

# Workshop - Shape Optimization of a Steering Knuckle

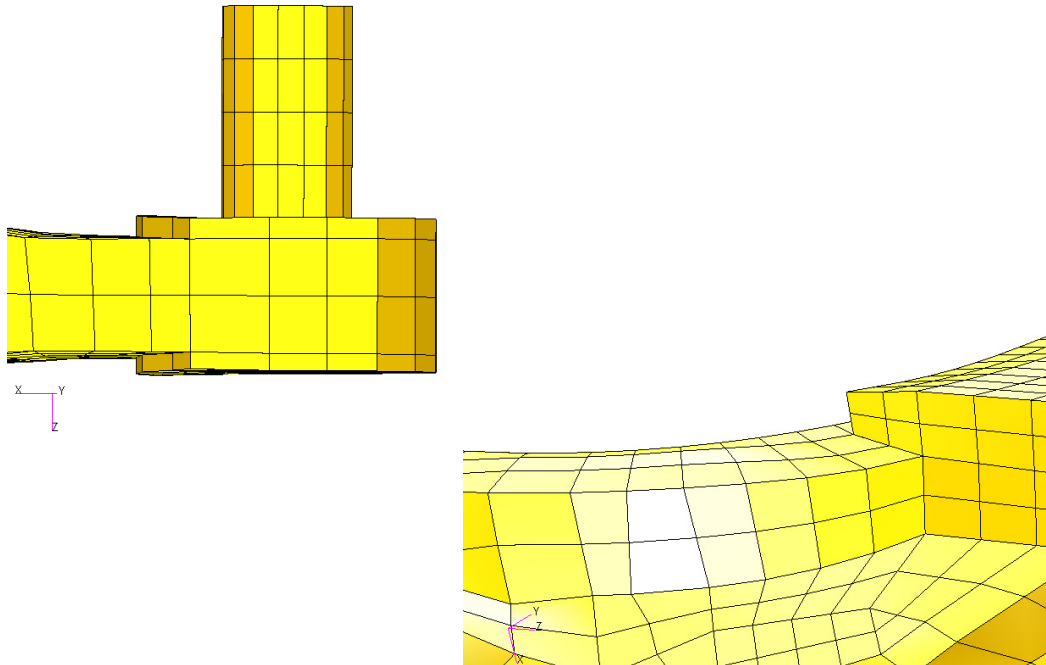
---

AN MSC NASTRAN SOL 200 TUTORIAL

# Results

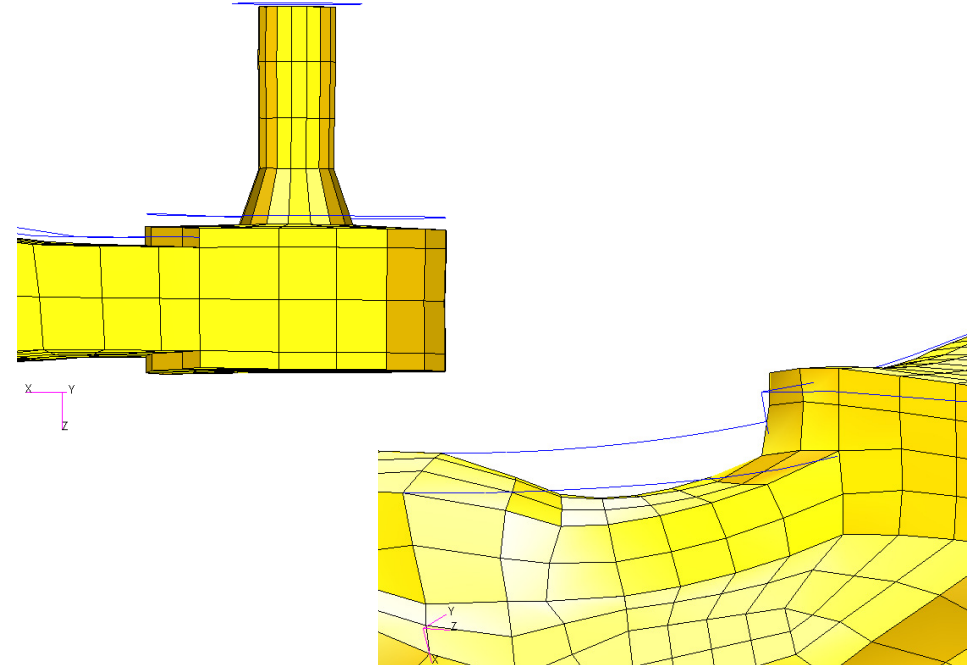
## Before Optimization

- Weight:  $8.081499\text{E}+07$
- Max Stress: 36.8



## After Optimization

- Weight:  $8.019459\text{E}+07$
- Max Stress: 39.9



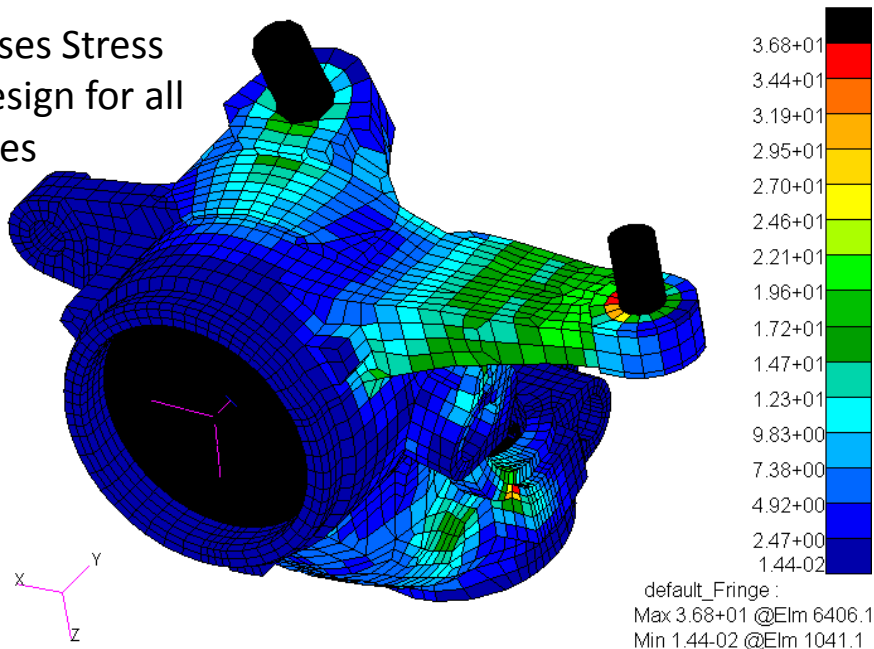
# Results

## Before Optimization

- Weight:  $8.081499\text{E}+07$
- Max Stress: 36.8

Fringe: Max (Initial), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)

Max von Mises Stress  
for Initial Design for all  
12 Load Cases

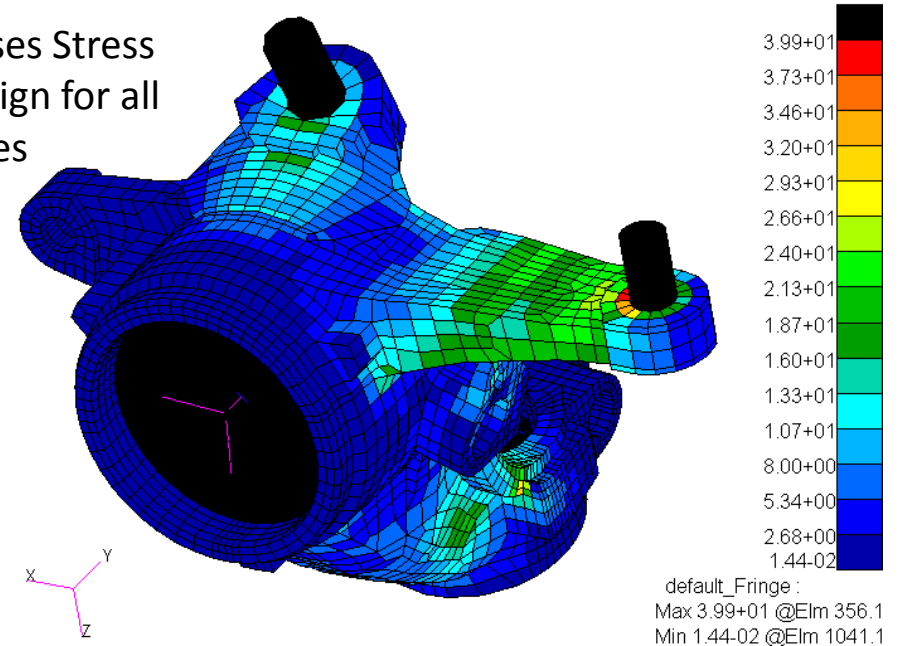


## After Optimization

- Weight:  $8.019459\text{E}+07$
- Max Stress: 39.9

Fringe: Max (Final), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)

Max von Mises Stress  
for Final Design for all  
12 Load Cases

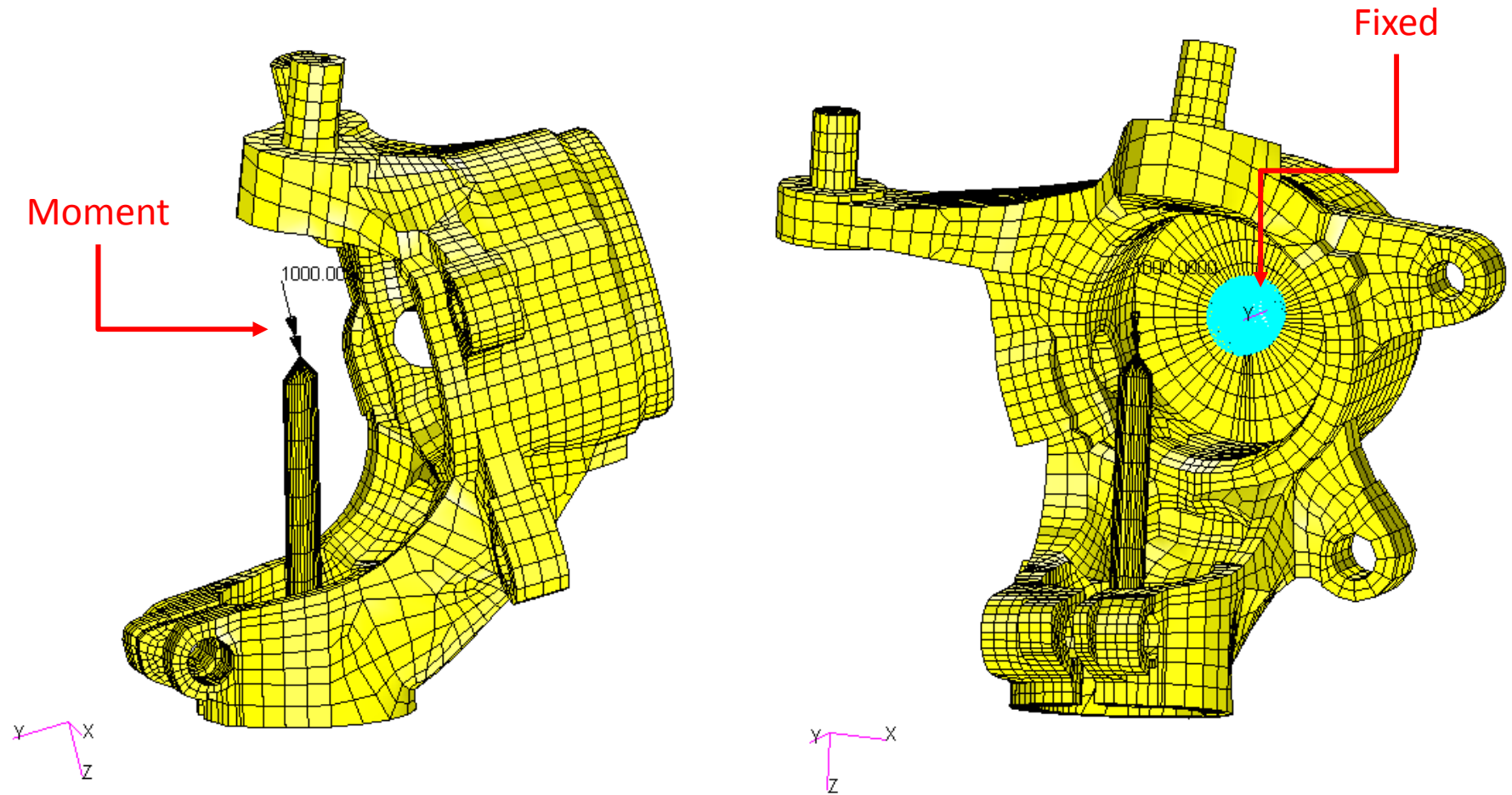


# Details of the Structural Model

This model is fixed at the indicated hole.

12 load cases apply point loads and moments.

Only the load of load case 12 is displayed.

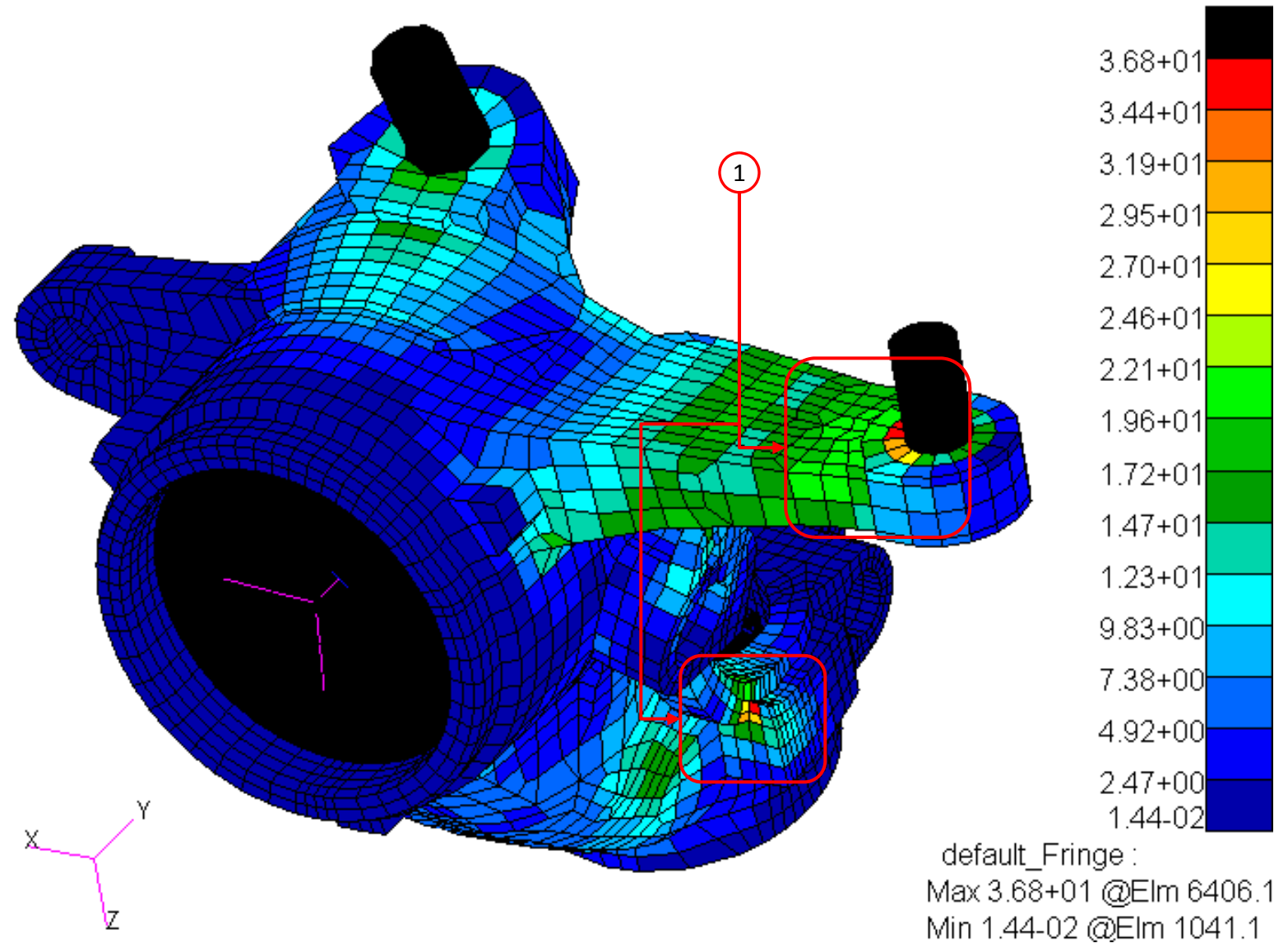


# Shape Optimization Strategy

The max von Mises stress across all 12 load cases is plotted.

1. Two regions of the structure have high stresses. The shape in these regions of high stress will be optimized to minimize mass while constraining the stress.

Fringe: Max (Initial), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)



# Optimization Problem Statement

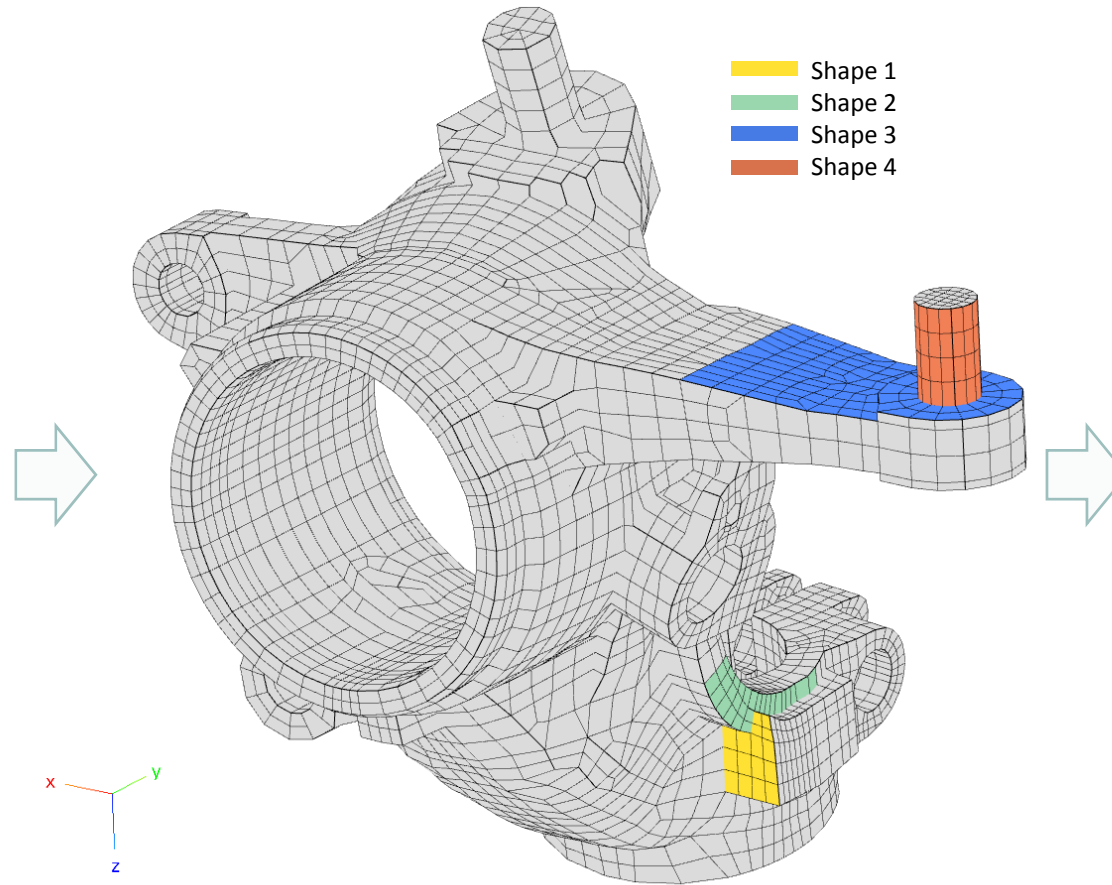
## Design Variables

y1: Shape 1 – Expansion/contraction region 1  
y2: Shape 2 – Expansion/contraction region 2  
y3: Shape 3 – Expansion/contraction region 3  
y4: Shape 4 – Expansion/contraction region 4

$$\begin{aligned} 4.0 < y1 < 15.0 \\ 4.0 < y2 < 15.0 \\ 4.0 < y3 < 13.0 \\ 7.0 < y4 < 12.0 \end{aligned}$$

When the initial value of the shape variables is 10.0, the equivalent bounds on  $\Delta y_i$  are:

$$\begin{aligned} -6.0 < \Delta y1 < 5.0 \\ -6.0 < \Delta y2 < 5.0 \\ -6.0 < \Delta y3 < 3.0 \\ -3.0 < \Delta y4 < 2.0 \end{aligned}$$



## Design Objective

r0: Minimize weight

## Design Constraints

r1: von Mises stress at the center of the elements  
356, 355, 6406

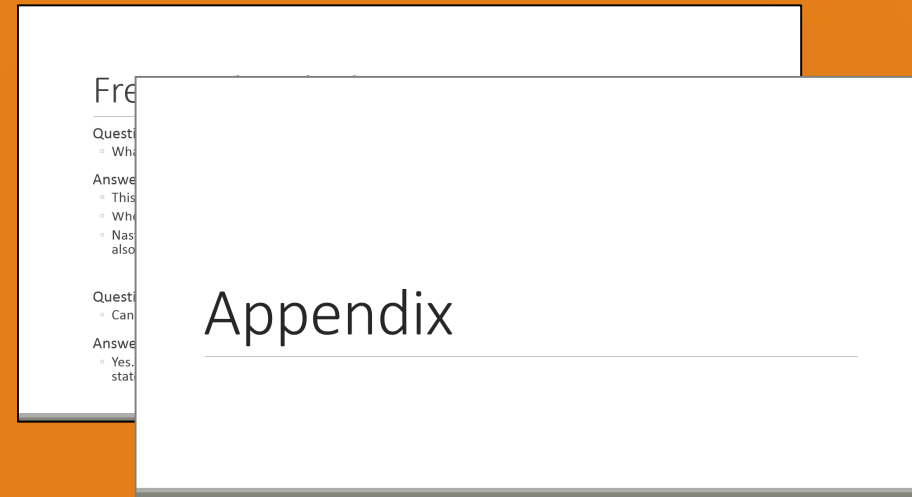
$$R1 < 40.0$$

# More Information Available in the Appendix

---

The Appendix includes information regarding the following:

- Frequently Asked Questions
  - How to view the shape optimization results in Patran?



# Contact me

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

christian@ the-engineering-lab.com



# Tutorial

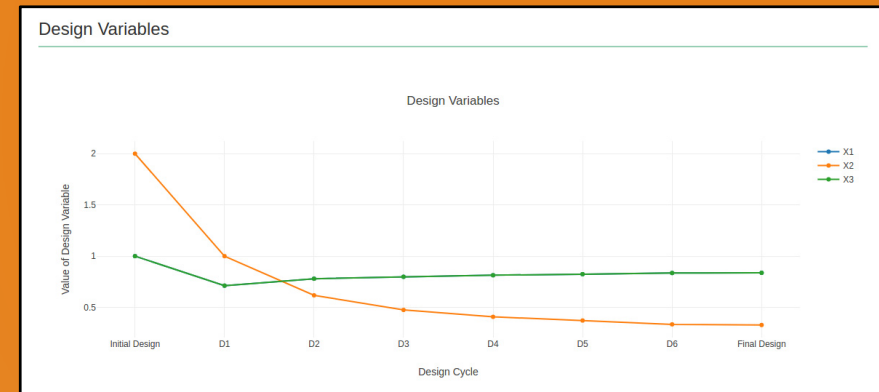
---

# Tutorial Overview

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

## Special Topics Covered

**Automatic Plots** - After an optimization is complete and result files are created, the change during the optimization process for design variables and objective may be automatically plotted by the Nastran Web App. This tutorial describes how to create these plots. The plotting capability may also be used to plot design sensitivities.



# SOL 200 Web App Capabilities

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

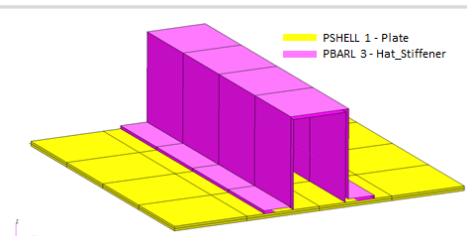
## Compatibility

- 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.

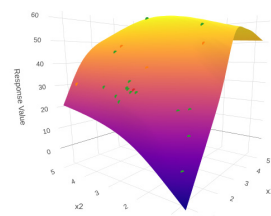
## Benefits

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

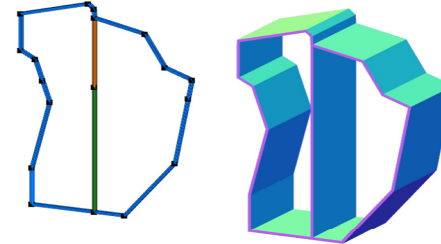
## Web Apps



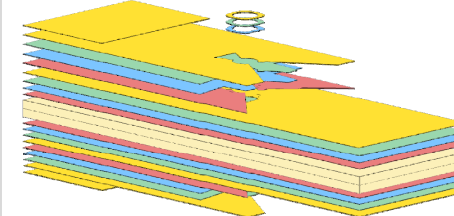
**Web Apps for MSC Nastran SOL 200**  
Pre/post for MSC Nastran SOL 200.  
Support for size, topology, topometry, topography, multi-model optimization.



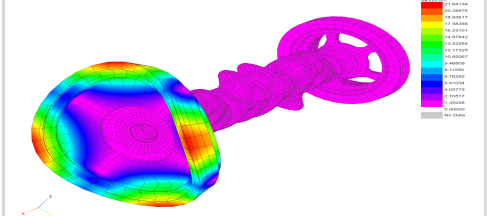
**Machine Learning Web App**  
Bayesian Optimization for nonlinear response optimization (SOL 400)



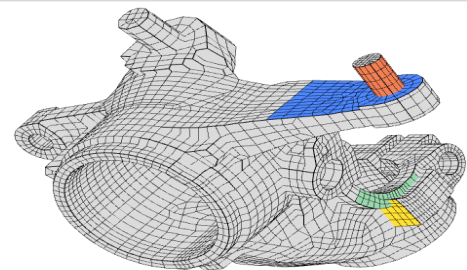
**PBMSECT Web App**  
Generate PBMSECT and PBRSECT entries graphically



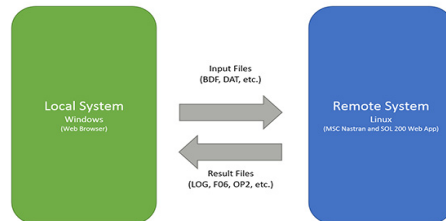
**Ply Shape Optimization Web App**  
Optimize composite ply drop-off locations, and generate new PCOMPG entries



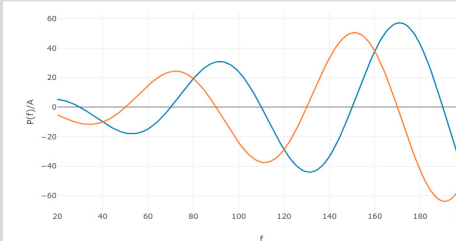
**Post-processor Web App**  
View MSC Nastran results in a web browser on Windows and Linux



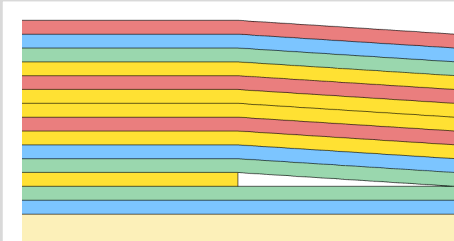
**Shape Optimization Web App**  
Use a web application to configure and perform shape optimization.



**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

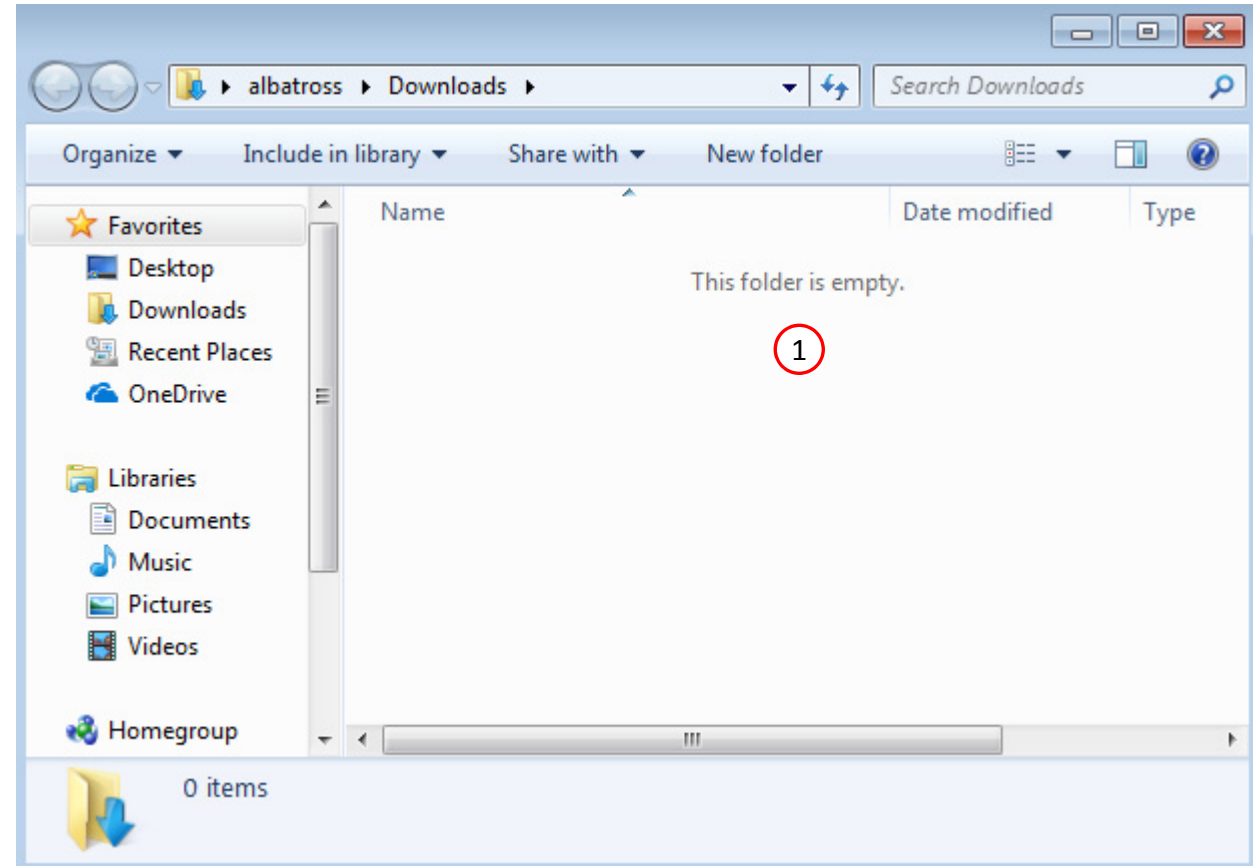


**HDF5 Explorer Web App**  
Create graphs (XY plots) using data from the H5 file

# 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

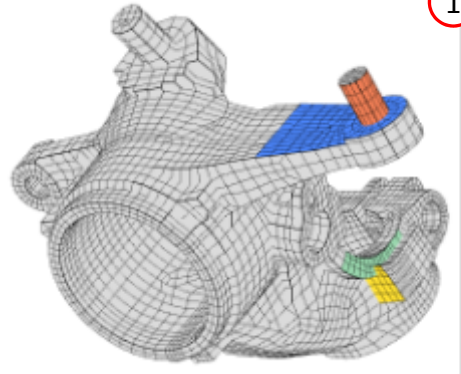
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.



# 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.

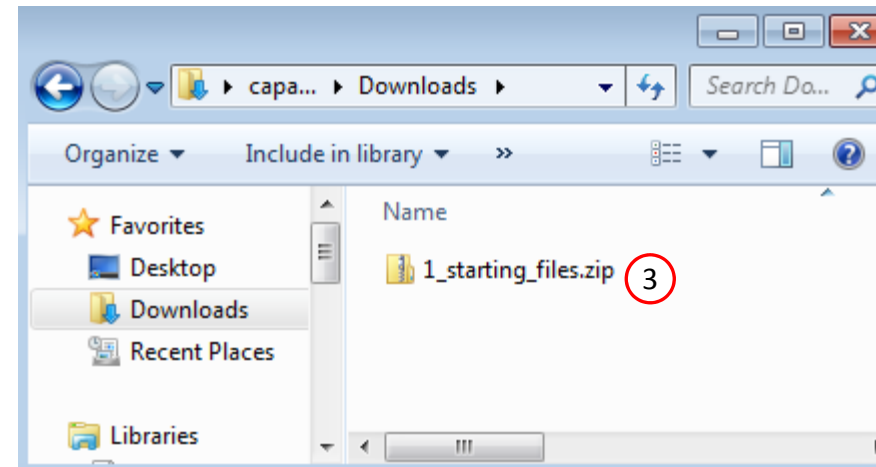


**1 Shape Optimization of a Steering Knuckle**

A steering knuckle is configured for a shape optimization. The goal is to minimize the mass while satisfying stress constraints. Twelve load cases are considered. Four regions of the model are allowed to expand or contract and define the shapes that will vary during the optimization. This tutorial is an advanced shape optimization tutorial and utilizes MSC Nastran's shape optimization capability.

Starting BDF Files: [Link](#) **2**

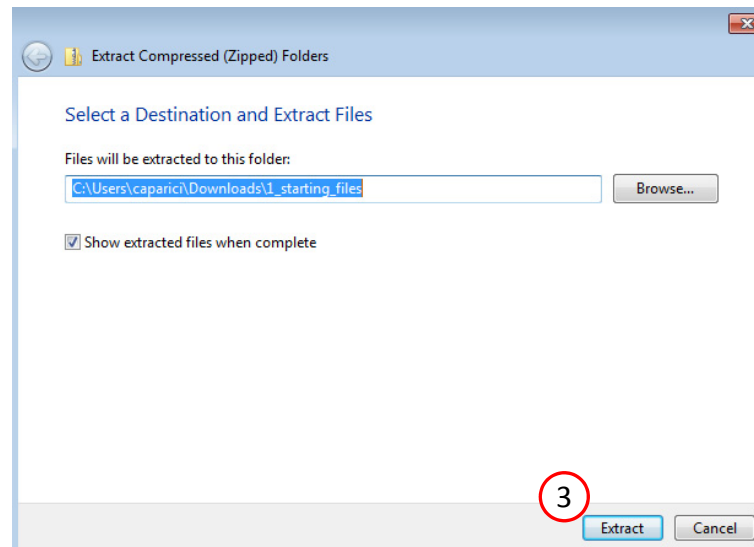
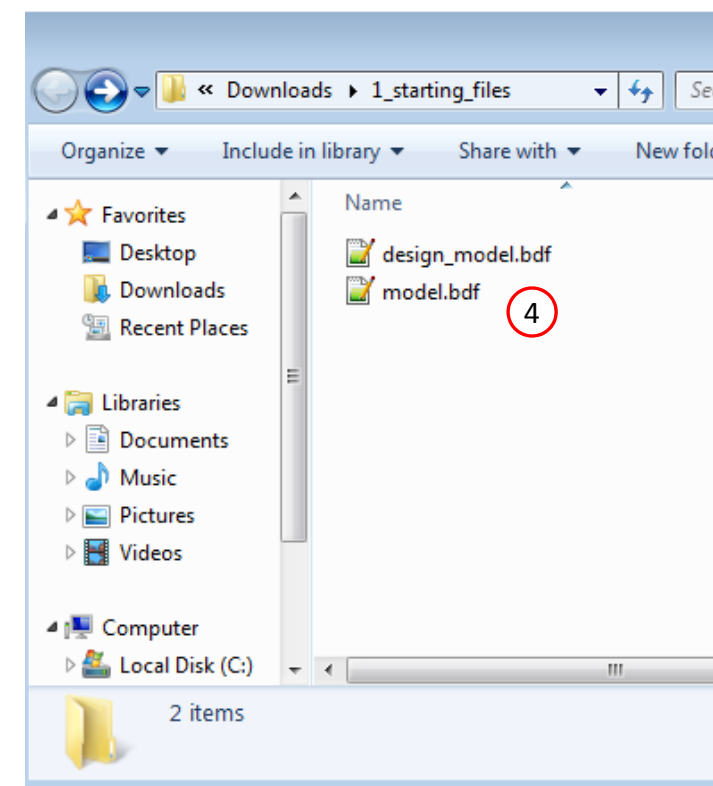
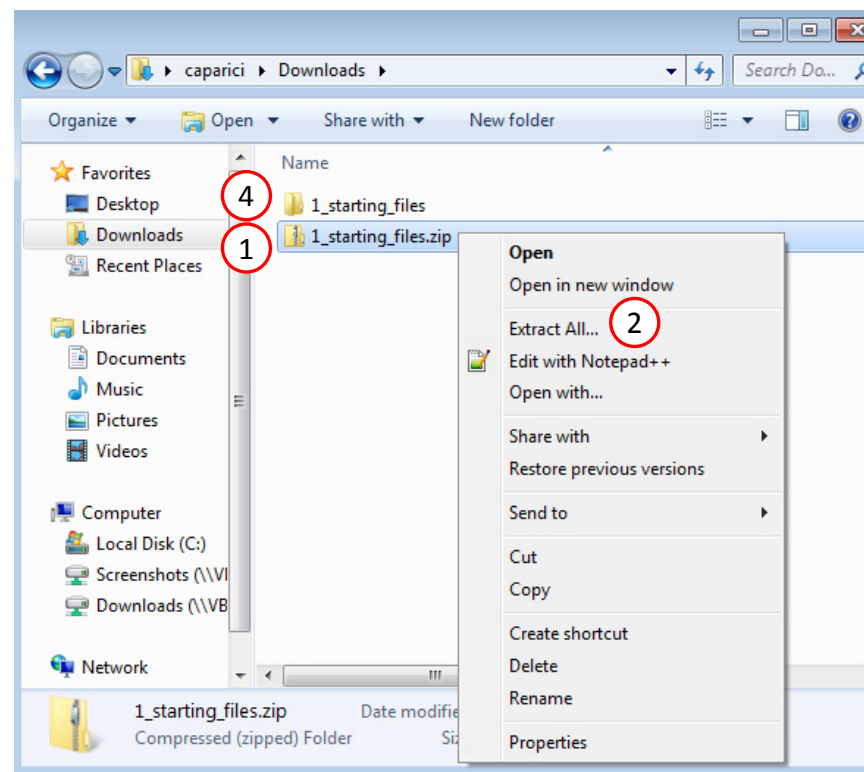
Solution BDF Files: [Link](#)



# 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

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





# Open the Correct Page

1. Click on the indicated link


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






# Open the Viewer

1. Navigate to the Optimization section
2. Click Viewer

[illegible]

Year	Number of Publications
2000	~2500
2001	~4200
2002	~1000
2003	~3800
2004	~3700
2005	~2800
2006	~4200
2007	~2500
2008	~2500
2009	~5500

[illegible]

Viewer (.des, .ply000i)

```

REQN% 1  DER(DERIV_P2_E,L,SDEN) = 7.00 * L**2 * SDEN0
          D2(L) = (DERIV_P2_E)**2;
          DER(LSD) = -D2 * M2P / SDEN0

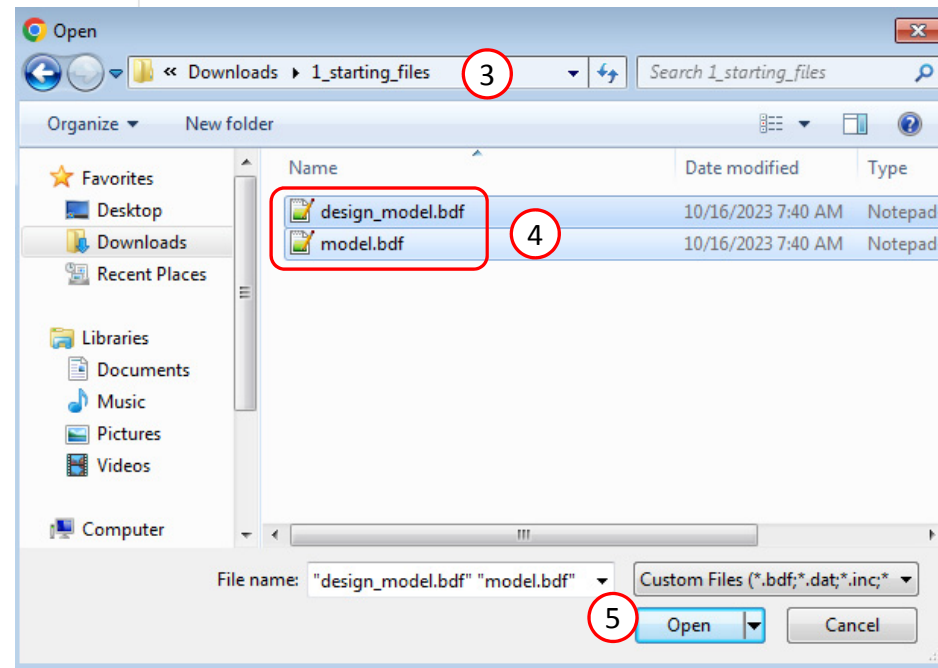
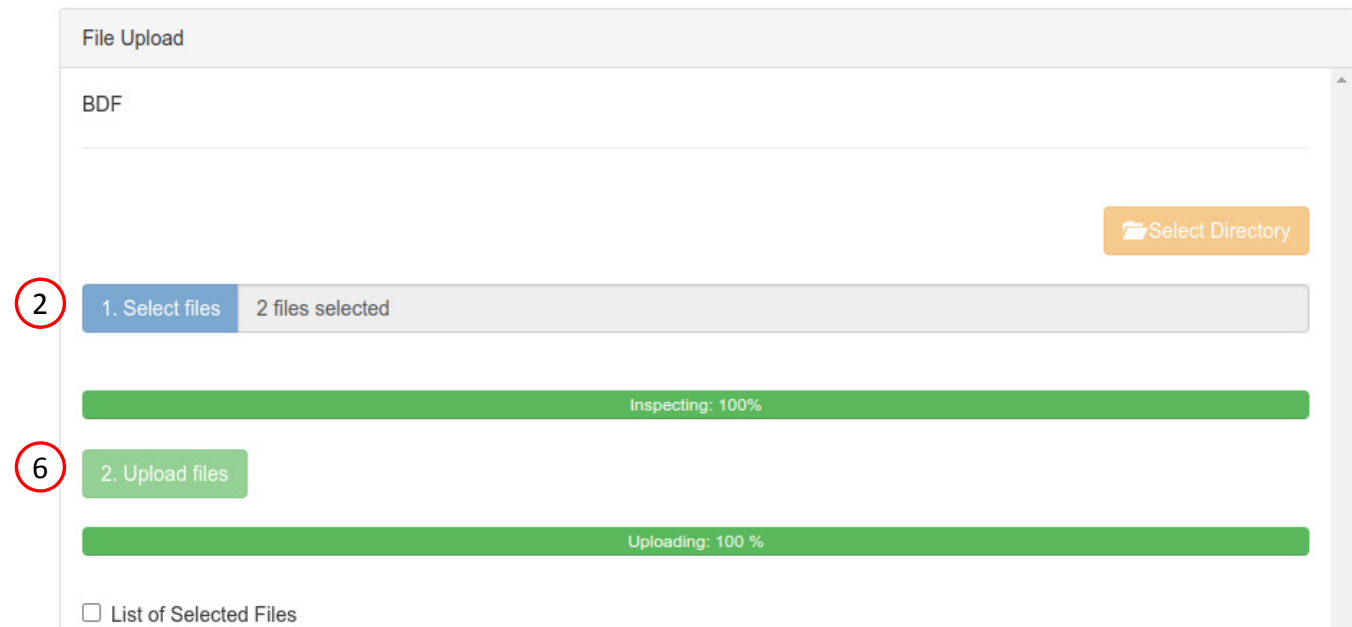
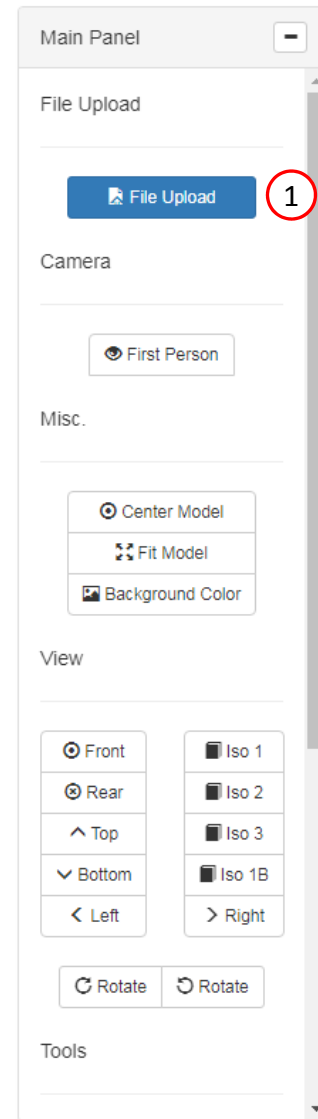
REQN% 7  T0660
          G(L,F) =
          7.00 * TS_007**2 * F(L) * SDEN00 * (3.3438 * Y(L)**271.007) * BURG(LINE) =
          -1.25 * G * SDEN0

```

2

# Import BDF Files

1. Click File Upload
2. Click Select files
3. Navigate to directory 1\_starting\_files
4. Select the indicated files
5. Click Open
6. Click Upload files



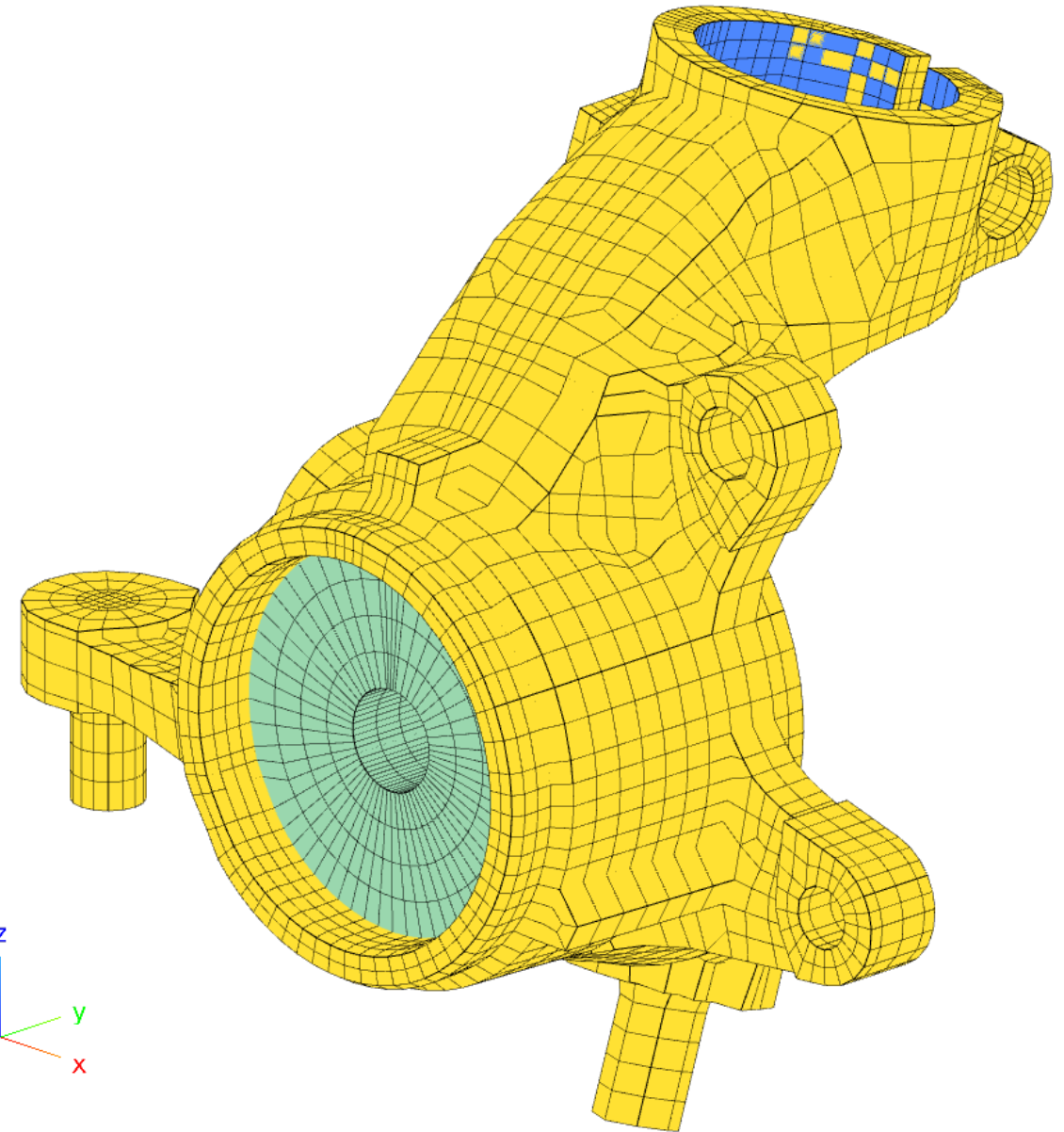
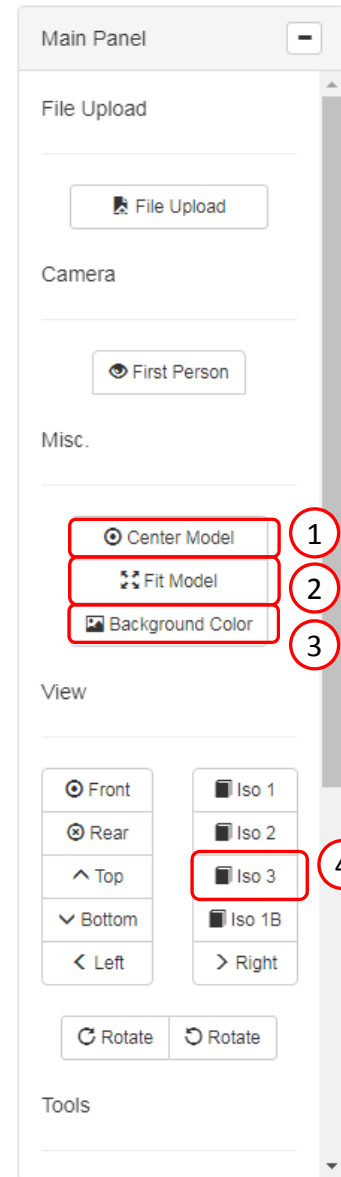
# Before Continuing

Throughout this exercise, the following buttons will be useful for viewing the model

1. Center Model
2. Fit Model
3. Background Color
4. View Iso 3

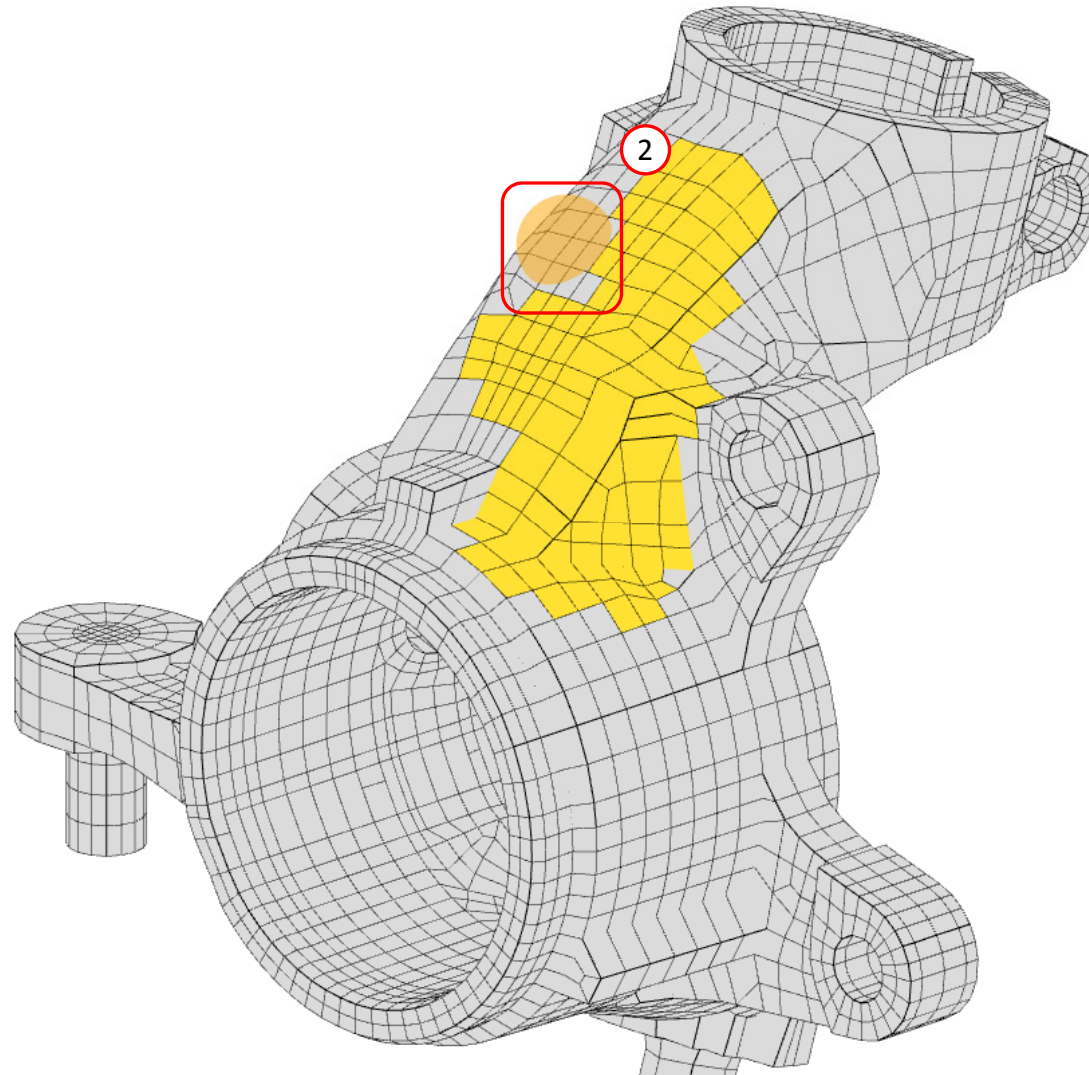
The following mouse combinations will orient the model.

- Rotation: Left Mouse Click + Mouse Drag
  - After rotation, it sometimes helps to click Center Model to restore the center of rotation
- Translation: Right Mouse Click + Mouse Drag
- Zoom: Mouse Scroll Wheel



# Before Continuing

1. The pick modes available include selecting and deselecting element faces and are accessed via the indicated buttons
2. When in a pick mode, a pick sphere appears. Left click and dragging the mouse will select or deselect the element faces.
3. To exit pick mode, click on the indicate button.
4. Alternatively, you can pick on the original pick mode button to exit pick model.



Shape

Select a PSOLID

Shapes
New Entries
Download

3
Pick mode on. Model rotation disabled. Click to exit pick mode.

Shapes - PSOLID 1

1) Select Shape Regions

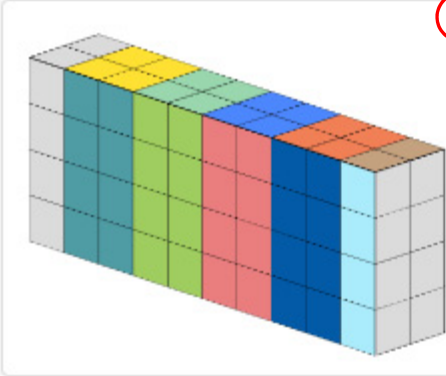
Picking Sphere Radius (Real World Units)
8.7578

+ Add Shape
Reset Table
+ Options

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	▼	Search	St	Search	
	□				
×	✓	y1	Yellow	LOAD4 ▼	<div> 1 4 </div>

# Before Continuing

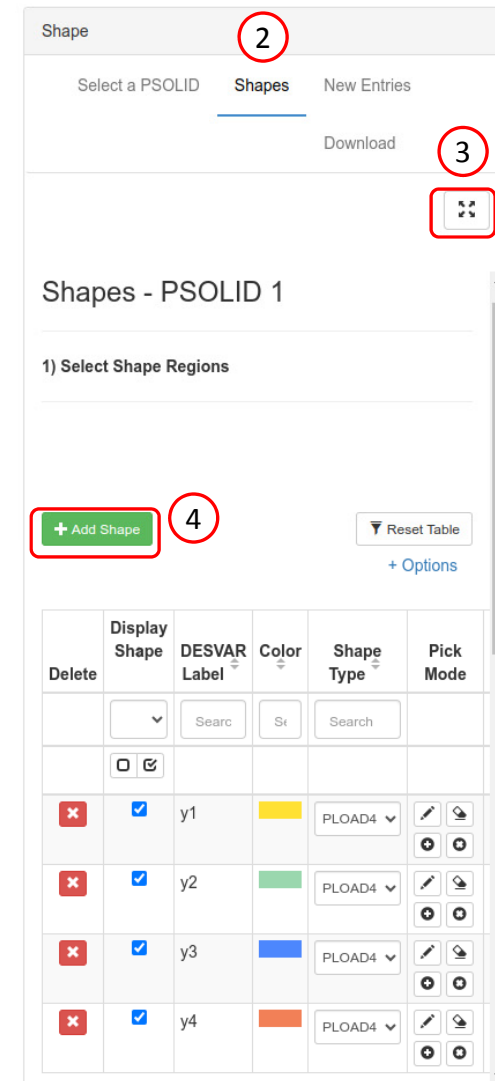
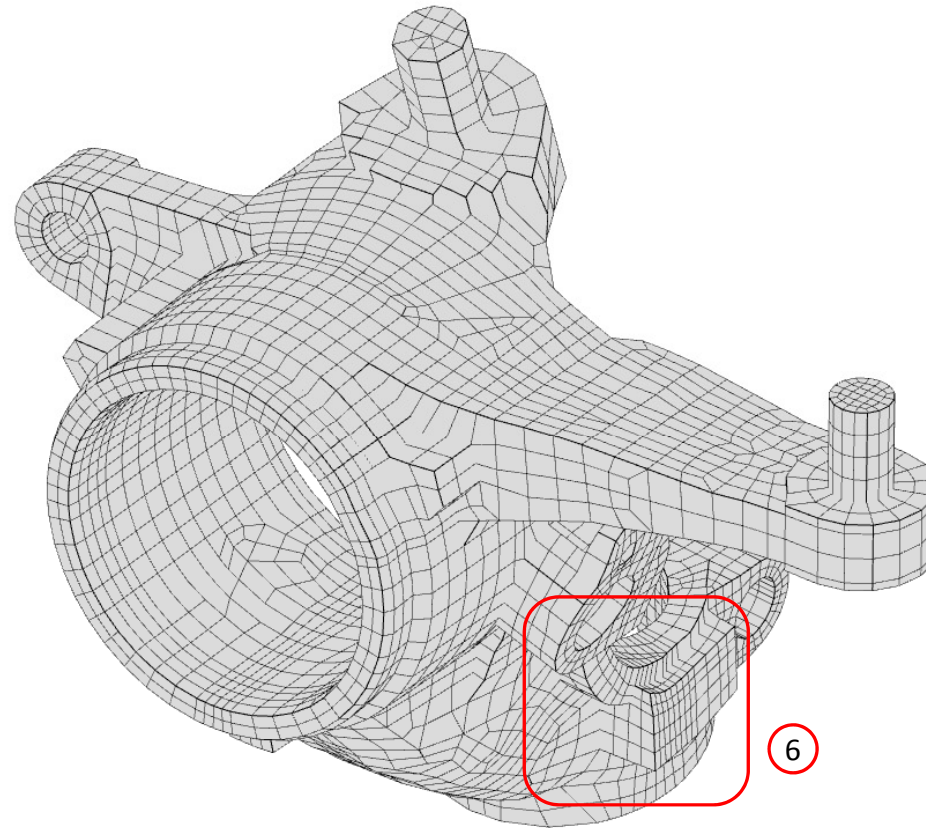
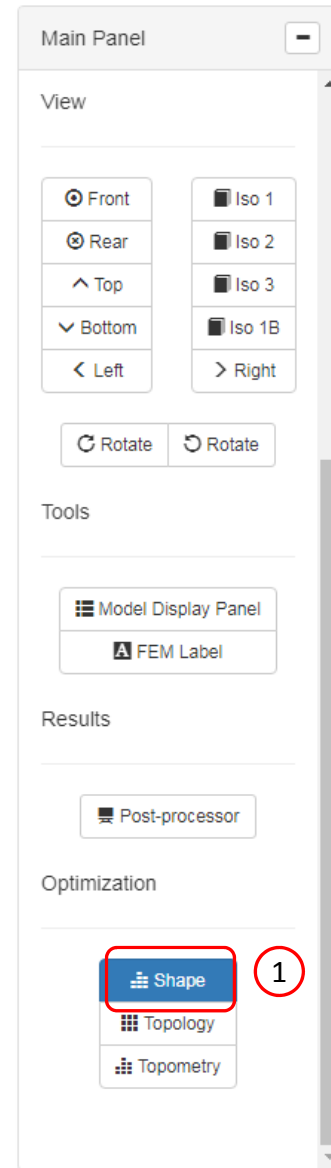
1. It is assumed that you have thoroughly covered the introductory workshop titled *Shape Optimization of a Cantilever Beam* that is found in the tutorials section of User's Guide. It is assumed you have an understanding of how to create, edit or remove shapes, which is covered in great detail in workshop *Shape Optimization of a Cantilever Beam*.

	Title and Description
	<p><b>1 Shape Optimization of a Cantilever Beam</b></p> <p>This tutorial is an introduction to MSC Nastran's Shape Optimization capability.</p> <p>A cantilever beam is configured for a shape optimization. The goal is to minimize the mass while satisfying stress constraints. Specified regions of the beam are allowed to expand or contract and define the shapes that will vary during the optimization. This tutorial discusses the following concepts: auxiliary models, shape basis vectors, scaling shape basis vectors, configuring variable bounds, strategies to prevent mesh distortions, results interpretation, updating the model, and more.</p> <p>Starting BDF Files: <a href="#">Link</a> Solution BDF Files: <a href="#">Link</a></p>



# Open the Shape Panel

1. Click Shape
2. Click Shapes
3. Click the Toggle button to adjust the width of the panel
4. Click Add Shape 4 times to create 4 shapes
5. Rotate the model to align to the displayed orientation
6. Zoom in to the indicated region



# Create Shapes

1. If needed, click the Toggle button to adjust the width of the panel
2. Use the indicated buttons to create the indicated shape regions
3. The size of the pick sphere may be adjusted in the indicated input box. A size of 1.0 is used.

The screenshot displays the Hexagon software interface for creating shapes on a 3D model. The 3D view on the left shows a grey mesh with a yellow rectangular region and a green curved region. The right-hand panel contains the 'Shape' tool settings.

**Shape Panel:**

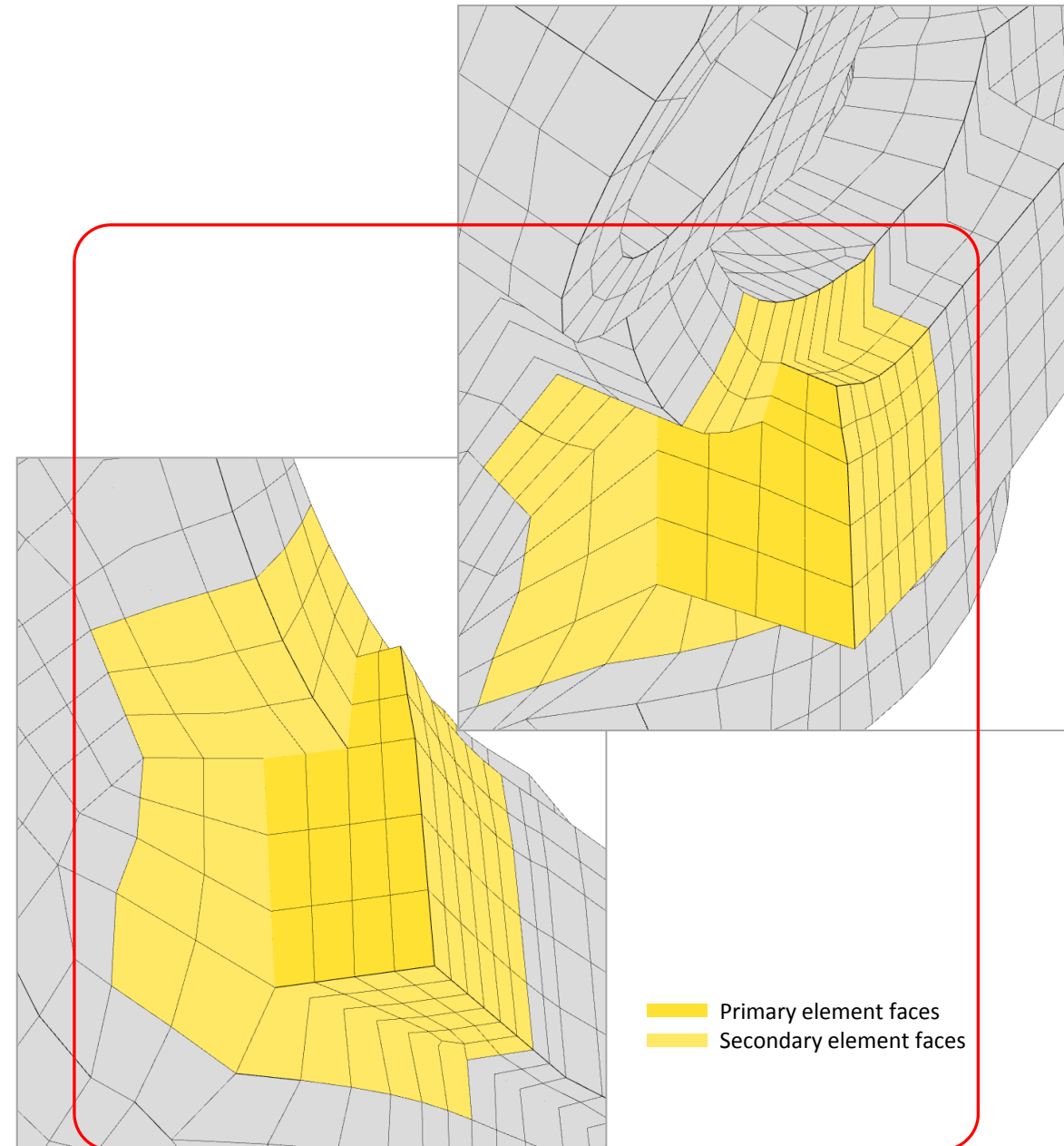
- Select a PSOLID** | **Shapes** | **New Entries**
- Download** (1)
- Pick mode on. Model rotation disabled. Click to exit pick mode.** (2)
- 1) Select Shape Regions**
- Picking Sphere Radius (Real World Units)** (3): 1.0
- + Add Shape** | **Reset Table** | **+ Options**
- Download Test Aux. Model**
- Output SES For PSOLID Group** | **Download BNDGRIDS**
- Auto Manage DESVARs**

**Table:**

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	y1	Yellow	PLOAD4	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	y2	Green	PLOAD4	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	y3	Blue	PLOAD4	<input checked="" type="checkbox"/>

# Configure Free Regions

1. Use the indicated buttons to select the secondary faces



Shape

Select a PSOLID   **Shapes**   New Entries

Download

Pick mode on. Model rotation disabled. Click to exit pick mode.

1) Select Shape Regions

Picking Sphere Radius (Real World Units)

1.0

+ Add Shape   Reset Table   + Options

Download Test Aux. Model   Output SES For PSOLID Group   Download BNDGRIDS

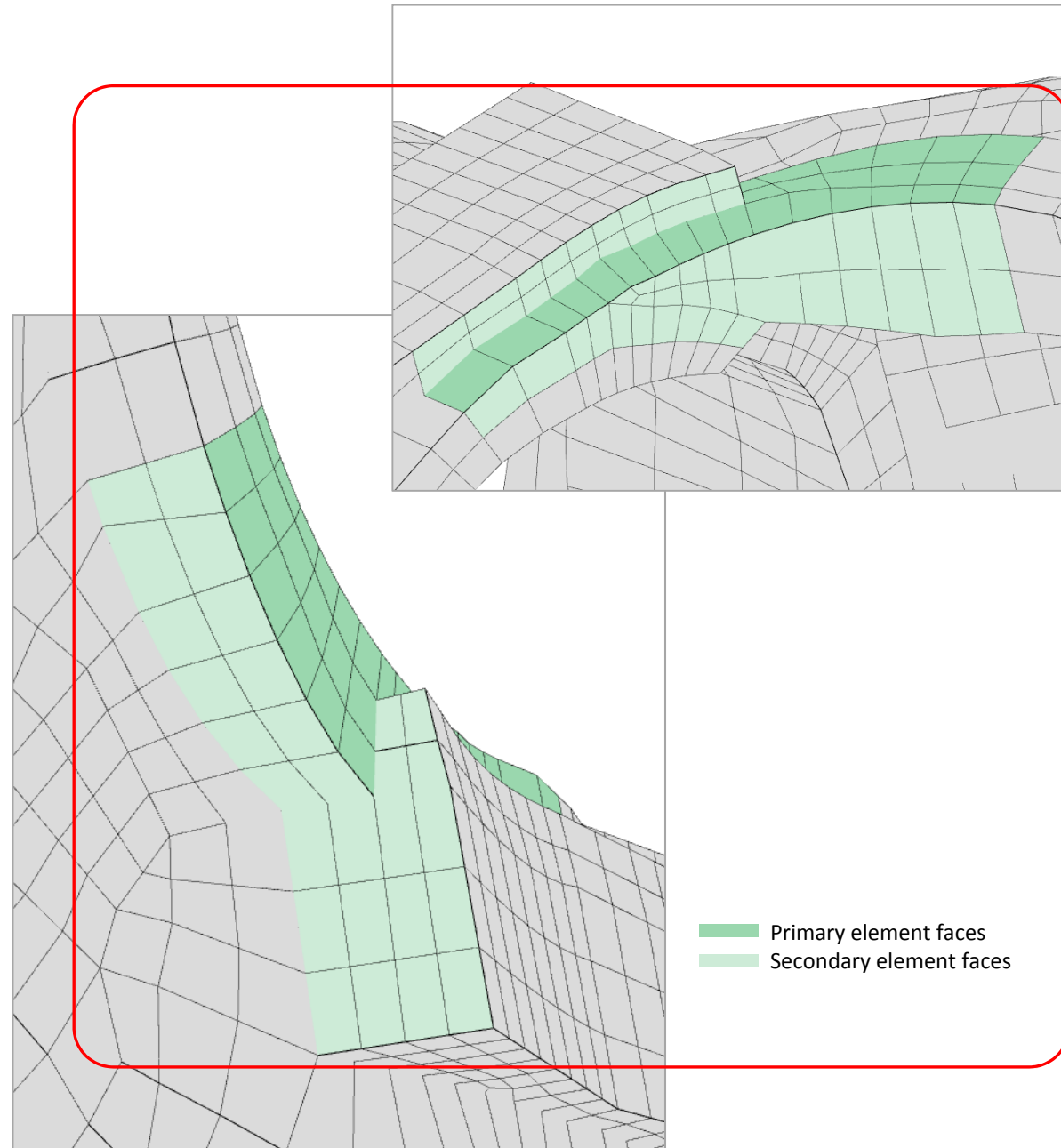
Auto Manage DESVARs

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	▼	Search	St	Search	
	<input type="checkbox"/> <input checked="" type="checkbox"/>				
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y1	Yellow	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y2	Green	PLOAD4 ▼	<input type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y3	Blue	PLOAD4 ▼	<input type="checkbox"/> <input type="checkbox"/>



# Configure Free Regions

1. Use the indicated buttons to select the secondary faces



Shape

Select a PSOLID

**Shapes**

New Entries

Download

Pick mode on. Model rotation disabled. Click to exit pick mode.

1) Select Shape Regions

Picking Sphere Radius (Real World Units)

1.0

+ Add Shape

Reset Table

+ Options

Download Test Aux. Model

Output SES For PSOLID Group

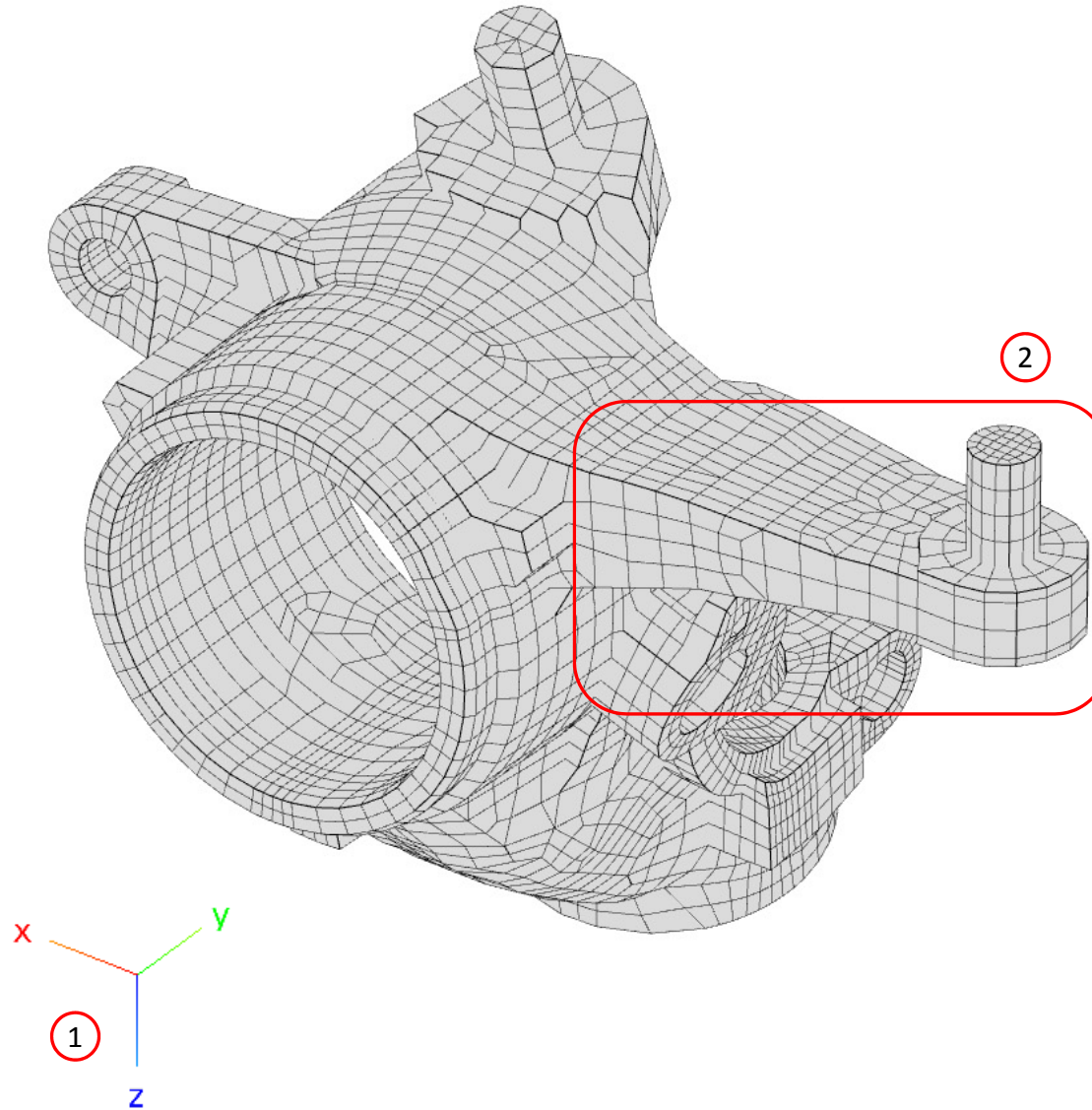
Download BNDGRIDs

Auto Manage DESVARs

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	▼	Search	St	Search	
	<input type="checkbox"/> <input checked="" type="checkbox"/>				
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y1	Yellow	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y2	Green	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y3	Blue	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>

# Create Shapes

1. Orient the shape as shown
2. Zoom in to the indicated region



Shape

Select a PSOLID **Shapes** New Entries

Download

Shapes - PSOLID 1

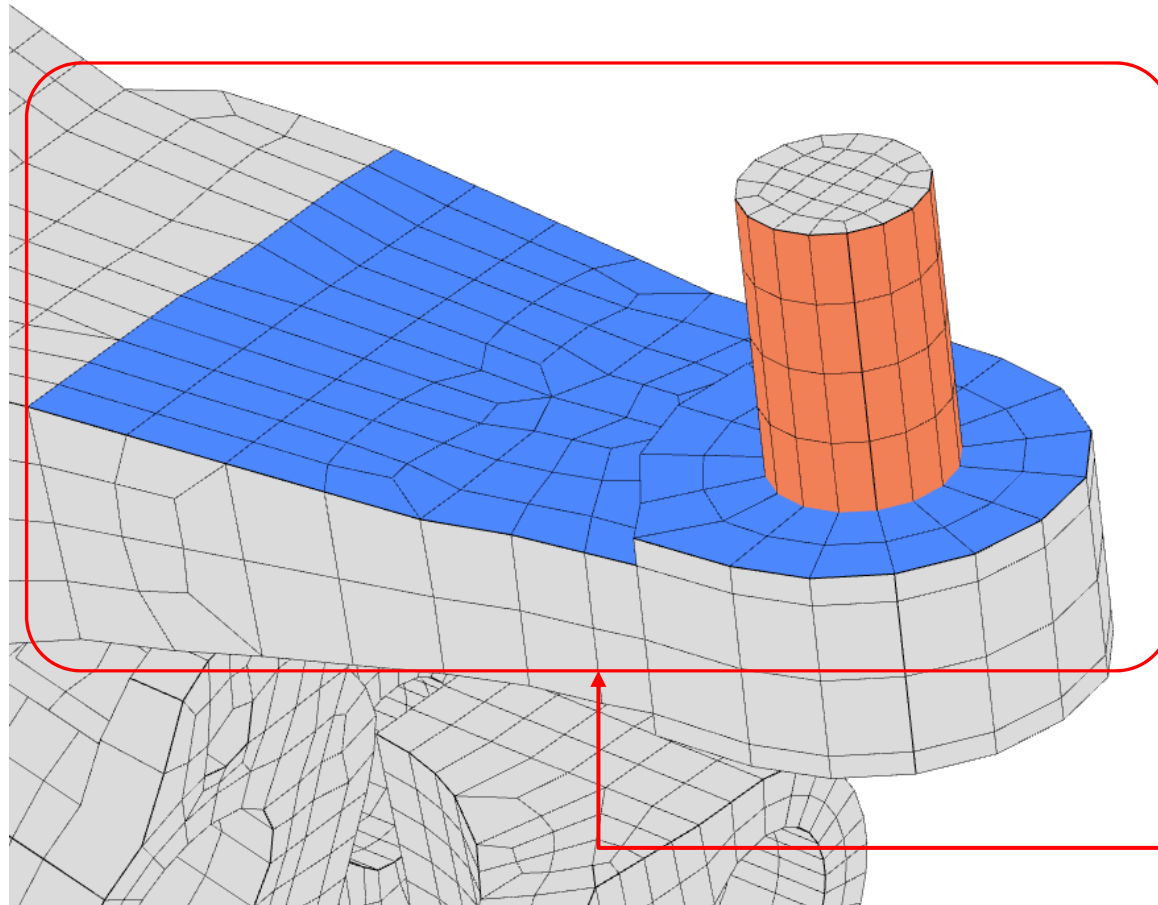
1) Select Shape Regions

+ Add Shape Reset Table + Options

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	<input type="checkbox"/>	Search	St	Search	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y1		PLOAD4	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y2		PLOAD4	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y3		PLOAD4	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y4		PLOAD4	<input checked="" type="checkbox"/>

# Select Secondary Faces

1. Use the indicated buttons to create the indicated shape regions



Shape

Select a PSOLID   **Shapes**   New Entries

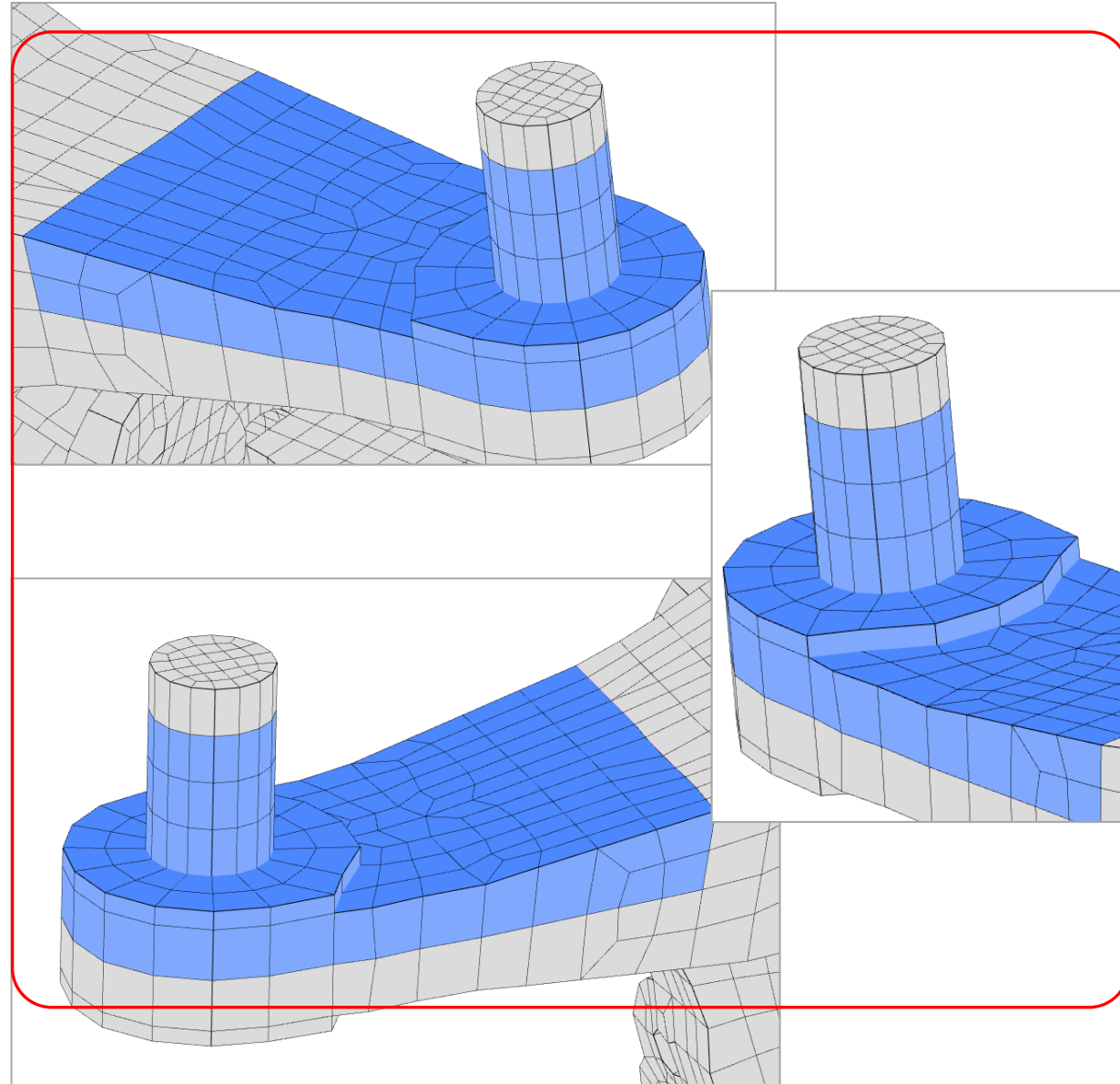
Download

Pick mode on. Model rotation disabled. Click to exit pick mode.

delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	<input type="button" value="v"/>	<input type="text" value="Search"/>	<input type="text" value="St"/>	<input type="text" value="Search"/>	
	<input type="checkbox"/>				<input type="checkbox"/>
<input type="button" value="x"/>	<input type="checkbox"/>	y1		PLOAD4	<input type="button" value="pick"/> <input type="button" value="delete"/>
<input type="button" value="x"/>	<input type="checkbox"/>	y2		PLOAD4	<input type="button" value="pick"/> <input type="button" value="delete"/>
<input type="button" value="x"/>	<input checked="" type="checkbox"/>	y3		PLOAD4	<input type="button" value="pick"/> <input type="button" value="delete"/>
<input type="button" value="x"/>	<input checked="" type="checkbox"/>	y4		PLOAD4	<input type="button" value="pick"/> <input type="button" value="delete"/>

# Configure Free Regions

1. Use the indicated buttons to select the secondary faces



Shape

Select a PSOLID   **Shapes**   New Entries

Download

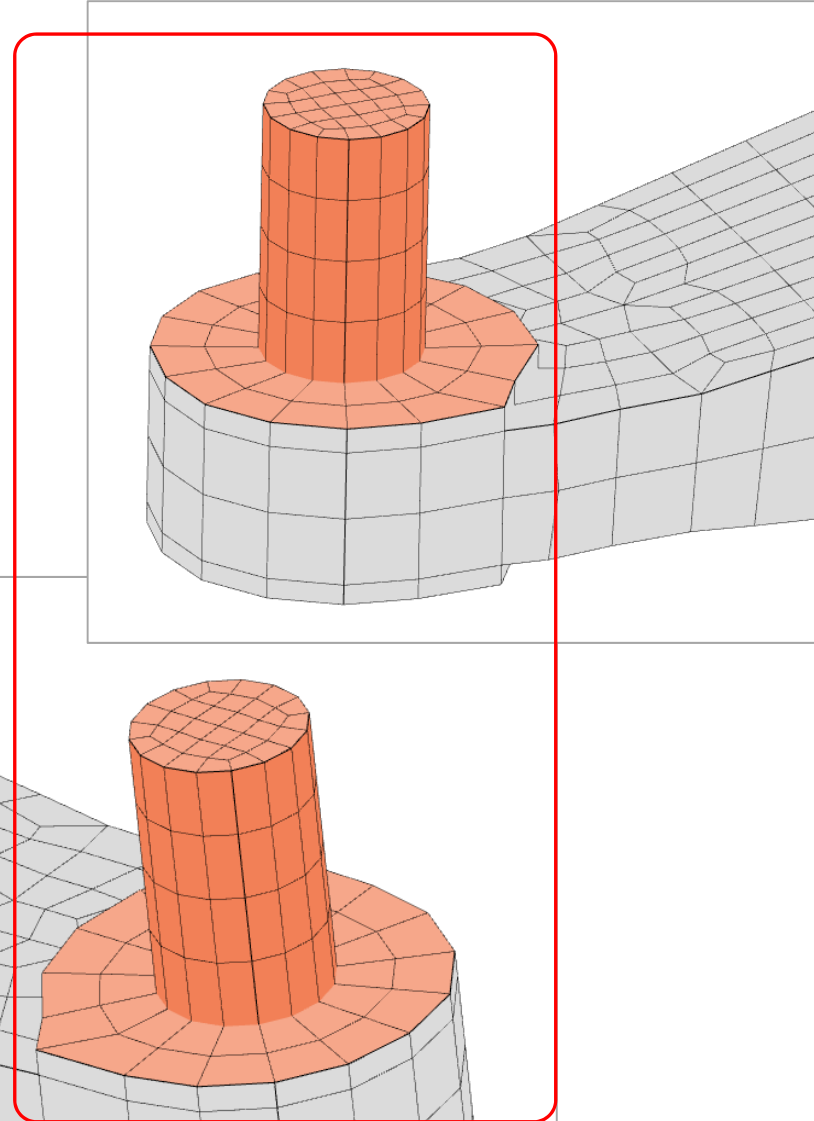
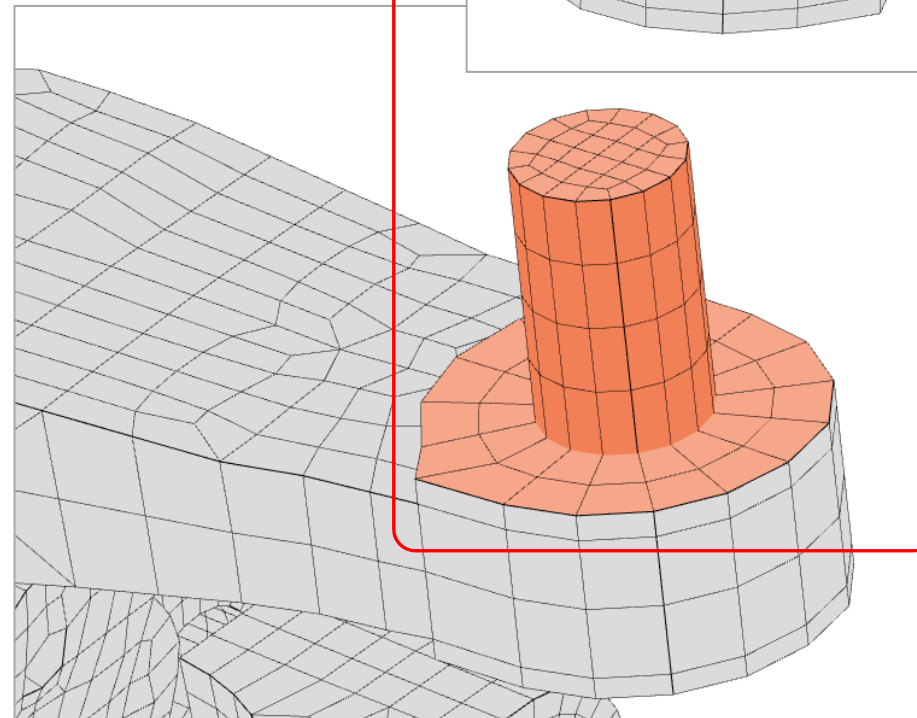
Pick mode on. Model rotation disabled. Click to exit pick mode.

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	▼	Search	St	Search	
	<input type="checkbox"/> <input checked="" type="checkbox"/>				
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y1	Yellow	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y2	Green	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y3	Blue	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y4	Orange	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>

Primary element faces  
Secondary element faces

# Configure Free Regions

1. Use the indicated buttons to select the secondary faces



Primary element faces  
Secondary element faces

Shape

Select a PSOLID   **Shapes**   New Entries

Download

Pick mode on. Model rotation disabled. Click to exit pick mode.

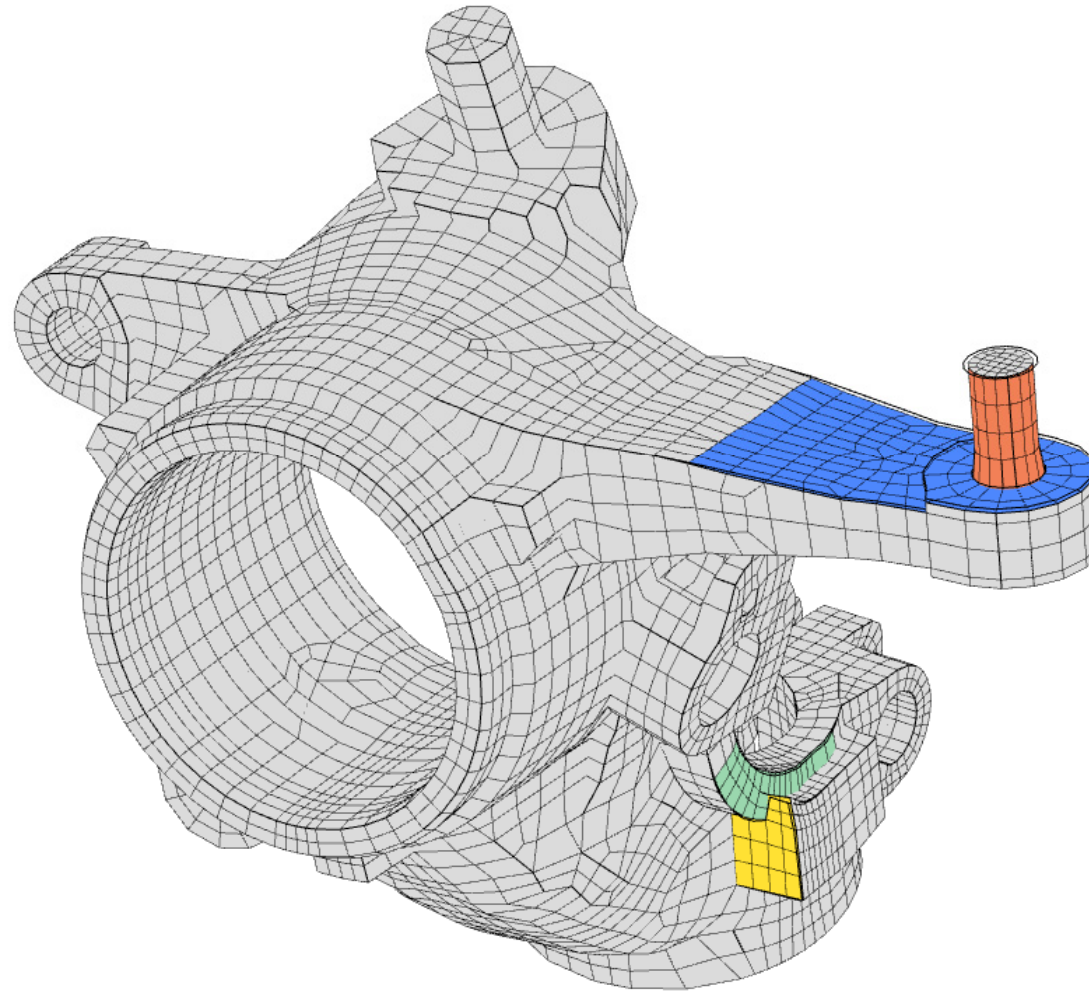
Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode
	▼	Search	St	Search	
	<input type="checkbox"/> <input checked="" type="checkbox"/>				
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y1	Yellow	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y2	Green	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	y3	Blue	PLOAD4 ▼	<input checked="" type="checkbox"/> <input type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	y4	Orange	PLOAD4 ▼	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/>

1



# Run MSC Nastran to Generate Shapes

1. Scroll to section 2) Generate Shapes
2. Click Run MSC Nastran
3. Continue after the status reads Complete. The duration of this MSC Nastran run will depend on the size of the model.
4. Optional – Click Display F06 Section to inspect the F06 output.



Shape

Select a PSOLID
Shapes
New Entries
Download

Preview
update
complete

1 2) Generate Shapes

Download Test Aux. Model
Run MSC Nastran
Display F06 Section

3 Complete

3) Preview Shape Changes

Display Preview Shape
Look Inside (Experimental)
Reset Table

DESVAR Label	Color	Include Shape	Shape Type	Test Δy	Δy Lower Bound	Δy Upper Bound
Search	Search	▼	Search			
		☐ ☑		↓		
y1	Yellow	☑	PLOAD4	-1.0	-6.	5.
y2	Green	☑	PLOAD4	-1.0	-6.	5.

# DVBSHAP

1. After MSC Nastran is complete, the web app will update the scaling factor for each shape defined by DVBSHAP entries. The scaling factor is set in field SF1 (field 5) of the DVBSHAP entry.

- If the scaling factors are 1.0, which will happen if MSC Nastran was not executed, it is suggested that you manually supply ideal scaling factors.

File: design\_shapes\_psolid\_1.bdf

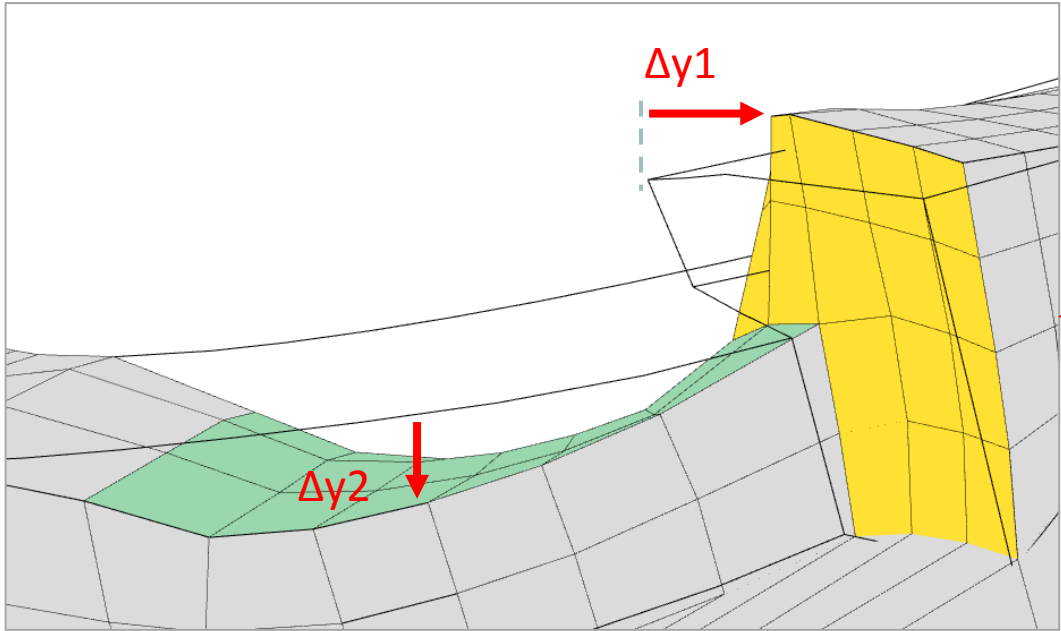
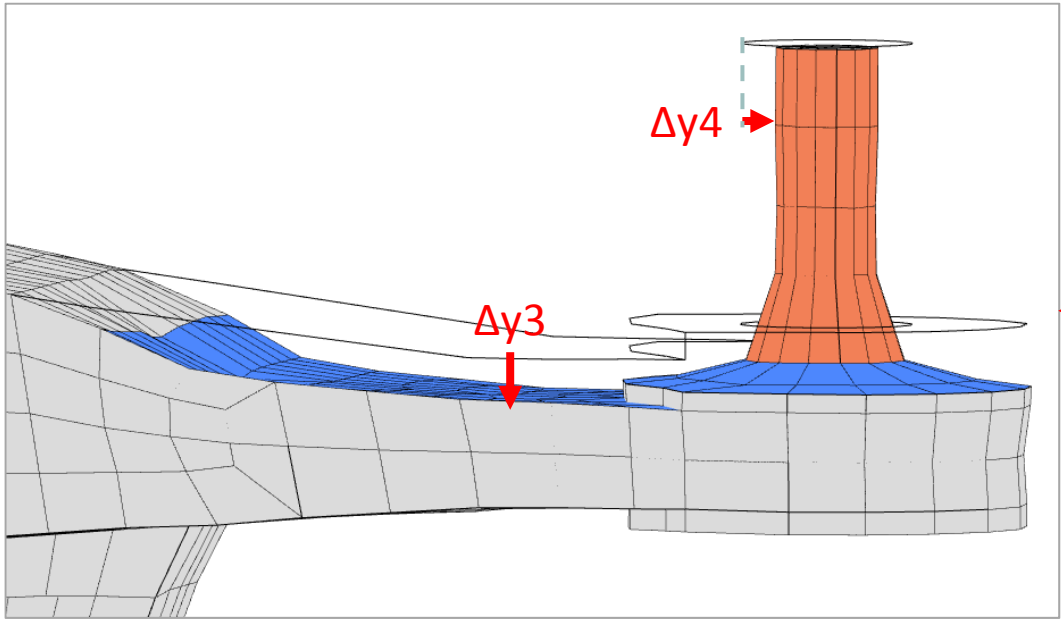
\$	1	2	3	4	5	6	7	8	9	10
DVBSHAP	200001	1	1		2.466e-2					
DVBSHAP	200002	1	2		5.601e-2					
DVBSHAP	200003	1	3		5.564e-2					
DVBSHAP	200004	1	4		.1363515					
DESVAR	200001	y1	10.	4.	15.					
DESVAR	200002	y2	10.	4.	15.					
DESVAR	200003	y3	10.	4.	13.					
DESVAR	200004	y4	10.	7.	12.					
BNDGRID	123	1	2	3	4	5	6	7		
	8	9	10	14	15	17	18	19		
	21	22	23	24	25	27	28	29		
	30	31	32	33	34	35	36	37		
	39	40	41	42	43	44	45	46		
	47	48	50	51	52	53	54	55		
	56	57	58	59	65	66	67	68		
	69	70	71	77	78	84	85	86		
	87	88	89	90	91	92	93	97		
	98	99	109	112	113	114	119	126		
	128	129	135	139	143	144	150	151		

# Shape Change Preview

Previewing the shape change is an important step in configuring a shape optimization. A preview of the shape change is inspected in this section.

1. Use trial and error to determine which combinations of  $\Delta y$  yield mesh distortions. Below is an example of  $\Delta y$  value combinations that have a high probability of NOT yielding mesh distortions.  $\Delta y$  has real units of length.
2. The indicated button is sometimes useful for inspecting the interior for possible mesh distortions.

$\Delta y_i$	Lower Bound	Upper Bound
$\Delta y_1$	-6	5
$\Delta y_2$	-6	5
$\Delta y_3$	-6	3
$\Delta y_4$	-3	2



Shape

Select a PSOLID

Shapes

New Entries

Download

Run MSC Nastran

Display F06 Section

3) Preview Shape Changes

Display Preview Shape

Look Inside (Experimental)

Reset Table

DESVAR Label	Color	Include Shape	Shape Type	Test $\Delta y$	$\Delta y$ Lower Bound	$\Delta y$ Upper Bound
		<input type="checkbox"/>				
y1		<input checked="" type="checkbox"/>	PLOAD4	-6.	-6.	5.
y2		<input checked="" type="checkbox"/>	PLOAD4	-6.	-6.	5.
y3		<input checked="" type="checkbox"/>	PLOAD4	-6.	-6.	3.
y4		<input checked="" type="checkbox"/>	PLOAD4	-3.	-3.	2.



# Adjustment of Variable Bounds

1. Click the toggle button 2 times to restore the width of the panel
2. Return to section 1) Select Shape Regions
3. Use the  $\Delta y$  values determined on the previous page to update the lower and upper bounds in the indicated table.

$\Delta y_i$	Lower Bound	Upper Bound
$\Delta y_1$	-6	5
$\Delta y_2$	-6	5
$\Delta y_3$	-6	3
$\Delta y_4$	-3	2

Shape


Select a PSOLID

Shapes

New Entries

Download

1



2

1) Select Shape Regions

+ Add Shape

Reset Table

+ Options

Delete	Display Shape	DESVAR Label	Color	Shape Type	Pick Mode	$\Delta y$ Lower Bound	$\Delta y$ Upper Bound
	<div><div></div><div></div></div>	<div>Search</div>	<div>Search</div>	<div>Search</div>			
	<div><div></div><div></div></div>					<div>3</div> <div></div>	<div></div> <div></div>
<div></div>	<div></div>	y1	<div></div>	<div>PLOAD4</div>	<div><div></div><div></div></div>	<div>-6.</div>	<div>5.</div>
<div></div>	<div></div>	y2	<div></div>	<div>PLOAD4</div>	<div><div></div><div></div></div>	<div>-6.</div>	<div>5.</div>
<div></div>	<div></div>	y3	<div></div>	<div>PLOAD4</div>	<div><div></div><div></div></div>	<div>-6.</div>	<div>3.</div>
<div></div>	<div></div>	y4	<div></div>	<div>PLOAD4</div>	<div><div></div><div></div></div>	<div>-3.</div>	<div>2.</div>

# Inspect New Entries

1. Click New Entries
2. Click the toggle button 2 times to expand the width of the panel.
3. The changes that will be performed to the bulk data files are listed.

Shape

Select a PSOLID   Shapes   **New Entries**   Download

1

2

## New Entries

Before

```
BEGIN BULK
```

After

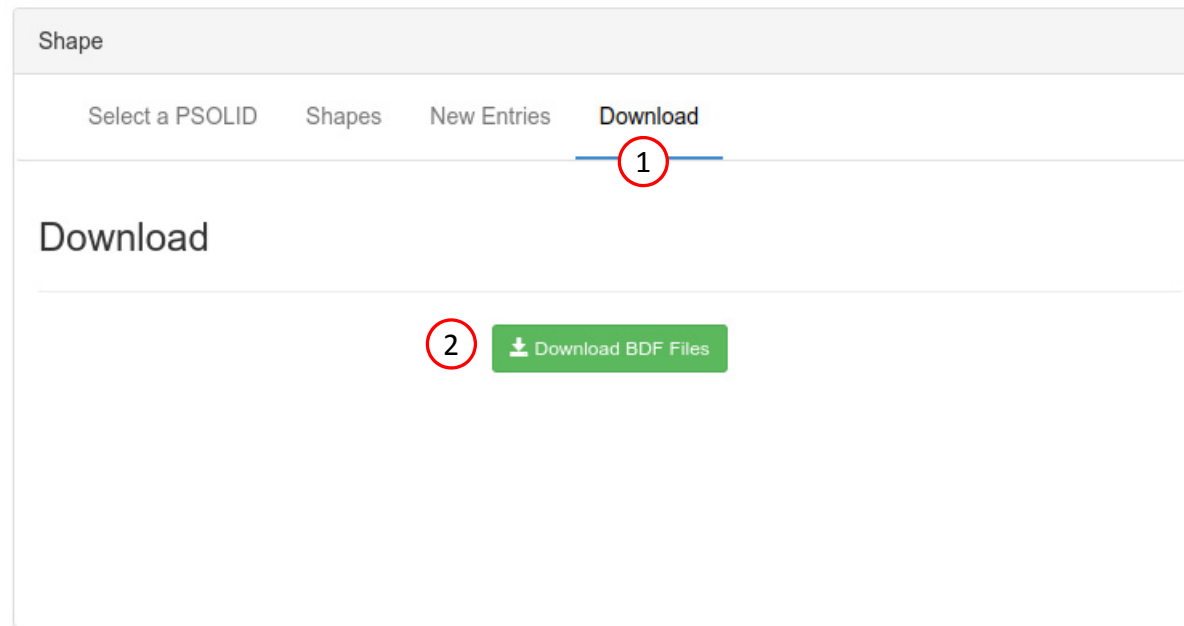
```
$assign userfile = 'optimization_results.csv', status = unknown,
$form = formatted, unit = 52
NASTRAN SYSTEM(316)=19
$
SOL 200
CEND
ECHO= PUNCH(NEWBULK)
$
$ Elements for group : KNUCKLE_ONLY
SET 1 = 51,52,54,61,62,63,65,67,68,69,72,74,79,80,82,83,84,85,88,89,
92,94,95,96,135,139,148,150,151,154,156,157,165,166,172,173,176,182,184,
185,216,223,228,230,231,234,235,236,242,243,246,247,254,256,261,262,285,
287,288,289,291,296 THRU 300,303 THRU 311,314 THRU 320,323,324,341,
342 THRU 378,395 THRU 419,421,424,425,426,427,431,434,435,436,440,441,
449,452,453,454,470 THRU 503,520 THRU 536,538,540,541,543,545,549,550,
556,558,561,562,566,567,575 THRU 610,613 THRU 621,632 THRU 649,664,
665 THRU 678,680,681,683,685,688,691,692,696,699,704,705,714 THRU 744,
754,755,767 THRU 785,794,795,796,797,800 THRU 853,862 THRU 873,875,876,
877,879,882,884,887,888,892,893,901,902,903,908,909,913 THRU 939,942,
944,946 THRU 951,966 THRU 987,994 THRU 1114,1117 THRU 1125,1127,1128,
1129,1130,1132,1136,1137,1139,1140,1145,1146,1153,1154,1156,1161,1162,
1166 THRU 1195,1198,1199,1200,1201,1203 THRU 1210,1214 THRU 1316,1320,
1321 THRU 1347,1349,1350,1352,1354,1356,1358,1360,1361,1368,1370,1371,
1374,1375,1379,1380,1384 THRU 1442,1444 THRU 1535,1542 THRU 1547,1549,
1550 THRU 1595,1597,1598,1602,1603,1607,1608,1610,1612,1615,1616,1617,
1623 THRU 1679,1681,1682,1685,1687 THRU 1750,1758 THRU 1879,1881,1882,
1883,1887,1888,1889,1894,1896,1897,1901 THRU 1905,1907 THRU 1961,1963,
1965,1966,1971,1972,1976 THRU 2019,2023 THRU 2127,2129,2130,2134,2135,
2136,2137,2142,2144,2145,2146,2150 THRU 2214,2216,2217,2219,2220,2225,
2226,2233 THRU 2353,2355,2357,2359,2365,2367,2368,2369,2370,2374,
2375 THRU 2430,2432,2433,2434,2437,2439,2440,2443,2444,2445,2452,
2453 THRU 2578,2580,2582,2584,2590,2591,2592,2597 THRU 2626,2628,2629.
```

3

# Export New BDF Files

1. Click Download
2. Click on Download BDF Files

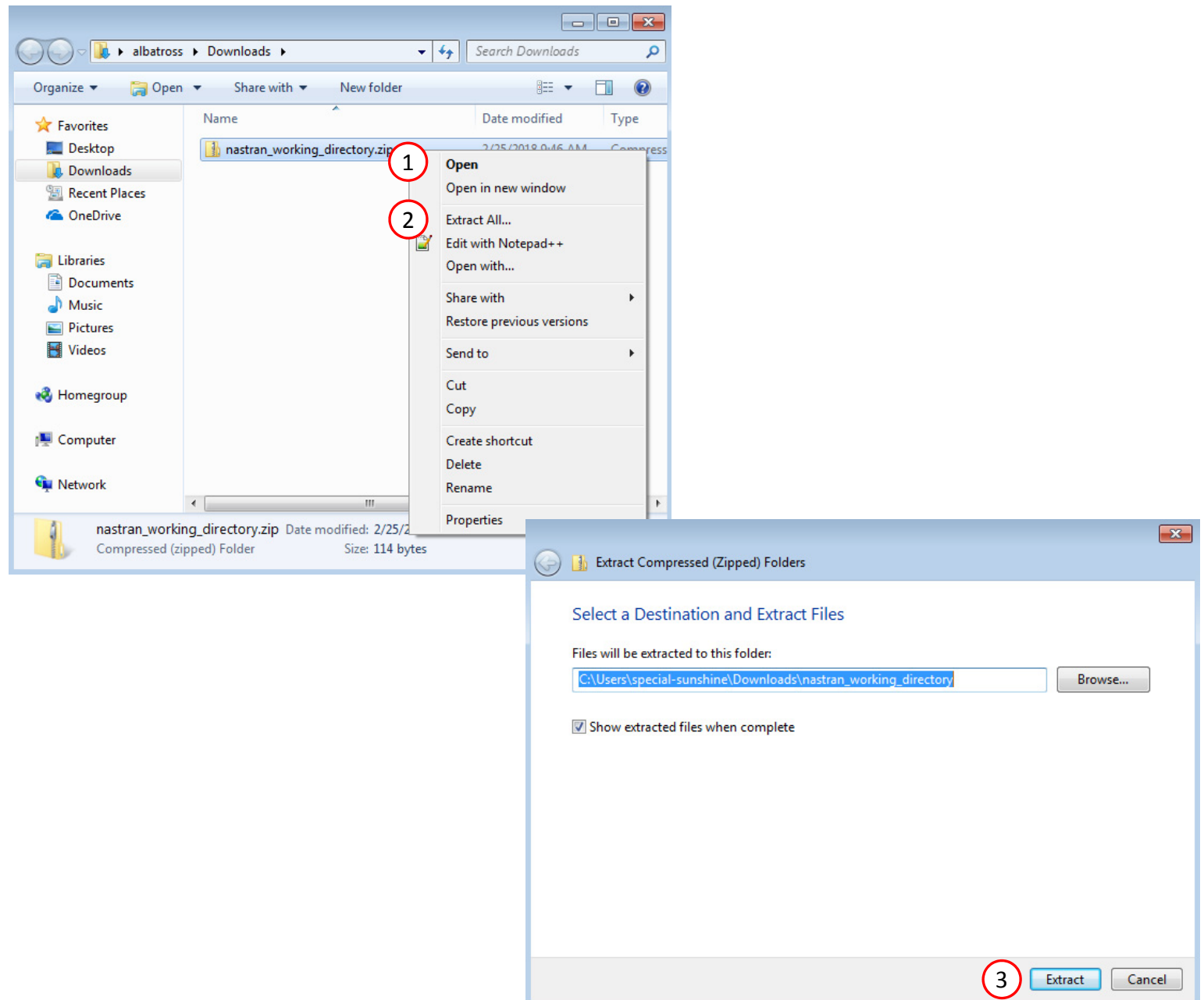
- When the download button is clicked a new file named “nastran\_working\_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran\_working\_directory (1).zip”



# Perform the Optimization with Nastran SOL 200

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

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



# Perform the Optimization with Nastran SOL 200

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

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

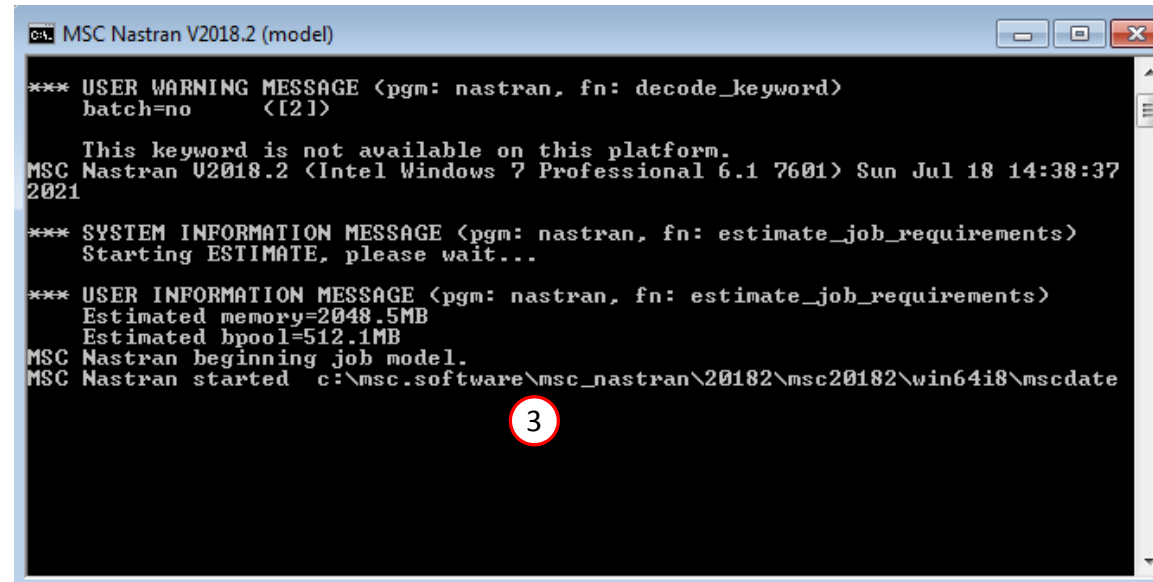
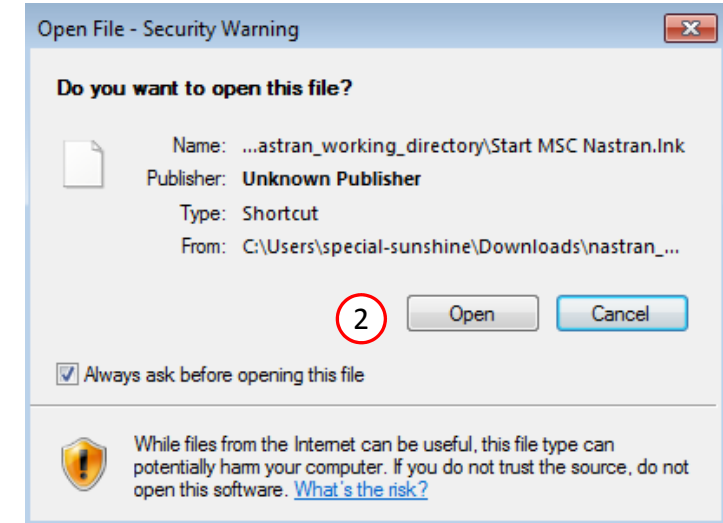
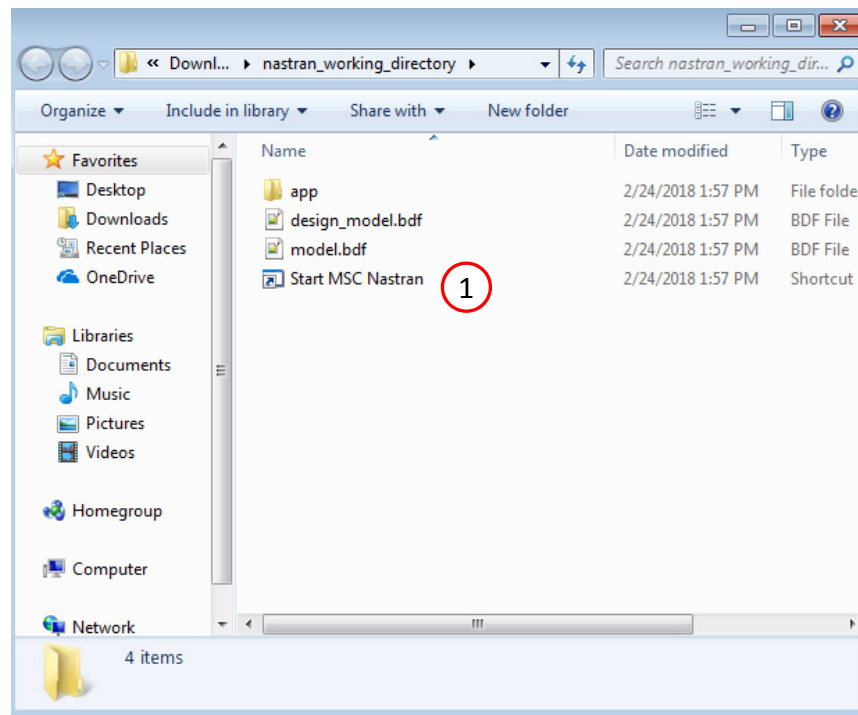
## Using Linux?

Follow these instructions:

- 1) Open Terminal
- 2) Navigate to the nastran\_working\_directory  
`cd ./nastran_working_directory`
- 3) Use this command to start the process  
`./Start_MSC_Nastran.sh`

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

```
sudo chmod -R u+x ./nastran_working_directory
```



# Status

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

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

## SOL 200 Web App - Status

 Python  MSC Nastran

### Status

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

# Review Optimization Results

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

1. Ensure the messages shown have green checkmarks. This is indication of success. Any red icons indicate challenges.
2. The final value of objective, normalized constraints and design variables can be reviewed.

- After an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- The Normalized Constraints plot indicates the final design cycle has yielded a design that has a max normalized constraint very close to zero. Max normalized constraints that are negative or close to zero indicate a feasible design has been obtained. Feasible designs are designs that satisfy all design constraints.

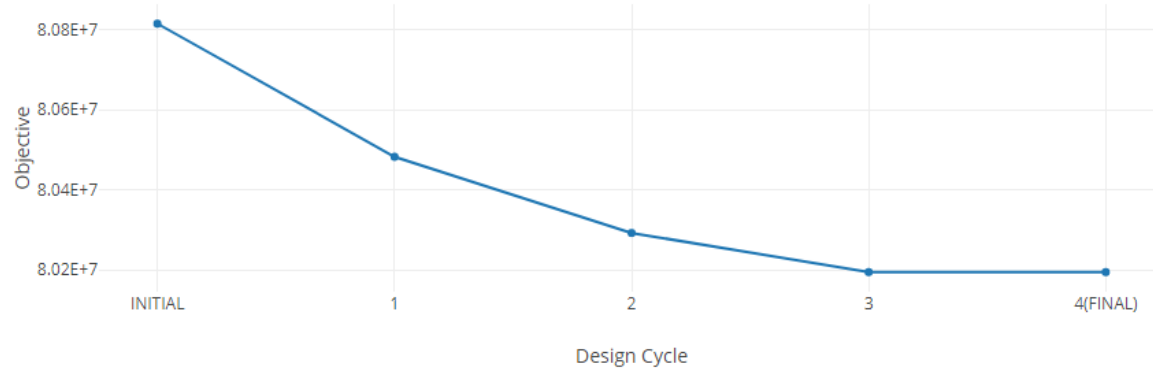
## Final Message in .f06

1



RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 4.

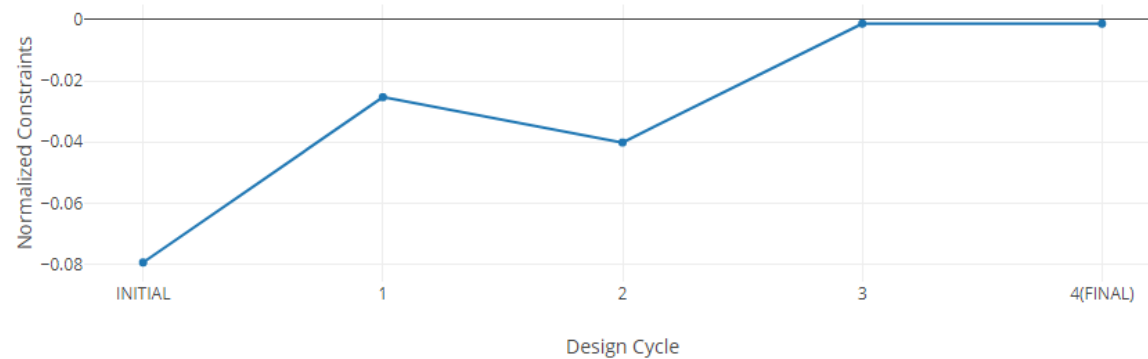
## Objective



2

## Normalized Constraints

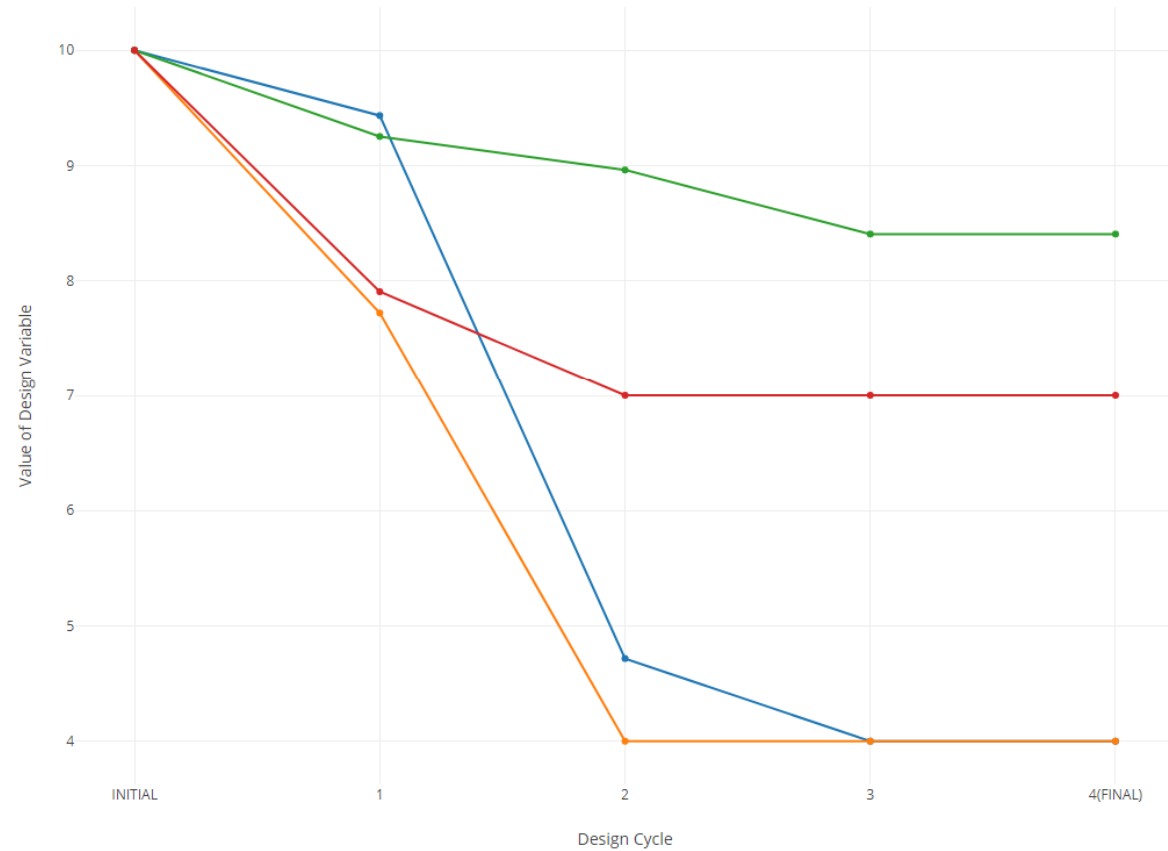
+ Info



# Review Optimization Results

The shape variables are constantly decreasing, indicating the shapes are being contracted during the optimization.

Design Variables



Reset Table

Display None Display All

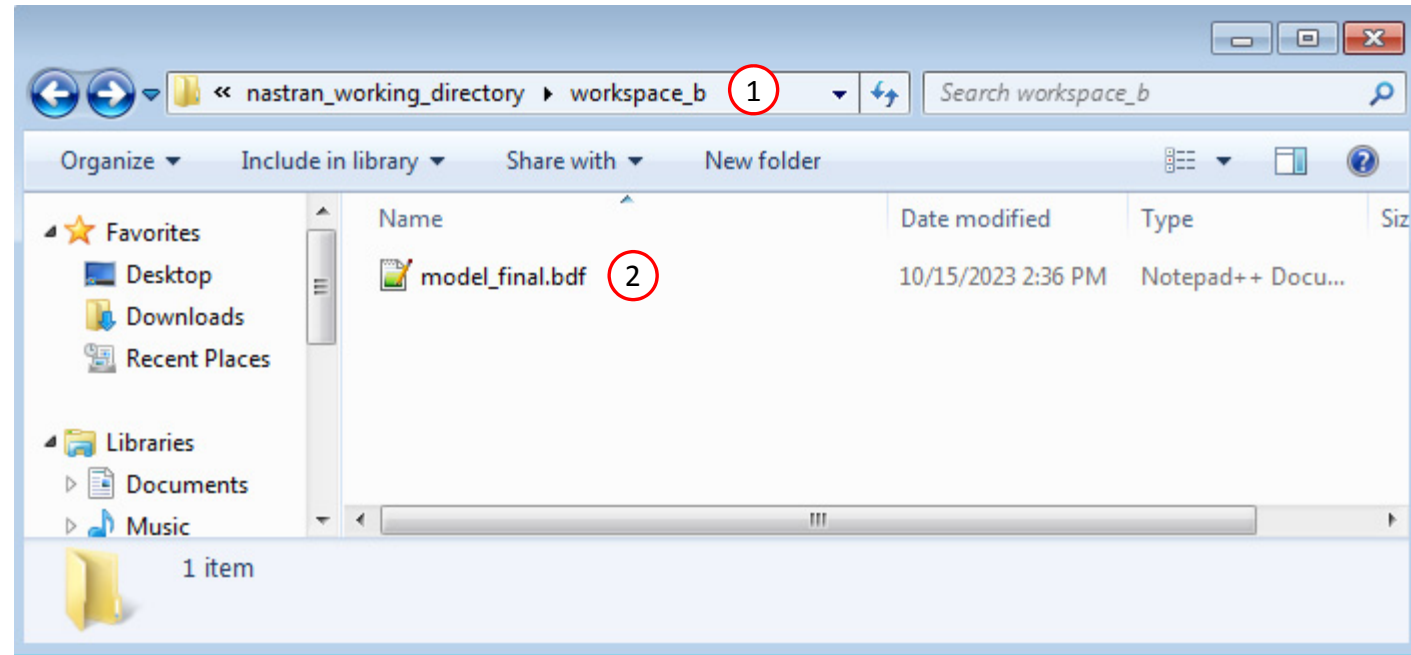
Display	Color	Label	Label Comments
		Search	Search
<input checked="" type="checkbox"/>	Blue	y1	Shape 1 of PSOLID 1
<input checked="" type="checkbox"/>	Orange	y2	Shape 2 of PSOLID 1
<input checked="" type="checkbox"/>	Green	y3	Shape 3 of PSOLID 1
<input checked="" type="checkbox"/>	Red	y4	Shape 4 of PSOLID 1

5102050100200



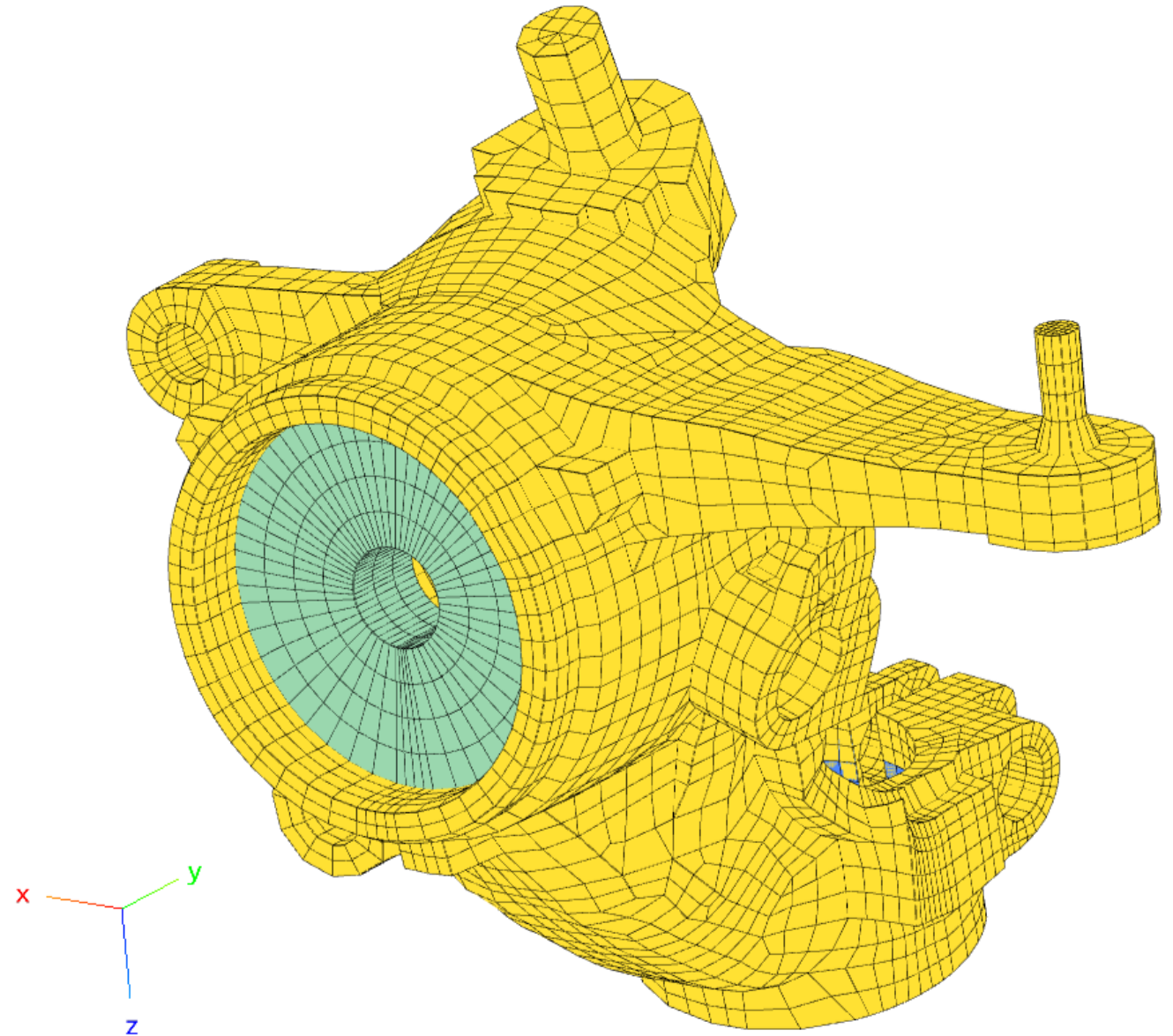
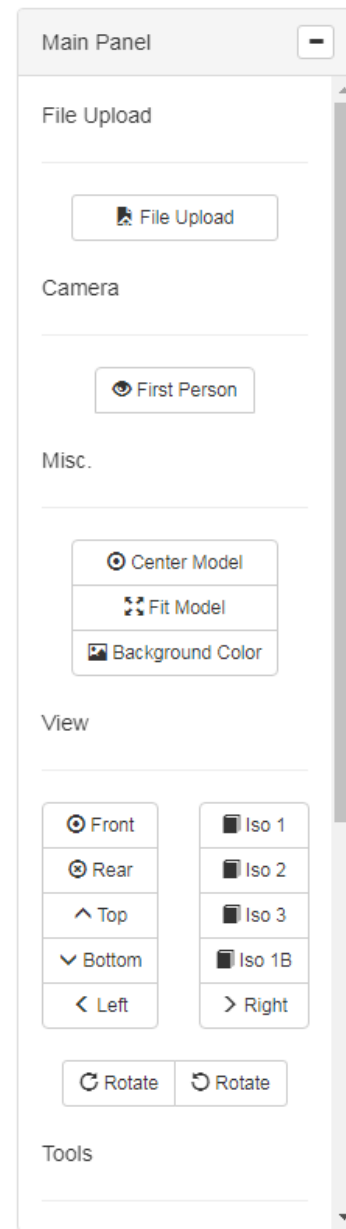
# New Updated BDF File

1. After the optimization, a new directory named workspace\_b is created
2. This directory contains a new BDF file where the node positions have been updated to reflect the optimized shape. Specifically, the optimized GRID entries found in the file model.pch were used to replace the old GRID entries.



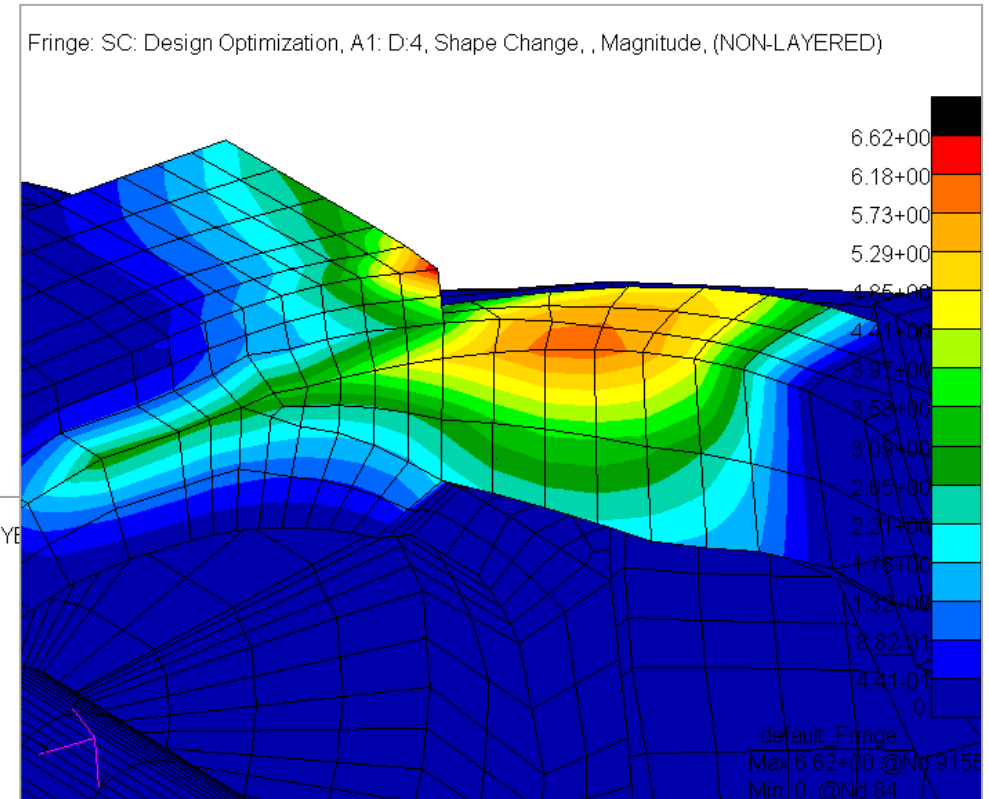
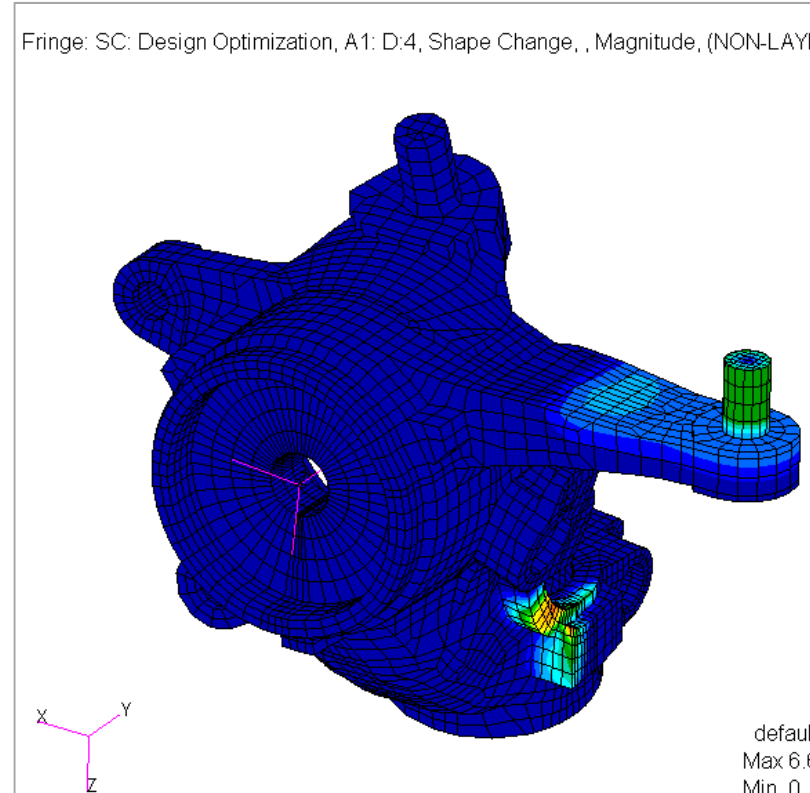
# Optimized Shape

1. The Viewer is used to import the new file model\_final.bdf. The shape is confirmed to have changed.



# Plot of Shape Change

1. A fringe plot showing the shape change is useful in determining which regions have expanded or contracted the most.

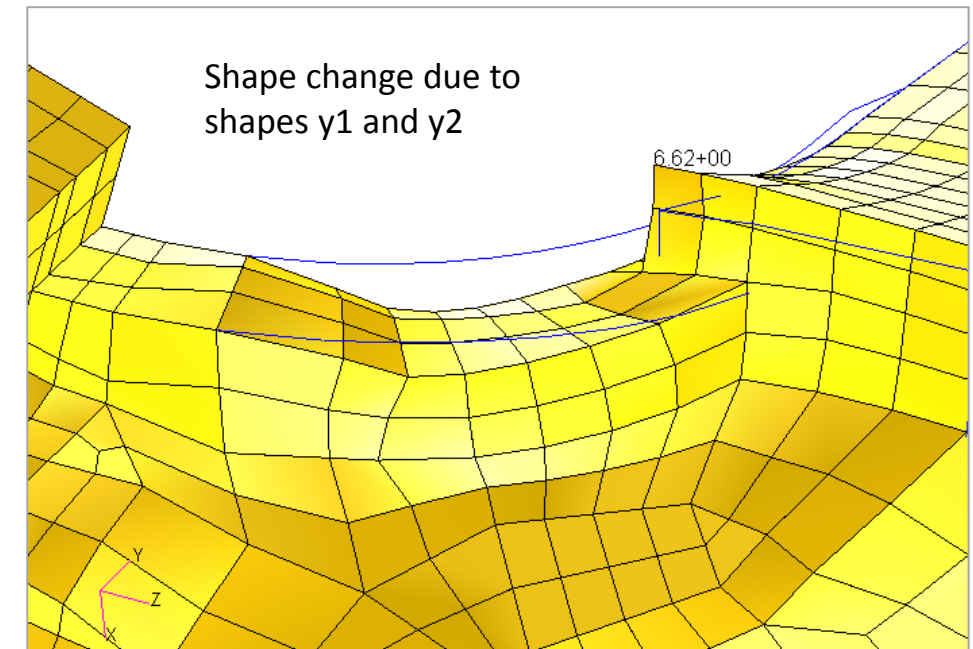
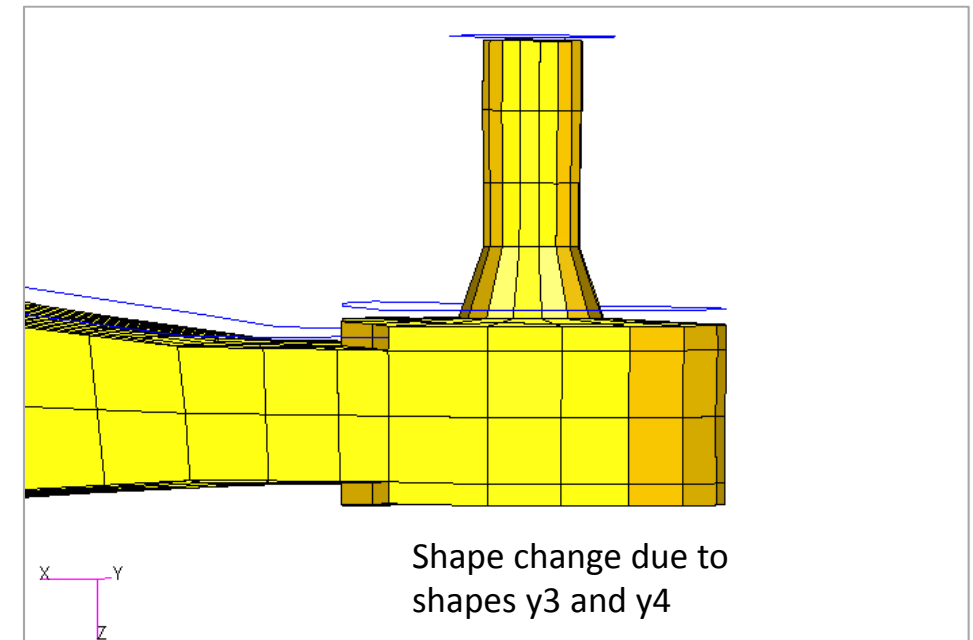
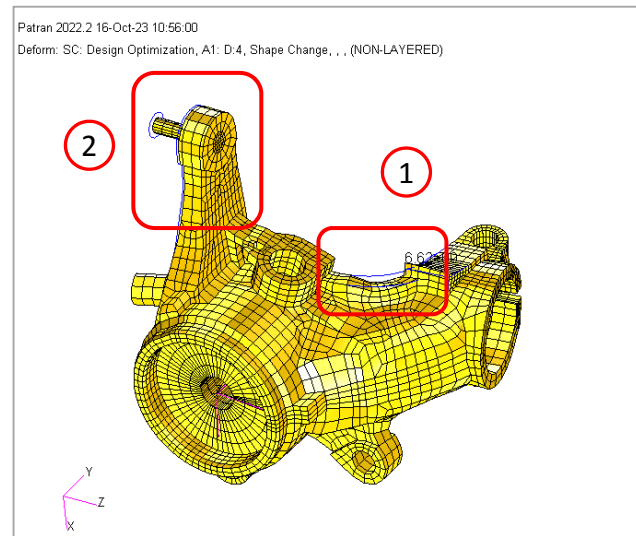


# Plot of Shape Change

A comparison between the initial and final design is made.

1. Shape change due to shapes y1 and y2
2. Shape change due to shapes y3 and y4

The shape changes are characterized by pure contraction.



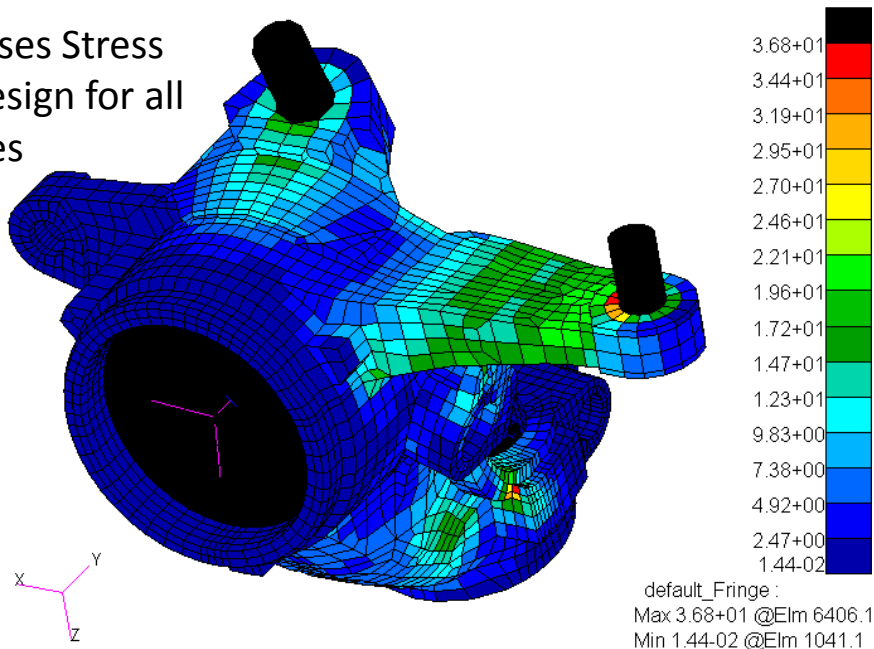
# Results

## Before Optimization

- Weight:  $8.081499\text{E}+07$
- Max Stress: 36.8

Fringe: Max (Initial), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)

Max von Mises Stress  
for Initial Design for all  
12 load cases

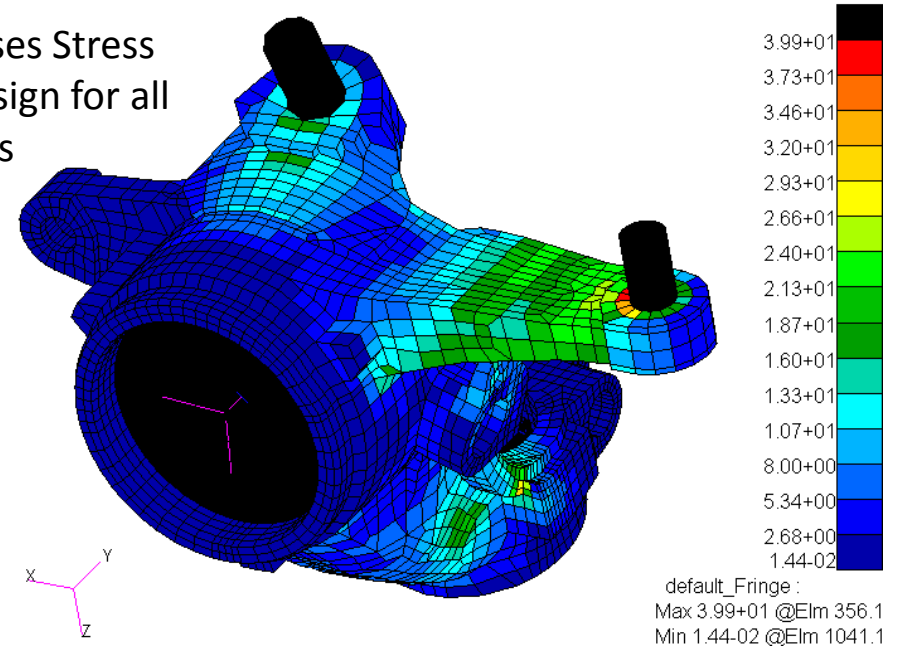


## After Optimization

- Weight:  $8.019459\text{E}+07$
- Max Stress: 39.9

Fringe: Max (Final), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)

Max von Mises Stress  
for Final Design for all  
12 load cases



End of Tutorial

# Appendix

---



# Appendix Contents

---

- Frequently Asked Questions
  - How to view the shape optimization results in Patran?

# How to view the shape optimization results in Patran?

---

# Shapes Optimization Results in Patran

Many of the images in this workshop that display the shape optimization results were generated by Patran. The following are steps on how to view the shape optimization results in Patran.

1. Generate an H5 file during the shape optimization. The following entries output an H5 file.

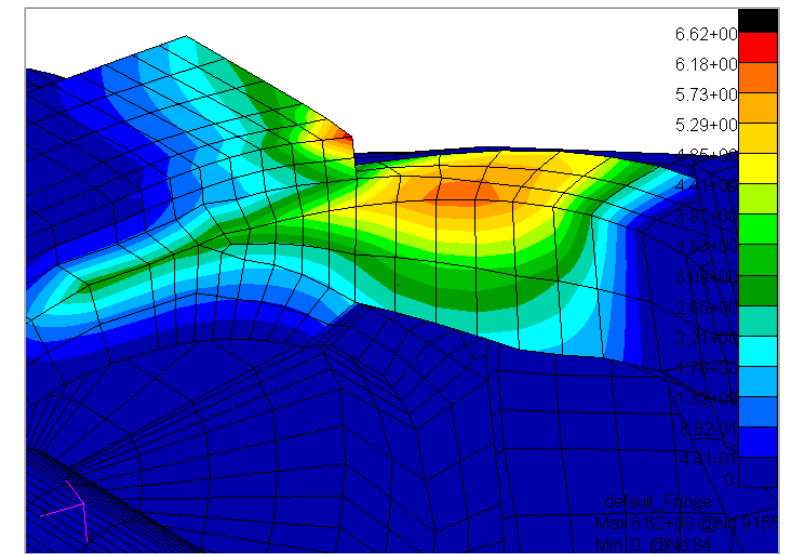
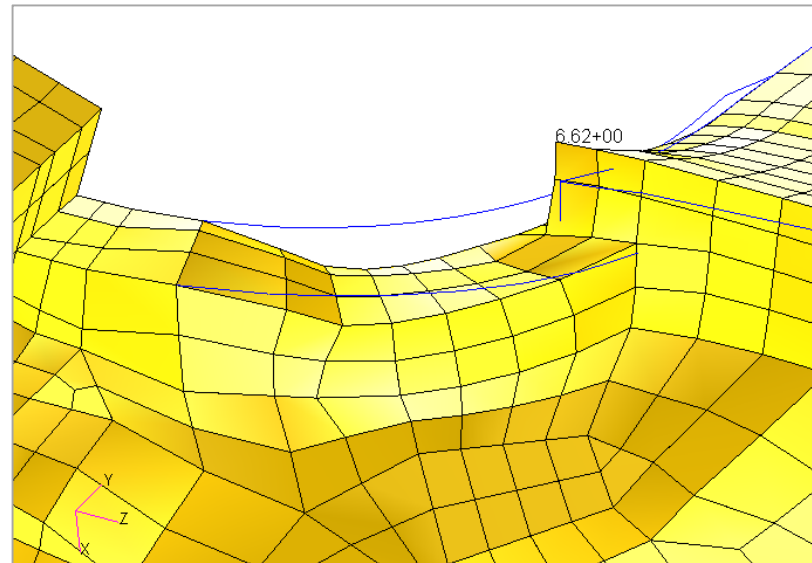
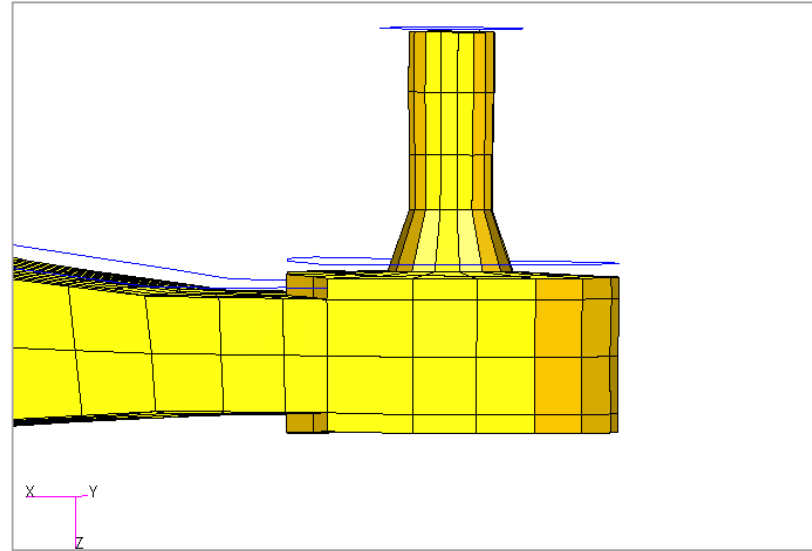
```
HDF5OUT $ MSC Nastran 2022.1 and newer
```

```
MDLPRM,HDF5,1 $ MSC Nastran 2016 or newer
```

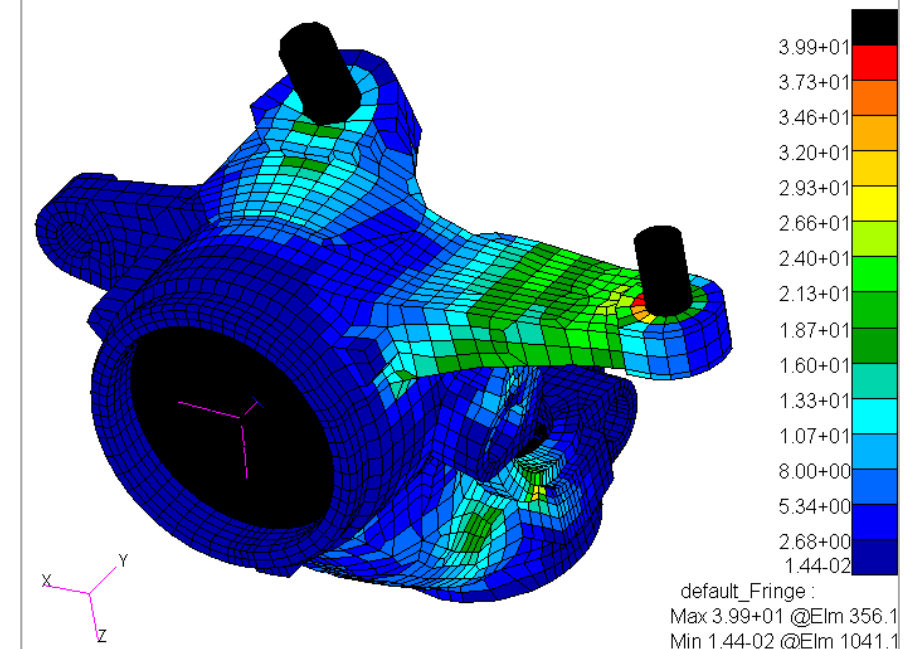
2. Import the H5 file to Patran

Note that option 2 does not output the shape change data to the H5 file. Use option 1.

- OK: MDLPRM,HDF5,1
  - NOT OK: MDLPRM,HDF5,2
- Alternatively, use HDF5OUT



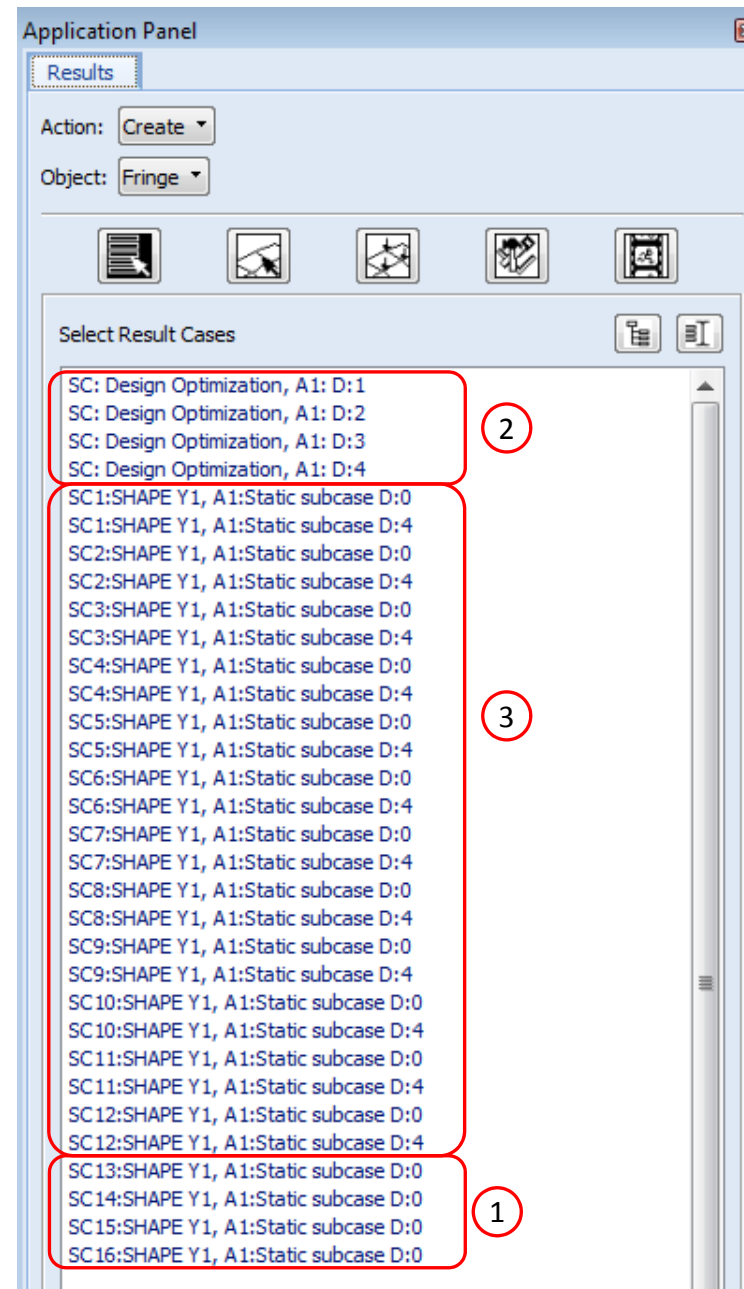
Fringe: Max (Final), All Subcases, Stress Tensor, , von Mises, (NON-LAYERED)



# Interpreting the Subcases

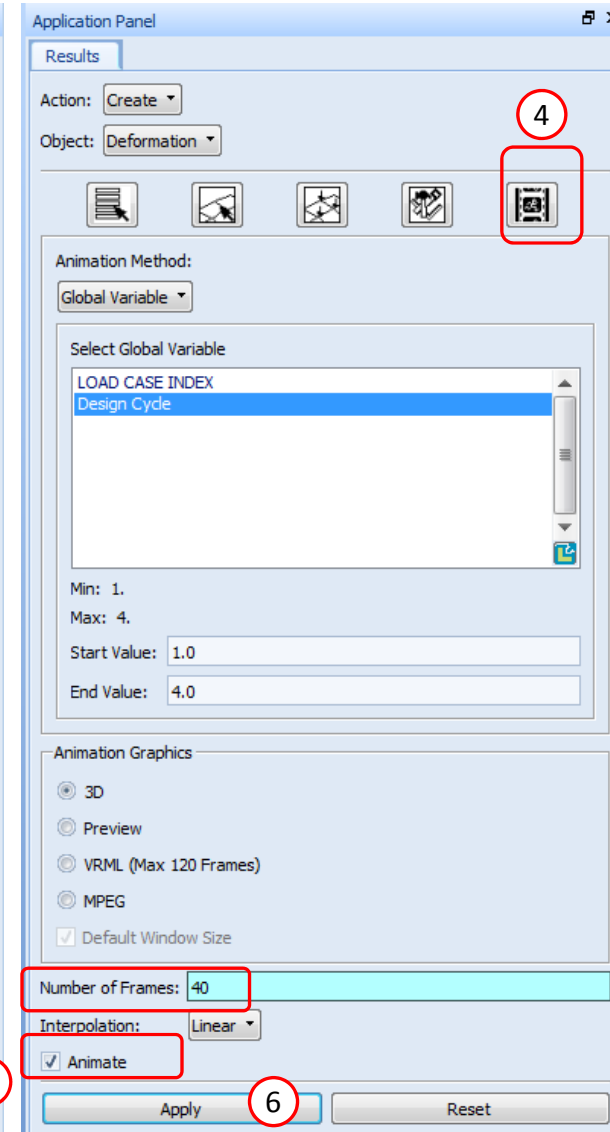
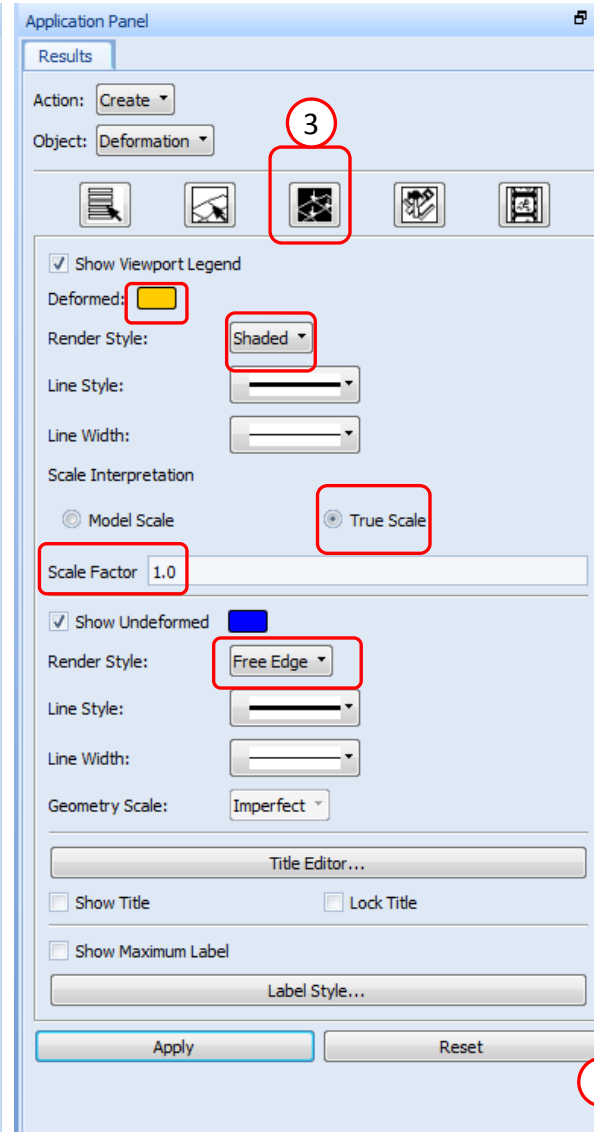
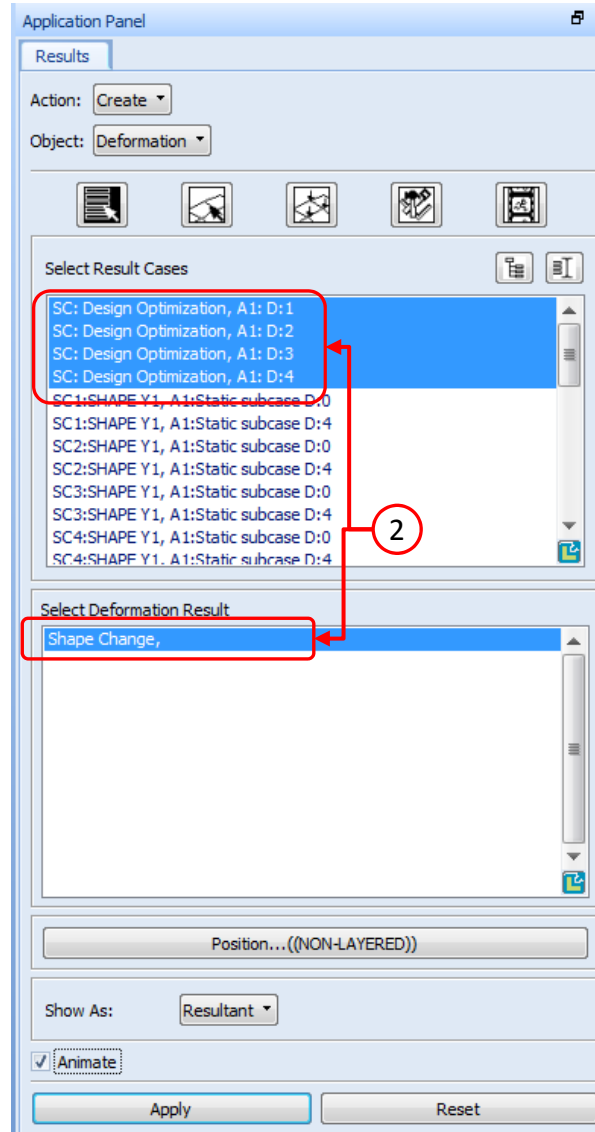
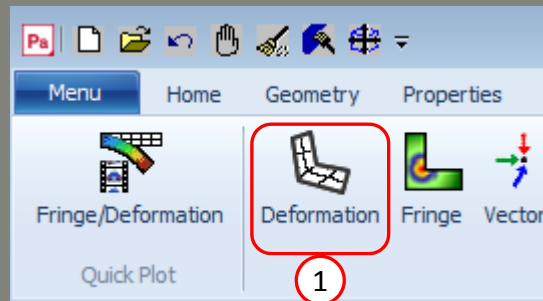
This shape optimization involved 4 shapes , converged in 4 design cycles and 12 load cases.

1. The last 4 rows contain the results of the interpolation subcases for the 4 shapes.
2. The first 4 rows contain the shape change results for the first 4 design cycles.
3. The indicated rows contain the results of the 12 load cases. The results of the initial design are indicated by a trailing "D:0" string. The results of the final design are indicated by a trailing "D:4" string. There are a total of 24 rows.



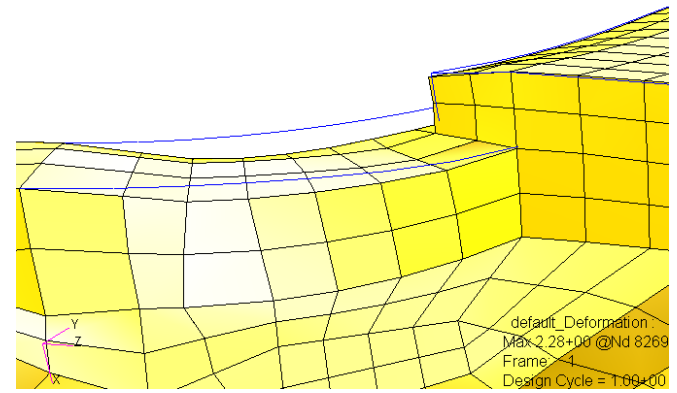
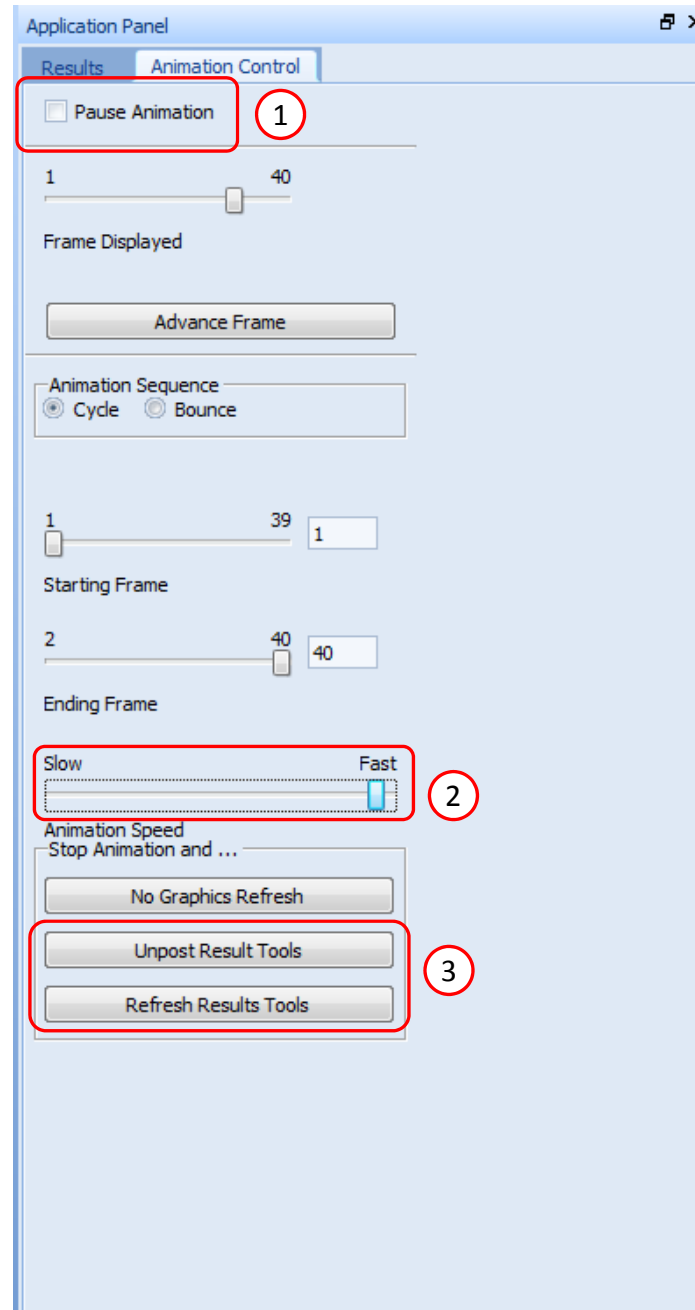
# Animating the Shape Change

1. Click Deformation in the top left hand corner of the Patran window
2. Select the indicated rows
3. Click the indicated button and set the following
  - Deformed: Orange or your preferred color
  - Render Style: Shaded
  - Scale Interpretation: True Scale
  - Scale Factor: 1.0
  - Render Style: Free Edge
4. Click the indicated button and set the following
  - Number of Frames: 40
5. Mark the checkbox for Animate
6. Click Apply and the animation will be created

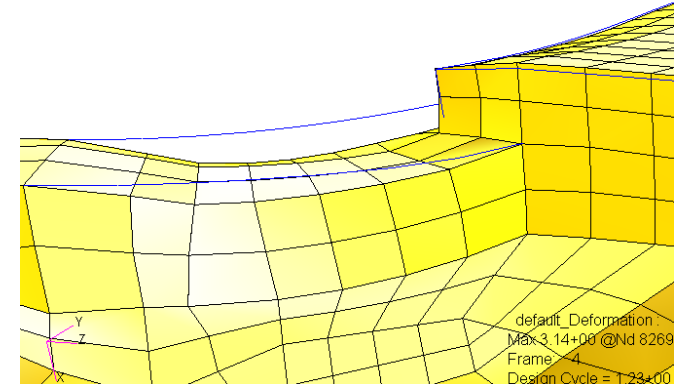


# Controlling the Animation of Shape Changes

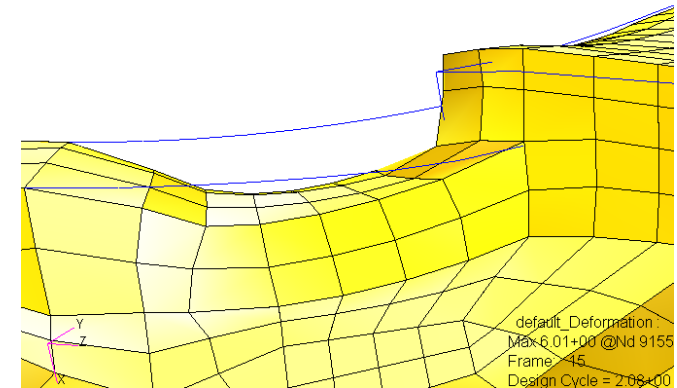
1. Mark the checkbox Pause Animation to pause or unpause the animation
2. Use the indicated slider to control the speed of the animation
3. To exit the animation click on one of the buttons Unpost Result Tools or Refresh Results Tools



Frame 1



Frame 4



Frame 15