# Workshop – Composite Panel – Phase B – Baseline Core Thickness Optimization

AN MSC NASTRAN SOL 200 TUTORIAL

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

# Composite Workshop

This workshop is phase B of a 3-phase workshop.

Phase B

Workshop – Composite Panel – Phase B – Baseline Core Thickness Optimization

- Perform a core thickness optimization with a constant thickness core
- Tools Used: SOL 200 Web App (Viewer and Optimization web apps) and MSC Nastran

Phase C

Workshop – Composite Panel – Phase C – Topometry Optimization to Determine Optimal Core Shape

- Generate PLY000i Files via Topometry Optimization
- Tools Used: Patran, MSC Nastran and SOL 200 Web App

Phase D

Workshop – Composite Panel – Phase D – Core Shape and Core Thickness Optimization

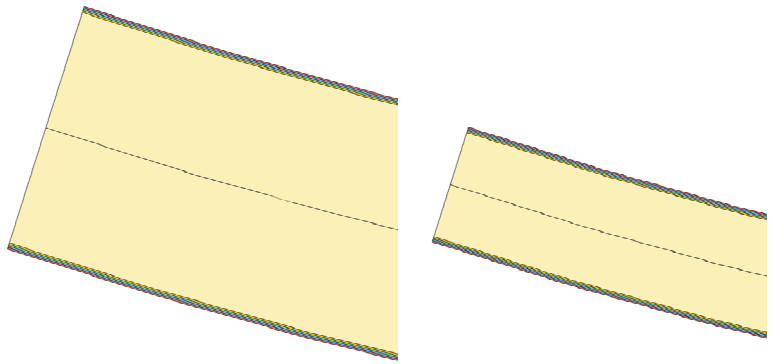
- Input BDF and PLY000i Files
- Create Core Shapes
- Perform Core Thickness Optimization
- Inspect Core
- Tools Used: SOL 200 Web App (Viewer and Optimization web apps) and MSC Nastran

Baseline Core Thickness Optimization → Core Shape Optimization → Core Thickness Optimization

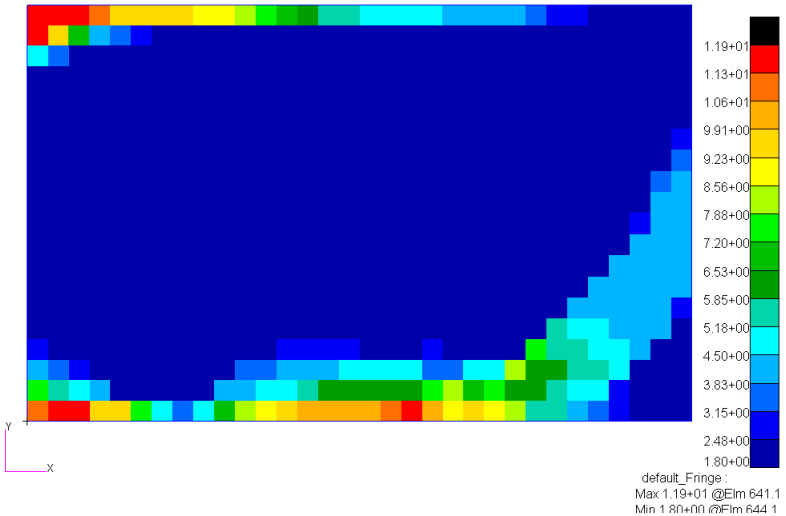
# Composite Workshop

This workshop is phase B of a 3-phase workshop.

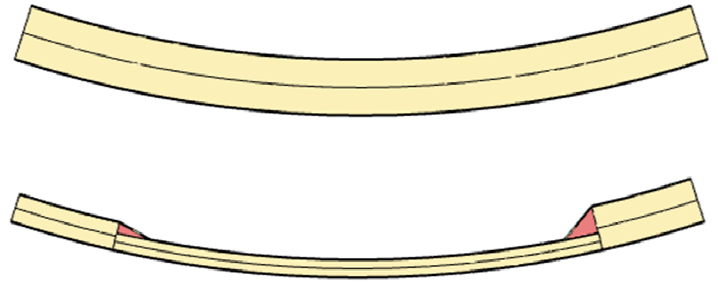
Phase B



Phase C




Phase D



Baseline Core Thickness Optimization

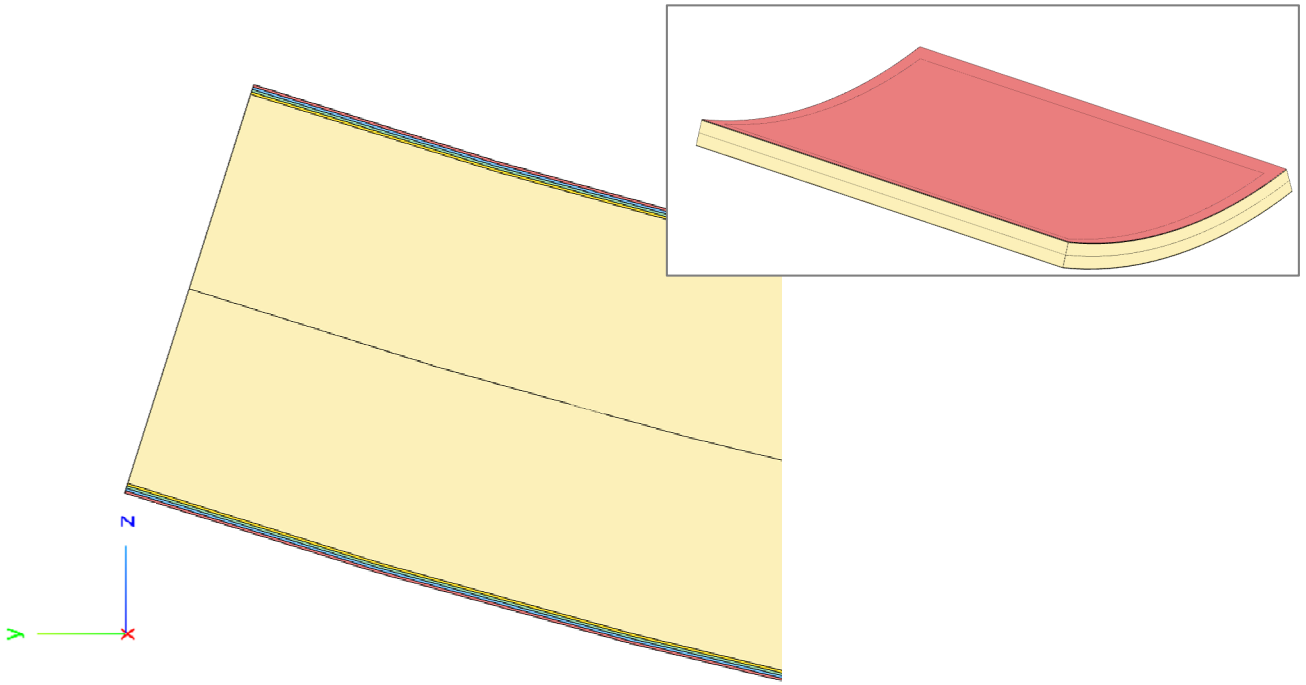
Core Shape Optimization

Core Thickness Optimization

# Goal: Use Nastran SOL 200 Optimization

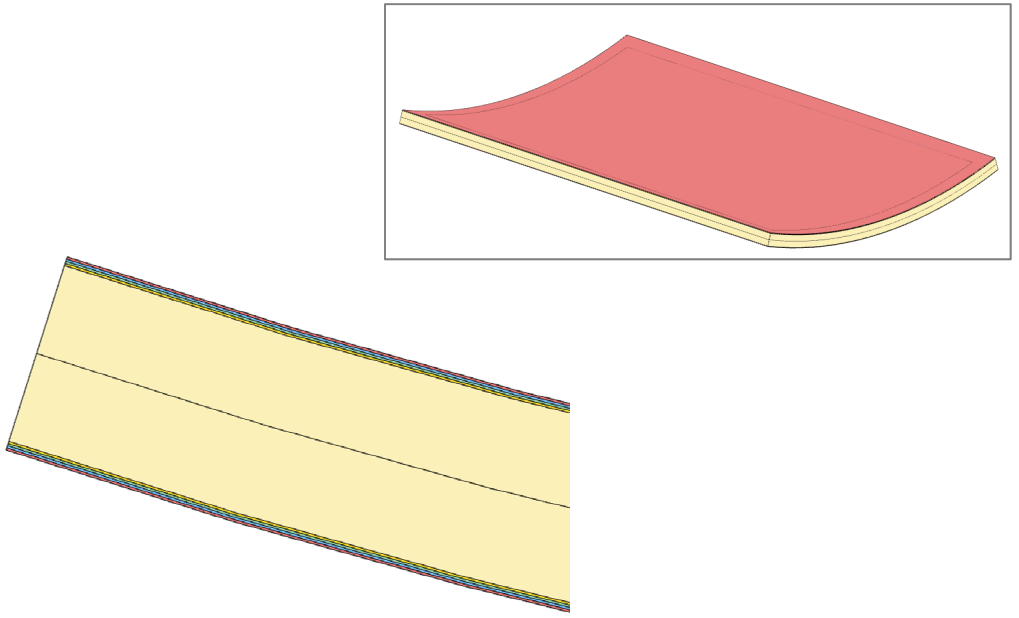
Before Optimization

- Weight:  6.153587E-04
- Buckling Load Factor: 3.364003

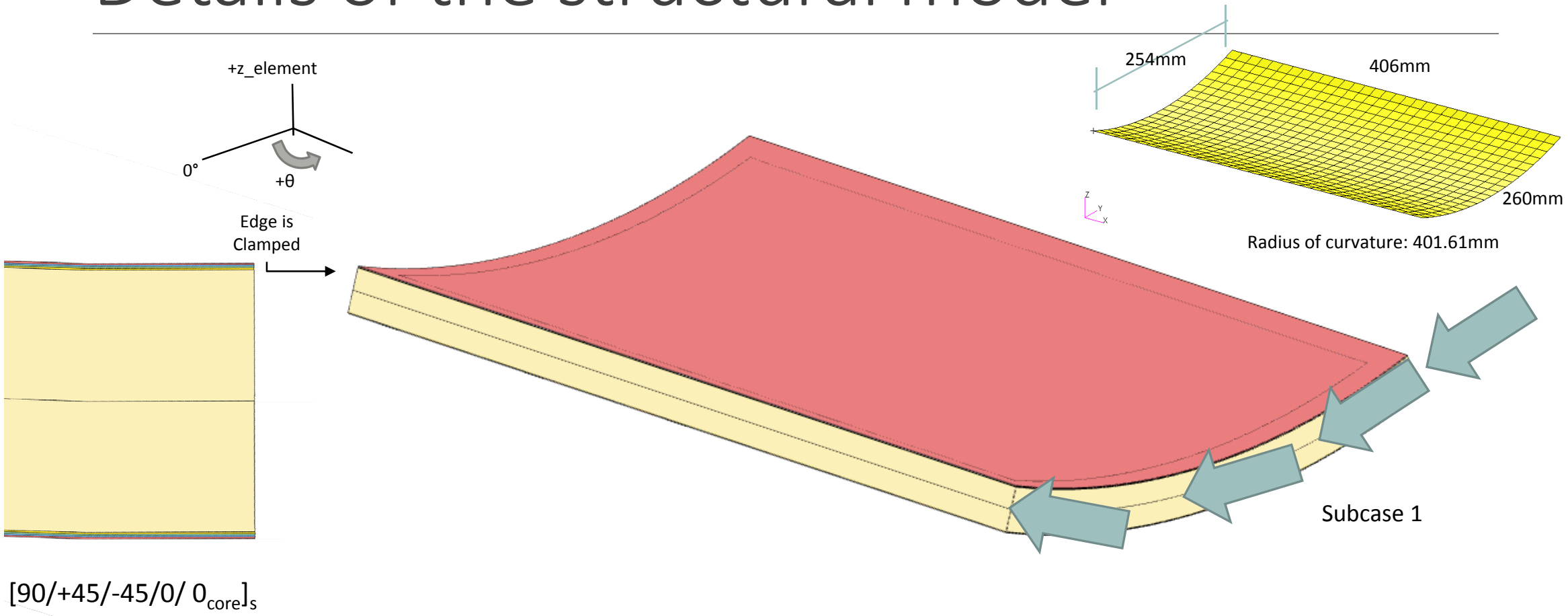



After Optimization

- Weight: 3.9503E-04
- Buckling Load Factor: 1.064771



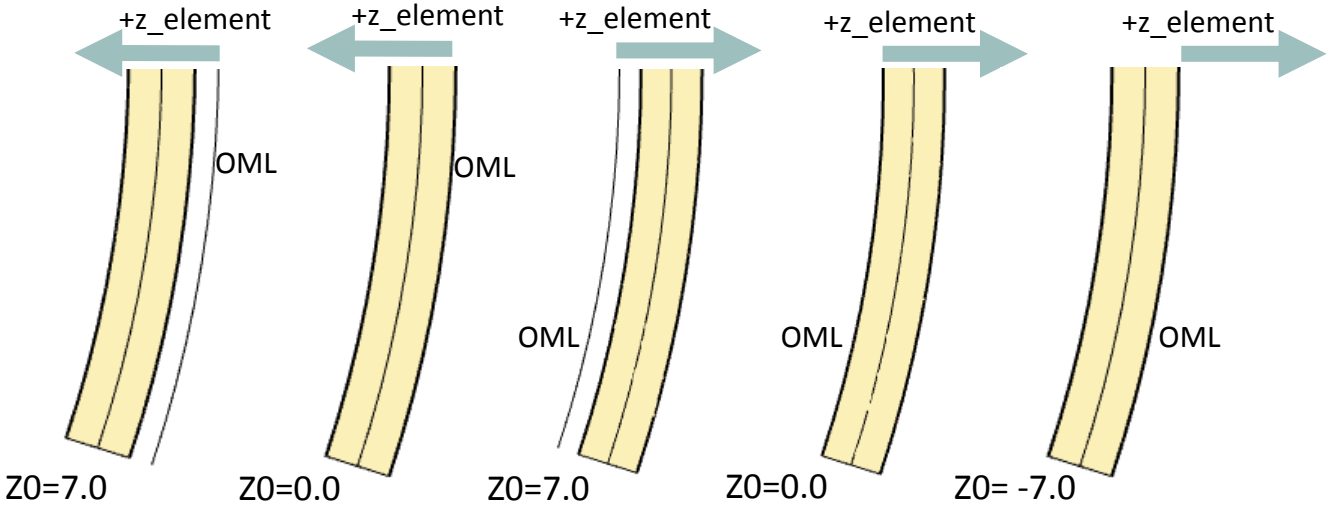
# Details of the structural model



# Adjustments Made to the BDF File

1) Element Normals

For this model, the nodal plane represents the outer mold line (OML). For manufacturing purposes, the composite is to be left of the OML. The placement of the composite is controlled by the Z0 field on the PCOMP entry. The element normals are purposely adjusted to point towards the center of curvature, and doing this offers the convenience of using only Z0=0.0 throughout the optimization procedure. If the element normals are pointed away from the center curvature and to place the composite left of the OML, the PCOMP entry's Z0 field must be updated to be -T, where T is the total thickness of the laminate. This will be tedious when the composite thickness varies throughout the composite.




2) Limit eigenvalues to only positive eigenvalues

For symmetric models, certain loadings will produce both positive and negative buckling load factors. This optimization only considers positive buckling load factors. This is achieved by editing the EIGRL entry and specifying a lower bound of 0.0, i.e. the eignevalue extraction will only extract eigenvalues greater than 0.0. A negative buckling load factor (eigenvalue) indicates buckling if the load were reversed.

```
Before
EIGRL    1                              1        0

After
EIGRL    1       0.0                    1        0
```

3) Output the mass to the F06 file

The GRDPNT parameter is added to the BDF file, so the mass it output to the F06 file in the section OUTPUT FROM GRID POINT WEIGHT GENERATOR.

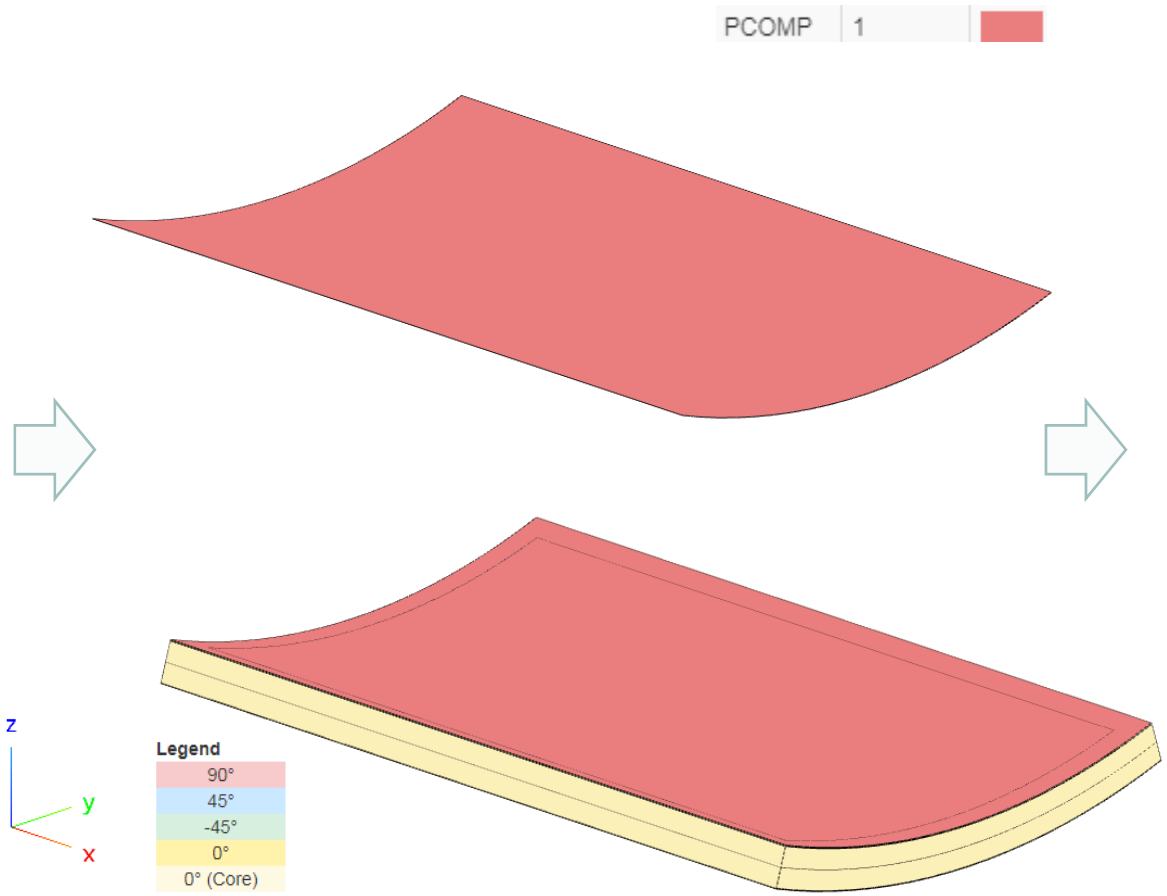
```
param    grdpnt   0
```

# Optimization Problem Statement

## Design Variables

x1: T5, Thickness of layer 5 (0°), of PCOMP 1 (pcomp.1)

- Initial value: 10.0
- Lower Bound: 3.0
- Upper Bound: 25.0
- Allowed Discrete Values: 1, 2, 3, …, 30




## Design Objective

Minimize r0: weight

## Design Constraints

r1: 1st buckling load factor

1.0 < r1

# Contact me

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

christian@ the-engineering-lab.com

# 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**

**Core Thickness Optimization** - This tutorial demonstrates the process to configure a core thickness optimization when the core is constant thickness.

# SOL 200 Web App Capabilities

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

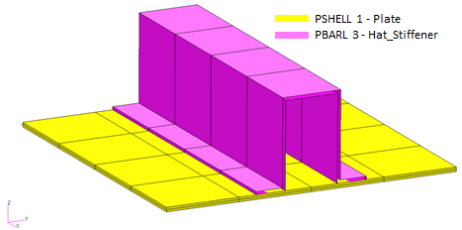
## Compatibility

- 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.

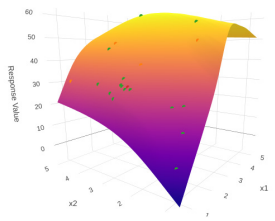
## Benefits

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

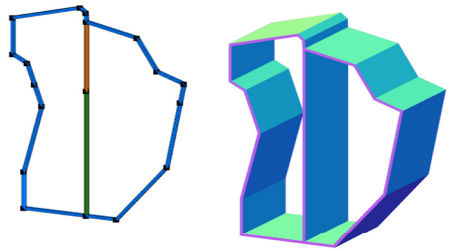
## Web Apps



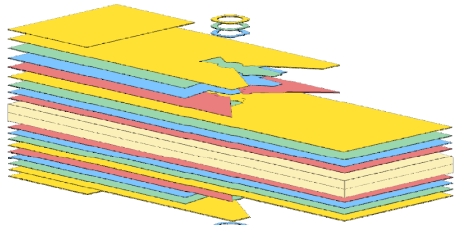

**Web Apps for MSC Nastran SOL 200**
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



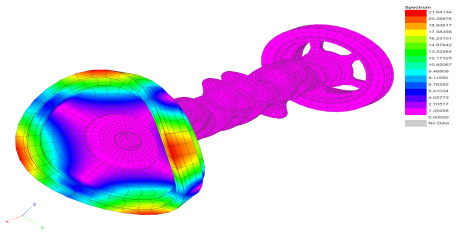
**Machine Learning Web App**
Bayesian Optimization for nonlinear response optimization (SOL 400)



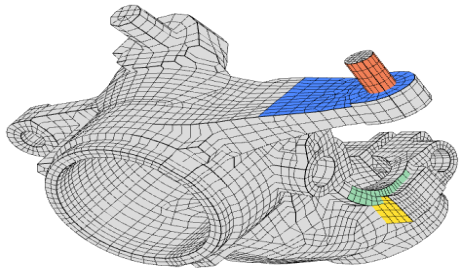
**PBMSECT Web App**
Generate PBMSECT and PBRSECT entries graphically



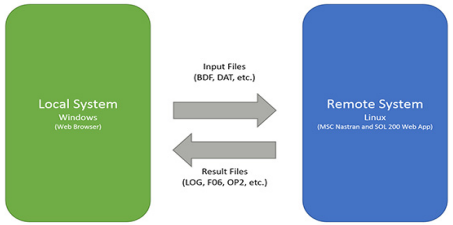
**Ply Shape Optimization Web App**
Optimize composite ply drop-off locations, and generate new PCOMPG entries



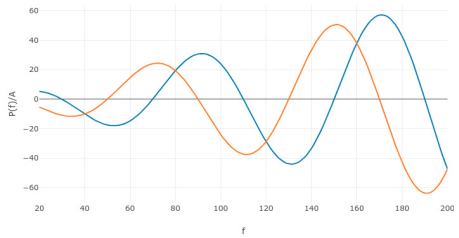
**Post-processor Web App**
View MSC Nastran results in a web browser on Windows and Linux



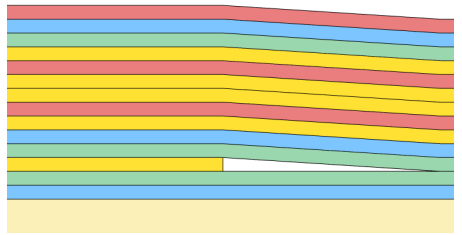
**Shape Optimization Web App**
Use a web application to configure and perform shape optimization.




**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



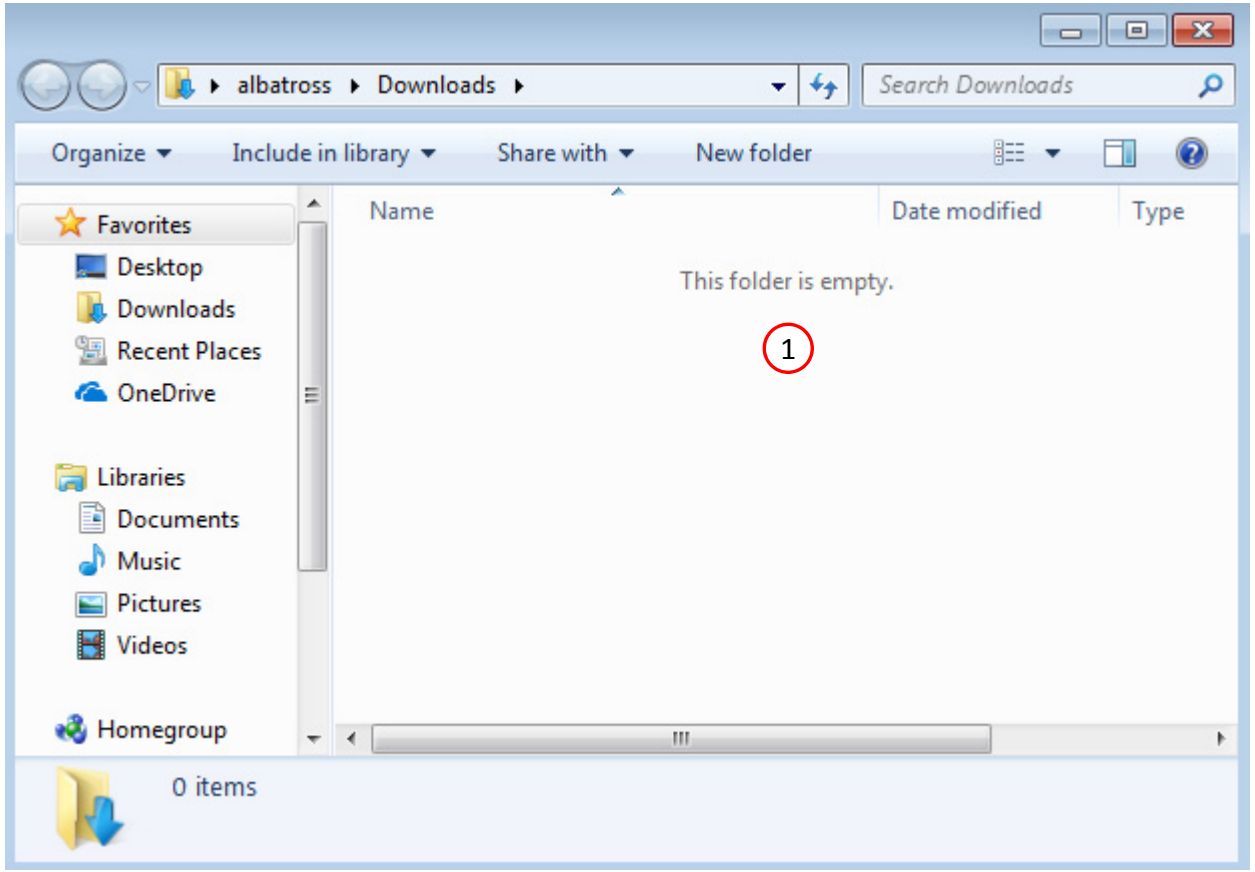
**Stacking Sequence Web App**
Optimize the stacking sequence of composite laminate plies

**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

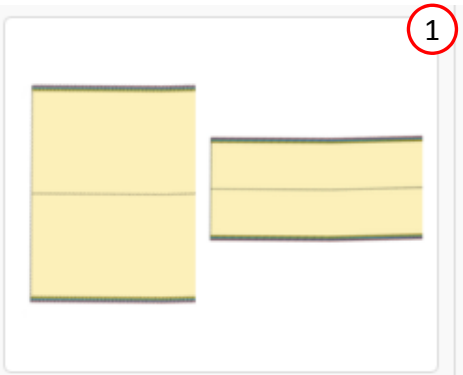
1. Click on the indicated link

- 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.



1

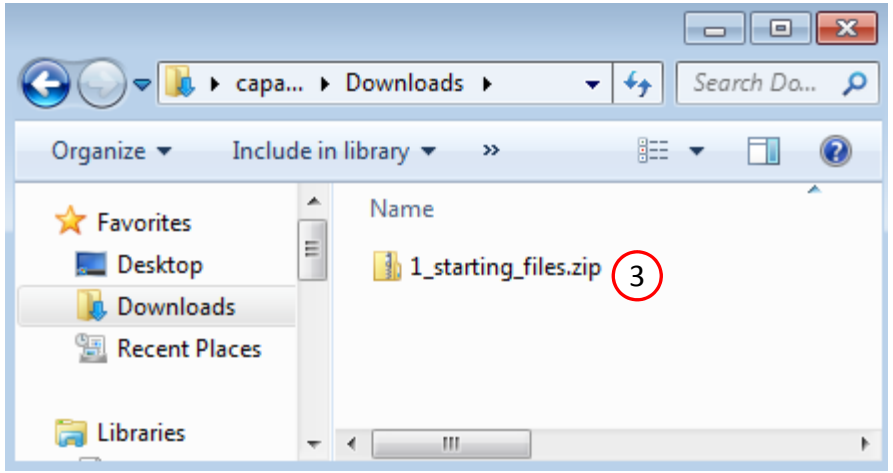
**Composite Panel – Phase B – Baseline Core Thickness Optimization**

The goal of this 3-phase tutorial series is to optimize a curved composite panel, with a core, and produce a lightweight composite that satisfies constraints on the buckling load factor. This tutorial series focuses exclusively on optimizing the thickness of the core.

This tutorial demonstrates how to configure a basic core thickness optimization where the core has a constant thickness throughout the entire model. The goal of this tutorial is to demonstrate basic actions such as creating variables, a weight objective and constraints on the buckling load factor. The results of this core thickness optimization serve as a baseline for future comparisons. In a subsequent tutorial, the core will be allowed to have a variable thickness throughout the model and will be optimized to minimize weight.

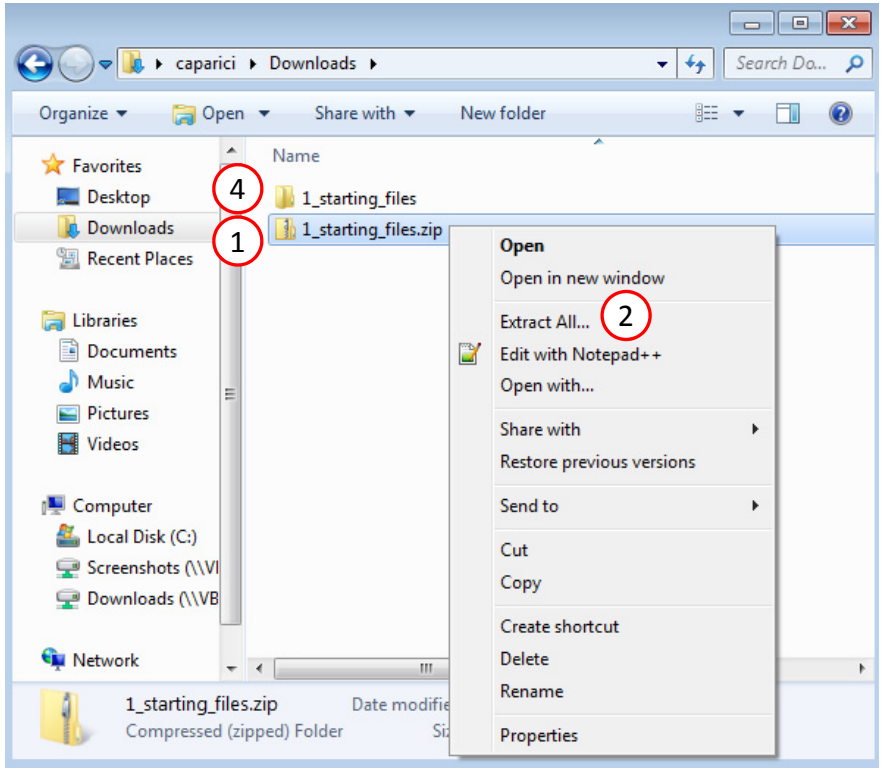
This is the first phase in a 3-phase tutorial series.

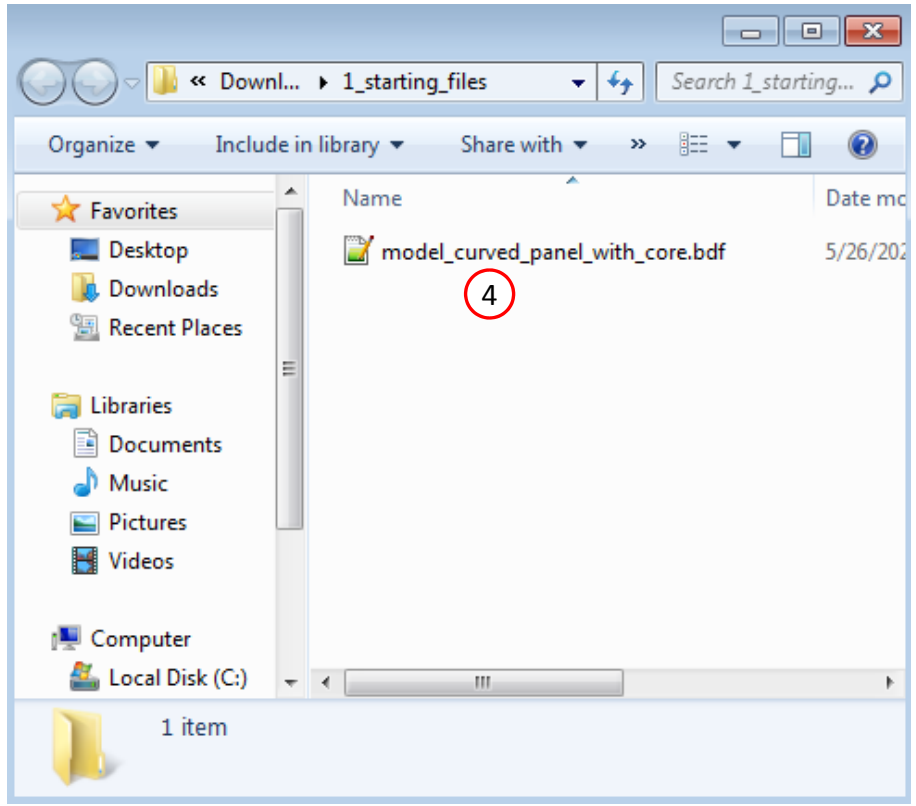
Starting BDF Files: Link 2
Solution BDF Files: Link

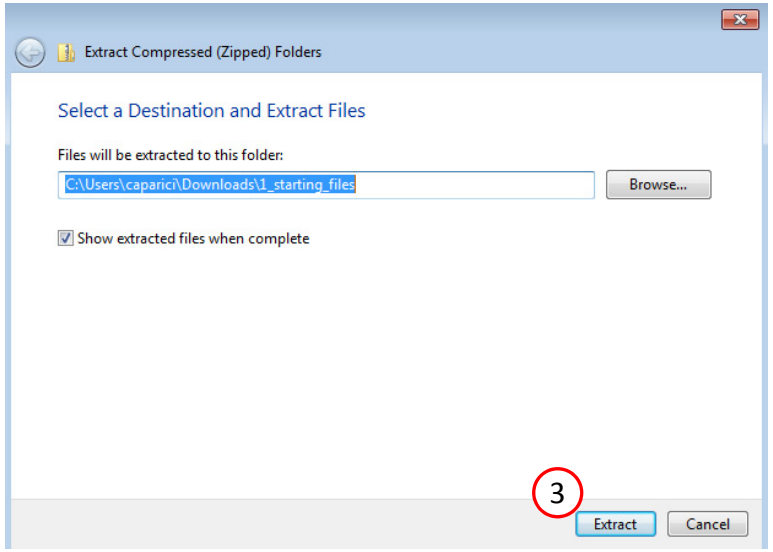


# Obtain Starting Files

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



# Open the Correct Page

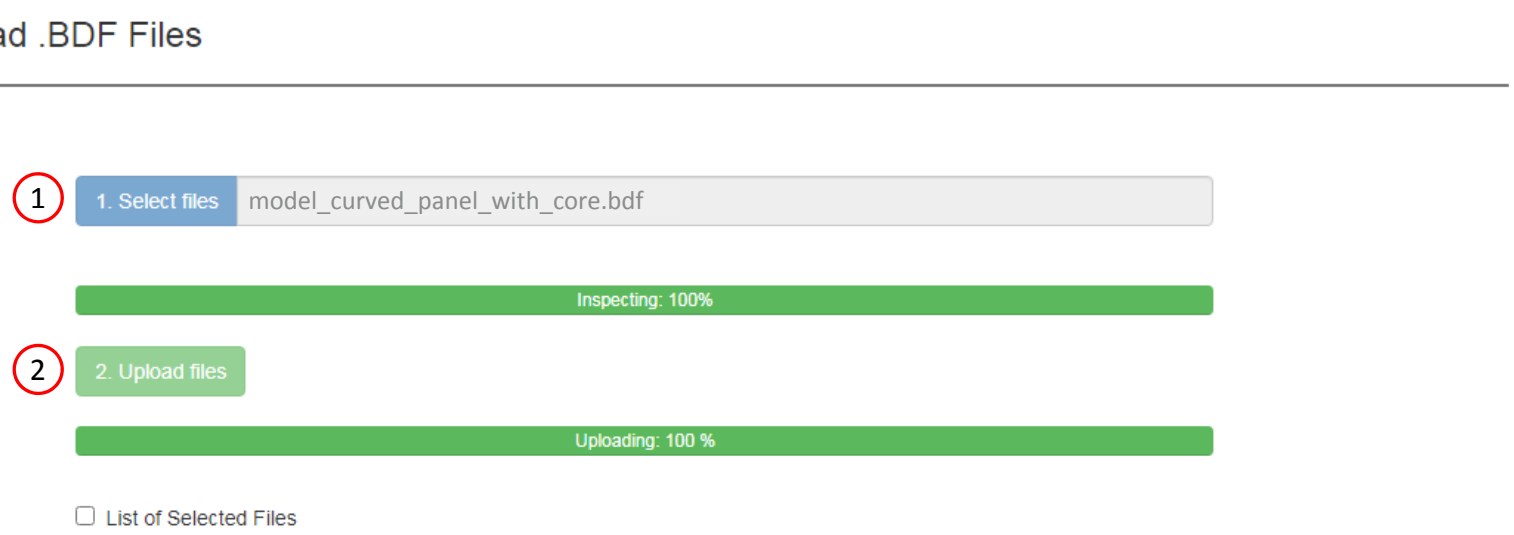
1. Click on the indicated link

- 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_curved_panel_with_core.bdf
2. Click Upload Files

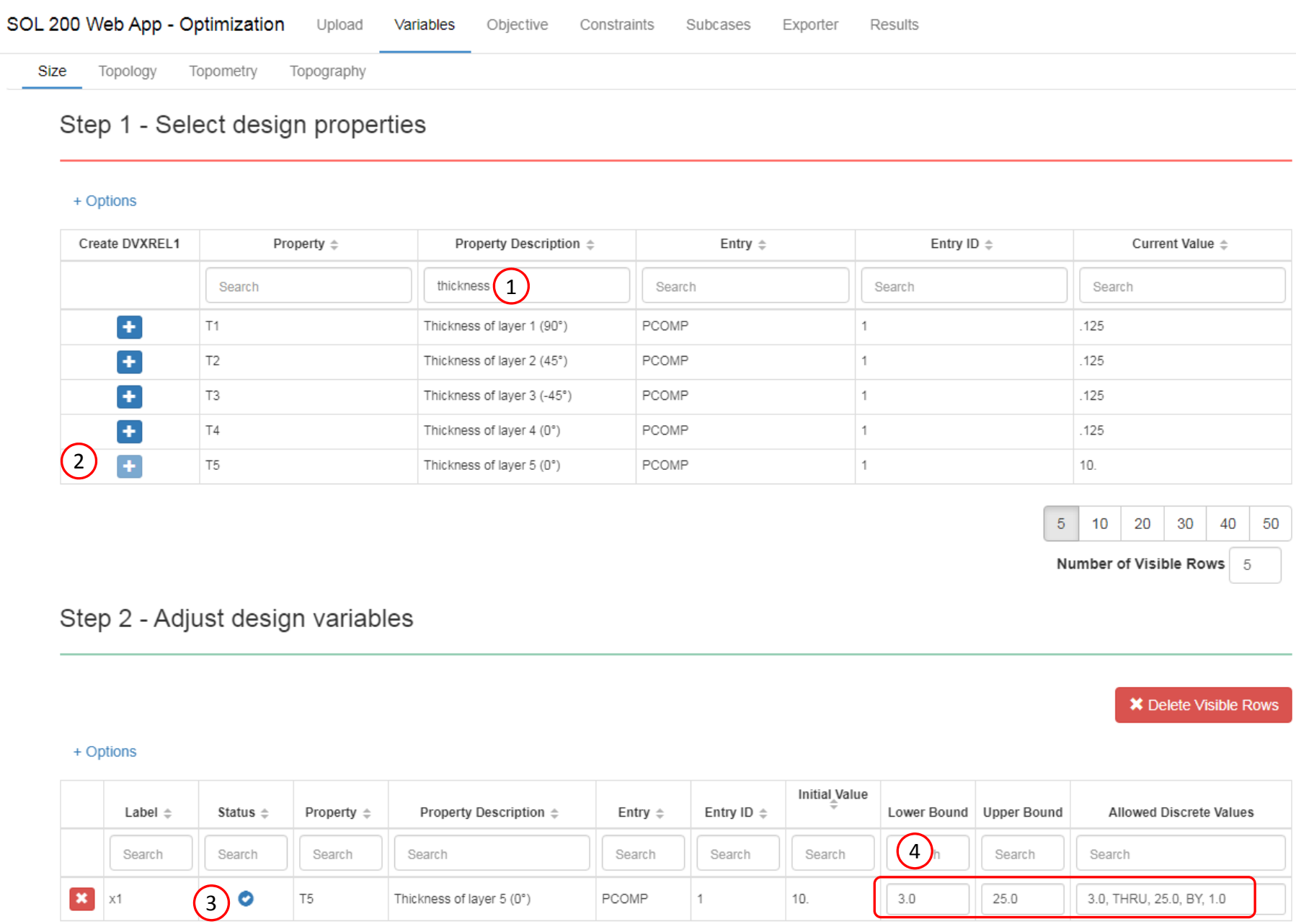
- The process starts by uploading all the necessary BDF files. The BDF files can be files of your own or files found in the Tutorials section of the User's Guide.



# Create Design Variables

1. In the search box, type: thickness
2. Click on the plus (+) icons to set the 5th layer thickness (T5) as a design variable
3. Confirm the design variable has been created
4. Make the following changes to the variables
   - Lower Bound: 3.0
   - Upper Bound: 25.0
   - Allowed Discrete Values: 3.0, THRU, 25.0, BY, 1.0

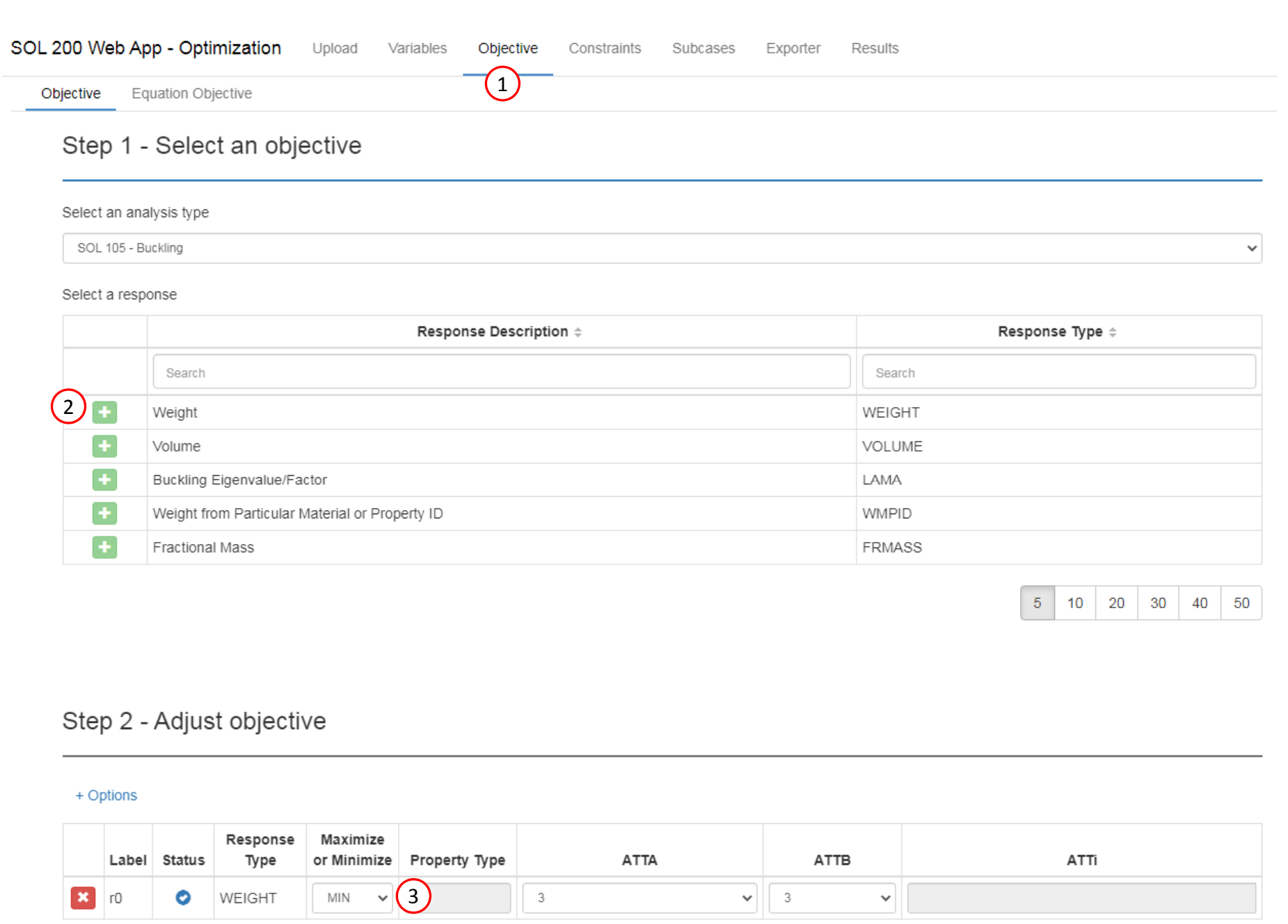
- Each step has hidden functionality for advanced users. The visibility is controlled by clicking + Options.
- If the property entry, e.g. PSHELL, was given a name in Patran, e.g. Car Door, the name can be shown by marking the checkbox titled Entry Name.



# Create Design Objective

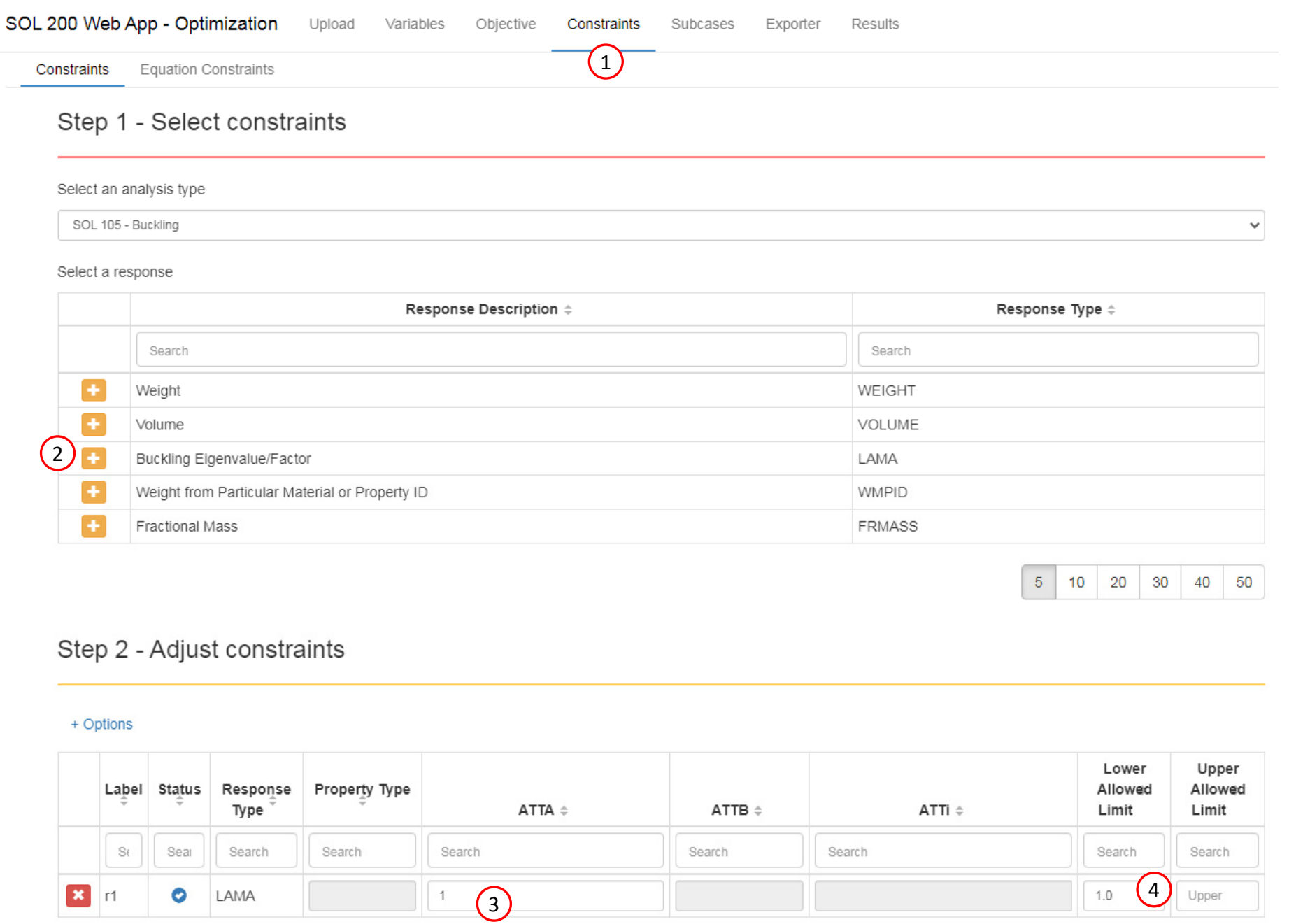
1. Click Objective
2. Select the plus (+) icon for weight
3. The objective has been set to minimize the weight, no further modification is necessary

- 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. Click the plus (+) icon for Buckling Eigenvalue/Factor to create one constraint
3. Set the Buckling Mode Number (ATTA) to 1
4. Set the Lower Allowed Limit to 1.0



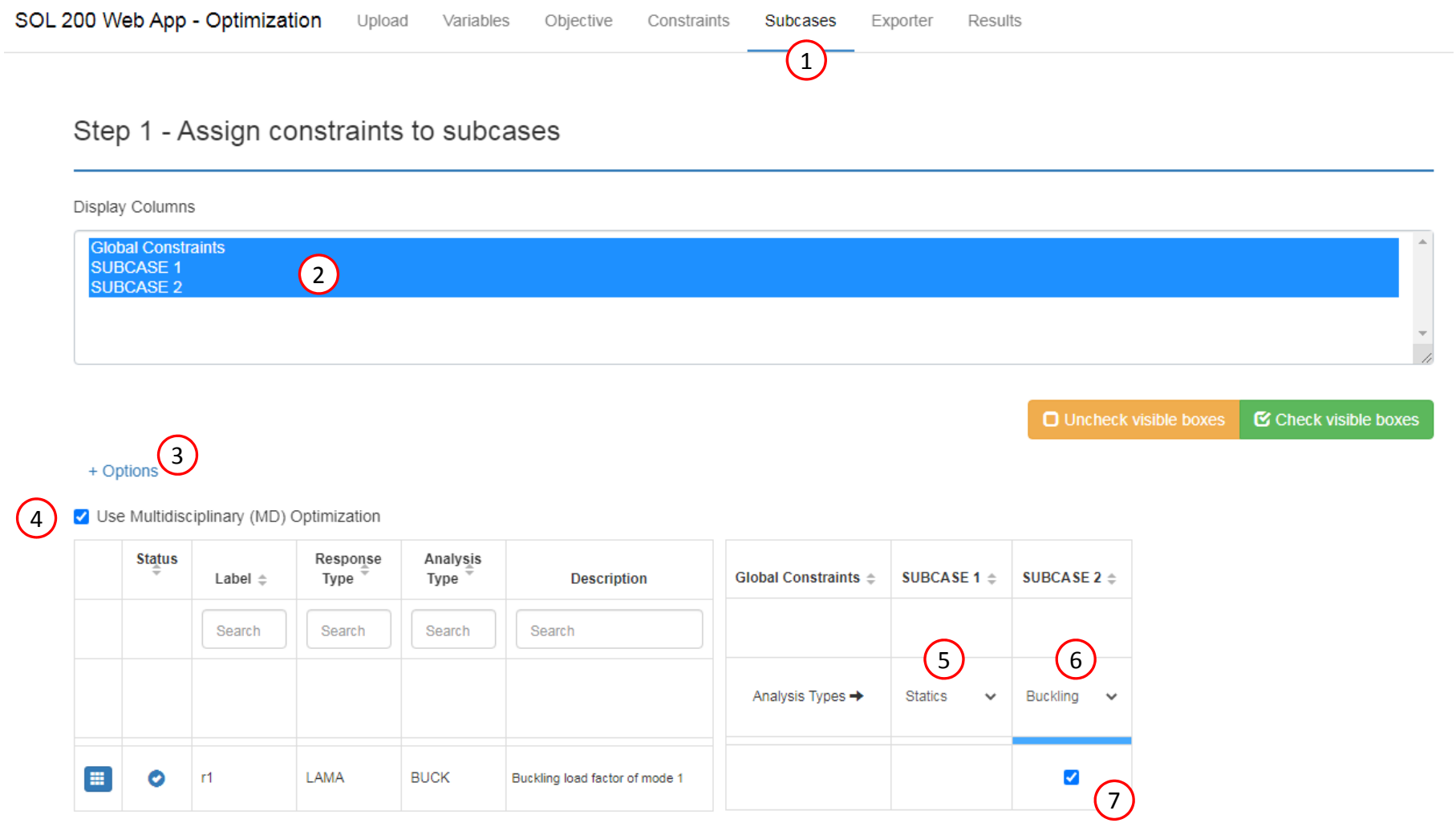
# Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Select all the subcases
3. Click +Options
4. Mark the checkbox for Use Multidisciplinary (MD) Optimization
5. For subcase 1, set the Analysis Type as Statics
6. For subcase 2, set the Analysis Type as Buckling
7. Mark the indicated checkbox

- The r1 constraint has been assigned to SUBCASE 2
- When hundreds of SUBCASEs must be configured, the following options expedite the process:

Uncheck visible boxes

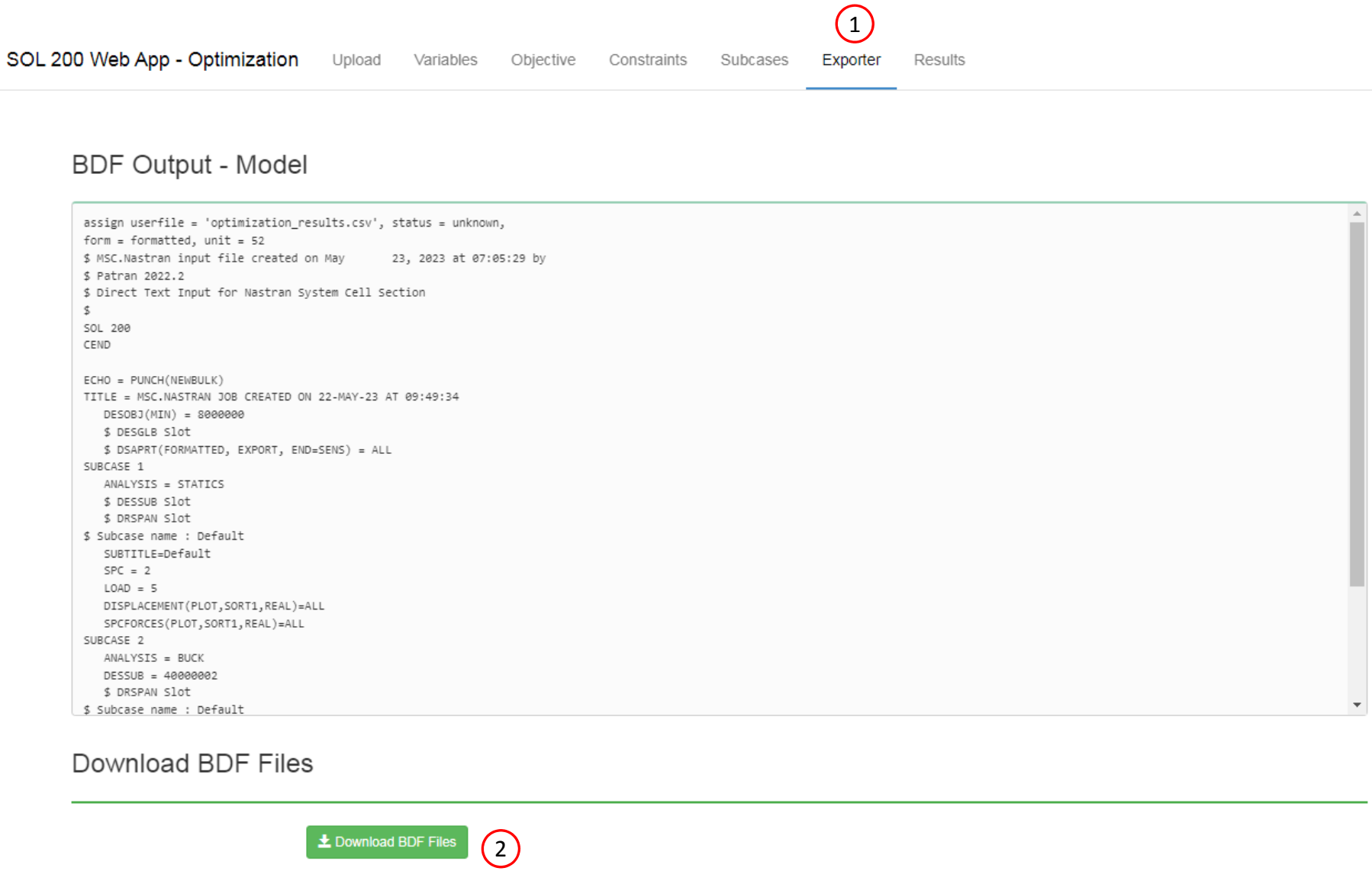
Check visible boxes



# Export New BDF Files

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

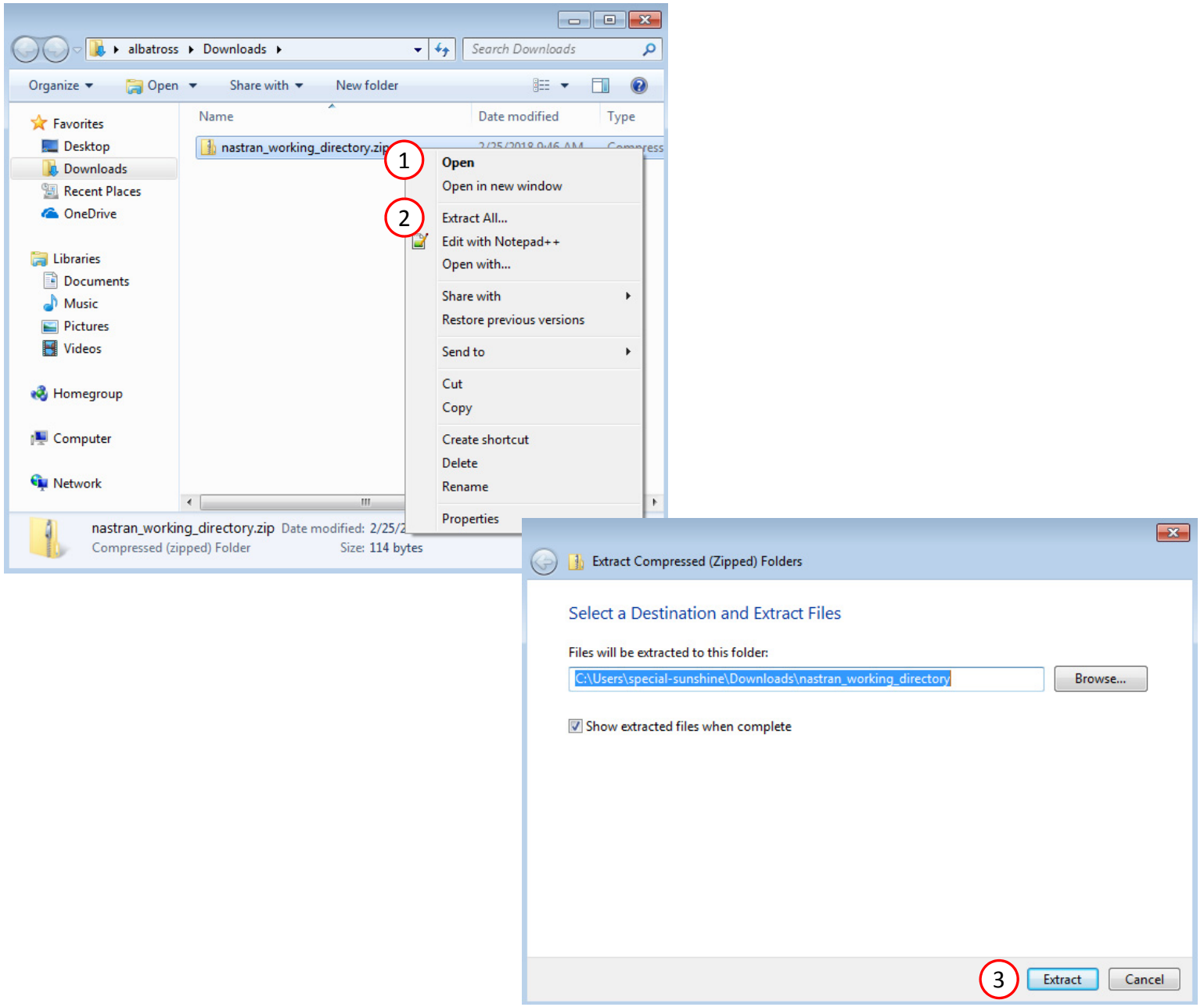
- When the download button is clicked a new file named “nastran_working_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran_working_directory (1).zip”



# 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

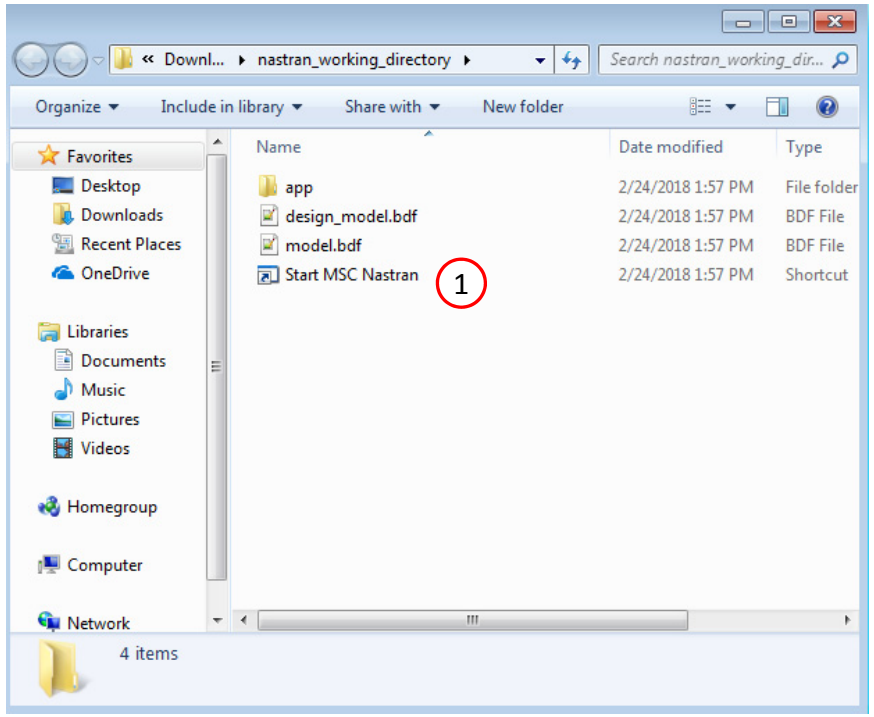
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

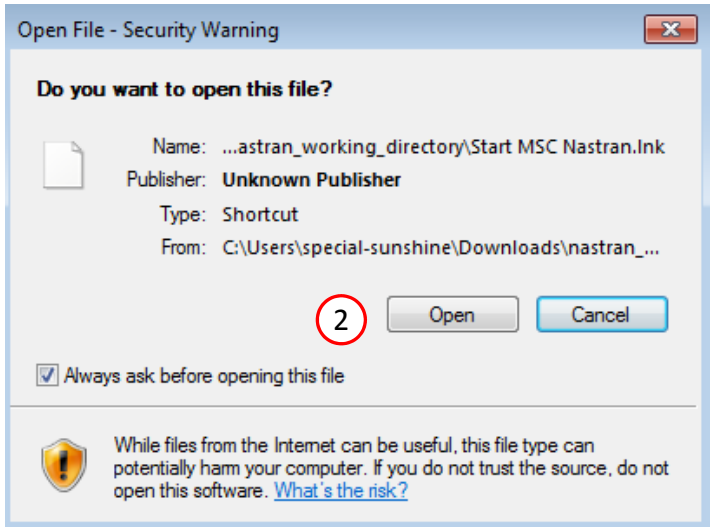
**Using Linux?**

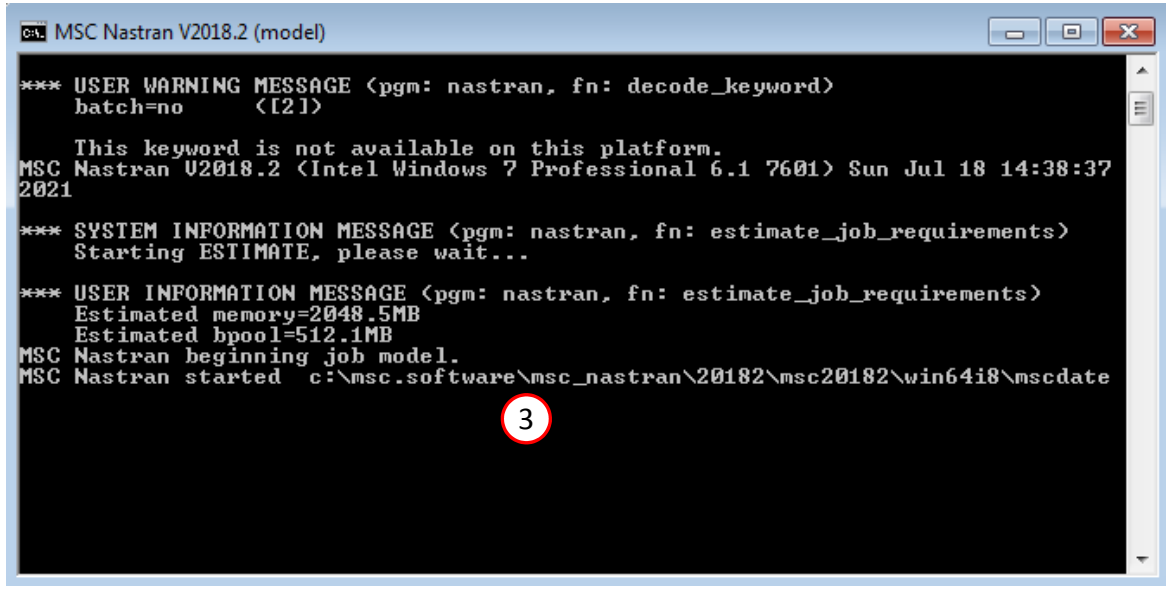
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

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

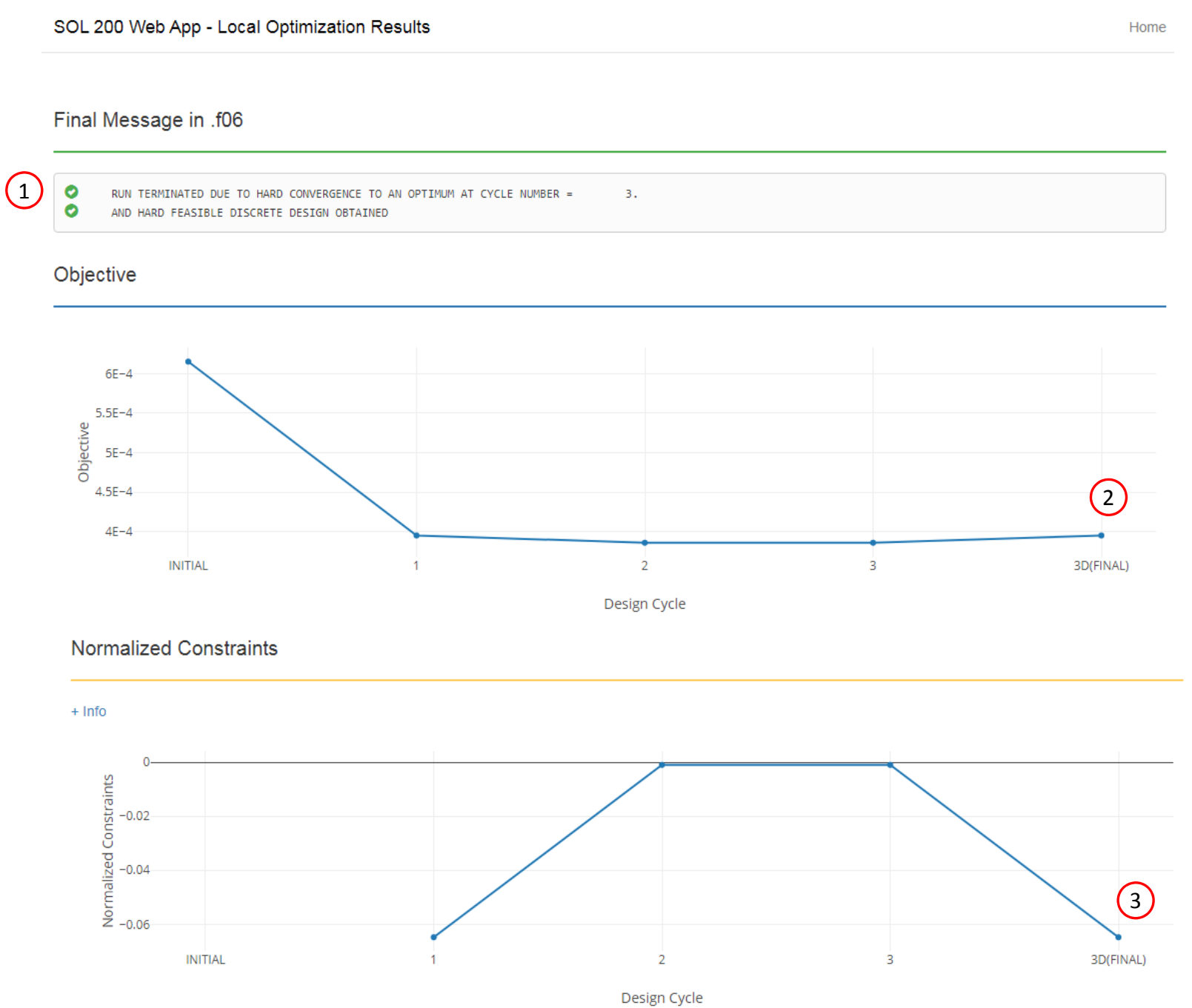
| Name | Status of Job | Design Cycle | RUN TERMINATED DUE TO |
|---|---|---|---|
| model.bdf | Running | None | |

# 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 and design variables (not shown) can be reviewed.

- The final max normalized constraint is negative, indicating the design is feasible. The fact the objective was minimized and the final design is feasible indicates this has been a successful optimization.



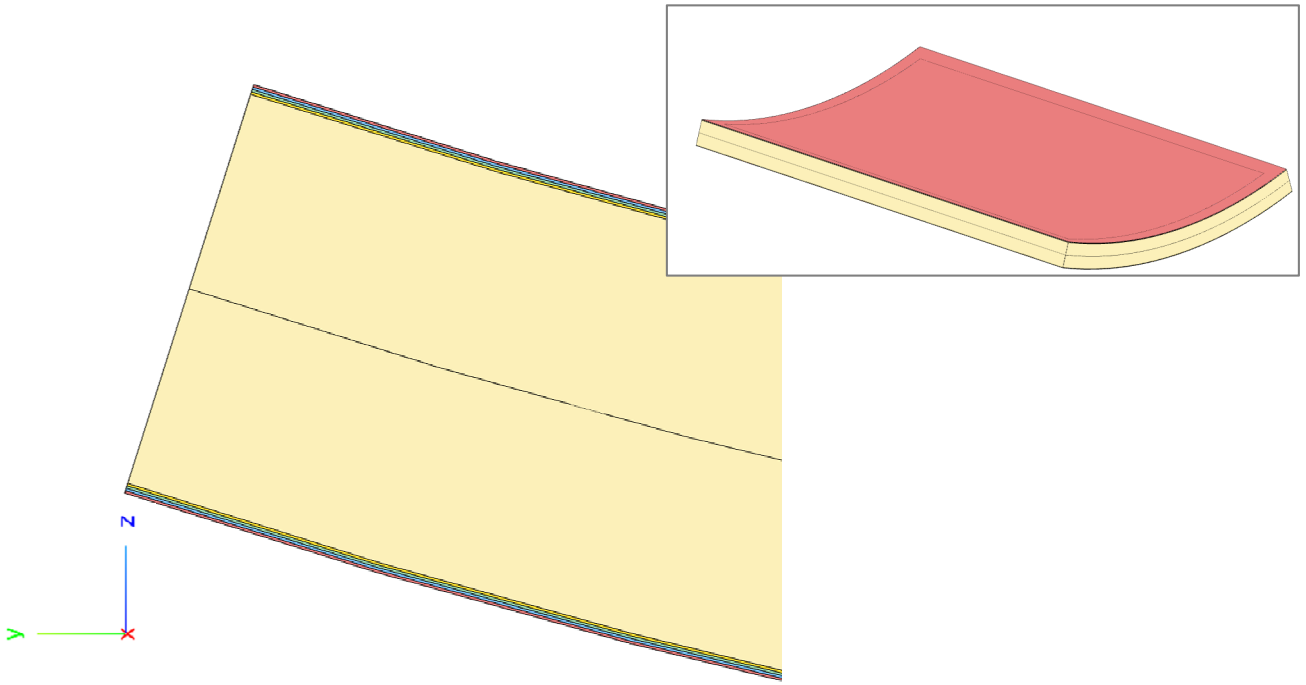
# Review Optimization Results

1. A plot of the change of the design variables during the optimization is displayed
2. The continuous variable optimization, design cycles 1-3, yielded a value of ~4.8
3. Since the variable is only allowed to take on specified discrete values, the optimizer performs a 3D design cycle, where D stands for discrete. Ultimately, the value ~4.8 becomes 5.0, where 5.0 is one of the discrete values.

# Results

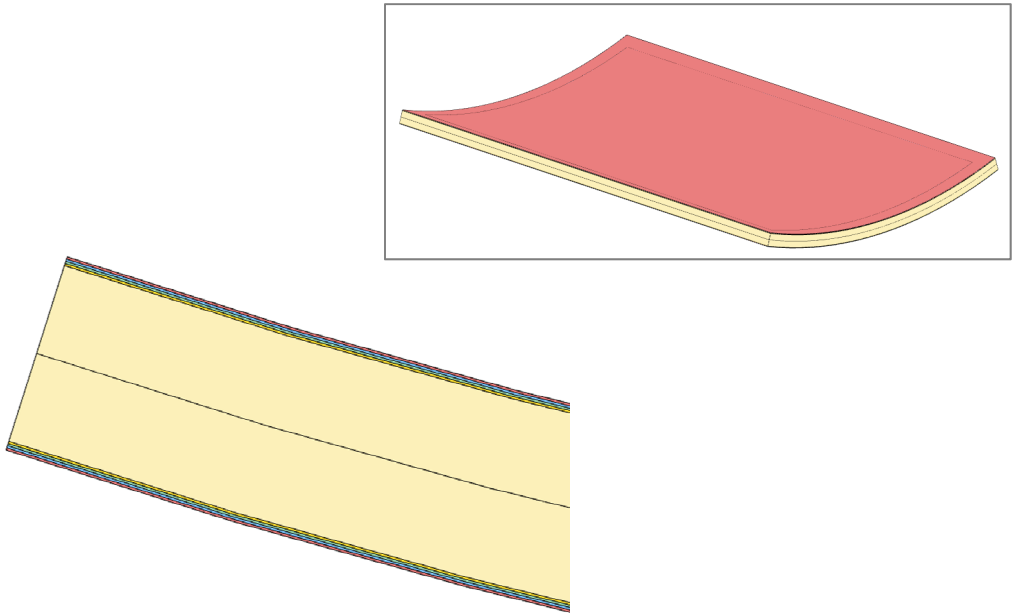
Before Optimization

- Weight:  6.153587E-04
- Buckling Load Factor: 3.364003




After Optimization

- Weight: 3.9503E-04
- Buckling Load Factor: 1.064771



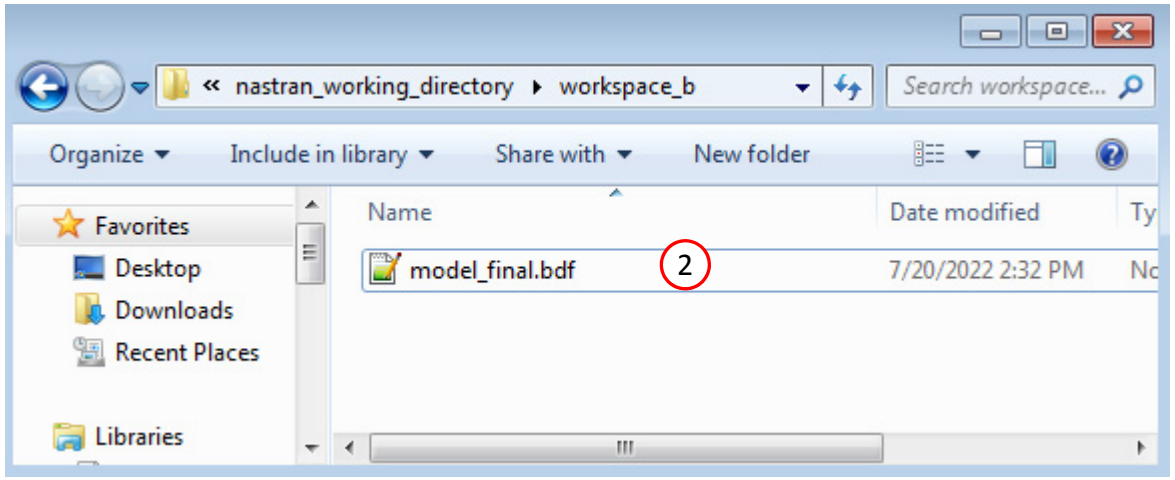
# Baseline Model

- The composite in this tutorial currently uses a core layer, with a fixed thickness, that spans the entire panel. A future tutorial will demonstrate how to optimize the core thickness for different sections of the model.
- This core thickness optimization was performed to establish a baseline of results. The optimal mass, 3.9503E-04, and a buckling load factor of 1.064771, from this tutorial are recorded in the table shown. The results after core shape optimization in phases C and D will be compared with this baseline model.

| | Starting Design | Design After Topometry Optimization | Design After Core Shape and Core Number Optimization |
|---|---|---|---|
| | Tutorial Phase B | Tutorial Phase C | Tutorial Phase D |
| Total Mass | 3.9503E-04 | | |
| Mass of Non-design Region (Plies) | 1.746926E-04 | | |
| Mass of Design Region (Core) | **2.203330E-04** | | |
| Buckling Load Factor, Subcase 2 | 1.064771 (OK) | | |

# 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.

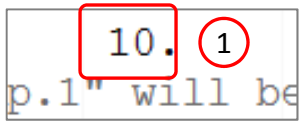



## Original Input Files

model_curved_panel_with_core.bdf

```
PCOMP     1       0.0             90.     HILL                    SYM
          101     .125    90.     YES
          101     .125    45.     YES
          101     .125    -45.    YES
          101     .125    0.      YES
          501     10.     0.      YES
$ Pset: "pcomp.1" will be imported as: "pcomp.1"
CQUAD4    641     1       725     726     798     724     0.      0.
CQUAD4    642     1       726     727     799     798     0.      0.
CQUAD4    643     1       727     728     800     799     0.      0.
CQUAD4    644     1       728     729     801     800     0.      0.
```

1

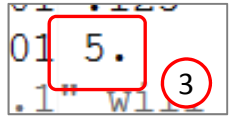



## Updated BDF File (model_final.bdf)

model_final.bdf

```
PCOMP          1   0.0     0.0     90.         HILL    0.0     0.0     SYM
          101 .125    90.         YES     101 .125    45.         YES
          101 .125    -45.        YES     101 .125    0.0         YES
          501 5.      0.0         YES
$ Pset: "pcomp.1" will be imported as: "pcomp.1"
CQUAD4    641     1       725     726     798     724     0.      0.
CQUAD4    642     1       726     727     799     798     0.      0.
CQUAD4    643     1       727     728     800     799     0.      0.
CQUAD4    644     1       728     729     801     800     0.      0.
CQUAD4    645     1       729     730     802     801     0.      0.
CQUAD4    646     1       730     731     803     802     0.      0.
```

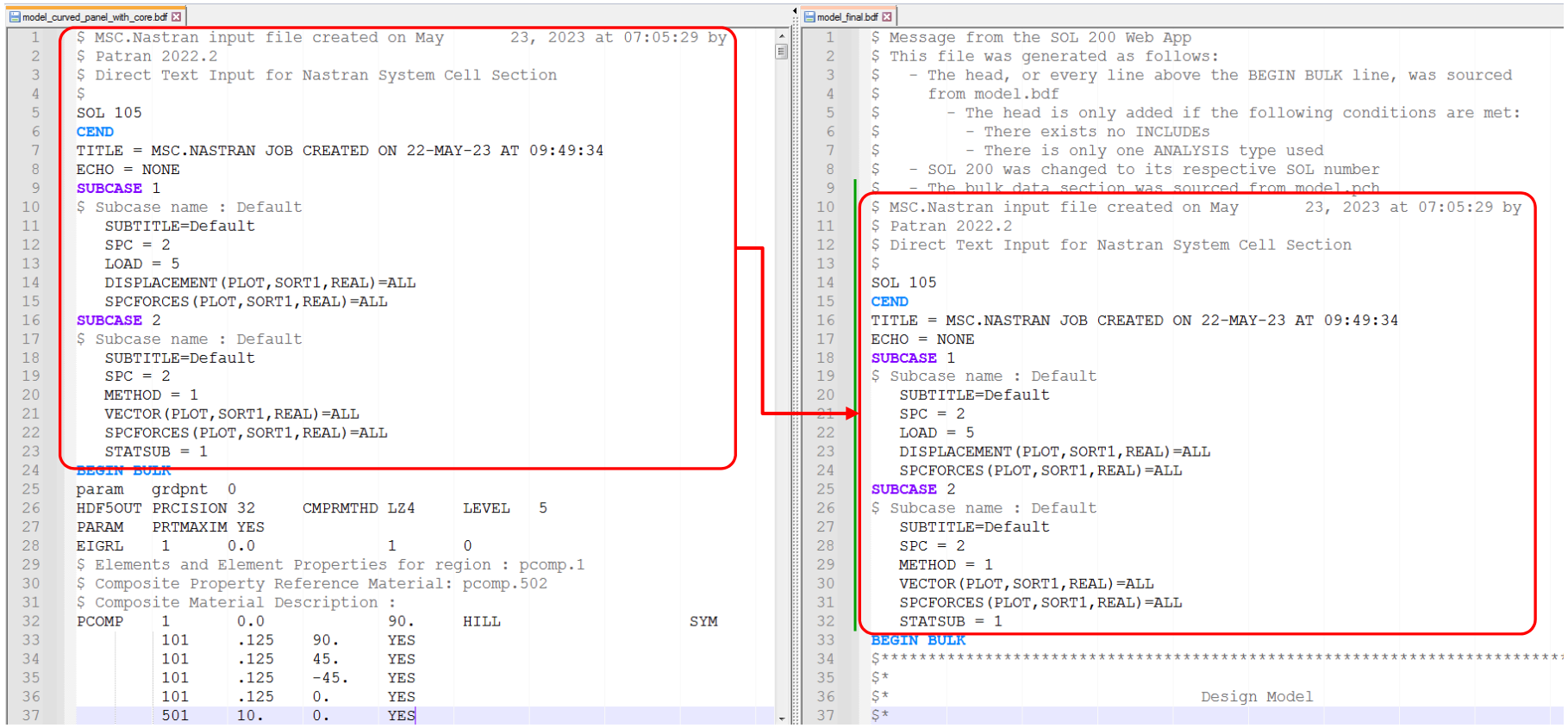
3



# Update the Original Model

1. It should be noted that since this was a multidisciplinary optimization, the update to the file model_fina.bdf is incomplete. Manually copy the section above the BEGIN BULK delimiter from the original file (model_curved_panel_with_core.bdf) to the new file (model_final.bdf).

- 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.



model_curved_panel_with_core.bdf

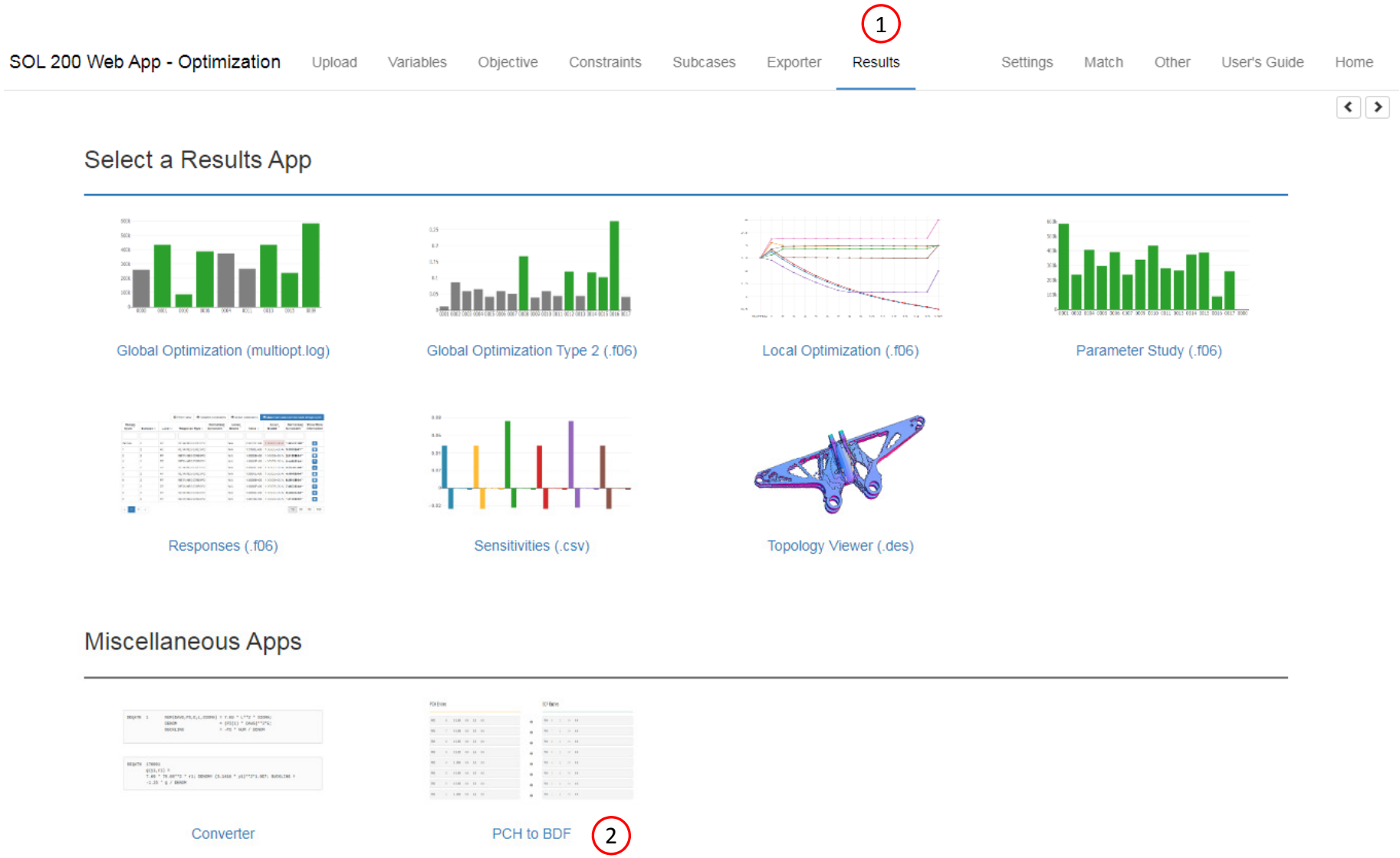
```
$ MSC.Nastran input file created on May       23, 2023 at 07:05:29 by
$ Patran 2022.2
$ Direct Text Input for Nastran System Cell Section
$
SOL 105
CEND
TITLE = MSC.NASTRAN JOB CREATED ON 22-MAY-23 AT 09:49:34
ECHO = NONE
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   LOAD = 5
   DISPLACEMENT(PLOT,SORT1,REAL)=ALL
   SPCFORCES(PLOT,SORT1,REAL)=ALL
SUBCASE 2
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   METHOD = 1
   VECTOR(PLOT,SORT1,REAL)=ALL
   SPCFORCES(PLOT,SORT1,REAL)=ALL
   STATSUB = 1
BEGIN BULK
param   grdpnt  0
HDF5OUT PRCISION 32     CMPRMTHD LZ4     LEVEL   5
PARAM   PRTMAXIM YES
EIGRL    1      0.0             1       0
$ Elements and Element Properties for region : pcomp.1
$ Composite Property Reference Material: pcomp.502
$ Composite Material Description :
PCOMP    1       0.0             90.     HILL                    SYM
         101     .125    90.     YES
         101     .125    45.     YES
         101     .125    -45.    YES
         101     .125    0.      YES
         501     10.     0.      YES
```

model_final.bdf

```
$ Message from the SOL 200 Web App
$ This file was generated as follows:
$   - The head, or every line above the BEGIN BULK line, was sourced
$     from model.bdf
$       - The head is only added if the following conditions are met:
$         - There exists no INCLUDEs
$         - There is only one ANALYSIS type used
$   - SOL 200 was changed to its respective SOL number
$   - The bulk data section was sourced from model.pch
$ MSC.Nastran input file created on May       23, 2023 at 07:05:29 by
$ Patran 2022.2
$ Direct Text Input for Nastran System Cell Section
$
SOL 105
CEND
TITLE = MSC.NASTRAN JOB CREATED ON 22-MAY-23 AT 09:49:34
ECHO = NONE
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   LOAD = 5
   DISPLACEMENT(PLOT,SORT1,REAL)=ALL
   SPCFORCES(PLOT,SORT1,REAL)=ALL
SUBCASE 2
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   METHOD = 1
   VECTOR(PLOT,SORT1,REAL)=ALL
   SPCFORCES(PLOT,SORT1,REAL)=ALL
   STATSUB = 1
BEGIN BULK
$*************************************************************************
$*
$*                                Design Model
$*
```

# Update the Original Model

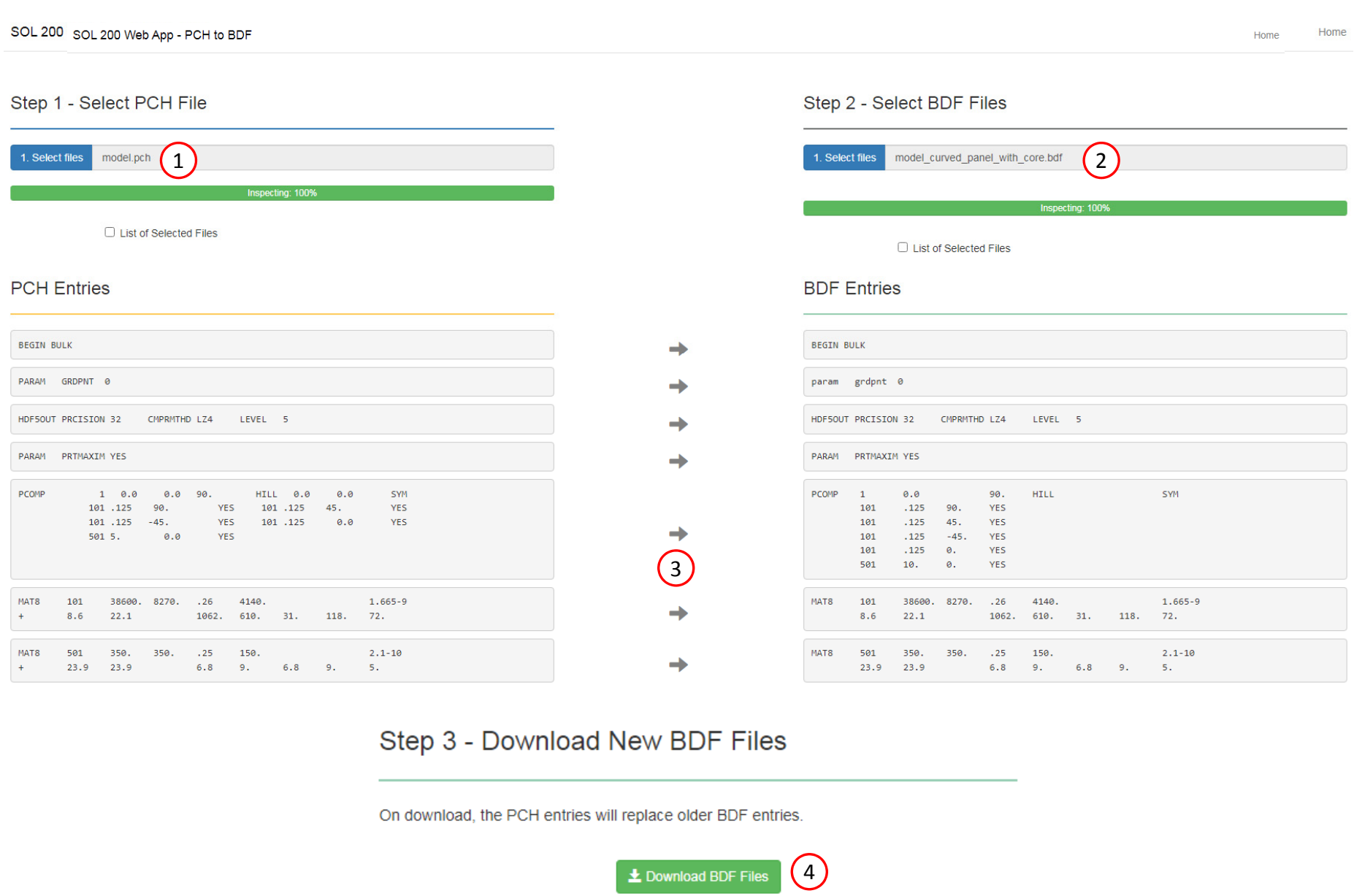
1. Click Results
2. Click PCH to BDF



# Update the Original Model

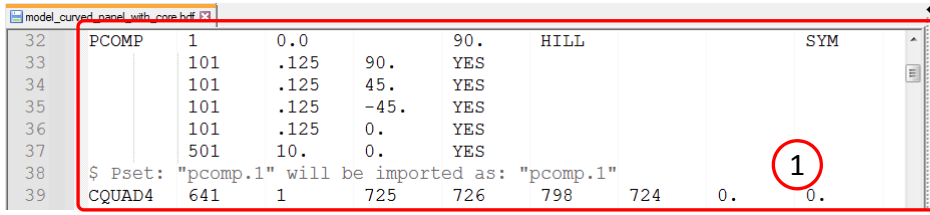
The original .bdf/.dat file has old information about the properties. The properties will be updated.

1. Select the model.pch file
2. Select the original file: model_curved_panel_with_core.bdf
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

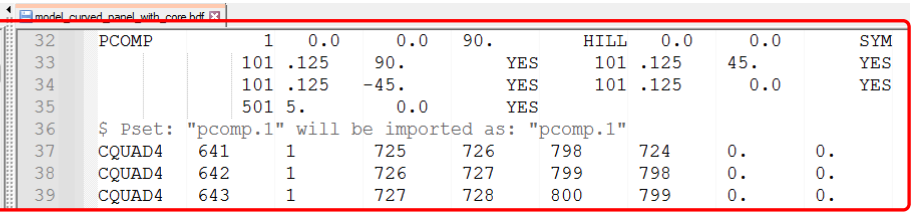
1. Note the entries have been updated with the optimized properties



```
32  PCOMP    1       0.0             90.     HILL                    SYM
33           101     .125    90.     YES
34           101     .125    45.     YES
35           101     .125    -45.    YES
36           101     .125    0.      YES
37           501     10.     0.      YES
38  $ Pset: "pcomp.1" will be imported as: "pcomp.1"
39  CQUAD4   641     1       725     726     798     724     0.      0.
```

1

Original BDF/DAT File



```
32  PCOMP          1   0.0     0.0   90.       HILL   0.0     0.0     SYM
33                 101 .125    90.       YES    101 .125    45.     YES
34                 101 .125    -45.      YES    101 .125    0.0     YES
35                 501 5.      0.0       YES
36  $ Pset: "pcomp.1" will be imported as: "pcomp.1"
37  CQUAD4   641     1       725     726     798     724     0.      0.
38  CQUAD4   642     1       726     727     799     798     0.      0.
39  CQUAD4   643     1       727     728     800     799     0.      0.
```

Downloaded BDF/DAT File

# 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.

# Open the Viewer

1. Navigate to the Composites section
2. Click Viewer

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# Upload BDF Files

1. Click Upload BDF
2. Click Select files
3. Click workspace_b
4. Select the indicated files
5. Click Open
6. Click Upload files
7. Click Background Color (Optional)

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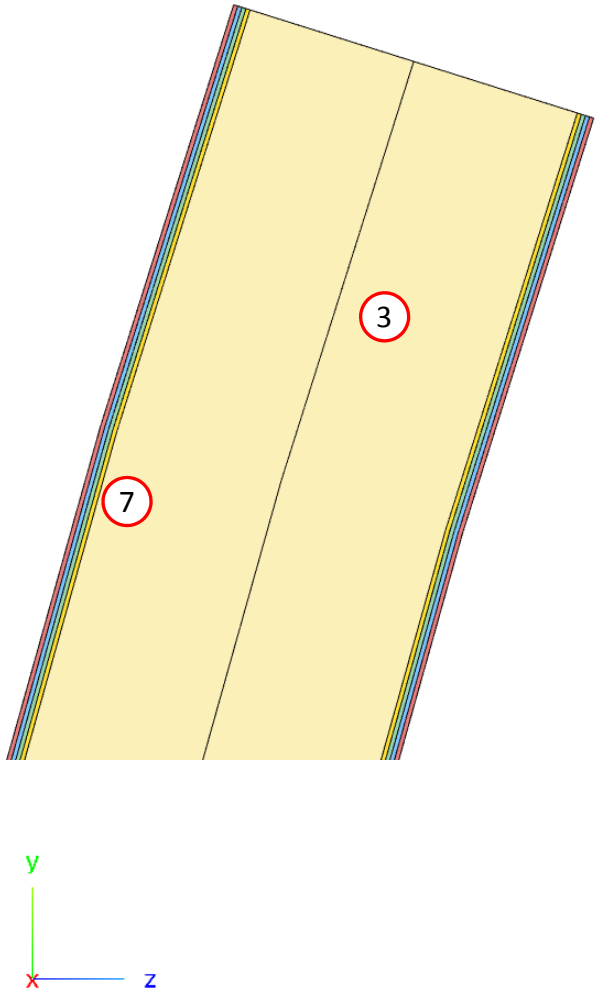
# Display Plies

1. Click Model Display Panel
2. Click Left
3. Right click and hold the right mouse button, and move the mouse to translate the model into view. Use the scroll wheel to zoom into the model.
4. Click the indicated icon
5. Click the indicated icon
6. Click the indicated icon to recolor the plies
7. The core, along with the plies, is now displayed

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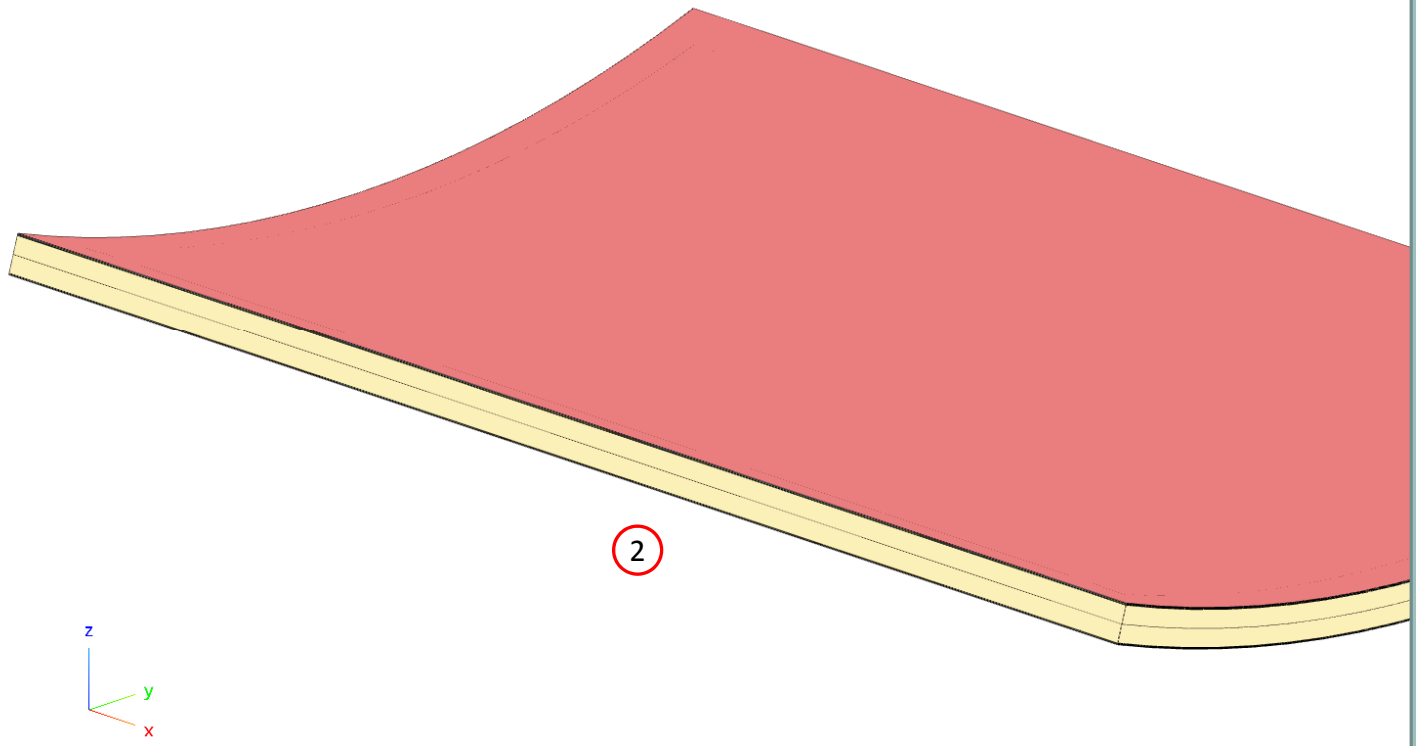
# Display Plies

1. Click Model Display Panel
2. Rotate and/or zoom out to view the entire model

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End of Tutorial