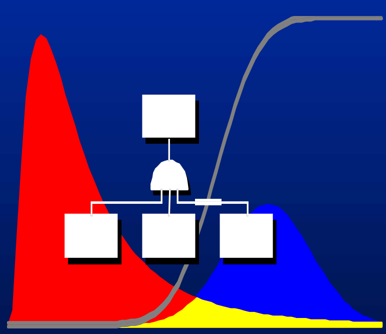
Fast Discovery of the Best Designs



by

Andreas Vlahinos, Ph.D.

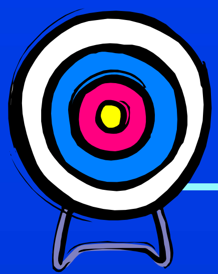
Principal,

Advanced Engineering Solutions, LLC

4547 N. Lariat Dr., Castle Rock, CO 80104

Phone: 303-814-0455; email: andreas@aes.nu

www.aes.nu



Learning Outcomes

- Understand the basics of designed experiments and robust design
- Enable designs to be driven by their product specifications
- Know how to use simple graphical techniques to analyze multi-objective study data
- Perform automated design space exploration
- Optimize automatically the design for a set of performance attributes
- Design for Six-sigma quality levels

Application Activity # 1

Identification of the most influential Pro/E parameters (DOE)

Application activity #1:
Identification of the most influential Pro/E parameters

- Problem Statement:

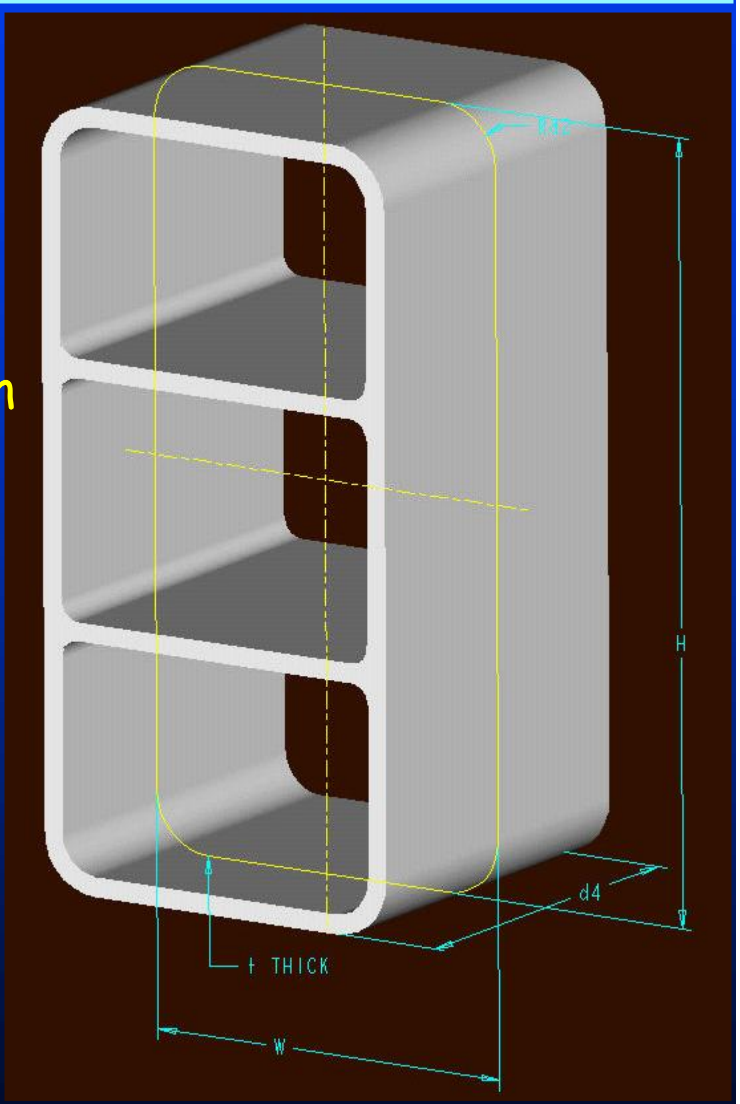
  Using 2 level 3 factor design of experiments determine the Pro/E parameters W, H, t that are the most influential on the performance attribute (Ixx/A) for the aluminum extruded section shown.

  where:

  $80 < W < 120$

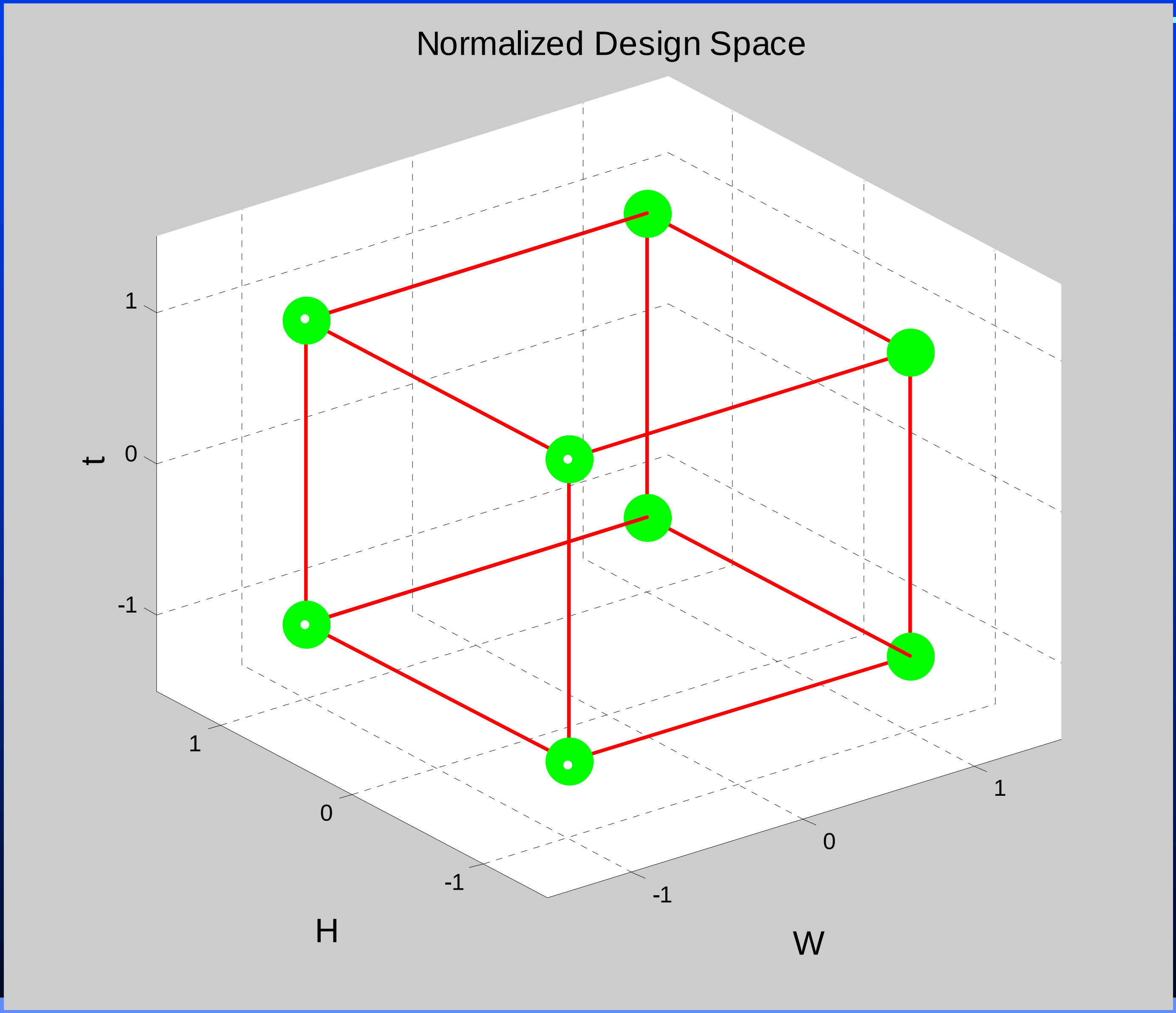
  $160 < H < 240$

  $4 < t < 6$

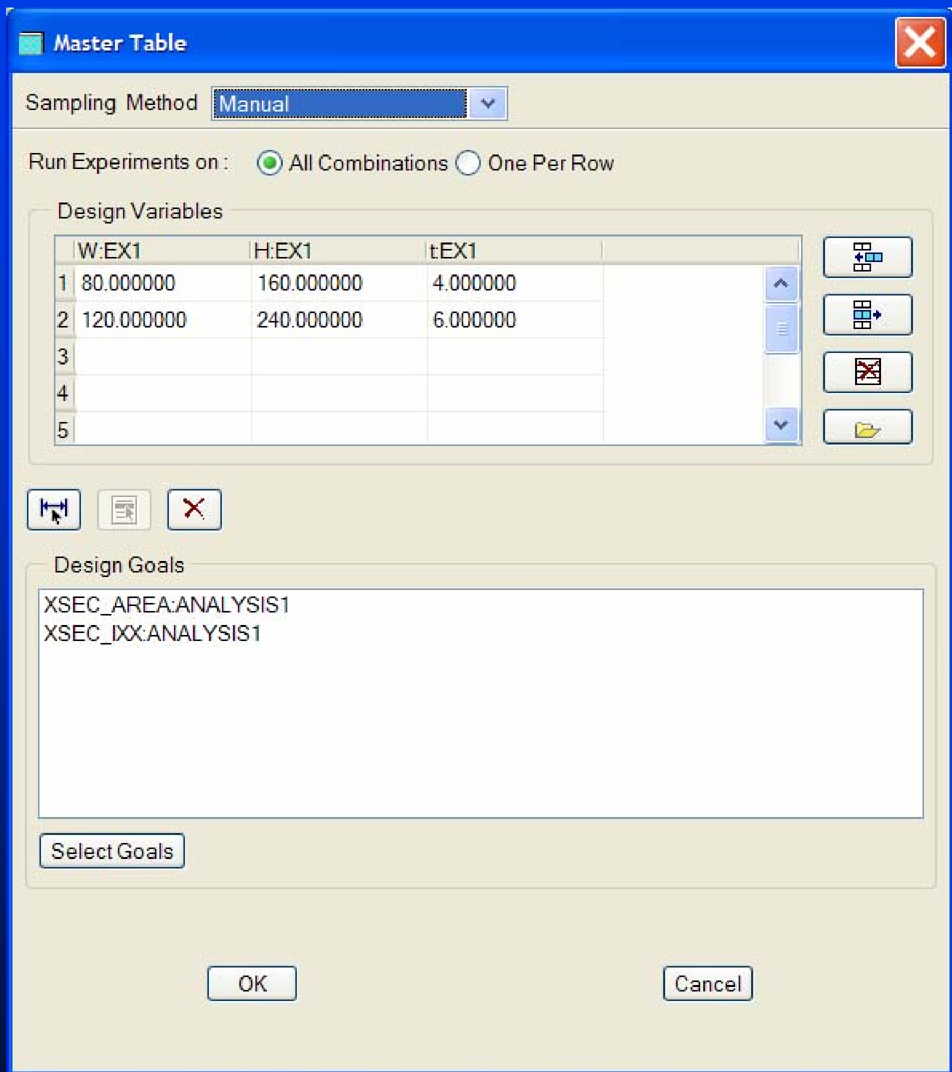


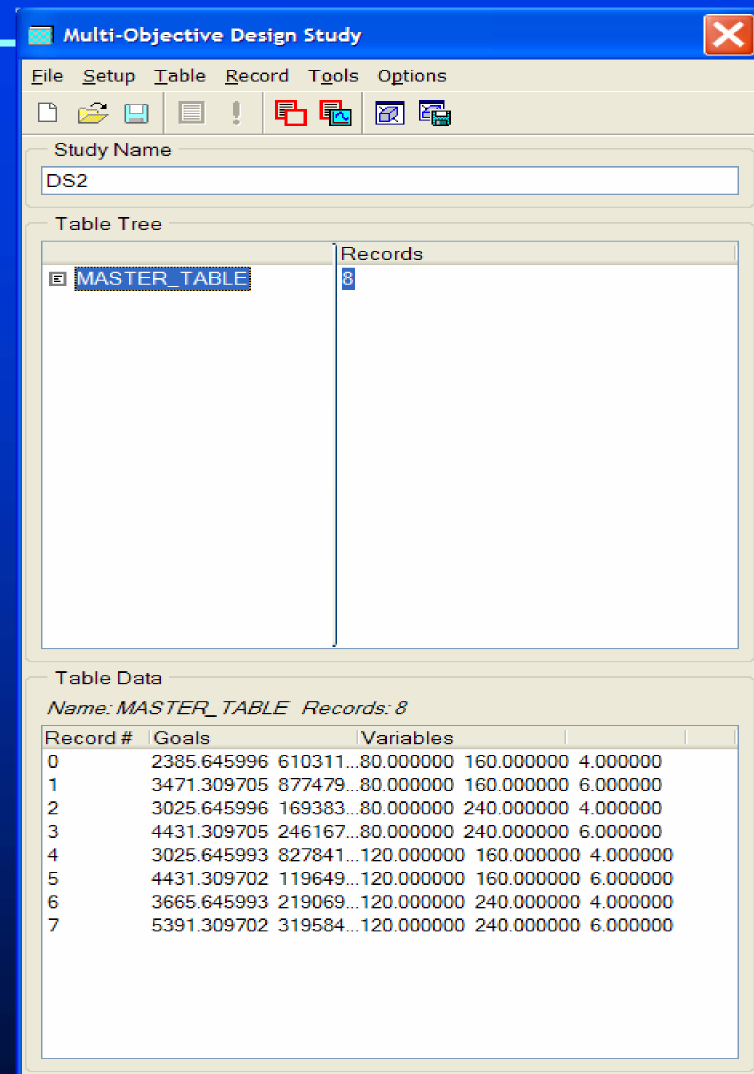
- Learning Goals:
  - Understanding the fundamentals of Designs Of Experiments

Design Exploration for Full Factorial, 2 level - 3 factor design



Multi-Objective Design Study – Full Factorial





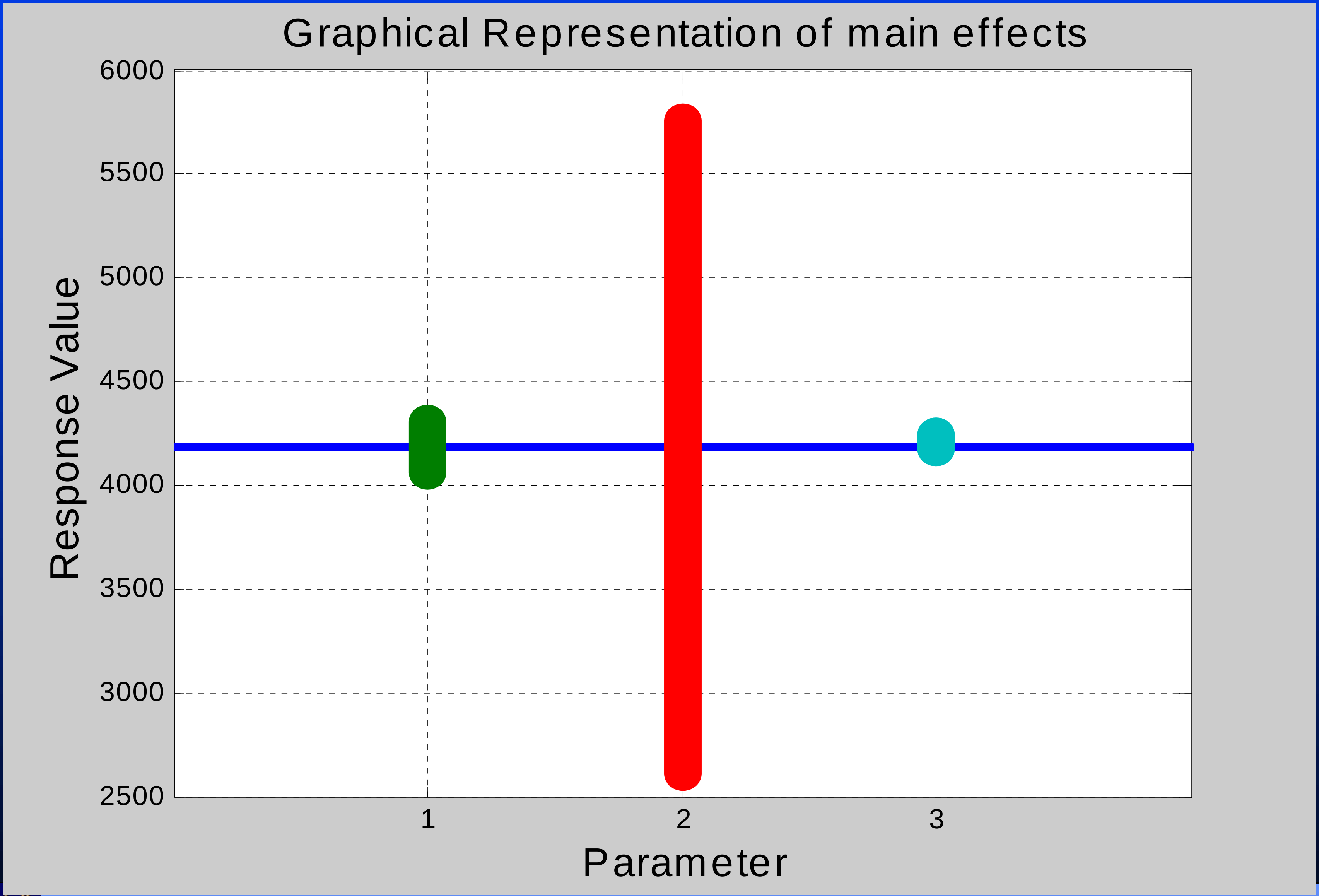
Response Table for Three-factor Experiment

Experiment Number	Response Value	W (Width)		H (Height)		t (thickness)	
		min 80	max 120	min 160	max 240	min 4	max 6
1	R1	R1		R1		R1	
2	R2	R2		R2			R2
3	R3	R3			R3	R3	
4	R4	R4			R4		R4
5	R5		R5	R5		R5	
6	R6		R6	R6			R6
7	R7		R7		R7	R7	
8	R8		R8		R8		R8
AVERAGE	R	W1	W2	H1	H2	t1	t2
EFFECT		W2-W1		H2-H1		t2-t1	

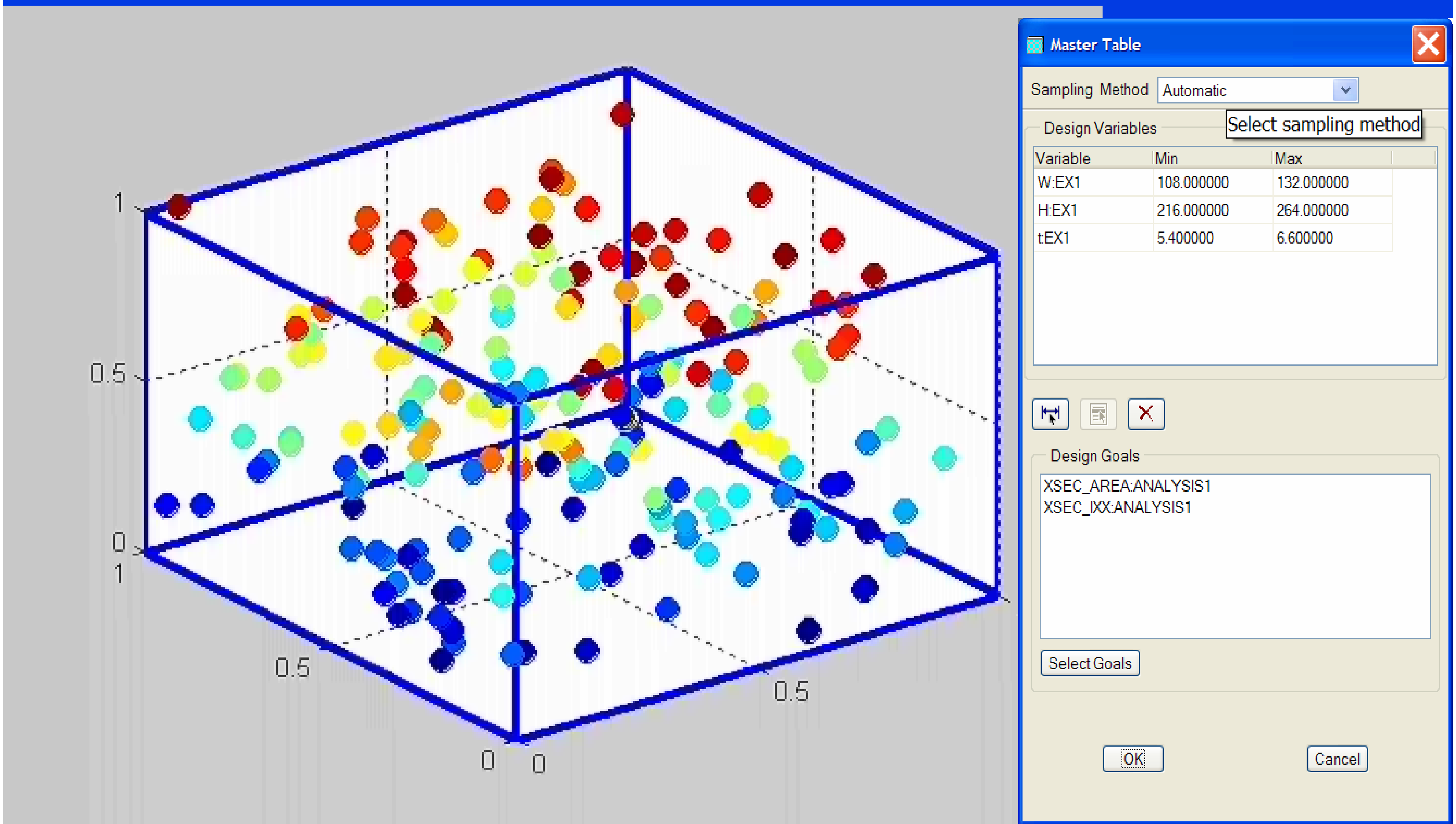
Response Table for Three-factor Experiment

Experiment Number	Response Value	W (Width)		H (Height)		t (thickness)	
		min 80	max 120	min 160	max 240	min 4	max 6
1	2558	2558		2558		2558	
2	2527	2527		2527			2527
3	5598	5598			5598	5598	
4	5555	5555			5555		5555
5	2636		2636	2636		2636	
6	2700		2700	2700			2700
7	5976		5976		5976	5976	
8	5927		5927		5927		5927
AVERAGE	4184.6	4059.5	4309.8	2605.3	5764.0	4192.0	4177.3
EFFECT		250.25		3158.75		-14.75	

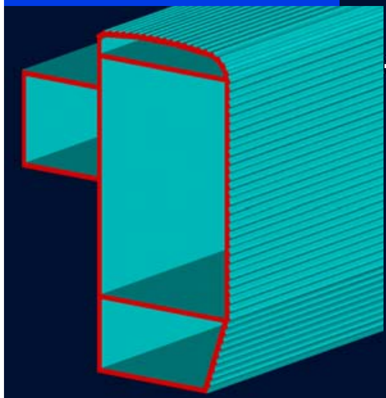
Graphical Representation of Main Effects

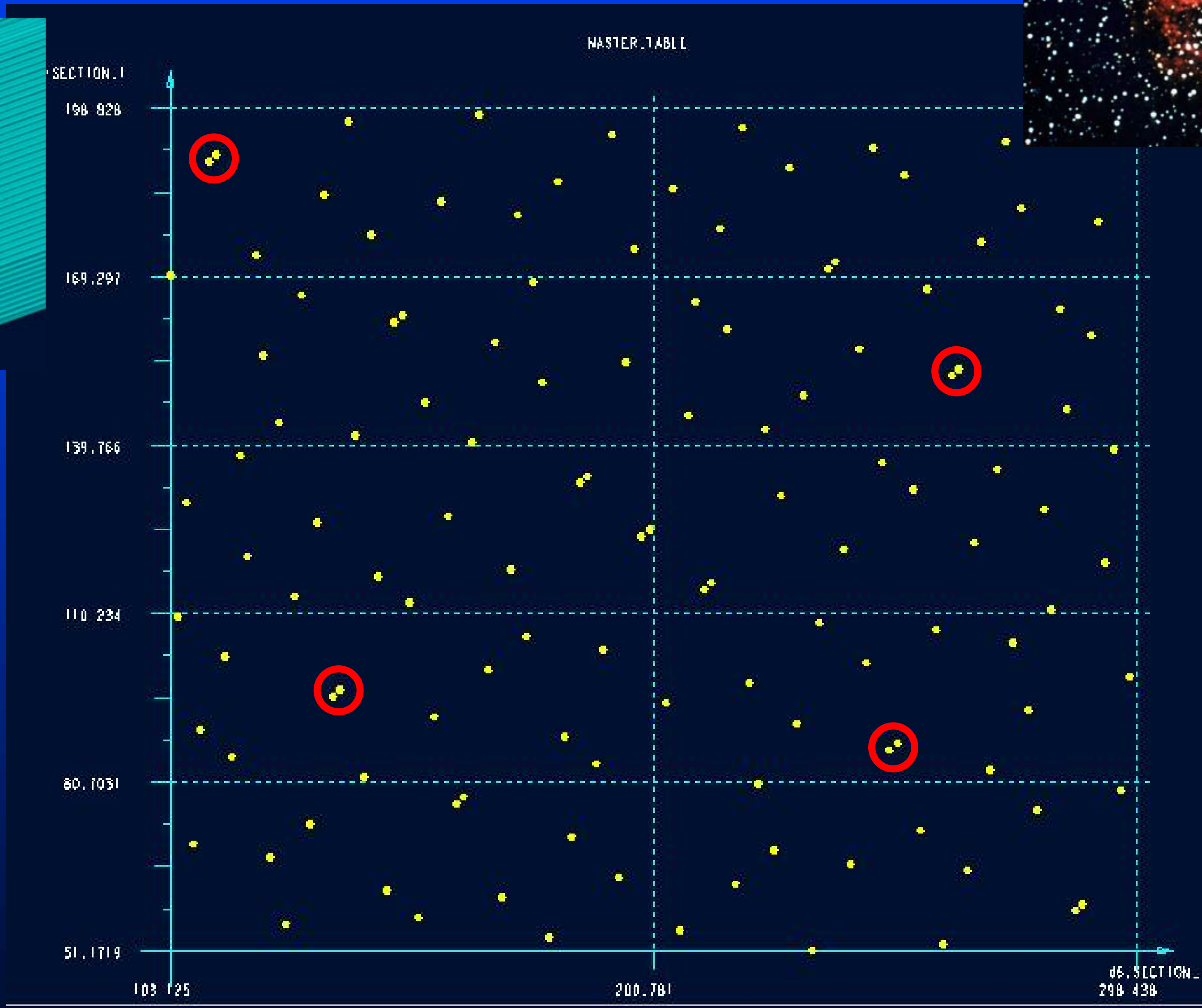


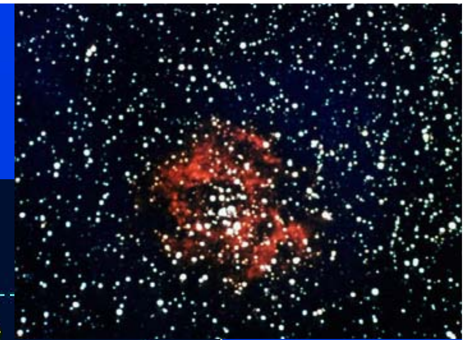
Automatic Design Exploration



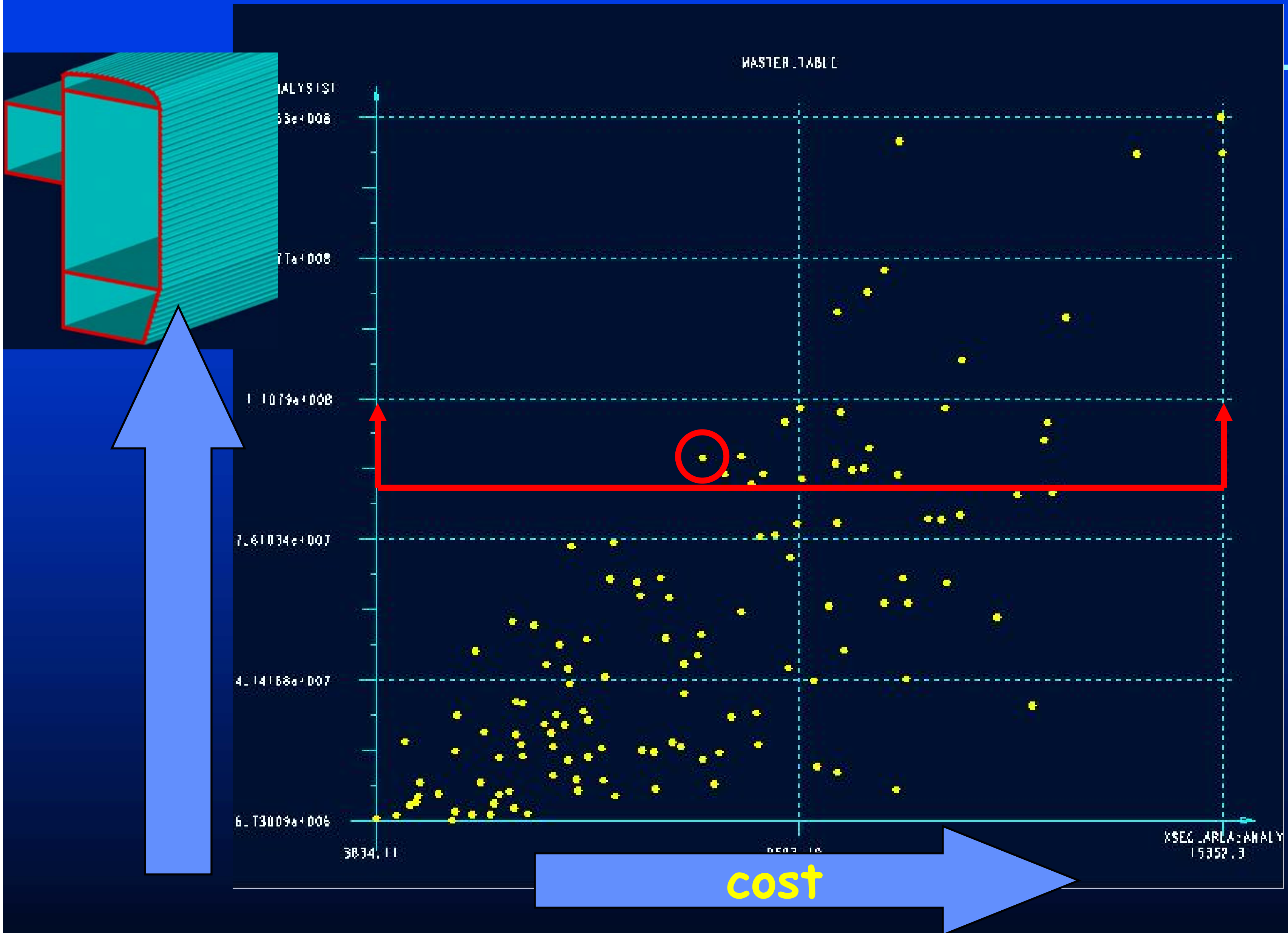
Scatter Plot for two of Design Variables







Scatter Plot of Ixx versus Area



Application activity # 2

Minimum Cost Container

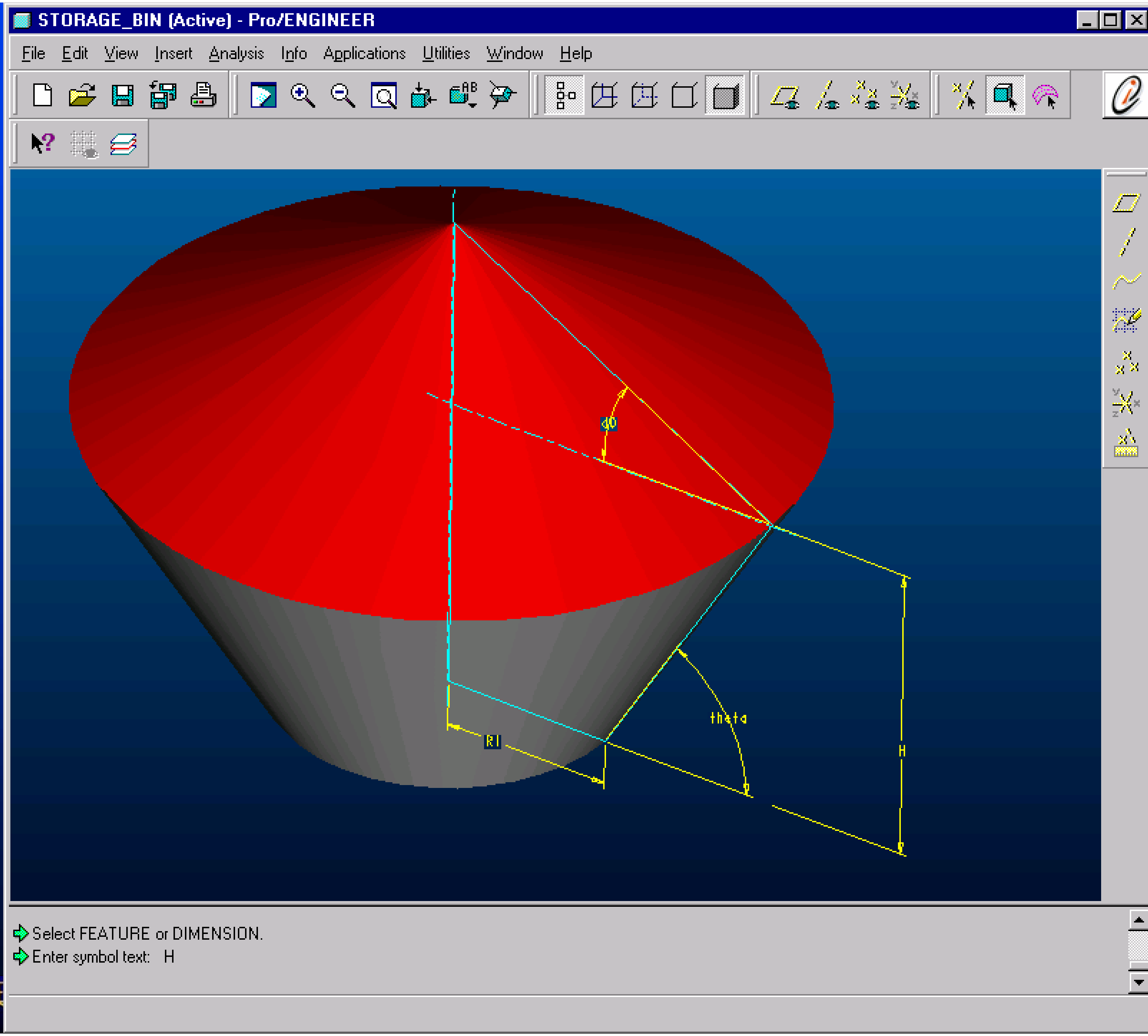
Application activity # 6
Minimum Cost Container

Problem Statement:

Consider the open top circular storage bin container shown. Choose the height h, the width d, and the slope θ such that the bin holds a prescribed volume V = 10 m^3 and it is of a minimum cost. The cost of the base per unit area is C1=1.00 $/$m^2$ and the cost of the side per unit area is C2 =1.50 $/$m^2$

BMX Learning Goals:

- Create an optimization study that holds a prescribed value constant and minimizes a cost function.


STORAGE_BIN (Active) - Pro/ENGINEER
File Edit View Insert Analysis Info Applications Utilities Window Help
theta
R1
H
Select FEATURE or DIMENSION.
Enter symbol text: H

2004

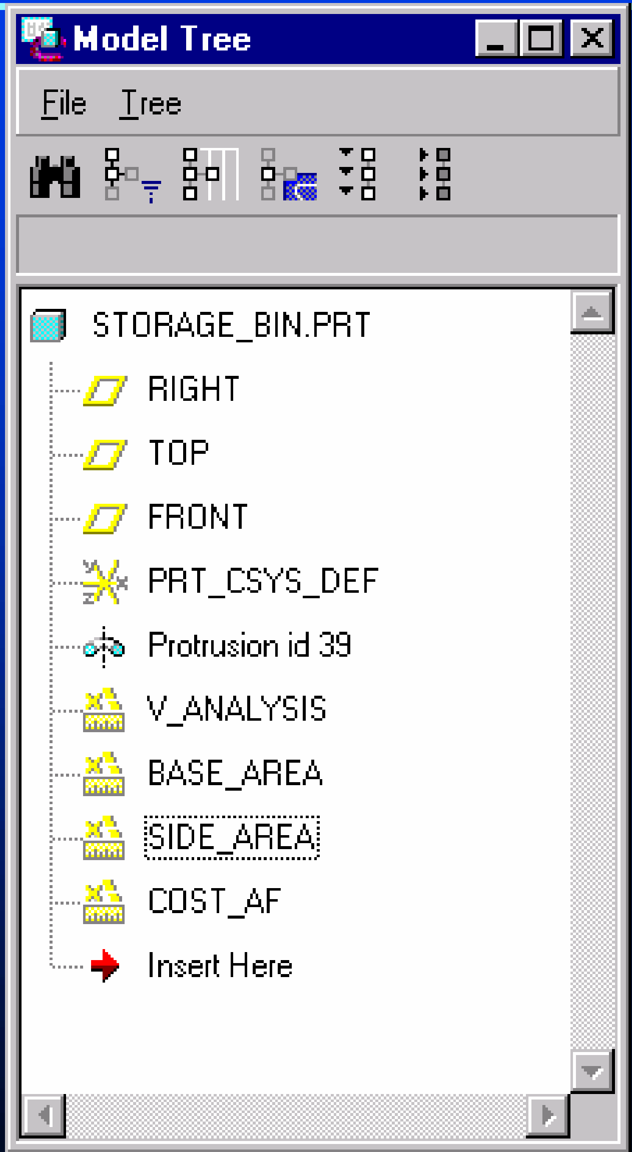
Volume, Area and Cost Analyses Features

- Insert a model analysis feature to compute the volume
- Insert a measure analysis feature to compute the base area
- Insert a measure analysis feature to compute the side area
- Insert a Relation Analysis Feature to compute the cost:

  cost=

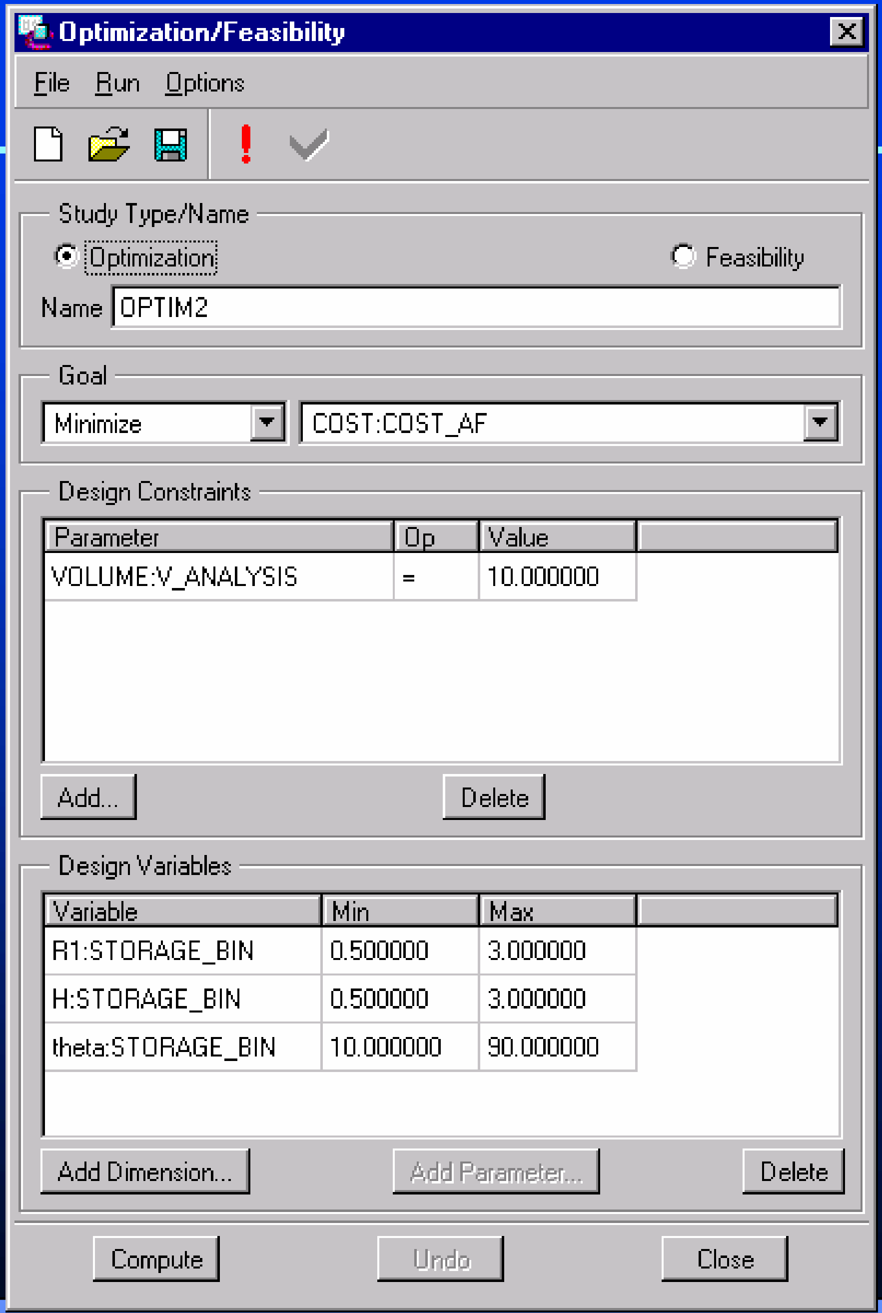
  1.00*AREA:FID_BASE_AREA+

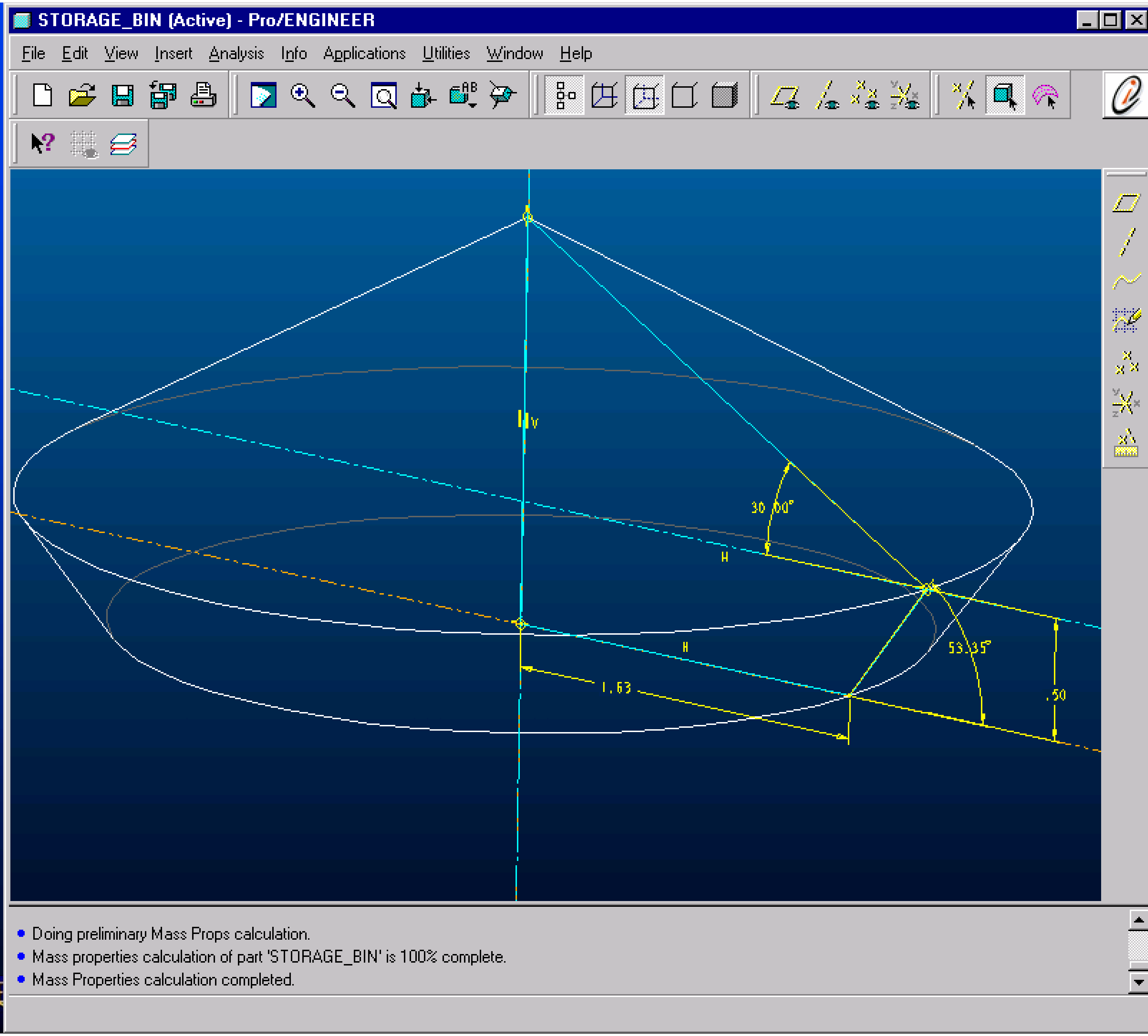
  1.5*AREA:FID_SIDE_AREA



Optimization of storage container

- Goal:
  - Minimize cost
- Constraints:
  - Volume = 10
- Design Variables:
  - 0.5 < RADIUS < 3
  - 0.5 , HEIGHT < 3
  - 10 < ANGLE < 90
- Optimum Solution:
  - RADIUS = 1.63
  - HEIGHT = 0.50
  - ANGLE = 53.35




STORAGE_BIN (Active) - Pro/ENGINEER
File Edit View Insert Analysis Info Applications Utilities Window Help
30.00°
53.35°
1.63
.50
Doing preliminary Mass Props calculation.
Mass properties calculation of part 'STORAGE_BIN' is 100% complete.
Mass Properties calculation completed.

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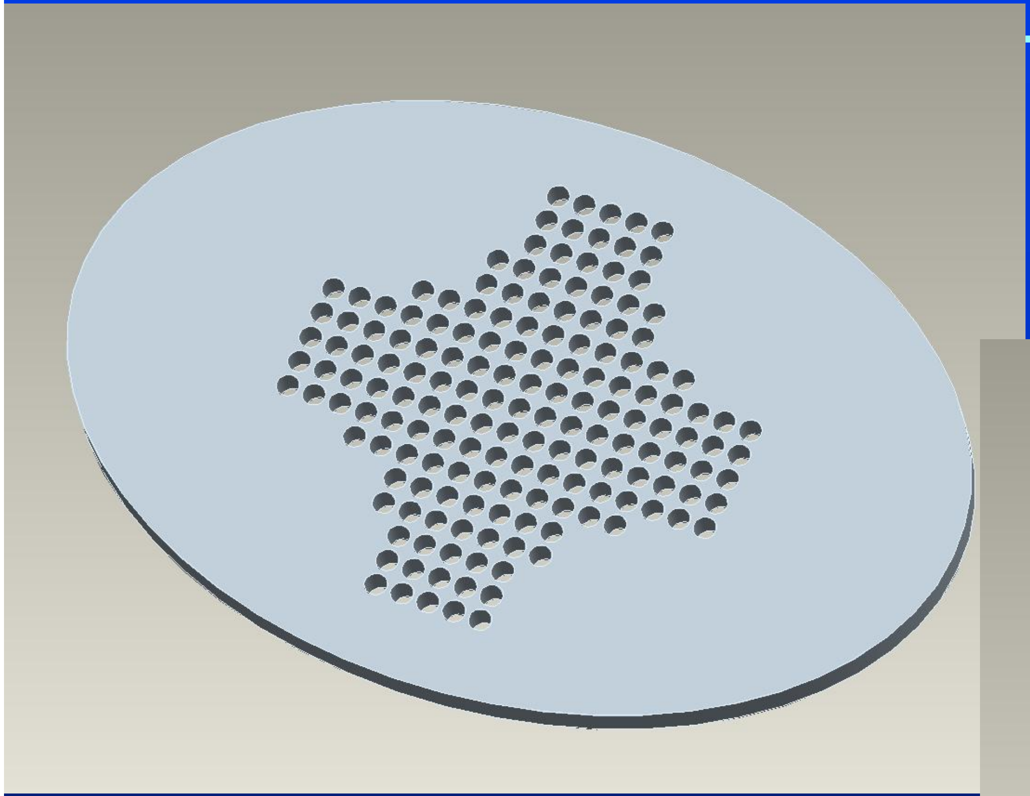
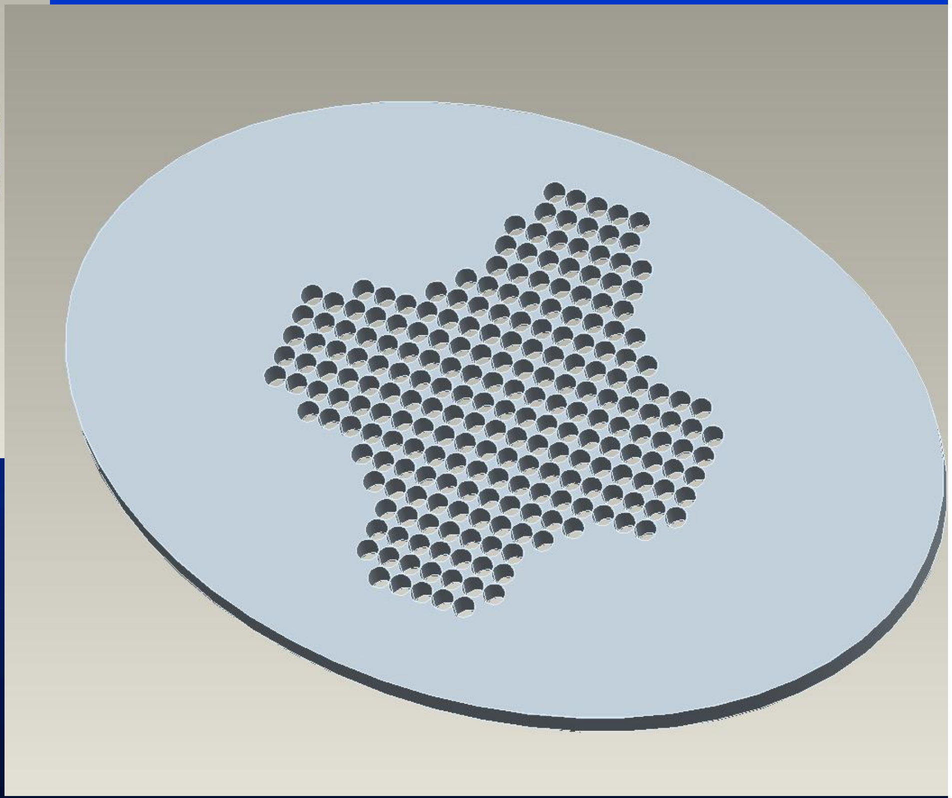
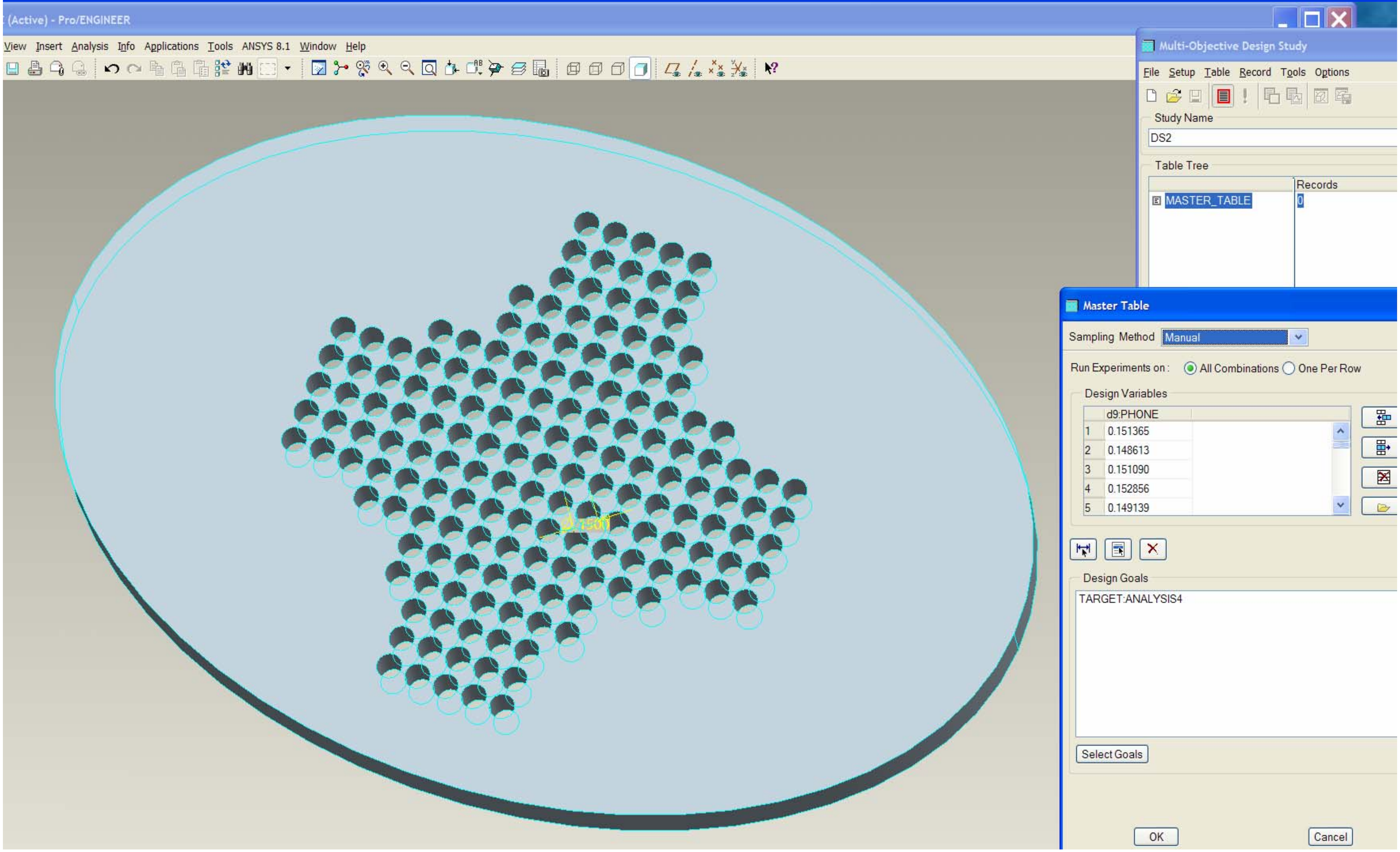
Application activity # 3
Cell Phone speaker - Spacing Sensitivity



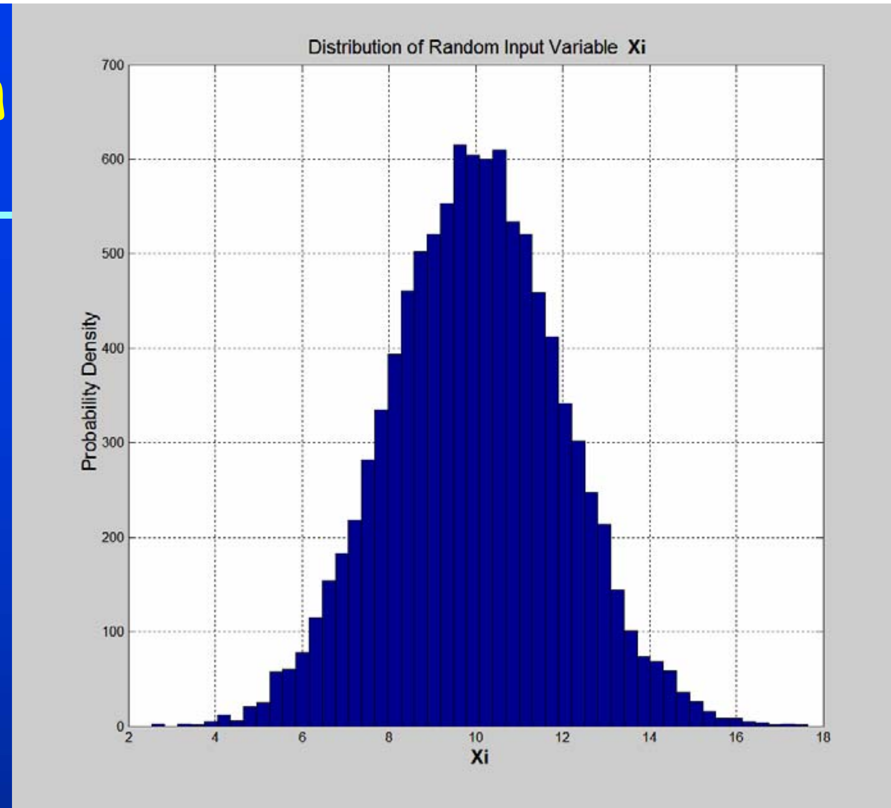


Spacing Sensitivity on Area Ratio

Robust Design Using Multi Objective Design Study

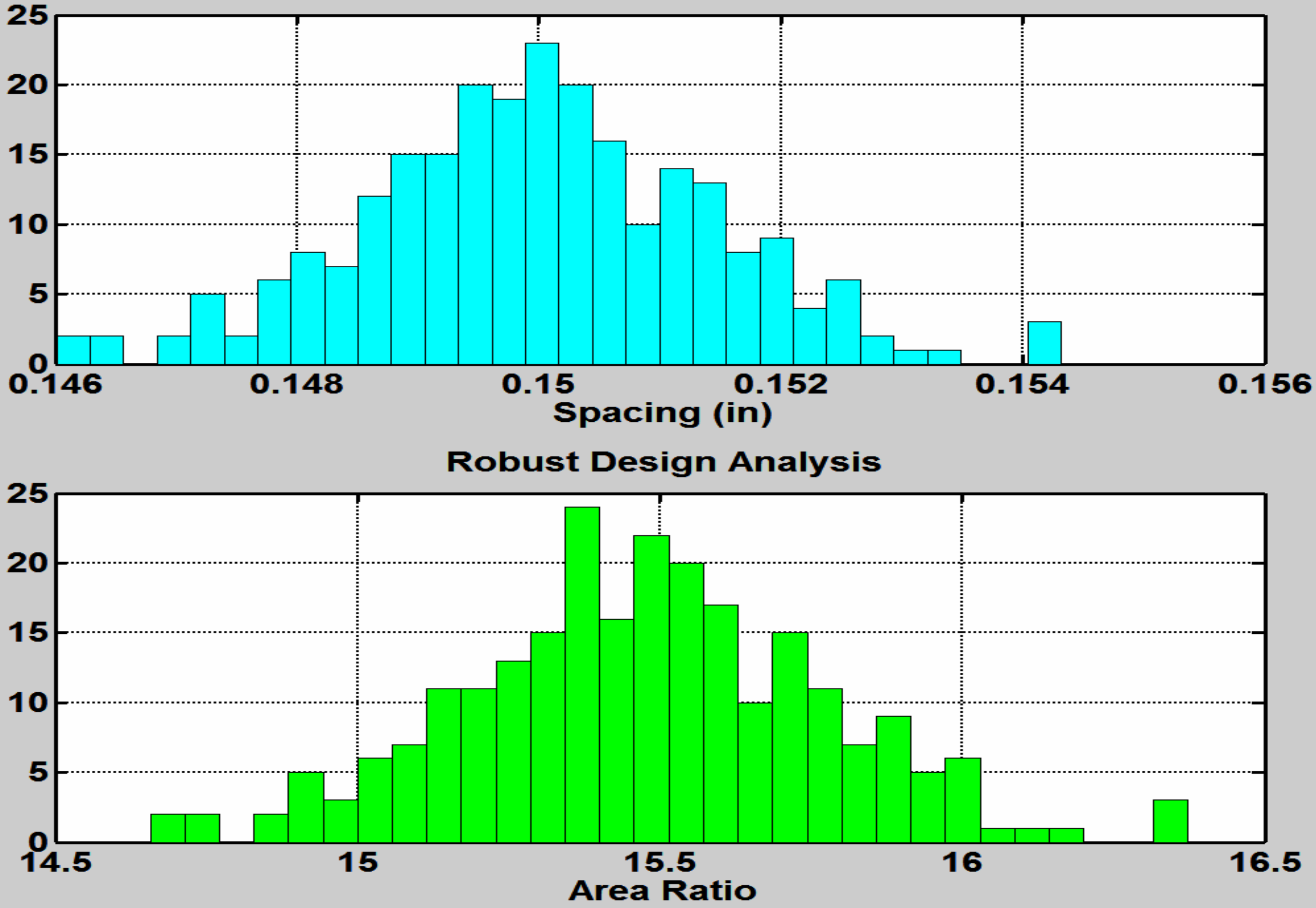


Random Number Generation



- Random numbers for common distributions can be obtained using Box-Muller method in Excel and the equations:
  - Standard Normal Distribution
  - Xi= $\mu+\sigma*Rn$
  - Where:
    - $Rn = \sqrt{(-2*\ln(Ru)} * \cos(2\pi Ru)$
    - Ru a uniform random number generator
    - In Excel =SQRT(-2*LN(RAND()))*COS(2*PI()*RAND())
  - Distribution of 10,000 random input variables generated in Excel with a mean of 10 and standard deviation of 2

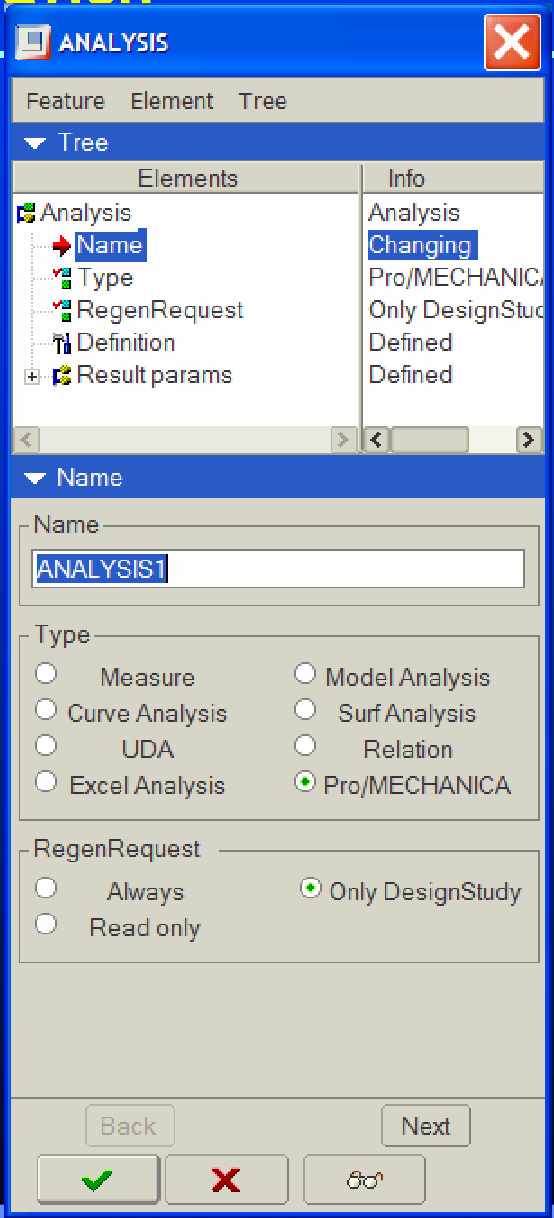
Random spacing Input and Area Ratio Output



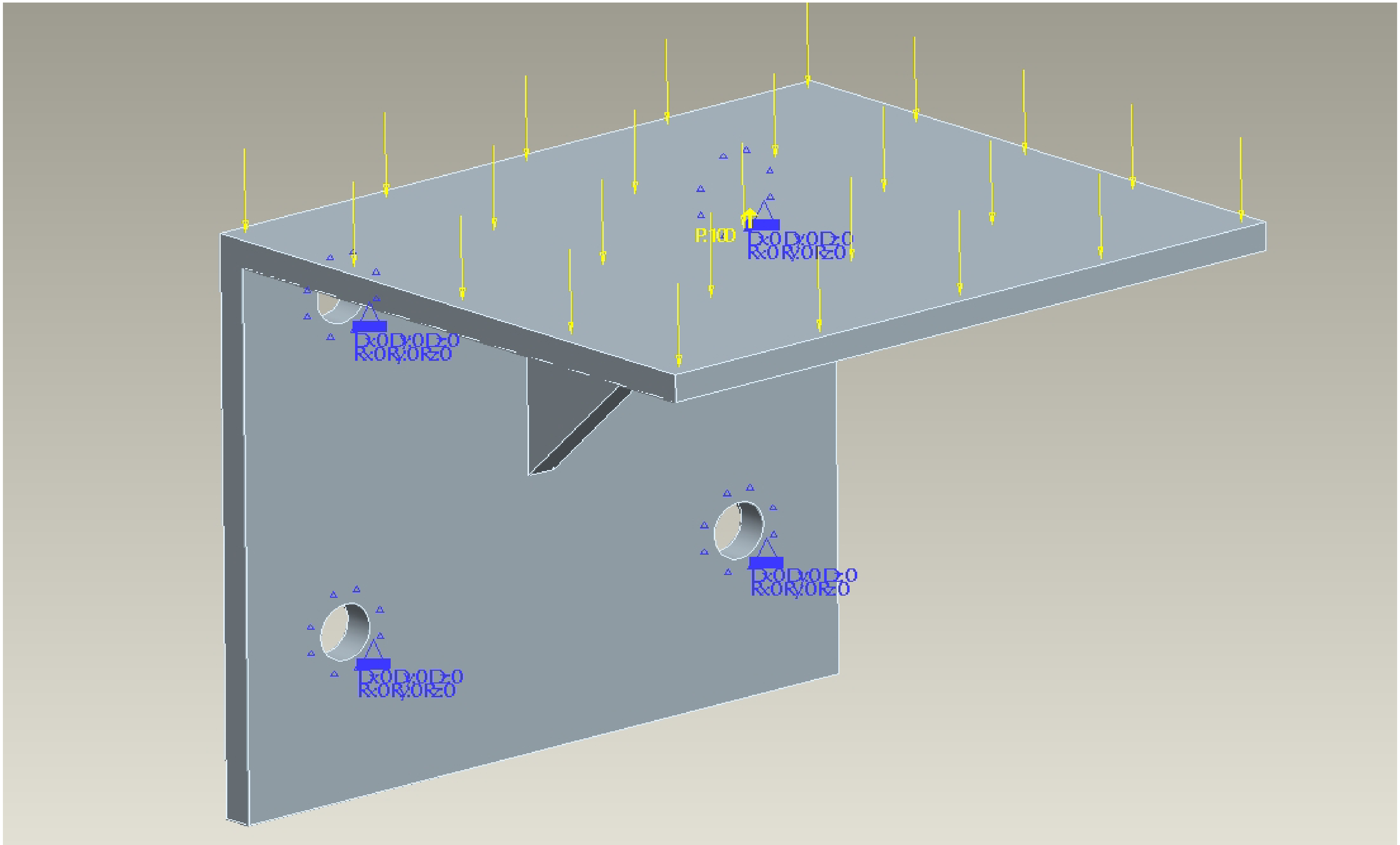
Application activity # 4

BMX - Pro/MECHANICA Integration

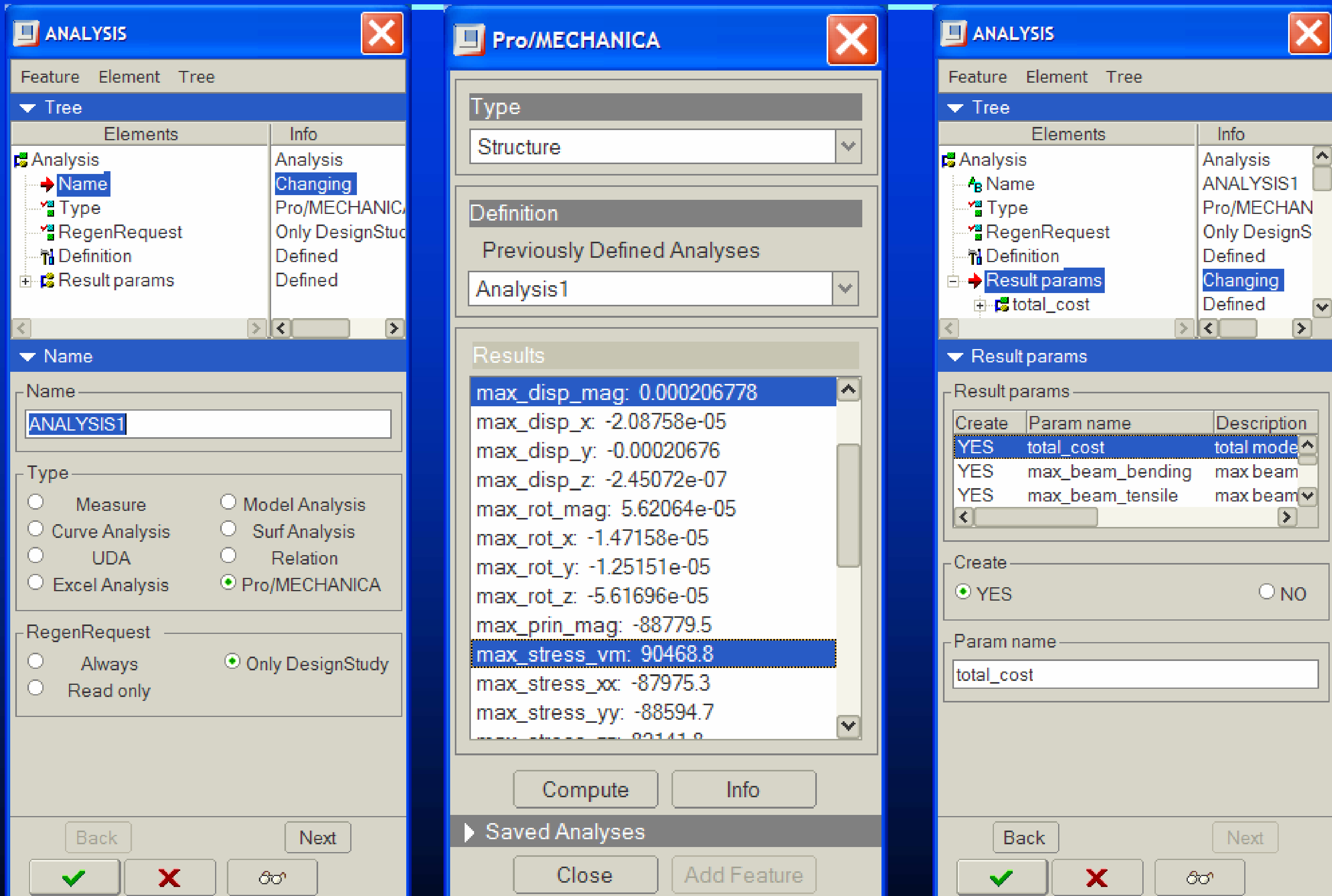
- Set up an analysis in Pro/MECHANICA,
- Set up a BMX Analysis feature.
  - tag the list of quantified results from the Mechanica analysis as a computed parameter.
- Use these computed parameters for relations, Sensitivity, Global Optimization and Multi-Objective Design Studies.



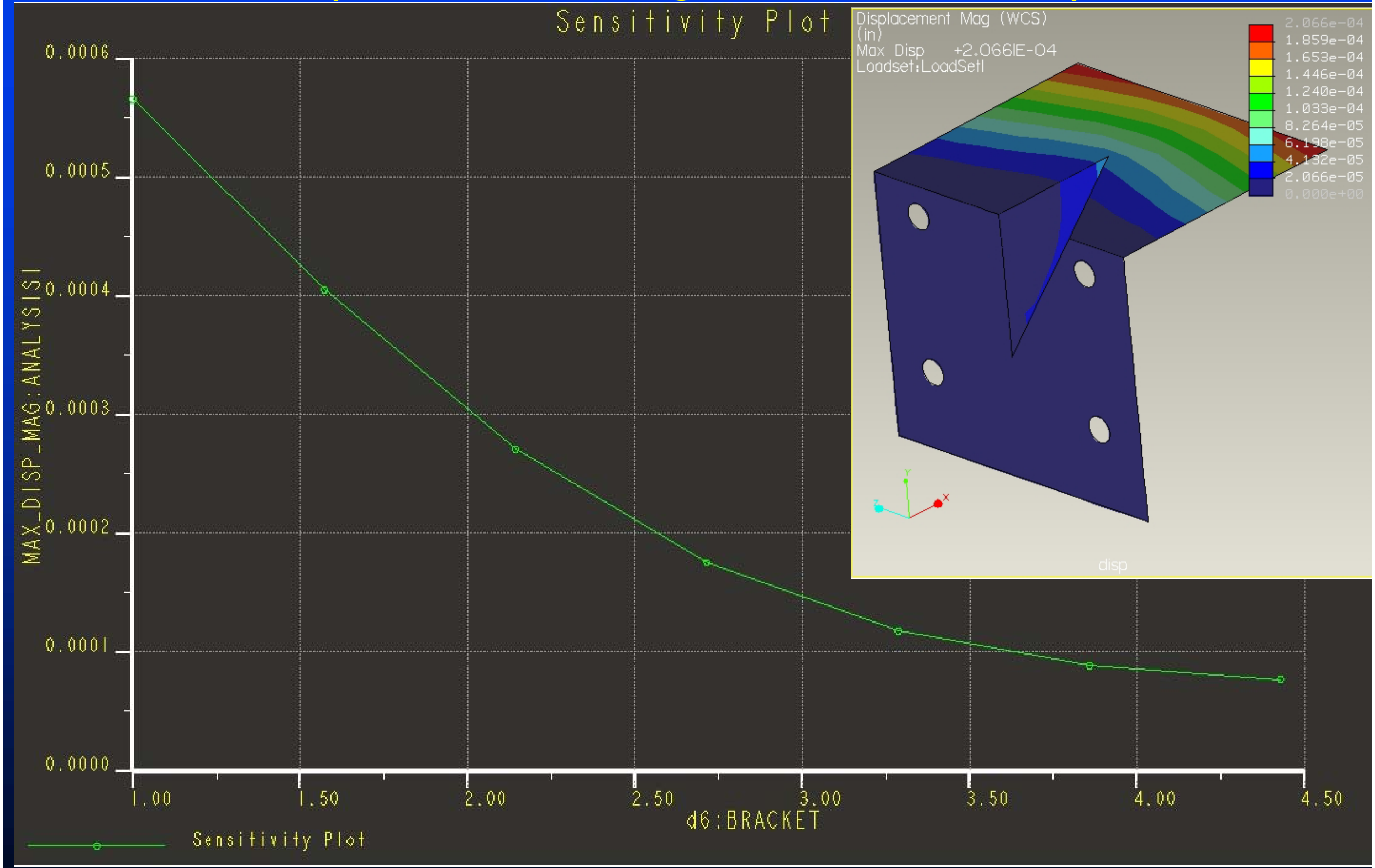
Set up an analysis in Pro/MECHANICA



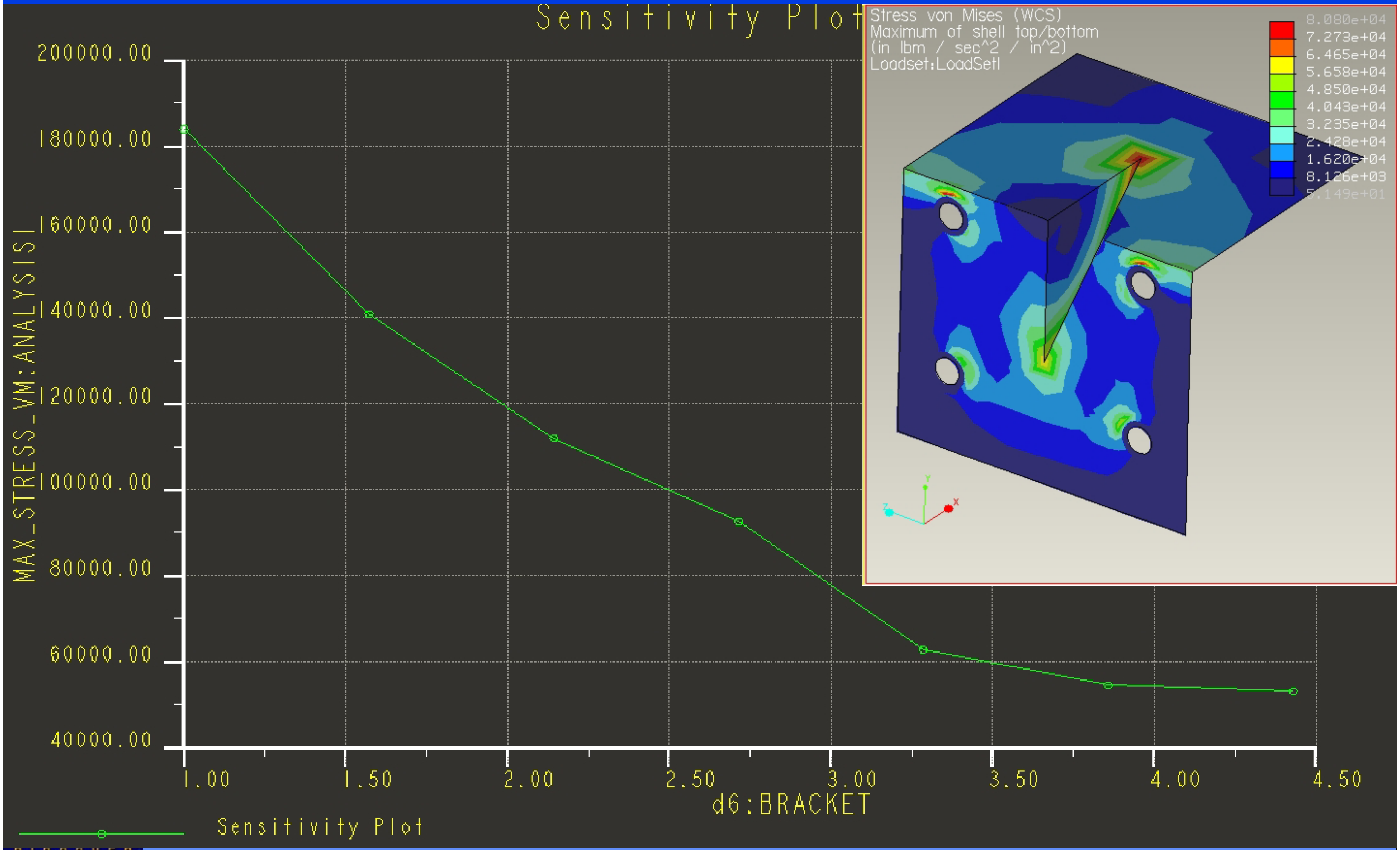
Tag the list of quantified results from the Mechanica analysis as a computed parameter

- 

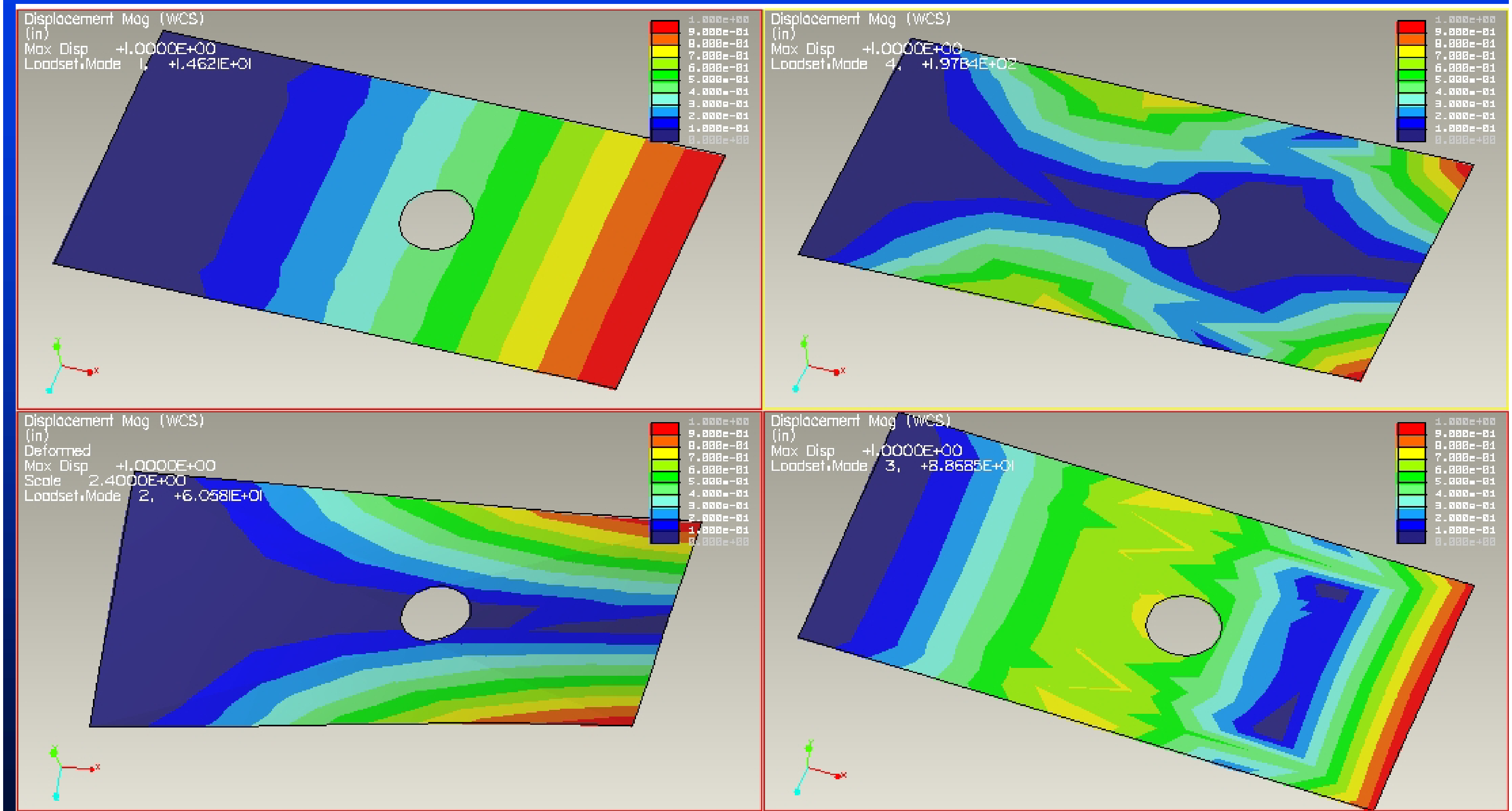
Sensitivity of Rib's length on Max Displacement



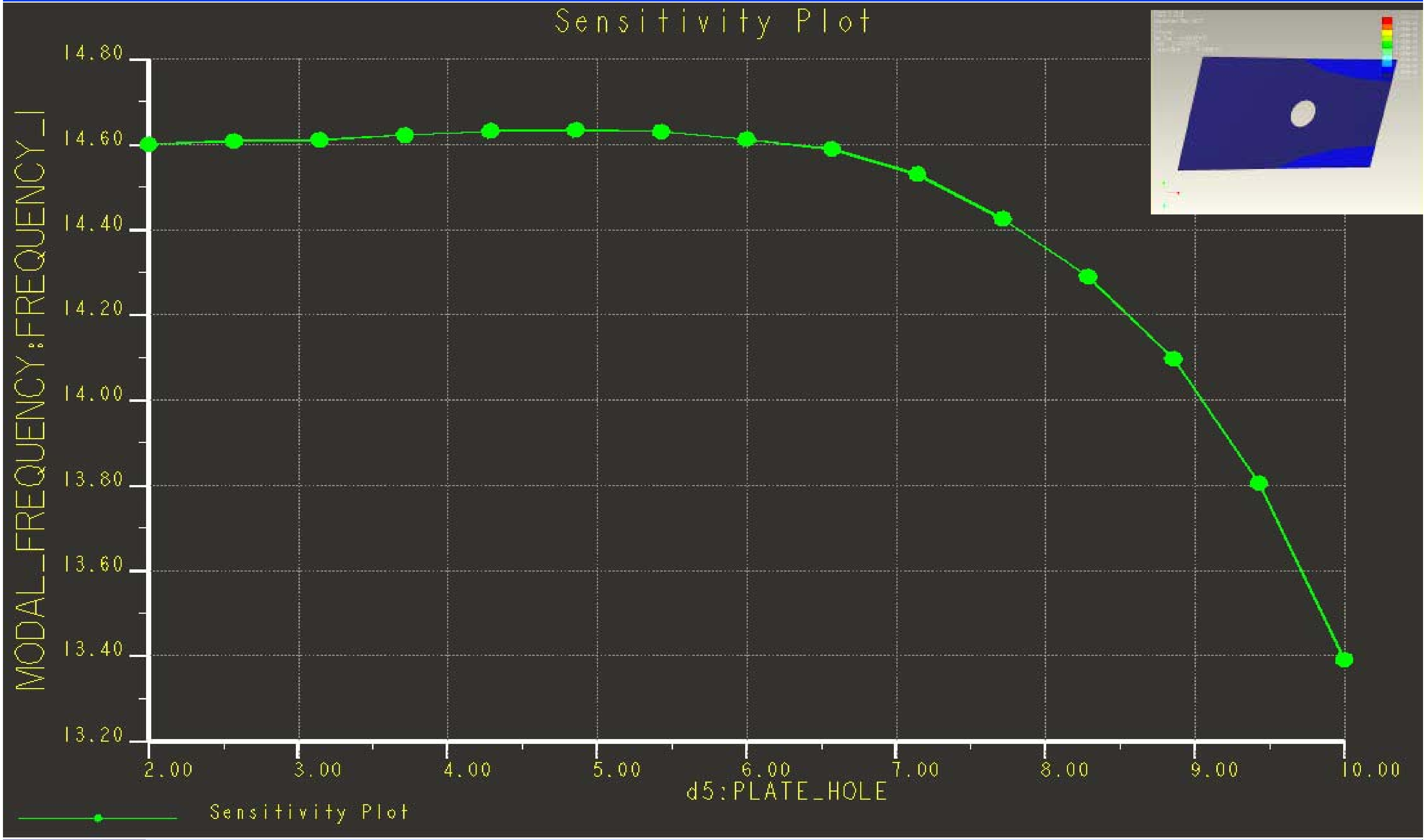
Sensitivity of Rib's length on Max stress



BMX-Modal analysis



Sensitivity of Hole Diameter on Natural Frequency

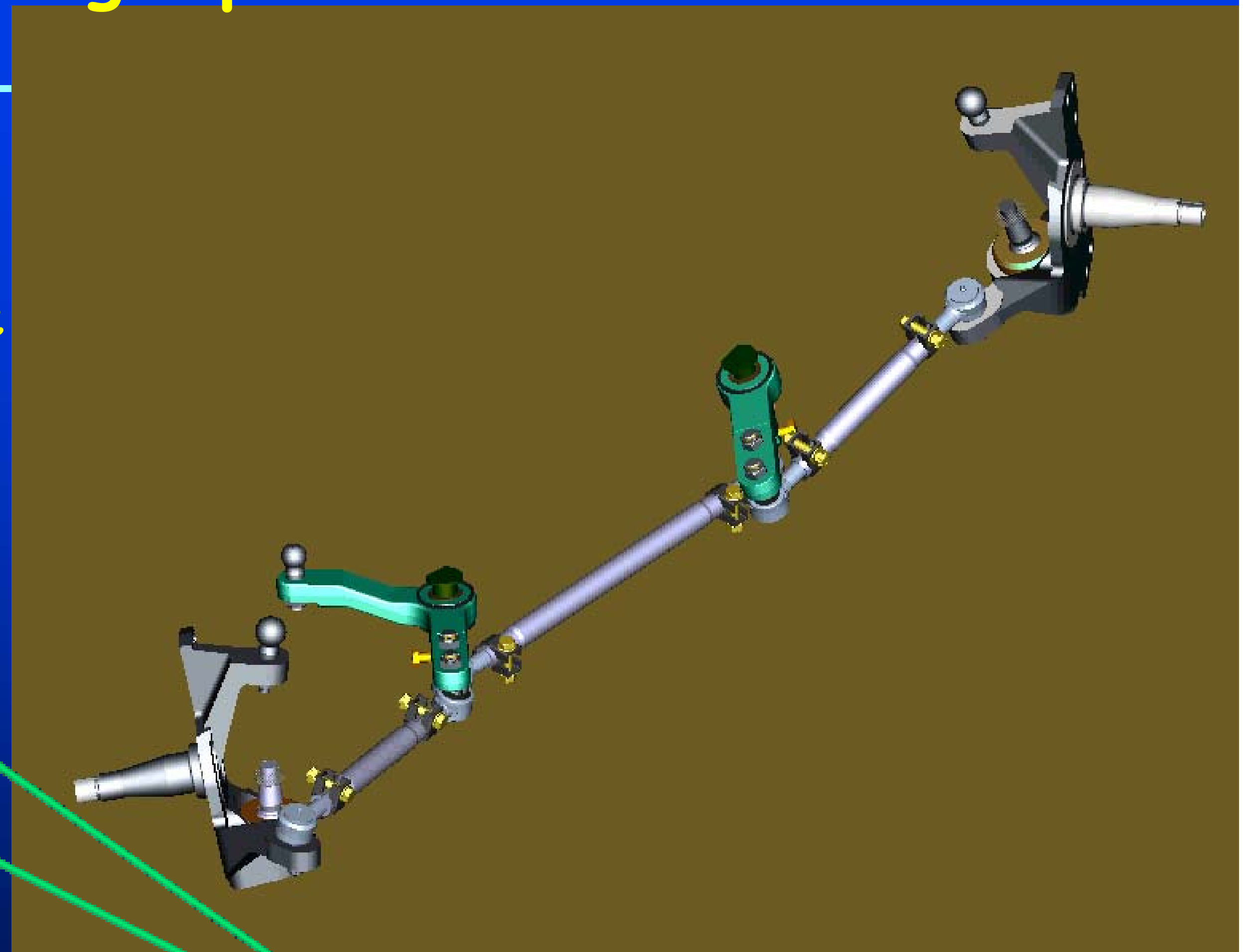


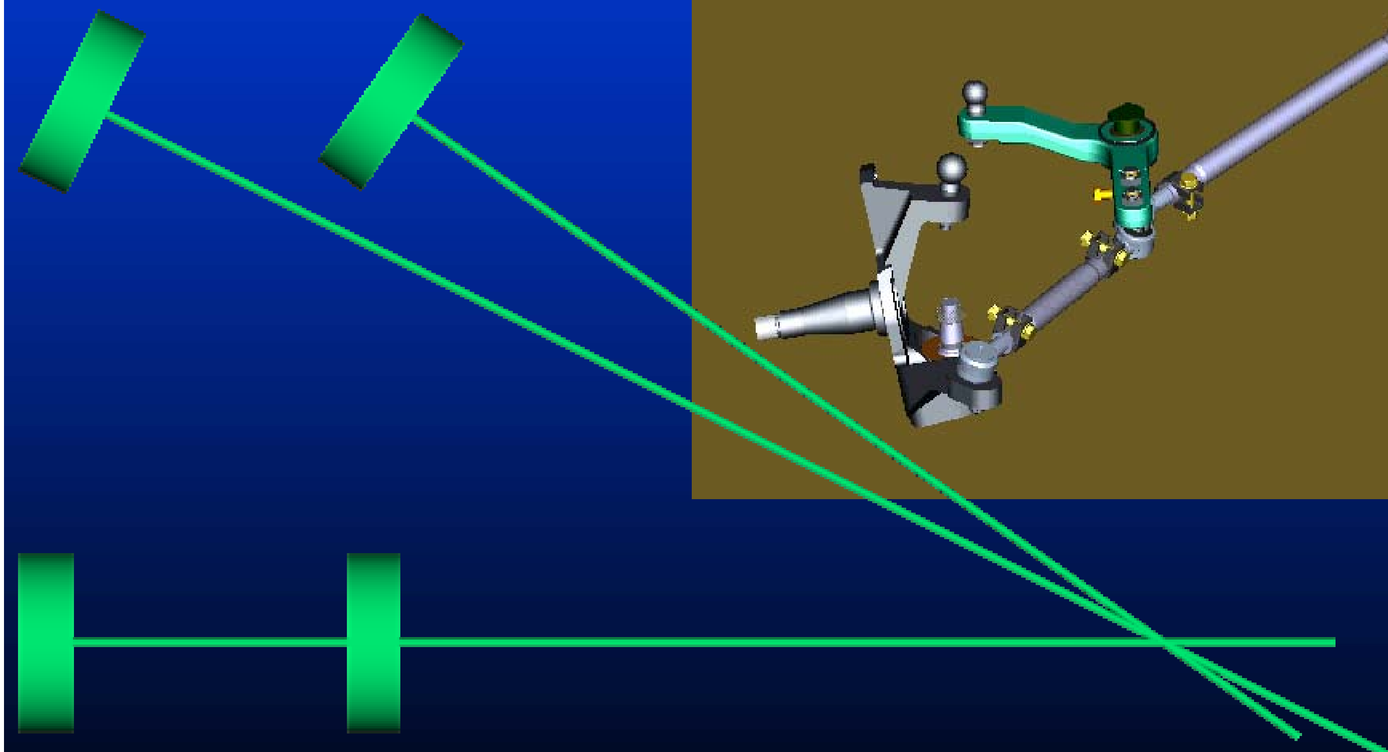
Application activity # 5

Mechanism Optimization

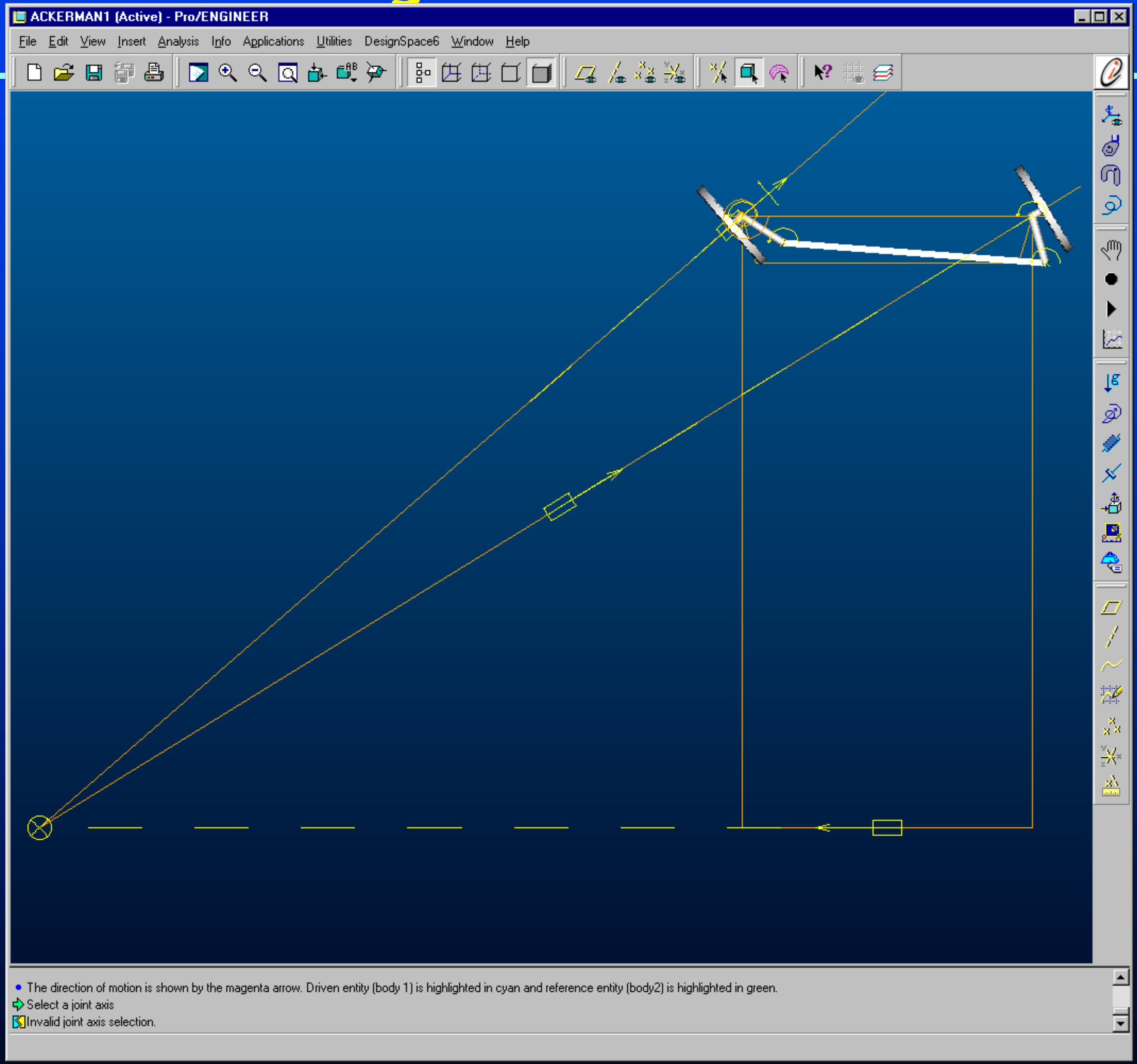
Ackerman Steering Optimization

Find optimum Ackerman angle that minimizes the steering error





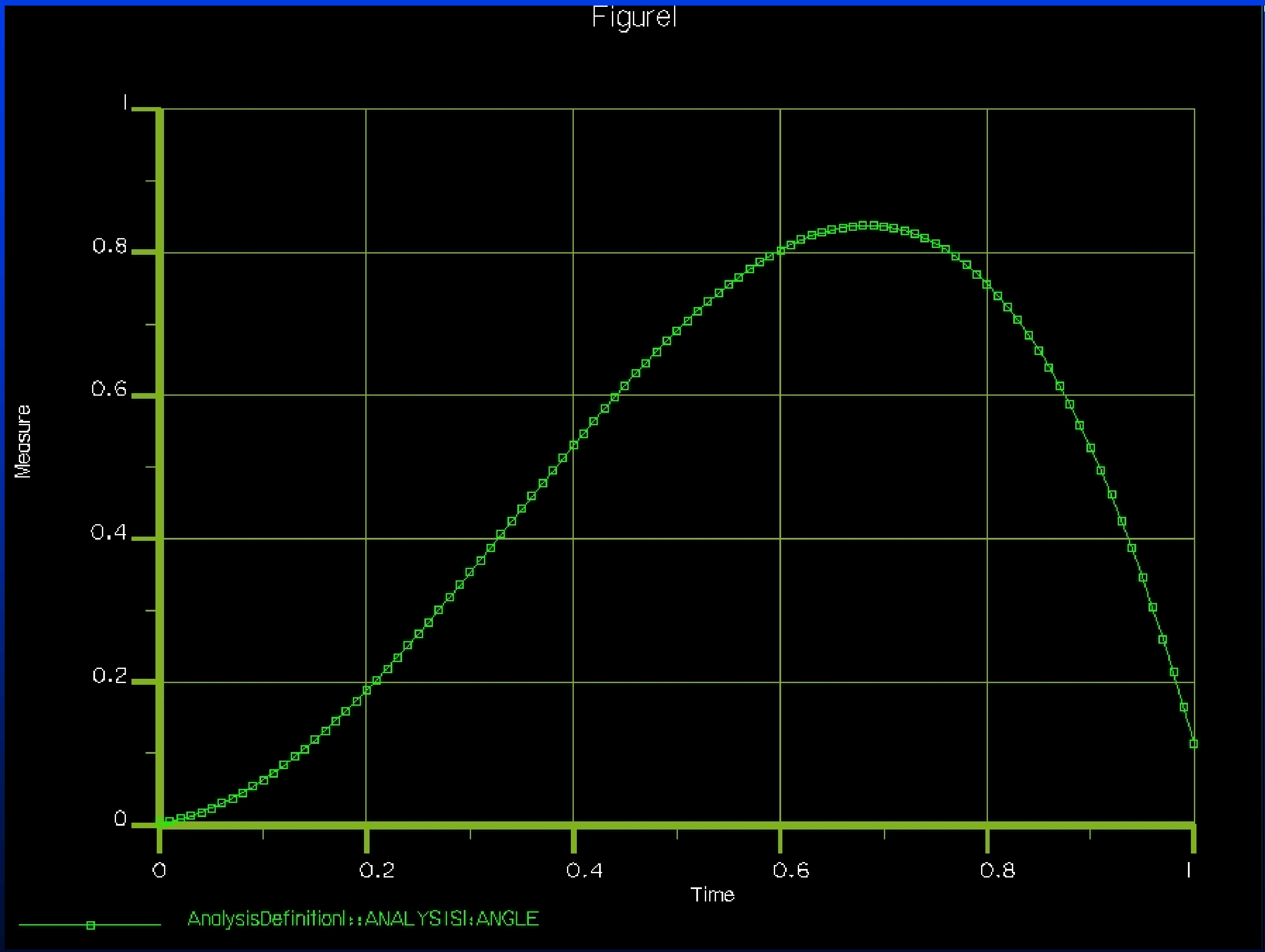
Ackerman Steering Mechanism



Ackerman Steering Optimization

- Assumptions:
  - Low speed steering is achieved by pure rolling of wheels
  - For low speed the slip angles are negligible small
- Goals:
  - Identify the instantaneous center of rotation
  - Establish measures for the steering error
  - Plot the steering error versus time for a given Ackerman angle
  - Using Behavioral Modeling plot the maximum steering error versus the Ackerman angle
  - Find the optimum Ackerman angle that minimizes the steering error

Steering error versus time for Ackerman angle = 16 deg




Create a Vision,
Adopt it,
Adapt to Achieve it