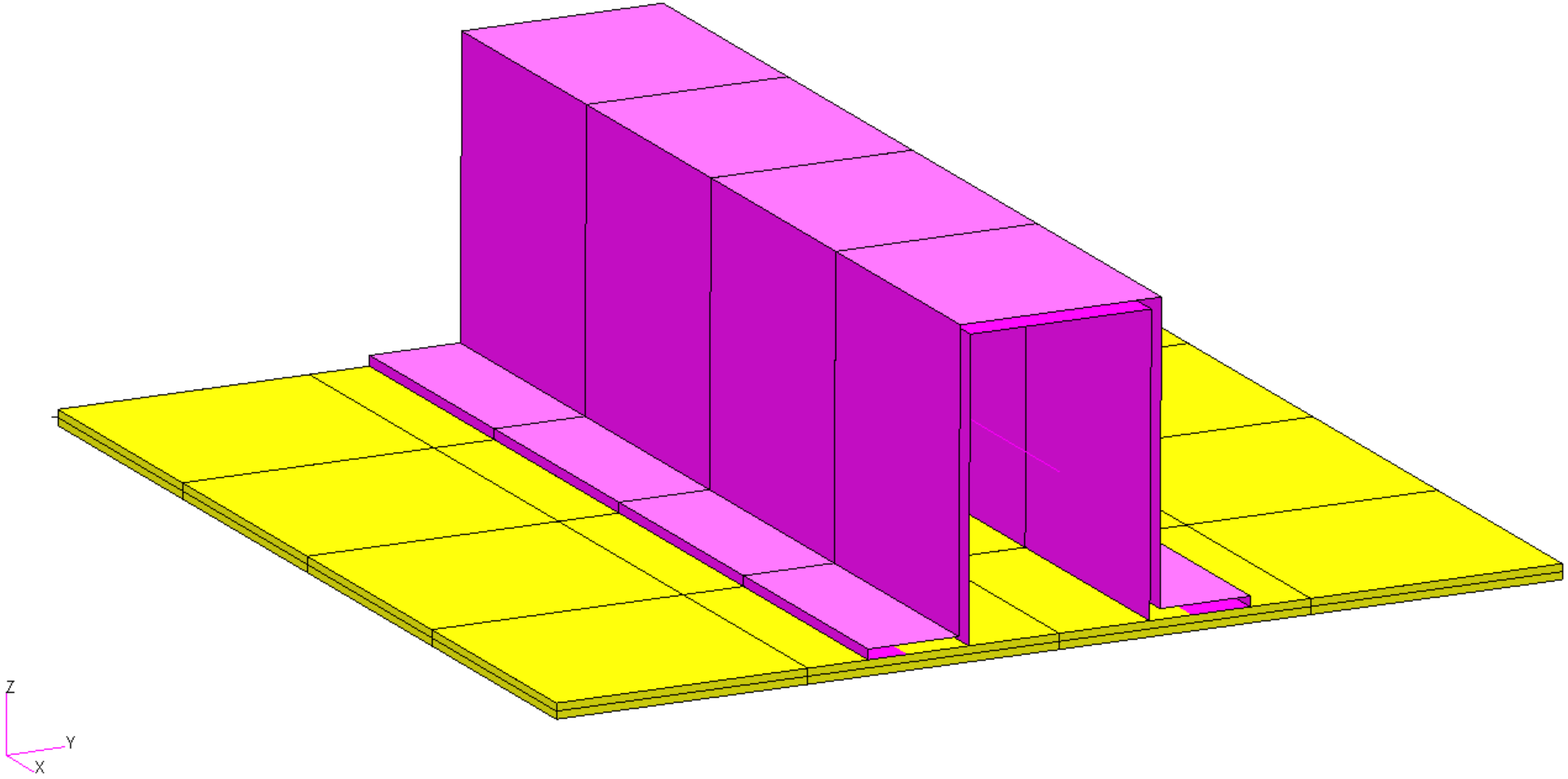
# Automated Structural Optimization of a Stiffened Plate

PRESENTED BY CHRISTIAN APARICIO

# Goal: Use Nastran SOL 200 Optimization



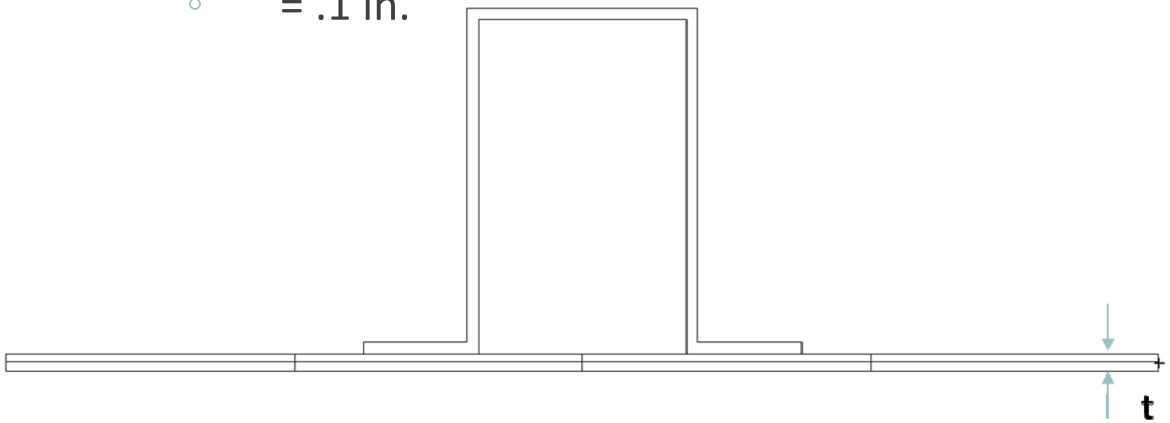
# Goal: Use Nastran SOL 200 Optimization

Optimize the weight of this structure while constraining stress and displacement

## Before Optimization

- Weight: 6.962

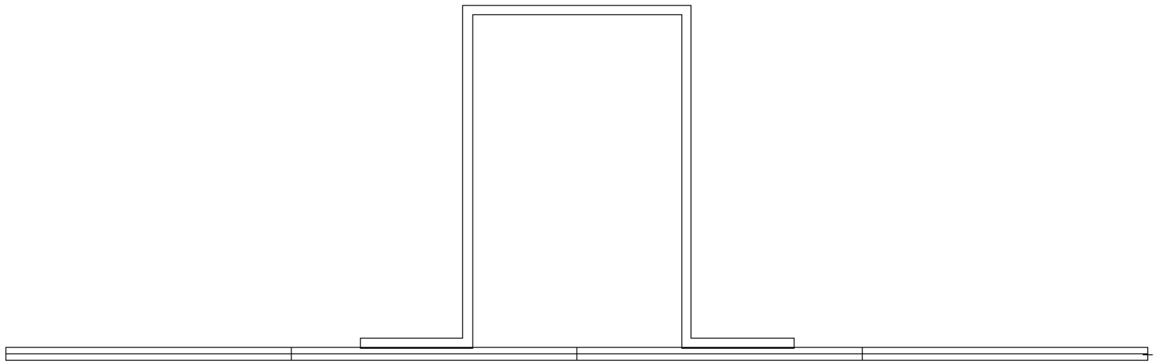
- x1 = T, thickness of shell
-     =  .15
- x2 = DIM2
-     = .1 in.




## After Optimization

- Weight: 5.477

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



# Agenda

Details of the structural model

Optimization Problem Statement

Steps to use Nastran SOL 200 (Optimization)

- Convert a .bdf file to SOL 200
- Create:
  - Design Variables
  - Design Objective
  - Design Constraints
- Perform optimization with Nastran SOL 200

View optimization results

- Online Plotter
- Structural Results

Update the original structural model with optimized parameters

# Contact me

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

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# Details of the structural model

## Stiffened Plate

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

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

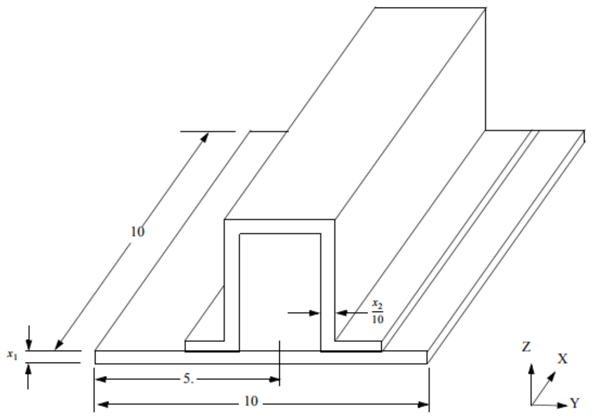
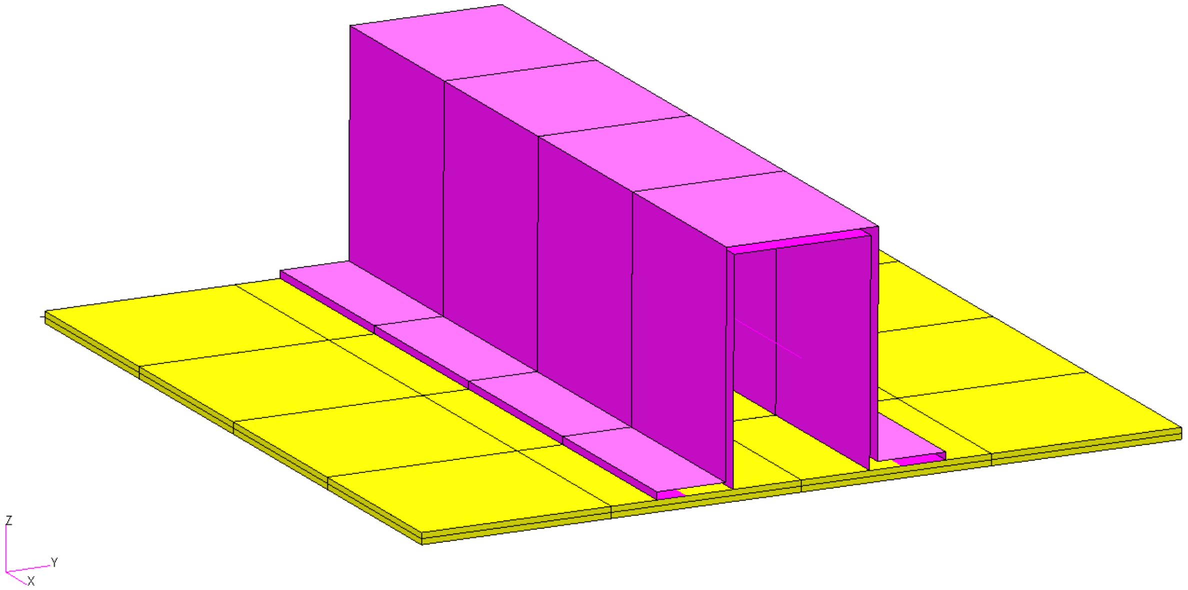
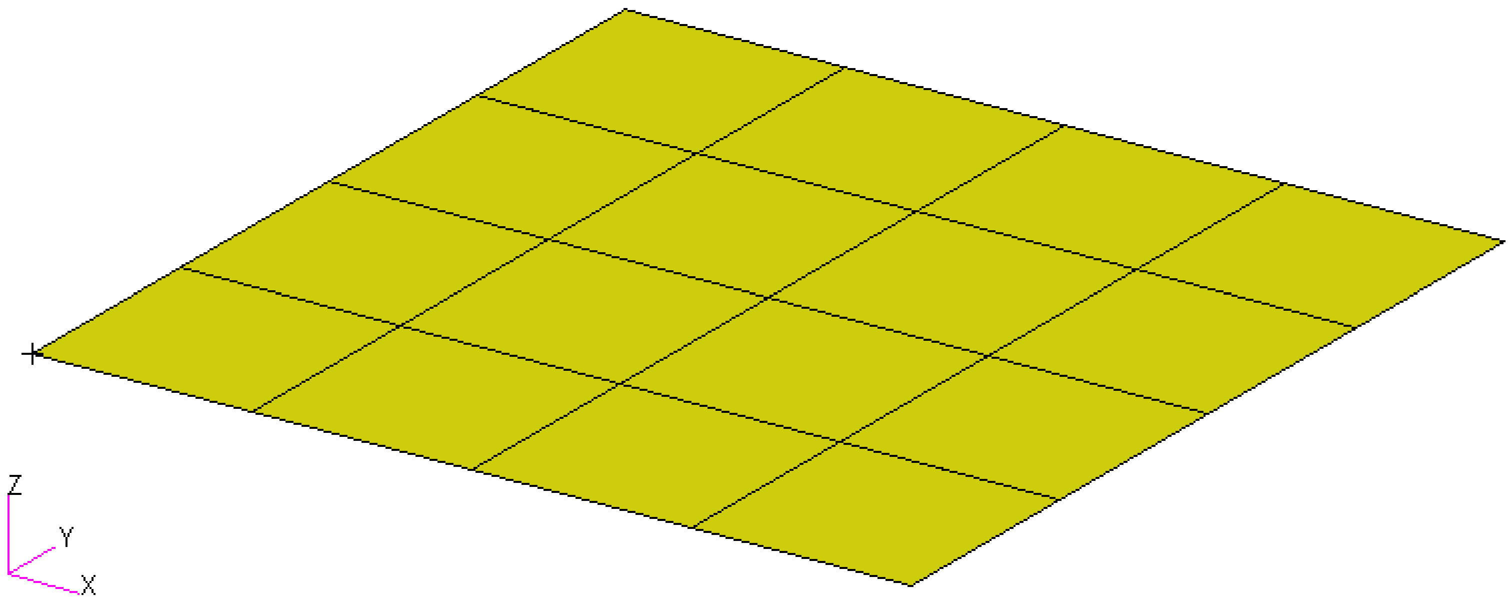



Figure 8-20 Plate with a HAT Stiffener

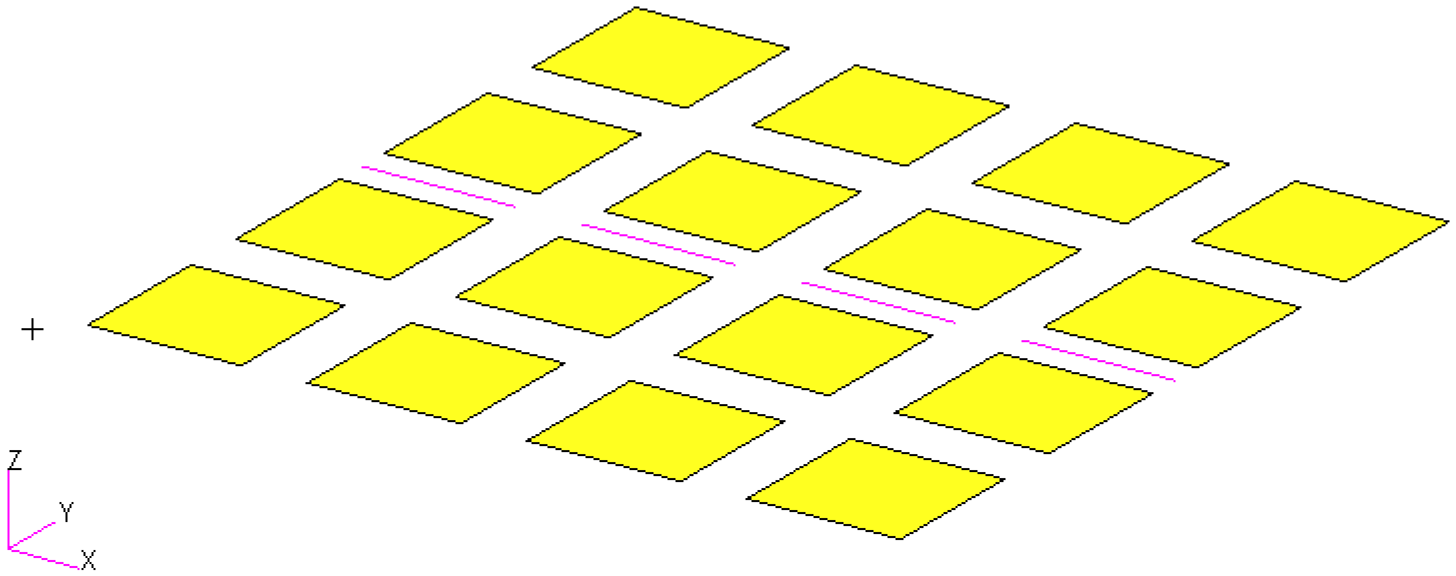



*MSC Nastran Design Sensitivity and Optimization User's Guide*
*Chapter 8 – Example Problems – Stiffened Plate*

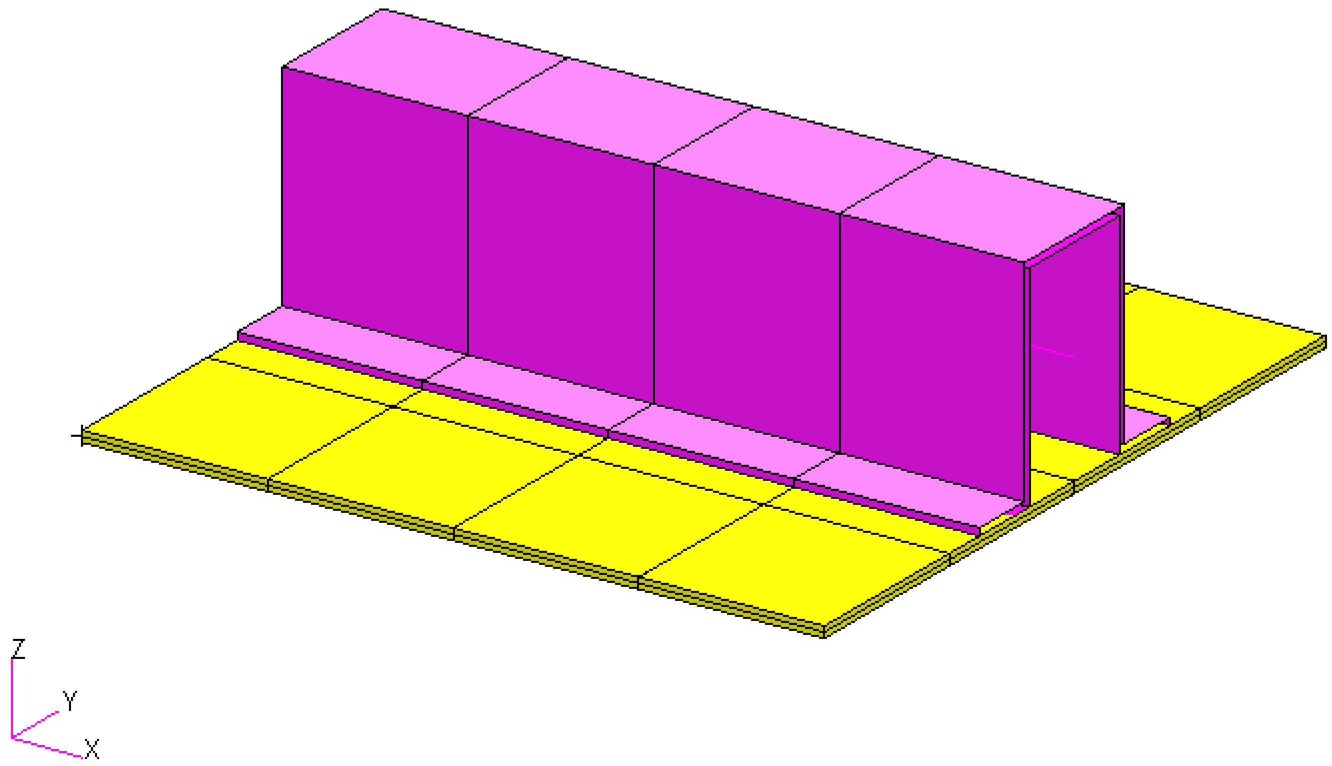
# Details of the structural model
# Stiffened Plate

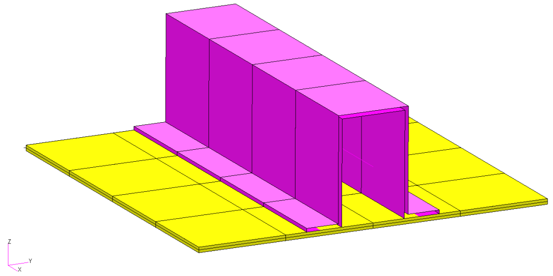


# Details of the structural model
# Stiffened Plate with Elements Shrunk



# Details of the structural model Stiffened Plate



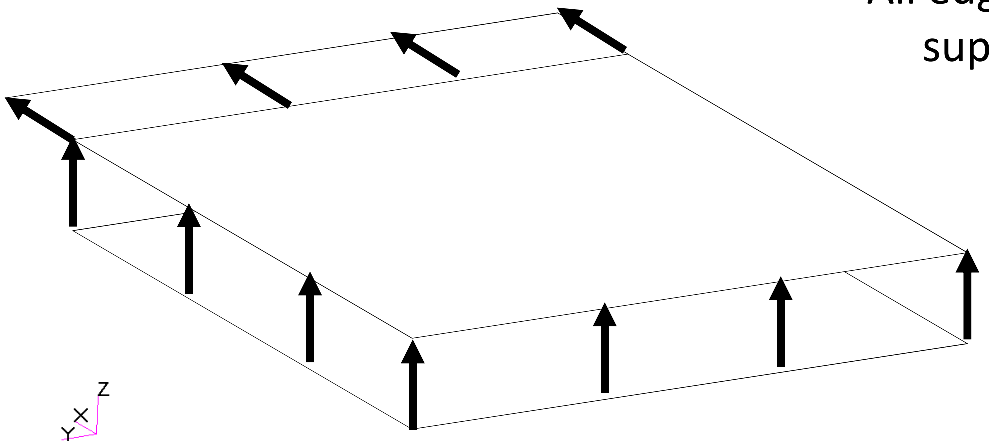


# Loadcases (SUBCASEs)

Load Case 1: r1, r2, r3, r4, r5

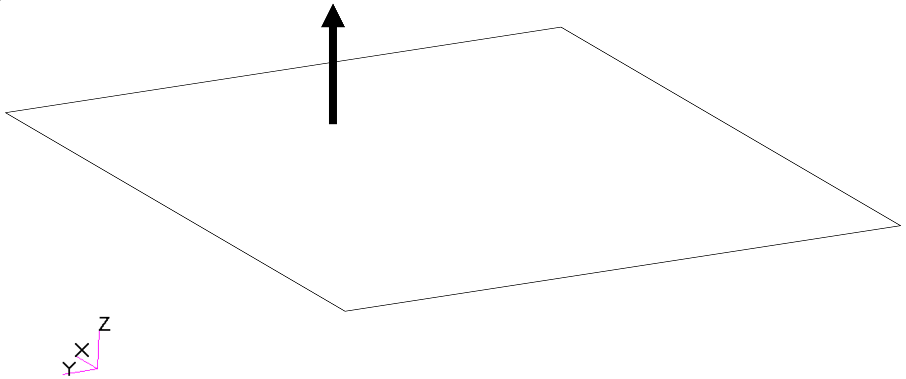
Load Case 2: r1, r2, r3, r4, r6

Loadcase 1




All edges simply supported

Loadcase 2



# Optimization Problem Statement
# Design Variables

## Design Variables

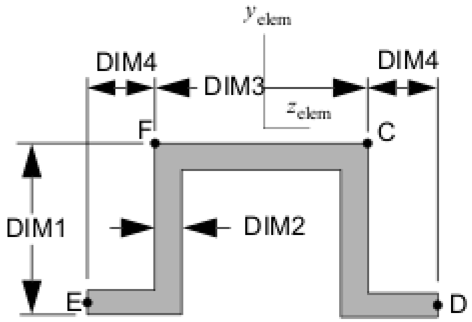
- x1 = T, thickness of shell

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

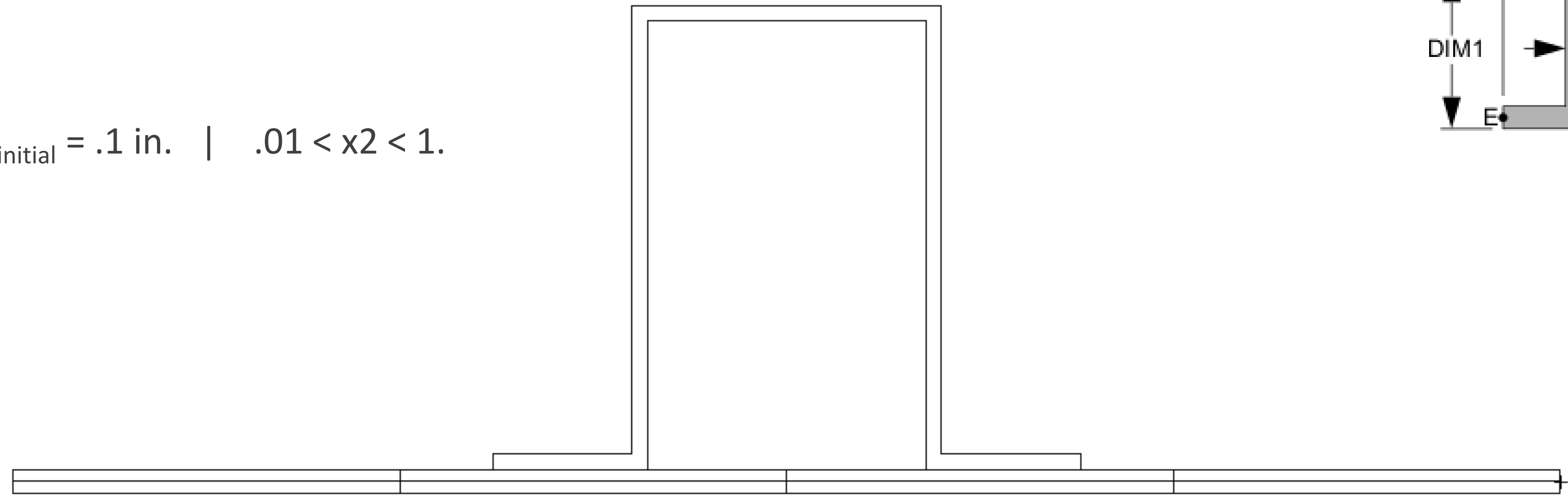
- x2 = DIM2

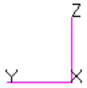
  $x2_{initial}$ = .1 in. | .01 < x2 < 1.

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




TYPE="HAT"





# Optimization Problem Statement
# Design Variables

## Design Variables

- x1 = T, thickness of shell

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

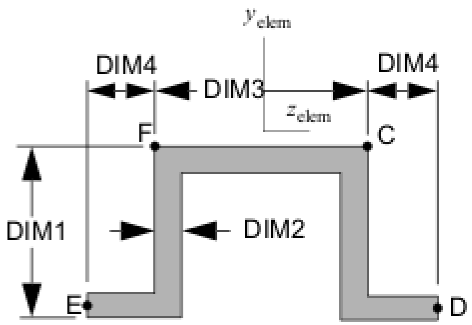
- x2 = DIM2

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

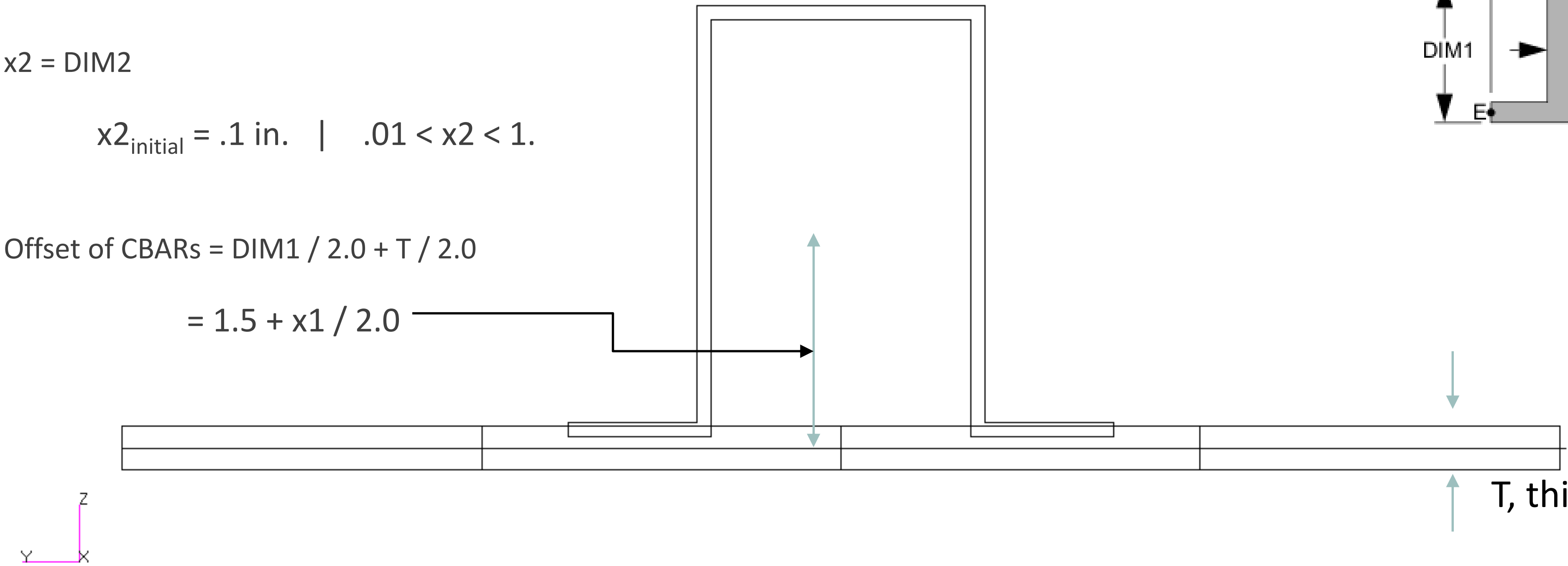
- Offset of CBARs = DIM1 / 2.0 + T / 2.0

  = 1.5 + x1 / 2.0

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




TYPE="HAT"



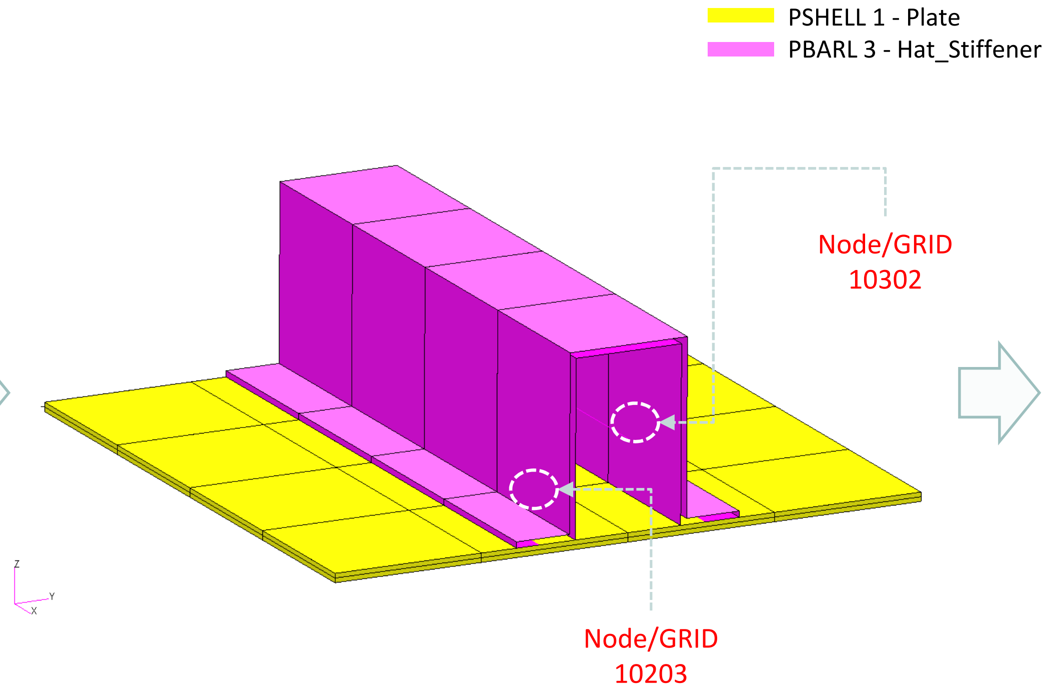

T, thickness of shell

# Optimization Problem Statement

## Design Variables

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

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




## Responses (Outputs)

- Weight
- Volume
- Displacements
- Strains
- Stresses
- ....

# Optimization Problem Statement Design Objective

Design Objective

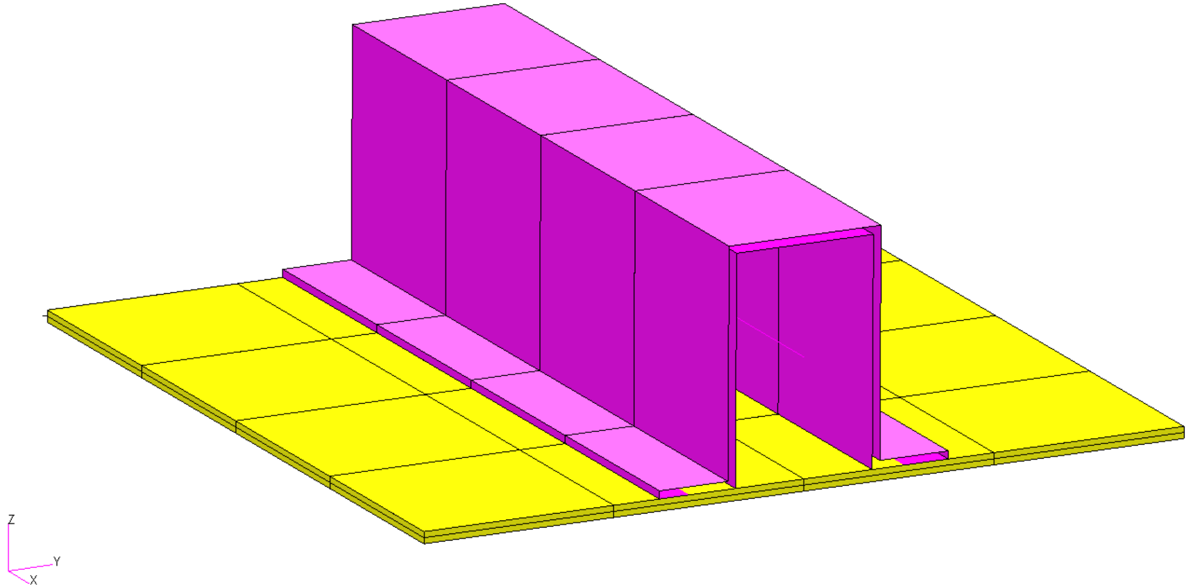
- r0: Minimize Weight

# Optimization Problem Statement
# Design Constraints

Loads will produce bending and axial stress in beam elements

Must make sure the combined max bending stress and axial stress is within allowable bounds

- r1: The max stress at end A for PBARL 3
- -25000. < r1 < 25000.
- r2: The max stress at end B for PBARL 3
- -25000. < r2 < 25000.



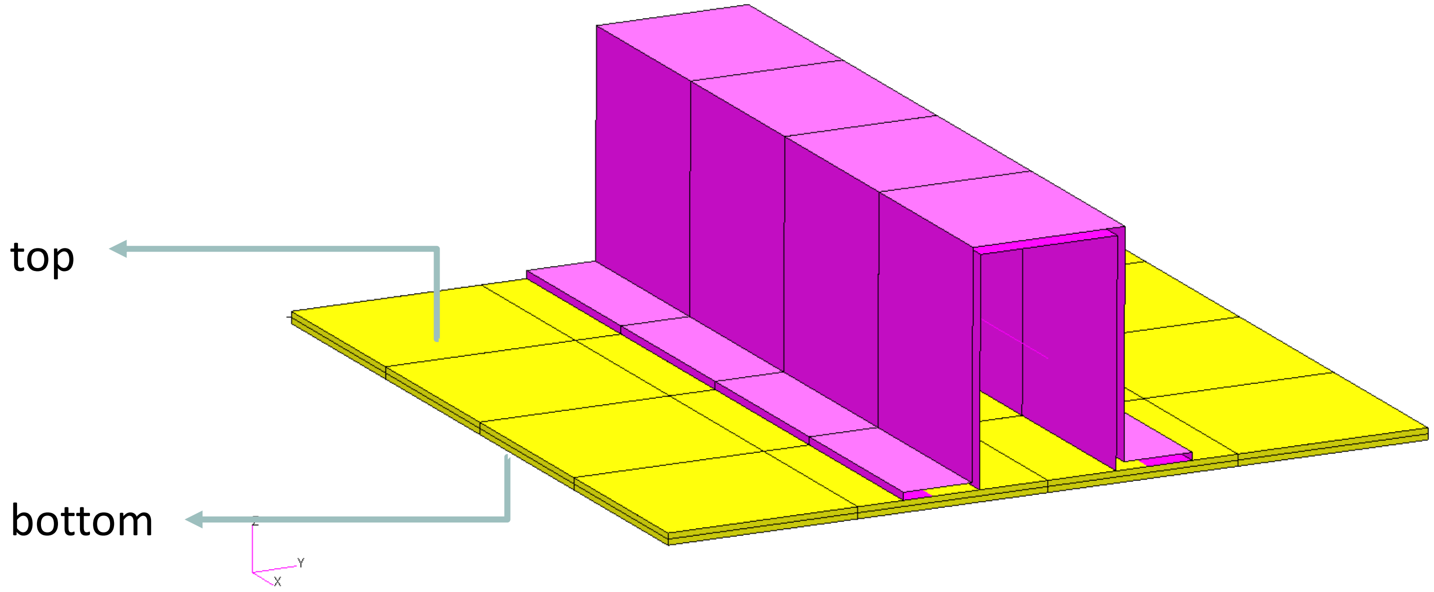
# Optimization Problem Statement
# Design Constraints

r3: The von Mises Stress of the top fiber (z1)

$$r3 < 25000.$$

r4: The von Mises Stress of the bottom fiber (z2)

$$r4 < 25000.$$



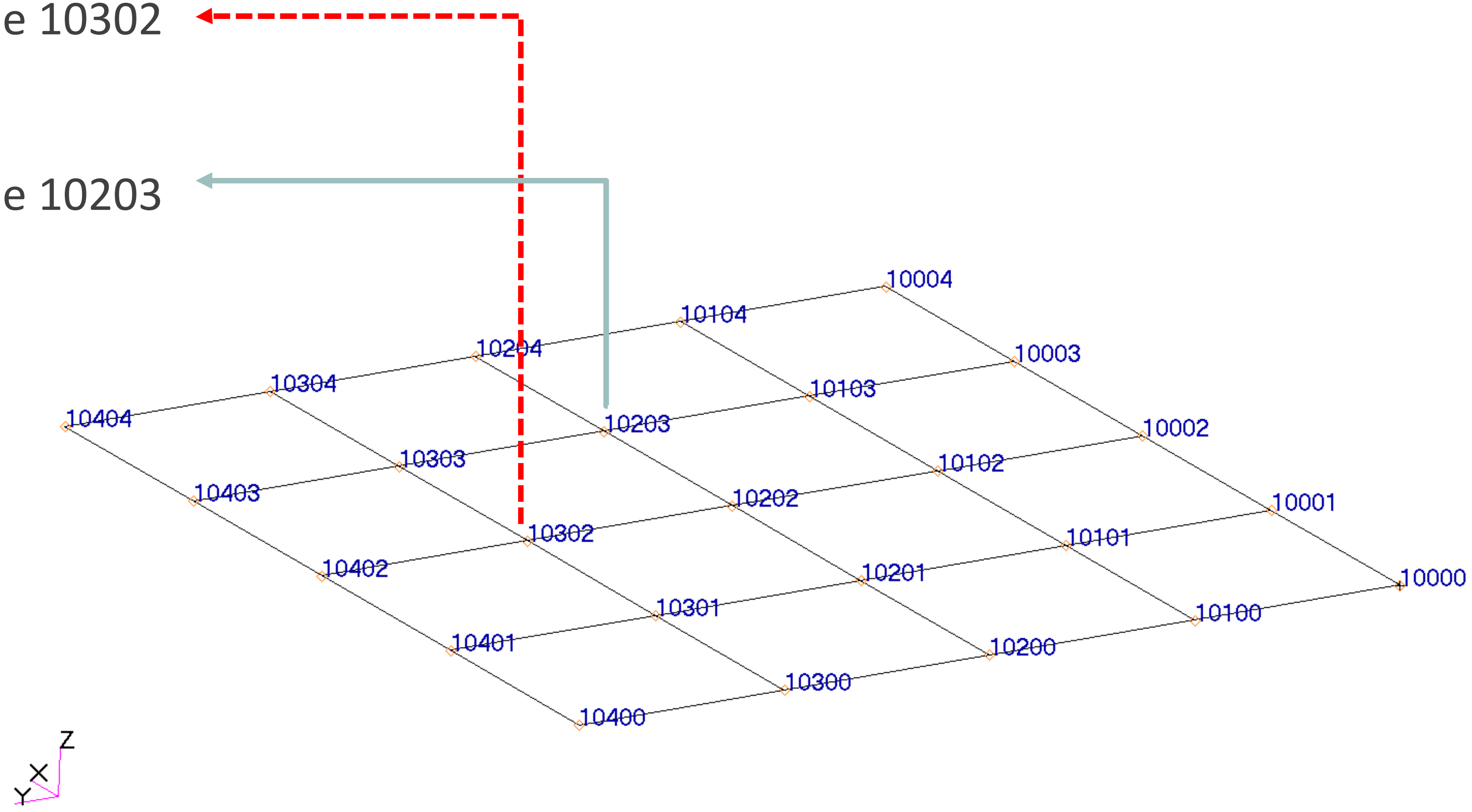
# Optimization Problem Statement
# Design Constraints

r5: The z displacement of node 10302

-.1 < r5 < .1

r6: The z displacement of node 10203

-.03 < r6 < .03

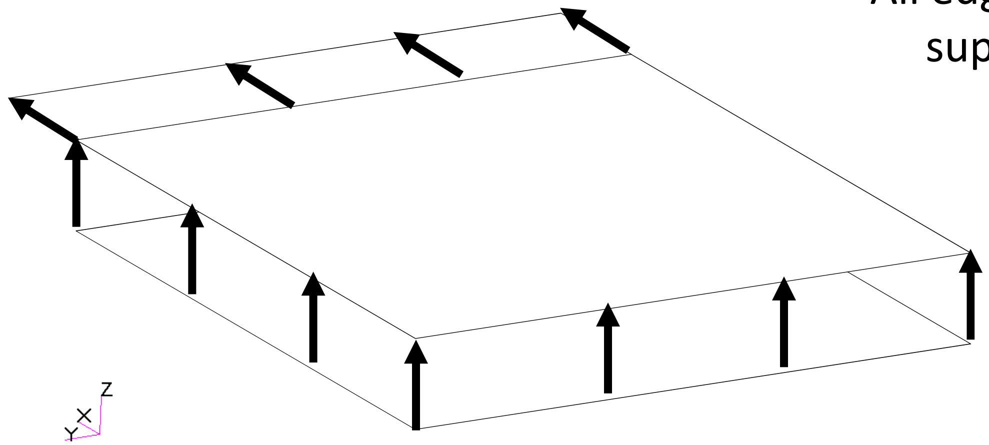


# Optimization Problem Statement
# Design Constraint Groups

Load Case 1: r1, r2, r3, r4, r5

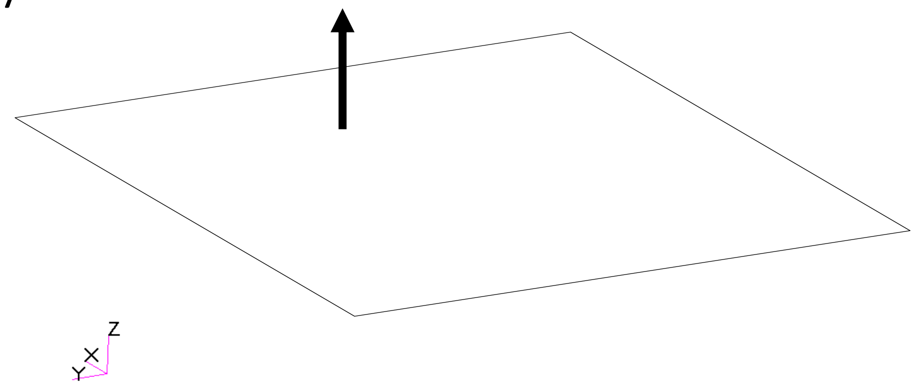
Load Case 2: r1, r2, r3, r4, r6

Loadcase 1




All edges simply supported

Loadcase 2

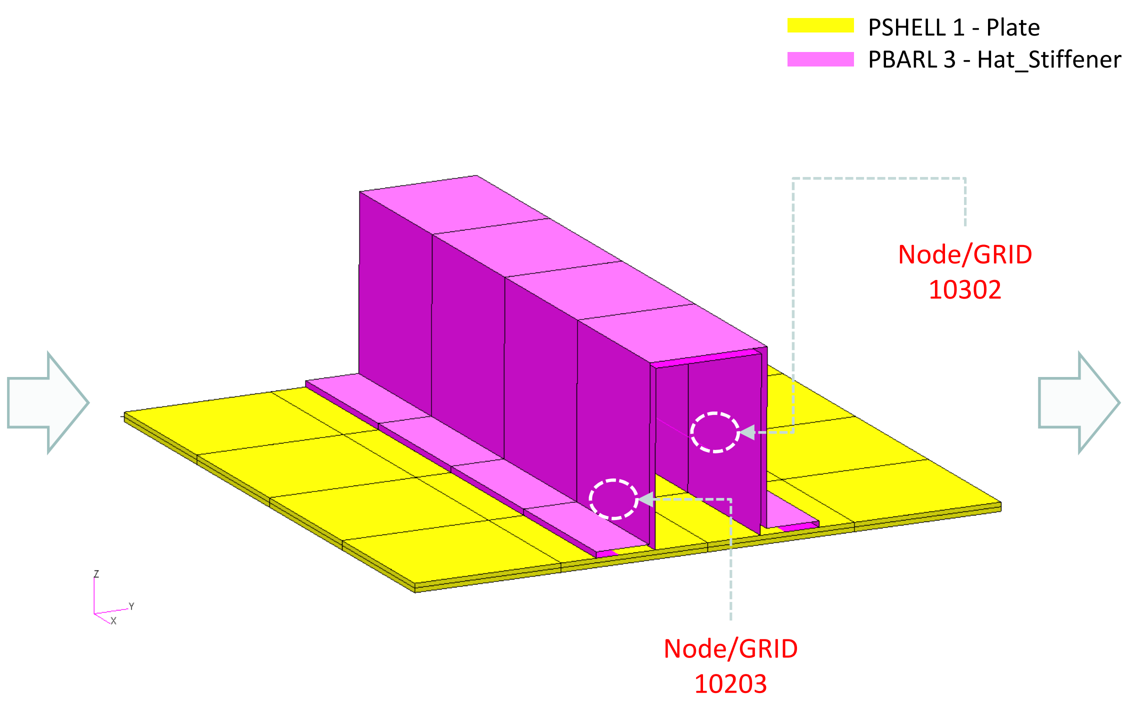


# Optimization Problem Statement

## Design Variables

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

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




## Design Objective

r0: Minimize weight

## Design Constraints

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

-25000 < r1, r2 < 25000

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

r3, r4 < 25000

r5: The z component of displacement for node 10302

-.1 < r5 < .1

r6: The z component of displacement for node 10203

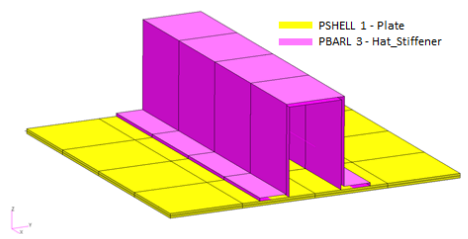
-.03 < r6 < .03

# Steps to use Nastran SOL 200 (Optimization)

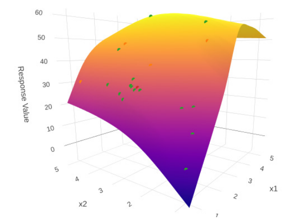
1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
     - Design Variables
     - Design Objective
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Review optimization results
   - Online Plotter
   - Optimized structural results
4. Update the original model with optimized parameters

# SOL 200 Web App Capabilities

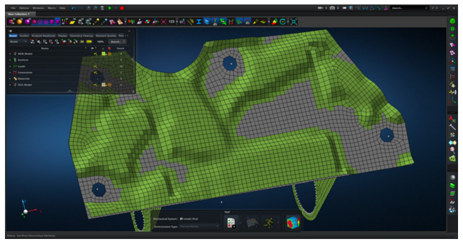
## Capabilities



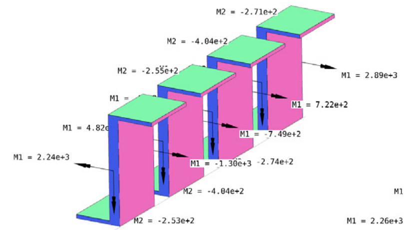

**Web Apps for SOL 200**
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry and topography.



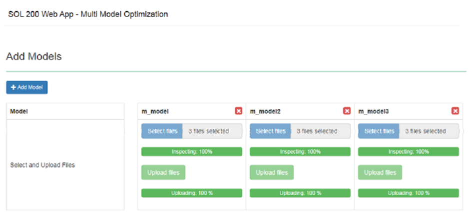
**Machine Learning Web App**
Bayesian Optimization for nonlinear response optimization (SOL 400)



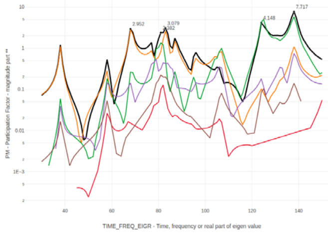
**MSC Apex Post Processing Support**
View the newly optimized model after an optimization



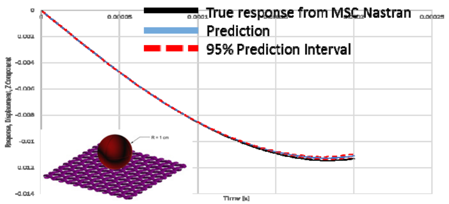
**Beams Viewer Web App**
Post process 1D element forces, including shear forces, moments, torque and axial forces



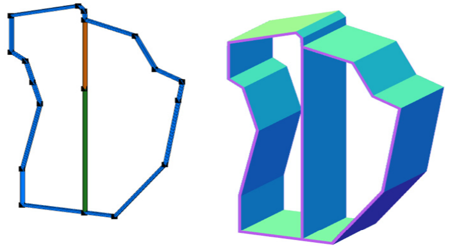

**Multi-model Optimization Web App**
Pre/post for multi model optimization



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




**Prediction Analysis Web App**
Gaussian process regression to predict output of MSC Nastran without time consuming analyses



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

## Benefits

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

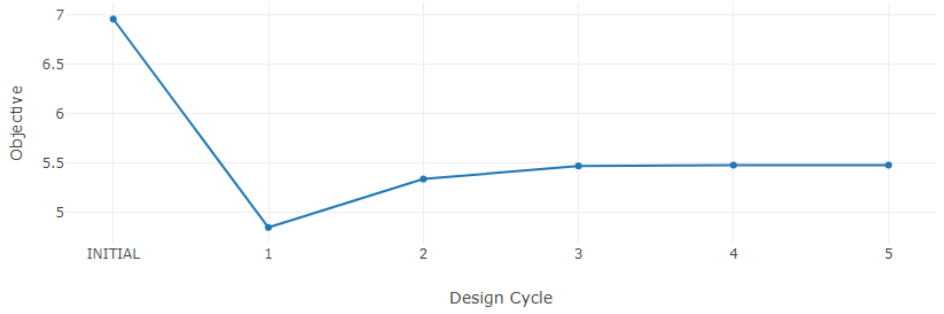
# View Optimization Results

## Online Plotter

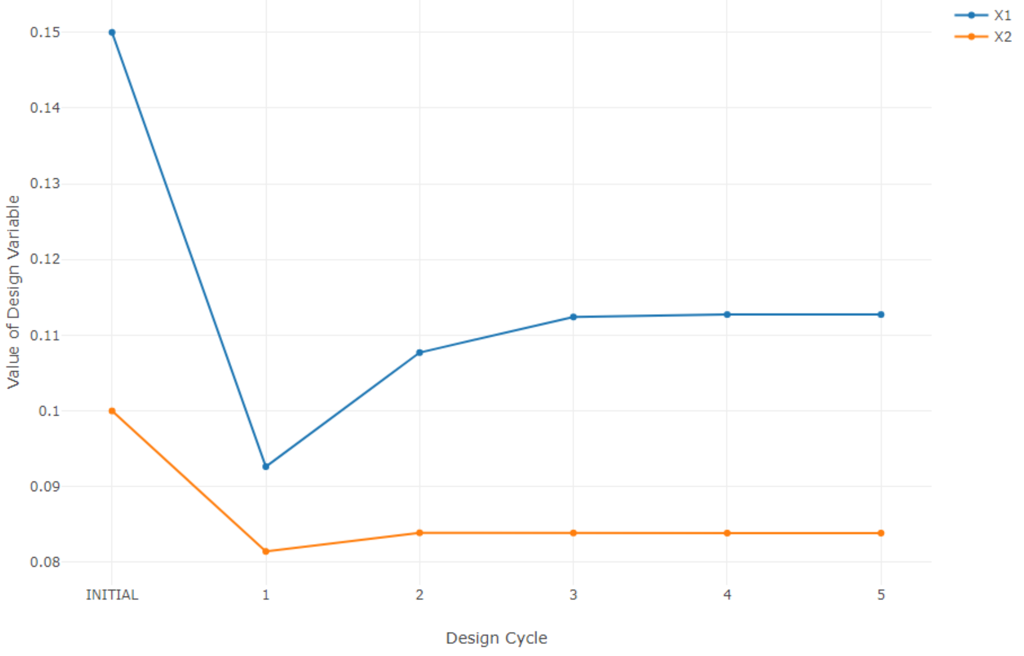
### Final Message in .f06

RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 5.

### Objective



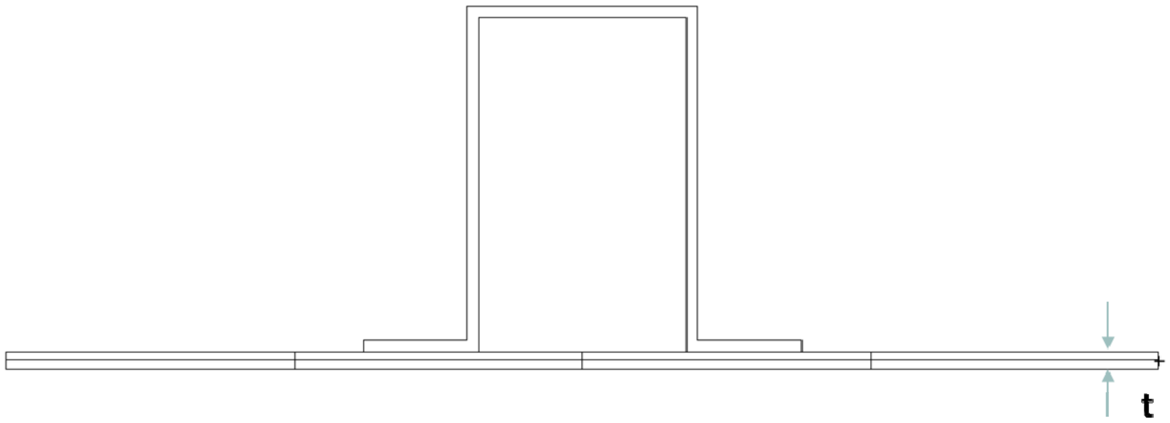

### Design Variables



# Goal: Use Nastran SOL 200 Optimization

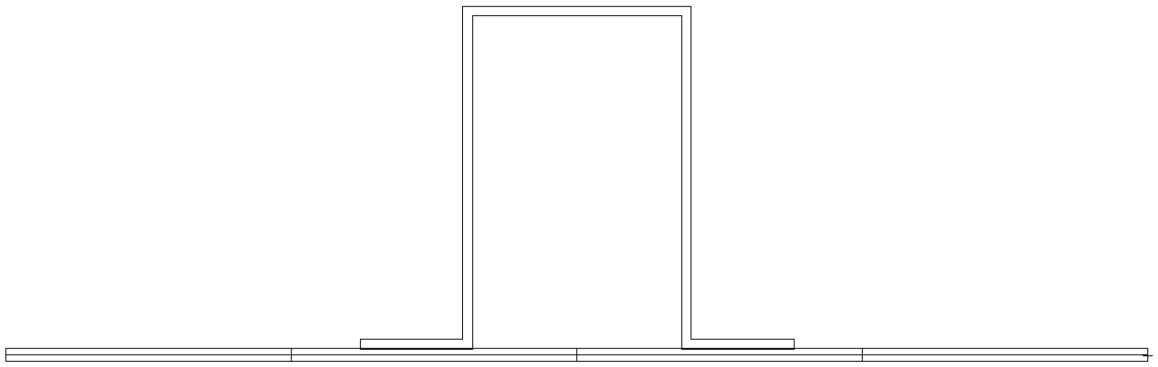
Initial Design
- Weight: 6.962

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




Optimized Design
- Weight: 5.477

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



# Update the original structural model with optimized parameters

Use the .pch file

# Contact me

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- Structural optimization questions
- Access to the SOL 200 Web App

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