Modeling Space Debris – A Guided Modeling Project

2. What is space debris, in your own words?

**Modeling the Problem**

We cannot locate, count, and weigh all objects in orbit, and we cannot predict when objects in orbit will collide. We will make simple mathematical models that will help us understand the problem

1. Let’s start with the simplest model. Using the reported 1990 rate of increase of 1.8 million pounds per year, and assuming 4 million pounds of existing debris at the beginning of 1990, write a linear model to predict the number of pounds of orbital debris at the end of any given year, with t = 0 representing 1990.

2. Write a second linear model using the predicted 2.7 million pounds per year for 1990.

3. Evaluate each model to determine the year (give the actual year) in which you would predict orbital debris to reach 9.5 million pounds.

a) With the first model:

b) With the second model:

4. Do you think that either of your linear models accurately represents the situation of increasing amounts of space debris as described in the original paragraph? Why or why not?

**Refining the Model: Quadratic Growth**

Does either rate, 1.8 million pounds per year or 2.7 million pounds per year, tell us how much debris is building up between 1990 and 2000? Which rate of increase should we use? The amount being added each year is changing during the period, but by how much each year? We need to adjust our model.

Again, let’s make the simplest assumption: the rate at which we are adding debris increases at a constant rate from 1.8 million pounds per year in 1990 to 2.7 million pounds per year in 2000. This change means that over the ten-year period from the end of 1990 through 2000, the rate of littering will increase by 0.9 million pounds per year (2.7 – 1.8 = 0.9) and we are making the assumption that this increase is achieved in equal annual increments of 0.9 million pounds per year in each year of the decade.



3. Make a scatterplot of your data in Excel or by hand. Try to find a function that best fits the accumulation of debris (the last column) over time. Decide whether it appears to be linear. Write your conclusion and describe the evidence on which you based your decision.

4. Using a graphing calculator or Excel, calculate a regression equation for your data. Try a linear and a quadratic function. Decide which one is best and explain why.

5. Compare your new quadratic regression equation with the two linear equations that you developed in #1 and #2 in the **Modeling the Problem** Section. Use each model to predict the accumulation of debris after 20 years, 30 years, and 50 years. SHOW YOUR WORK. Describe the behavior of the linear model versus the quadratic model over time.

6. For the period from 1990 to 2000, the graph of the quadratic model should lie between the graphs of the two linear models. Explain why this result is reasonable.

7. Will the quadratic always lie between the two linear graphs? Explain.

**One More Perspective: Exponential Growth**

4. Compare this model with the quadratic and the linear. When does it predict less debris? When does it predict more?

**Extension (must be completed for a 100% project)**

All the models you have developed thus far assume that no space debris is destroyed. However, some of it slows down enough to re-enter the atmosphere, where it burns up, or sometimes even returns to Earth.

1. Modify your linear, quadratic, and exponential models to account for the situation in which additional debris is being added each year, while 10 percent of what was already in orbit is destroyed.

2. In which case – linear, quadratic, or exponential – does the assumption of a 10% re-entry rate have the greatest effect?

3. Assume the same rates of adding debris as you did when you generated the models, but try different rates of annual destruction of orbital debris. In each situation, does a destruction rate exist that will result in a net decrease in orbital debris, despite the fact that additional debris is being added?

4. What might be some advantages of knowing if such a rate is possible?