Workshop - Working with Multiple Subcases and Multi Discipline Optimization

AN MSC NASTRAN SOL 200 TUTORIAL

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

Optimization Problem Statement

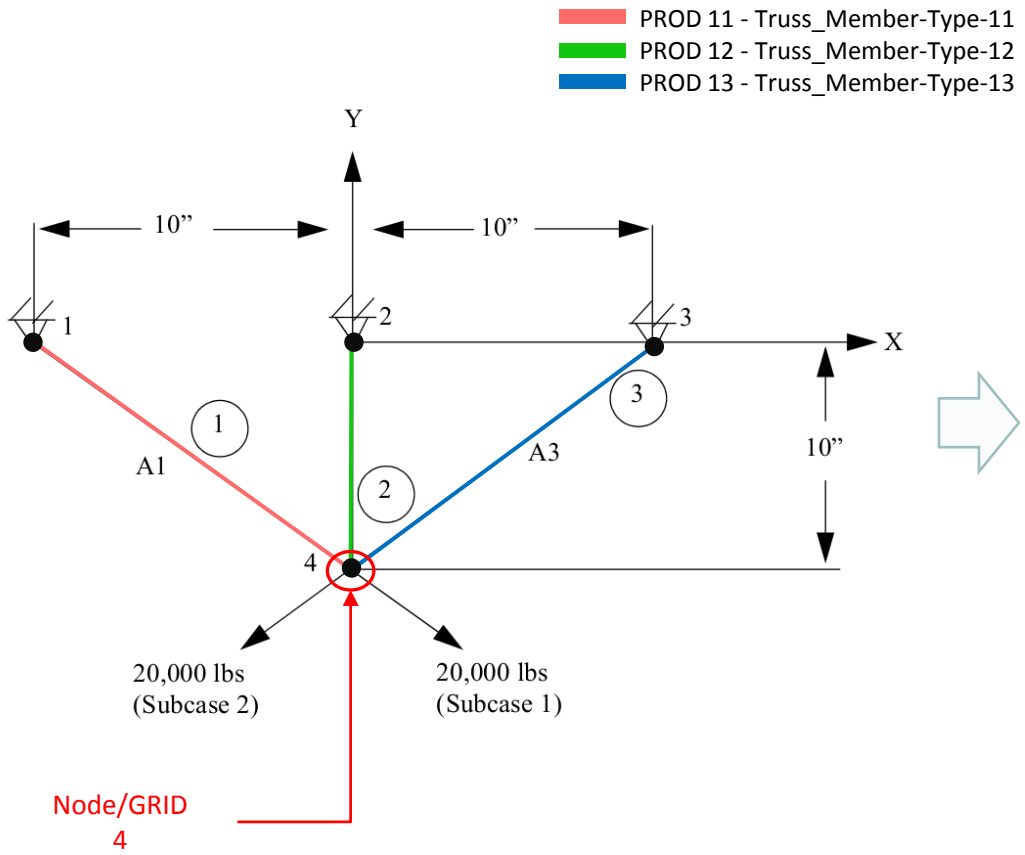
Design Variables

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

.1 < x1, x2, x3 < 100.

Variable Link

x3 = x1



Design Objective

r0: Minimize weight

Design Constraints

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

-15000 < r1 < 20000

r2: x and y component of displacement for node 4

-.2 < r2 < .2

r3: natural frequency of mode 1
80 Hz < r3

Optimization Problem Statement Subcase Assignment

This tutorials describes how to assign constraints across different subcases when the analysis types are different. This example deals with a multidiscipline optimization. Subcases 1 corresponds to a normal modes analysis. Subcases 2-20 correspond to statics subcases. Each subcase is assigned constraints.

	Status	Label	Response Type	Analysis Type	Description
		Search	Search	Search	Search
		r1	DISP	STATICS	T1, T2 component(s) of displacement at grid 4
		r2	STRESS	STATICS	Stress, item code 2, of elements associated with PROD 11, 12, 13
		r3	FREQ	MODES	Natural frequency of mode 1

Global Constraints	SUBCASE 1	SUBCASE 2	SUBCASE 3	SUBCASE 4	SUBCASE 5	SUBCASE 6	SUBCASE 7	SUBCASE 8	SUBCASE 9	SU
Analysis Types →	Normal Modes	Statics	Statics	Statics	Statics	Statics	Statics	Statics	Statics	Sta
		☑	☑	☑	☑	☑	☑	☑	☑	
		☑	☑	☑	☑	☑	☑	☑	☑	
	☑									

Contact me

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

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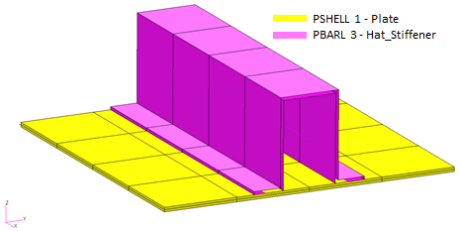
Tutorial

SOL 200 Web App Capabilities

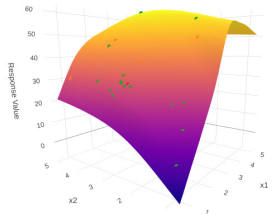
Benefits

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

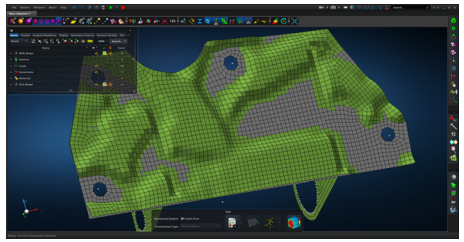
Capabilities



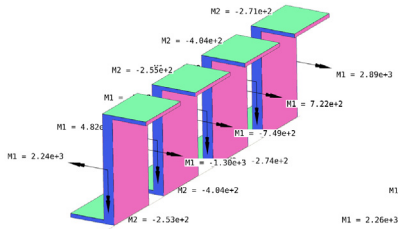
Web Apps for SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography and multi-model.



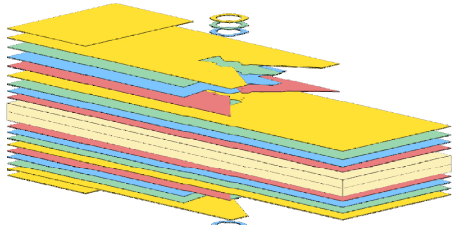
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



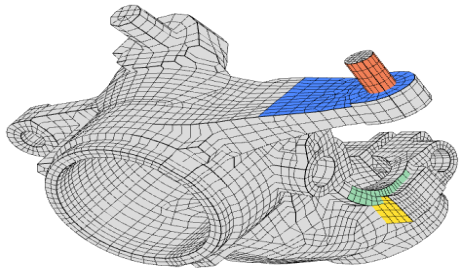
MSC Apex Post Processing Support
View the newly optimized model after an optimization



Beams Viewer Web App
Post process 1D element forces, including shear forces, moments, torque and axial forces

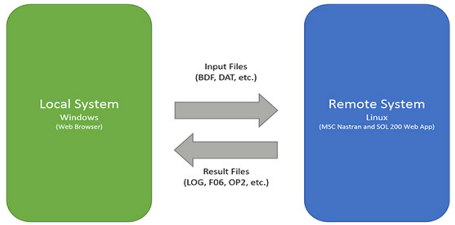


Ply Shape Optimization Web App
Spread plies optimally and generate new PCOMPG entries

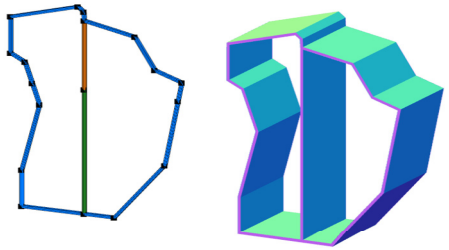


Shape Optimization Web App
Use a web application to configure and perform shape optimization.

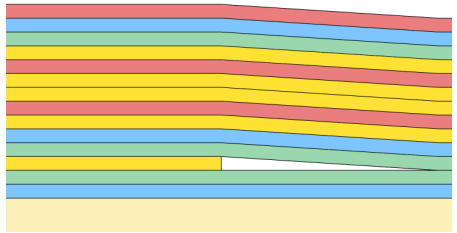
HDF5 Explorer Web App
Create XY plots using data from the H5 file



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



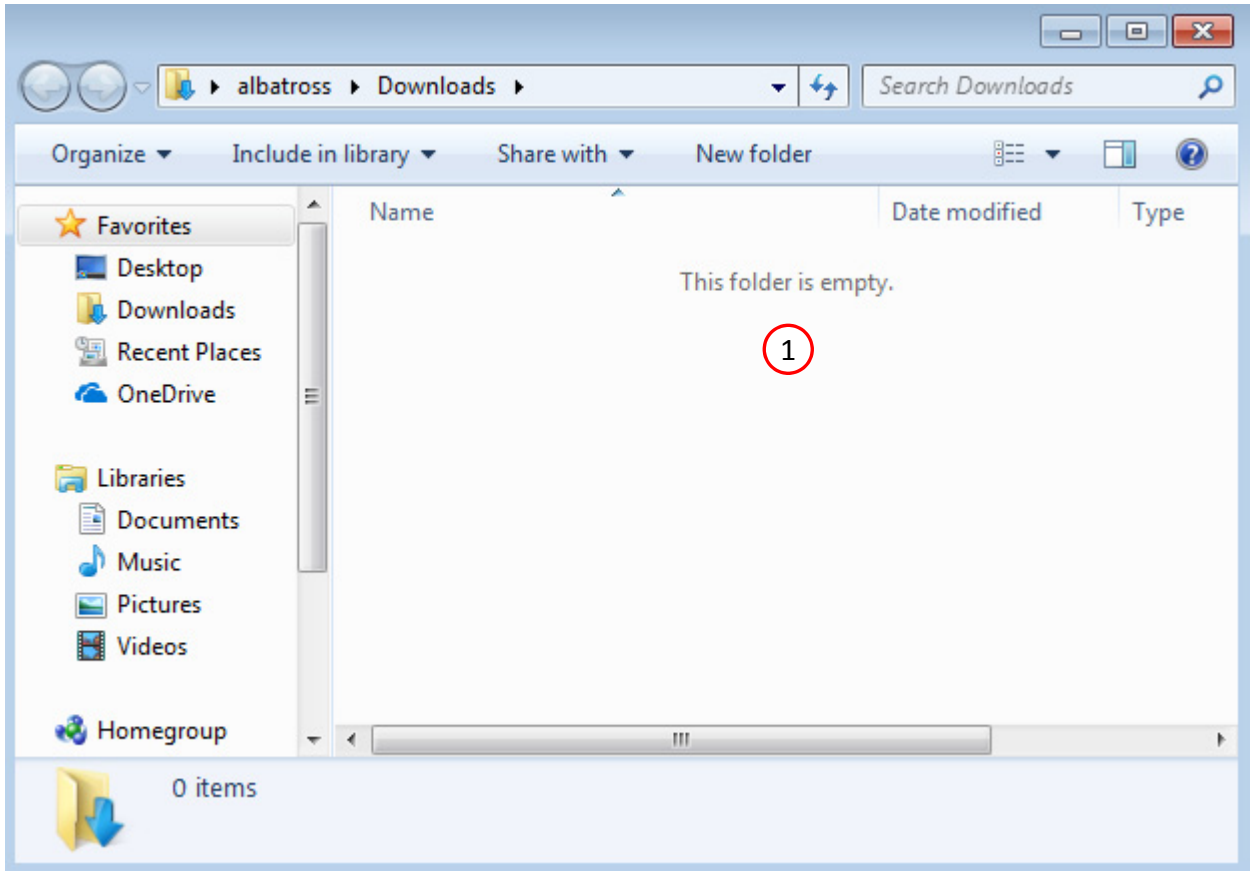
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



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

Before Starting

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



- Throughout this workshop, you will be working with multiple file types and directories such as:
  - .bdf/.dat
  - nastran_working_directory
  - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.

Go to the User’s Guide

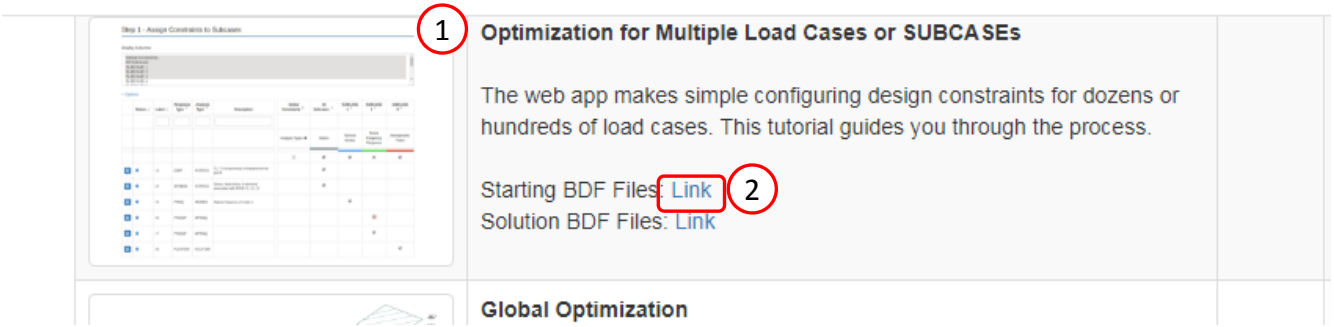
1. Click on the indicated link

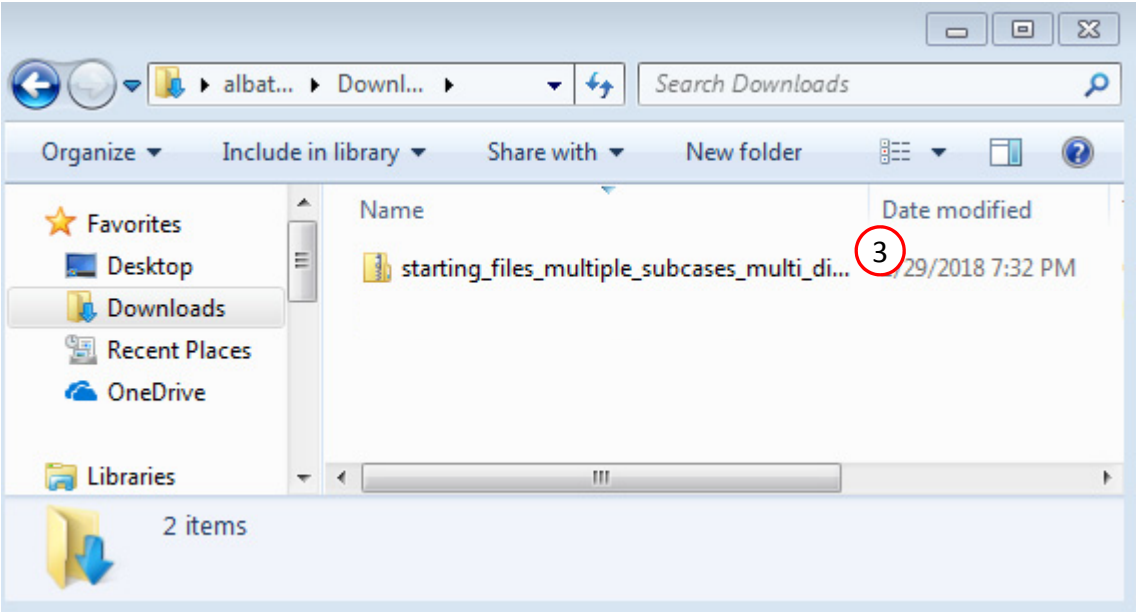
- The necessary BDF files for this tutorial are available in the Tutorials section of the User’s Guide.

Obtain Starting Files

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

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





Open the Correct Page

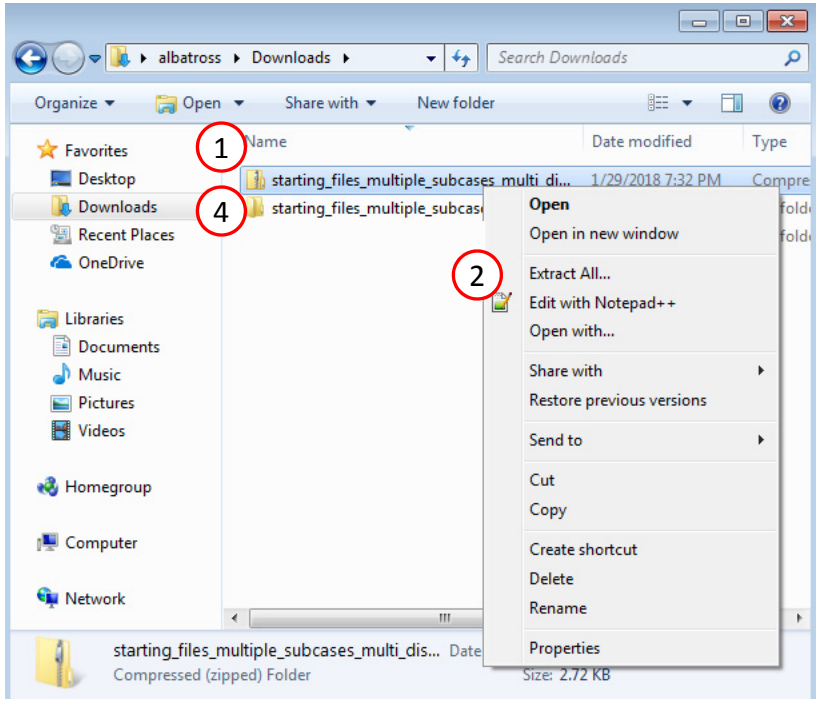
1. Click on the indicated link

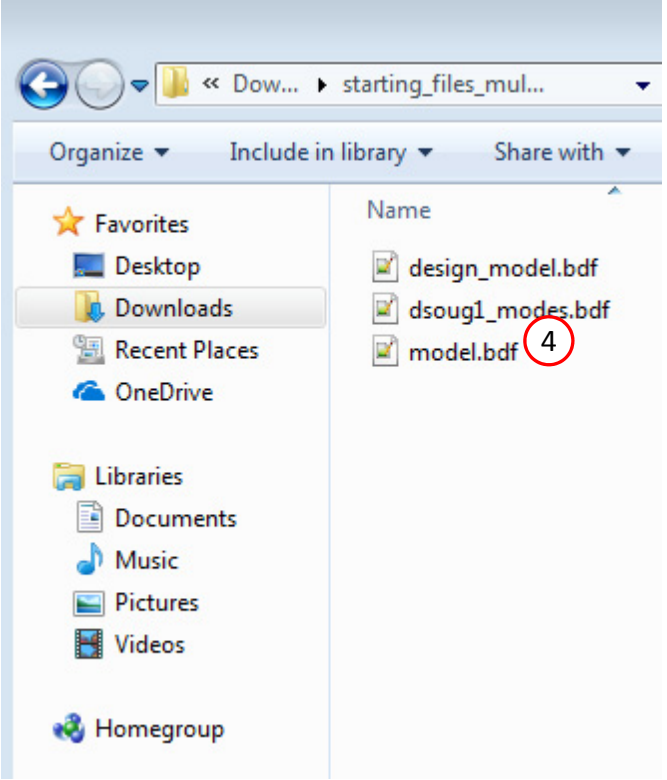
- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
  - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
  - Multi Model Optimization
  - Machine Learning
- The web app also features the HDF5 Explorer, a web application to extract results from the H5 file type.

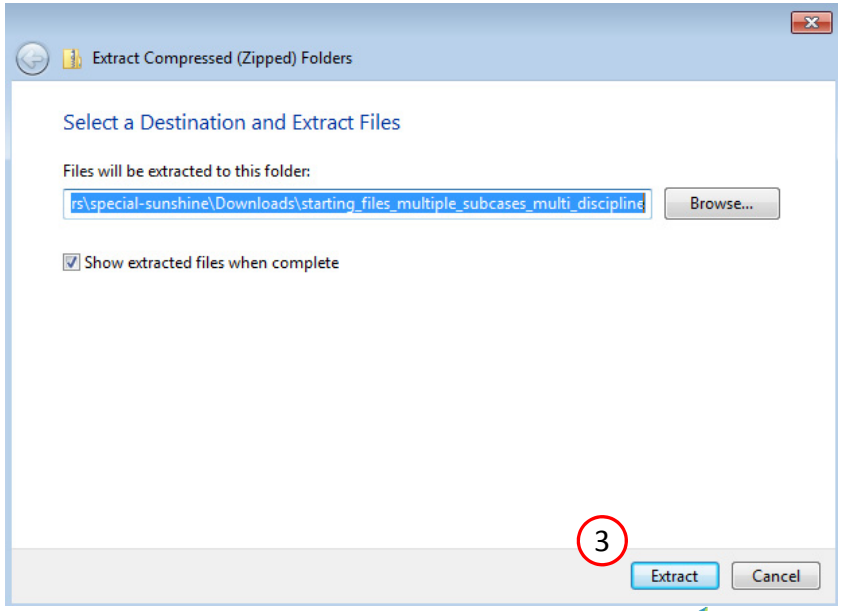
Obtain Starting Files

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

- This example is using a previously created design model. The design model is a model that has been converted to SOL 200 and contains bulk data entries describing the optimization problem statement, e.g. variables, objective and constraints.







Merge the BDF files

Two sets of bulk data files (BDF) have been provided.

- Set 1: model.bdf and design_model.bdf
- Set 2: dsoug1_modes.bdf

The Set 1 files are configured to perform only a static analysis optimization and contains 19 load cases. The Set 2 file is the same Finite Element Model, but configured to perform an eigenvalue or normal modes analysis. The procedure below merges information from Set 2 to Set 1. Afterwards, the files of Set 1 can be modified to perform both a static and normal modes analysis for 20 subcases.

1. Open *dsoug1_modes.bdf*. Take SUBCASE 1 and move it to *model.bdf*.
2. Take the line with EIGRL at the beginning and move it to *model.bdf*
3. Save *model.bdf*

- There are 2 methods to perform multidisciplinary optimization:
  - Method 1 - Merge the necessary bulk data files and use ANALYSIS in each SUBCASE, e.g. ANALYSIS=STATICS, ANALYSIS=MODES. This method is used for this tutorial.
  - Method 2 – Use the Multi Model Optimization capability. This does not require that manual merging of files as shown on this page.

E:\md_exampl\2_solution_statics_only\dsoug1_modes.bdf - Notepad++

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

model.bdf

```
assign userfile = 'optimization_results.csv', status = new,
form = formatted, unit = 52
$ 1___||__2___||__3___||__4___||__5___||__6___||__7___||__8___||__9___||__10__|
ID MSC  DSOUG1 $ v2004 ehj 25-Jun-2003
TIME  10      $
SOL 200
CEND

TITLE = SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION  -       DSOUG1
SUBTITLE = BASELINE - 2 CROSS SECTIONAL AREAS AS DESIGN VARIABLES
$ Result Output
ECHO        = SORT
SPC         = 100
DISPLACEMENT(SORT1,REAL)=ALL
SPCFORCES(SORT1,REAL)=ALL
STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
$ Subcases
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
   ANALYSIS = STATICS
   DESOBJ(MIN) = 8000000
   DESSUB = 40000004
   $ DESSUB Slot
SUBCASE 1
   SUBTITLE=Modes Analysis
   METHOD = 1
   SPC = 100
   VECTOR(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
SUBCASE 2
   $ DESSUB Slot
   $ ANALYSIS Slot
   $ DRSPAN Slot
   SUBTITLE=Static Analysis 1
```

dsoug1_modes.bdf

```
$ MSC.Nastran input file created on November  02, 2017 at 15:0
$ Patran 2017.0.2
$ Direct Text Input for Nastran System Cell Section
$ Direct Text Input for File Management Section
$ Direct Text Input for Executive Control
$ Normal Modes Analysis, Database
SOL 103
CEND
$ Direct Text Input for Global Case Control Data
TITLE = SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION  -
ECHO = NONE
$ Using Nastran default values for RESVEC
SUBCASE 1
   SUBTITLE=Modes Analysis
   METHOD = 1
   SPC = 100
   VECTOR(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
$ Direct Text Input for Bulk Data
PARAM    POST    0
PARAM   PRTMAXIM YES
EIGRL    1                       3       0
$ Elements and Element Properties for region : prod.11
PROD     11      1       1.
$ Pset: "prod.11" will be imported as: "prod.11"
CROD     1       11      1       4
$ Elements and Element Properties for region : prod.12
PROD     12      1       2.
$ Pset: "prod.12" will be imported as: "prod.12"
CROD     2       12      2       4
$ Elements and Element Properties for region : prod.13
PROD     13      1       1.
```

1

```
BEGIN BULK

INCLUDE './design_model.bdf'

param, post, 0
PARAM   PRTMAXIM YES
EIGRL    1                       3       0                       MASS
$
$-----------------------------------------------------------------------
$ ANALYSIS MODEL
$-----------------------------------------------------------------------
$
$ GRID DATA
$       2       3       4       5       6       7       8       9       10
GRID    1               -10.0     0.0   0.0
GRID    2                 0.0     0.0   0.0
GRID    3                10.0     0.0   0.0
GRID    4                 0.0   -10.0   0.0
$ SUPPORT DATA
SPC1    100     123456  1   THRU    3
$ ELEMENT DATA
CROD    1       11      1       4
CROD    2       12      2       4
CROD    3       13      3       4
$ PROPERTY DATA
PROD    11      1       1.0
PROD    12      1       2.0
PROD    13      1       1.0
MAT1    1       1.0E+7          0.33    0.1
$ EXTERNAL LOADS DATA
FORCE   300     4               20000.   0.8    -0.6
FORCE   310     4               20000.  -0.8    -0.6
ENDDATA
```

2

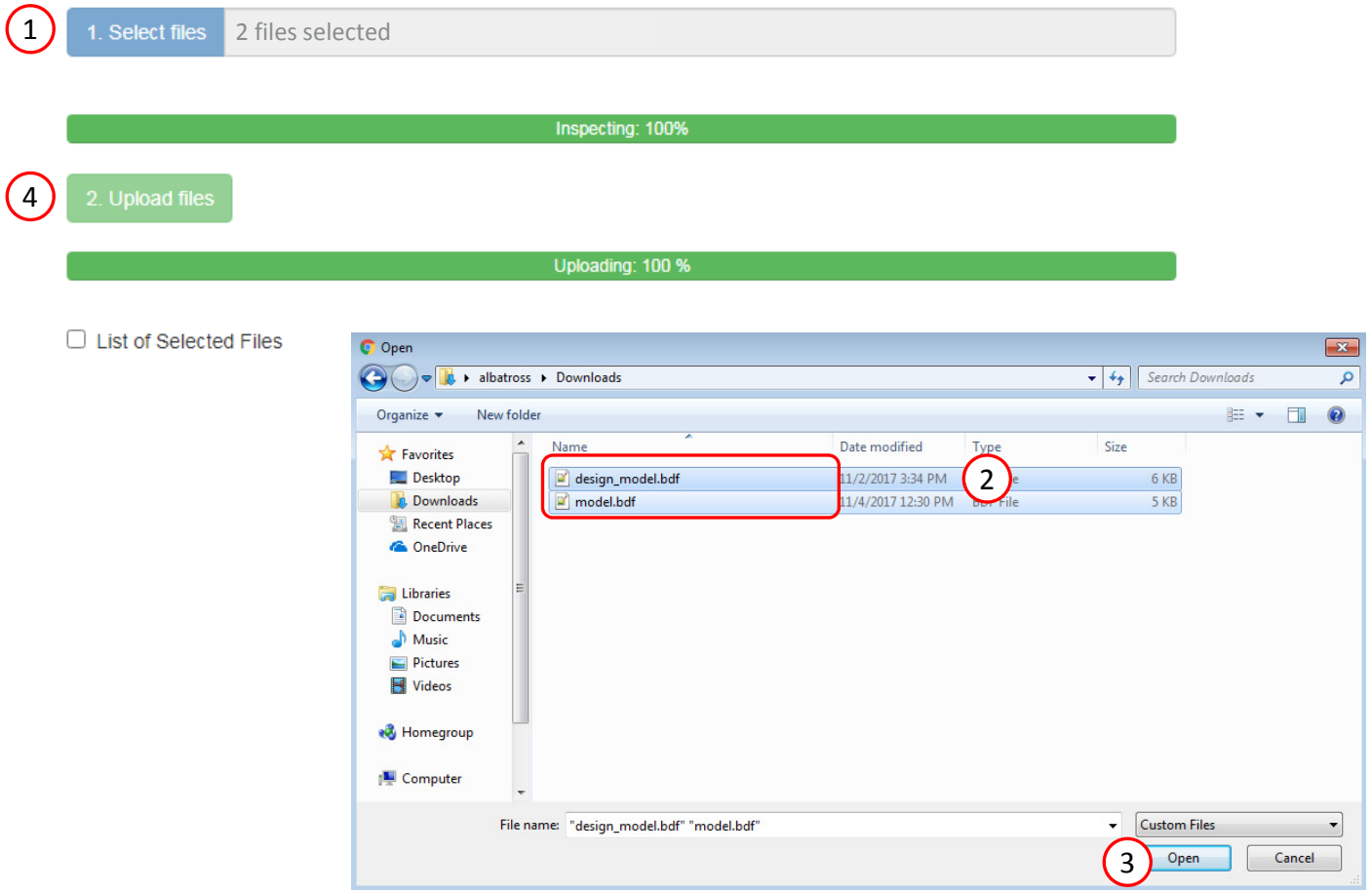
```
BEGIN BULK
$ Direct Text Input for Bulk Data
PARAM    POST    0
PARAM   PRTMAXIM YES
EIGRL    1                       3       0
$ Elements and Element Properties for region : prod.11
PROD     11      1       1.
$ Pset: "prod.11" will be imported as: "prod.11"
CROD     1       11      1       4
$ Elements and Element Properties for region : prod.12
PROD     12      1       2.
$ Pset: "prod.12" will be imported as: "prod.12"
CROD     2       12      2       4
$ Elements and Element Properties for region : prod.13
PROD     13      1       1.
$ Pset: "prod.13" will be imported as: "prod.13"
CROD     3       13      3       4
$ Referenced Material Records
$ Material Record : mat1.1
$ Description of Material :
MAT1     1      1.+7    3.7594+6.33     .1
$ Nodes of the Entire Model
GRID     1              -10.      0.      0.
GRID     2               0.       0.      0.
GRID     3              10.       0.      0.
GRID     4               0.     -10.      0.
$ Loads for Load Case : Default
SPCADD   2       100
$ Displacement Constraints of Load Set : spc1.100
SPC1     100     123456  1       2       3
$ Referenced Coordinate Frames
ENDDATA 202082fa
```

Upload BDF Files

1. Click 1. Select Files
2. Select these two files:
   - model.bdf
   - design_model.bdf
3. Click Open
4. Click Upload Files

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

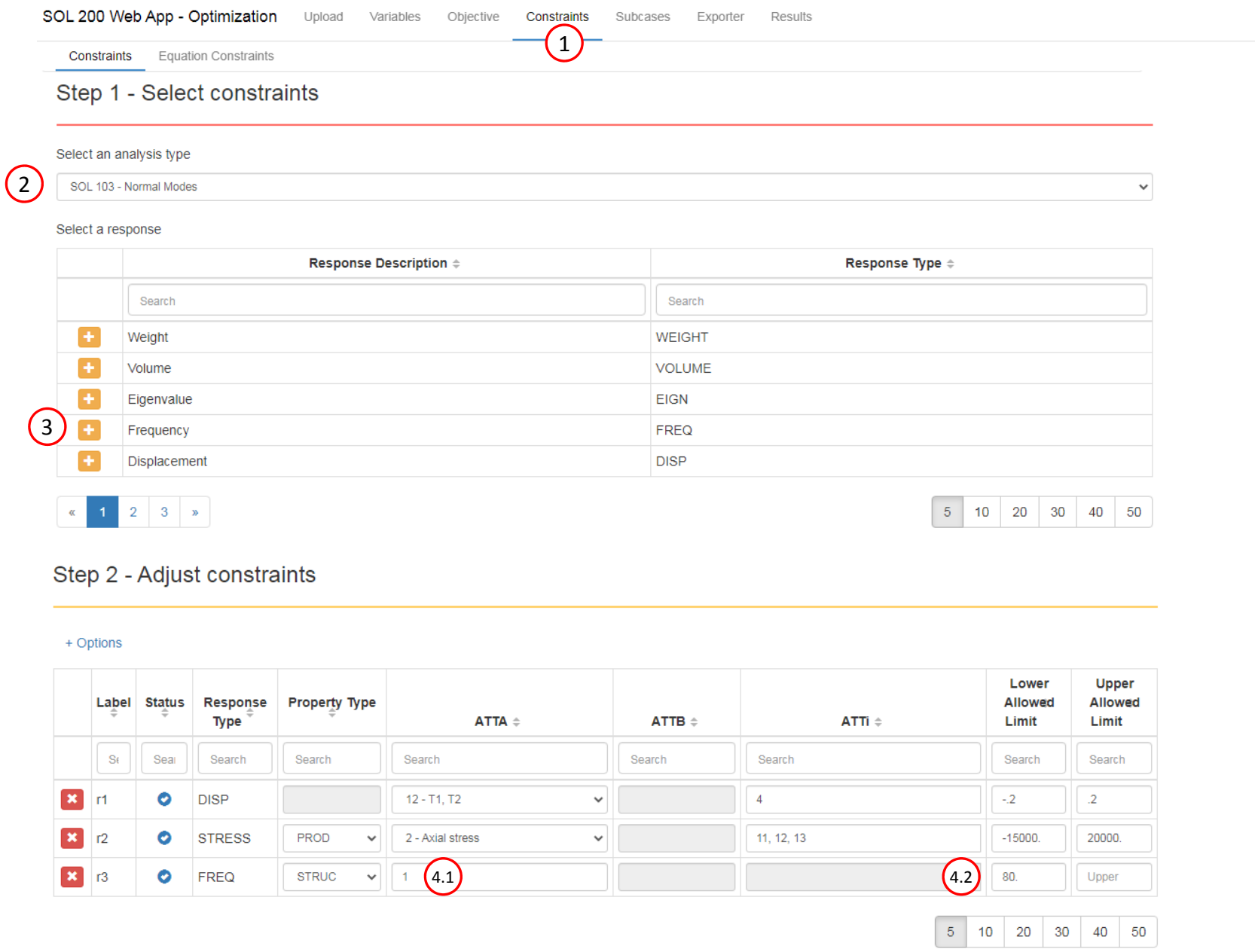
Step 1 - Upload .BDF Files



Create Design Constraints

1. Click Constraints
2. Set the analysis type to Normal Modes
3. Click the plus (+) icon for Frequency
4. Configure the following for constraint r1
    1. ATTA: 1 (mode 1)
    2. Lower Allowed Limit: 80. (80. Hz)

- Part of the design model has already been created. The variables, objective and constraints for a statics optimization have been configured. On this page, a new constraint for the 1st natural frequency is created. The goal is to perform both a statics and modes optimization.



Export New BDF Files

1. Click on Exporter
2. Note that a cautionary message is presented.
3. Click Jump To Table

- The natural frequency constraint was just created, but a message appears indicating that the constraint was not assigned to a SUBCASE.

1

SOL 200 Web App - Optimization | Upload | Variables | Objective | Constraints | Subcases | Exporter | Results | Settings | Match | Other | User's Guide | Home

BDF Output - Model

```
assign userfile = 'optimization_results.csv', status = unknown,
form = formatted, unit = 52
$__1___||__2___||__3___||__4___||__5___||__6___||__7___||__8___||__9___||__10__|
ID MSC  DSOUG1 $ v2004 ehj 25-Jun-2003
TIME  10      $
SOL 200
CEND

TITLE = SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION  -       DSOUG1
SUBTITLE = BASELINE - 2 CROSS SECTIONAL AREAS AS DESIGN VARIABLES
$ Result Output
ECHO        = NONE
SPC         = 100
DISPLACEMENT(SORT1,REAL)=ALL
SPCFORCES(SORT1,REAL)=ALL
STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
$ Subcases
   DESOBJ(MIN) = 8000000
   $ DESGLB Slot
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 1
   ANALYSIS = MODES
   $ DESSUB Slot
   $ DRSPAN Slot
   SUBTITLE=Modes Analysis
   METHOD = 1
   SPC = 100
   VECTOR(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
SUBCASE 2
```

Download BDF Files

Download BDF Files

2

Caution! Not all constraints have been assigned to a subcase. Check the Status column of the following tables.
Correct: . Incorrect: .

Constraints | Jump to table | Step 1 - Assign constraints to subcases

3

BDF Output - Design Model

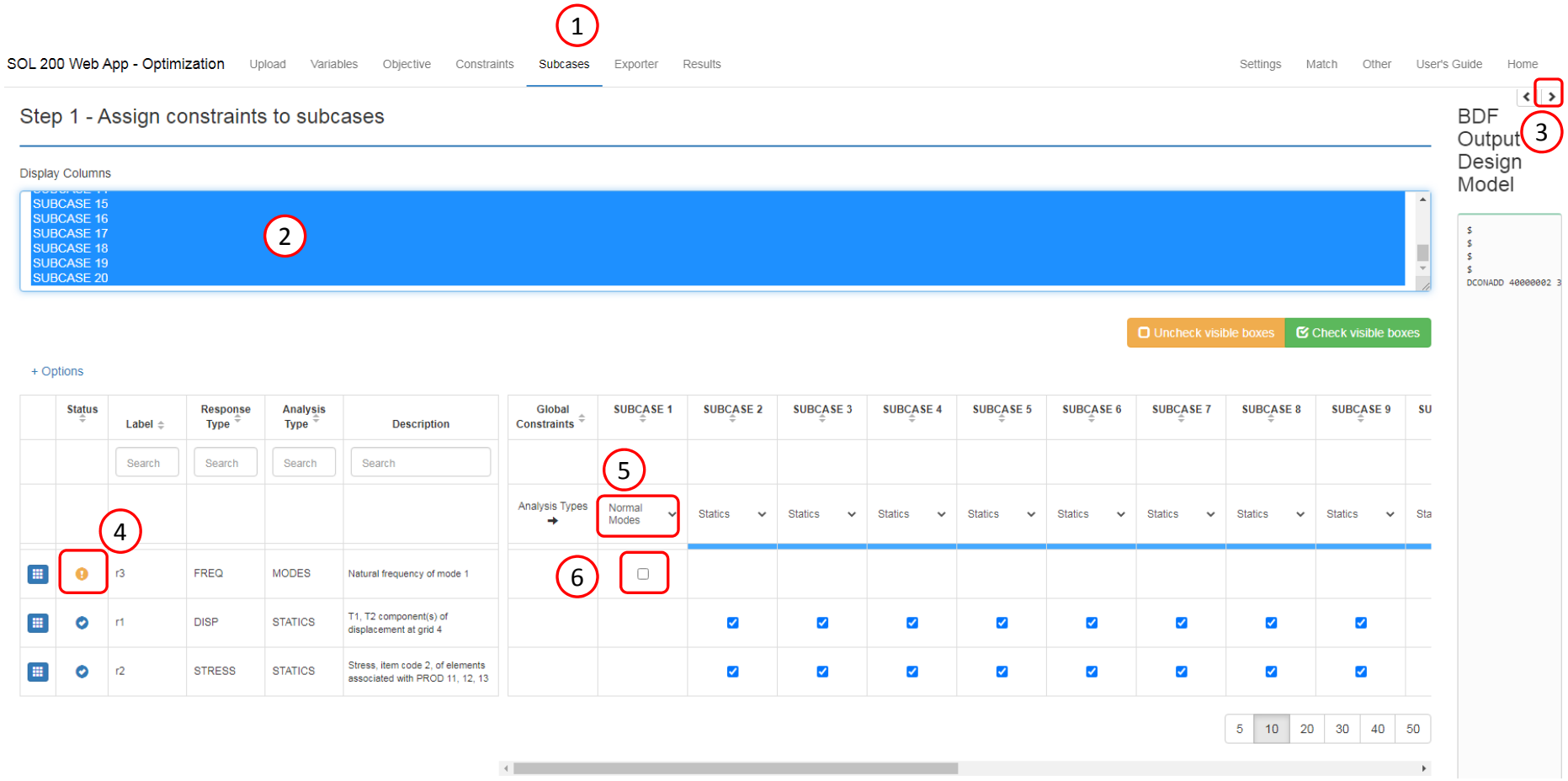
```
$*********************************************************************
$*                                                                   *
$*                          Design Model                             *
$*                                                                   *
$*********************************************************************
$
$                        Design Variables - Type 1
$---------------------------------------------------------------------
$
$
$

DVPREL1 1000001 PROD    11      A
        100001  1.0
DVPREL1 1000002 PROD    12      A
        100002  1.0
DVPREL1 1000003 PROD    13      A
        100003  1.0
$
$
DESVAR  100001  x1      1.0     .001    100.
DESVAR  100002  x2      2.0     .001    100.
DESVAR  100003  x3      1.0     .001    100.
$
$

$
$
DLINK   1       100003                  100001  1.0

$                        Design Variables - Type 2
$---------------------------------------------------------------------
$
$

$
$

$
$                          Design Objective
$---------------------------------------------------------------------
$
$
DRESP1  8000000 r0      WEIGHT                  3       3

$
```

Developed by The Engineering Lab

Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Select each option in the select box (Hold down the Shift key on the keyboard and use the mouse to select multiple options)
3. Click the Right Arrow to expand the width of the table
4. Note that the r3 constraint for natural frequency has a yellow status icon, indicating that the constraint is not assigned to any subcases
5. Change the analysis type of column SUBCASE 1 to Normal Modes
6. Mark the checkbox

- A change from a yellow to blue status (=>) means the constraint is assigned to at least one column
- r3 or the natural frequency constraint is applied to SUBCASE 1



Assign Constraints to Load Cases (SUBCASES)

1. Click 2 times the Label column to sort the Label column in descending order

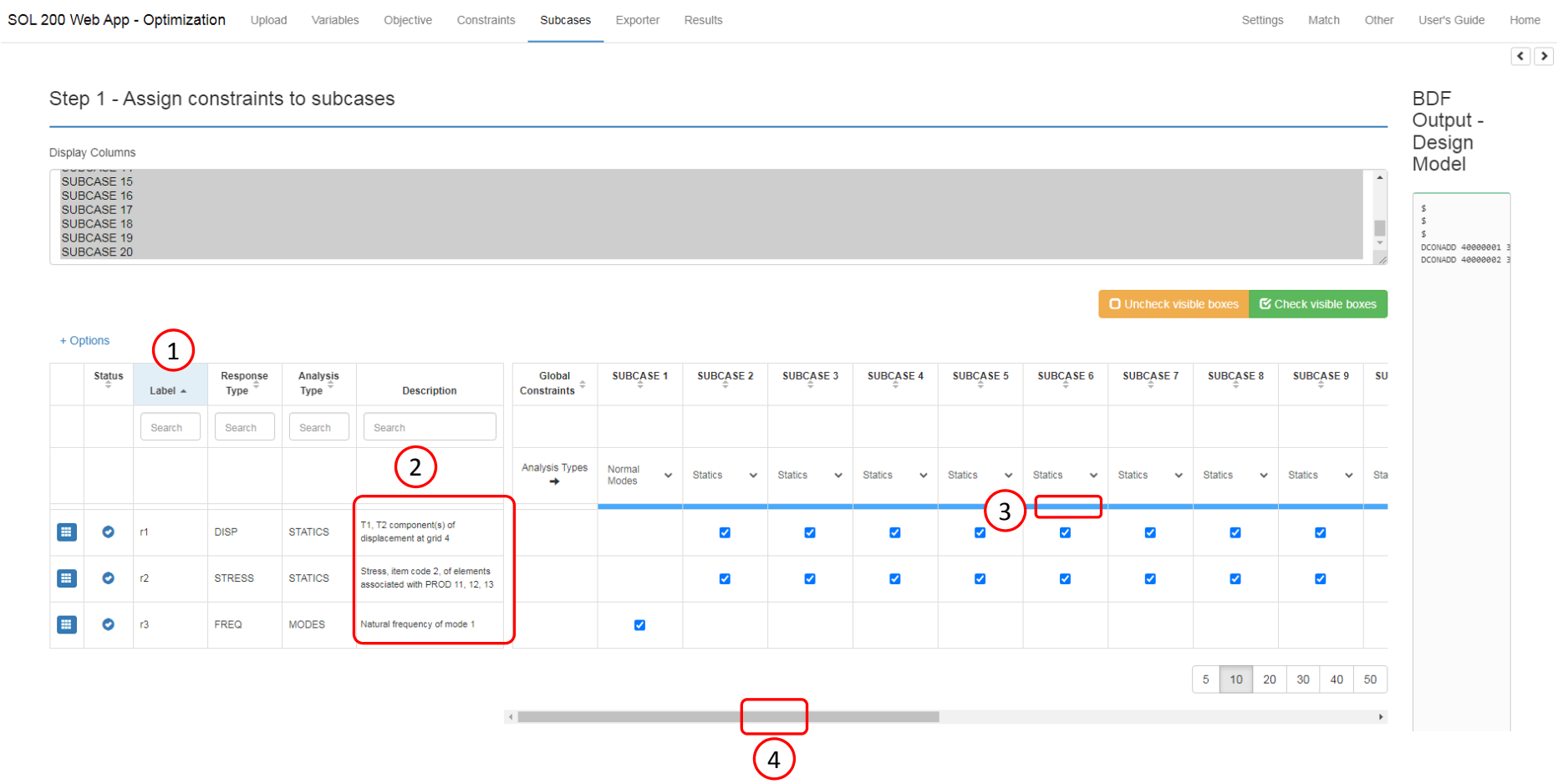
Other information

2. Descriptions of each constraint are available and can be used to confirm the constraint has been properly configured
3. The blue bar indicates at least one constraint has been applied to the column/SUBCASE
4. The horizontal scroll bar can be used to navigate across multiple SUBCASEs

- When hundreds of SUBCASEs must be configured, the following options expedite the process:

Uncheck visible boxes

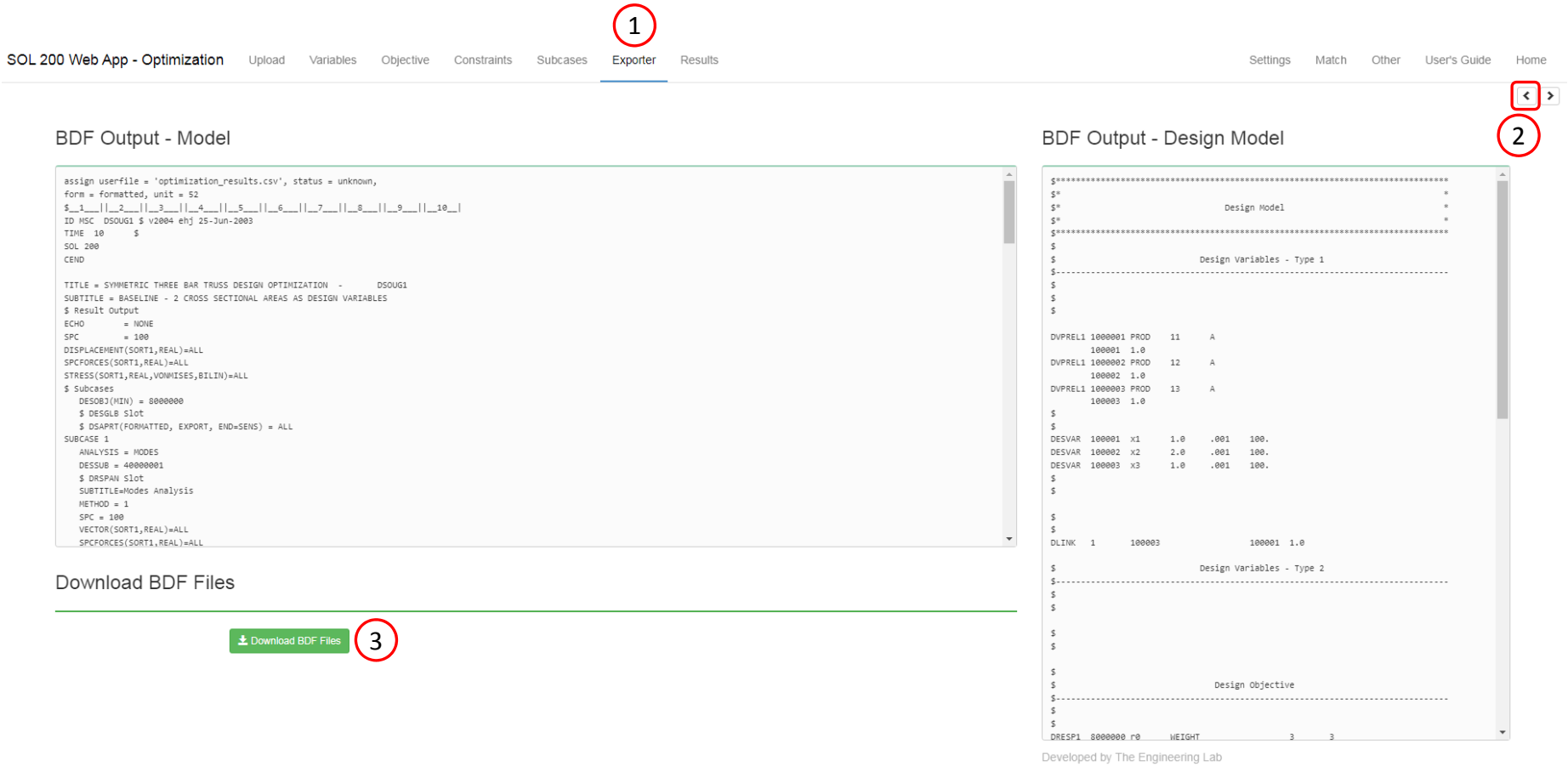
Check visible boxes



Export New BDF Files

1. Click on Exporter
2. Click the Left Arrow to expand the width of the section BDF Output – Design Model
3. Click on Download BDF Files

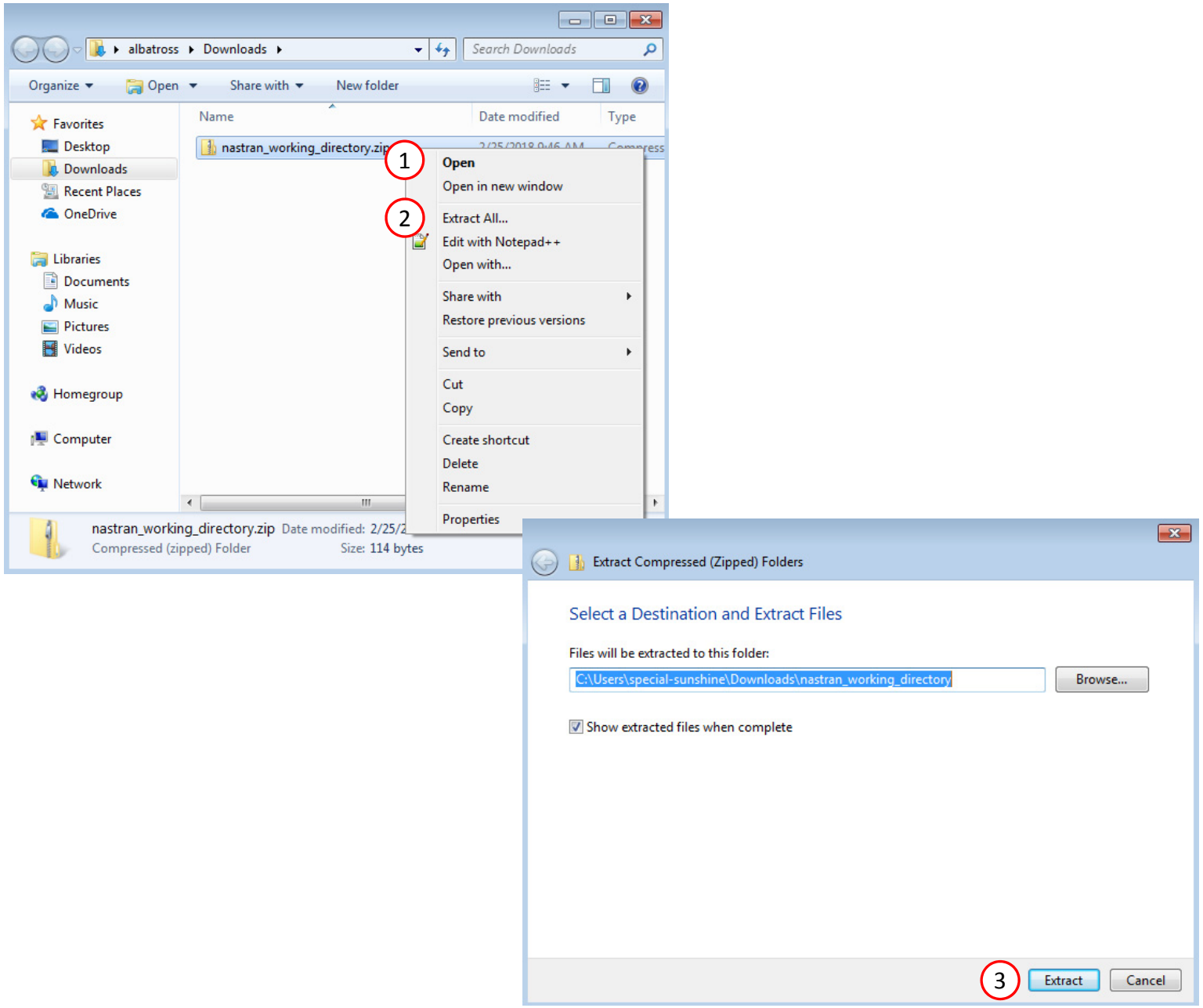
- When the download button is clicked a new file named “nastran_working_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran_working_directory (1).zip”



Perform the Optimization with Nastran SOL 200

1. A new .zip file has been downloaded
2. Right click on the file
3. Click Extract All
4. Click Extract on the following window

- Always extract the contents of the ZIP file to a new, empty folder.



Perform the Optimization with Nastran SOL 200

1. Inside of the new folder, double click on Start MSC Nastran
2. Click Open, Run or Allow Access on any subsequent windows
3. MSC Nastran will now start

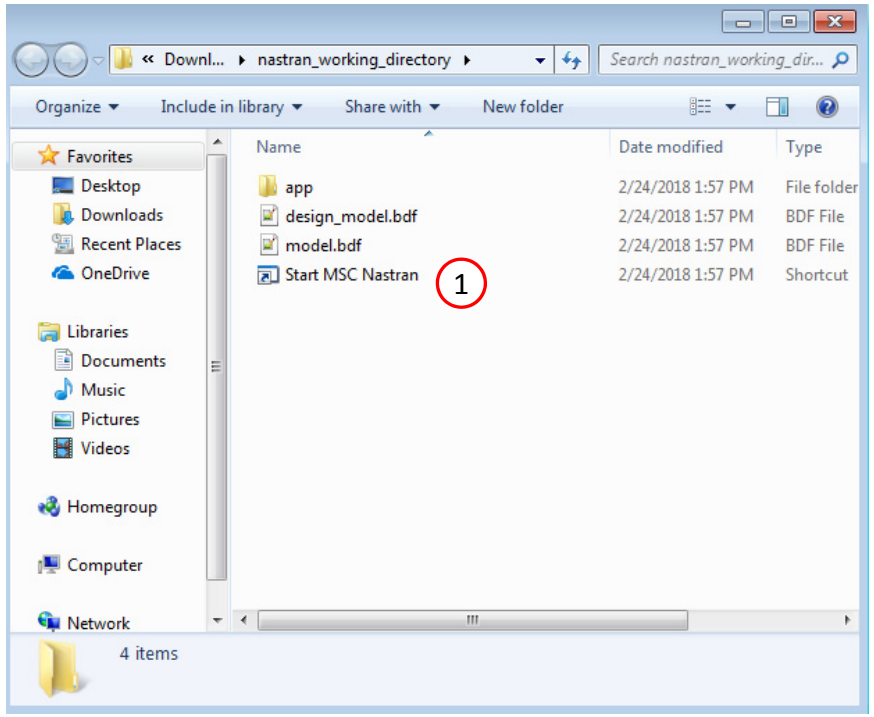
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the remote machine. 3) After completion, copy the BDF, F06, LOG, H5 files to the local machine. 4) Click "Start MSC Nastran" to display the results.

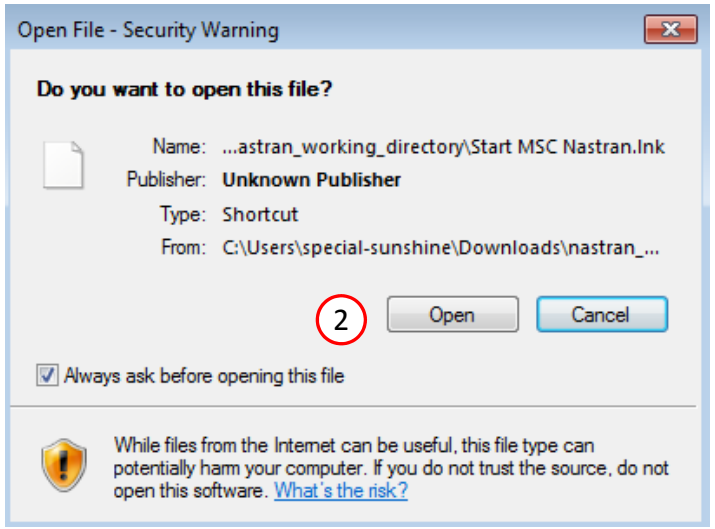
Using Linux?

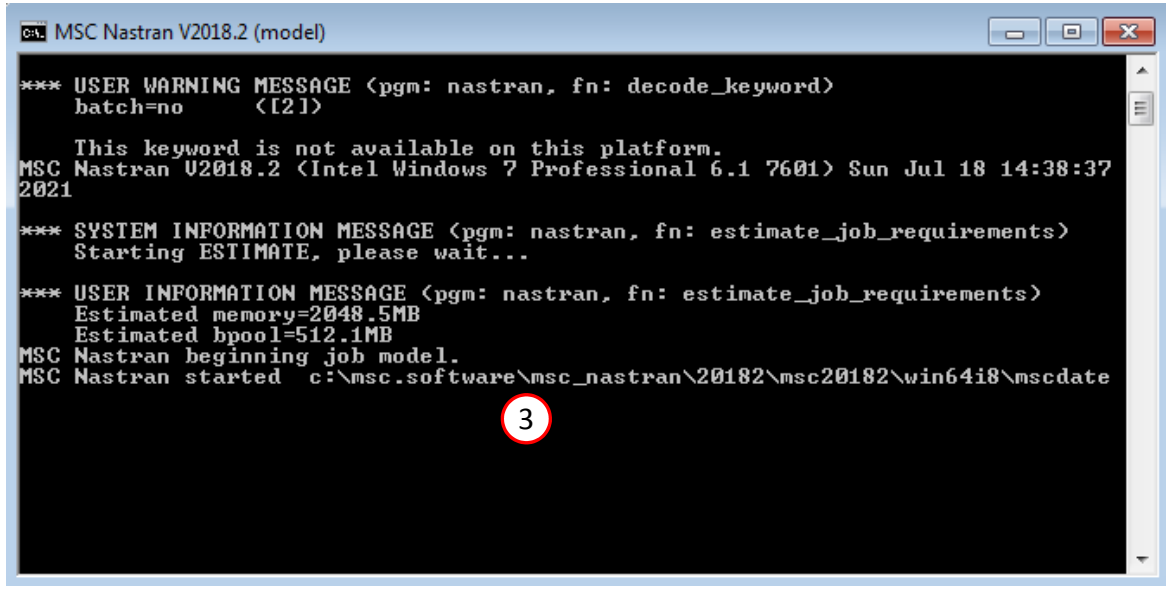
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

In some instances, execute permission must be granted to the directory. Use this command. This command assumes you are one folder level up.

sudo chmod -R u+x ./nastran_working_directory







Status

1. While MSC Nastran is running, a status page will show the current state of MSC Nastran

- The status of the MSC Nastran job is reported on the Status page. Note that Windows 7 users will experience a delay in the status updates. All other users of Windows 10 and Red Hat Linux will see immediate status updates.

SOL 200 Web App - Status

Python MSC Nastran

Status

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

Review Optimization Results

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

1. Ensure the messages shown have green checkmarks. This is indication of success. Any red icons indicate challenges.
2. The final value of objective, normalized constraints (not shown) and design variables can be reviewed.

- The results shown are the outcome of a multidisciplinary optimization for both statics and modes.

SOL 200 Web App - Local Optimization Results

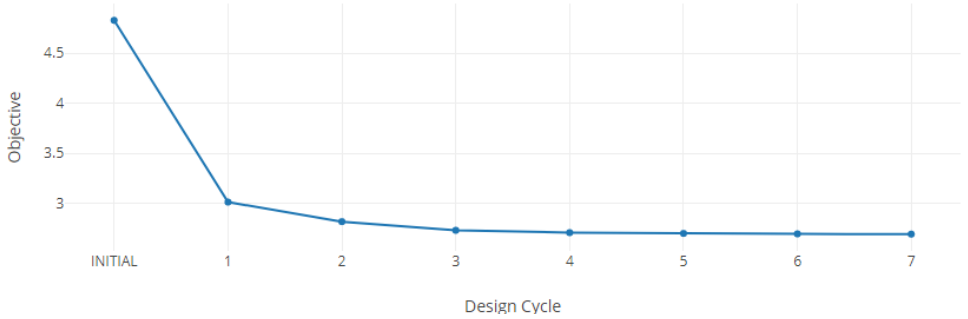
Home

Final Message in .f06

1

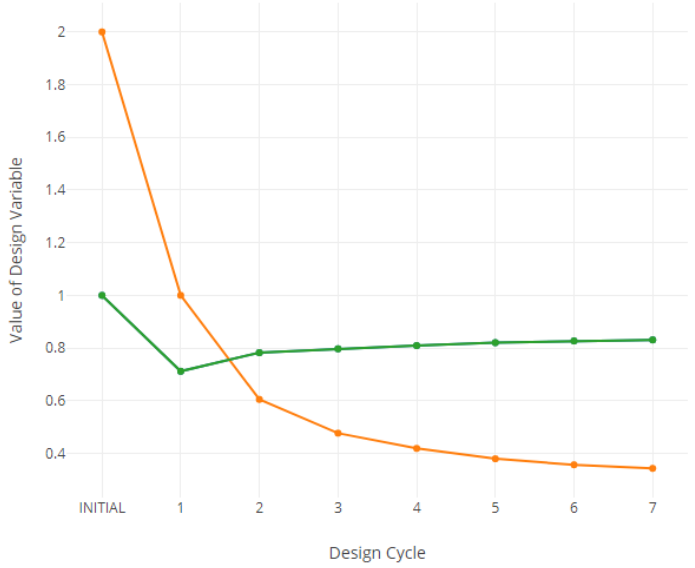
```
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =       7.
```

Objective



2

Design Variables



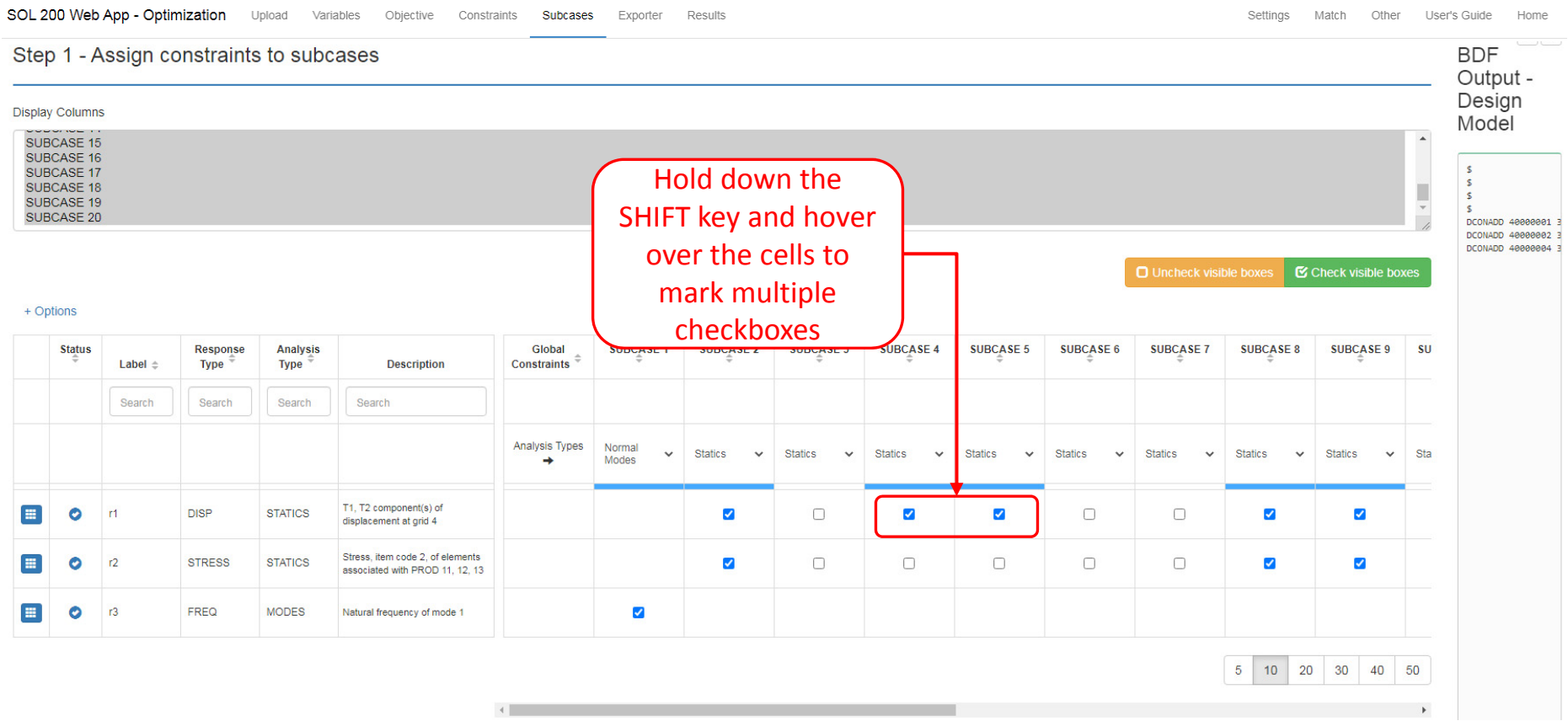
Display None | Display All

Display	Color	Label	Label Comments
☑		x1	A, Area of the rod, of PROD 11 (Truss_Member-Type-11)
☑		x2	A, Area of the rod, of PROD 12 (Truss_Member-Type-12)
☑		x3	A, Area of the rod, of PROD 13 (Truss_Member-Type-13)

Extra Information

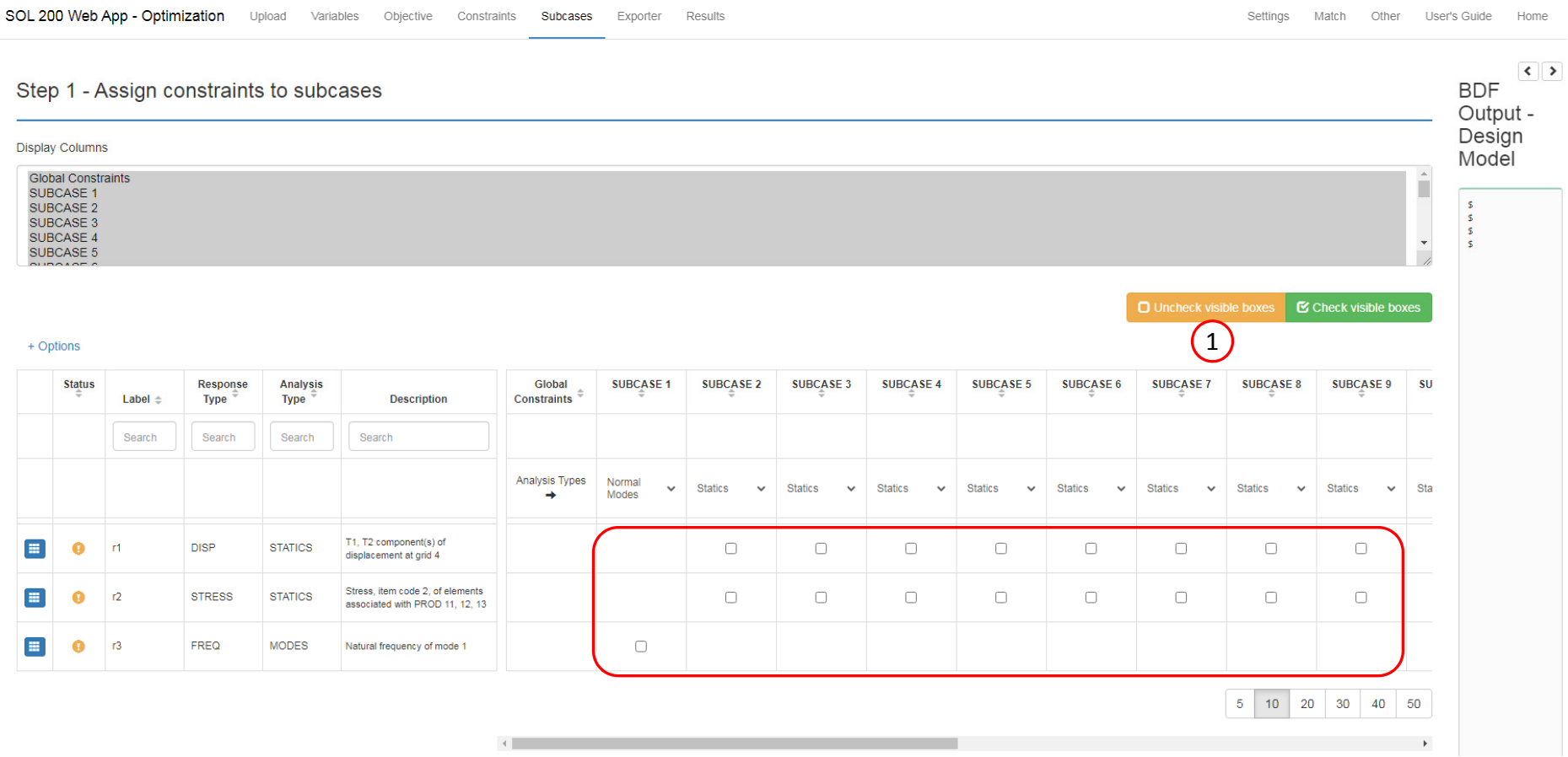
Assign Constraints to Load Cases (SUBCASES)

1. Hold down the SHIFT key on the keyboard and hover the mouse cursor over checkboxes to mark multiple checkboxes without mouse clicking frequently



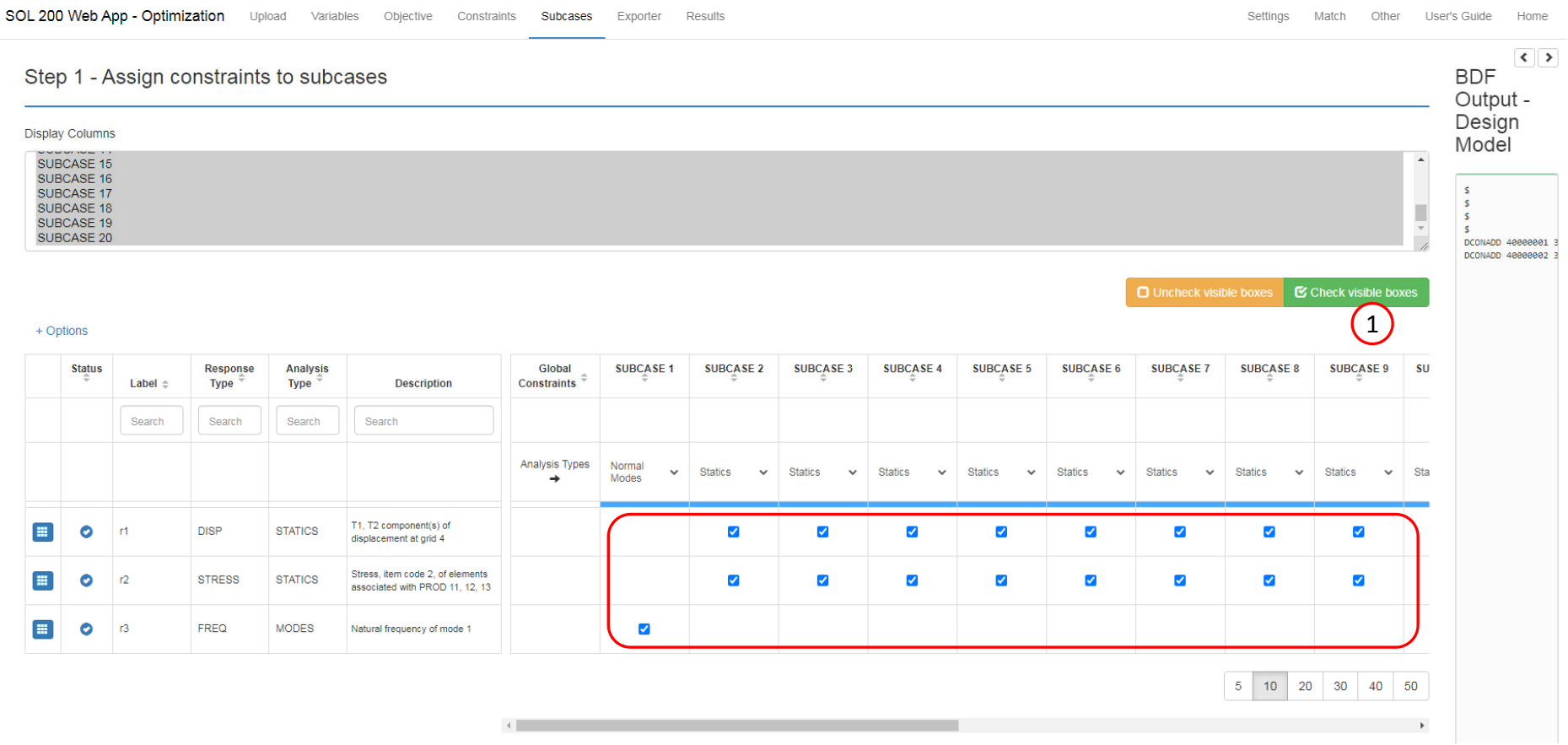
Assign Constraints to Load Cases (SUBCASES)

1. If you click Uncheck visible boxes, every visible checkbox will be unmarked



Assign Constraints to Load Cases (SUBCASES)

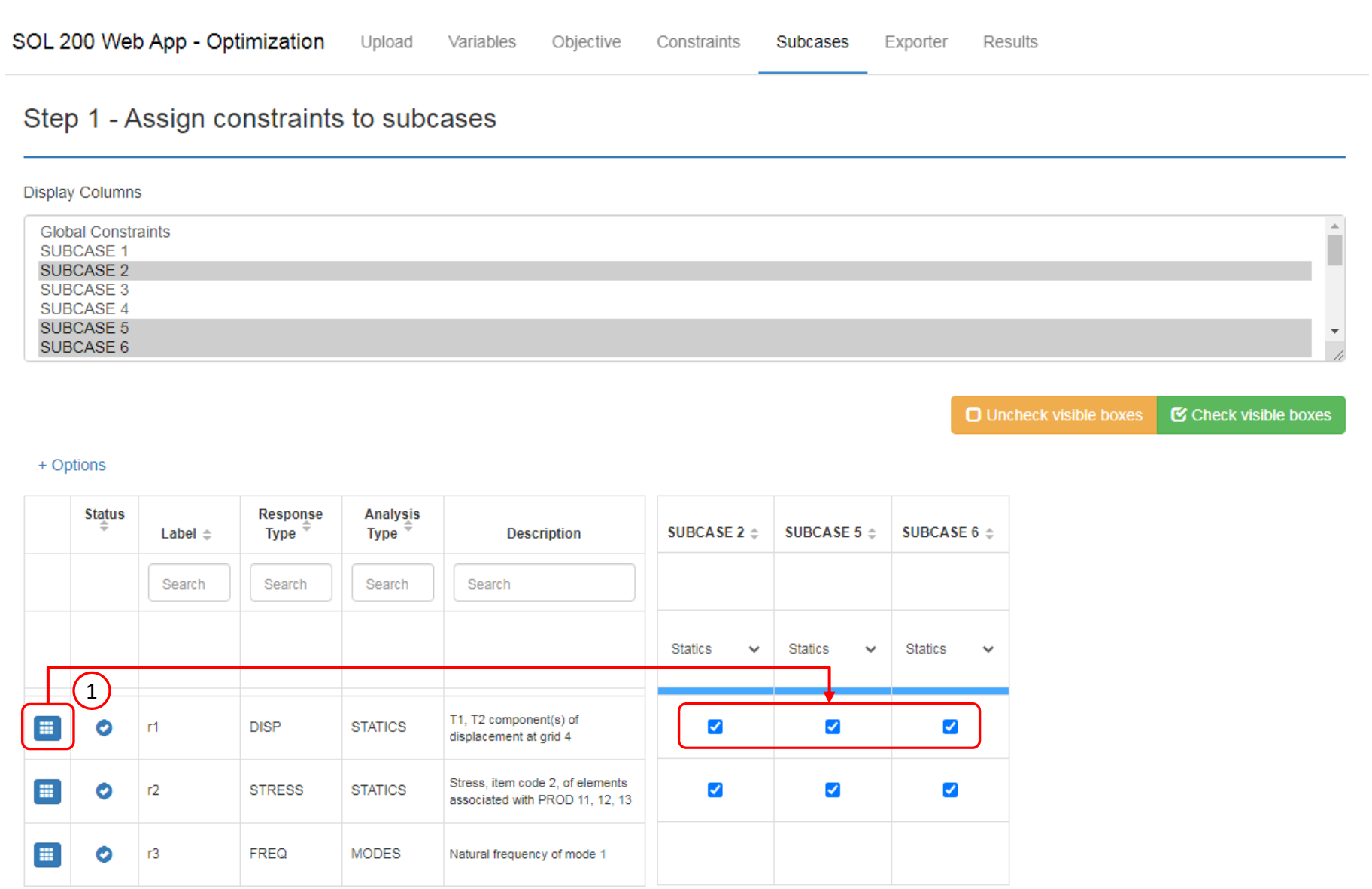
1. If you click Check visible boxes, every visible checkbox will be marked



Assign Constraints to Load Cases (SUBCASES)

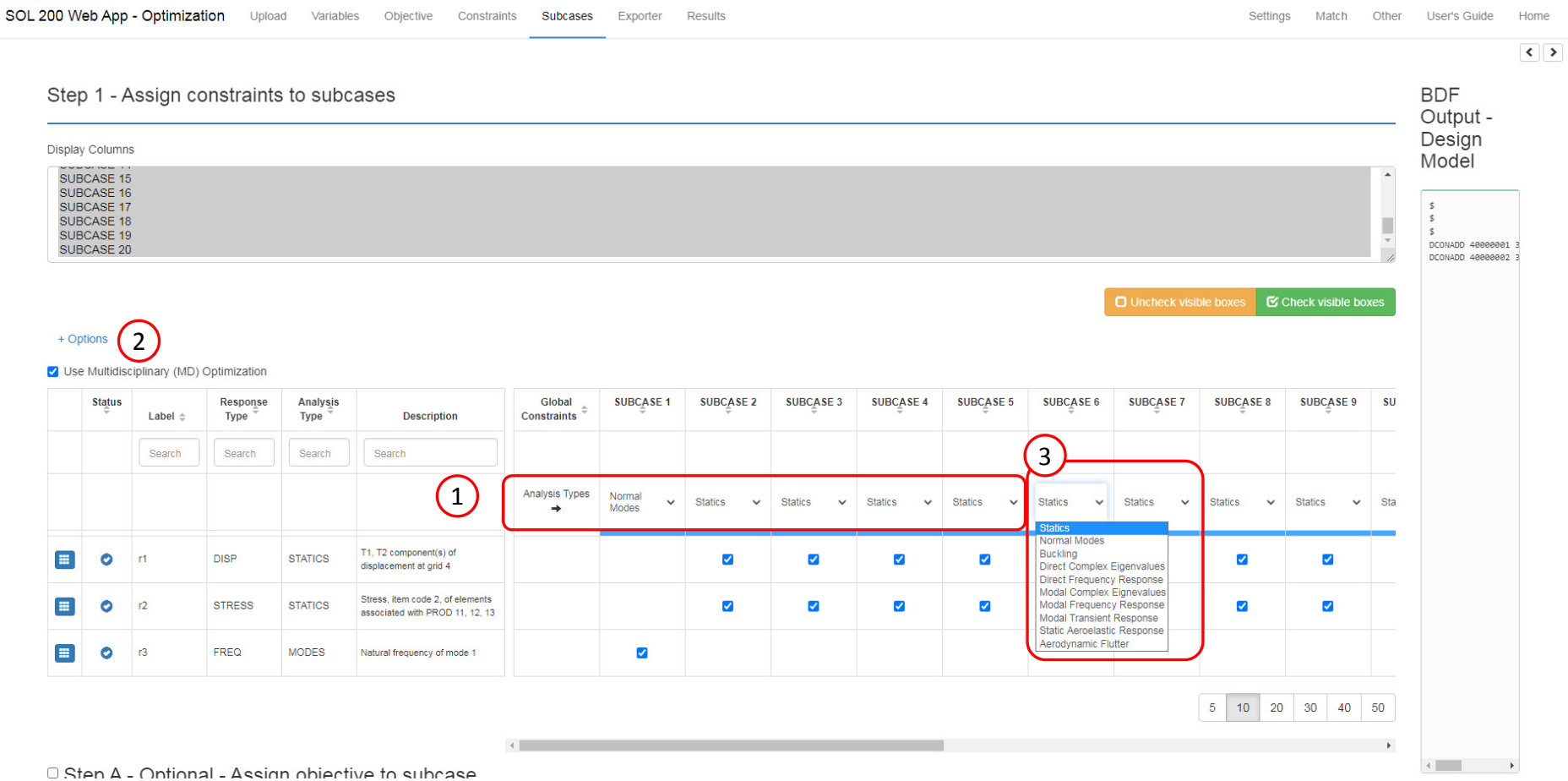
1. Click the indicated icon and the SUBCASEs in which the constraint has been assigned will be displayed.

In this example, the columns for SUBCASE 2, 5 and 6 have been displayed because the r1 constraint has been assigned to these SUBCASESs



Assign Constraints to Load Cases (SUBCASES)

1. The Analysis Type bar will be shown automatically if constraints of different analysis types are created
2. Alternatively, the Analysis Type bar can be manually turned on by clicking *+Options* , then mark the checkbox for Use Multidisciplinary (MD) Optimization
3. The analysis type for each SUBCASE can be manually changed



End of Tutorial