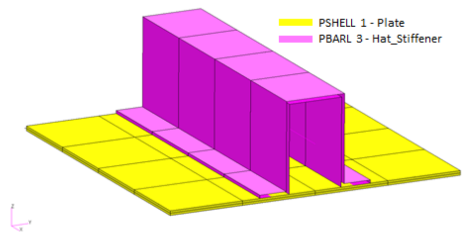
## Compatibility

- 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.

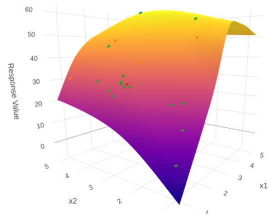
## Benefits

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

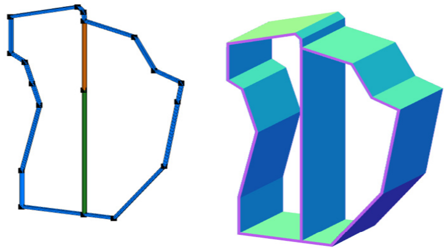
## Web Apps



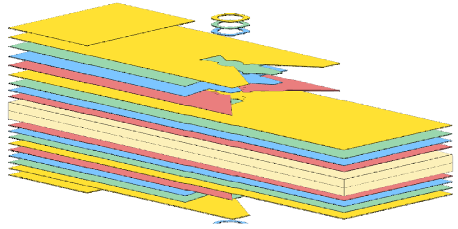

**Web Apps for MSC Nastran SOL 200**
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



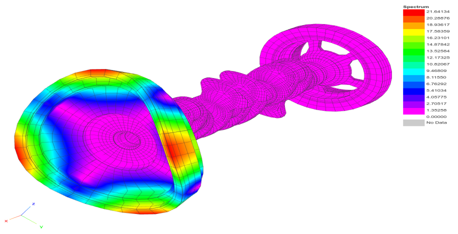
**Machine Learning Web App**
Bayesian Optimization for nonlinear response optimization (SOL 400)



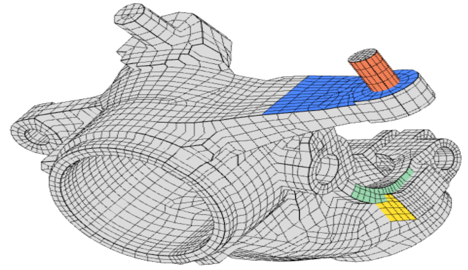
**PBMSECT Web App**
Generate PBMSECT and PBRSECT entries graphically



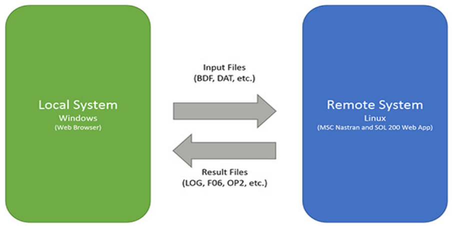
**Ply Shape Optimization Web App**
Optimize composite ply drop-off locations, and generate new PCOMPG entries



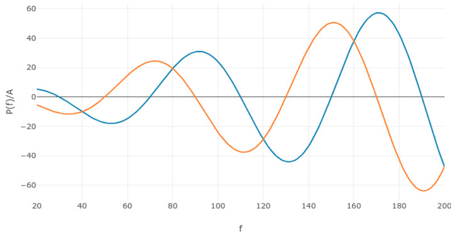
**Post-processor Web App**
View MSC Nastran results in a web browser on Windows and Linux



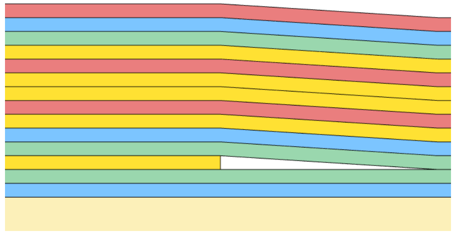
**Shape Optimization Web App**
Use a web application to configure and perform shape optimization.



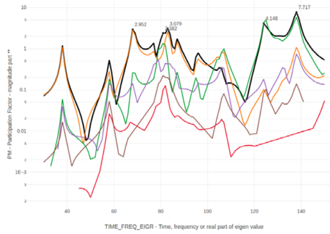

**Remote Execution Web App**
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



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



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

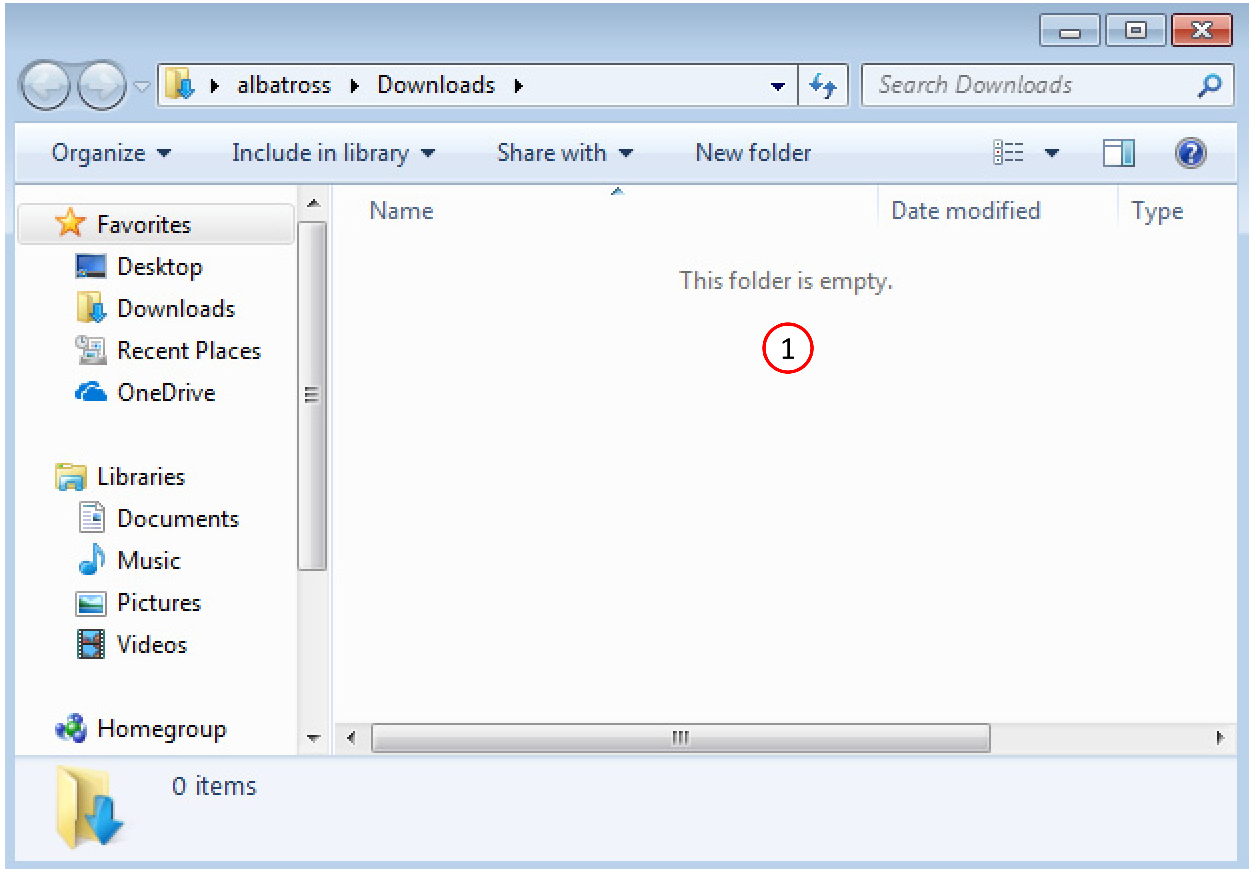


**HDF5 Explorer Web App**
Create graphs (XY plots) using data from the H5 file

# Before Starting

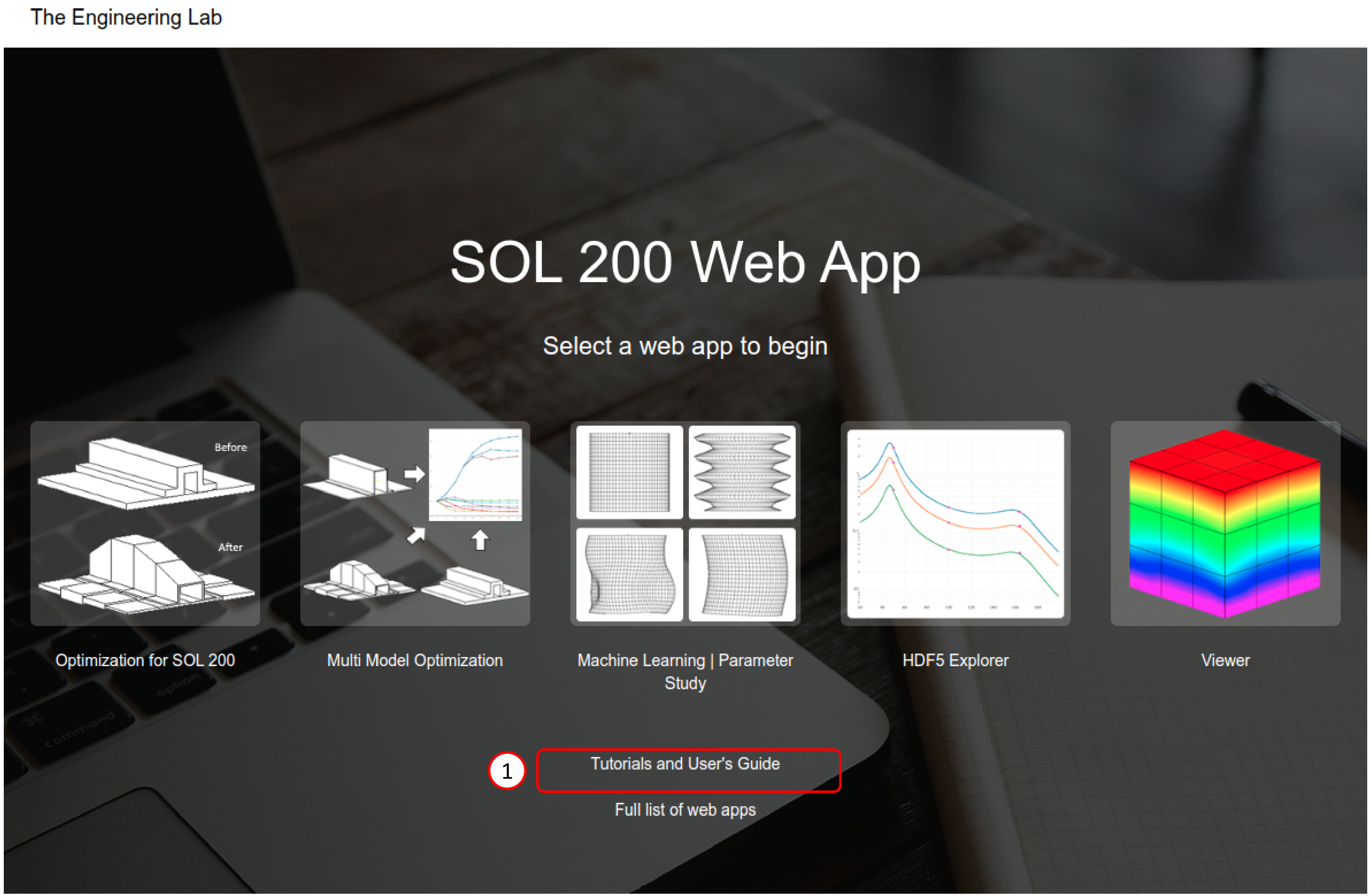
1. Ensure the Downloads directory is empty in order to prevent confusion with other files

- 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

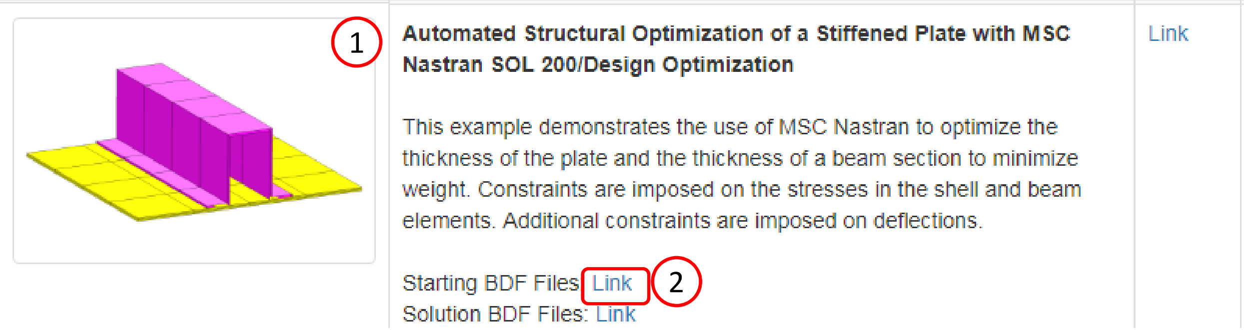


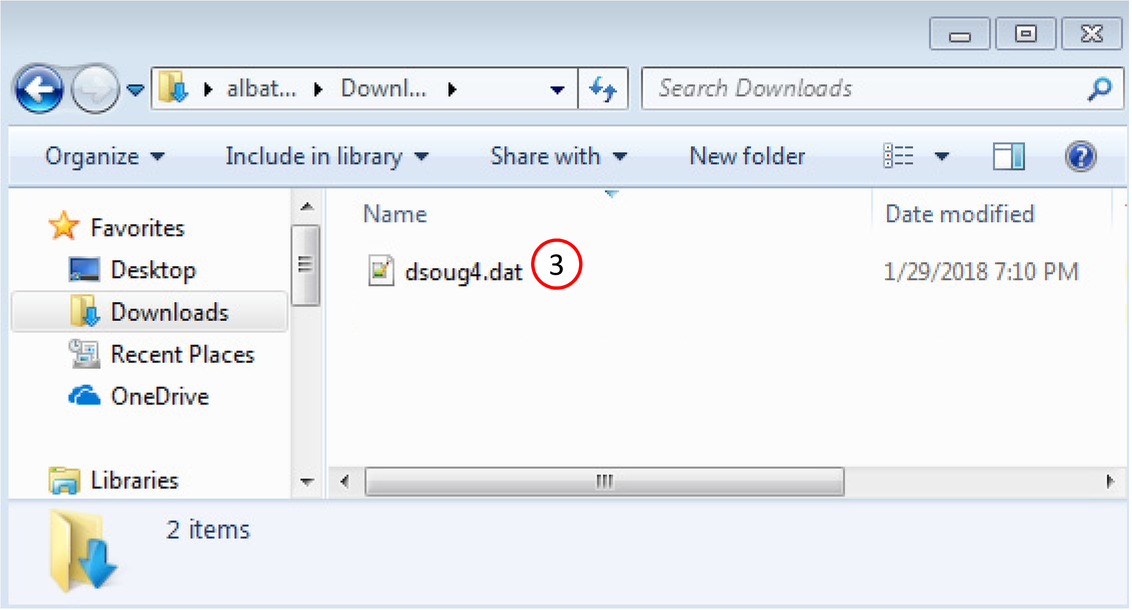

- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

# Obtain Starting Files

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

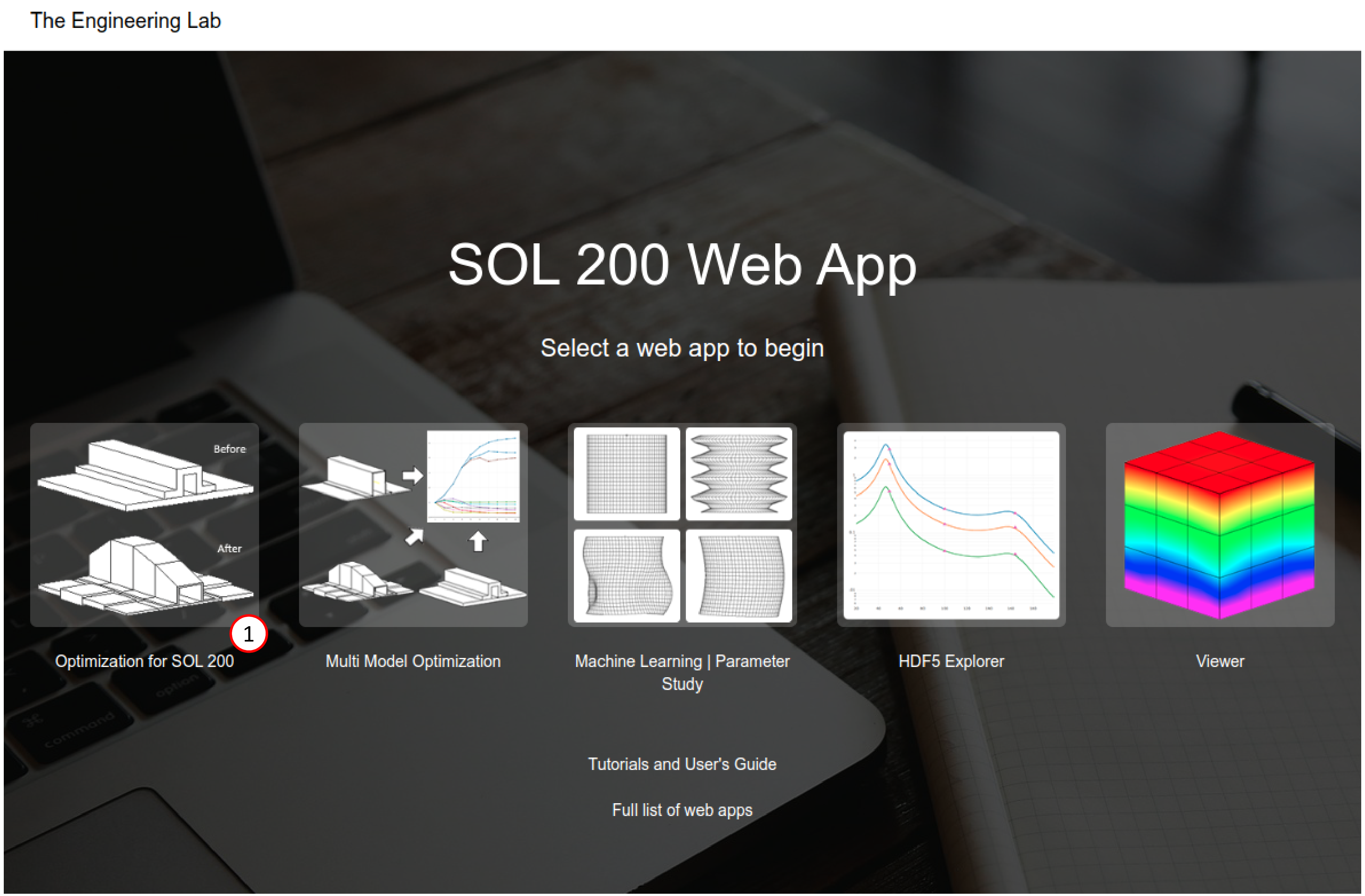
- When starting the procedure, all the necessary BDF files must be collected together.



# Open the Correct Page

1. Click on the indicated link

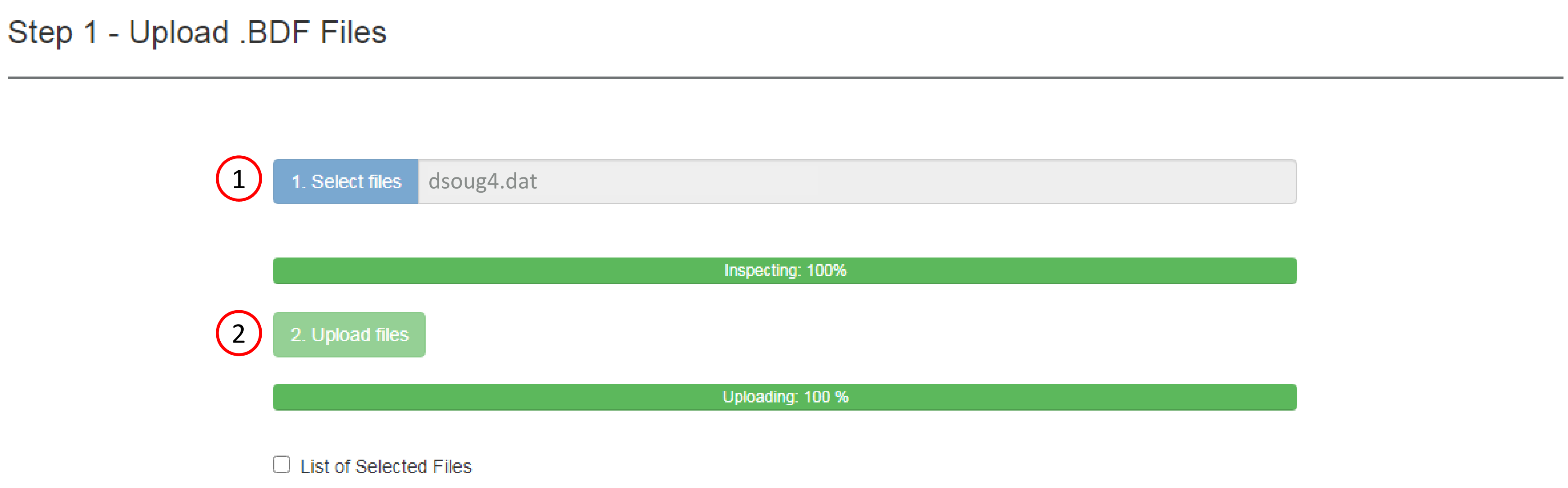



- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
    - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
    - Multi Model Optimization
    - Machine Learning
- 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 dsoug4.dat
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.



# Create Design Variables

1. In the search box, type ‘t’
2. Click on the plus (+) icons to set the thickness as a design variable
3. In the search box, type ‘dim’
4. Click on the plus (+) icons to set DIM2 as a design variable
5. Specify the lower bound as .01 for design variables x1, x2
6. Specify the upper bound as 1. for design variables x1, x2

- The necessary design variables, as detailed in the optimization problem statement, are created.
- The search boxes are used to filter the tables for the T and DIM2 properties.
- Each step has hidden functionality for advanced users. The visibility is controlled by clicking + Options.

## Step 1 - Select design properties

+ Options

| Create DVXREL1 | Property | Property Description | Entry | Entry ID | Current Value |
|---|---|---|---|---|---|
| | t (1) | Search | Search | Search | Search |
| (2) + | T | Thickness | PSHELL | 1 | 0.15 |
| + | T | Thickness | PSHELL | 2 | 0.2 |

## Step 1 - Select design properties

+ Options

| Create DVXREL1 | Property | Property Description | Entry | Entry ID | Current Value |
|---|---|---|---|---|---|
| | dim (3) | Search | Search | Search | Search |
| + | DIM1 | HAT - Height of beam | PBARL | 3 | 3.0 |
| (4) + | DIM2 | HAT - Thickness of flange, web and li… | PBARL | 3 | 0.1 |
| + | DIM3 | HAT - Width of flange, top | PBARL | 3 | 2.0 |
| + | DIM4 | HAT - Width of lip | PBARL | 3 | 0.9 |

## Step 2 - Adjust design variables

✖ Delete Visible Rows

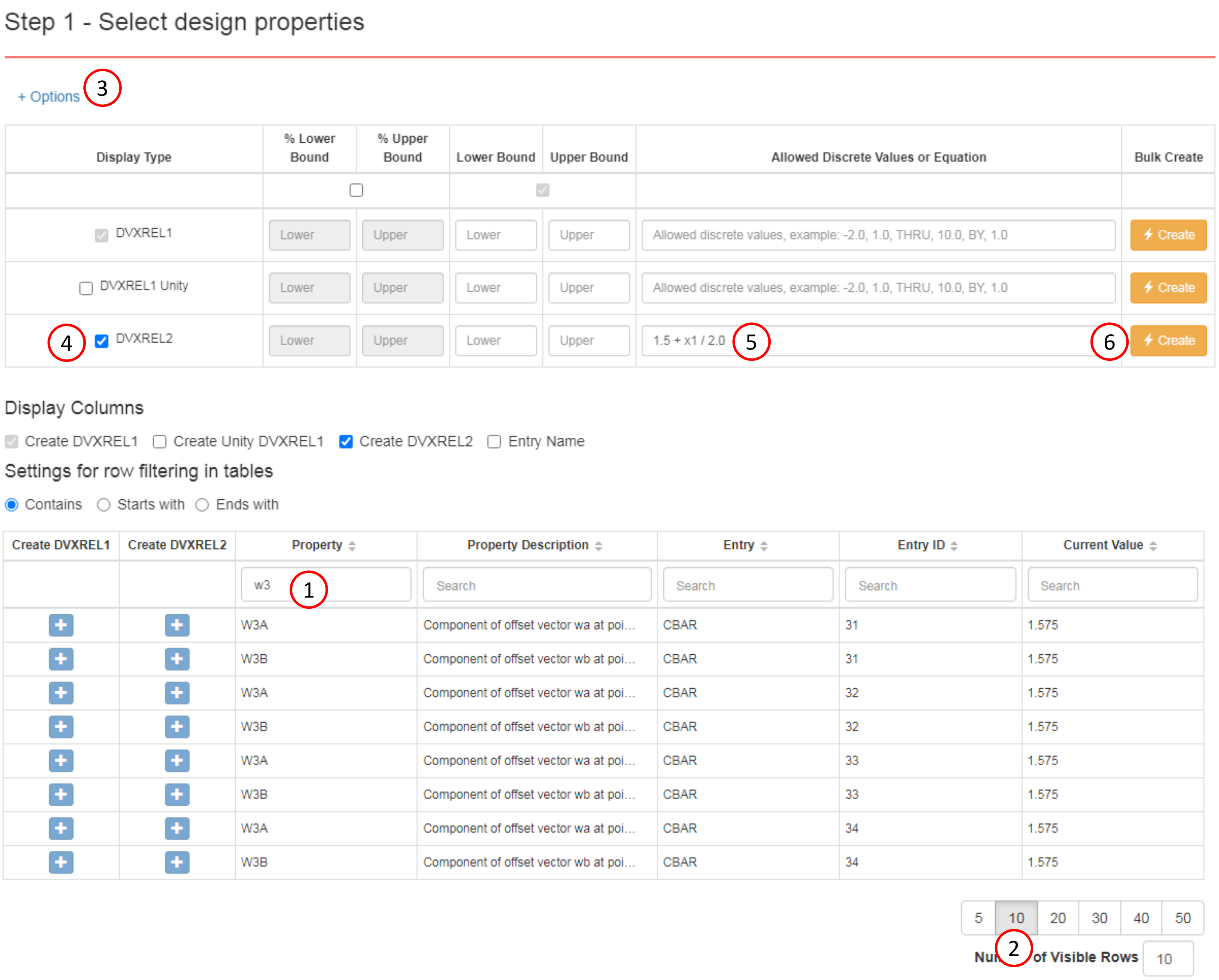
+ Options

| | Label | Status | Property | Property Description | Entry | Entry ID | Initial Value | Lower Bound | Upper Bound | Allowed Discrete Values |
|---|---|---|---|---|---|---|---|---|---|---|
| | Search | Search | Search | Search | Search | Search | Search | (5) | (6) | Search |
| ✖ | x1 | ✔ | T | Thickness | PSHELL | 1 | 0.15 | .01 | 1. | Examples: -2.0, 1.0, THRU, |
| ✖ | x2 | ✔ | DIM2 | HAT - Thickness of flange, web and li… | PBARL | 3 | 0.1 | .01 | 1. | Examples: -2.0, 1.0, THRU, |

# Create Design Variables

1. In the search box, type ‘w3’
2. Select ’10’ in the pagination bar
3. Click +Options
4. Check the DVXREL2 option
5. Type in this equation:
   - 1.5 + x1 / 2.0
6. Click on Create

- In order to avoid interference between the beam cross section and thickness of the plate, a relationship is created between the beam offsets (W3A,B) and the variable representing the plate thickness (x1). A DVXREL2 entry defines this relationship.
- Design variables (DVXREL1) and DVXREL2 relationships can be individually created by clicking the blue plus (+) icons.
- If dozens or hundreds of variables or relationships must be created, the table can be used create these entries in one click by clicking the yellow icons named Create. In addition, the bounds, discrete values or equation can be configured rapidly.



# Create Design Variables

1. Click 10 on the pagination bar
2. 8 DVXREL2 entries have been created

- These entries define relationships between the beam offsets (W3A,B) and the plate thickness variable (x1). As the thickness variable changes, the offset is also updated and will avoid the situation where the beam cross section interferes with the plate thickness.

## Step 5 - Adjust DVXREL2

✖ Delete Visible Rows

+ Options

| | Label | Status | Property | Property Description | Entry | Entry ID | Initial Value | Lower Bound | Upper Bound | Equation |
|---|---|---|---|---|---|---|---|---|---|---|
| | Search | Search | Search | Search | Search | Search | Search | Search | Search | Search |
| ✖ | C1 | ✔ | W3A | Component of offset vector wa a... | CBAR | 31 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C2 | ✔ | W3B | Component of offset vector wb a... | CBAR | 31 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C3 | ✔ | W3A | Component of offset vector wa a... | CBAR | 32 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C4 | ✔ | W3B | Component of offset vector wb a... | CBAR | 32 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C5 | ✔ | W3A | Component of offset vector wa a... | CBAR | 33 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C6 | ✔ | W3B | Component of offset vector wb a... | CBAR | 33 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C7 | ✔ | W3A | Component of offset vector wa a... | CBAR | 34 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C8 | ✔ | W3B | Component of offset vector wb a... | CBAR | 34 | 1.575 | Minimum | Maximum | 1.5 + x1 / 2.0 |

2

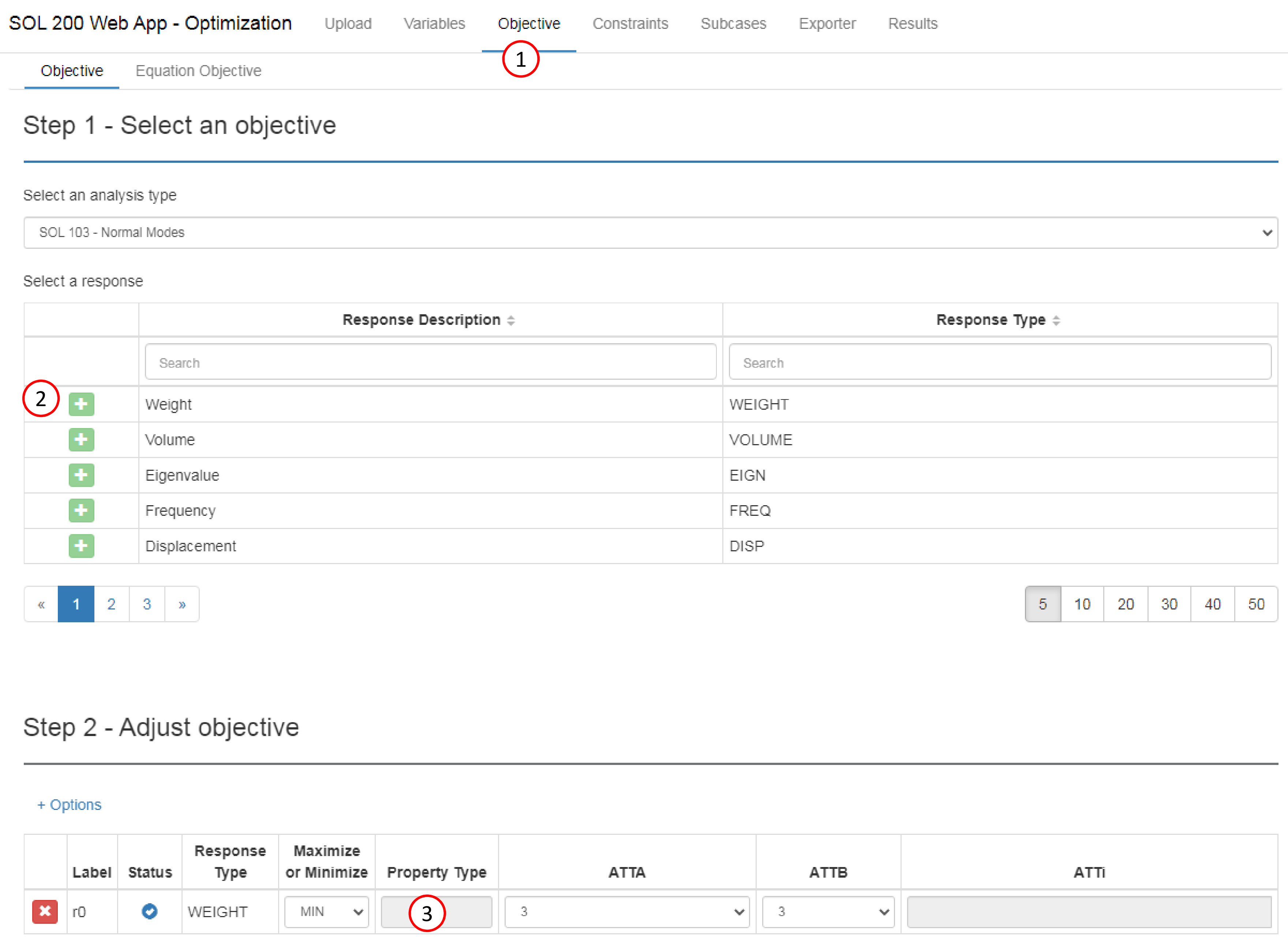
5 | 10 | 20 | 30 | 40 | 50

1

# Create Design Objective

1. Click Objective
2. Select the plus (+) icon for weight
3. The objective has been set to minimize the weight, no further modification is necessary

- The objective must always be a single and global response. A response such as weight and volume are single responses, are independent of load case, and can be used as an objective. Other responses require special care when set as an objective. For example, if the objective is stress, only the stress of a single component, e.g. von Mises, of a single element, of a single load case may be used.

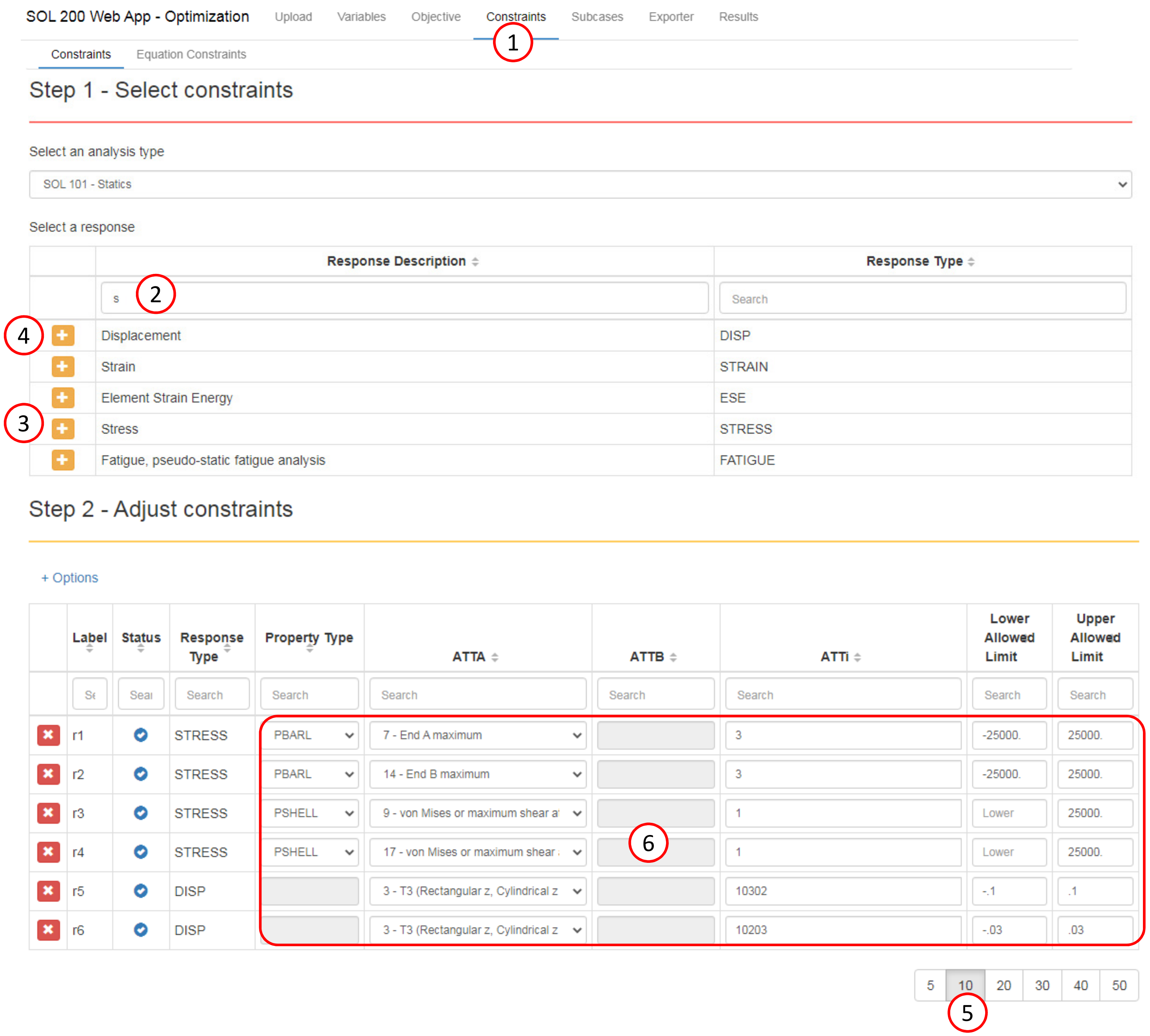


# Create Design Constraints

1. Click Constraints
2. In the search box, type ‘s’
3. Select the plus(+) icon 4 times for Stress to create 4 stress constraints
4. Select the plus(+) icon 2 times for Displacement to create 2 displacement constraints
5. Select ’10’ in the pagination bar
6. Configure the constraints as shown to the right

- Example: Configure the following for r1
  - Property Type: PBARL
  - ATTA: 7 - End A maximum
  - ATTi: 3 (PID 3)
  - Lower Allowed Limit: -25000.
  - Upper Allowed Limit: 25000.

- The r1 label is configured as follows: A stress constraint is created for all elements associated with the entry PBARL 3, for component 7 (End A Maximum). PBARL 3 has 4 elements associated, so 4 stress quantities are constrained.
- The r3 label is configured as follows: A stress constraint is created for all elements associated with PSHELL 1 for component 9 (von Mises). PSHELL 1 has 16 elements associated, so 16 stress quantities are constrained.



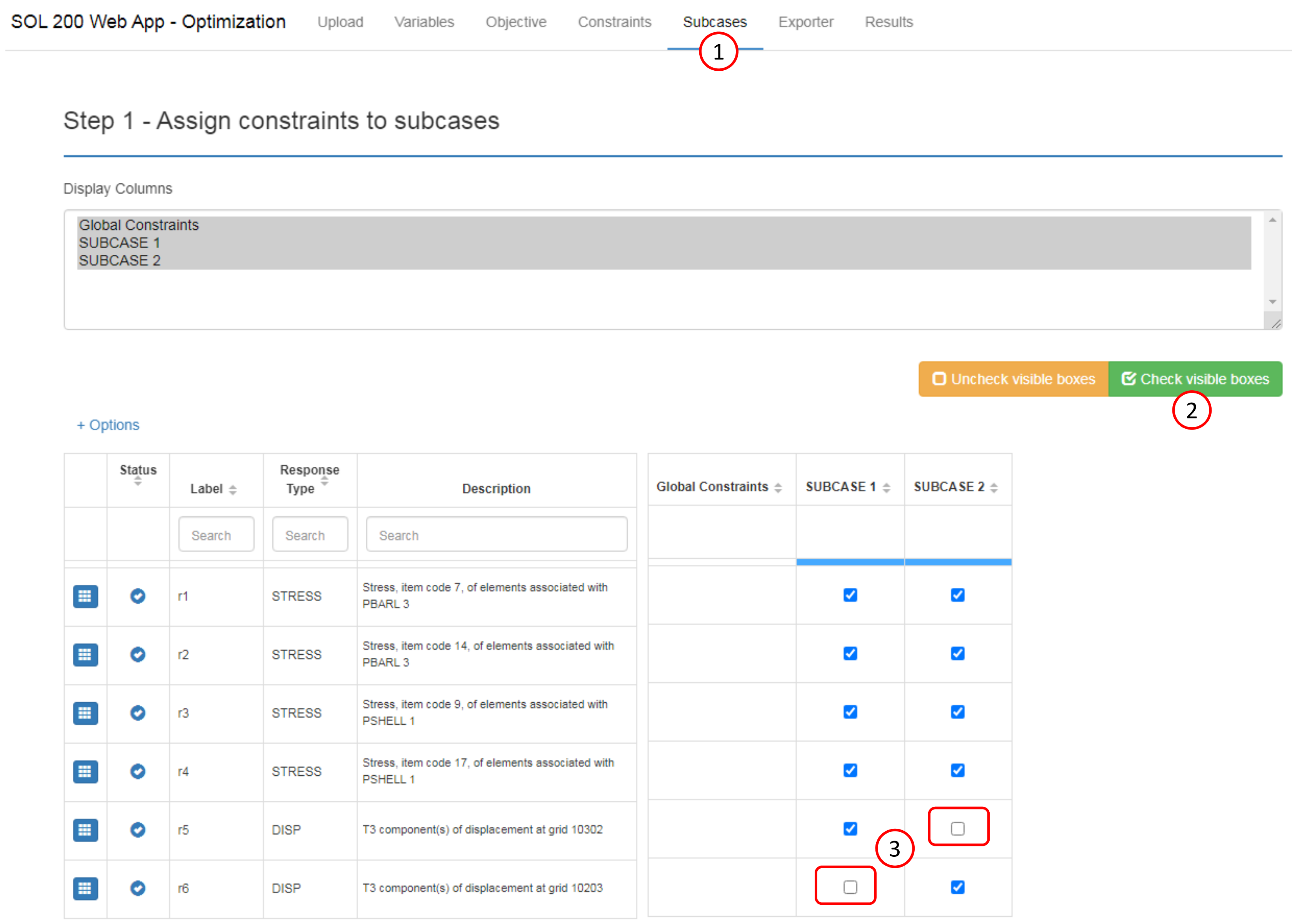
# Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Click Check visible boxes
3. Unmark the indicated checkboxes

- The following constraints have been applied to SUBCASE 1: r1, r2, r3, r4, r5
- The following constraints have been applied to SUBCASE 2: r1, r2, r3, r4, r6
- When hundreds of SUBCASEs must be configured, the following options expedite the process:

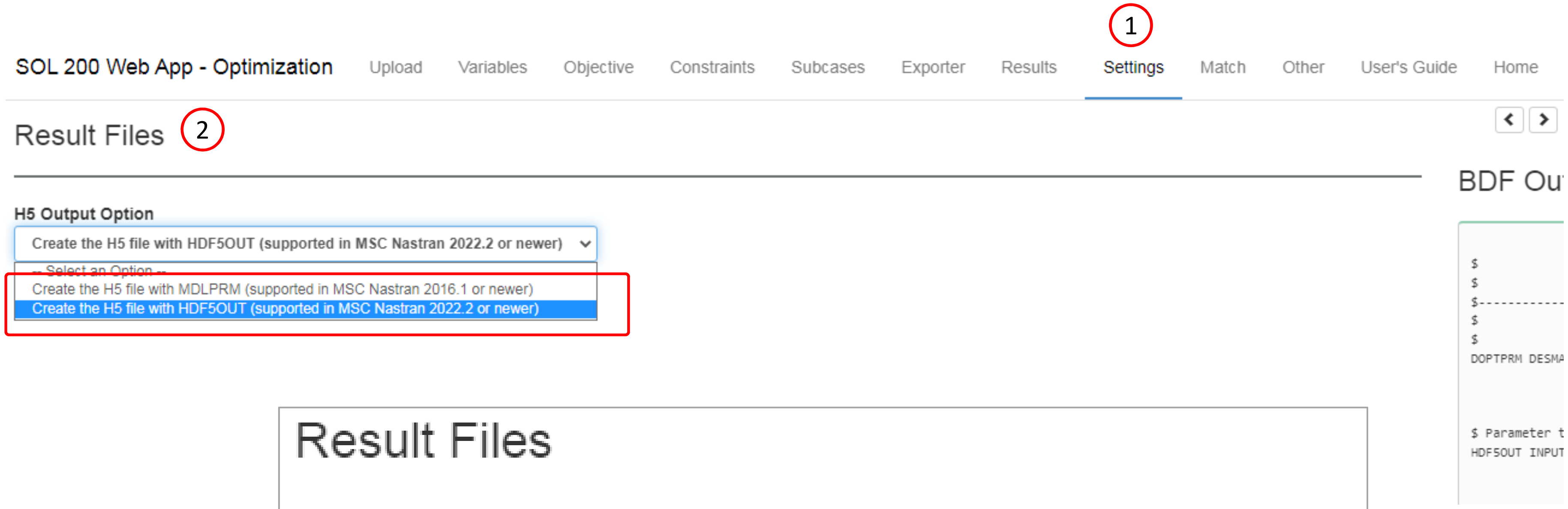
Uncheck visible boxes

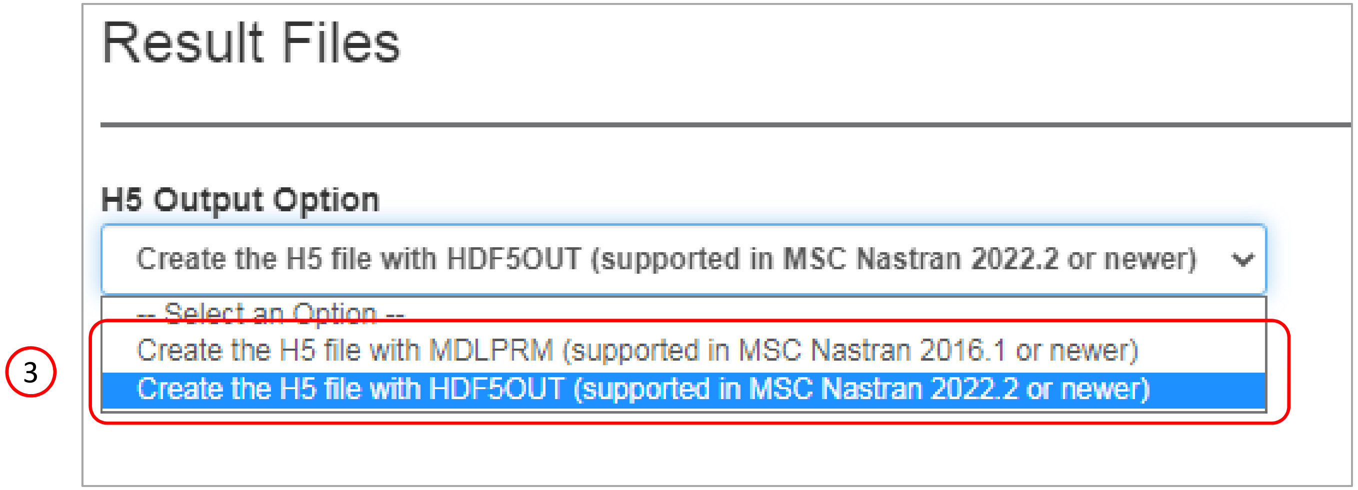
Check visible boxes



# Configure Settings

1. Click Settings
2. Scroll to section Result Files
3. Select one of the following H5 output options
    - Create the H5 file with MDLPRM
    - Create the H5 file with HDF5OUT

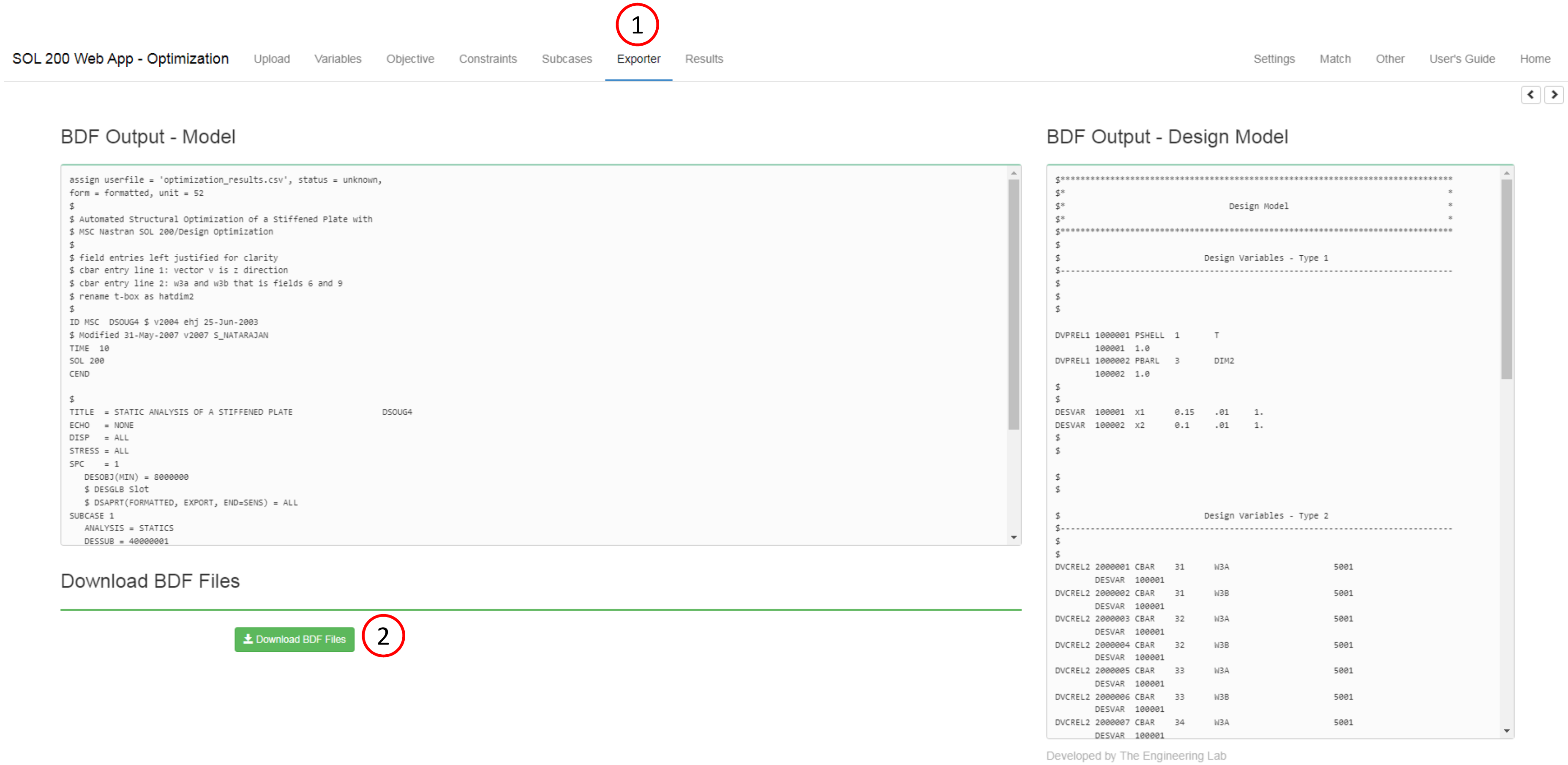



- The H5 file is used by the Post-processor web app to display MSC Nastran results.
- The H5 file is used by the HDF5 Explorer to create graphs (XY Plots) of MSC Nastran results.

# Export New BDF Files

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

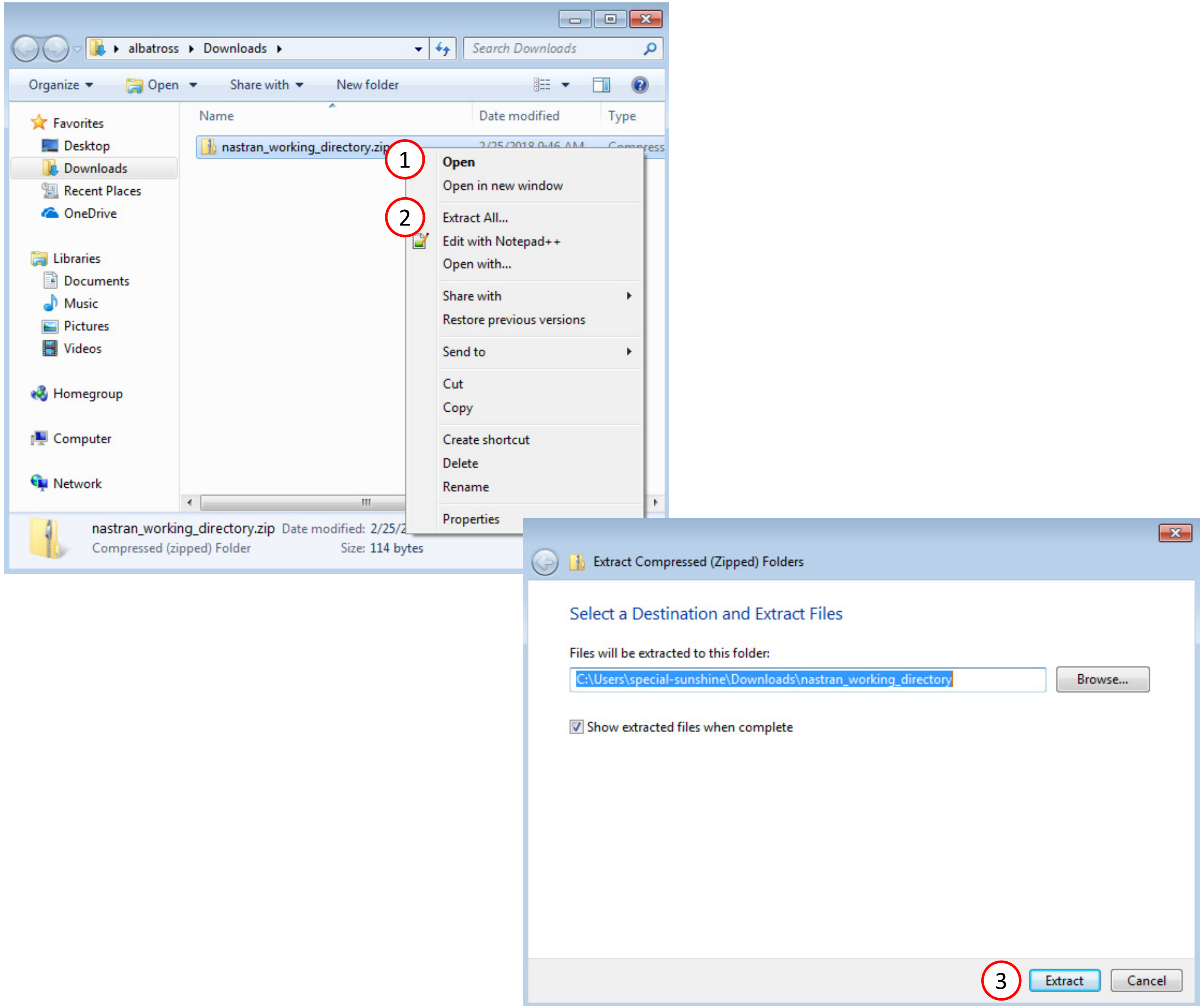



- When the download button is clicked a new file named "nastran_working_directory" is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. "nastran_working_directory (1).zip"

# 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

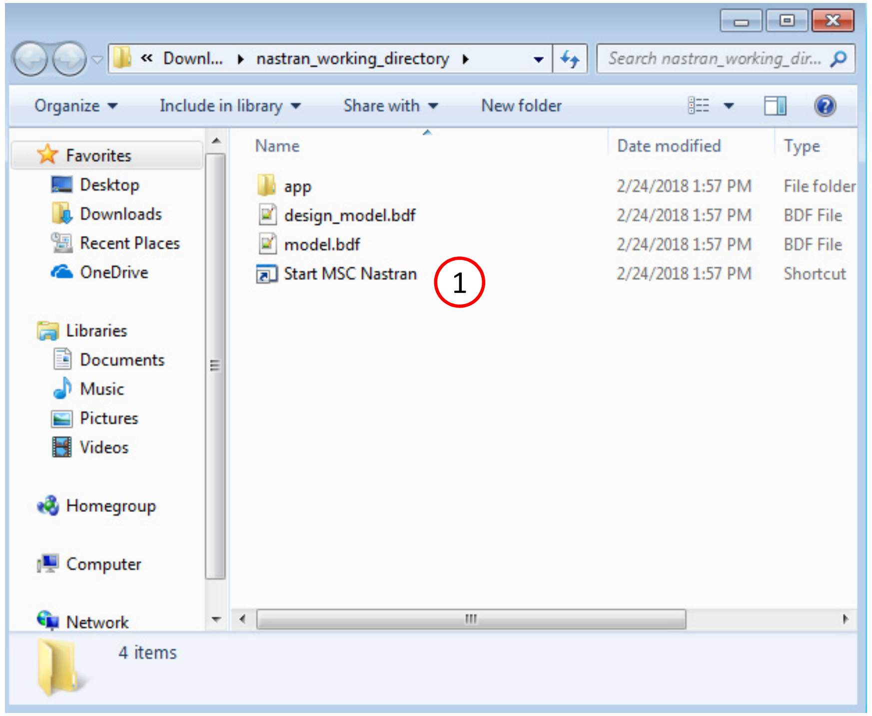
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

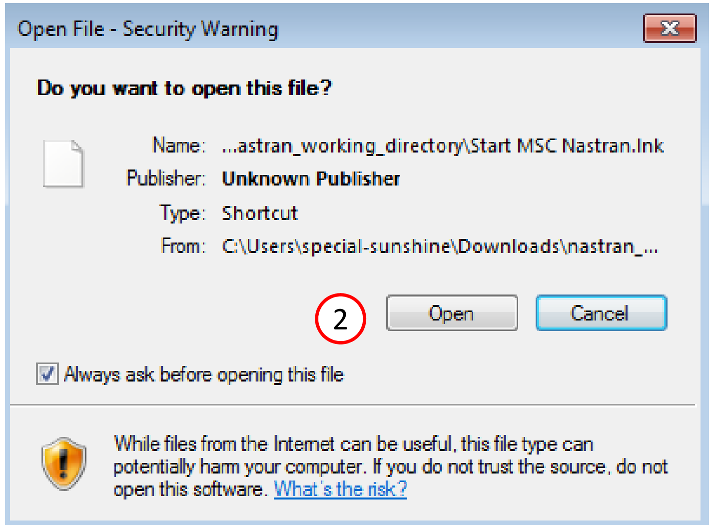
**Using Linux?**

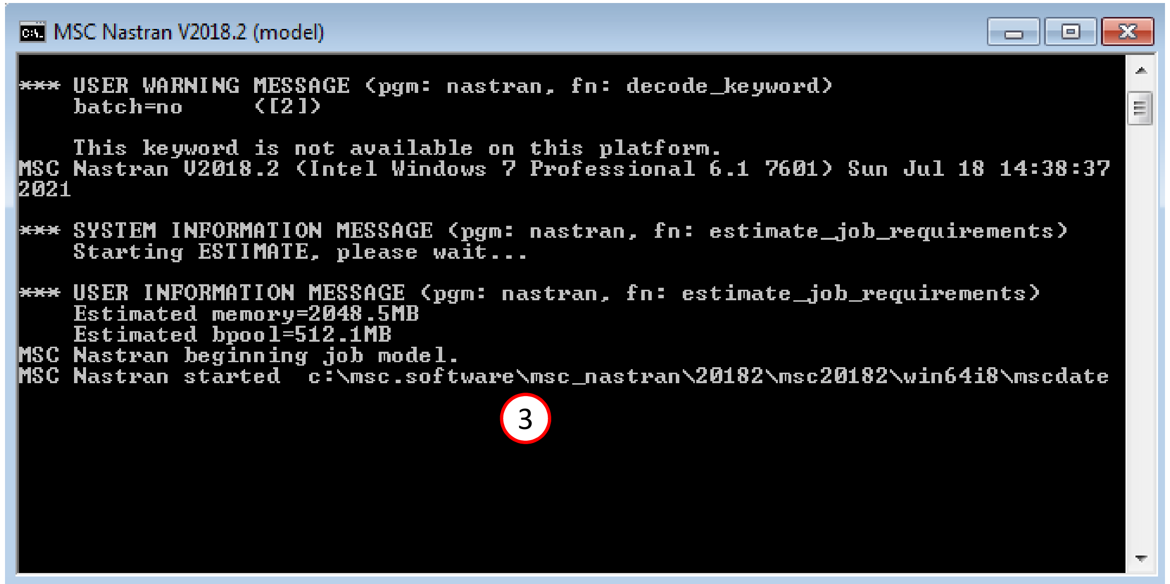
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
cd ./nastran_working_directory
3) Use this command to start the process
./Start_MSC_Nastran.sh

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 finished, the results will be automatically uploaded.

1. Ensure the messages shown have green checkmarks. This is indication of success. Any red icons indicate challenges.

2. The final value of objective, normalized constraints (not shown) and design variables can be reviewed.

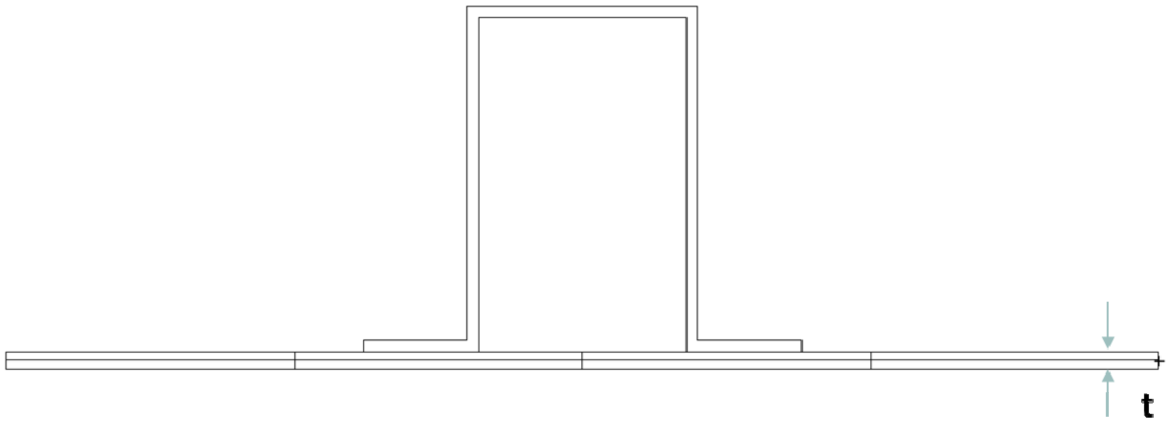
- After an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- After the first design cycle, the weight is minimized from 7 to ~4.8, but after the second design cycle, the weight increases to ~5.4. This drop in weight, then slight increase is sometimes an indication a constraint was violated or near violation when minimizing weight, but then corrected by increasing weight. The normalized constraint at the initial design, after design cycle 1 and 2 are, -.1.64, .654 and .087, respectively, note the increase to .654, then drop to .087. The normalized constraint plot is not shown on this page but is visible to you when viewing the web app.

# Results

## Before Optimization

- Weight: 6.962

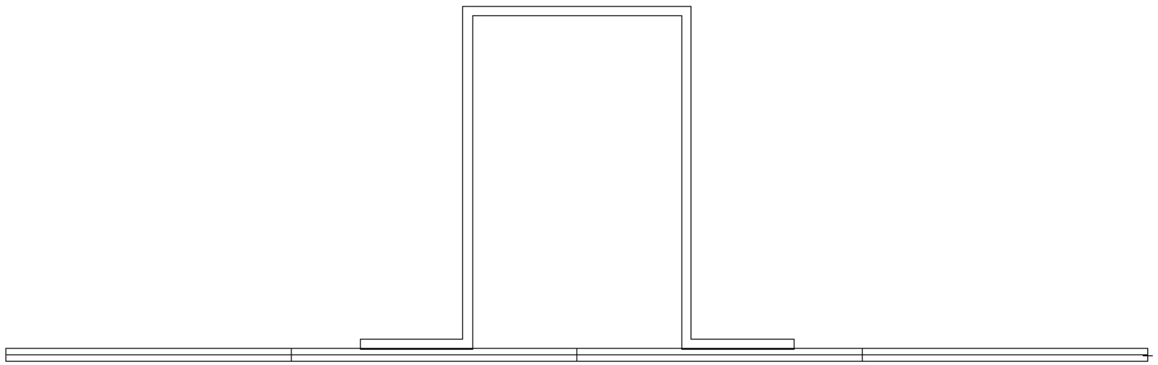
- x1 = T, thickness of shell
-  = .15
- x2 = DIM2
-  = .1 in.




## After Optimization

- Weight: 5.477

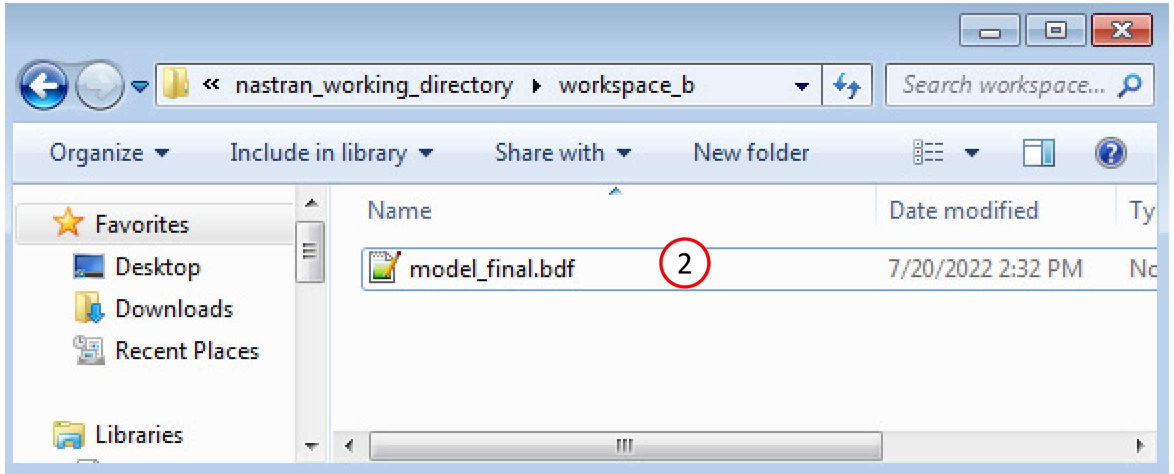
- x1 = T = .113 in.
- x2 = DIM2 = .0839 in.



# Update the Original Model

1. The original input files, e.g. DAT, BDF, etc., contains the original values for the designed properties. These original values must be updated to use the new and optimized values.
2. A new BDF file has been created in nastran_working_directory/workspace_b/ model_final.bdf.
3. The file model_final.bdf is a copy of the original input files but the original values for the designed properties have been updated to use the optimized values.

- If you were using multiple INCLUDE files, model_final.bdf is a combination of all INCLUDE files. The next few slides discuss an alternative method of using the PCH to BDF web app to update the values for the designed properties while preserving separate INCLUDE files.




## Original Input Files

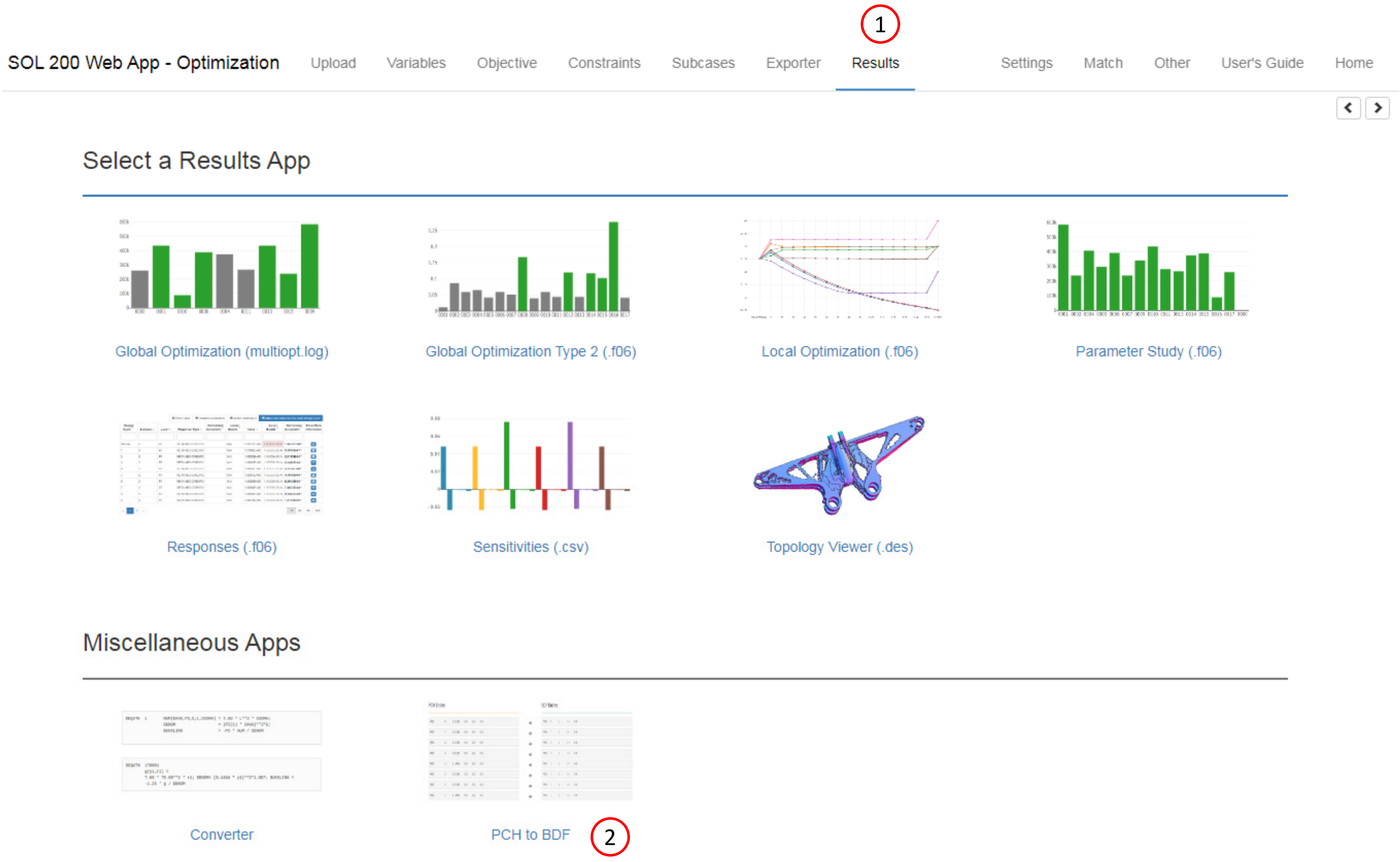
```
CBAR    31      3               10200   10201   0.0     0.0     1.0
                                                1.575                   1.575
CBAR    32      3               10201   10202   0.0     0.0     1.0
                                                1.575                   1.575
CBAR    33      3               10202   10203   0.0     0.0     1.0
                                                1.575                   1.575
CBAR    34      3               10203   10204   0.0     0.0     1.0
                                                1.575                   1.575
$
$ Elements and Element Properties for region : Plate
PSHELL  1       1       0.15    1
$ Elements and Element Properties for region : Plate_2
PSHELL  2       1       0.2     1
$111111122222222333333334444444455555555666666667777777788888888999999999
$ Elements and Element Properties for region : Hat_Stiffener
PBARL   3       1               hat
        3.0     0.1     2.0     0.9
$
```

## Updated BDF File (model_final.bdf)

```
CBAR          31       3   10200   10201     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          32       3   10201   10202     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          33       3   10202   10203     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          34       3   10203   10204     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
$
$ Elements and Element Properties for region : Plate
PSHELL         1       1 .112735       1     1.0           0 .833333     0.0
                               0
$ Elements and Element Properties for region : Plate_2
PSHELL  2       1       0.2     1
$111111122222222333333334444444455555555666666667777777788888888999999999
$ Elements and Element Properties for region : Hat_Stiffener
PBARL          3       1MSCBML0 HAT
              3. .083866 2.          .9     0.0
```

# Update the Original Model

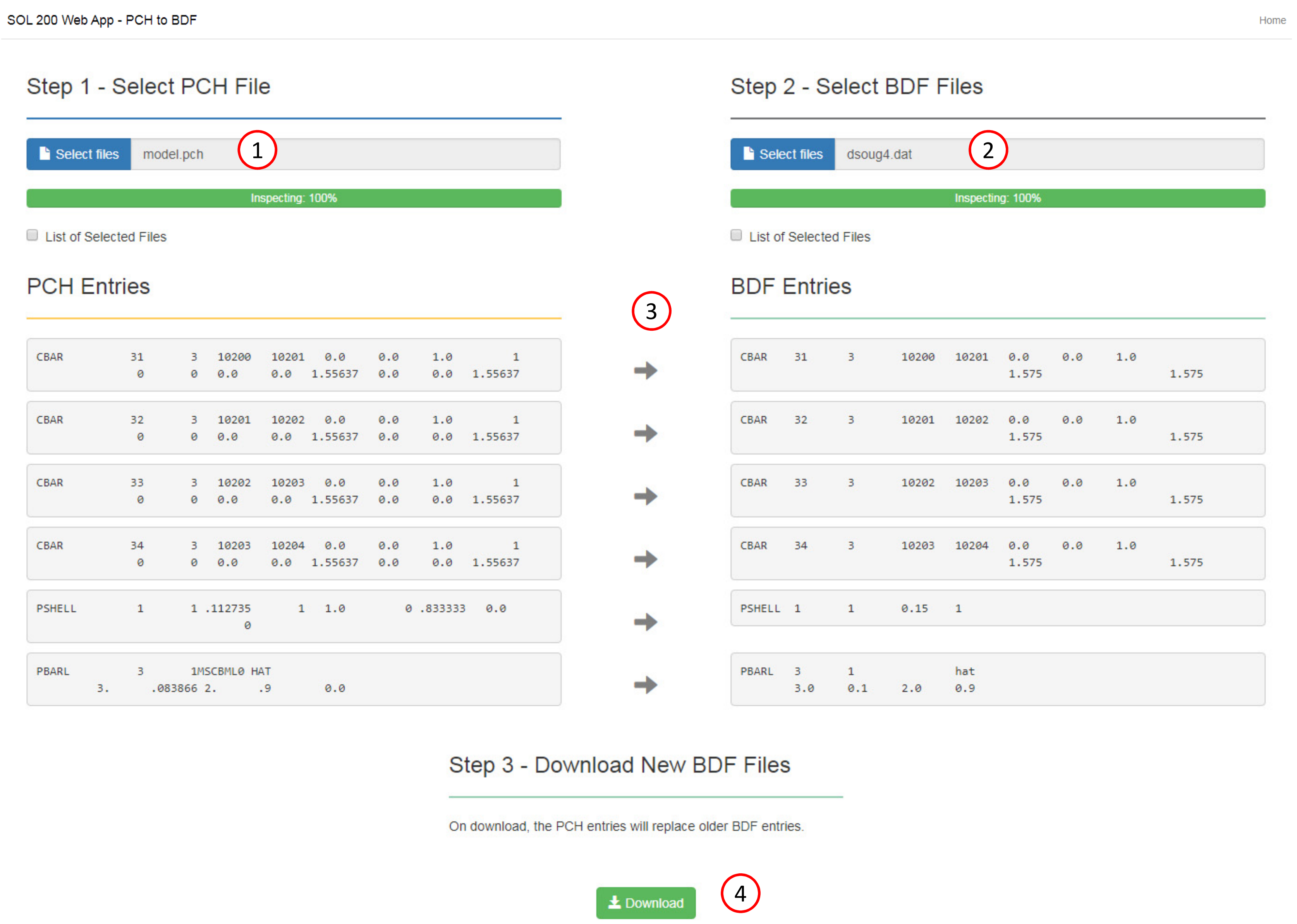
1. Click Results
2. Click PCH to BDF



# Update the Original Model

The original .bdf/.dat file has old information about the properties. The properties will be updated.

1. Select the model.pch file
2. Select the original file: dsoug4.dat
3. A summary of updates that will be performed are shown
4. Click Download and a new updated BDF file is downloaded



# Update the Original Model

1. Note the entries have been updated with the optimized properties

```
CQUAD4  14      1       10301   10302   10402   10401
CQUAD4  15      1       10302   10303   10403   10402
CQUAD4  16      1       10303   10304   10404   10403
$
$1111111122222222333333334444444455555555666666667777777788888888999999999
CBAR    31      3       10200   10201   0.0     0.0     1.0
                                        1.575                           1.575
CBAR    32      3       10201   10202   0.0     0.0     1.0
                                        1.575                           1.575
CBAR    33      3       10202   10203   0.0     0.0     1.0
                                        1.575                           1.575
CBAR    34      3       10203   10204   0.0     0.0     1.0
                                        1.575                           1.575
$
$ Elements and Element Properties for region : Plate
PSHELL  1       1       0.15    1
$ Elements and Element Properties for region : Plate_2
PSHELL  2       1       0.2     1
$1111111122222222333333334444444455555555666666667777777788888888999999999
$ Elements and Element Properties for region : Hat_Stiffener
PBARL   3       1               hat
        3.0     0.1     2.0     0.9
$
$ Material Record : Aluminum
$ Description of Material : Date: 17-Apr-18          Time: 17:36:49
MAT1    1       1.0E+7          0.33    0.283
$
FORCE   1       10004           2000.0  1.0     0.0     0.0
FORCE   1       10104           2000.0  1.0     0.0     0.0
FORCE   1       10204           2000.0  1.0     0.0     0.0
FORCE   1       10304           2000.0  1.0     0.0     0.0
FORCE   1       10404           2000.0  1.0     0.0     0.0
FORCE   2       10203           10000.0 0.0     0.0     1.0
PLOAD2  1       50.     1       THRU    16
$
SPC1    1       1236    10000
SPC1    1       136     10100   10300   10400
SPC1    1       36      10001   10002   10003   10004   10104
SPC1    1       36      10401   10402   10403   10404   10304
SPC1    1       3       10204
SPC1    1       13      10200
SPC1    1       6       10101   10102   10103   10104
SPC1    1       6       10301   10302   10303   10304
$
```

Original BDF/DAT File

```
CQUAD4  14      1       10301   10302   10402   10401
CQUAD4  15      1       10302   10303   10403   10402
CQUAD4  16      1       10303   10304   10404   10403
$
$1111111122222222333333334444444455555555666666667777777788888888999999999
CBAR          31       3   10200   10201     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          32       3   10201   10202     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          33       3   10202   10203     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
CBAR          34       3   10203   10204     0.0     0.0     1.0       1
               0       0     0.0     0.0 1.55637     0.0     0.0 1.55637
$
$ Elements and Element Properties for region : Plate
PSHELL         1       1 .112735       1     1.0         0 .833333     0.0
                       0
$ Elements and Element Properties for region : Plate_2
PSHELL  2       1       0.2     1
$1111111122222222333333334444444455555555666666667777777788888888999999999
$ Elements and Element Properties for region : Hat_Stiffener
PBARL          3       1MSCBML0 HAT
        3.      .083866 2.      .9      0.0
$
$ Material Record : Aluminum
$ Description of Material : Date: 17-Apr-18          Time: 17:36:49
MAT1    1       1.0E+7          0.33    0.283
$
FORCE   1       10004           2000.0  1.0     0.0     0.0
FORCE   1       10104           2000.0  1.0     0.0     0.0
FORCE   1       10204           2000.0  1.0     0.0     0.0
FORCE   1       10304           2000.0  1.0     0.0     0.0
FORCE   1       10404           2000.0  1.0     0.0     0.0
FORCE   2       10203           10000.0 0.0     0.0     1.0
PLOAD2  1       50.     1       THRU    16
$
SPC1    1       1236    10000
SPC1    1       136     10100   10300   10400
SPC1    1       36      10001   10002   10003   10004   10104
SPC1    1       36      10401   10402   10403   10404   10304
SPC1    1       3       10204
SPC1    1       13      10200
SPC1    1       6       10101   10102   10103   10104
SPC1    1       6       10301   10302   10303   10304
```

Downloaded BDF/DAT File

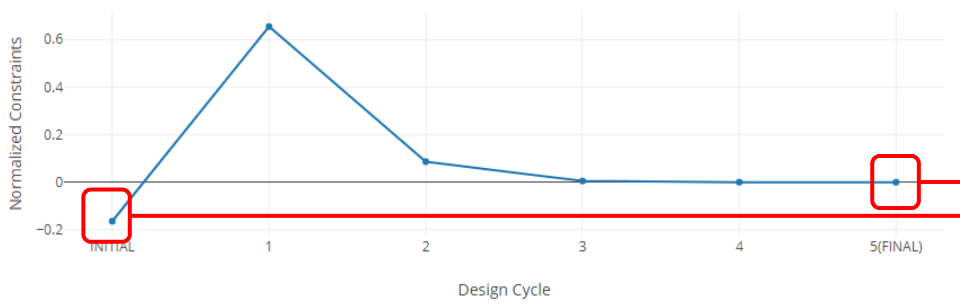
# Inspection of MSC Nastran Results with the Post-processor Web App

# Normalized Constraints

- All constraints are normalized. For each design cycle, the maximum normalized constraint (NC) is reported in the Normalized Constraints plot.
- The Responses web app is used to inspect the corresponding response for each maximum normalized constraint value.
    - For the initial design, the maximum NC is -.16392 and corresponds to a beam stress of 20,902.
    - For the final design, the maximum NC is .000024418 and corresponds to a von Mises stress of 25,001.

Normalized Constraints

+ Info




SOL 200 Web App - Responses

Home

## Responses

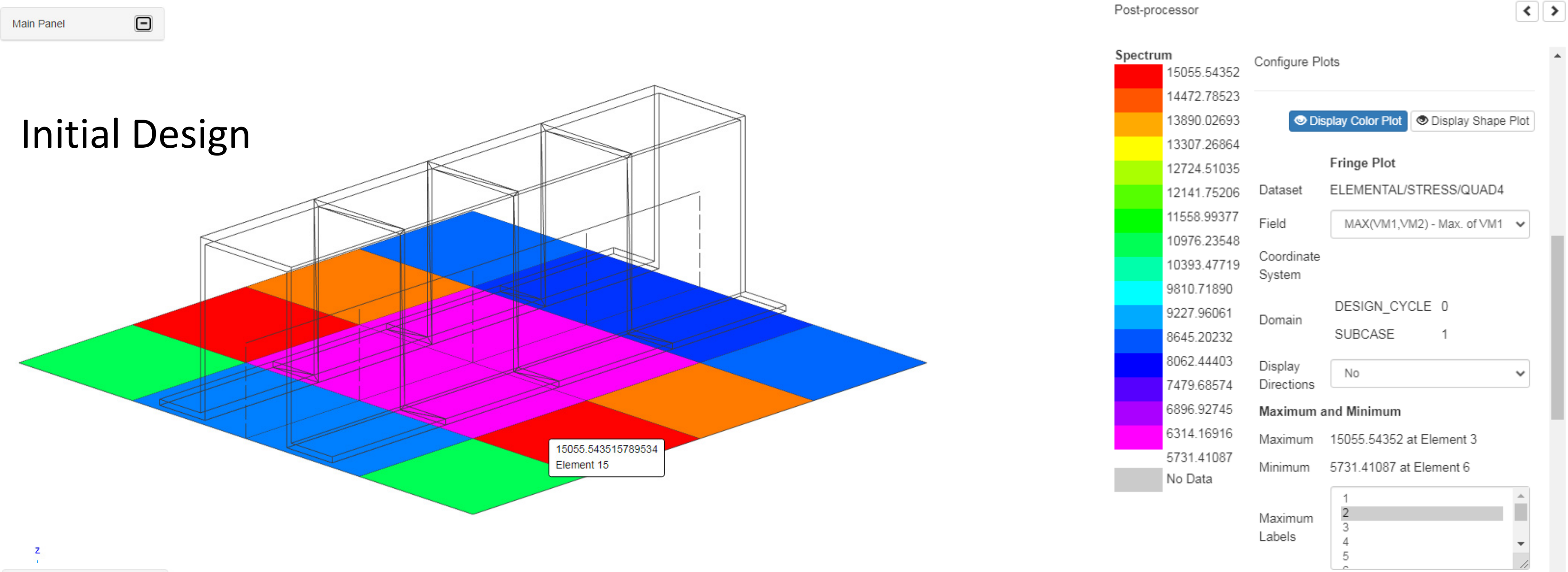
Reset view | Violated constraints | Active constraints | Maximum constraint for each design cycle

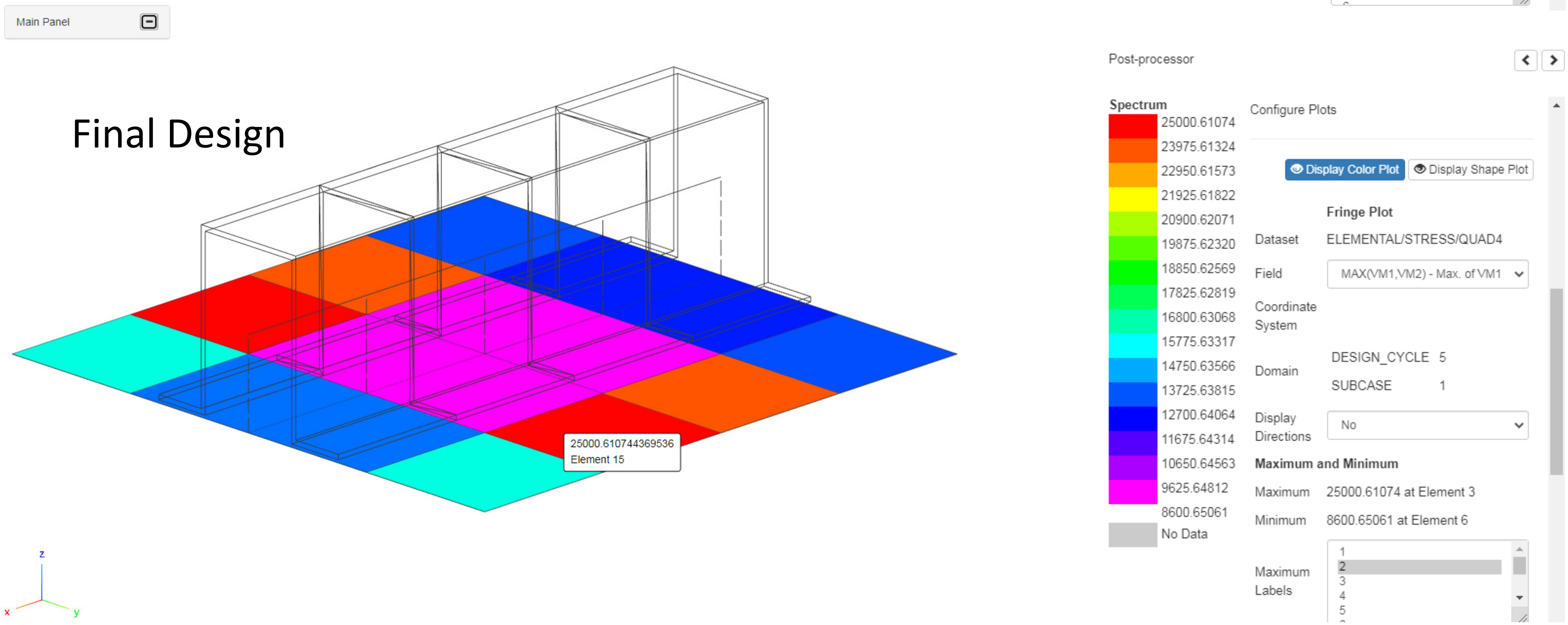
| Design Cycle | Subcase | Label | Response Type | Normalized Constraint | Lower Bound | Value | Upper Bound | Normalized Constraint | Show More Information | designCycleNumber | ELEMENT ID | COMPONENT NO. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Search | Searc | Se | Search | Search | Sea | Search | Search | Search | | | | |
| INITIAL | 2 | r1 | STRESS | | N/A | 2.0902E+04 | 2.5000E+04 | -1.6392E-01** | | 0 | 34 | 7 |
| 1 | 1 | r5 | DISPLACEMENT | | N/A | 1.6545E-01 | 1.0000E-01 V | 6.5446E-01** | | 1 | | 3 |
| 2 | 1 | r3 | STRESS | | N/A | 2.7165E+04 | 2.5000E+04 V | 8.6588E-02** | | 2 | 3 | 9 |
| 3 | 1 | r3 | STRESS | | N/A | 2.5133E+04 | 2.5000E+04 V | 5.3229E-03** | | 3 | 3 | 9 |
| FINAL - 5(FI | 1 | r3 | STRESS | | N/A | 2.5001E+04 | 2.5000E+04 A | 2.4418E-05** | | 5 | 15 | 9 |

# Post-processor Web App

- The Post-processor web app is used to inspect the MSC Nastran results.
- Consider the maximum von Mises stress for the top and bottom of the thickness and for subcase 1.
    - For the initial design, for element 15, the von Mises stress is 15,055.
    - For the final design, for element 15, the von Mises stress is 25,000.61 ≈ 25,001.

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.



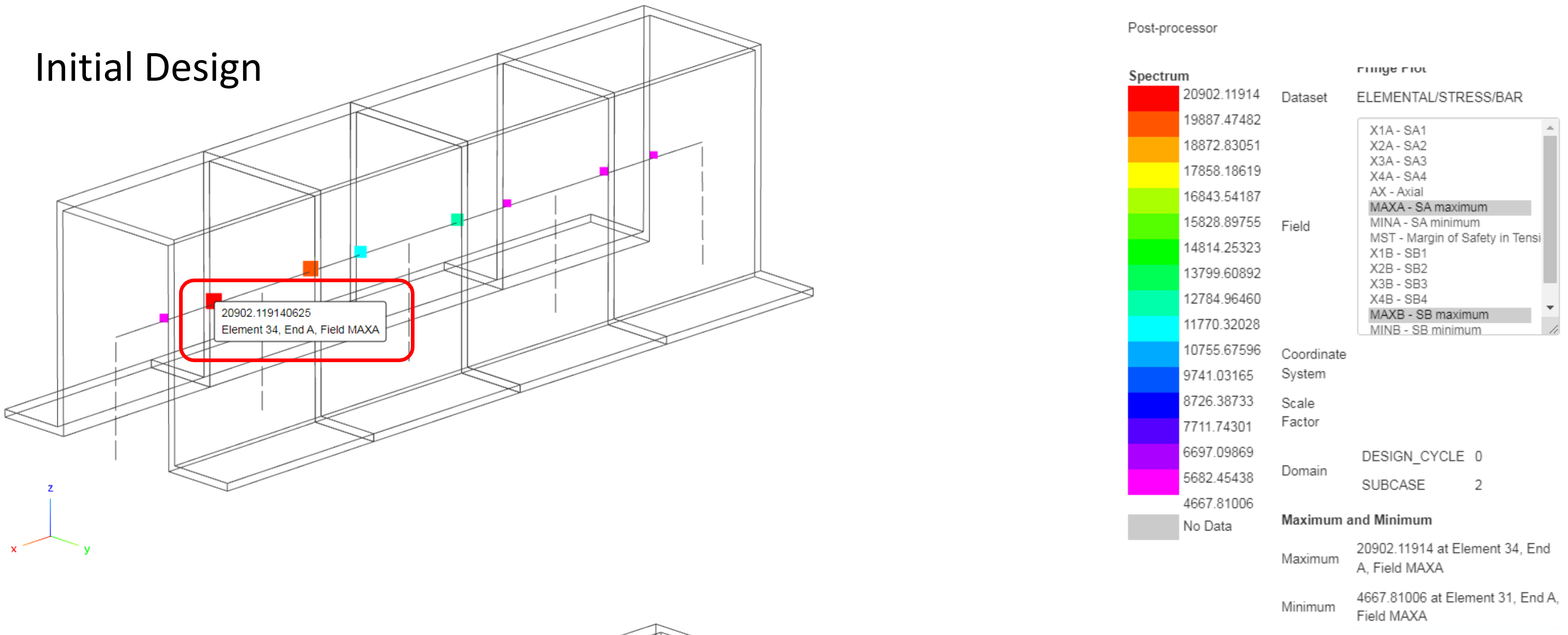



# Post-processor Web App

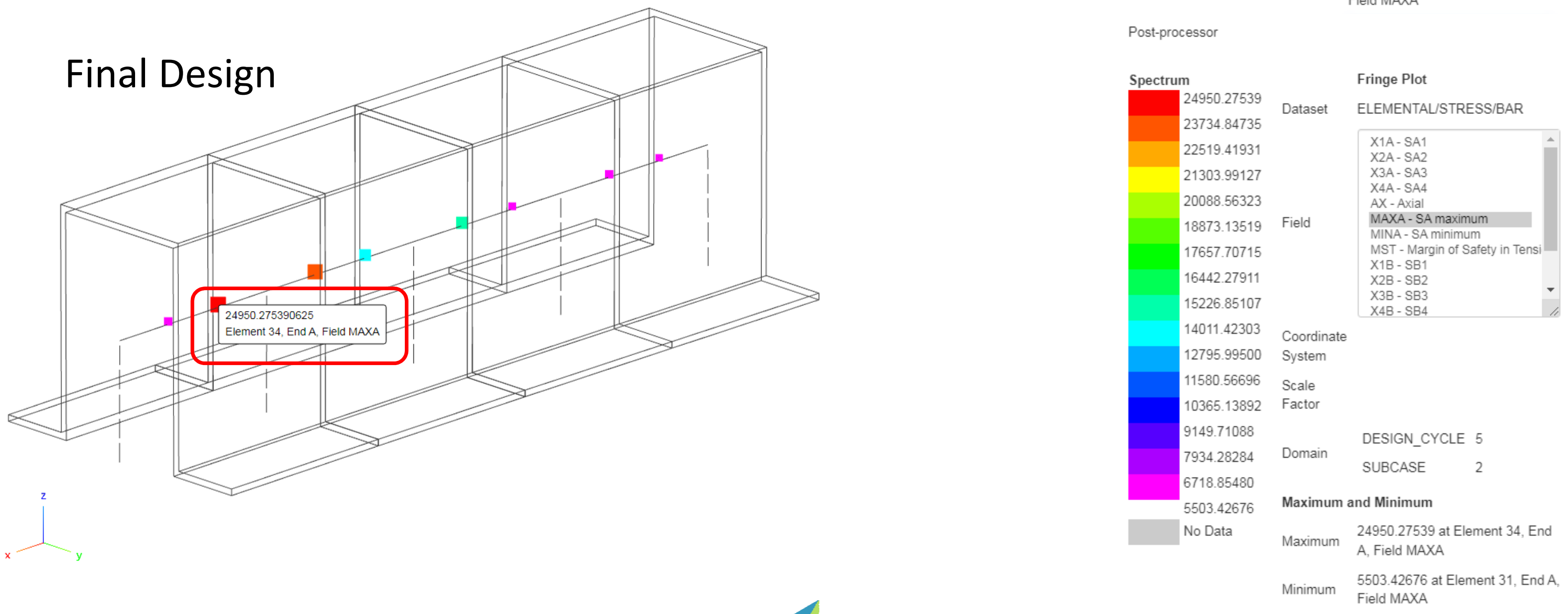
- The Post-processor web app is used to inspect the MSC Nastran results.
- Consider the maximum beam stress for the end A and B of the beam elements for subcase 2.
    - For the initial design, for element 34, the maximum beam stress is at end A and is 20,902.
    - For the final design, for element 34, the maximum beam stress is at end A and is 24,950.

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

Initial Design




Final Design

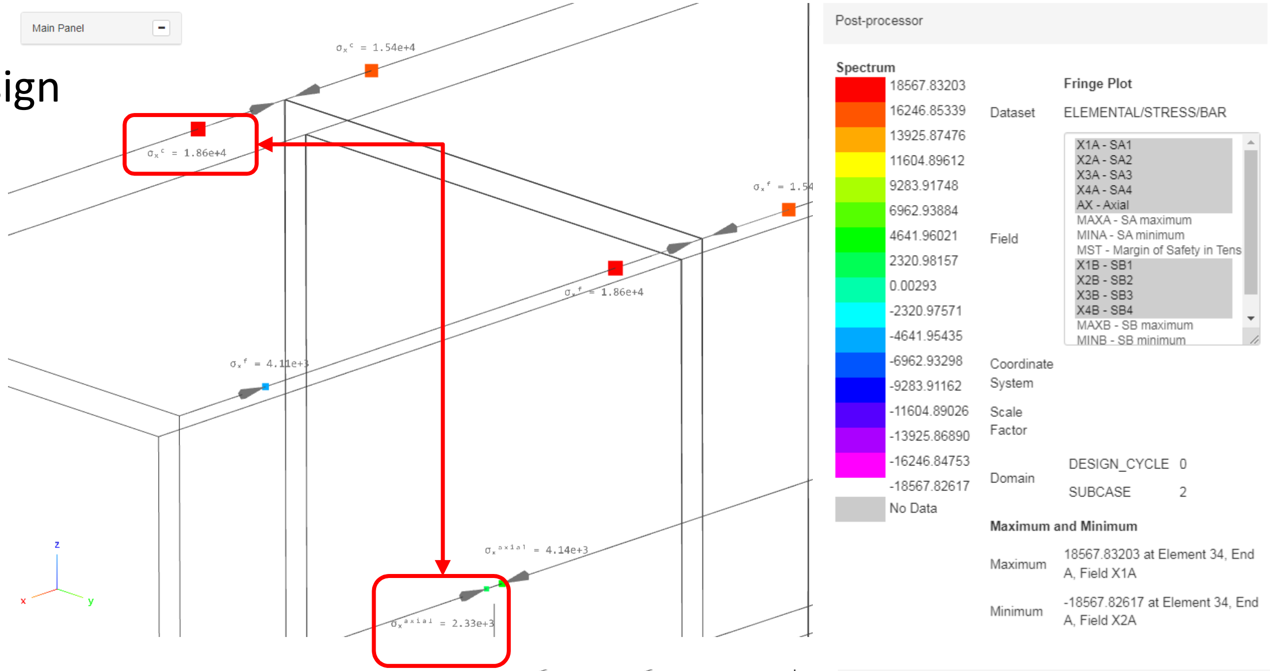


# Post-processor Web App

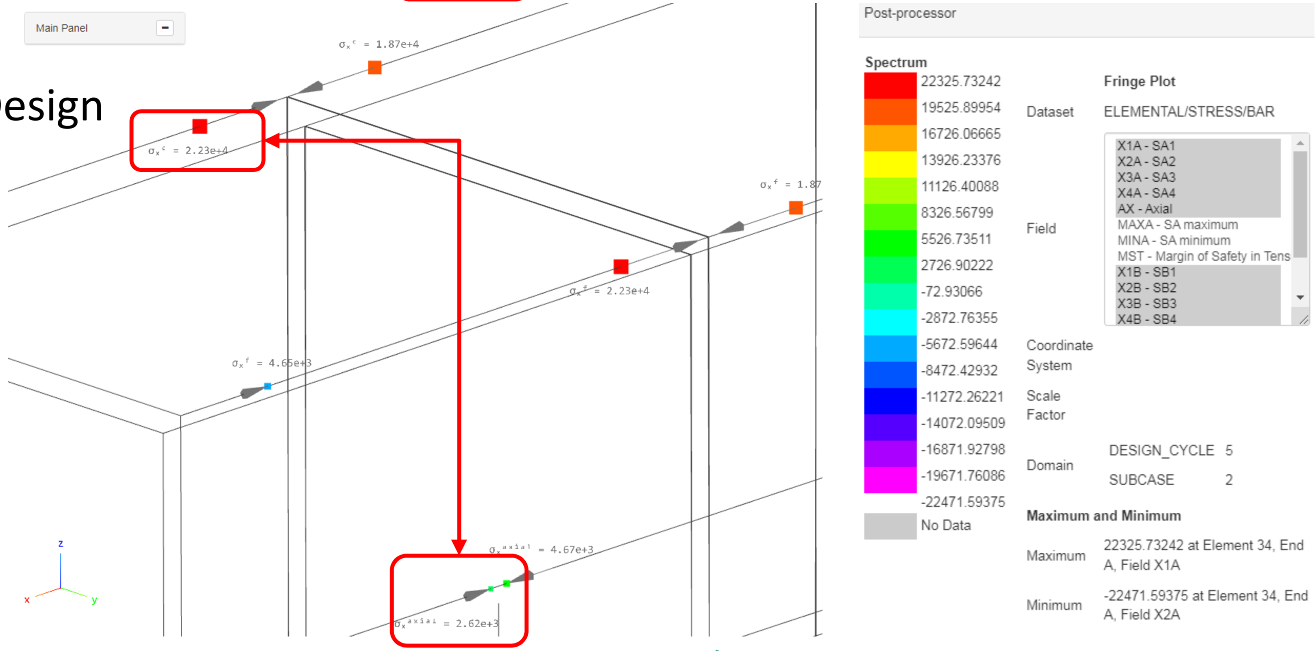
- The maximum stress and end A and B was constrained during the optimization. What is the maximum stress?
- The maximum stress is the sum of the bending stress and axial stress.
- For subcase 2, element 34:
  - For the initial design, the max stress is 20,902 = 18,567.83 + 2,334.29
  - For the final design, the max stress is 24,950 = 22,325 + 2,625

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

Initial Design




Final Design

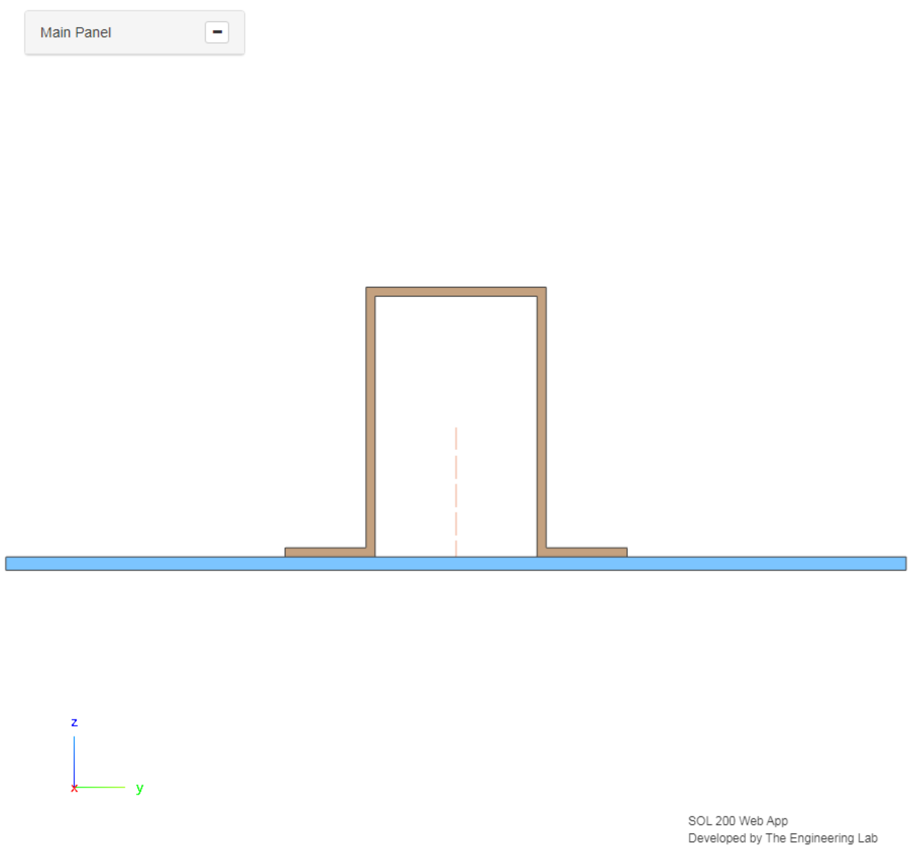


# Post-processor Web App

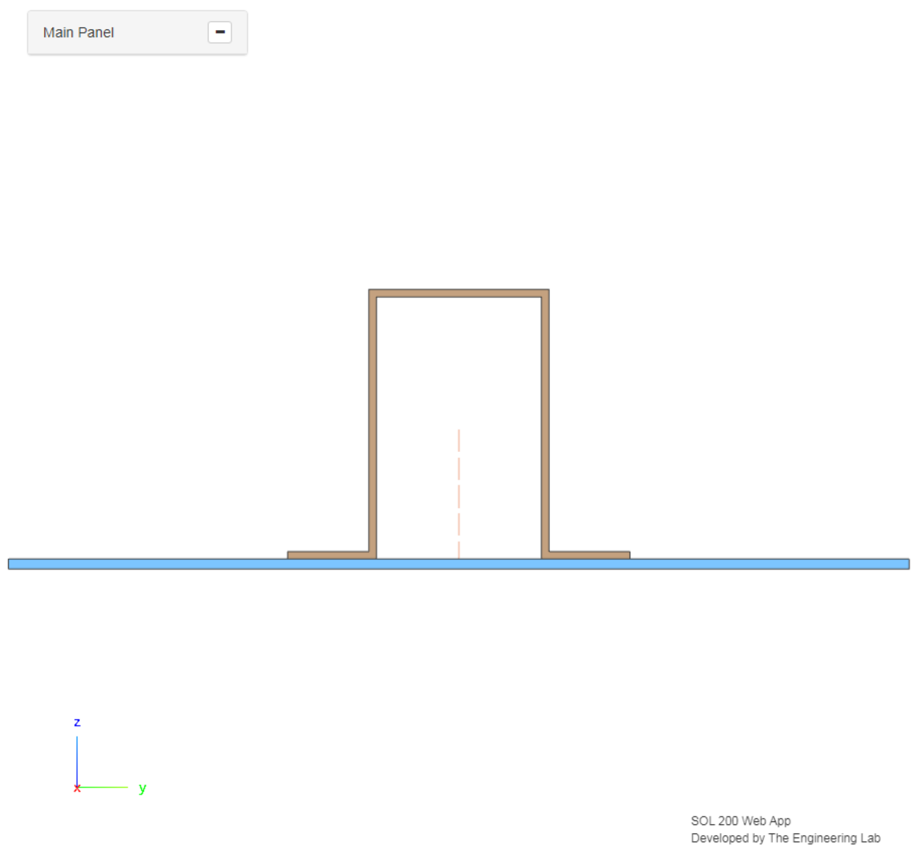
- The CBAR cross sections of the initial and final design are compared.
- The CQUAD4 thicknesses of the initial and final design are compared

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

## Thickness of CQUAD4 elements
## Beam cross section of CBAR elements




Initial Design




Final Design

End of Tutorial

# Appendix

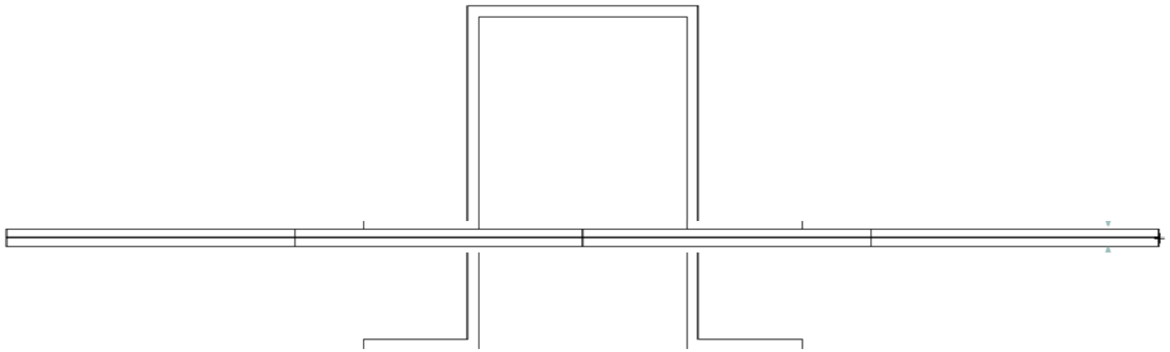
# Appendix Contents

- Frequently Asked Questions
  - How do I avoid the scenario where the offset causes the cross section to interfere with the plate?

# Frequently Asked Questions

Question:

- How do I avoid the scenario where the offset causes the cross section to interfere with the plate?



The offset (W3A and W3B) in this example causes the beam cross section to interfere with the plate

# Frequently Asked Questions

Answer:

- In ‘Step 4 - Adjust DVXREL2’, specify bounds that the offset property can take
- In this tutorial, this step was not necessary because the offset is in terms of x1 and x1 already has bounds applied

Step 5 - Adjust DVXREL2

✖ Delete Visible Rows

+ Options

| | Label | Status | Property | Property Description | Entry | Entry ID | Initial Value | Lower Bound | Upper Bound | Equation |
|---|---|---|---|---|---|---|---|---|---|---|
| | Search | Search | Search | Search | Search | Search | Search | Search | Search | Search |
| ✖ | C1 | ✔ | W3A | Component of offset vector wa a... | CBAR | 31 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C2 | ✔ | W3B | Component of offset vector wb a... | CBAR | 31 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C3 | ✔ | W3A | Component of offset vector wa a... | CBAR | 32 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C4 | ✔ | W3B | Component of offset vector wb a... | CBAR | 32 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C5 | ✔ | W3A | Component of offset vector wa a... | CBAR | 33 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C6 | ✔ | W3B | Component of offset vector wb a... | CBAR | 33 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C7 | ✔ | W3A | Component of offset vector wa a... | CBAR | 34 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |
| ✖ | C8 | ✔ | W3B | Component of offset vector wb a... | CBAR | 34 | 1.575 | .1 | Maximum | 1.5 + x1 / 2.0 |