# Teacher's Guide
## IMAGE Satellite Scaling

## Introduction

Scientists need to consider size, mass and cost when designing a satellite Although more data is returned by larger satellites, it isn't simply a matter of doubling or tripling the dimensions of a satellite that lead to a good design. When you double the size of a design, the volume increases by 8 times and so does the mass and cost of the satellite. The IMAGE satellite is designed to be built for under $30 million, and has a mass of 70 kilograms, but doubling its size would cause the mass to increase to 1/2 ton and its cost to rise to $240 million!

## Objective

The student will calculate the volume of the satellite. Based on the results, the student will determine patterns and relationships to see how change affects the mass and the cost of the instruments.

## Procedure

## Materials

1) Read the students the introduction to the IMAGE Dimension Activity, or discuss the key points with the students.

2) Allow students to complete questions 1, 2 and 3. Discuss student responses to these questions and the implications of increasing the size of the instruments on the satellite .Refer to the Introduction as necessary.

3) Discuss how the change in the dimensions affects the mass. Allow students time to complete activity 4. Discuss the results.

4) Discuss how the cost of the satellite is affected by increasing the dimensions and how it is proportional to the mass. Allo students to complete question 5. Discuss the results.

5) Have students complete question 6 and 7. Provide time for students to give possible responses. Discuss why a scientist may want a bigger satellite and the implications of scaling to the independent components.

—Introduction to the
    IMAGE Dimension
    Activit
—Teacher Answer Ke
—Student Pages



## Conclusion

When designing spacecraft, it is important to know how the cost and capabilities of the satellite will scale as you change its dimensions.
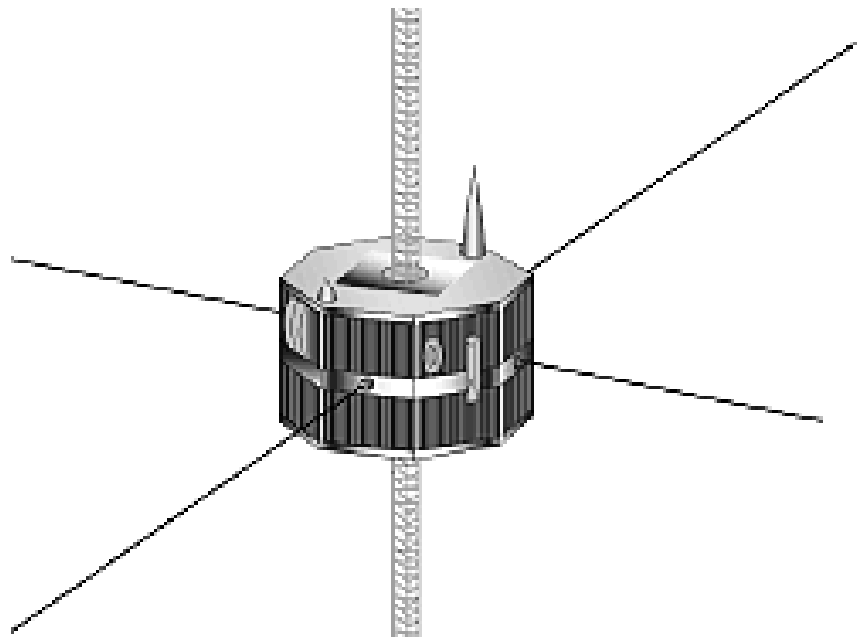
# Introduction to the IMAGE Dimension Activity

The IMAGE satellite must meet certain requirements. It must meet a two year mission lifetime, and must be launched on a Delta II rocket with a payload mass limit of 1000 kilograms. It must also cost less than $50 million.

The scientists need to consider mass, cost, and volume when designing a satellite. There are numerous instruments that need to be scaled, and all of the factors mentioned above must be considered.

For instance, if a detector is chosen, the dimensions need to be investigated to determine the final instrument cost. As in the following activity, if a dimension is doubled, the mass increases b 2x2x2 or a factor of 8. In turn, the cost increases in proportion to the mass, which in this case is also a factor of 8.

In addition, any change in the dimensions impacts on the other instruments in the satellite, the labor needed to assemble it, salaries, and the launch vehicle required for the extra mass and size. The IMAGE satellite will require a rocket to launch it. If the satellite's size is quadrupled, it would require the Space Shuttle to launch it. The difference in the launch cost alone is $50 million for the rocket compared to $700 million for the Space Shuttle.

The major constraint on the IMAGE project is cost. The IMAGE satellite must be built, launched and operated for 2 years at a total cost less than or equal to $60 million. Nearly all of the cost of any mission is in the salaries of the scientists and engineers needed to manufacture the satellite and the rocket.

In response to the question of why a scientist would want a bigger satellite, it is purely based on the amount of information that is being sought. The IMAGE satellite is designed to provide 2-D images of various phenomena in space. An increase in the dimensions will cause an increase in the size due to the need to acquire more data. Doubling the sizes of an electronic camera, in turn, quadruples the amount of data it can capture and send down to the scientists on the ground.

However, the question of size is more involved than this. The instruments of the IMAGE satellite, which have been the major focus, are not the only things to consider in satellite design. In terms of scaling, when the size of the instruments double, it does not necessarily mean that the size of the satellite will double. Actually, the instruments are only a small part of the total spacecraft size compared to the other satellite systems and hardware. The components of the satellite can also be scaled independently. Doubling the size of one instrument may not necessarily double the size of the electrical power required to operate it, and so, double the size of the power supply needed to provide the electricity.

The IMAGE satellite's construction involves a number of different instruments. These instruments are analyzed to determine the dimensions that will provide the most efficient satellite while minimizing the weight and cost. In order to help you understand the possible factors involved in the dimensions, mass and cost; complete the following activities.

1. Calculate the volume of the following instruments and spacecraft components. The dimensions are given in cubic centimeters in the following table:

| Instrument | 1x Volum | 8x Volum | 27x Volume | 64x Volume |
|---|---|---|---|---|
| LENA | 8100 | 64800 | 218700 | 518400 |
| MENA | 8100 | 64800 | 218700 | 518400 |
| HENA | 9000 | 72000 | 243000 | 576000 |
| TAC/ADC | 1620 | 12960 | 43740 | 103680 |
| HV Electronics | 2592 | 20736 | 69984 | 165888 |
| Spectrometer | 35712 | 285696 | 964224 | 2285568 |
| WB Camera | 5070 | 40560 | 136890 | 324480 |
| Electronics | 5400 | 38400 | 129600 | 307200 |
| Sensors | 2250 | 18000 | 60750 | 144000 |

2. When the dimensions of the satellite are doubled, by what factor is the volume increased What factor is the increase when the dimensions are tripled and quadrupled
**8, 27, 64**

3. Is there any noticeable connection between two or more of these factors of increase
**Doubling and quadrupling are multiples of each other, and the results of 8 and 64 are multiples as well.**

4. The mass of the IMAGE satelllite increases proportional to the volume. If the dimensions are doubled, the mass increases by the cube of the factor or 2x2x2=8. The mass of the satellite is 261 kg. Determine the mass increase when the dimensions are doubled, tripled and quadrupled.

Doubled = **2088 kg**     Tripled= **7047 kg**     Quadrupled= **16704 kg**

5. The cost of the satellite also increases proportional to the mass. The cost for the original dimensions is $28.4 million. What is the cost for each of the various increases

Doubled= **$227.2 million**     Tripled= **$766.8 million**     Quadrupled= **$1.818 billion**

6. In your own words, please write the process involved in determining the volume, mass and cost of the IMAGE satellite. Why would a scientist want a 'bigger' satellite
**Students response will vary. The bigger the satellite, the more information that is being sent to the scientists. Bigger does not necessarily mean better.**

The IMAGE satellite's construction involves a number of different instruments. These instruments are analyzed to determine the dimensions that will provide the most efficient satellite while minimizing the weight and cost. In order to help you understand the possible factors involved in the dimensions, mass and cost; complete the following activities.

1. Calculate the volume of the following instruments and spacecraft components. The dimensions are given in centimeters in the following table:

| Instrument | Dimension | Double | Triple | Quadruple |
| --- | --- | --- | --- | --- |
| LENA | 36x15x15 | 72x30x30 | 108x45x45 | 144x60x60 |
| MENA | 36x15x15 | 72x30x30 | 108x45x45 | 144x60x60 |
| HENA | 30x10x30 | 60x20x60 | 90x30x90 | 120x40x120 |
| TAC/ADC | 18x18x5 | 36x36x10 | 54x54x15 | 72x72x20 |
| HV Electronics | 18x18x8 | 36x36x16 | 54x54x24 | 72x72x32 |
| Spectrometer | 62x36x16 | 124x72x32 | 186x108x48 | 248x144x64 |
| WB Camera | 26x15x13 | 52x30x26 | 78x45x39 | 104x60x52 |
| Electronics | 15x20x18 | 30x40x32 | 45x60x48 | 60x80x64 |
| Sensors | 15x15x10 | 30x30x20 | 45x45x30 | 60x60x40 |

2. When the dimensions of the satellite are doubled, by what factor is the volume increased What factor is the increase when the dimensions are tripled and quadrupled

3. Is there any noticeable connection between two or more of these factors of increase

4. The mass of the IMAGE satelllite increases proportional to the volume. If the dimensions are doubled, the mass increases by the cube of the factor or 2x2x2=8. The mass of the satellite is 261 kg. Determine the mass increase when the dimensions are doubled, tripled and quadrupled.

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6. In your own words, please write the process involved in determining the volume, mass and cost of the IMAGE satellite. Why would a scientist want a 'bigger' satellite