Behavioral Modeling (BMX):

Table of Contents:

Objective:

At the end of this tutorial, you will:

- Understand the basic concepts of Behavioral Modeling
- Know how to instrument your model to provide constant and immediate feedback to design changes
- Know how to use Sensitivity studies to better understand your designs
- Know how to use Feasibility studies to improve designs
- Know how to use Optimization to produce the best version of your products

Overview:

The Problem - The way each engineer solves a problem is unique, and engineers don't get enough time to investigate all possible design solutions. Imagine if you could capture how your engineers solve problems and then let the computer automatically investigate all possible alternatives and present you with the optimal design. Imagine the impact of this on your company.

The Solution - These were the problems we solved with Behavioral Modeling -- a solution that captures product-intent as a natural part of the engineering process, and then automatically builds virtual prototypes that satisfy multiple objectives. What's more because the problem and solution have been captured electronically in the design, the system can automatically solve future real engineering problems.

The Technology - This unique solution is at the heart of PTC's Pro/ENGINEER. It is patent-pending and called Behavioral Modeling. It delivers significant productivity gains to the people who use it and there is nothing else quite like it: so much so that it won awards from INDUSTRYWEEK and Computer Graphics World.

Tutorial:

This tutorial will cover four major topics related to behavioral modeling:

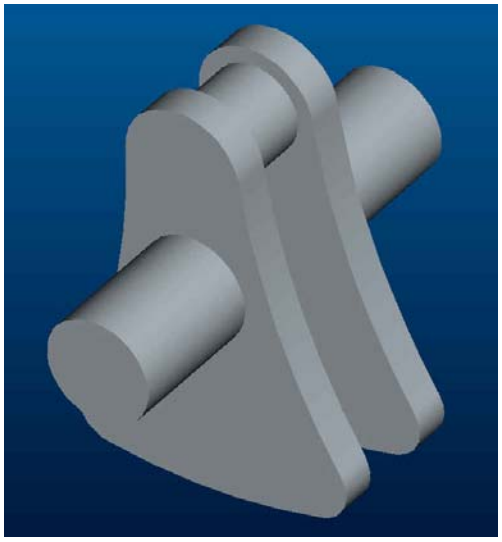
- Instrumenting your design
- Sensitivity Studies
- Feasibility Studies
- Optimization Studies

This tutorial is only an introduction; it is not a substitute for training. As such it has a few limitations:

- Multi-Objective Design Studies are not covered
- User Defined Analyses are not covered
- One simple type of optimization is accomplished. BMX can be used to solve a vast array of engineering problems

The picks are for Pro/ENGINEER 2000i2

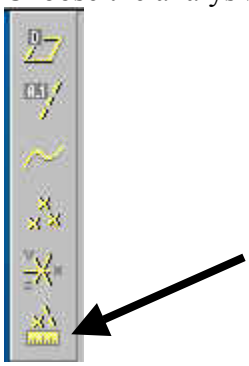
The task here is to balance the simple crankshaft model shown below:



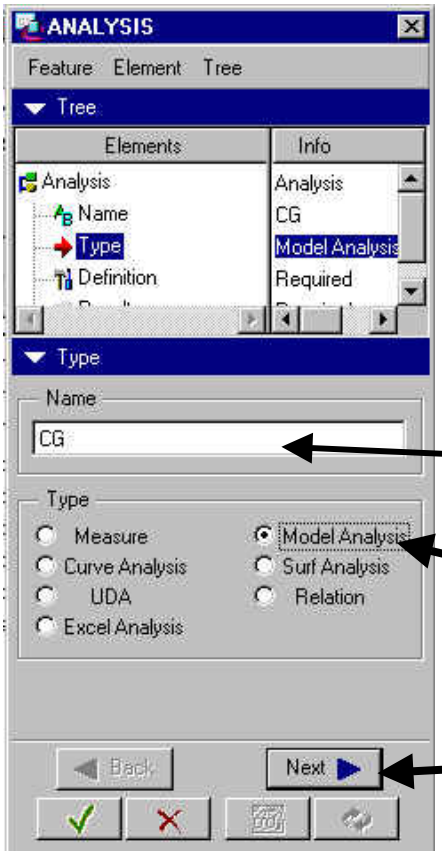
We need the Center of Mass (CG) to be aligned with the axis of rotation. The first step is to do some analysis to understand where the CG is. With BMX we will perform and save this analysis as a feature. Embedded in this feature will be a point placed at the CG. The benefit of placing this as a feature is that the CG point will automatically re-locate every time the model changes. To create this analysis feature:

Instrumenting the design:

Choose the analysis feature icon:



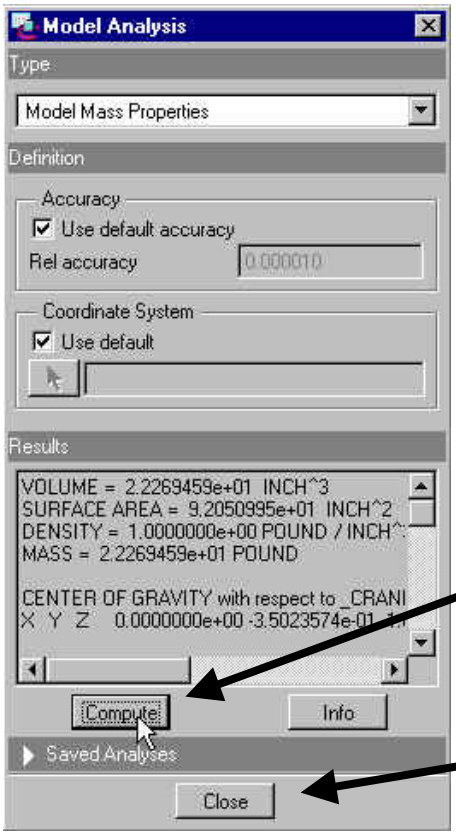
The Analysis dialog box will appear.



Change the name and hit enter if desired

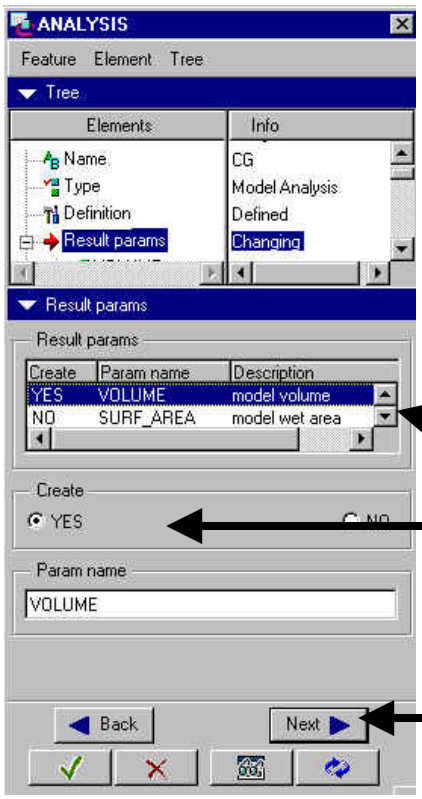
Choose Model Analysis

Hit **Next** to continue



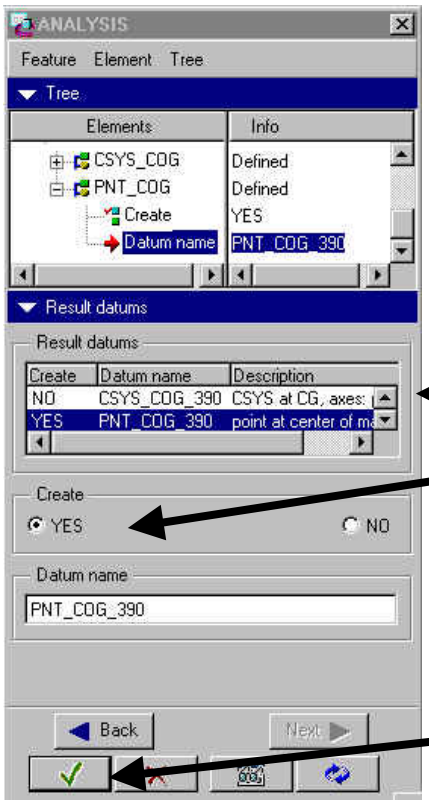
Select Compute

Then choose close



Parameters can be created for all the results of the analysis. These can be used later in relations, in notes in drawings, or to drive optimizations. For this example create a parameter for volume. This should happen by default.

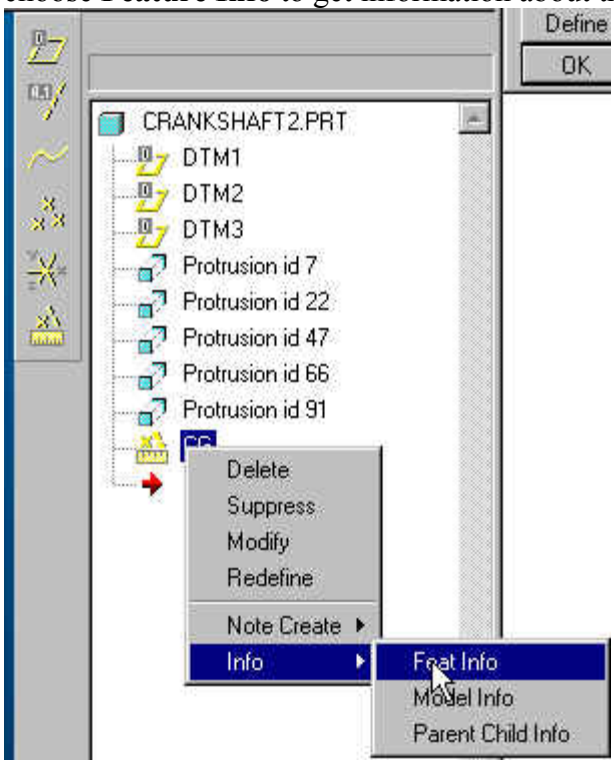
Then choose **Next**



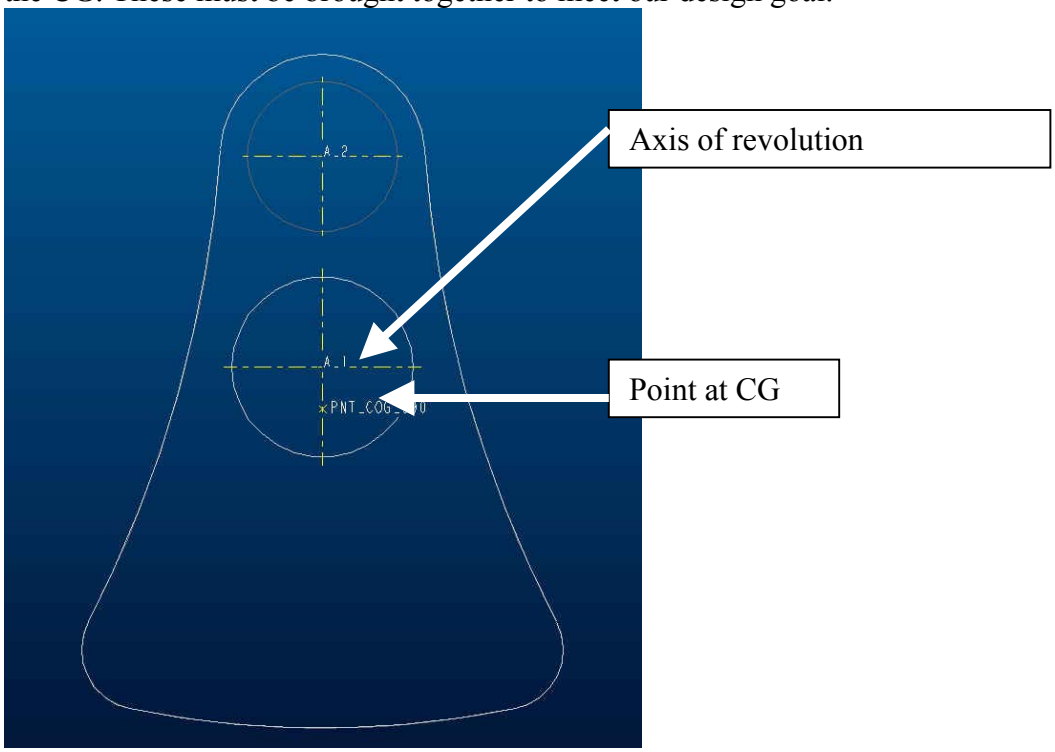
Features can be created at the center of gravity. For this example create a point at the center of gravity. Select PNT_COG… and toggle the create option to yes

Choose the green check mark to finish

The analysis feature is now in the model tree. You can right click on the feature and choose **Feature Info** to get information about the feature.



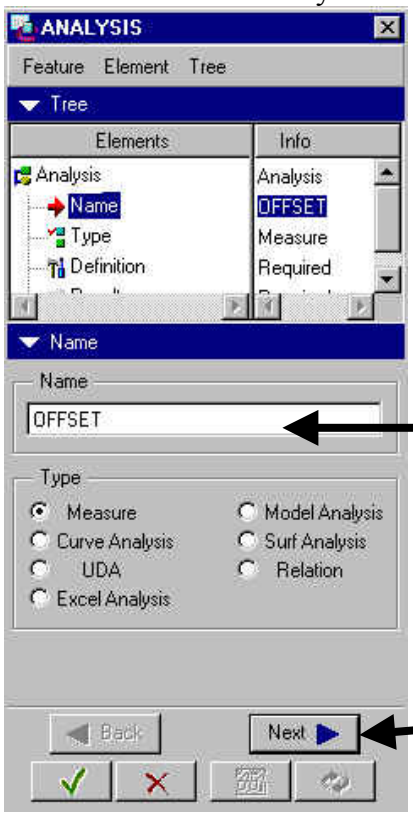
A view of the model from the side shows the axis of revolution and the Point located at the CG. These must be brought together to meet our design goal.



Now use a second analysis feature to Analyze the distance between the axis and point.

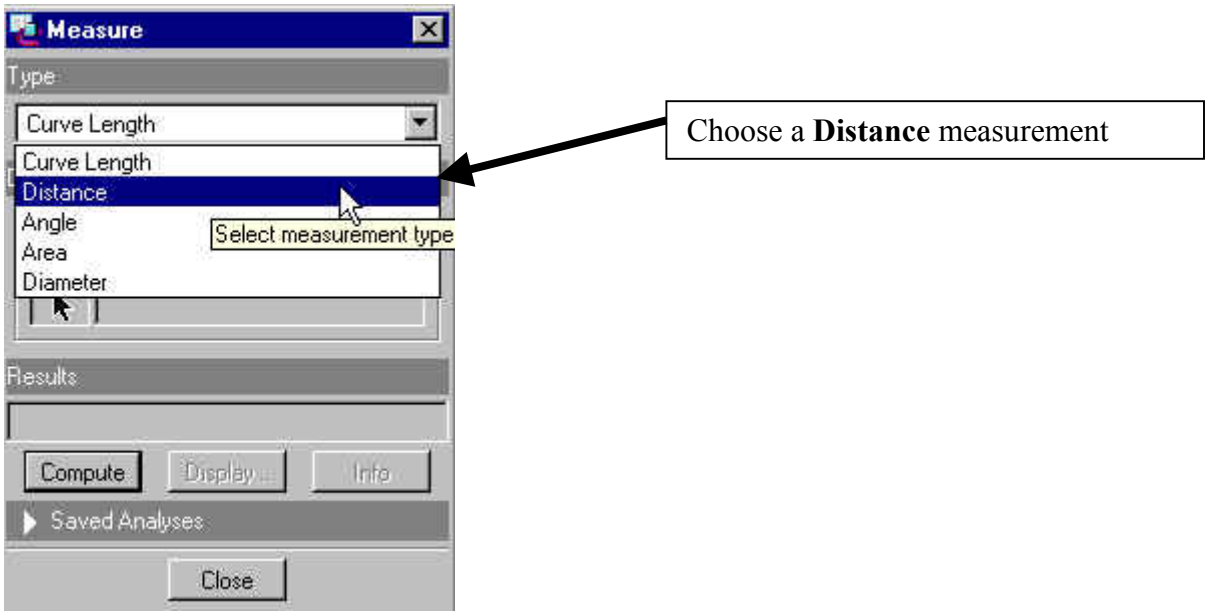
Choose the analysis icon

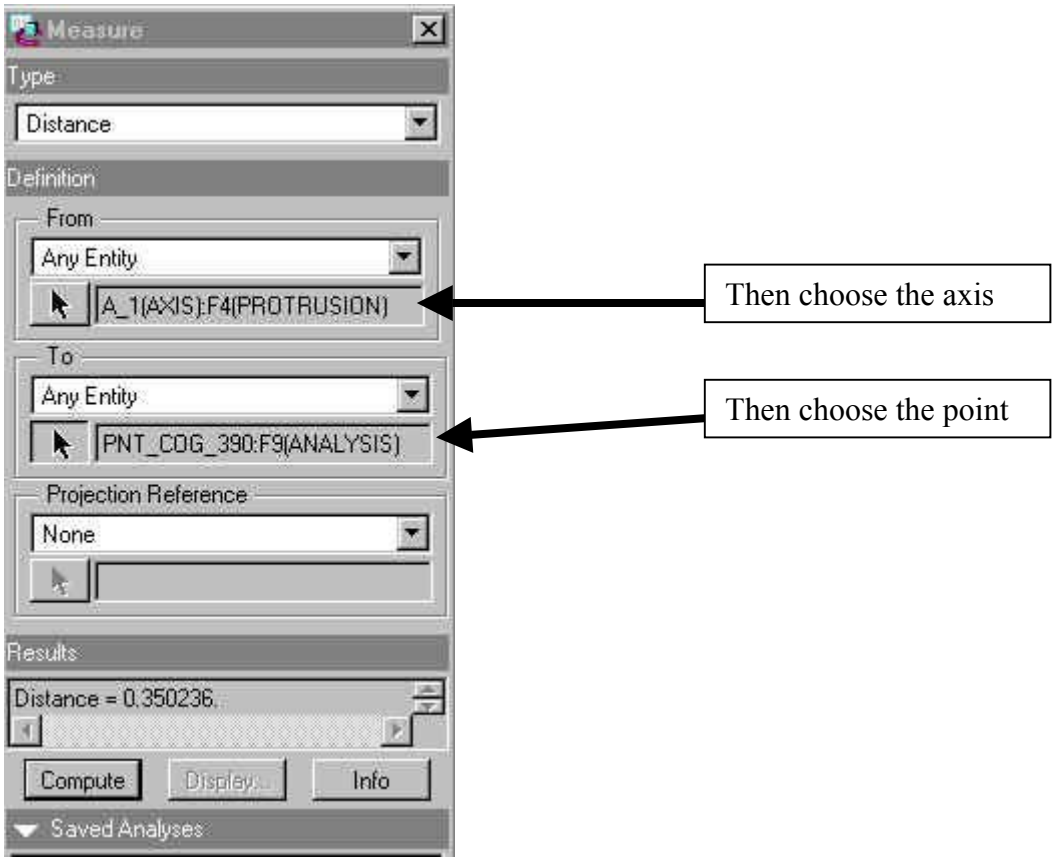
Use a measurement analysis feature this time:



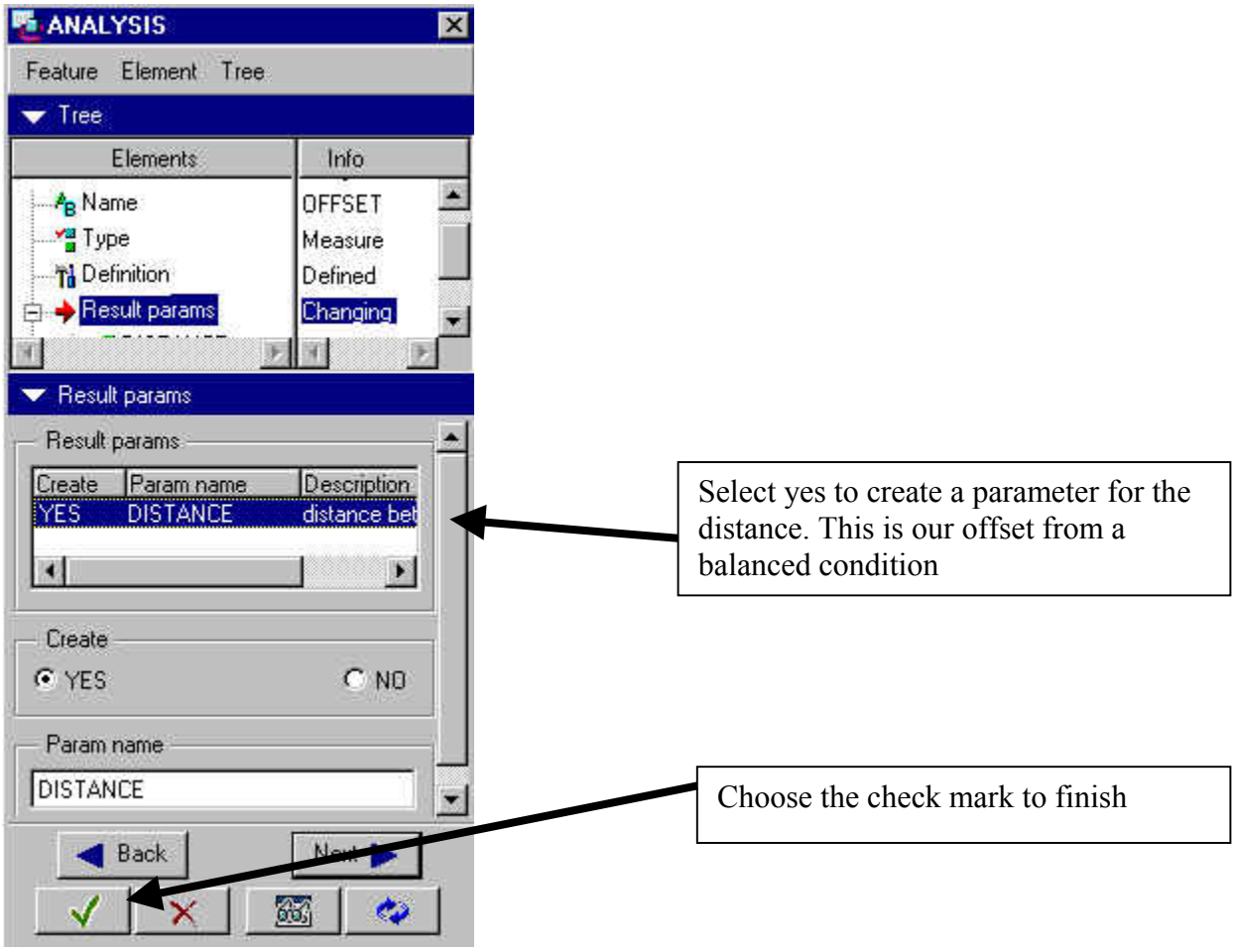
Enter a name for the feature if desired

Select **Next**



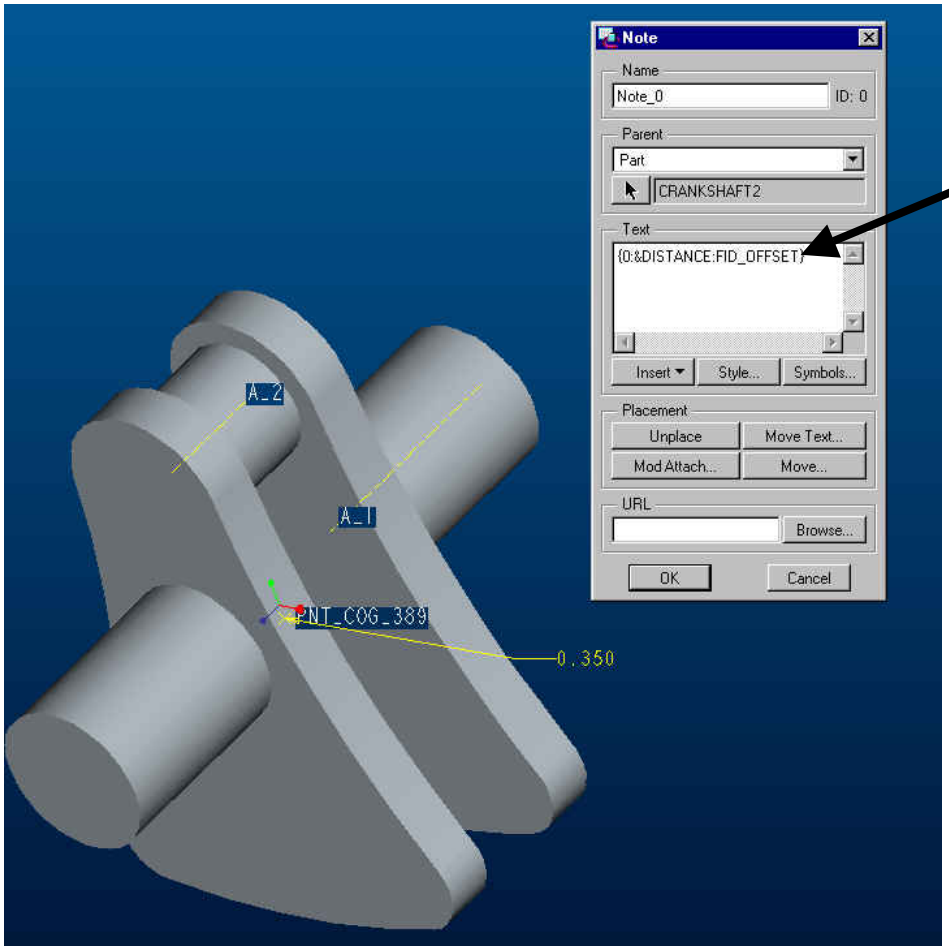


Choose Close.



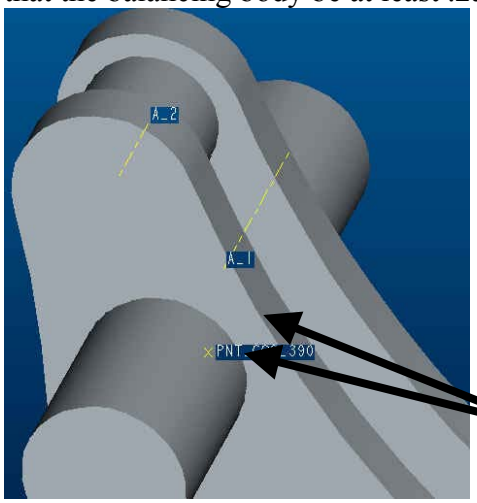
You should now have two analysis features in your model.

If you like you could place a 3Dnote showing the results of the offset analysis feature. Use the guide below:



This relation drives the note

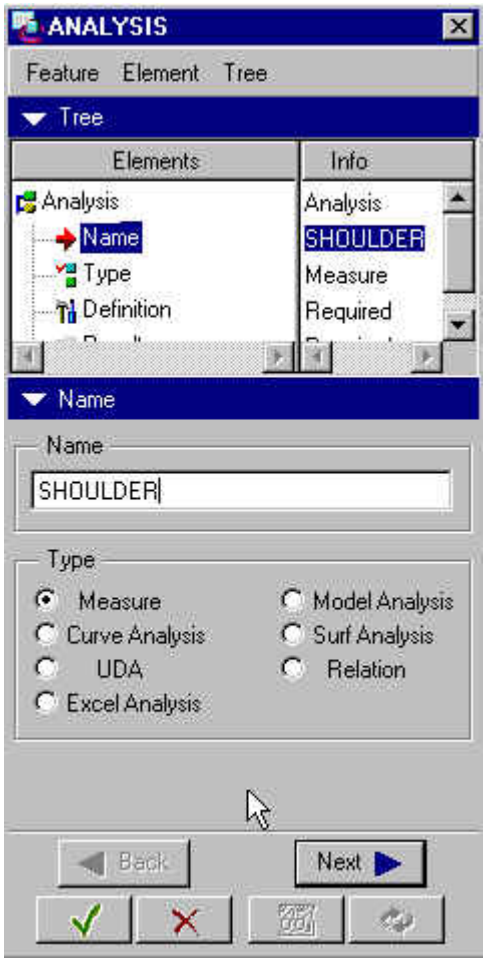
Before we balance the crankshaft, we have one other condition to capture. It is required that the balancing body be at least .25 in larger that the shaft.



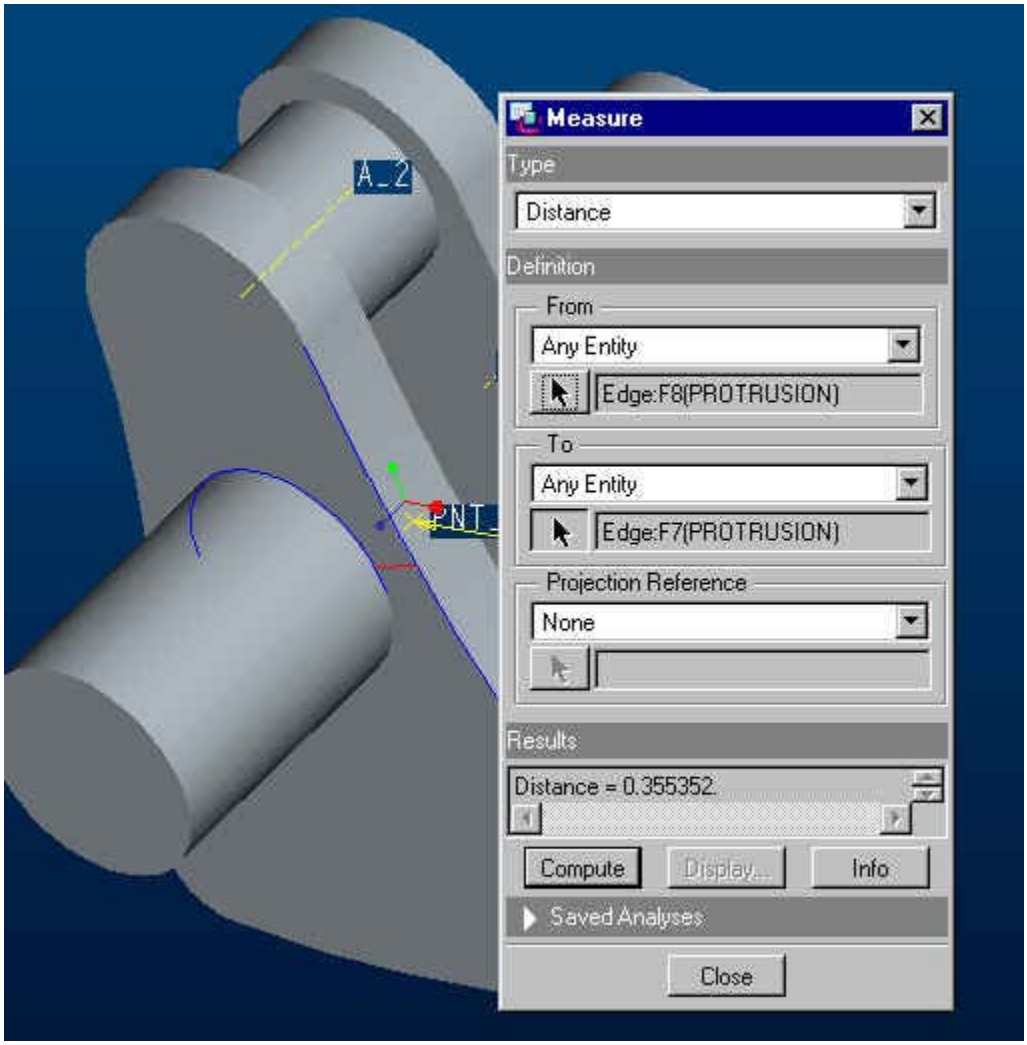
The desired clearance is measured here

An analysis feature measuring between edges or surfaces can be used.

Choose the analysis feature icon. Match the dialog box below, then choose **Next**:



I measured the distance between the edges shown below.



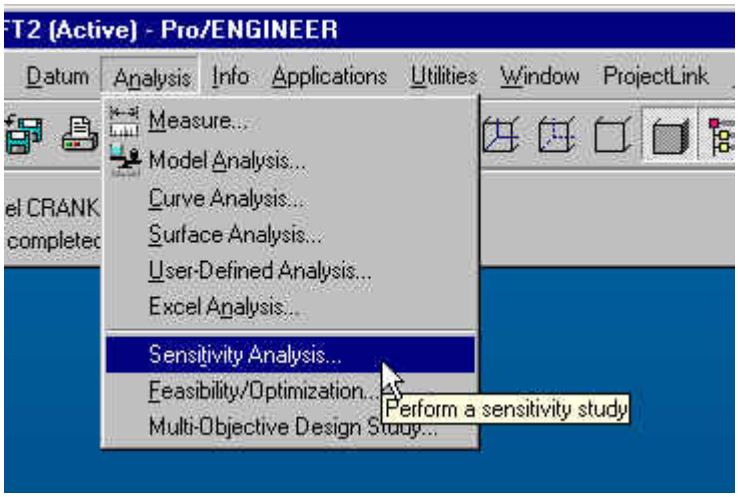
I allowed the analysis feature to create the parameter distance, but did not create any resulting features.

Now we can balance the crankshaft.

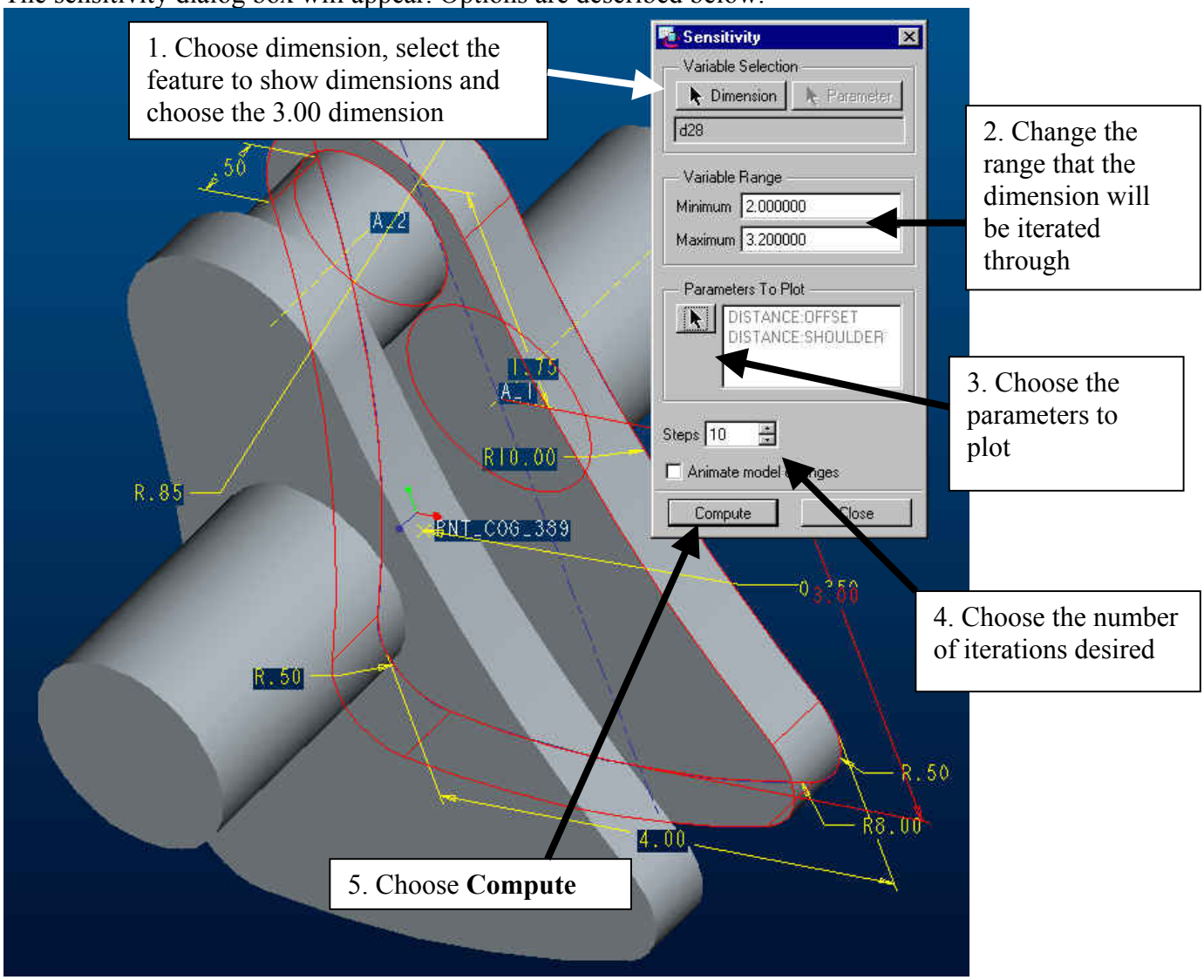
Sensitivity Studies:

Sensitivity studies allow you to see how changing a model will affect your design goals. You select a given dimension to modify and describe the range through which it will move. Pro/ENGINEER evaluates you model at intervals throughout the range of the variable and graphs one or more design parameters (like the offset distance in this example) vs. the dimension.

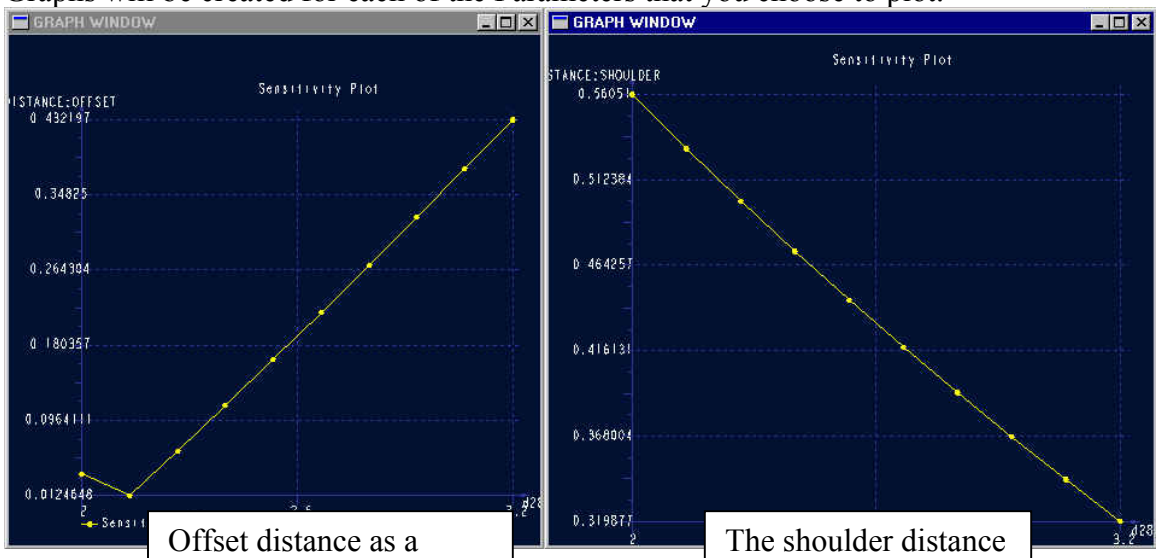
Choose **Analysis; Sensitivity Analysis**:



The sensitivity dialog box will appear. Options are described below.



Pro/ENGINEER will evaluate your model through out the range of dimensions specified. Graphs will be created for each of the Parameters that you choose to plot.



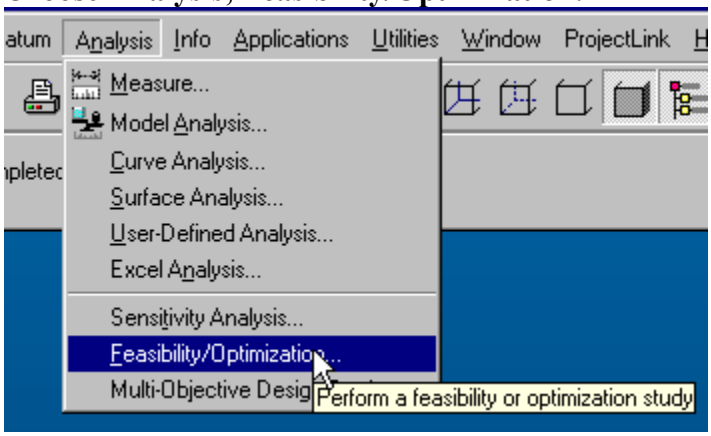
Offset distance as a function of the section height dimension. Balanced at around 2.2

The shoulder distance is greater than .25 for the entire range of values

Feasibility Studies:

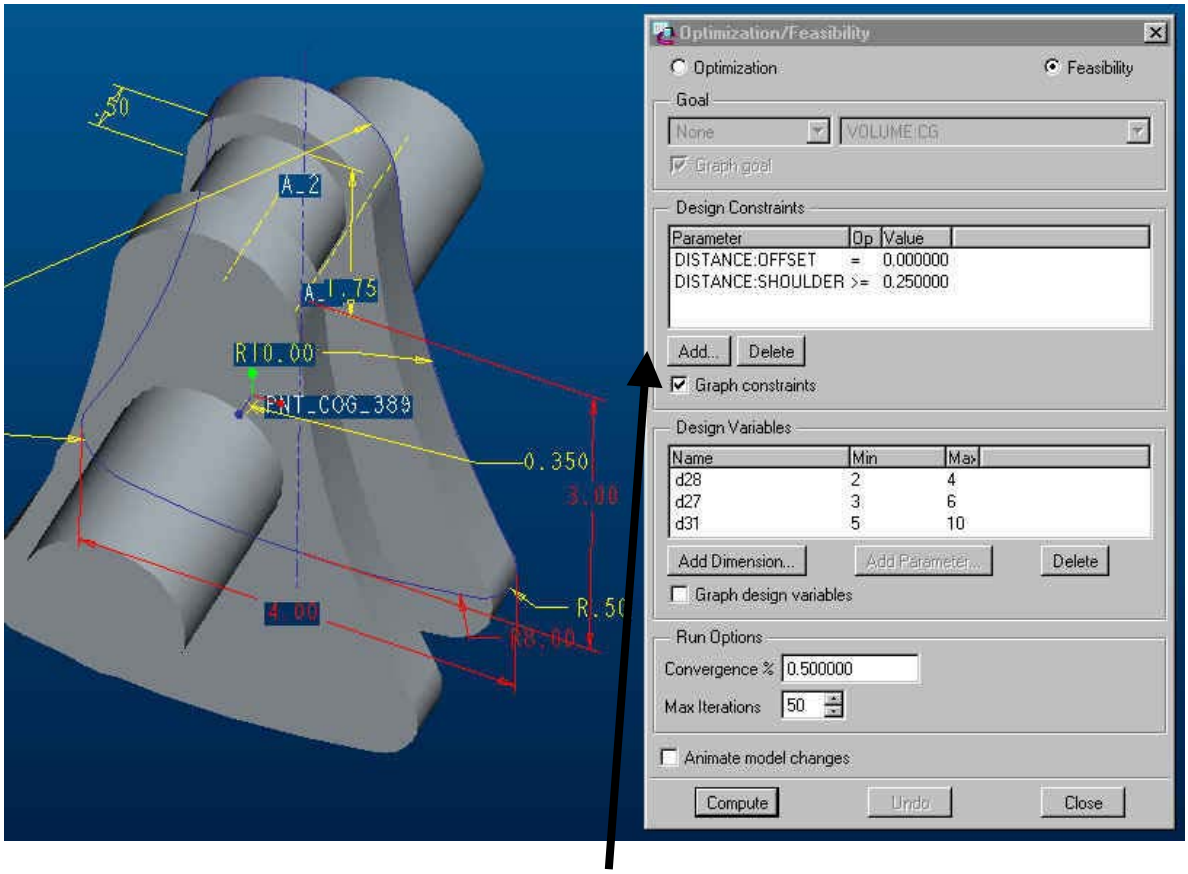
Feasibility Studies determine if any solution is available for a given set of dimensional changes coupled with a design goal.

Choose **Analysis; Feasibility/Optimization**:

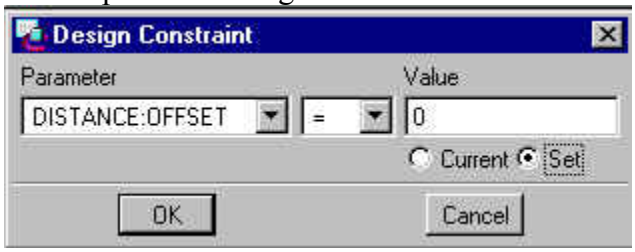


In this example we will seek to satisfy two design constraints. First that the crankshaft is balanced, and second that the shoulder distance maintains a value of .25 in or greater

Select option to make the feasibility study appear as below:



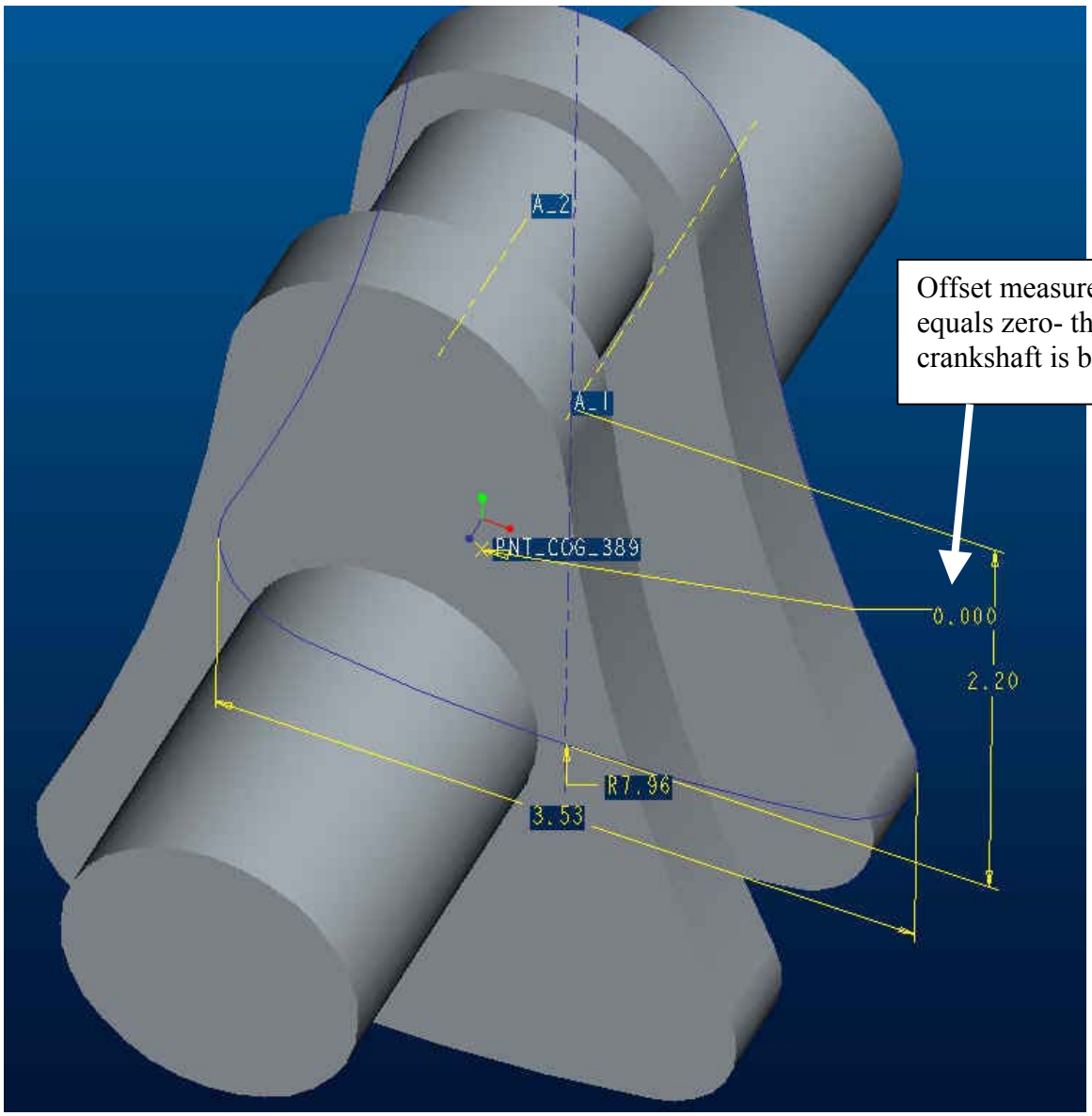
To complete the Design Constraints section select **Add** and use the guide below.



You will need to toggle the **Set** option. Use the pulldowns to change Parameters, =, <, and >=.

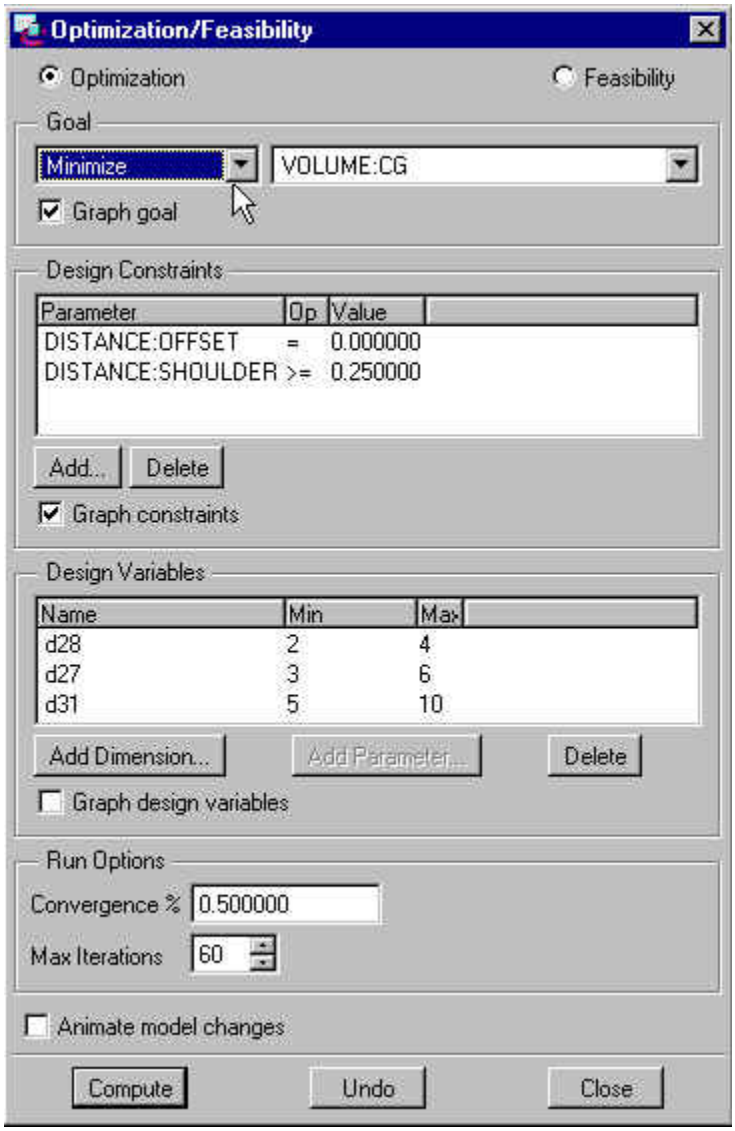
To give dimensional ranges, choose **Add Dimension**, select appropriate dimensions and input ranges when prompted. The three dimensions highlighted in red above are used for this study.

Choose **Compute**. Graphs will be displayed showing that the goal is reached. The model will also change to match the new, balanced configuration. Notice that the 3D note showing the offset dimension analysis has updated and now shows zero.



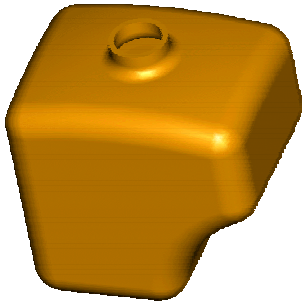
Optimization Studies:

The optimization study is setup very much like the feasibility. The main difference (and power) is that you can specify a goal. This means that you not only arrive at a solution that works: you arrive at the best solution possible. Here we will set a goal of minimizing volume (and weight). Fill out the dialog box as shown below and hit compute.

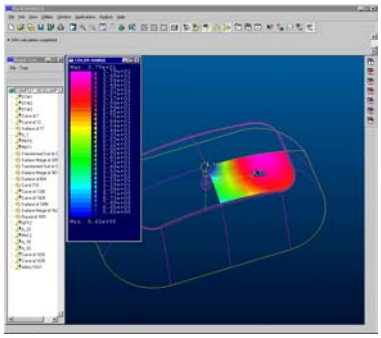


Analyze the resulting graph. If you like the changes to your model select close; otherwise, select Undo to return the model to its earlier state.

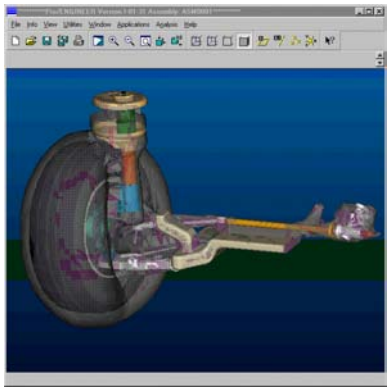
Some Other Types of Problems that have been solved with BMX:



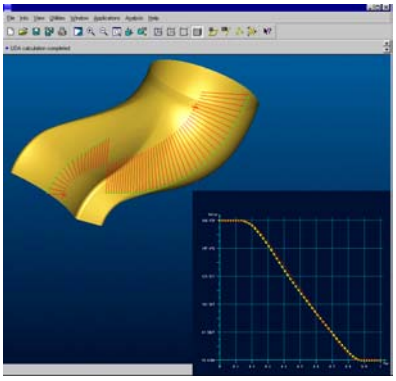
- Configuring containers to hold an exact amount of liquid



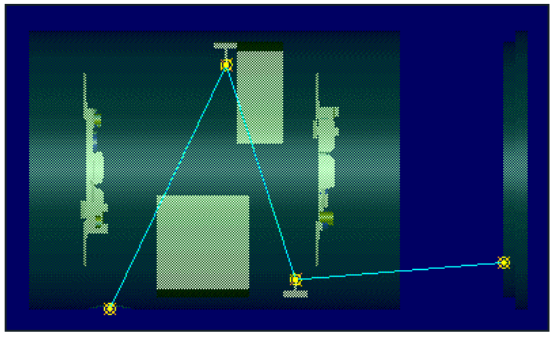
- Tuning the angle of reflection of a dish



- Keep suspension components moving in a tight envelope



- Design exhaust manifold to meet flow criteria



- Design Camera mirrors to direct a beam along a specific path

Tutorial Evaluation:

Title:	☐ Engineer ☐ Designer ☐ Draftsmen ☐ Mfg. Engr. ☐ Tech. Pubs. ☐ Analyst
PTC Products Used:	☐ Foundation ☐ Advanced Assembly Extension ☐ Advanced Surface Extension ☐ Behavioral Modeling ☐ Intralink ☐ Modelcheck ☐ All
Time using Pro/E:	☐ 0-6 months ☐ 6-12 months ☐ 1-2 years ☐ 2-5 years ☐ 5+ years

1 – Strongly Disagree
3 – Agree
5 – Strongly Agree

1.	This tutorial content met my expectations:	.....	1	2	3	4	5
2.	The exercise was easy to understand:	.....	1	2	3	4	5
3.	This tutorial will help me on current projects:	.....	1	2	3	4	5
4.	These techniques make Pro/E a more effective tool:	.....	1	2	3	4	5
5.	These techniques will increase my speed using Pro/E:	.....	1	2	3	4	5

What concepts/techniques learned from this tutorial will you apply on the job?

1)	
2)	
3)	

What would you like to see as a future tutorial at your company?

1)	
2)	
3)	

What can be done to improve these tutorials for your company?

1)	
2)	
3)	

Additional Comments: