Workshop - Multi Model Optimization

AN MSC NASTRAN SOL 200 TUTORIAL

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

Goal: Minimize the weight of three different models of different analyses under constraints

In the structure design, it is necessary to perform design optimization using multi-models (MMO: Multi-Model Optimization) that combines two or more related optimization tasks into a single combined optimization task. The benefits are as follows:

A: Allows users to have different models that differ in their topology or in their analyses that are created to satisfy different analysis needs with proper models

B: Allows users to design the variants of vehicles or airplane with shared parts or components

C: Help users to get the best trade-off solutions using one combined optimization task rather than get different so-called optimized results from different optimization tasks

Optimization Problem Statements
Separate Design Models: Independent Design Variables, Objectives and Design Constraints

Model 1 - m_stress

Analysis: Statics

Objective: Minimize Weight

Constraints:

r1: von Mises of stress, at z1, for PSHELL 1, 7

r2: von Mises of stress, at z2, for PSHELL 1, 7

r3: von Mises of stress, at z1, for PSHELL 3, 8

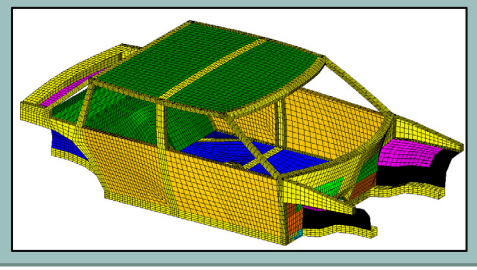
r4: von Mises of stress, at z2, for PSHELL 3, 8

r5: von Mises of stress, at z1, for PSHELL 8, 9, 10

r6: von Mises of stress, at z2, for PSHELL 8, 9, 10

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9 , x10



Model 2 - m_modes

Analysis: Modes

Objective: Minimize Weight

Constraints:

r1: Natural frequency of mode 1, 25Hz < r1

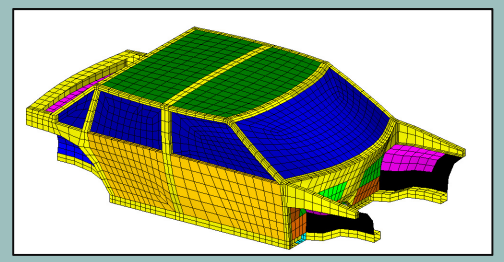
r2: Natural frequency of mode 2, 30Hz < r2

Settings

Mode tracking is used

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



Model 3 - m_storsp

Analysis: Statics

Objective: Minimize Weight

Constraints:

r1: Displacement, y component, of node 19998

-.15 < r1 < .15

Equation Constraint:

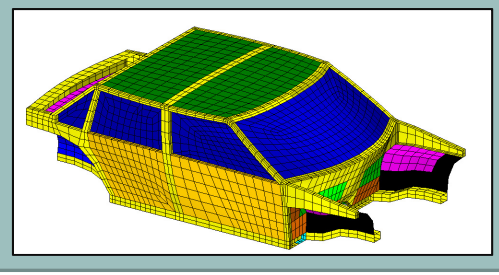
R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)

5E13 < R1 < 5E14

b1: Displacement, 4th component, of node 19998

Variables:

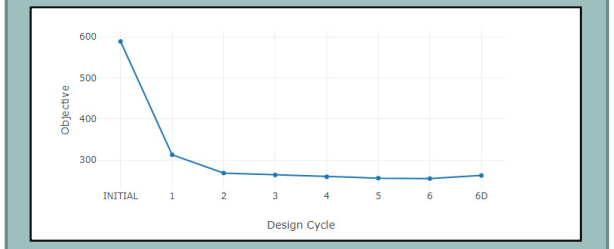
x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



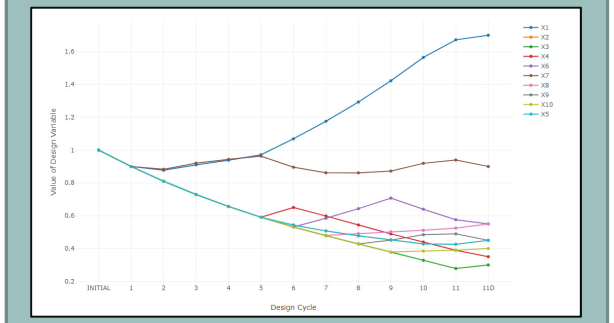
Optimization Problem Statements
Separate Design Models: Results

Model 1 - m_stress

Objective

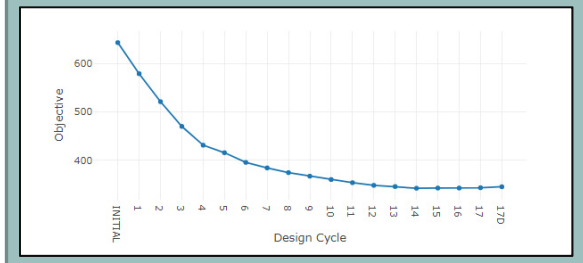


Variables

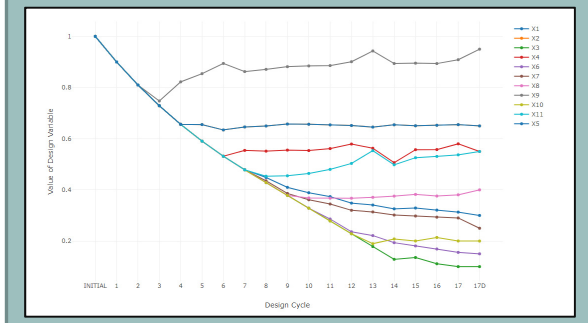


Model 2 - m_modes

Objective

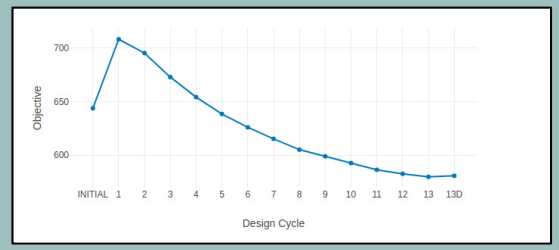


Variables

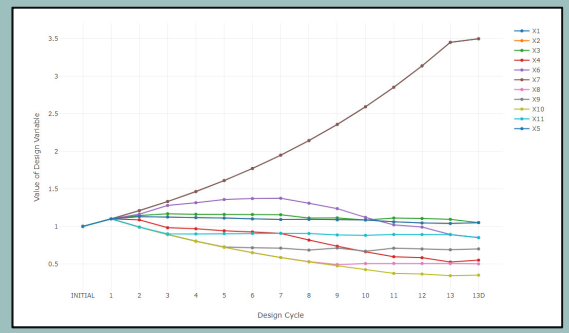


Model 3 - m_storsp

Objective



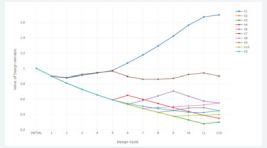
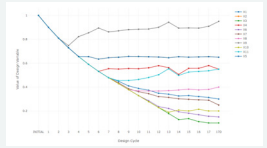
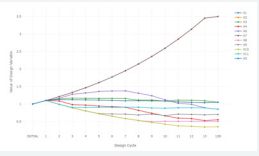
Variables



Separate Optimizations Tasks Without MMO

With separate optimizations for each model, different values for the variables are achieved.

For example, the thickness of the door, x8, is different after each optimization. There are 3 different values for the door thickness: .55, .40 and .50.

	Without MMO		
Design Model	**Model 1**	**Model 2**	**Model 3**
Objective			
Minimize Weight	✓	✓	✓
Constraints			
Constraints of Model 1	✓		
Constraints of Model 2		✓	
Constraints of Model 3			✓
Variables			
x1	✓ 1.7	✓ .30	✓ 3.50
x2	✓ .45	✓ .65	✓ 1.05
x3	✓ .30	✓ .10	✓ 1.05
x4	✓ .35	✓ .55	✓ .550
x5	✓ .45	✓ .65	✓ 1.05
x6	✓ .55	✓ .15	✓ .850
x7	✓ .90	✓ .25	✓ 3.50
x8	✓ .55	✓ .40	✓ .500
x9	✓ .45	✓ .95	✓ .700
x10	✓ .40	✓ .20	✓ .350
x11		✓ .55	✓ .850
Final values of design variables			

Optimization Problem Statements
Multi-model Optimization: Merged Design Model

Model 1 - m_stress

Analysis: Statics

Constraints:

- r1: von Mises of stress, at z1, for PSHELL 1, 7
- r2: von Mises of stress, at z2, for PSHELL 1, 7
- r3: von Mises of stress, at z1, for PSHELL 3, 8
- r4: von Mises of stress, at z2, for PSHELL 3, 8
- r5: von Mises of stress, at z1, for PSHELL 8, 9, 10
- r6: von Mises of stress, at z2, for PSHELL 8, 9, 10

Model 2 - m_modes

Analysis: Modes

Constraints:

- r1: Natural frequency of mode 1, 25Hz < r1
- r2: Natural frequency of mode 2, 30Hz < r2

Settings

- Mode tracking is used

Model 3 - m_storsp

Analysis: Statics

Constraints:

- r1: Displacement, y component, of node 19998

  -.15 < r1 < .15

Equation Constraint:

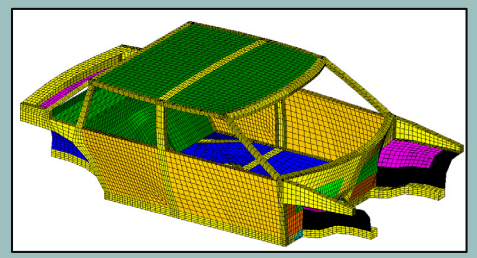
- R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)

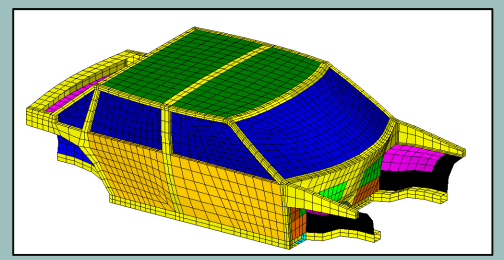
  5E13 < R1 < 5E14

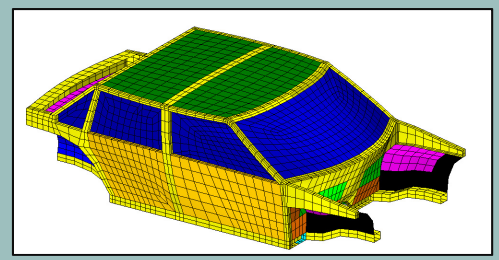
  b1: Displacement, 4th component, of node 19998

Objective: Minimize Weight

Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



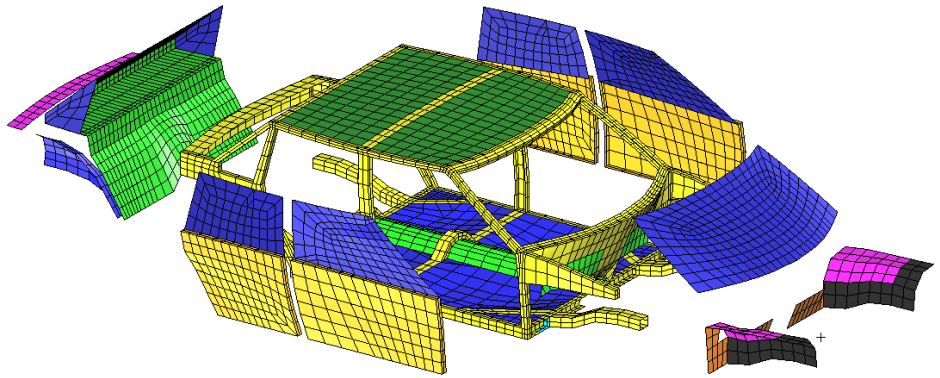




Optimization Problem Statements
Merged Design Model: Linked Variables

Variables Links

- For the design variables having the same IDs from two or more models, they are optimized as shared variables and indicated as “linked.” The shared variables must have the same labels, lower/upper bounds, etc. across several models or all models. Attention is needed to make sure the shared design variables are used for the same physical properties/parts across different models.
- For the design variables existing only in one model, they are unique variables to that specific model and indicated as “not linked”
- Refer to Part B for the details of corrections if there are conflicting in the definition of the design variables across models.



Color	Label	Description	Entry Name	Bounds	m_stress	m_modes	m_storsp	Is variable linked?
	x1	T of PSHELL 1	floor_roll	.1 < xi < 10.	✓	✓	✓	Linked
	x2	T of PSHELL 2	frame	.1 < xi < 10.	✓	✓	✓	Linked
	x3	T of PSHELL 3	floor	.1 < xi < 10.	✓	✓	✓	Linked
	x4	T of PSHELL 4	spoiler	.1 < xi < 10.	✓	✓	✓	Linked
	x5	T of PSHELL 5	front_mount	.1 < xi < 10.	✓	✓	✓	Linked
	x6	T of PSHELL 6	engine_walls	.1 < xi < 10.	✓	✓	✓	Linked
	x7	T of PSHELL 7	front_panel	.1 < xi < 10.	✓	✓	✓	Linked
	x8	T of PSHELL 8	doors_skin	.1 < xi < 10.	✓	✓	✓	Linked
	x9	T of PSHELL 9	roof	.1 < xi < 10.	✓	✓	✓	Linked
	x10	T of PSHELL 10	back_panel	.1 < xi < 10.	✓	✓	✓	Linked
	x11	T of PSHELL 11	windows	.1 < xi < 10.		✓	✓	Linked

T is for thickness

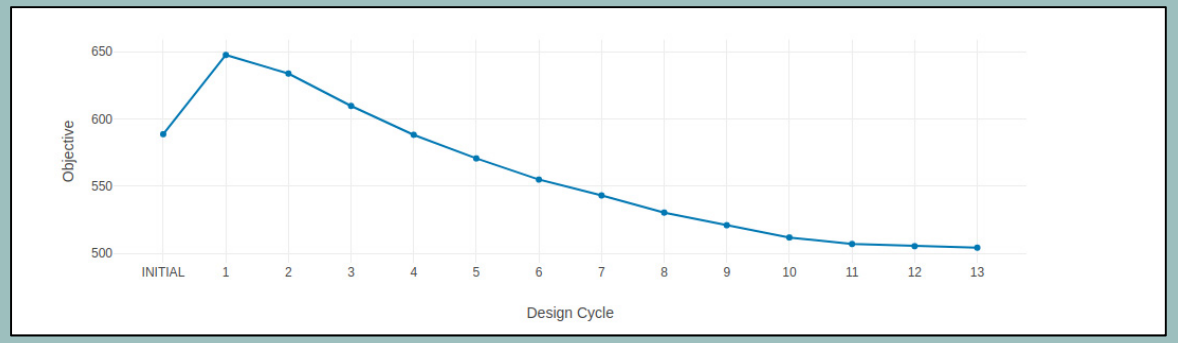
Optimization Problem Statements
Merged Design Model: Results

Model 1 - m_stress

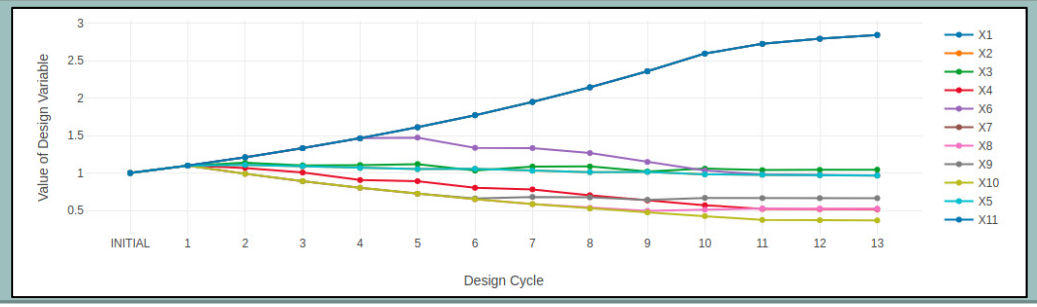
Model 2 - m_modes

Model 3 - m_storsp

Objective: Minimize Weight



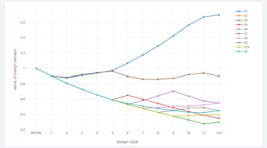
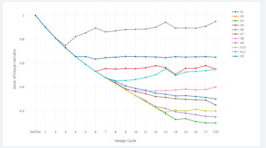
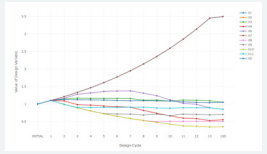
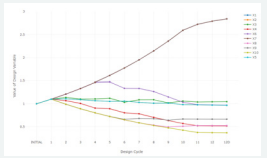
Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



Comparison Without and With MMO

With MMO, a single optimization is performed across multiple models. Single values for the design variables are achieved.

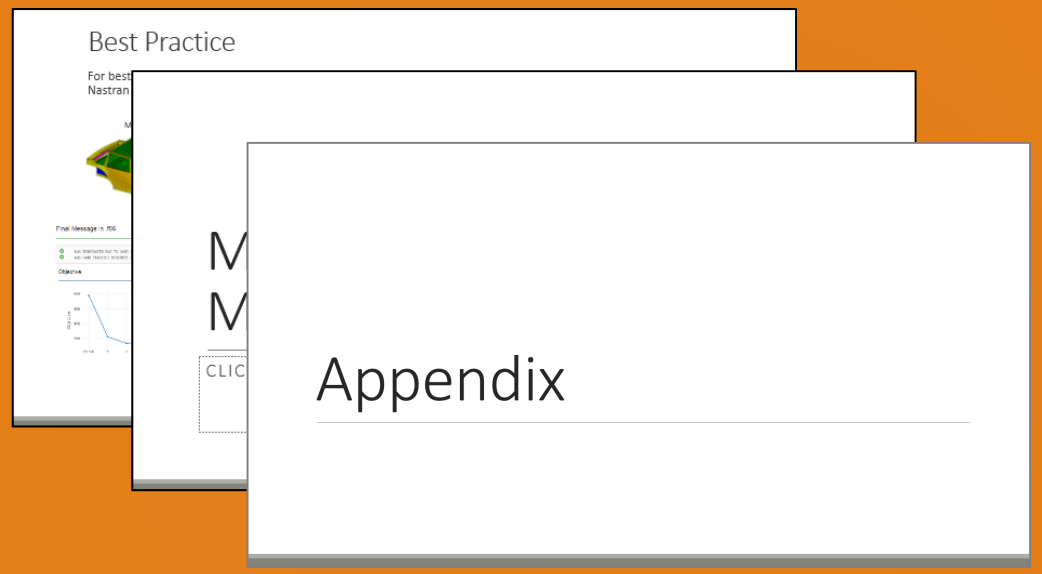
For example, the thickness of the door, x8, is a single value of .525 .

	Without MMO			With MMO
Design Model	**Model 1**	**Model 2**	**Model 3**	**Multi Model**
Objective				
Minimize Weight	✓	✓	✓	✓
Constraints				
Constraints of Model 1	✓			✓
Constraints of Model 2		✓		✓
Constraints of Model 3			✓	✓
Variables				
x1	✓ 1.7	✓ .30	✓ 3.50	✓ 2.84
x2	✓ .45	✓ .65	✓ 1.05	✓ .966
x3	✓ .30	✓ .10	✓ 1.05	✓ 1.04
x4	✓ .35	✓ .55	✓ .550	✓ .517
x5	✓ .45	✓ .65	✓ 1.05	✓ .966
x6	✓ .55	✓ .15	✓ .850	✓ .970
x7	✓ .90	✓ .25	✓ 3.50	✓ 2.84
x8	✓ .55	✓ .40	✓ .500	✓ .525
x9	✓ .45	✓ .95	✓ .700	✓ .665
x10	✓ .40	✓ .20	✓ .350	✓ .369
x11		✓ .55	✓ .850	✓ 2.84
Final values of design variables				

More Information Available in the Appendix

The Appendix includes information regarding the following:

- Manually Configuring Multi Model Optimization
  - Model Conversion for All Models
  - Constructing the Merged Objective
  - Linking Variables
  - Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?



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

PART A

Tutorial Overview

Part A

1. Perform a multi model optimization with 3 models

Part B

1. Repeat Part A
2. Add a new model, but the model has errors that must be corrected
3. Correct the errors
4. Complete a multi model optimization

Special Topics Covered

Multi Model Optimization (MMO) – MMO is the process of optimizing multiple design models concurrently.

Merged Objective - Each design model's objective, or selected objectives, can be combined into one merged objective and a multi model optimization may be performed. This example only considers only 1 objective for the merged objective.

Linked Variables – Design variables in separate models that should be treated as the same design variable must be *linked*. For example, as shown below, the design variables in separate models A and B must be linked.

- Variable x1 - Model A - Corresponding to thickness of Panel 1 in model A
- Variable x1 - Model B - Corresponding to thickness of Panel 1 in model B

SOL 200 Web App Capabilities

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

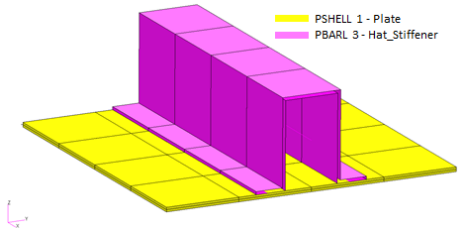
Compatibility

- 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.

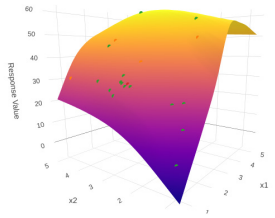
Benefits

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

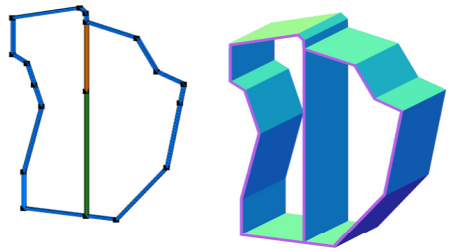
Web Apps



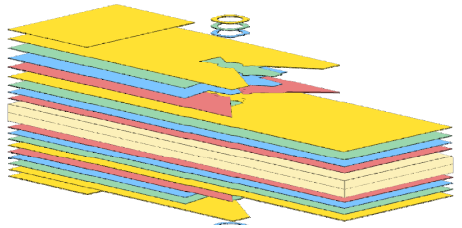
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



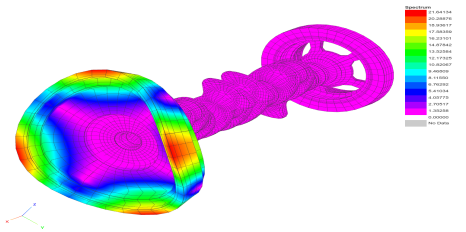
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



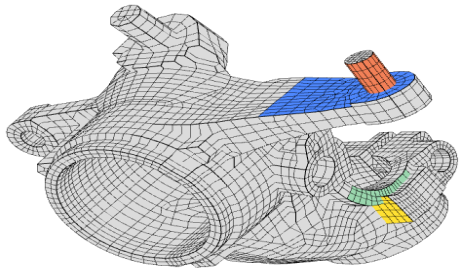
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



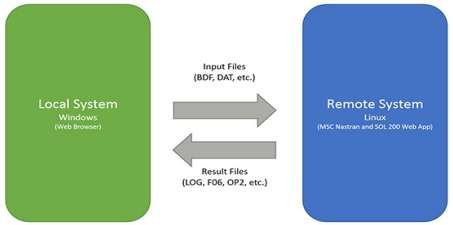
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



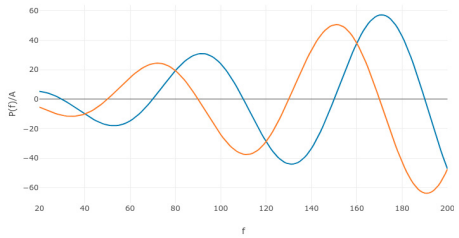
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



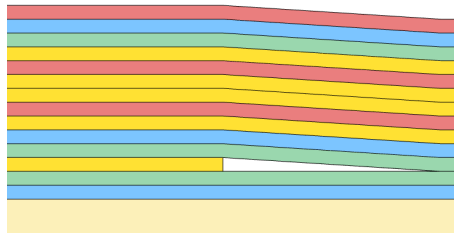
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



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



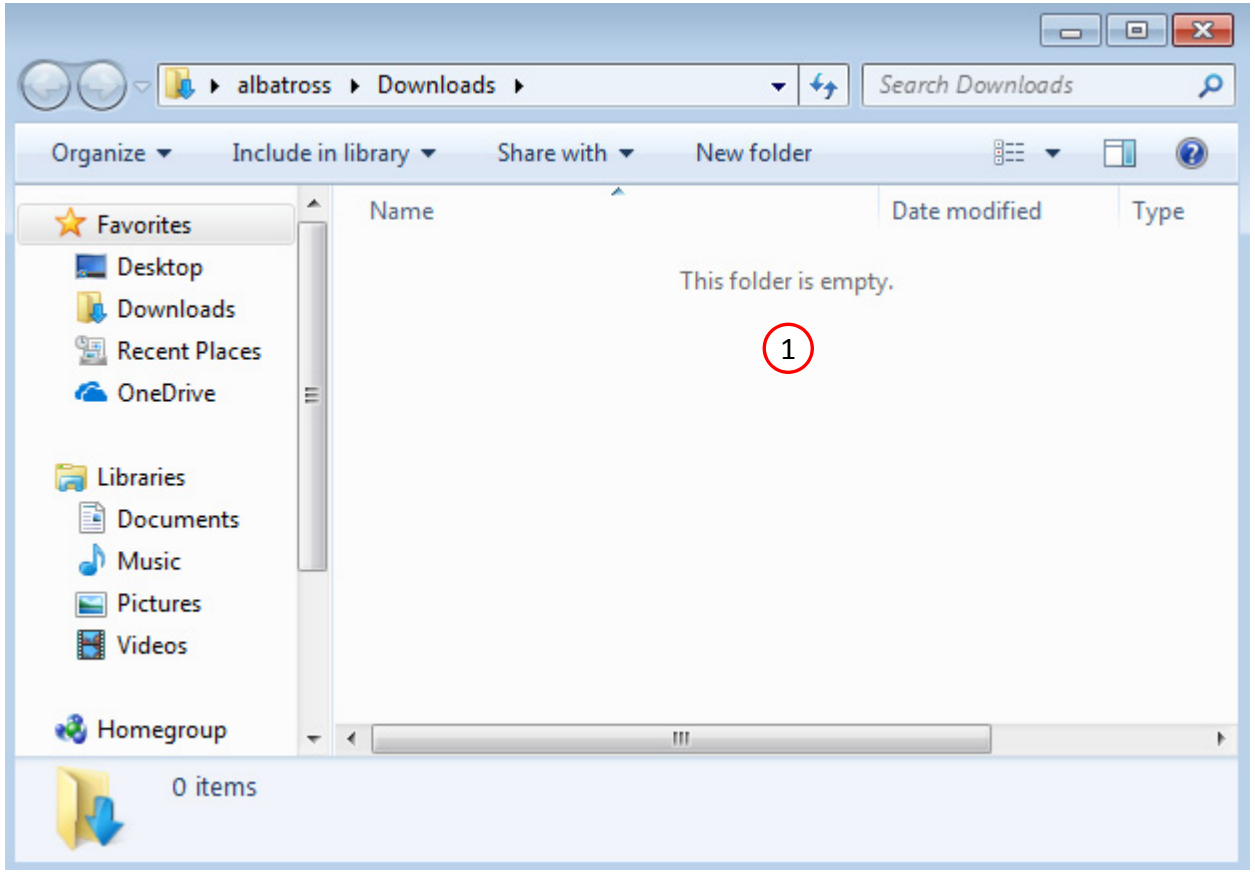
Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies

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

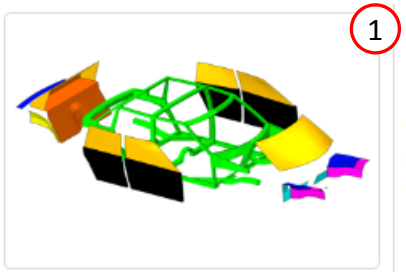
1. Click on the indicated link

- 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.



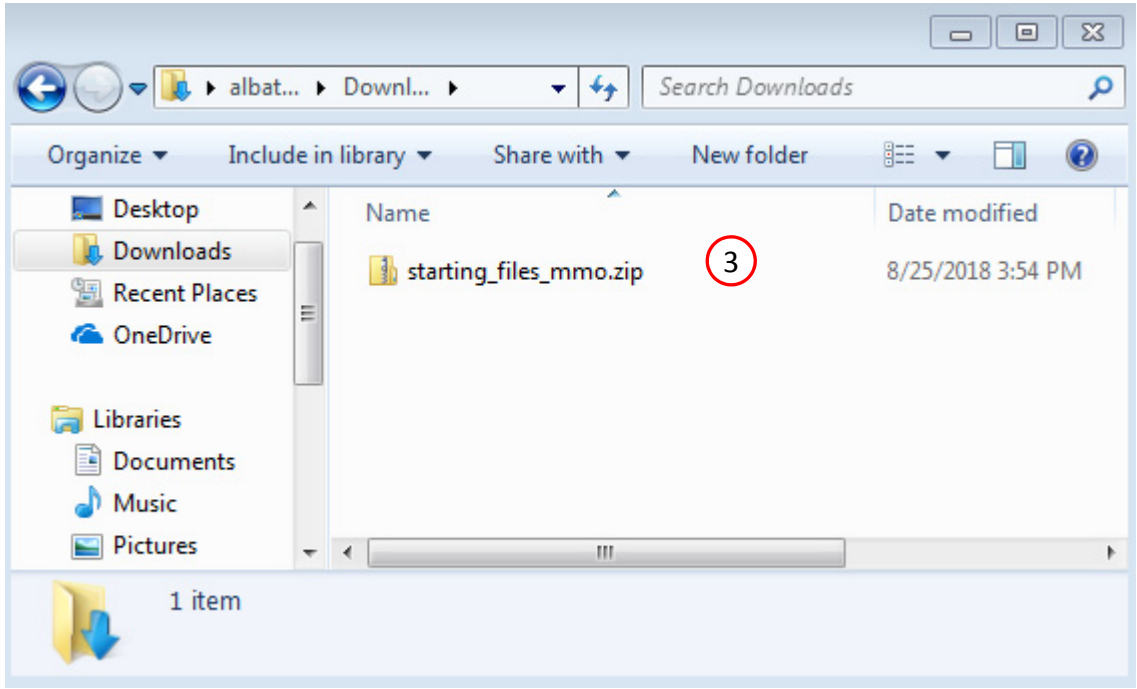
1

Multi Model Optimization

Multi Model Optimization (MMO) is the process of optimizing multiple design models concurrently. Design variables across multiple models can be linked and simultaneously optimized. A merged or combined objective can optimize the objective of each design model. The design constraints of each design model are also included in a multi model optimization.

This tutorial details the procedure to configure a multi model optimization.

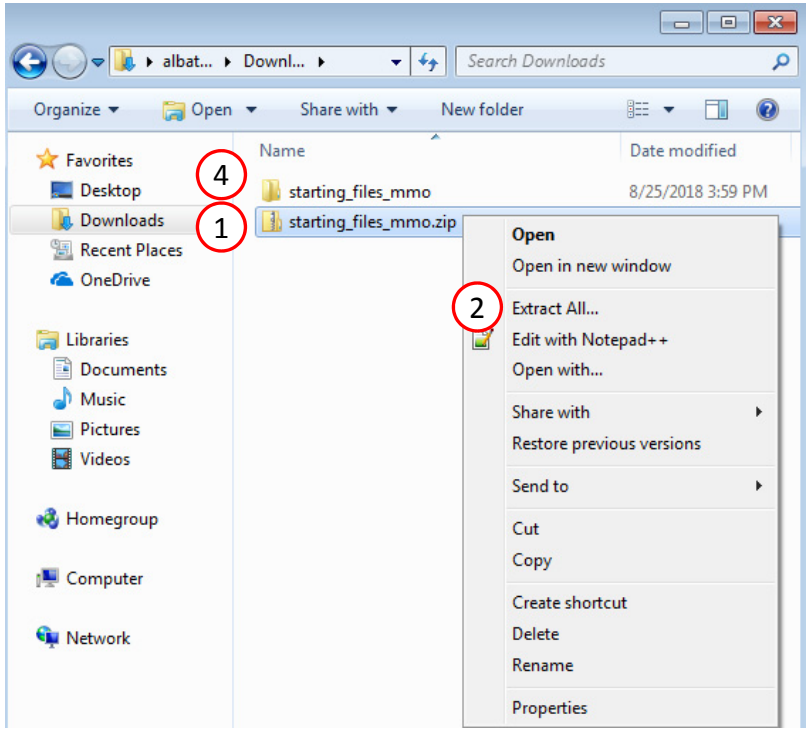
Starting BDF Files: Link 2
Solution BDF Files: Link

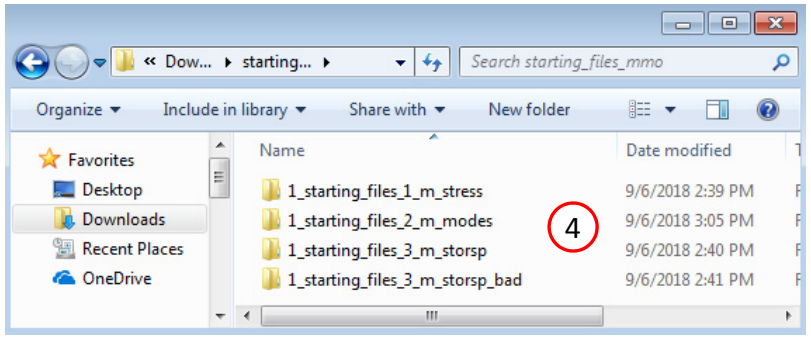


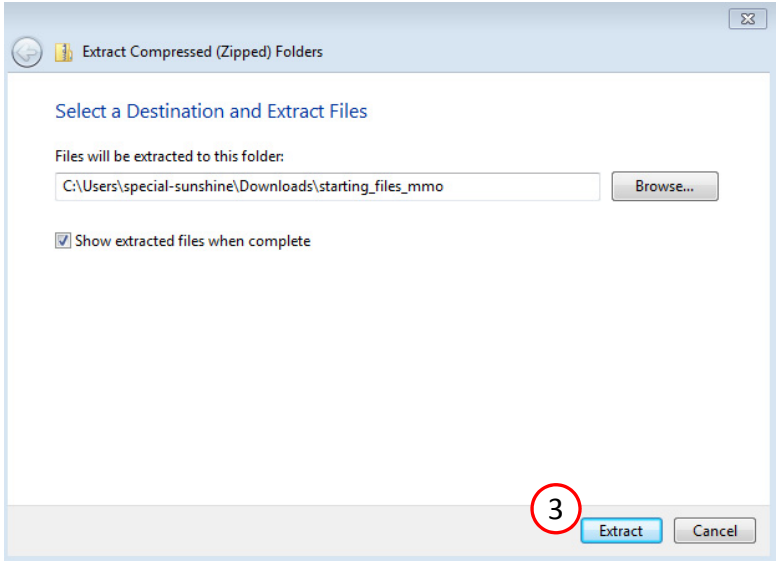
Obtain Starting Files

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

- The starting files for this tutorial are contained in a ZIP file and must be extracted as shown.







Open the Correct Page

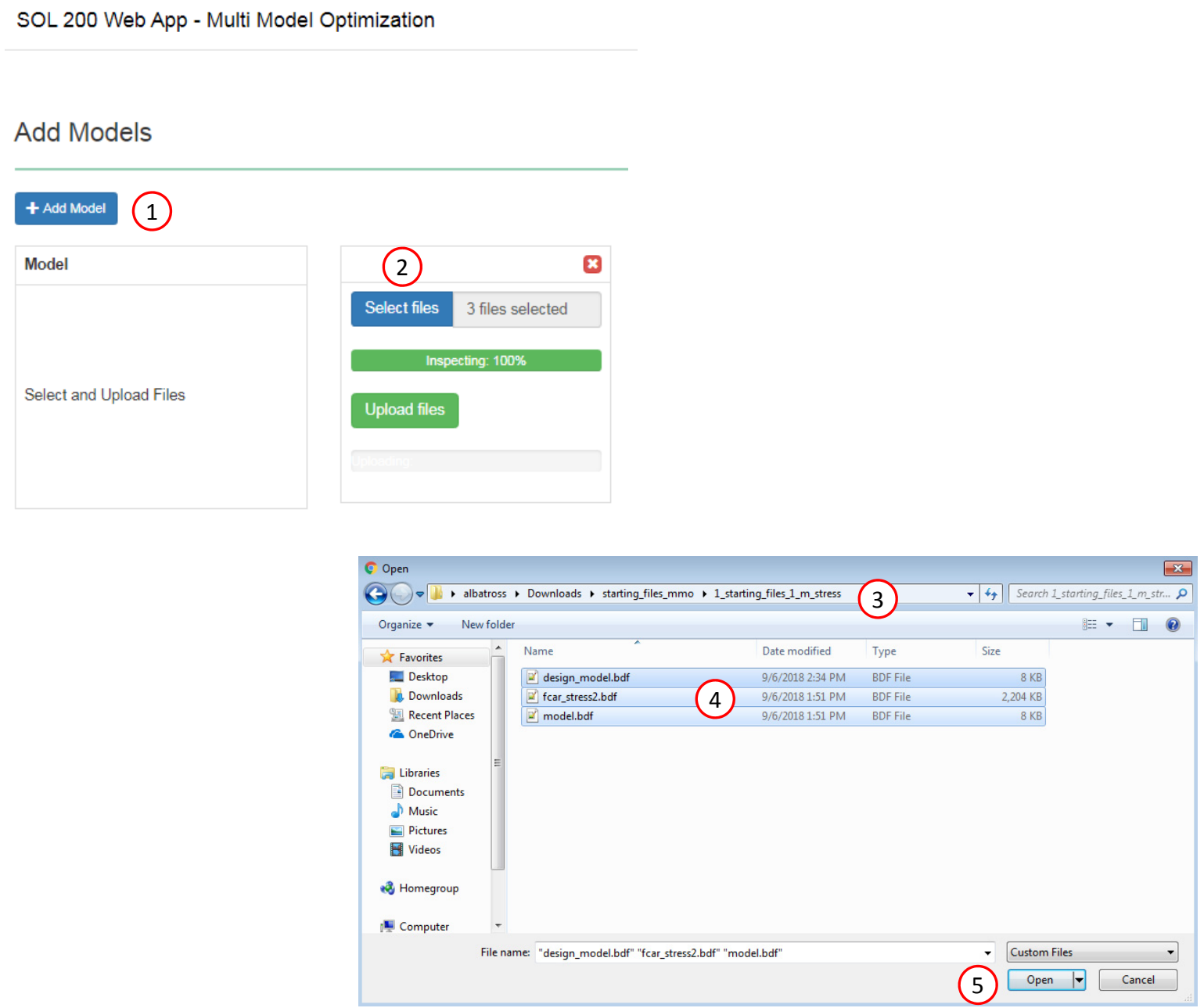
1. Click on the indicated link

- 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 Add Model
2. Click Select Files
3. Navigate to this folder: 1_starting_files_1_m_stress
4. Select the BDF files found in the folder
5. Click Open

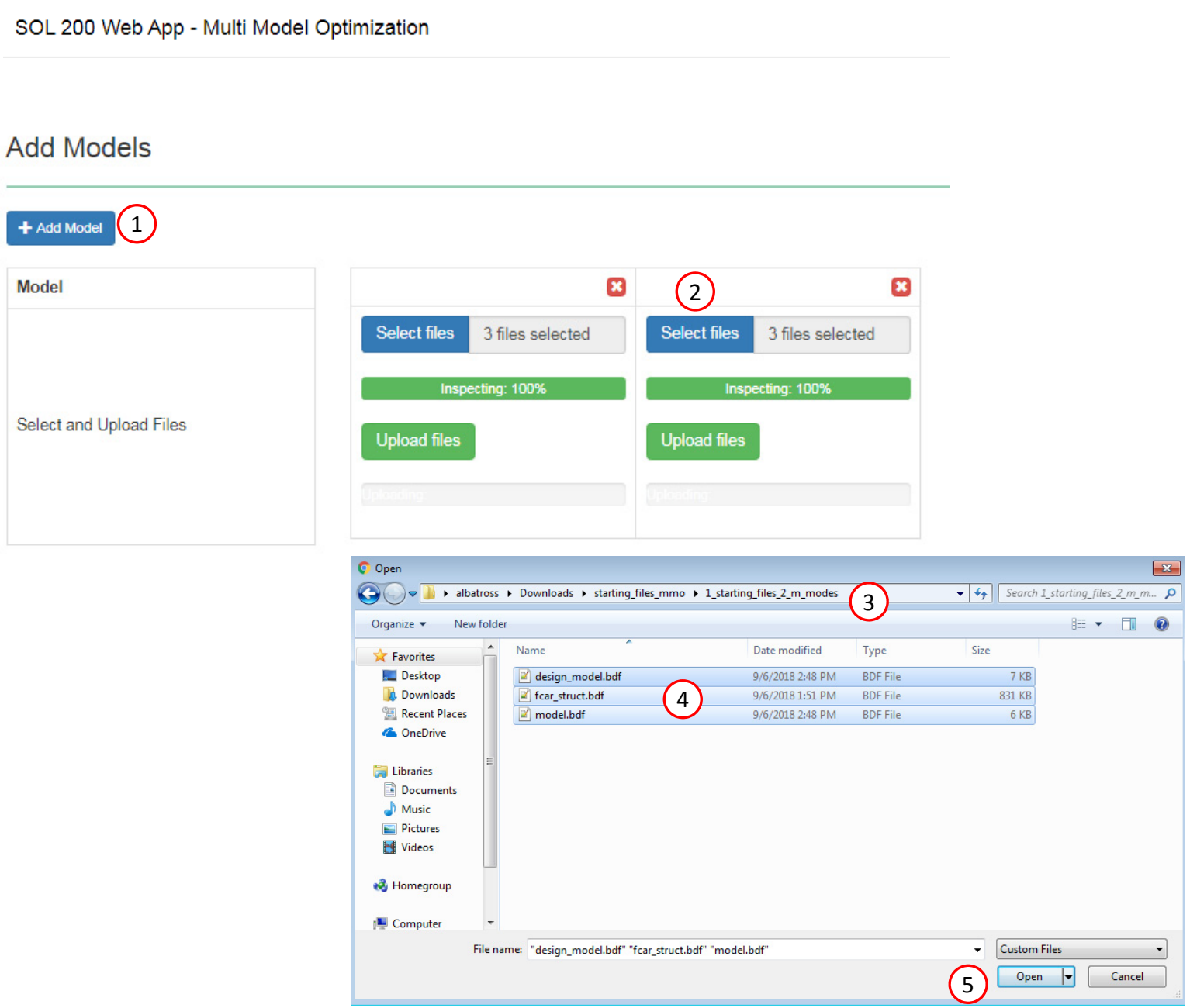
- This multi model optimization example involves 3 separate models. The first model is uploaded to the web app.



Upload BDF Files

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: 1_starting_files_2_m_modes
4. Select the BDF files found in the folder
5. Click Open

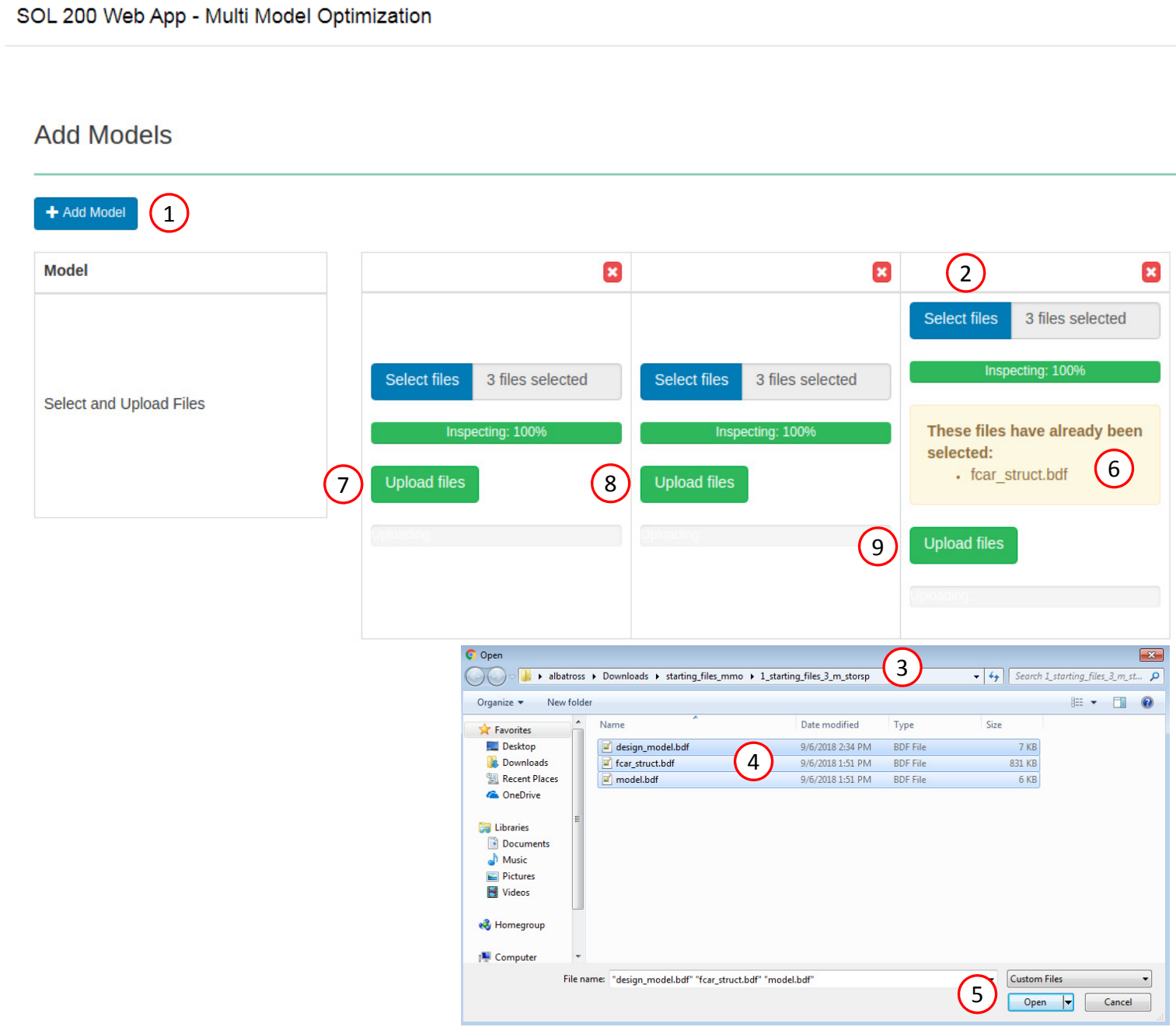
- The second model is uploaded to the web app.



Upload BDF Files

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: 1_starting_files_3_m_storsp
4. Select the BDF files found in the folder
5. Click Open
6. The cautionary message can be ignored
7. Click Upload Files
8. Click Upload Files
9. Click Upload Files

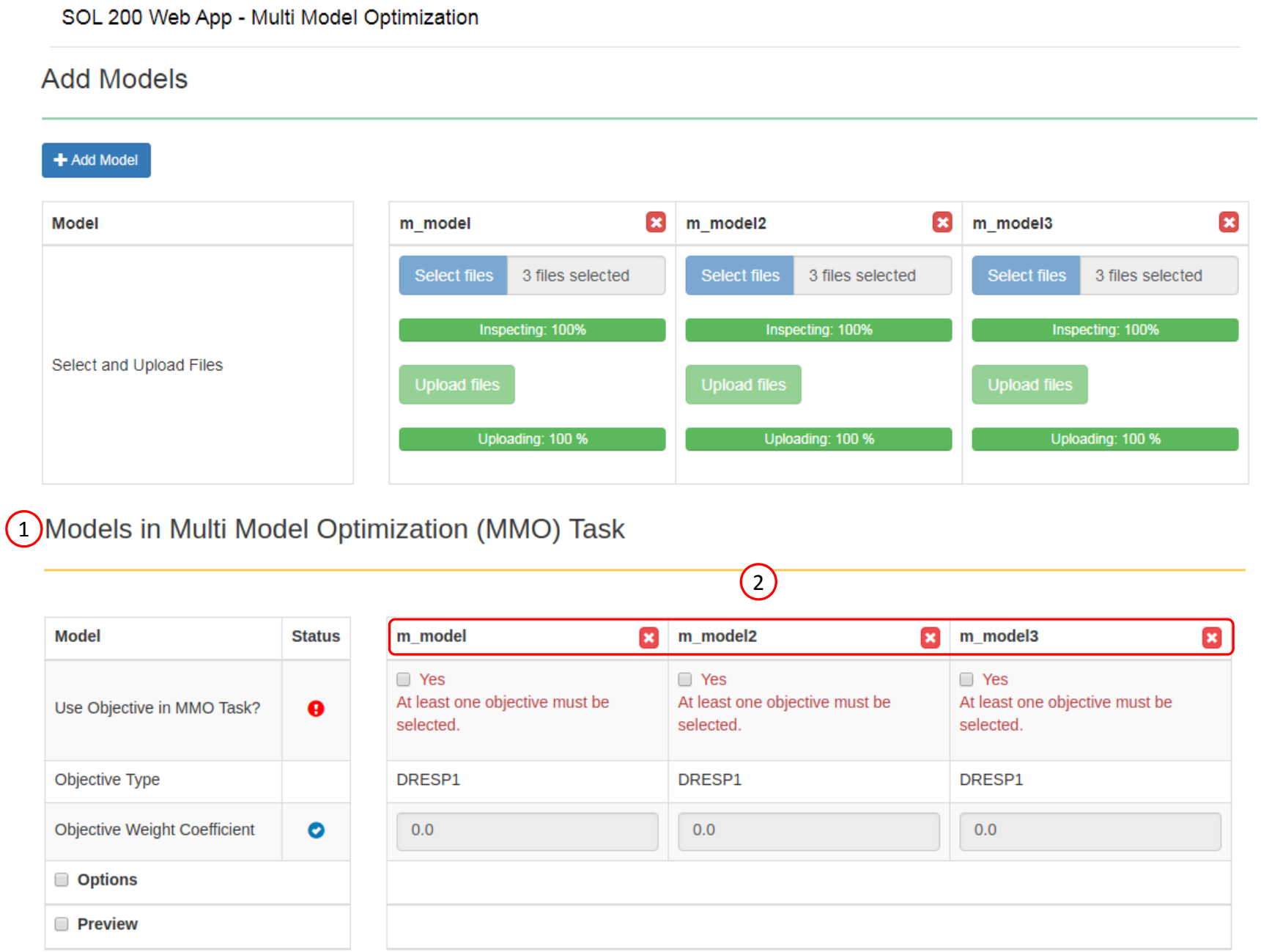
- The third model is uploaded to the web app.
- Multi model optimization involves handling multiple BDF files, and in the process the same BDF files may be uploaded inadvertently. In this example, model 2 and 3 share the BDF file: fcar_struct.bdf and a cautionary message is displayed regarding the same uploaded BDF file. The cautionary message can be ignored for this example but should be considered in all other examples.



Modify MMO Task

1. Find the section titled Models in Multi Model Optimization (MMO) Task
2. Note the names of each model have been automatically generated

- The model names can be customized as shown on the next slide.



Modify MMO Task

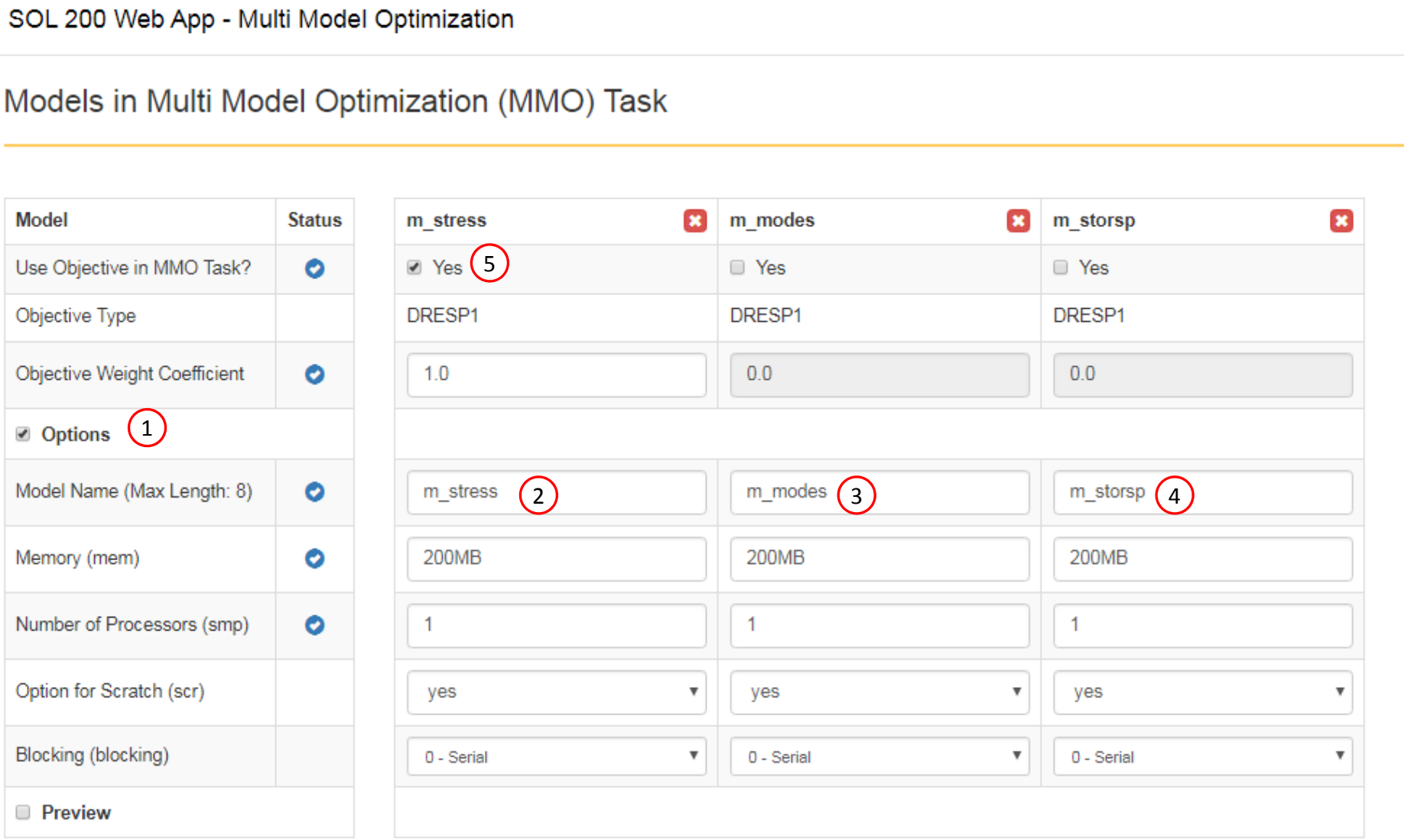
Rename the models

1. Mark the Options checkbox
2. For the 1st model (Column 1), change the model name from m_model to m_stress
3. For the 2nd model (Column 2), change the model name from m_model2 to m_modes
4. For the 3rd model (Column 3), change the model name from m_model3 to m_storsp

The merged objective will only consider the weight of model m_stress in this workshop.

5. Mark the checkbox of the 1st model (Column 1)

- The model names are limited to 8 characters.
- Marking the "Preview" checkbox will show all data changes based on the user's selections for the MMO job settings.



Modify MMO Task

1. Unmarking “Show only invalid” box under Linked Variables will show all linked or unlinked variables.

- In the event red status markers are visible, the design variables for the models must be modified for compatibility. Refer to Part B of this tutorial for the details regarding variable corrections.

Linked Variables

1 ☐ Show only invalid

Label	Status	m_stress	m_modes	m_storsp
x1	✓			
Variable Linked		Linked	Linked	Linked
x2	✓			
Variable Linked		Linked	Linked	Linked
x3	✓			
Variable Linked		Linked	Linked	Linked
x4	✓			
Variable Linked		Linked	Linked	Linked
x5	✓			
Variable Linked		Linked	Linked	Linked
x6	✓			
Variable Linked		Linked	Linked	Linked
x7	✓			
Variable Linked		Linked	Linked	Linked
x8	✓			
Variable Linked		Linked	Linked	Linked
x9	✓			
Variable Linked		Linked	Linked	Linked
x10	✓			
Variable Linked		Linked	Linked	Linked
x11	✓			
Variable Linked		Variable not in this model	Linked	Linked

Modify MMO Task

1. Scrolling down the page, one can see the Merged Objective which is included in the first model of the MMO job.

2. Settings for the Merged Model is also generated automatically and it will be output as MMO.XML for the MMO job run.

- This Merged Objective and Settings for Merged Model are auto generated by the MMO Web App. It is highly recommended that this data not be hand edited.
- More details regarding the changes on this page are covered in the Appendix, section Manually Configuring Multi Model Optimization.
- The same section also discusses the validations performed for Linked Variables.

Preview of Merged Objective

```
DRESP2  5000000 R0      570000
        DTABLE  c1      c2      c3
        DRESP1  8000000 8000000 8000000
DEQATN  570000
        g(c1, c2, c3, r1, r2, r3) = c1 * r1 + c2 * r2 + c3 * r3
DTABLE  c1      1.0     c2      0.0     c3      0.0

$ urlUsed: http://aptkoeng30:8080/optimization/
```

1

Settings for Merged Model

Option	Status	Configure
Minimize or Maximize Combined Objective		MIN
Memory (mem)	✓	200MB
Number of Processors (smp)	✓	1
Option for Scratch (scr)		yes

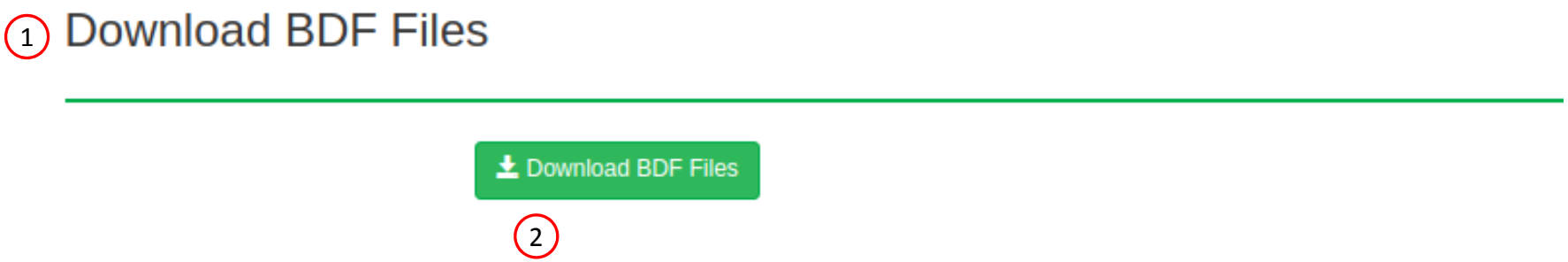
```
<?xml version="1.0" ?>
<rc OptTYpe="MMO" debug="no" >

    <Job name="m_stress" coef="1.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_modes" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_storsp" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>

    <Merge mem="200MB" smp="1" scr="yes" />

</rc>
```

2

Export New BDF Files

1. Find the section titled Download Files
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”

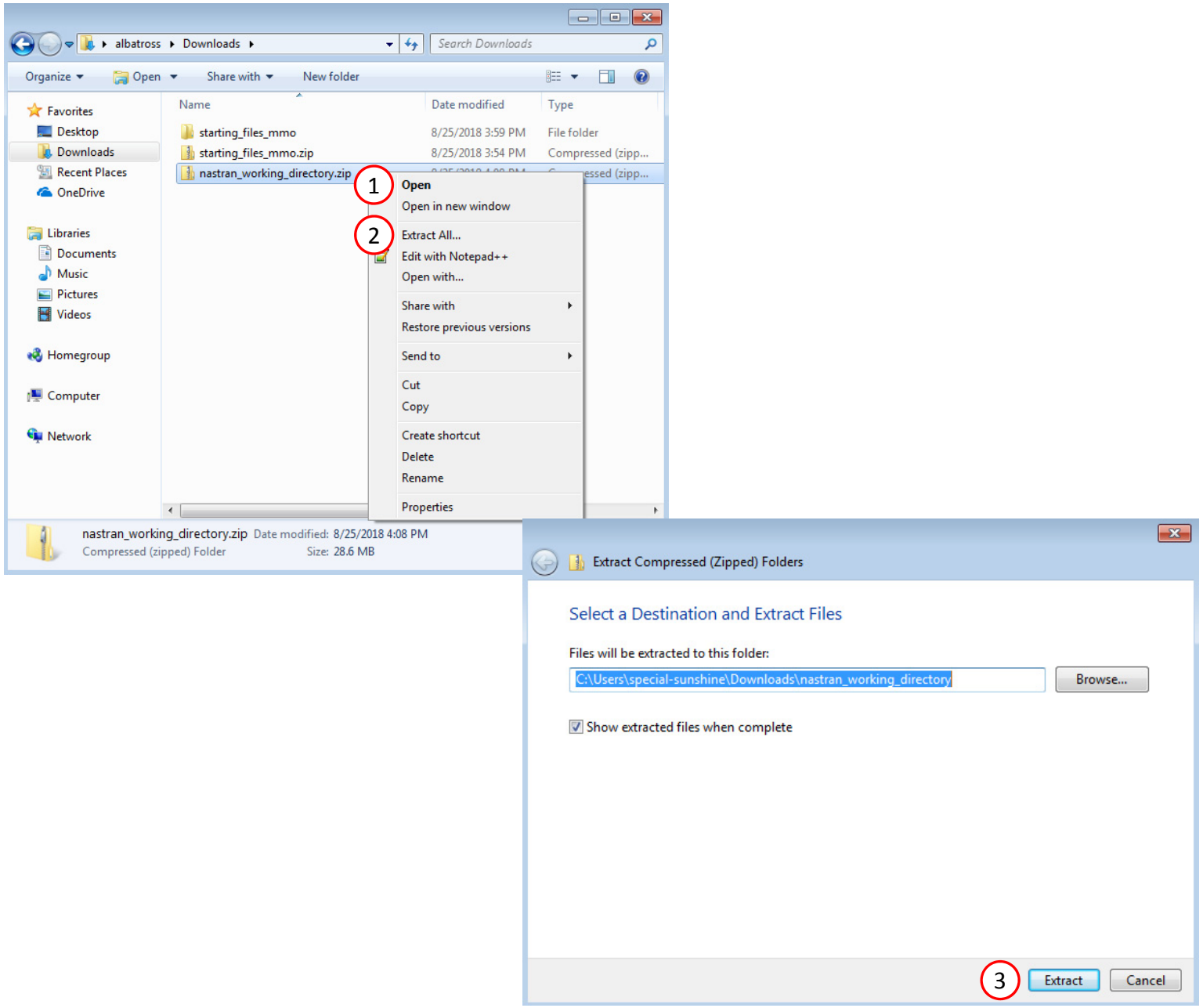


Perform the Optimization with Nastran SOL 200

A new .zip file has been downloaded

1. Right click on the file
2. Click Extract All
3. 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

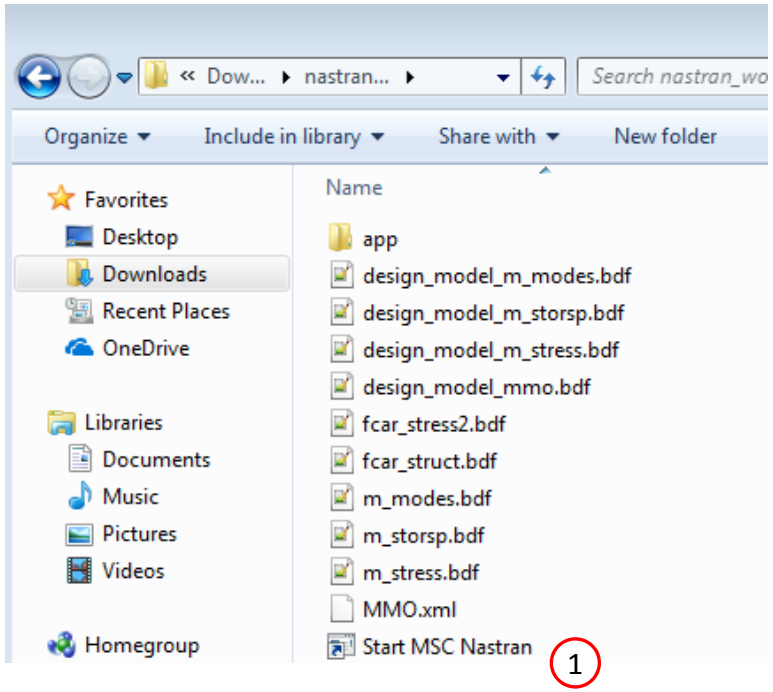
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

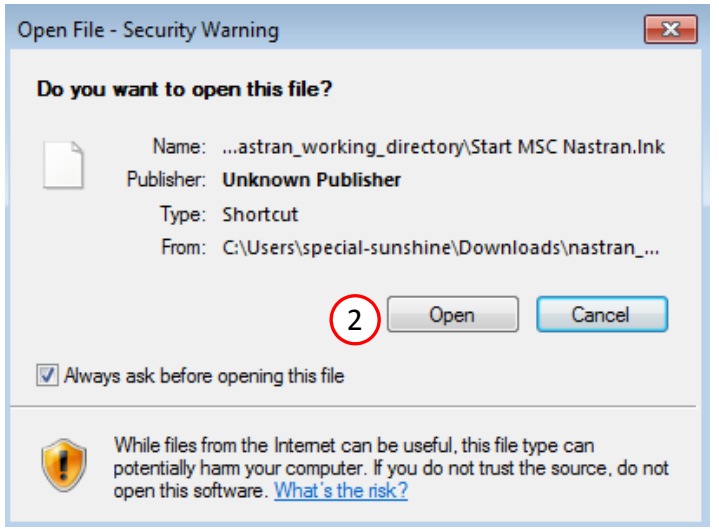
Using Linux?

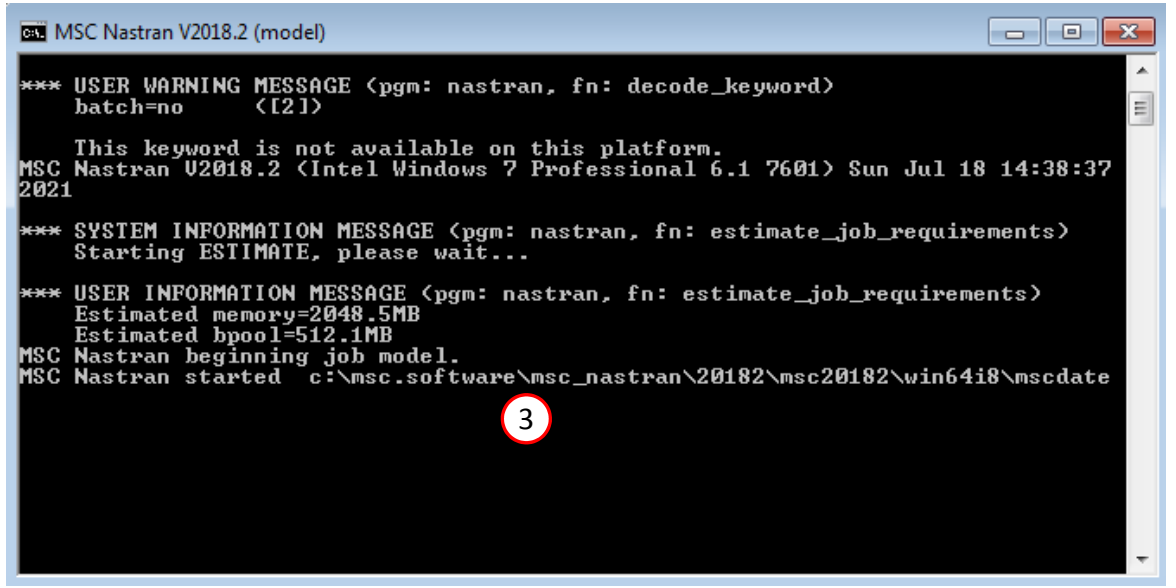
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
cd ./nastran_working_directory
3) Use this command to start the process
./Start_MSC_Nastran.sh

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



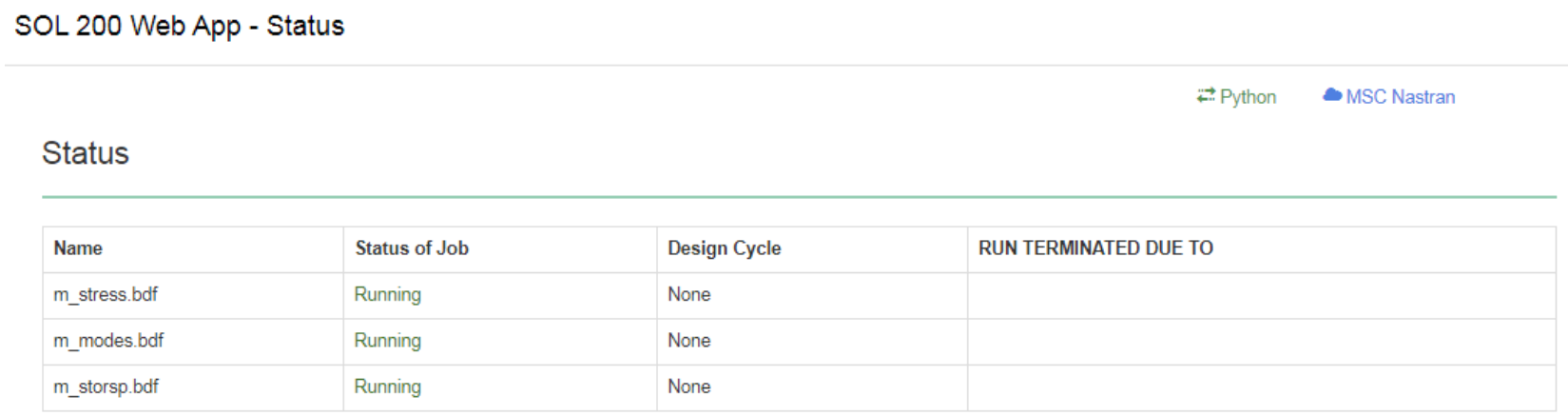




Status

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.

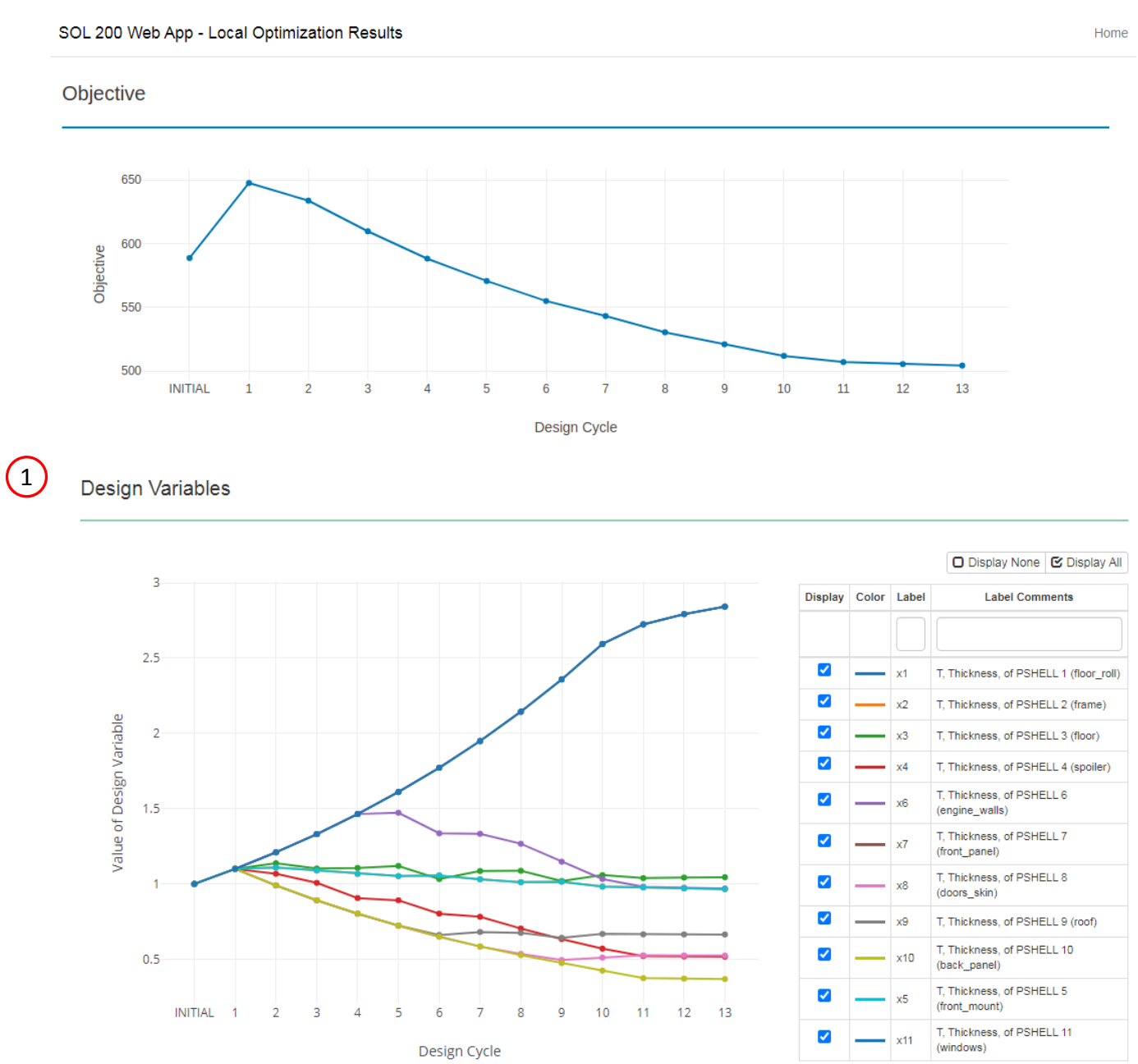


Review Optimization Results

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

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

- For all three models involved in the multi model optimization, it can be seen that a single result for the objective and design variables has been obtained and all the design constraints have been satisfied.



Tutorial

PART B

Open the Correct Page

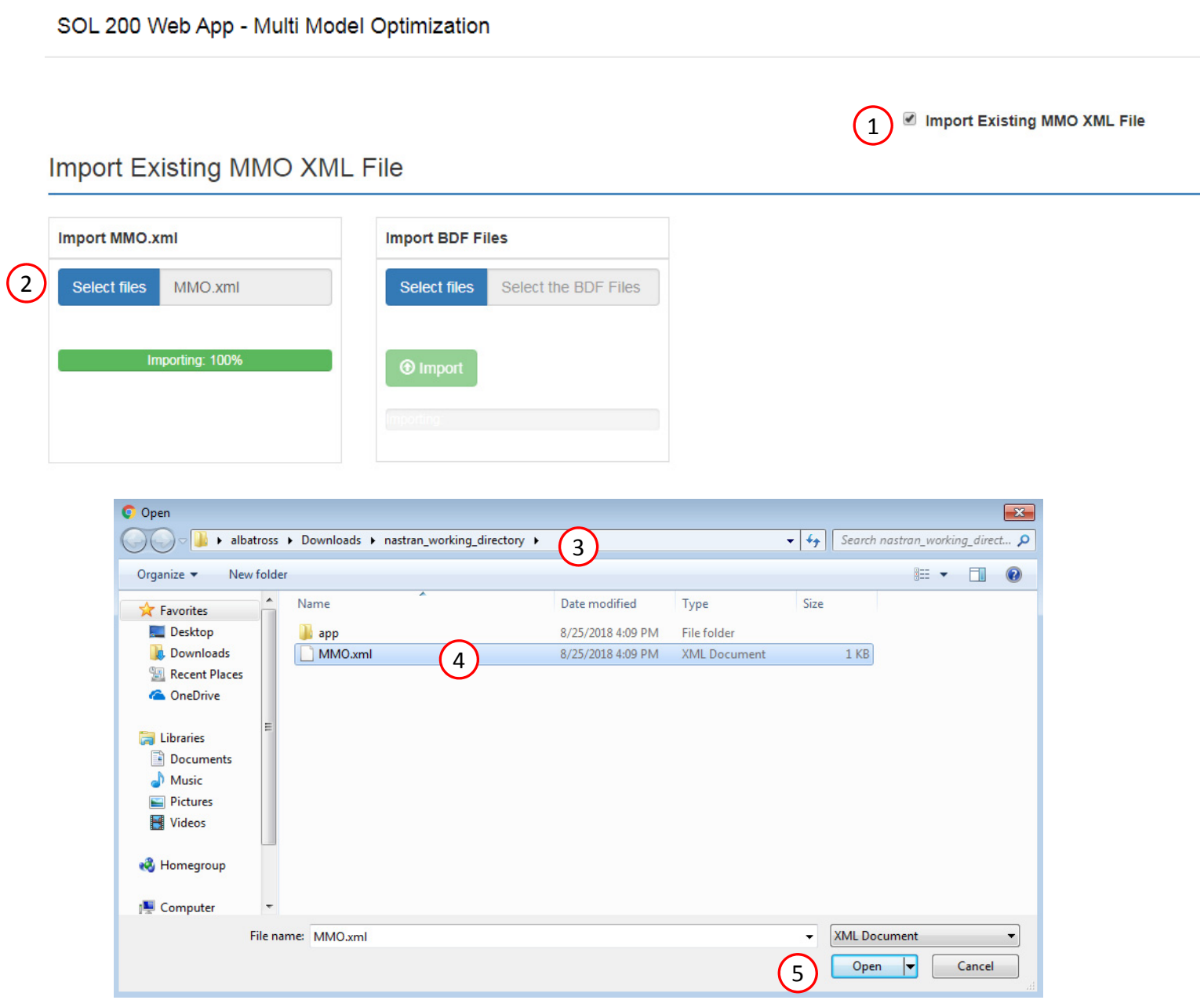
1. Click on the indicated link

- 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.

Import Existing MMO Files

1. Mark the checkbox titled Import Existing MMO XML File
2. Click Select files
3. Open the directory nastran_working_directory
4. Select the MMO.xml file
5. Click Open

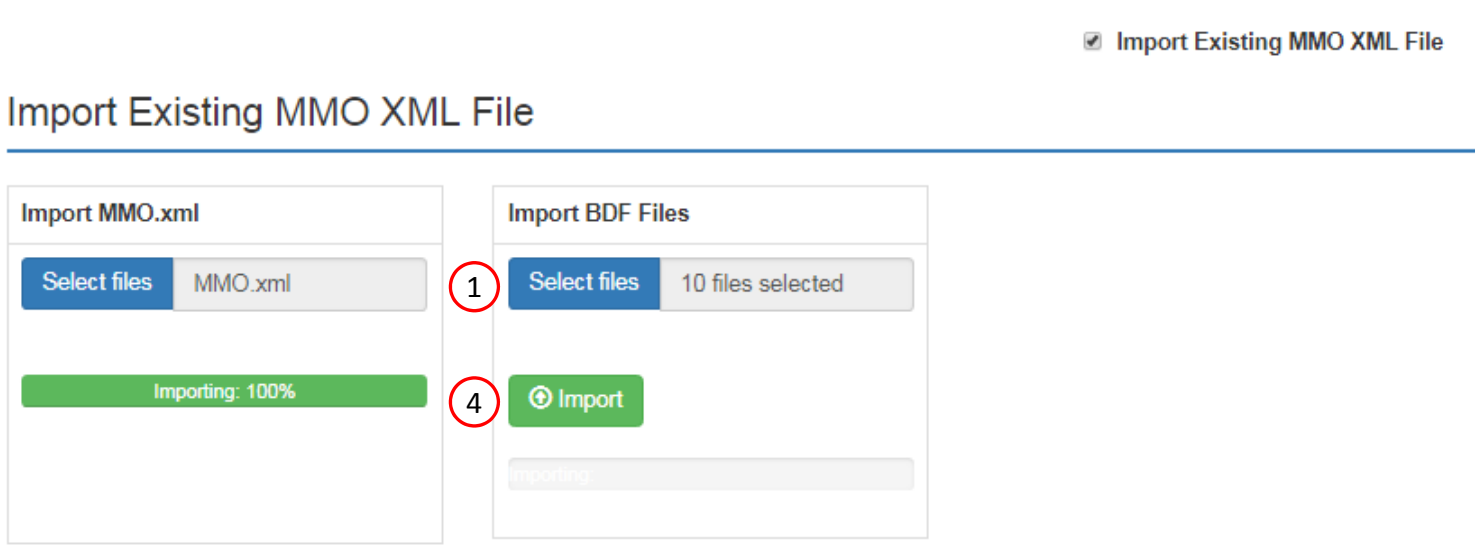
- The files from a previous MMO configuration can be re-uploaded to the MMO web app. This page shows the start of the re-upload process by uploading the XML file.

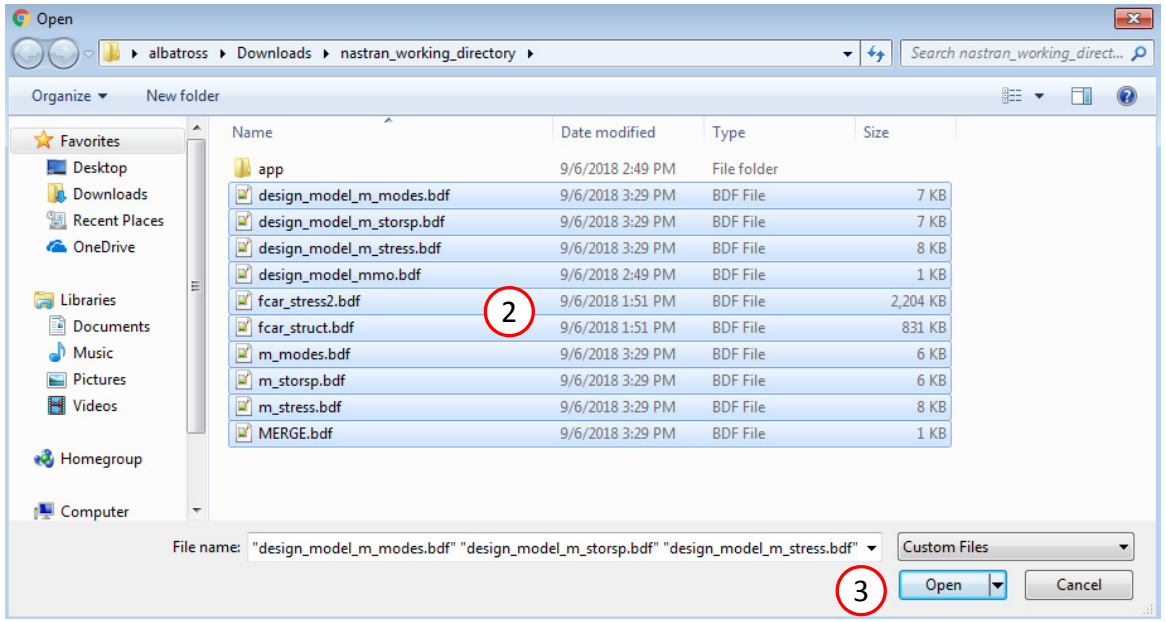


Import Existing MMO Files

1. Click Select files
2. Select all the BDF files
3. Click Open
4. Click Import

- The re-upload process continues by selecting all the BDF files and uploading.

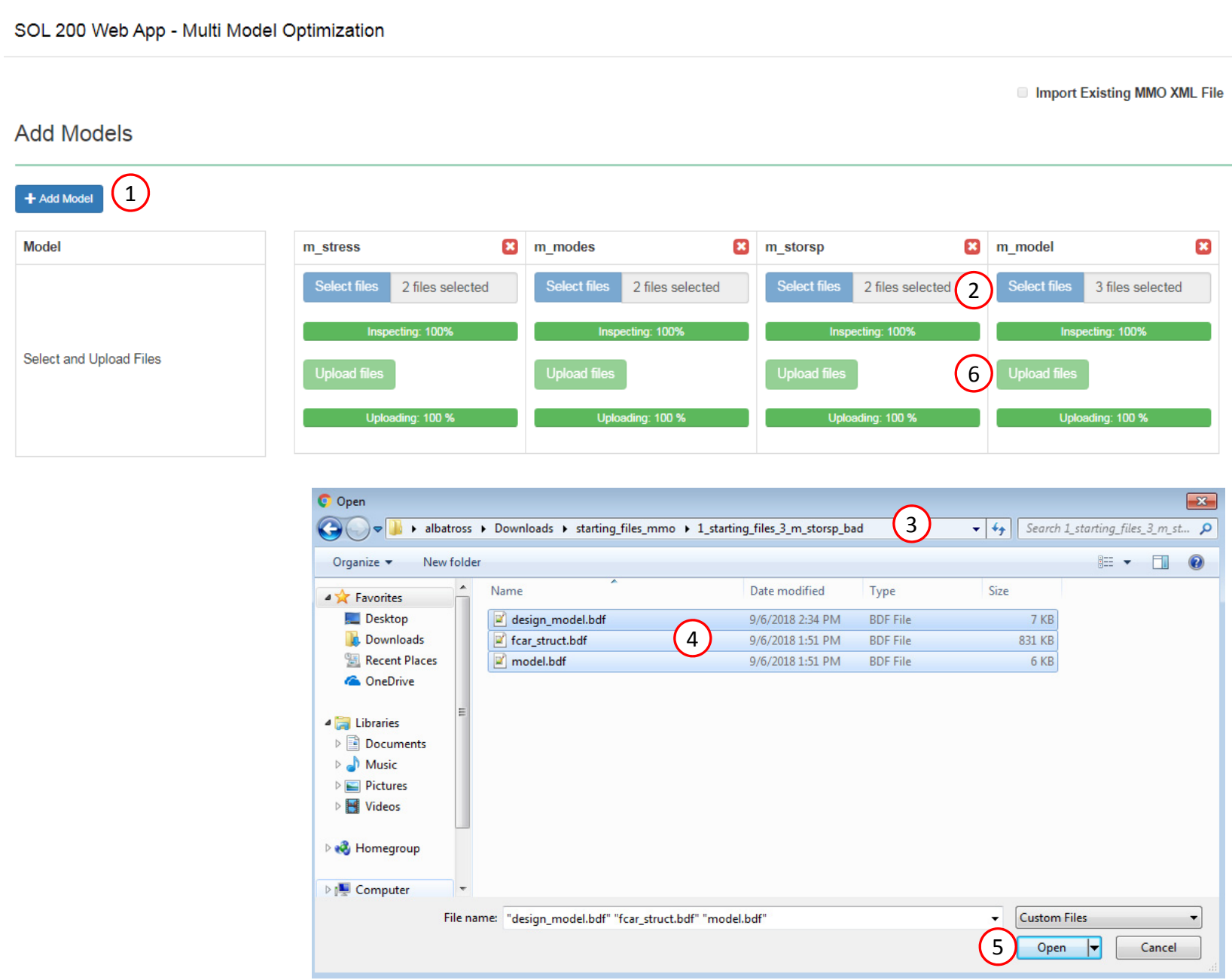




Add a 4th model

1. Click Add Model
2. Click Select files
3. Navigate to this directory: 1_starting_files_3_m_storsp_bad
4. Select the BDF files found in the folder
5. Click Open
6. Click Upload files

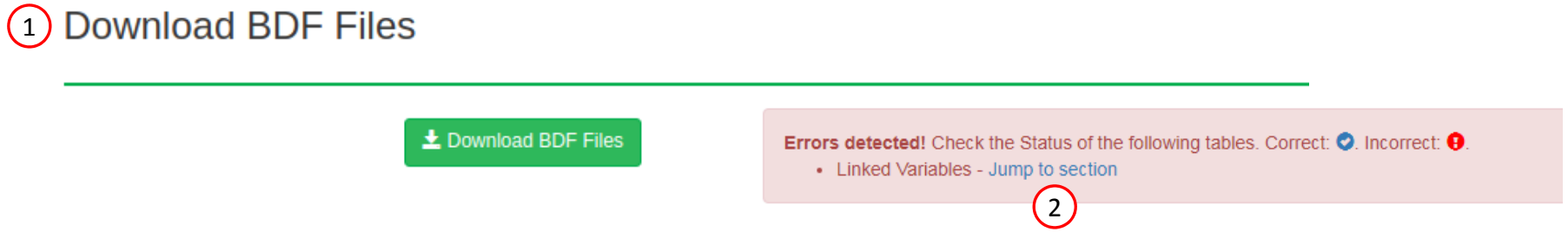
- The previous MMO task and its settings have been imported.
- A new 4th model will be added. The new model is identical to m_storsp, but has variable discrepancies that will prevent a successful Multi Model Optimization. The following steps discuss how to resolve such variable discrepancies.



Export New BDF Files

1. Find the section titled Download BDF Files.
2. Errors have been detected in the newly added model. Click Jump to section to inspect.

- The purpose of this part of the tutorial is demonstrate the procedure to take in the event a model is uploaded to the MMO web app, but has errors that must be fixed. The validations and status messages are available throughout the MMO web app, and the most significant validation is visible in the Download BDF Files section.

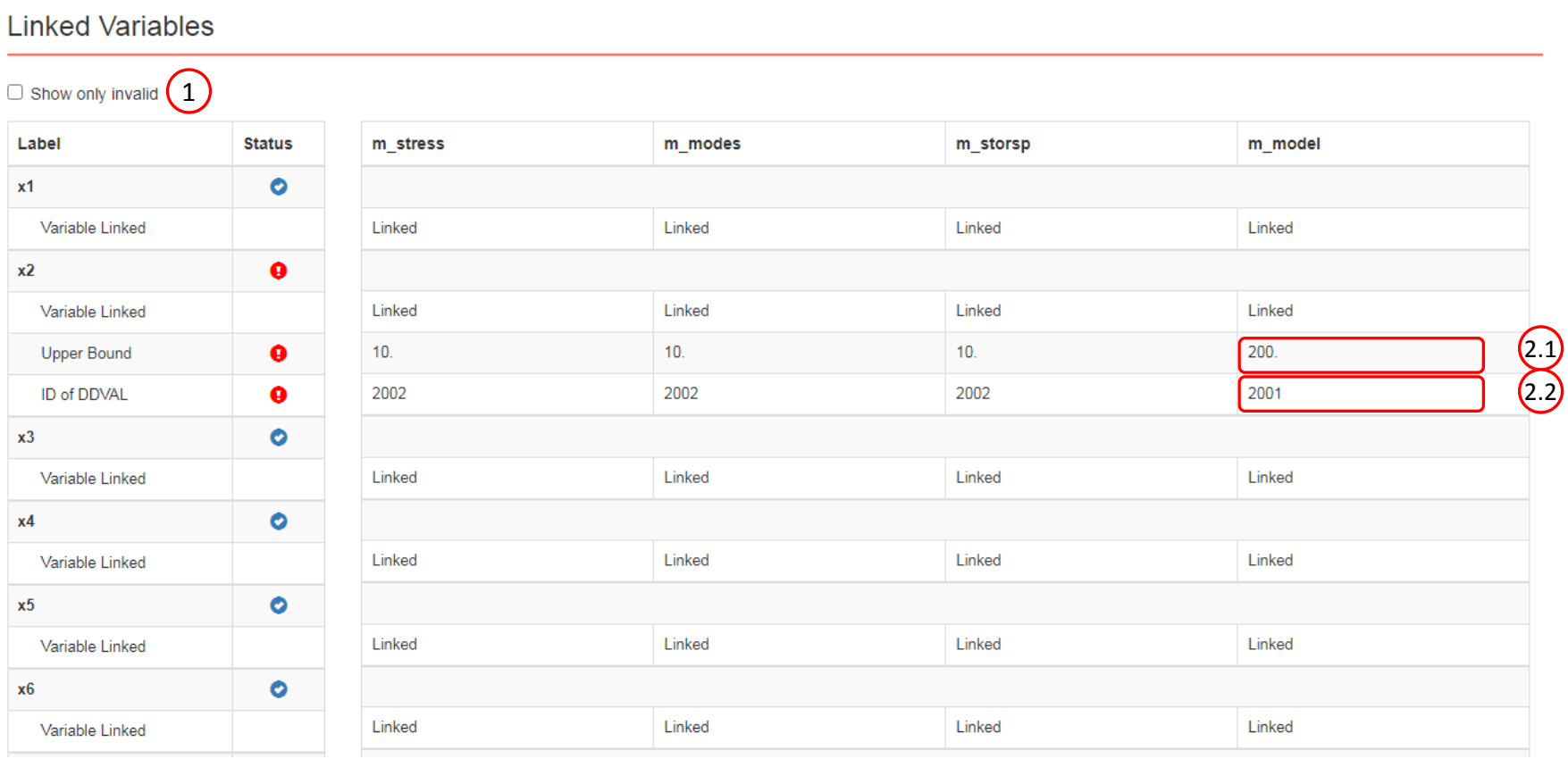


Review Linked Variables

There are 2 visible errors and 1 unlinked variable

1. Unmark the checkbox titled Show only invalid
2. For linked variable x2, 2 errors have been found:
    1. The upper bound of the 4th model (200.) is different from the other models (10.).
    2. The DDVAL ID of the 4th model (2001) is different form the other models (2002).

- Always check the status icons in each section of the web app. Red status markers indicate an error that will fail a multi model optimization. Blue status markers indicate the setting is valid.
- Errors found in the Linked Variables section require additional modifications to resolve. The purpose of this part of the tutorial is to demonstrate the process to correct issues found in the Linked Variables section.



Open the Correct Page

1. Click on the indicated link

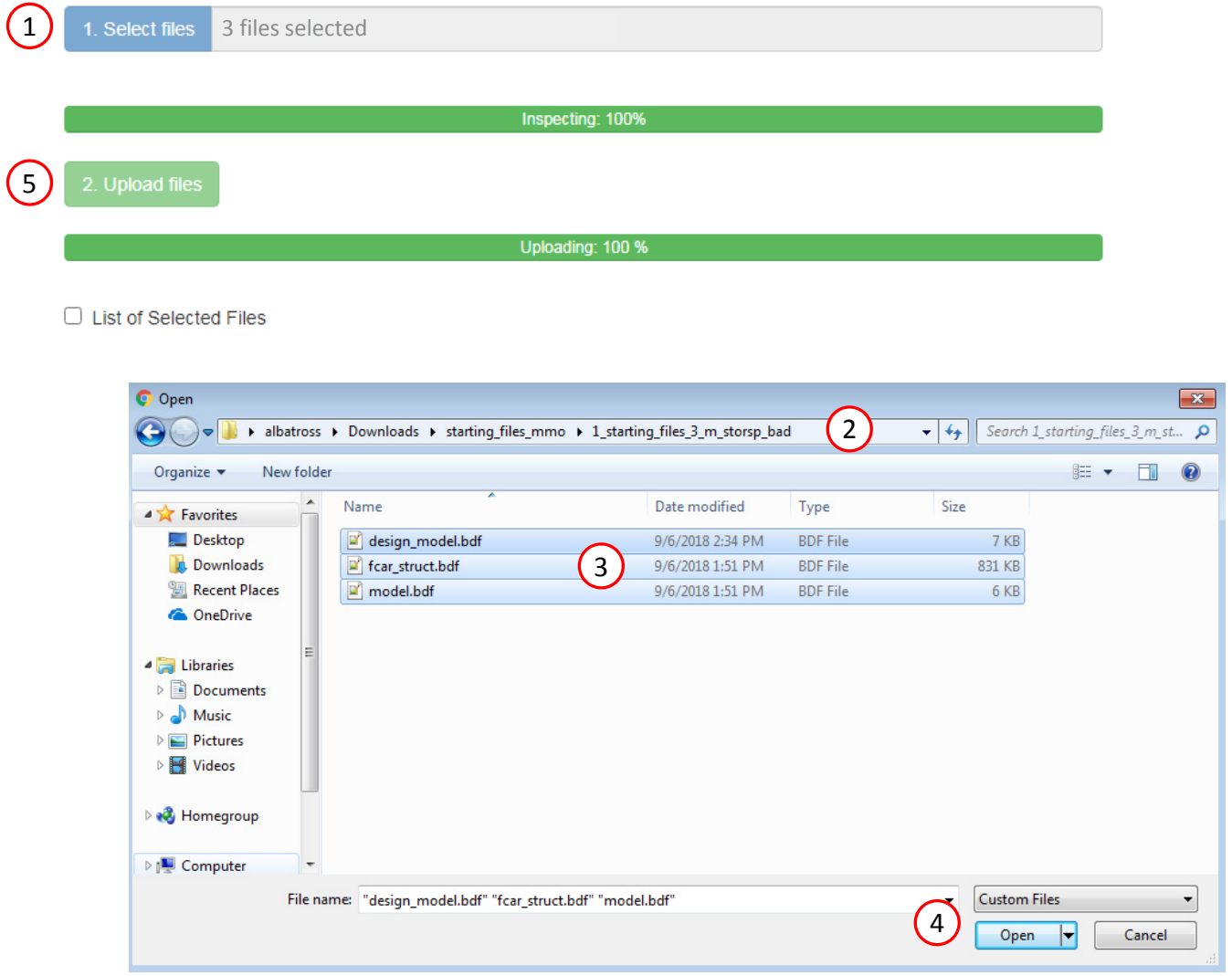
- In order to address the 2 visible errors and 1 unlinked variable detected in the 4th model in the MMO web app, currently named “m_model” in the last step, the 4th model must be taken to the Optimization web app and modified.

Upload BDF Files

1. Click 1. Select Files
2. Navigate to this folder: 1_starting_files_3_m_storsp_bad
3. Select all the BDF files found in the directory
4. Click Open
5. Click Upload Files

- The process starts by uploading all the necessary BDF files.

Step 1 - Upload .BDF Files



Modify Design Variables

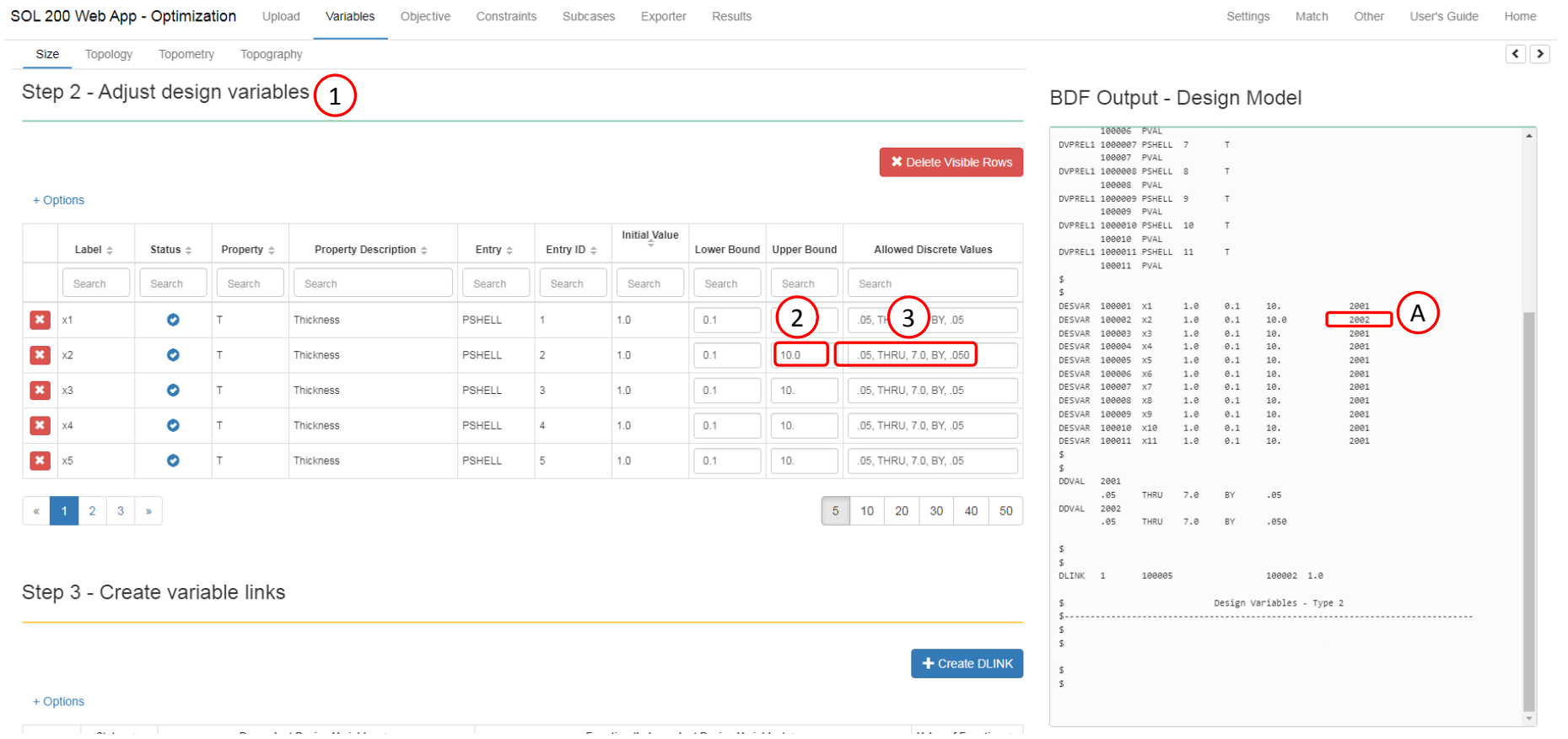
1. Find the section titled Step 2 – Adjust design variables

Perform the following edits to variable x2

2. Upper Bound: 10.0

3. Allowed Discrete Values: .05, THRU, 7.0, BY, .050

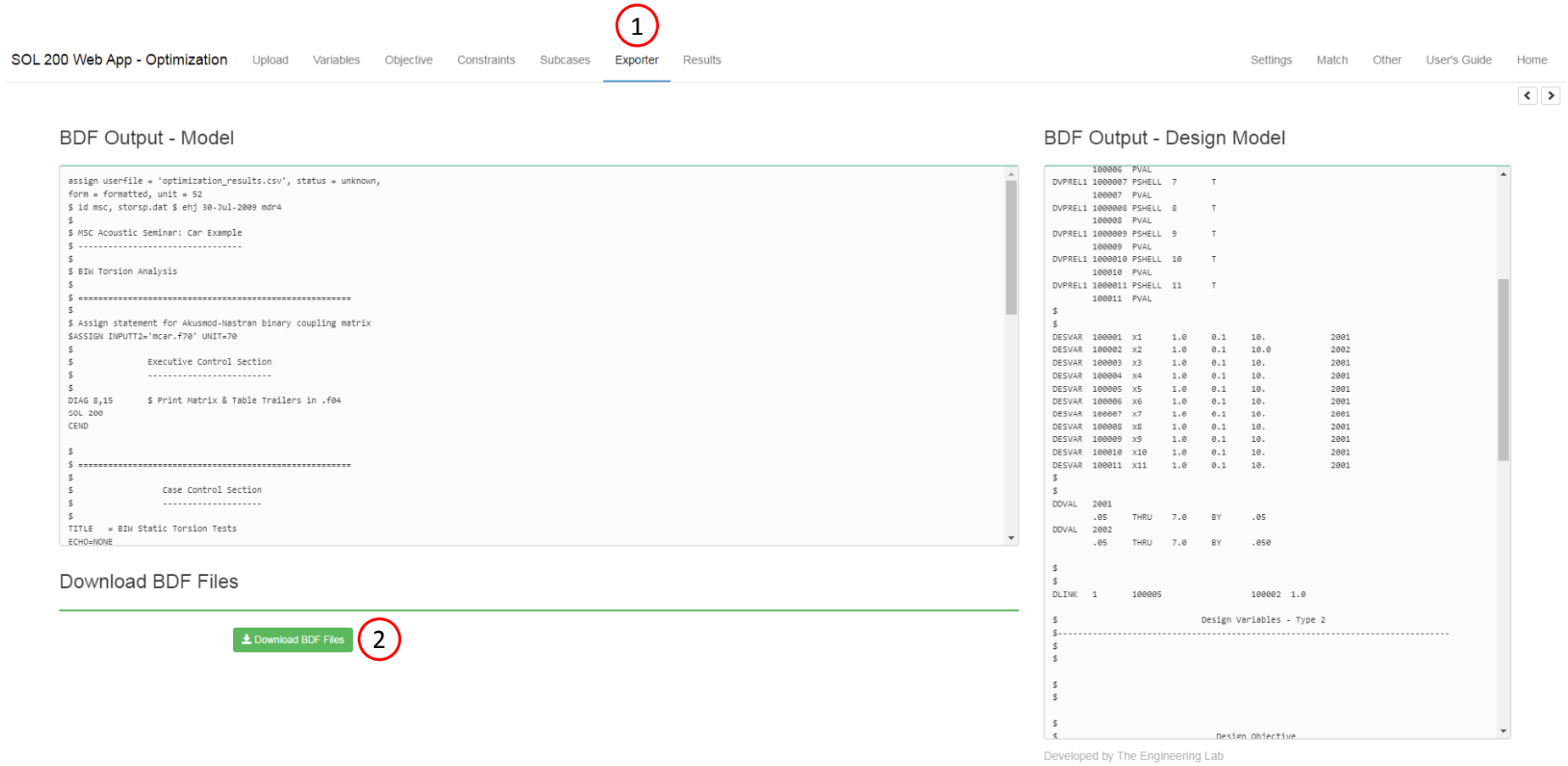
A. Some may notice that there is a trailing zero in the Allowed Values, i.e. .050: .05, THRU, 7.0, BY, .050
The goal of the extra 0 is to make the to make the entire string unique from the other allowed values. This triggers the web app to create a unique DDVAL entry with identification number of 2002. Multi Model Optimization requires that linked variable's (DESVAR and DDVAL entries) entries are identical across models. With this change, all x2 variables point to the same DDVAL 2002 entry.



Export New BDF Files

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

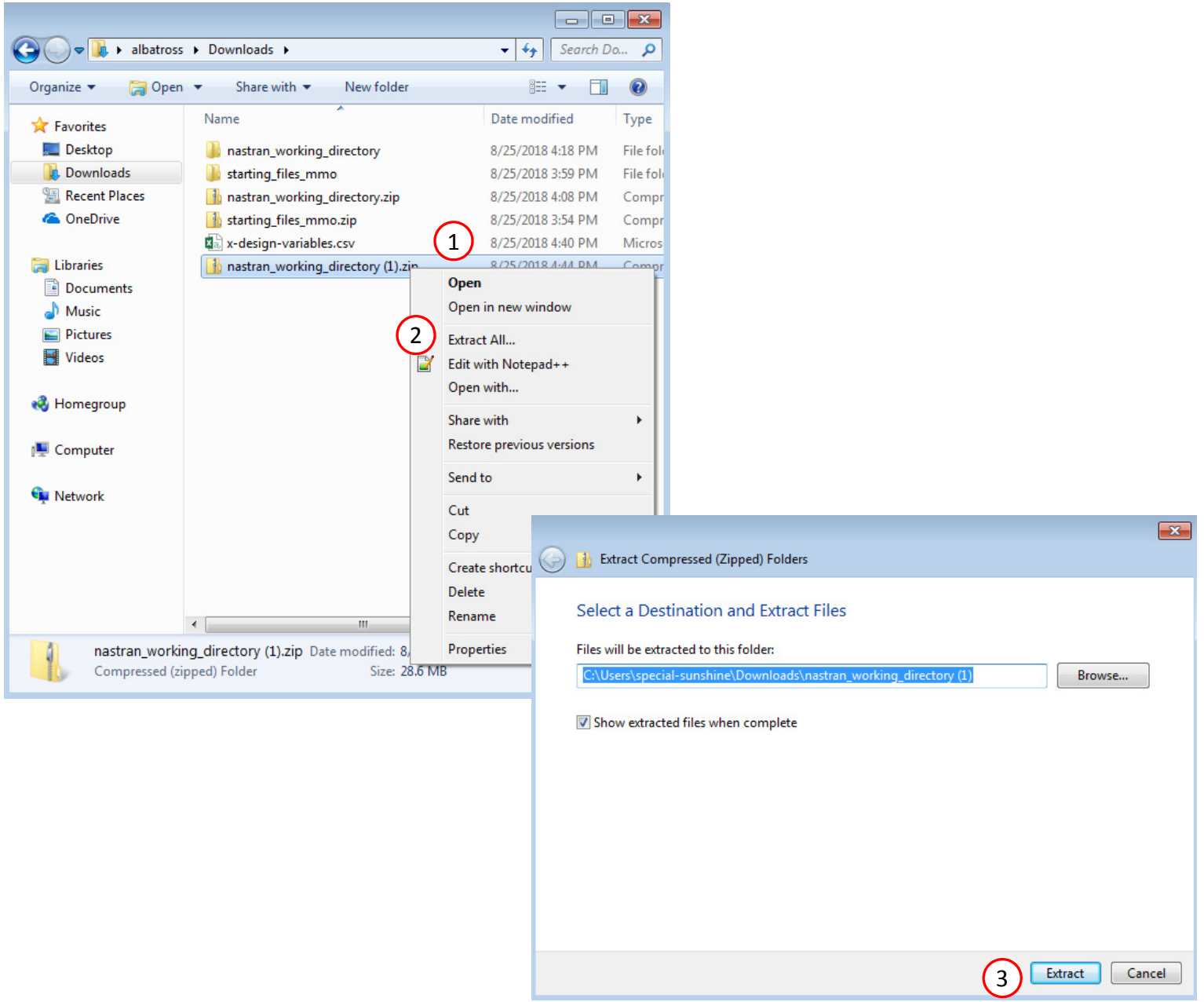
- To ensure this new design model yields the same solution as before, the updated BDF files are downloaded and an optimization is performed.



Perform the Optimization with Nastran SOL 200

1. A new .zip file has been downloaded
2. Right click on the file nastran_working_directory (1)
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

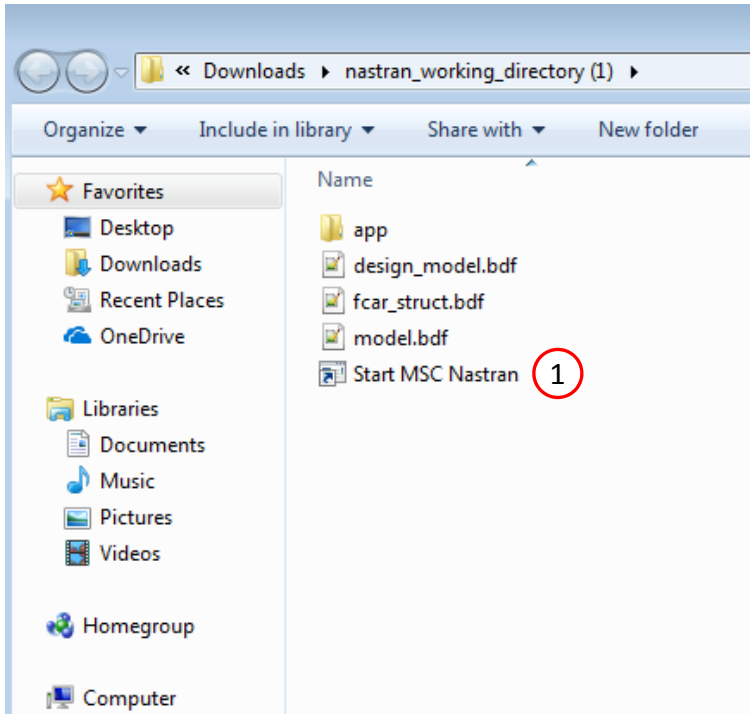
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

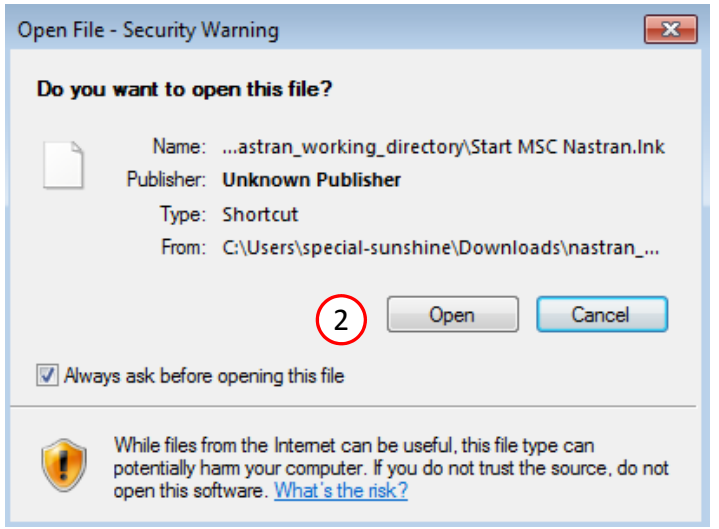
Using Linux?

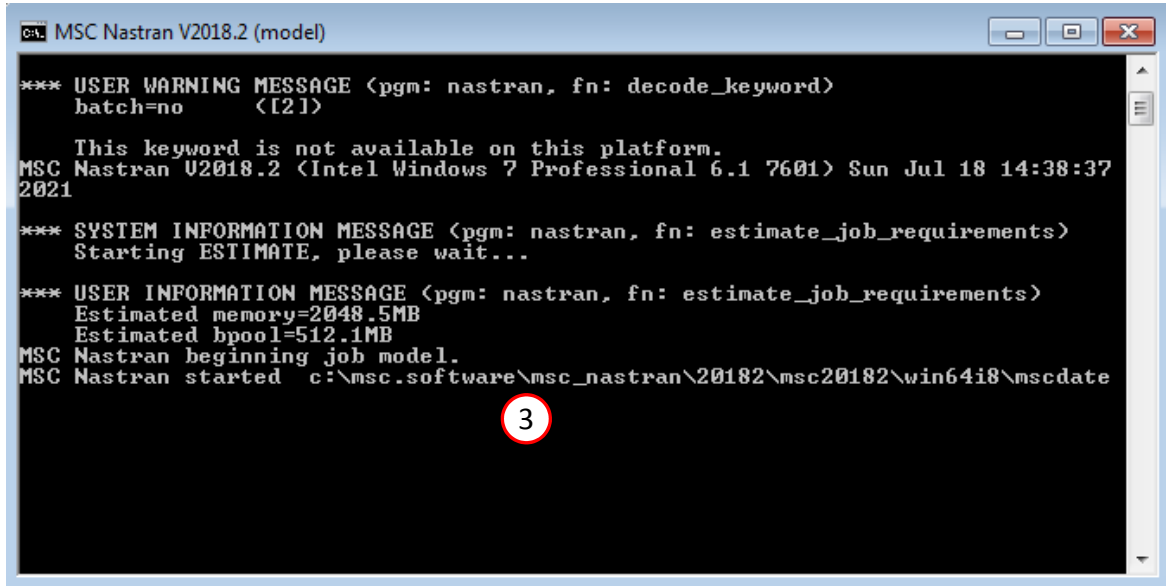
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
cd ./nastran_working_directory
3) Use this command to start the process
./Start_MSC_Nastran.sh

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



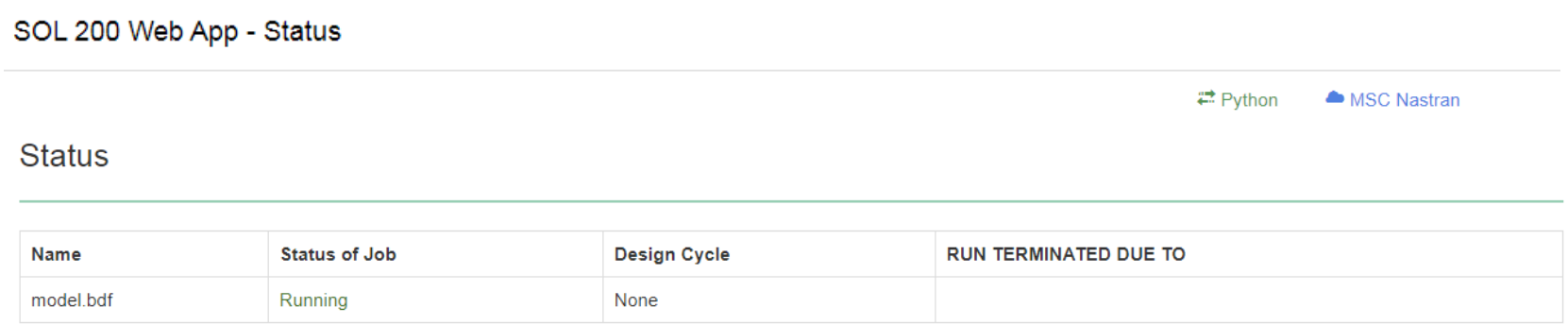




Status

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.



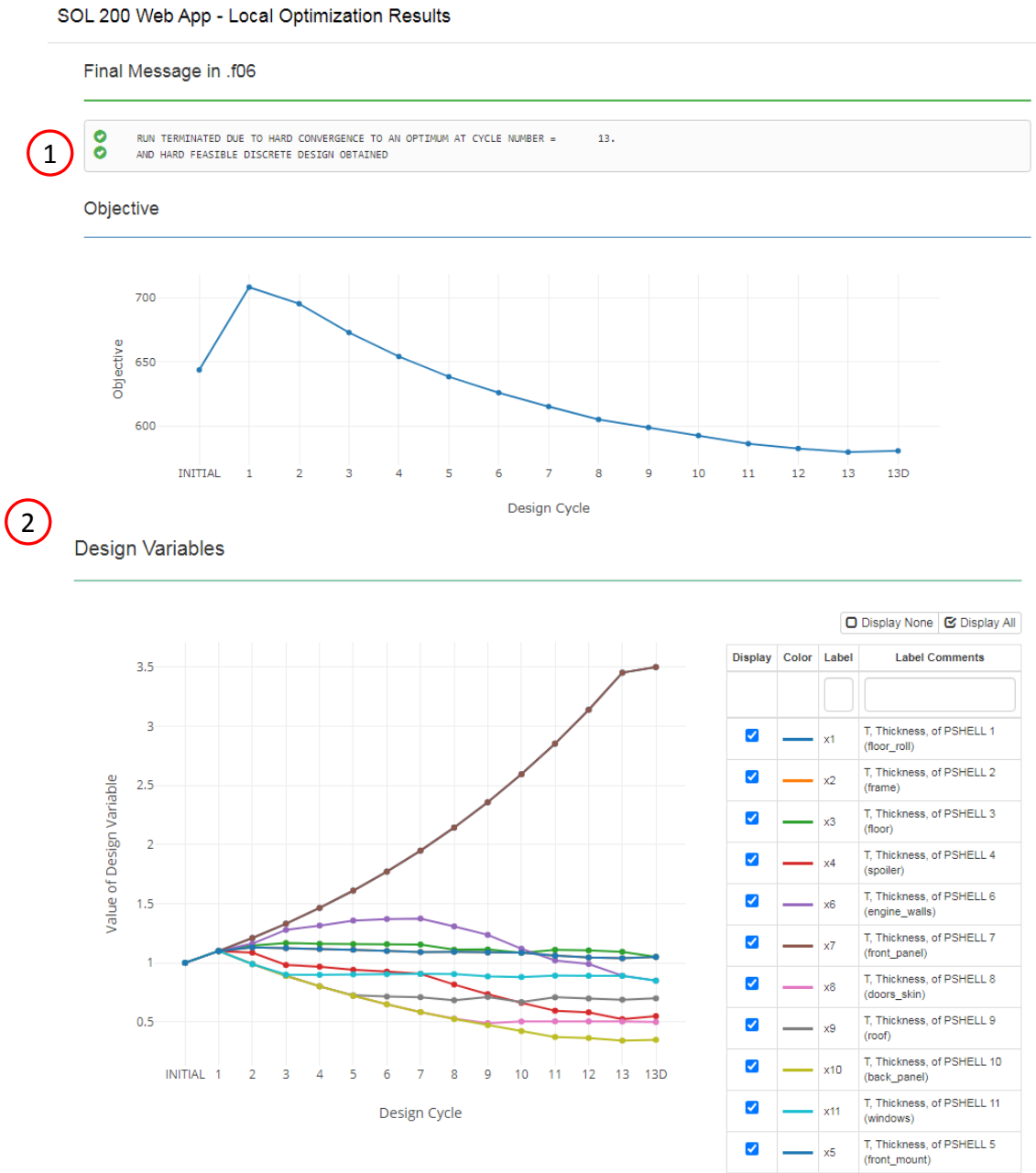
Review Optimization Results

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.

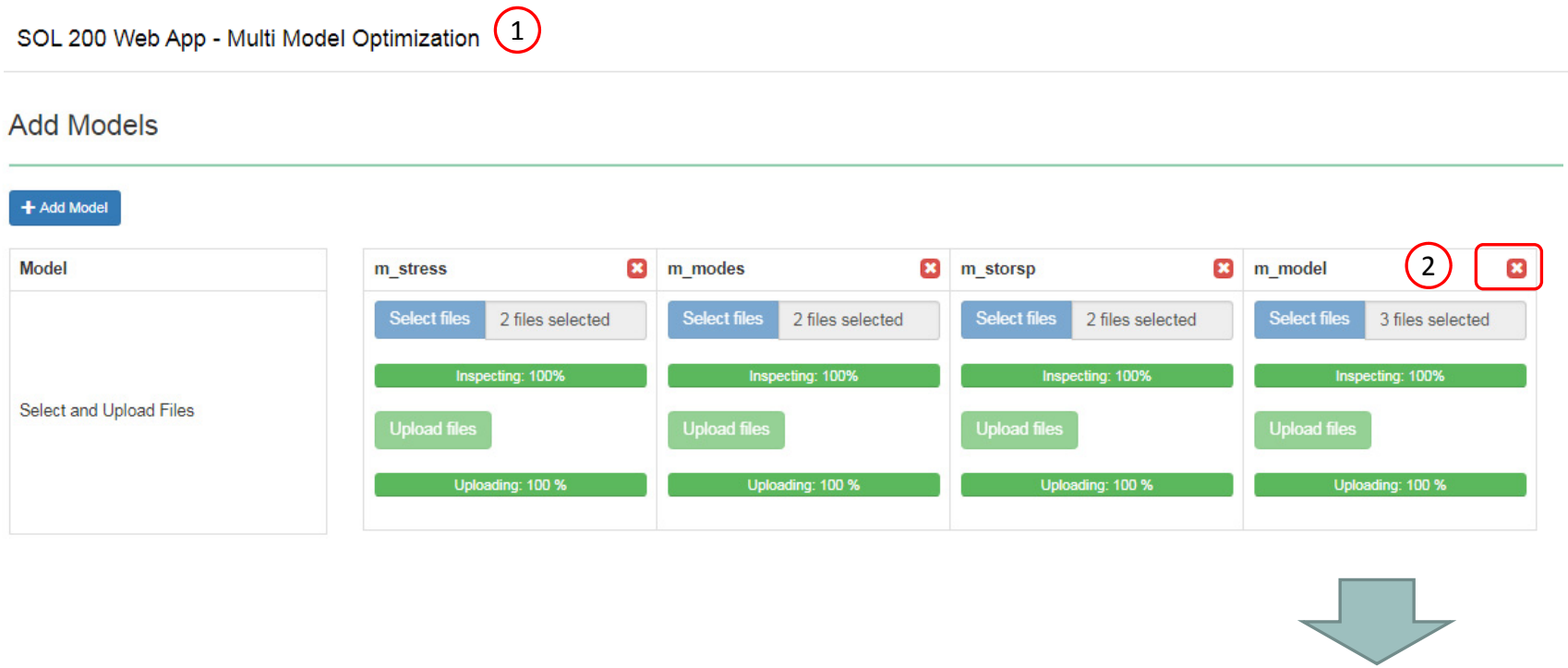
- This model has been previously optimized. In the last few steps, changes to the design variables have been done, but the optimization results should be identical to the optimization results before modification. Ensure the results are the same.
- This new design model, found in nastran_working_directory (1), has the necessary corrections in order to successfully add this design model to the MMO task.

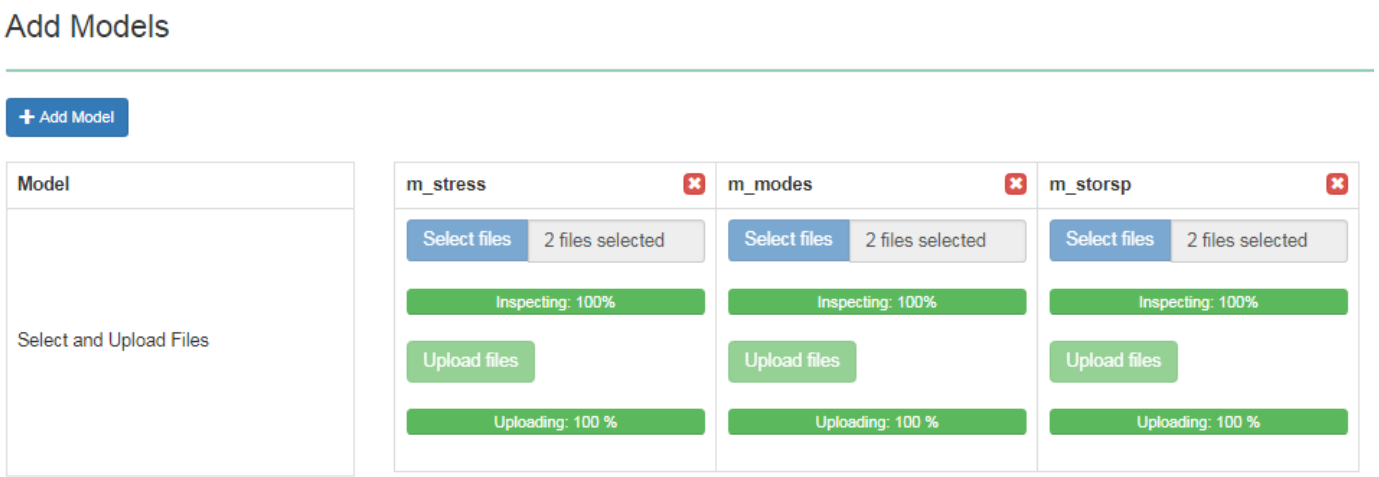


Open the MMO Web App

1. Open the existing MMO Web App
2. Click the red x to remove the 4th model. Recall that this model has errors and will not be used.

- The old 4th model is removed. This model contained the inconsistent variables x2 and x300.

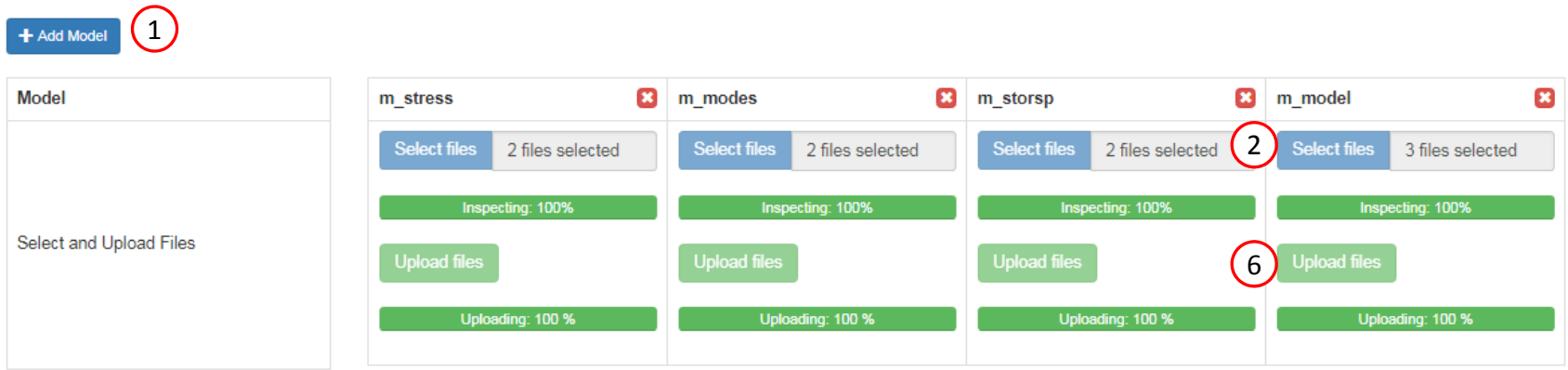


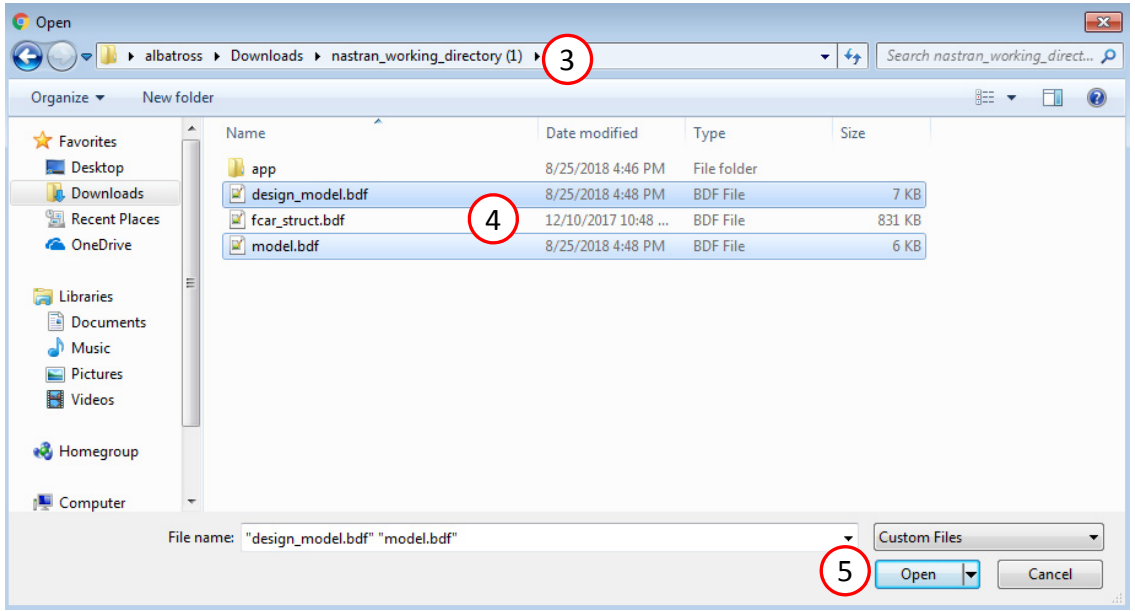


Add a 4th Model

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: nastran_working_directory (1)
4. Select the BDF files found in the folder
5. Click Open
6. Click Upload Files

- The new 4th model is added. This model was modified in the Optimization web app and is contained in the folder named nastran_working_directory (1).





Review Linked Variables

1. Note the 2 errors for x2 from before:
   1. The upper bound of the 4th model (200.) is different from the other models (10.).
   2. The DDVAL ID of the 4th model (2001) is different form the other models (2002).
2. After taking the 4th model, and updating the design model using the Optimization web app and the CSV file, the errors have been resolved and a blue checkbox is shown for variable x2.

- The original purpose of this part of the tutorial was to demonstrate the process to correct issues found in the Linked Variables section. As shown in the New View, the status markers for x2 is blue, meaning the variables are properly configured.

Old View

Linked Variables

☐ Show only invalid

Label	Status	m_stress	m_modes	m_storsp	m_model
x1					
Variable Linked		Linked	Linked	Linked	Linked
x2					
Variable Linked		Linked	Linked	Linked	Linked
Upper Bound		10.	10.	10.	200. (1.1)
ID of DDVAL		2002	2002	2002	2001 (1.2)
x3					
Variable Linked		Linked	Linked	Linked	Linked
x4					
Variable Linked		Linked	Linked	Linked	Linked

New View

Linked Variables

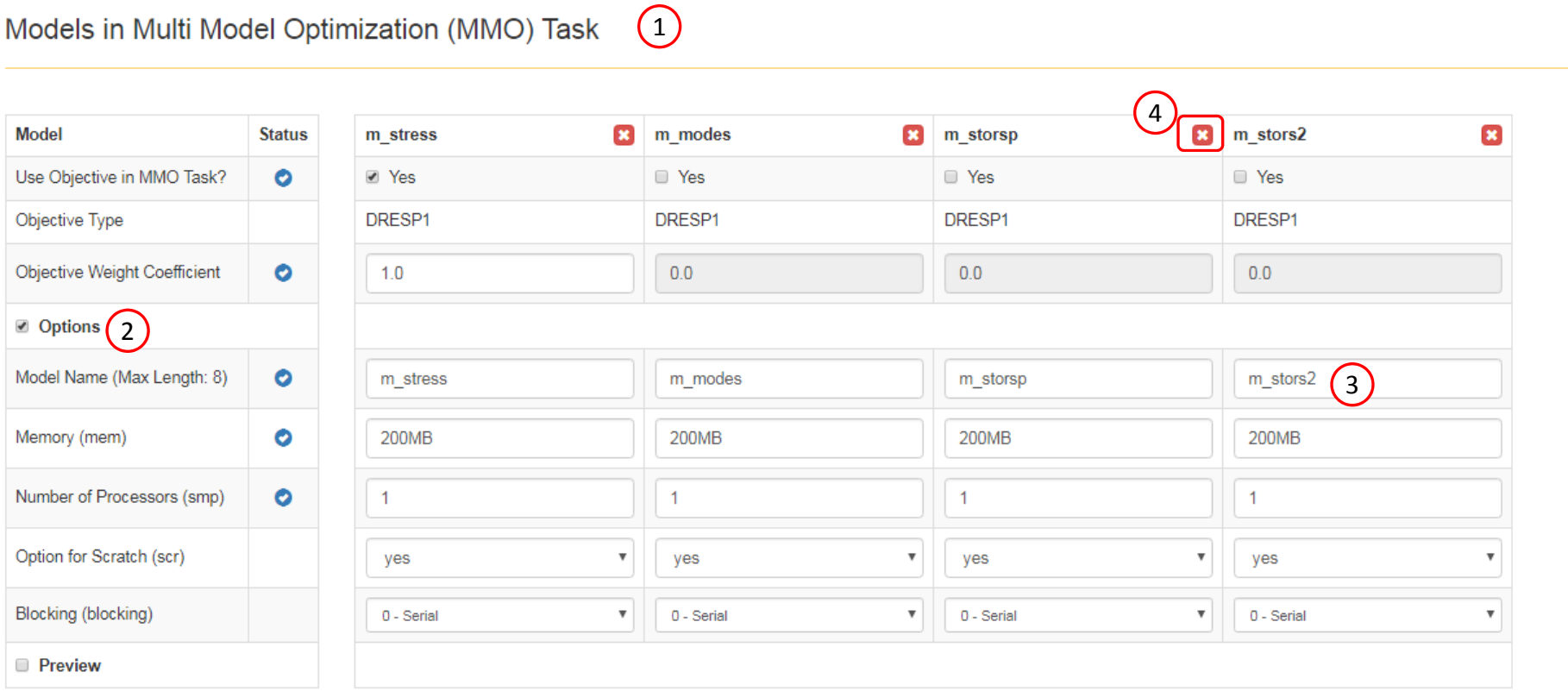
☐ Show only invalid

Label	Status	m_stress	m_modes	m_storsp	m_model
x1					
Variable Linked		Linked	Linked	Linked	Linked
x2 (2)					
Variable Linked		Linked	Linked	Linked	Linked
x3					
Variable Linked		Linked	Linked	Linked	Linked
x4					
Variable Linked		Linked	Linked	Linked	Linked

Modify MMO Task

1. Find the section titled Models in Multi Model Optimization (MMO) Task
2. Mark the Options checkbox
3. For the 4th model (Column 4), change the model name to m_stors2
4. Click the red x to remove the 3rd model.

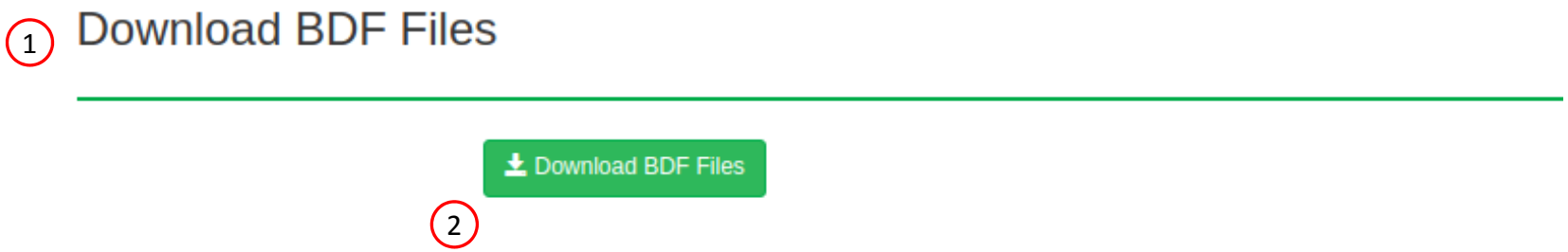
- Only the following 3 models should be included:
  - m_stress
  - m_modes
  - m_stors2
- Four models should not be included since the 3rd model and the 4th model are the same.



Export New BDF Files

1. Find the section titled Download Files
2. Click on Download BDF Files
3. Extract the contents of the .zip file and click Start MSC Nastran to begin the optimization (Not Shown)

- 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”
- This example requires the use of MSC Nastran’s MultiOpt utility. The MultiOpt utility does not allow directory name to have any special characters such as spaces,), (, !, ?. Name this directory with no special characters. For example, this directory name is valid: nastran_working_directory_1

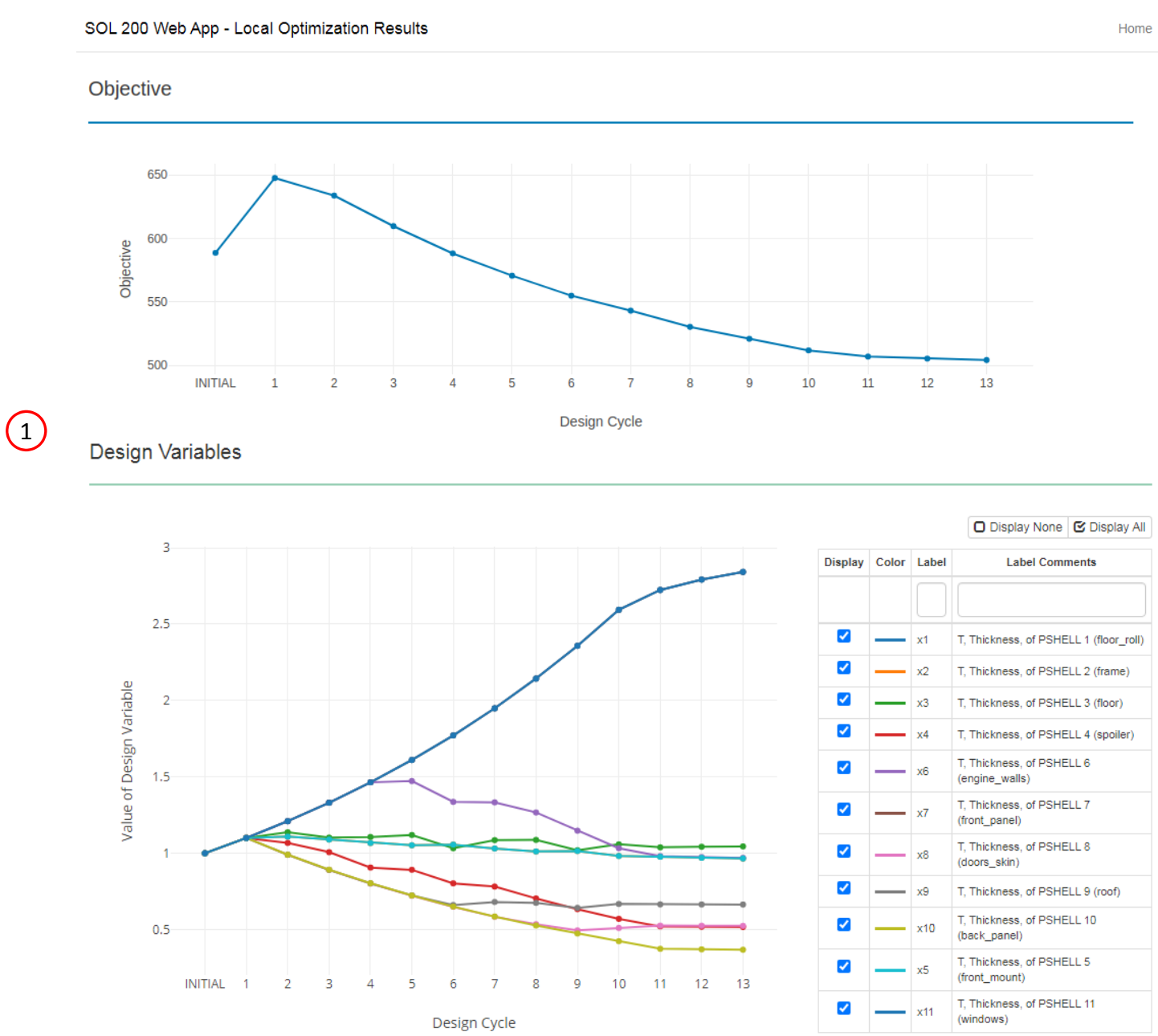


Review Optimization Results

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

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

- It should be noted that the results from Part A should match the results from this part, Part B (shown right).
- The main purpose in Part B is to show the procedure to make corrections when one finds any problem in some of the multiple models for MMO job run.



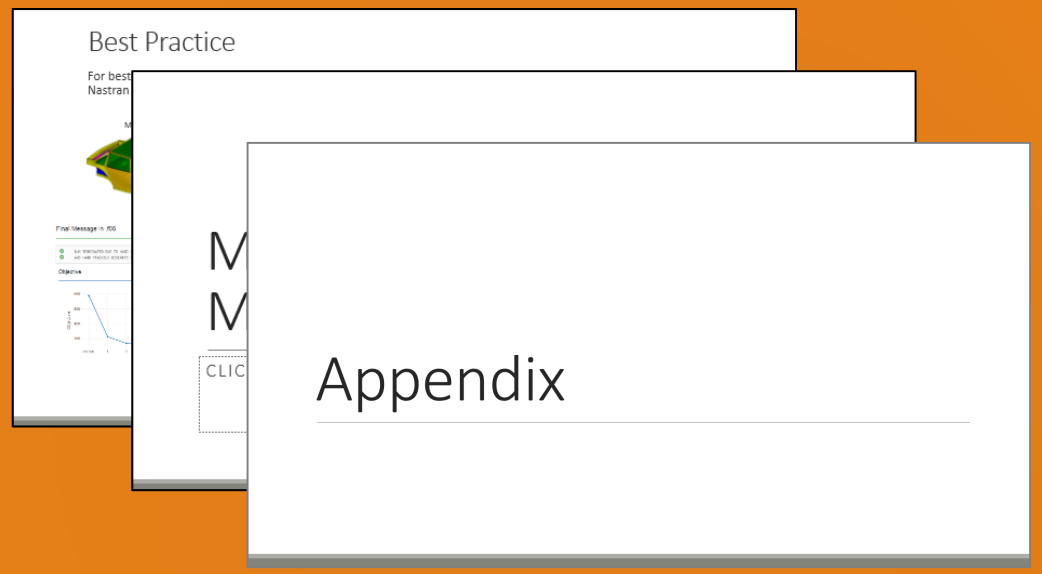
End of Tutorial

Appendix

More Information Available in the Appendix

The Appendix includes information regarding the following:

- Manually Configuring Multi Model Optimization
  - Model Conversion for All Models
  - Constructing the Merged Objective
  - Linking Variables
  - Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?



Appendix Contents

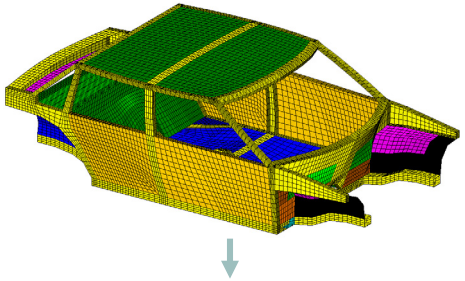
- Manually Configuring Multi Model Optimization
  - Model Conversion for All Models
  - Constructing the Merged Objective
  - Linking Variables
  - Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?

Manually Configuring Multi Model Optimization

Best Practice

For best results, each separate design model must already run successfully, for one or more design cycles, in MSC Nastran before including in Multi Model Optimization.

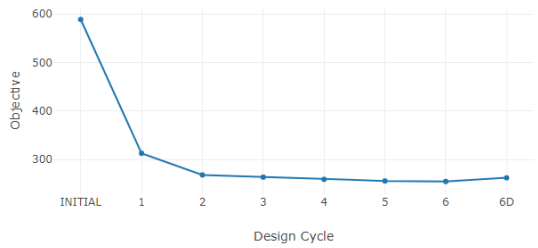
Model - m_stress



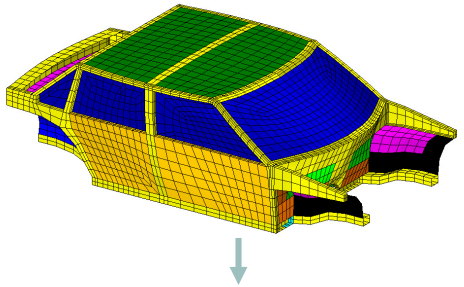
Final Message in .f06

```
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =      11.
AND HARD FEASIBLE DISCRETE DESIGN OBTAINED
```

Objective



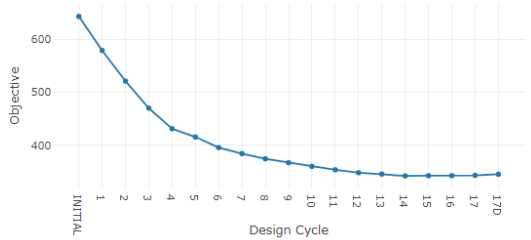
Model - m_modes



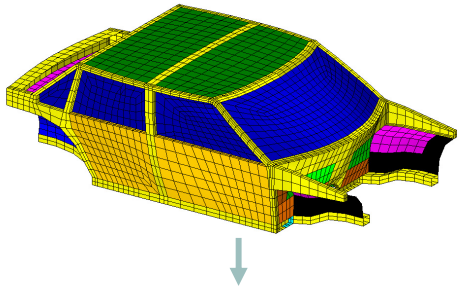
Final Message in .f06

```
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =      17.
AND HARD FEASIBLE DISCRETE DESIGN OBTAINED
```

Objective



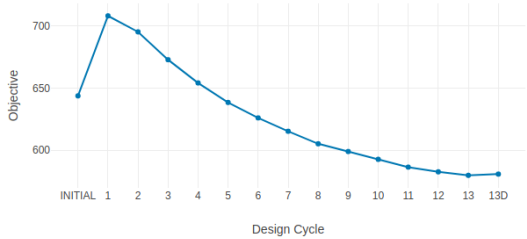
Model - m_storsp



Final Message in .f06

```
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =      13.
AND HARD FEASIBLE DISCRETE DESIGN OBTAINED
```

Objective



Manually Configuring Multi Model Optimization

The process is done in 4 steps:

1. Model Conversion for All Models
2. Constructing the Merged Objective
3. Linking Variables
4. Constructing the MMO.xml File

The MMO Web App automates these steps and no hand editing is necessary.

Manually Configuring Multi Model Optimization

MODEL CONVERSION FOR ALL MODELS

Model 1

BEFORE (MODEL.BDF)

```
assign userfile = 'optimization_results.csv', status = new,
form = formatted, unit = 52
$
DIAG 8,15    $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
TITLE    = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ --------------
$
DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 13
   ANALYSIS = STATICS
   DESSUB = 40000013
   $ DRSPAN Slot
  SUBTITLE = Front Left Interior Pillar Z
  LOAD = 113
SUBCASE 33
   ANALYSIS = STATICS
   DESSUB = 40000033
   $ DRSPAN Slot
  SUBTITLE = Center Left Pillar Z
  LOAD = 133
SUBCASE 53
   ANALYSIS = STATICS
   DESSUB = 40000053
   $ DRSPAN Slot
  SUBTITLE = Rear Left Pillar Z
  LOAD = 153
$
BEGIN BULK
INCLUDE './design_model.bdf'
```

AFTER (M_STRESS.BDF)

```
assign userfile='m_stress.csv', status=UNKNOWN, form=formatted, unit=52
$
DIAG 8,15    $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
TITLE    = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ --------------
$
DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
   DESOBJ(MIN) = 5000000
   $ DESGLB Slot
   DESMOD = m_stress
SUBCASE 13
   ANALYSIS = STATICS
   DESSUB = 40000013
   $ DRSPAN Slot
  SUBTITLE = Front Left Interior Pillar Z
  LOAD = 113
SUBCASE 33
   ANALYSIS = STATICS
   DESSUB = 40000033
   $ DRSPAN Slot
  SUBTITLE = Center Left Pillar Z
  LOAD = 133
SUBCASE 53
   ANALYSIS = STATICS
   DESSUB = 40000053
   $ DRSPAN Slot
  SUBTITLE = Rear Left Pillar Z
  LOAD = 153
$
BEGIN BULK
INCLUDE './design_model_m_stress.bdf'
INCLUDE './design_model_mmo.bdf'
```

Model 2

BEFORE (MODEL.BDF)

```
assign userfile = 'optimization_results.csv', status = new,
form = formatted, unit = 52
$
DIAG 8,15   $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
$
TITLE    = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$
SET 1 = 19998
DISP = 1
$DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPCF = ALL
$
SPC = 6
$
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 1
   ANALYSIS = MODES
   DESSUB = 40000001
   $ DRSPAN Slot
$ Subcase name : Default
   SUBTITLE=Default
   METHOD = 1
   VECTOR(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   modtrak=800
BEGIN BULK
INCLUDE './design_model.bdf'
```

AFTER (M_MODES.BDF)

```
assign userfile='m_modes.csv', status=UNKNOWN, form=formatted, unit=52
$
DIAG 8,15   $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
$
TITLE    = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$
SET 1 = 19998
DISP = 1
$DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPCF = ALL
$
SPC = 6
$
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   DESMOD = m_modes
SUBCASE 1
   ANALYSIS = MODES
   DESSUB = 40000001
   $ DRSPAN Slot
$ Subcase name : Default
   SUBTITLE=Default
   METHOD = 1
   VECTOR(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   modtrak=800
BEGIN BULK
INCLUDE './design_model_m_modes.bdf'
```

Model 3

BEFORE (MODEL.BDF)

```
assign userfile = 'optimization_results.csv', status = new,
form = formatted, unit = 52
$
DIAG 8,15   $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
$
TITLE    = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$
SET 1 = 19998
DISP = 1
$DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPCF = ALL
$
SPC = 6
$
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 20
   ANALYSIS = STATICS
   DESSUB = 40000020
   $ DRSPAN Slot
  SUBTITLE = Rear Transverse Force -Y 1000 N
  LOAD = 102
SUBCASE 40
   ANALYSIS = STATICS
   DESSUB = 40000040
   $ DRSPAN Slot
  SUBTITLE = Rear Torsion X 1000 N-mm
  LOAD = 104
$
BEGIN BULK
INCLUDE './design_model.bdf'
```

AFTER (M_STORSP.BDF)

```
assign userfile='m_storsp.csv', status=UNKNOWN, form=formatted, unit=52
$
DIAG 8,15   $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
$
TITLE    = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$
SET 1 = 19998
DISP = 1
$DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPCF = ALL
$
SPC = 6
$
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   DESMOD = m_storsp
SUBCASE 20
   ANALYSIS = STATICS
   DESSUB = 40000020
   $ DRSPAN Slot
  SUBTITLE = Rear Transverse Force -Y 1000 N
  LOAD = 102
SUBCASE 40
   ANALYSIS = STATICS
   DESSUB = 40000040
   $ DRSPAN Slot
  SUBTITLE = Rear Torsion X 1000 N-mm
  LOAD = 104
$
BEGIN BULK
INCLUDE './design_model_m_storsp.bdf'
```

Manually Configuring Multi Model Optimization

CONSTRUCTING THE MERGED OBJECTIVE

Merged Objective

A new file named design_model_mmo.bdf is created

This file contains a DRESP2 entry with ID=5000000

```
DRESP2  5000000 R0      570000
        DTABLE  c1      c2      c3
        DRESP1  8000000 8000000 8000000
DEQATN  570000
        g(c1, c2, c3, r1, r2, r3) = c1 * r1 + c2 * r2 + c3 * r3
DTABLE  c1      1.0     c2      0.0     c3      0.0
```

design_model_mmo.bdf

This file is auto generated by the MMO Web App. It is highly recommended that this file not be hand edited.

Merged Objective

The edit on the next slide happens only to the first model when the checkbox is marked.

In this example, m_stress is the 1st model.

Models in Multi Model Optimization (MMO) Task

Model	Status	m_stress	m_modes	m_storsp
Use Objective in MMO Task?		Yes	Yes	Yes
Objective Type		DRESP1	DRESP1	DRESP1
Objective Weight Coefficient		1.0	0.0	0.0
Options				
Model Name (Max Length: 8)		m_stress	m_modes	m_storsp
Memory (mem)		200MB	200MB	200MB
Number of Processors (smp)		1	1	1
Option for Scratch (scr)		yes	yes	yes
Blocking (blocking)		0 - Serial	0 - Serial	0 - Serial
Preview				

Only the first model is edited

BEFORE (M_STRESS.BDF)

```
assign userfile = 'optimization_results.csv', status = new,
form = formatted, unit = 52
$
DIAG 8,15    $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
TITLE    = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ --------------
$
DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
   DESOBJ(MIN) = 8000000
    $ DESGLB Slot
    $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 13
   ANALYSIS = STATICS
   DESSUB = 40000013
    $ DRSPAN Slot
  SUBTITLE = Front Left Interior Pillar Z
  LOAD = 113
SUBCASE 33
   ANALYSIS = STATICS
   DESSUB = 40000033
    $ DRSPAN Slot
  SUBTITLE = Center Left Pillar Z
  LOAD = 133
SUBCASE 53
   ANALYSIS = STATICS
   DESSUB = 40000053
    $ DRSPAN Slot
  SUBTITLE = Rear Left Pillar Z
  LOAD = 153
$
BEGIN BULK
INCLUDE './design_model.bdf'
```

AFTER (M_STRESS.BDF)

```
assign userfile='m_stress.csv', status=UNKNOWN, form=formatted, unit=52
$
DIAG 8,15    $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
TITLE    = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ --------------
$
DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
   DESOBJ(MIN) = 5000000
    $ DESGLB Slot
    DESMOD = m_stress
SUBCASE 13
   ANALYSIS = STATICS
   DESSUB = 40000013
    $ DRSPAN Slot
  SUBTITLE = Front Left Interior Pillar Z
  LOAD = 113
SUBCASE 33
   ANALYSIS = STATICS
   DESSUB = 40000033
    $ DRSPAN Slot
  SUBTITLE = Center Left Pillar Z
  LOAD = 133
SUBCASE 53
   ANALYSIS = STATICS
   DESSUB = 40000053
    $ DRSPAN Slot
  SUBTITLE = Rear Left Pillar Z
  LOAD = 153
$
BEGIN BULK
INCLUDE './design_model_m_stress.bdf'
INCLUDE './design_model_mmo.bdf'
```

Manually Configuring Multi Model Optimization

LINKING VARIABLES

Linking Variables

In order to Link Variables across models, the DESVAR entry must be identical in every model.

- Linked Variables - The following variables appear in every model and are linked: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10.
- Unlinked Variables - The following variable appear only in one model (Model 2) and will change independently during the optimization.

```
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DESVAR  ID       LABEL   XINIT    XLB      XUB      DELXV    DDVAL
DESVAR   100001   x1      1.0      .1       10.               2001
DESVAR   100002   x2      1.0      .1       10.               2002
DESVAR   100003   x3      1.0      .1       10.               2001
DESVAR   100004   x4      1.0      .1       10.               2001
DESVAR   100005   x5      1.0      .1       10.               2001
DESVAR   100006   x6      1.0      .1       10.               2001
DESVAR   100007   x7      1.0      .1       10.               2001
DESVAR   100008   x8      1.0      .1       10.               2001
DESVAR   100009   x9      1.0      .1       10.               2001
DESVAR   100010   x10     1.0      .1       10.               2001
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DDVAL   ID       DDVAL1   DDVAL2   DDVAL3   DDVAL4   DDVAL5   DDVAL6
DDVAL    2001
         .05      THRU     7.0      BY       .05
DDVAL    2002
         .05      THRU     7.0      BY       .050
```

Model 1
(design_model_m_stress.bdf)

```
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DESVAR  ID       LABEL   XINIT    XLB      XUB      DELXV    DDVAL
DESVAR   100001   x1      1.0      0.1      10.               2001
DESVAR   100002   x2      1.0      0.1      10.               2002
DESVAR   100003   x3      1.0      0.1      10.               2001
DESVAR   100004   x4      1.0      0.1      10.               2001
DESVAR   100005   x5      1.0      0.1      10.               2001
DESVAR   100006   x6      1.0      0.1      10.               2001
DESVAR   100007   x7      1.0      0.1      10.               2001
DESVAR   100008   x8      1.0      0.1      10.               2001
DESVAR   100009   x9      1.0      0.1      10.               2001
DESVAR   100010   x10     1.0      0.1      10.               2001
DESVAR   100011   x11     1.0      0.1      10.               2001
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DDVAL   ID       DDVAL1   DDVAL2   DDVAL3   DDVAL4   DDVAL5   DDVAL6
DDVAL    2001
         .05      THRU     7.0      BY       .05
DDVAL    2002
         .05      THRU     7.0      BY       .050
```

Model 2
(design_model_m_modes.bdf)

```
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DESVAR  ID       LABEL   XINIT    XLB      XUB      DELXV    DDVAL
DESVAR   100001   x1      1.0      0.1      10.               2001
DESVAR   100002   x2      1.0      0.1      10.               2002
DESVAR   100003   x3      1.0      0.1      10.               2001
DESVAR   100004   x4      1.0      0.1      10.               2001
DESVAR   100005   x5      1.0      0.1      10.               2001
DESVAR   100006   x6      1.0      0.1      10.               2001
DESVAR   100007   x7      1.0      0.1      10.               2001
DESVAR   100008   x8      1.0      0.1      10.               2001
DESVAR   100009   x9      1.0      0.1      10.               2001
DESVAR   100010   x10     1.0      0.1      10.               2001
DESVAR   100011   x11     1.0      0.1      10.               2001
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  |
$DDVAL   ID       DDVAL1   DDVAL2   DDVAL3   DDVAL4   DDVAL5   DDVAL6
DDVAL    2001
         .05      THRU     7.0      BY       .05
DDVAL    2002
         .05      THRU     7.0      BY       .050
```

Model 3
(design_model_m_storsp.bdf)

Linking Variables

The Linked Variable section in the MMO Web App performs the validation to ensure the DESVAR entries are matching.

Linked Variables

☐ Show only invalid

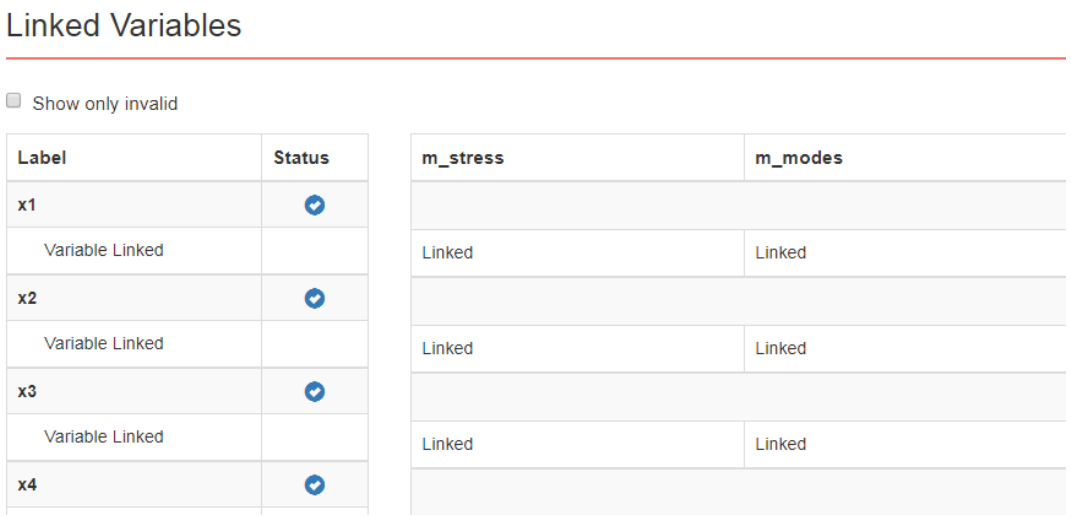
Label	Status	m_stress	m_modes	m_storsp
x1	✓			
Variable Linked		Linked	Linked	Linked
x2	✓			
Variable Linked		Linked	Linked	Linked
x3	✓			
Variable Linked		Linked	Linked	Linked
x4	✓			

Linking Variables

The following fields on the DESVAR entry must be identical: XINIT, XLB, XUB. If allowable values are used, the DDVAL ID and the values on the DDVAL entry must match.

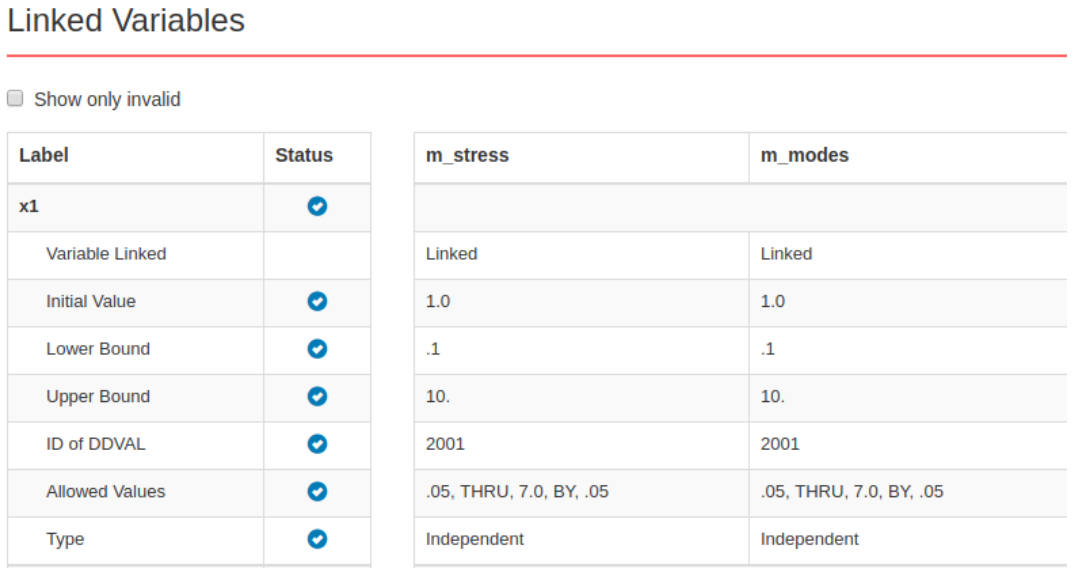
Commercial Version

The commercial version of the web app is designed to minimize the amount of information displayed. The full set of successful validations are hidden but unsuccessful validations will be fully shown to the user in red status markers.



Development Version

Below is a view of the full set of successful validations that would normally be hidden in the commercial version. This view was generated with a version of the web app only available to the developer of the web app.



An example of the comparison is shown.

Linked Variables

Show only invalid

Label	Status	m_stress	m_modes	m_storsp
x1	✓			
Variable Linked		Linked	Linked	Linked
Initial Value	✓	1.0	1.0	1.0
Lower Bound	✓	.1	.1	0.1
Upper Bound	✓	10.	10.	10.
ID of DDVAL	✓	2001	2001	2001
Allowed Values	✓	.05, THRU, 7.0, BY, .05	.05, THRU, 7.0, BY, .05	.05, THRU, 7.0, BY, .05
Type	✓	Independent	Independent	Independent

```
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DESVAR  ID       LABEL   XINIT   XLB     XUB     DELXV   DDVAL
DESVAR   100001   x1      1.0     .1      10.             2001
DESVAR   100002   x2      1.0     .1      10.             2002
DESVAR   100003   x3      1.0     .1      10.             2001
DESVAR   100004   x4      1.0     .1      10.             2001
DESVAR   100005   x5      1.0     .1      10.             2001
DESVAR   100006   x6      1.0     .1      10.             2001
DESVAR   100007   x7      1.0     .1      10.             2001
DESVAR   100008   x8      1.0     .1      10.             2001
DESVAR   100009   x9      1.0     .1      10.             2001
DESVAR   100010   x10     1.0     .1      10.             2001
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DDVAL   ID       DDVAL1  DDVAL2  DDVAL3  DDVAL4  DDVAL5  DDVAL6
DDVAL    2001
         .05     THRU    7.0     BY      .05
DDVAL    2002
         .05     THRU    7.0     BY      .050
```

Model 1
(design_model_m_stress.bdf)

```
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DESVAR  ID       LABEL   XINIT   XLB     XUB     DELXV   DDVAL
DESVAR   100001   x1      1.0     0.1     10.             2001
DESVAR   100002   x2      1.0     0.1     10.             2002
DESVAR   100003   x3      1.0     0.1     10.             2001
DESVAR   100004   x4      1.0     0.1     10.             2001
DESVAR   100005   x5      1.0     0.1     10.             2001
DESVAR   100006   x6      1.0     0.1     10.             2001
DESVAR   100007   x7      1.0     0.1     10.             2001
DESVAR   100008   x8      1.0     0.1     10.             2001
DESVAR   100009   x9      1.0     0.1     10.             2001
DESVAR   100010   x10     1.0     0.1     10.             2001
DESVAR   100011   x11     1.0     0.1     10.             2001
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DDVAL   ID       DDVAL1  DDVAL2  DDVAL3  DDVAL4  DDVAL5  DDVAL6
DDVAL    2001
         .05     THRU    7.0     BY      .05
DDVAL    2002
         .05     THRU    7.0     BY      .050
```

Model 2
(design_model_m_modes.bdf)

```
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DESVAR  ID       LABEL   XINIT   XLB     XUB     DELXV   DDVAL
DESVAR   100001   x1      1.0     0.1     10.             2001
DESVAR   100002   x2      1.0     0.1     10.             2001
DESVAR   100003   x3      1.0     0.1     10.             2001
DESVAR   100004   x4      1.0     0.1     10.             2001
DESVAR   100005   x5      1.0     0.1     10.             2001
DESVAR   100006   x6      1.0     0.1     10.             2001
DESVAR   100007   x7      1.0     0.1     10.             2001
DESVAR   100008   x8      1.0     0.1     10.             2001
DESVAR   100009   x9      1.0     0.1     10.             2001
DESVAR   100010   x10     1.0     0.1     10.             2001
DESVAR   100011   x11     1.0     0.1     10.             2001
$    1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   |
$DDVAL   ID       DDVAL1  DDVAL2  DDVAL3  DDVAL4  DDVAL5  DDVAL6
DDVAL    2001
         .05     THRU    7.0     BY      .05
DDVAL    2002
         .05     THRU    7.0     BY      .050
```

Model 3
(design_model_m_storsp.bdf)

Manually Configuring Multi Model Optimization

CONSTRUCTING THE MMO.XML FILE

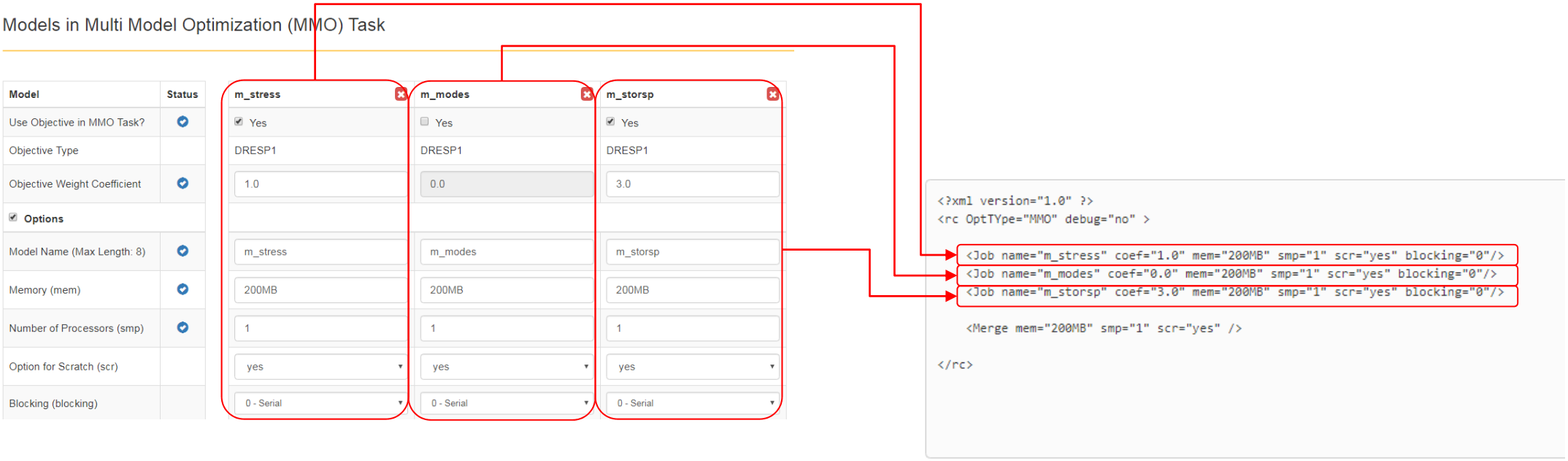
Constructing the MMO.xml File

A new file named MMO.xml is created

```
<?xml version="1.0" ?>
<rc OptTYpe="MMO" debug="no" >

    <Job name="m_stress" coef="1.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_modes" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_storsp" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>

    <Merge mem="200MB" smp="1" scr="yes" />

</rc>
```

MMO.xml

Constructing the MMO.xml File



MMO.xml

Constructing the MMO.xml File

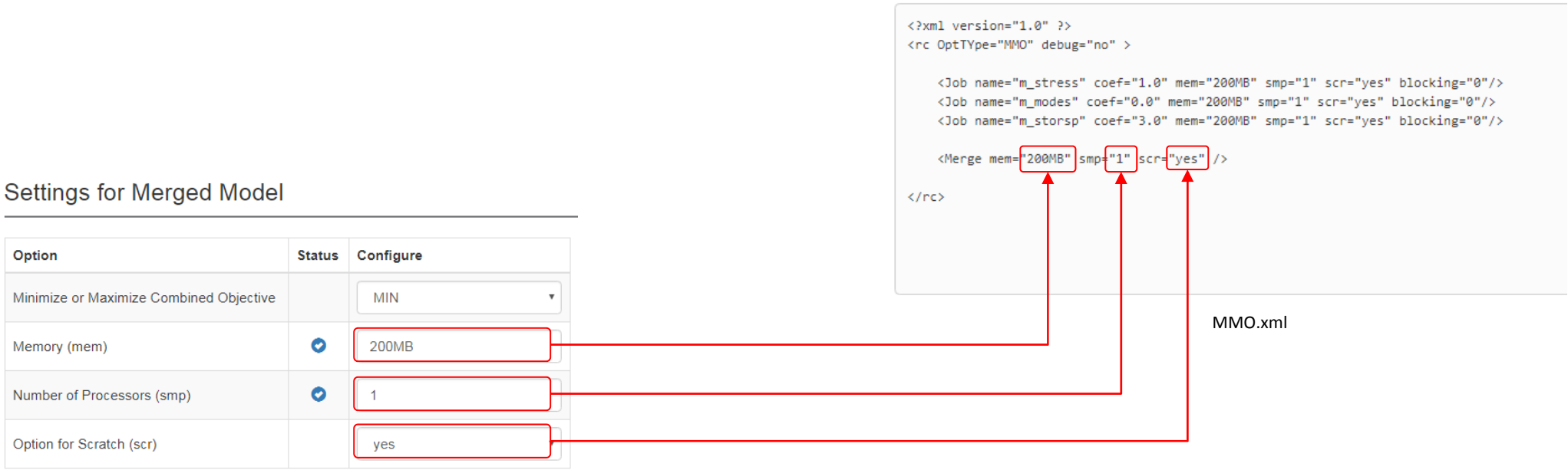
Models in Multi Model Optimization (MMO) Task

Model	Status	m_stress	m_modes	m_storsp
Use Objective in MMO Task?		Yes	Yes	Yes
Objective Type		DRESP1	DRESP1	DRESP1
Objective Weight Coefficient		1.0	0.0	3.0
Options				
Model Name (Max Length: 8)		m_stress	m_modes	m_storsp
Memory (mem)		200MB	200MB	200MB
Number of Processors (smp)		1	1	1
Option for Scratch (scr)		yes	yes	yes
Blocking (blocking)		0 - Serial	0 - Serial	0 - Serial

```
<?xml version="1.0" ?>
<rc OptTYpe="MMO" debug="no" >

    <Job name="m_stress" coef="1.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_modes" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
    <Job name="m_storsp" coef="3.0" mem="200MB" smp="1" scr="yes" blocking="0"/>

    <Merge mem="200MB" smp="1" scr="yes" />

</rc>
```

MMO.xml

Constructing the MMO.xml File



Constructing the MMO.xml File

Model 1 (m_stress.bdf)

```
assign userfile='m_stress.csv', status=UNKNOWN, form=formatted, unit=52
$
DIAG 8,15   $ Print Matrix & Table Trailers in .f04
SOL 200
CEND
TITLE    = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ --------------
$
DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
   DESOBJ(MIN) = 5000000
   $ DESGLB Slot
   DESMOD = m_stress
SUBCASE 13
   ANALYSIS = STATICS
   DESSUB = 40000013
   $ DRSPAN Slot
  SUBTITLE = Front Left Interior Pillar Z
  LOAD = 113
SUBCASE 33
   ANALYSIS = STATICS
   DESSUB = 40000033
   $ DRSPAN Slot
  SUBTITLE = Center Left Pillar Z
  LOAD = 133
SUBCASE 53
   ANALYSIS = STATICS
   DESSUB = 40000053
   $ DRSPAN Slot
  SUBTITLE = Rear Left Pillar Z
  LOAD = 153
$
BEGIN BULK
INCLUDE './design_model_m_stress.bdf'
INCLUDE './design_model_mmo.bdf'
```

Settings for Merged Model

Option	Status	Configure
Minimize or Maximize Combined Objective		MIN
Memory (mem)	✓	200MB
Number of Processors (smp)	✓	1
Option for Scratch (scr)		yes

Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?

Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?

1. Model 2 (m_modes) seeks to optimize a natural frequency and requires the use of Mode Tracking.

2. The DOPTPRM entry shown makes use of DELX1 and COVN2. The use of DELX and CONV2 are applicable to model 2.

1

Model 1 - m_stress

Analysis: Statics

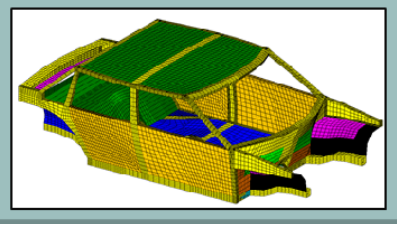
Objective: Minimize Weight

Constraints:

r1: von Mises of stress, at z1, for PSHELL 1, 7
r2: von Mises of stress, at z2, for PSHELL 1, 7
r3: von Mises of stress, at z1, for PSHELL 3, 8
r4: von Mises of stress, at z2, for PSHELL 3, 8
r5: von Mises of stress, at z1, for PSHELL 8, 9, 10
r6: von Mises of stress, at z2, for PSHELL 8, 9, 10

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9 , x10



Model 2 - m_modes

Analysis: Modes

Objective: Minimize Weight

Constraints:

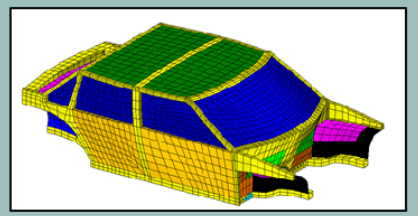
r1: Natural frequency of mode 1, 25Hz < r1
r2: Natural frequency of mode 2, 30Hz < r2

Settings

Mode tracking is used

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



Model 3 - m_storsp

Analysis: Statics

Objective: Minimize Weight

Constraints:

r1: Displacement, y component, of node 19998

-.15 < r1 < .15

Equation Constraint:

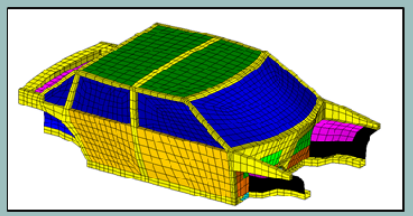
R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)

5E13 < R1 < 5E14

b1: Displacement, 4th component, of node 19998

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



2

```
$                          Optimization Control Settings
$-------------------------------------------------------------------------------
$   1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   ||   9   ||  10  |
$DOPTPRM PARAM1 VAL1     PARAM2  VAL2     PARAM3  VAL3     PARAM4  VAL4
DOPTPRM DESMAX  20       P1      1        P2      15       CONV2   3.0
        DELX    .1
```

Why is DELX=.1 used?

1. If DELX is not specified on the DOPTPRM entry, MSC Nastran uses the default DELX value of .5.
2. If model 2 is optimized without DELX specified, after the optimization, the F06 file reveals an error due to mode tracking failure.

```
$
$                          Optimization Control Settings
$-------------------------------------------------------------------------------
$   1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   ||   9   ||  10   |
$DOPTPRM PARAM1 VAL1    PARAM2  VAL2    PARAM3  VAL3    PARAM4  VAL4
DOPTPRM DESMAX  50      P1      1       P2      15
$
```

1

```
0                                                                                                                    SUBCASE 1
                                                    DESIGN VARIABLE HISTORY
-------------------------------------------------------------------------------------------------------------------------------
 INTERNAL |   EXTERNAL   |            |
  DV. ID. |    DV. ID.   |    LABEL   |   INITIAL    :      1       :      2       :      3       :      4       :      5       :
-------------------------------------------------------------------------------------------------------------------------------
        1 |     100001   |  X1        |   1.0000E+00 :   6.0047E-01 :
        2 |     100002   |  X2        |   1.0000E+00 :   6.2017E-01 :
        3 |     100003   |  X3        |   1.0000E+00 :   5.0000E-01 :
        4 |     100004   |  X4        |   1.0000E+00 :   5.0000E-01 :
        5 |     100006   |  X6        |   1.0000E+00 :   5.0000E-01 :
        6 |     100007   |  X7        |   1.0000E+00 :   5.0000E-01 :
        7 |     100008   |  X8        |   1.0000E+00 :   5.0000E-01 :
        8 |     100009   |  X9        |   1.0000E+00 :   1.2470E+00 :
        9 |     100010   |  X10       |   1.0000E+00 :   5.0000E-01 :
       10 |     100011   |  X11       |   1.0000E+00 :   7.5500E-01 :
       11 |     100005   |  X5        |   1.0000E+00 :   6.2017E-01 :
*** USER FATAL MESSAGE 6677 (DOM12E)
    RUN TERMINATED DUE TO MODE TRACKING FAILURE. SEE USER FATAL MESSAGE 6677 (MTFTRD) PRINTED ABOVE FOR INFORMATION.
*** USER INFORMATION MESSAGE 4110 (OUTPX2)
                              END-OF-DATA SIMULATION ON FORTRAN UNIT 12
                              (MAXIMUM SIZE OF FORTRAN RECORDS WRITTEN =      1 WORDS.)
                                    (NUMBER OF FORTRAN RECORDS WRITTEN =      1 RECORDS.)
                                    (TOTAL DATA WRITTEN FOR EOF MARKER =      1 WORDS.)
```

2

Why is DELX=.1 used?

1. Further inspection of the F06 file reveals recommendations to avoid a mode tracking failure.
2. One option is to reduce the move limit DELX.
3. After using a DELX value of .1, mode tracking is successful and the optimization is able to proceed.

Large changes in design variables may cause mode tracking to fail. For model 2, a DELX value of .5 resulted in too large of variable changes for mode tracking to operate. The idea is to limit the changes of the design variables so that the modes are better tracked.

```
                                        ******************************************
                                        *                                        *
                                        *   D E S I G N   O P T I M I Z A T I O N  *
                                        *                                        *
                                        *        M O D E   T R A C K I N G       *
                                        *         (FOR STRUCTURE MODES)          *
                                        ******************************************


                                         ----------------------------------------
                                        |            DESIGN CYCLE     3          |
                                         ----------------------------------------


 ************************************************
 *****                                      *****
 *****    REPORT ON MODE TRACKING ACTIVITY  *****
 *****        FOR DESIGN CYCLE:      2      *****
 *****                                      *****
 ************************************************
*** USER FATAL MESSAGE 6677 (MTFTRS)                    (1)
    MODES CANNOT BE TRACKED:
    IN ORDER TO TRACK THESE MODES, IT MAY BE APPROPRIATE TO:
        1. REDUCE MOVE LIMITS (DELP,DPMIN,DELX,DELXV,DXMIN), OR (2)
        2. DECREASE THE FILTERING PARAMETER, MTFILTER, OR
        3. BOTH 1 AND 2
    THE PUNCH FILE MAY CONTAIN UPDATED DRESP1 ENTRIES FROM A PREVIOUS DESIGN CYCLE, WITH 'EIGN IN FIELD 7 WRITTEN
    TO CORRESPOND WITH THE POSITIONS OF THE SUCCESSFULLY TRACKED MODES (OUTPUT OF UPDATED DRESP1 ENTRIES
    IS CONTROLLED BY BULK DATA PARAMETER DESPCH. SEE QUICK REFERENCE GUIDE FOR ITS DETAILED DESCRIPTION).
    THESE DRESP1 ENTRIES CAN BE USED TO RESTART FROM THE LAST DESIGN, WITH ANY OF MODIFICATIONS 1, 2, OR 3, ABOVE.

     THERE ARE A TOTAL OF        1 DESIGNED MODES THAT COULD NOT BE TRACKED
     THE CORRELATION TABLE FOR THE UNTRACKED MODES IS:
```

```
$
$                          Optimization Control Settings
$-------------------------------------------------------------------------------
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  ||   9  ||  10  |
$DOPTPRM PARAM1 VAL1    PARAM2  VAL2    PARAM3  VAL3    PARAM4  VAL4
DOPTPRM DESMAX  50      P1      1       P2      15      DELX    .1
$
```

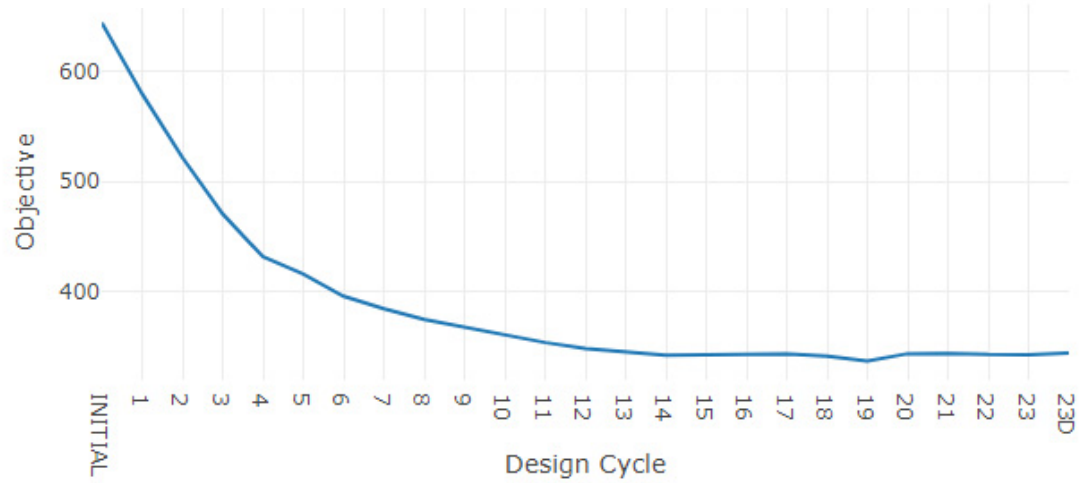
(3)

Why is CONV2=3.0 used?

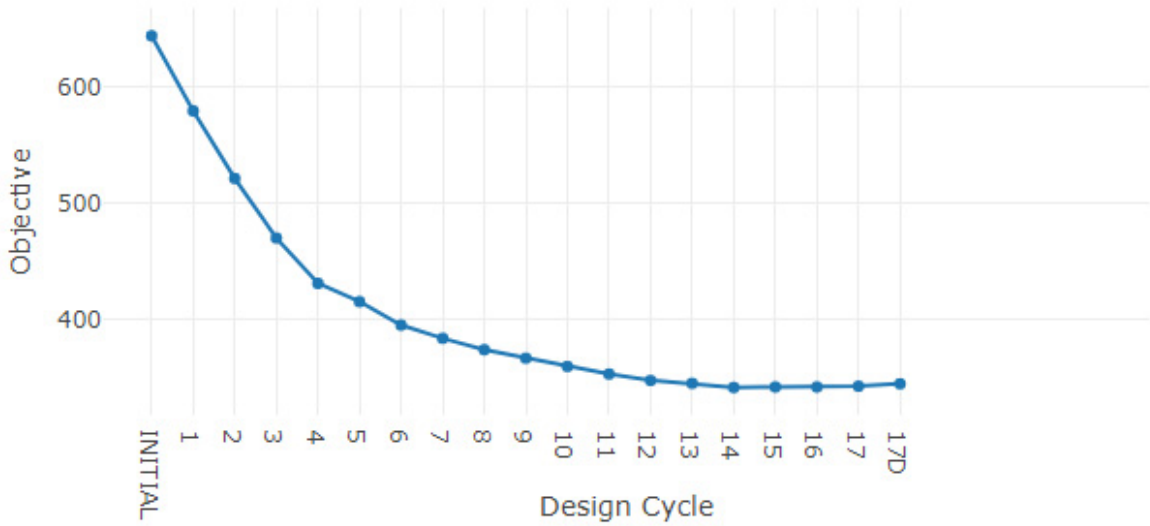
The CONV2 value is adjusted so that the optimization converges sooner.

To the right, a optimization without and with CONV2=3.0 is compared. The optimization with CONV2=3.0 converges sooner.

```
DOPTPRM DESMAX   30       P1       1        P2       15
```




```
DOPTPRM DESMAX   30       P1       1        P2       15       CONV2    3.0
```



Why is CONV2=3.0 used?

The CONV2 was determined as follows

1. Search the F06 section for the last reported section titled HARD CONVERGENCE DECISION LOGIC
2. The value of ABSOLUTE CHANGE IN OBJECTIVE is 1.4253E+00. A value of CONV2 greater than 1.4253 is chosen, e.g. 3.0.

Alternatively, the CONV1 setting can be used instead. The value of RELATIVE CHANGE IN OBJECTIVE is 2.2449E-03. A value of CONV1 greater than 2.2449E-03 is chosen and will result in termination due to convergence.

```
                                                                                1
***** NORMAL CONVERGENCE CRITERIA SATISFIED ***** (HARD CONVERGENCE DECISION LOGIC)

********************************************************************************
                CONVERGENCE ACHIEVED BASED ON THE FOLLOWING CRITERIA
                        (HARD CONVERGENCE DECISION LOGIC)

      RELATIVE CHANGE IN OBJECTIVE        2.2449E-03  MUST BE LESS THAN   1.0000E-03
 OR   ABSOLUTE CHANGE IN OBJECTIVE        1.4253E+00  MUST BE LESS THAN   3.0000E+00
                                  --- AND ---                                    2
      MAXIMUM CONSTRAINT VALUE           -3.3422E-02  MUST BE LESS THAN   5.0000E-03
                        (CONVERGENCE TO A FEASIBLE DESIGN)
                                  --- OR ---
      MAXIMUM OF RELATIVE PROP. CHANGES   0.0000E+00  MUST BE LESS THAN   1.0000E-03
 AND  MAXIMUM OF RELATIVE D.V. CHANGES    2.5000E-02  MUST BE LESS THAN   1.0000E-03
                (CONVERGENCE TO A BEST COMPROMISE INFEASIBLE DESIGN)
********************************************************************************
```

Use the same DOPTPRM entry in every model

1. Models 1 and 2 optimize successfully without specifying DELX and CONV2. Since this is a multi model optimization, it is required that the same DOPTPRM entry be used by all models. The DOPTPRM entry from model 2 is used in models 1 and 3.

1

Model 1 - m_stress

Analysis: Statics

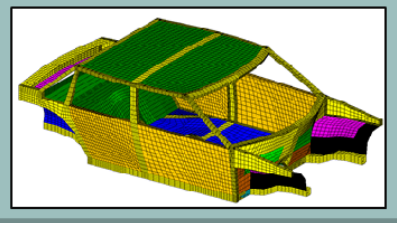
Objective: Minimize Weight

Constraints:

r1: von Mises of stress, at z1, for PSHELL 1, 7
r2: von Mises of stress, at z2, for PSHELL 1, 7
r3: von Mises of stress, at z1, for PSHELL 3, 8
r4: von Mises of stress, at z2, for PSHELL 3, 8
r5: von Mises of stress, at z1, for PSHELL 8, 9, 10
r6: von Mises of stress, at z2, for PSHELL 8, 9, 10

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9 , x10



Model 2 - m_modes

Analysis: Modes

Objective: Minimize Weight

Constraints:

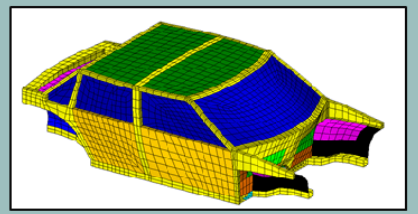
r1: Natural frequency of mode 1, 25Hz < r1
r2: Natural frequency of mode 2, 30Hz < r2

Settings

Mode tracking is used

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



Model 3 - m_storsp

Analysis: Statics

Objective: Minimize Weight

Constraints:

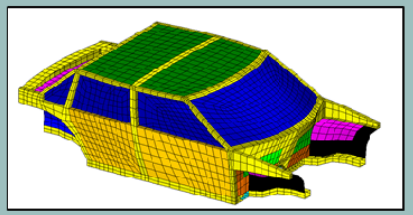
r1: Displacement, y component, of node 19998
-.15 < r1 < .15

Equation Constraint:

R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)
5E13 < R1 < 5E14
b1: Displacement, 4th component, of node 19998

Variables:

x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11



2

```
$                          Optimization Control Settings
$-------------------------------------------------------------------------
$   1   ||   2   ||   3   ||   4   ||   5   ||   6   ||   7   ||   8   ||   9   ||  10  |
$DOPTPRM PARAM1 VAL1     PARAM2  VAL2     PARAM3  VAL3     PARAM4  VAL4
DOPTPRM DESMAX  20       P1      1        P2      15       CONV2   3.0
        DELX    .1
```