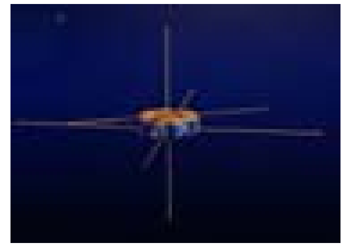
Appendix A: Template for K-W-L Chart

In the first column, write what you already **know** about the topic. In the second column, write what you **want** to know about the topic. After you have completed the lesson, write what you **learned** about the topic in the third column.

What I KNOW	What I WANT to Know	What I LEARNED

Appendix B: Directions for Paper Model, Edible Model and Model made of Lego bricks of MMS Satellite

1. Paper Model

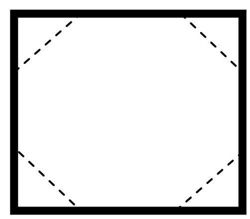


You will need
- Paper model (next page)
- Scissors
- Tape
- String or Thin Wire (Florist Wire)

The paper model is at the end of the guide. You will complete the model by cutting out and taping the top and bottom sections together. Make sure that each numbered side on the top section matches the numbered panel on the bottom section. Attach the string or florist wire to the model to simulate the eight deployable booms per satellite.

2. Edible Model

You will need
- Graham Crackers
- Frosting
- Chocolate bars with small sections
- Licorice whips
- Assorted small candies

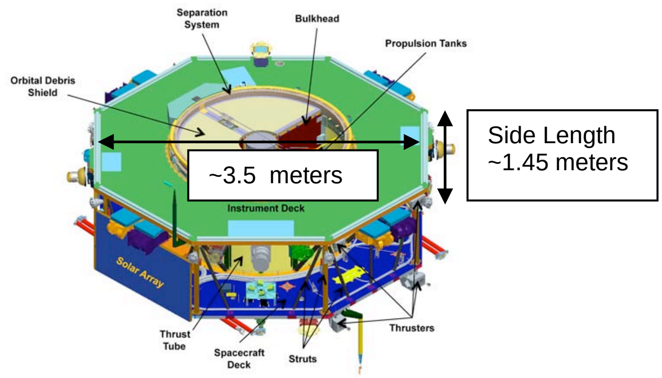


Procedure:
1. Use a square Graham Cracker for the top and bottom of the satellite. To form the octagonal shape cut a small triangle from each corner of the square. This will form an octagon when you have completed all four cuts. Make a top and a bottom for the satellite.
2. Use a generous layer of frosting to attach the top to the bottom. Put enough so that you will be able to add the solar panels to the eight sides.
3. Use the Chocolate bars for the solar panels. Break small rectangles of chocolate to fit on the eight sides.
4. Attach small candies to represent instruments on the sides.
5. Attach licorice whips for the booms.

3. Model made of Lego bricks

You can find the instructions for the model made of Lego bricks at the website http://mms.gsfc.nasa.gov/epo_mms_lego_model.html

Appendix C: Worksheet for Computing the Area of the Top and Bottom of the MMS Satellite



1. Look at the diagram of the satellite above. The shape of the top and bottom is a regular shape (all sides and angles are the same). What is this regular shape? Do not consider the circle in the center, just the outside side of the shape.

2. How can you compute the area of this shape? Do you know a formula or can you devise a strategy for computing the area? Write the formula or describe your strategy for finding the area.

3. Draw the shape of the top of the satellite below and then compute the area of the shape of the top of the satellite using your formula or strategy.

4. The satellite will be sent into space in a rocket with a circular cargo bay. How large would the cargo bay need to be? Calculate the circular radius and circumference that would hold the satellite and draw a diagram of the cross-section below to show how this will fit. Make sure you label your diagram.

Appendix D: Rocket Worksheet

Go to the website listed below and find the facts about the rockets (launch vehicles).
http://www.ulalaunch.com/site/pages/Education_RocketScience.shtml

1. Rockets (launch vehicles) deliver _______________________ into space.
2. A typical rocket produces more than _____________________ pounds of thrust.
3. A rocket can carry more than ___________________________ pounds.
4. A rocket can go a speed of up to _______________________ miles per hour.
5. The rocket delivers its payload to ___________________________.

Go to the website below and find additional facts about the Atlas V rocket, the specific rocket that will take the MMS satellites into space.
http://www.ulalaunch.com/site/pages/Products_AtlasV.shtml

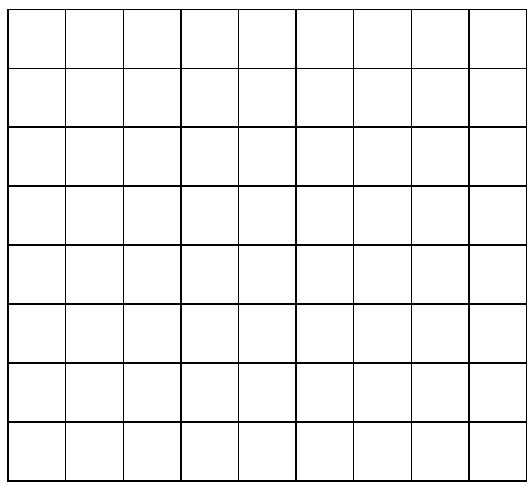
6. How many pounds of thrust can the Atlas V engine deliver at liftoff? ____________________
7. What does the Atlas V rocket use for fuel?
____
8. What is the diameter of the Atlas V 400 series payload fairing which carries the cargo into space?
____
9. Find the diagram of the Atlas V 400 series that shows the expanded view. From the diagram, where is the cargo bay that carries the satellites?
____
10. What are the different lengths of the payload fairing for the Atlas V 400 series rockets?
____

Appendix E: Worksheet for Computing the Speed of the Launch Rocket

The Atlas V 421 is the launch vehicle that takes the MMS satellites into space. The picture below shows the rocket taking off and the chart to the right shows the approximate height of the rocket at the different times.

Time (sec)	Height (m)	Speed (m/sec)
0	0	0
1	26	
2	58	
3	96	
4	140	

1. Graph Time (sec) vs. Height (m) of the rocket using the graph paper below. Use **Time** as the x-coordinate and **Height** of the rocket as the y-coordinate.



2. Compute the average speed for each time interval and complete the table above. Remember speed has the unit of meters/second. The calculation for average speed in a time interval is determined by

$$\textit{Average speed in a time interval} = \frac{Height\ 2 - Height\ 1}{Time\ 2 - Time\ 1}$$

Note: If you have studied the slope of a line this will look familiar to you. You are calculating the slope of the line between two adjacent points.

3. Graph Time vs. Speed of the rocket using the graph paper below. Use **Time** as the x-coordinate and **Speed** as the y-coordinate.

4. Assuming this pattern continues, use your graph to estimate **when** the rocket will be traveling near the speed of 100 meters per second?

Appendix F: Formation Flying Worksheet

Explore websites to find facts about how satellites fly in formation.

1. Give an example from nature of birds that fly in formation.__________________

2. Explain the concept of satellite formation flying.

   ____

   ____

   ____

   ____

   ____

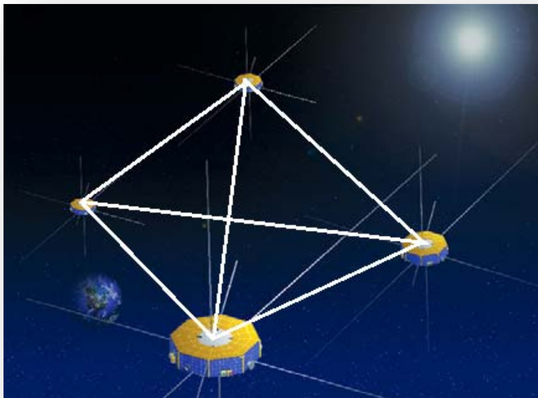
   ____

3. What satellites are examples of formation flying?

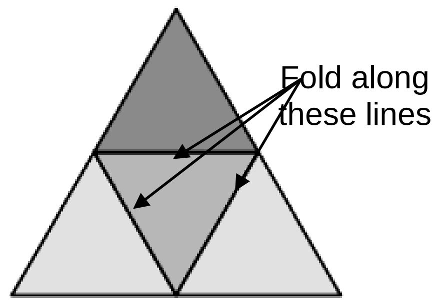
4. What do these satellites do?

5. Name the satellites that fly in formation.

Appendix G: Directions for Computing the Volume of the Flight Configuration



The four MMS satellites form a tetrahedron while flying through space. The picture on the left shows the satellites in their configuration. The satellites change position while traveling through space to change the volume of the tetrahedron they create.



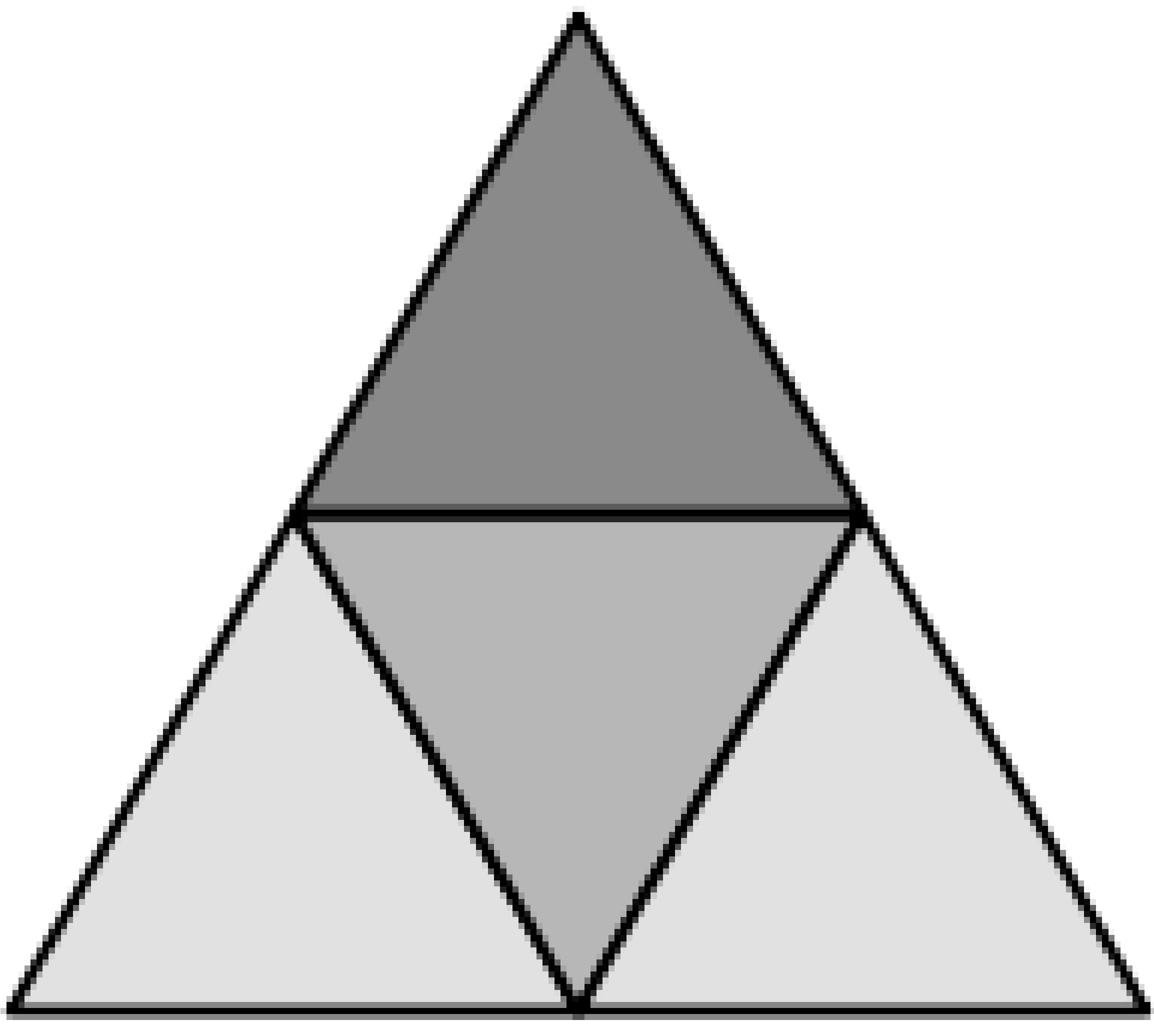
1. On the next page there is a net (two dimensional representation of a three dimensional object) the same as pictured to the right. Cut along the outside of the net and fold forward along the other lines. Assemble the tetrahedron by forming a peak with the three outside points and taping the sides.

2. Use a ruler to measure the side length of the base triangle and the height of the triangle. Using the formula for **area of a triangle** $A = \frac{1}{2}bh$. First, compute the area of the base triangle of the tetrahedron (any of the triangles can be used as the base.)

3. Use your ruler to measure the height of the tetrahedron when it is sitting on a table or your desk. The height of the triangle should be measured by putting the ruler base flat on the table and standing the ruler up straight to see how high the peak of the tetrahedron reaches. **DO NOT** measure along the side of the tetrahedron by laying the ruler on the tetrahedron (this would be the slant height.)

4. Compute the volume of a tetrahedron by using the pyramid volume formula:
   $V = \frac{1}{3}\mathrm{B}h$. *B* is the area of the base (the triangle area you computed in 2) and *h* the height from the base to the apex.

5. Use dot paper to draw several different shapes of tetrahedrons. These show examples of how the tetrahedron shape changes as the vertices (or satellites) change positions. Instructions: (1) Connect several dots in a line to form the base of a triangle. (2) Choose another dot **not** on the line to be your third vertex of the triangle. (3) Use a ruler to draw the other two sides of the triangle, connecting the third vertex to the line. (4) Now to form a tetrahedron, choose another dot outside of the triangle and connect all three vertices of the triangle to it. Create three different tetrahedra on your dot paper.



Appendix H: Spacecraft Solar Power Worksheet

Go to the website you or your group has been assigned and find facts about how NASA Missions use solar power to power spacecrafts and vehicles. Answer the following questions if possible, draw a diagram of the solar panels, and make note of other interesting facts.

Name of NASA Mission ____

Type of spacecraft or vehicle that uses solar power

____

Duration of mission ____

What is will be powered by the solar panels?

____

Configuration of solar array panels used (Draw diagram below).

Appendix I: Worksheet for Computing the Electrical Power Generated by the Solar Panels

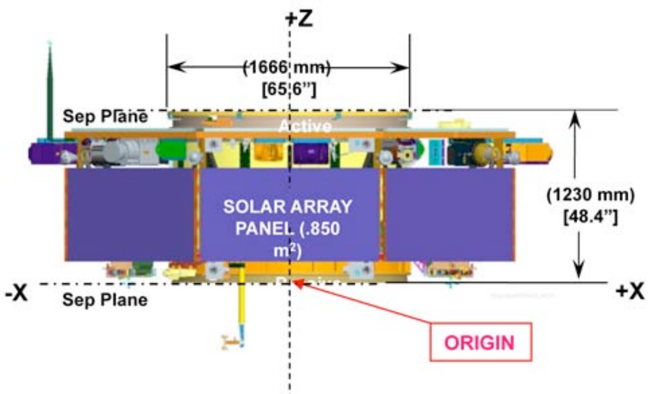


Figure 2: Diagram of MMS Satellite showing the Solar Array Panel

The MMS Satellites utilize solar array panels to produce electricity to power the systems on the satellite. Figure 1 illustrates how the solar arrays are positioned on the satellite and shows the size of the solar array panel is 0.850 meters squared.

1. Convert the size of the panel to square centimeters.
(Recall 100 cm = 1 m and m x m = m^2)
0.085 m^2 = _________________ cm^2

2. Suppose the solar array panel can produce 0.03 watts of power **per square centimeter** (cm^2). Then how much power can each panel produce?

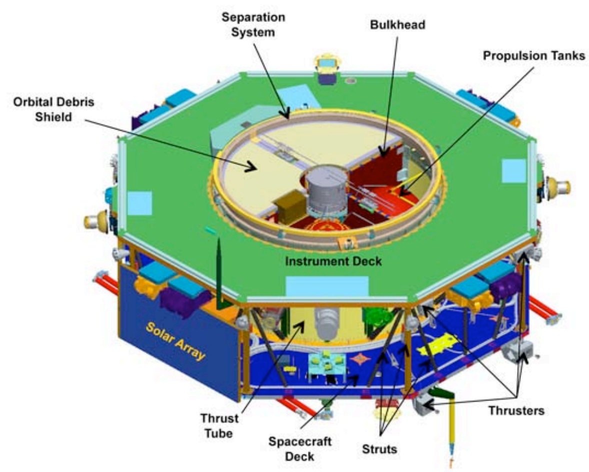


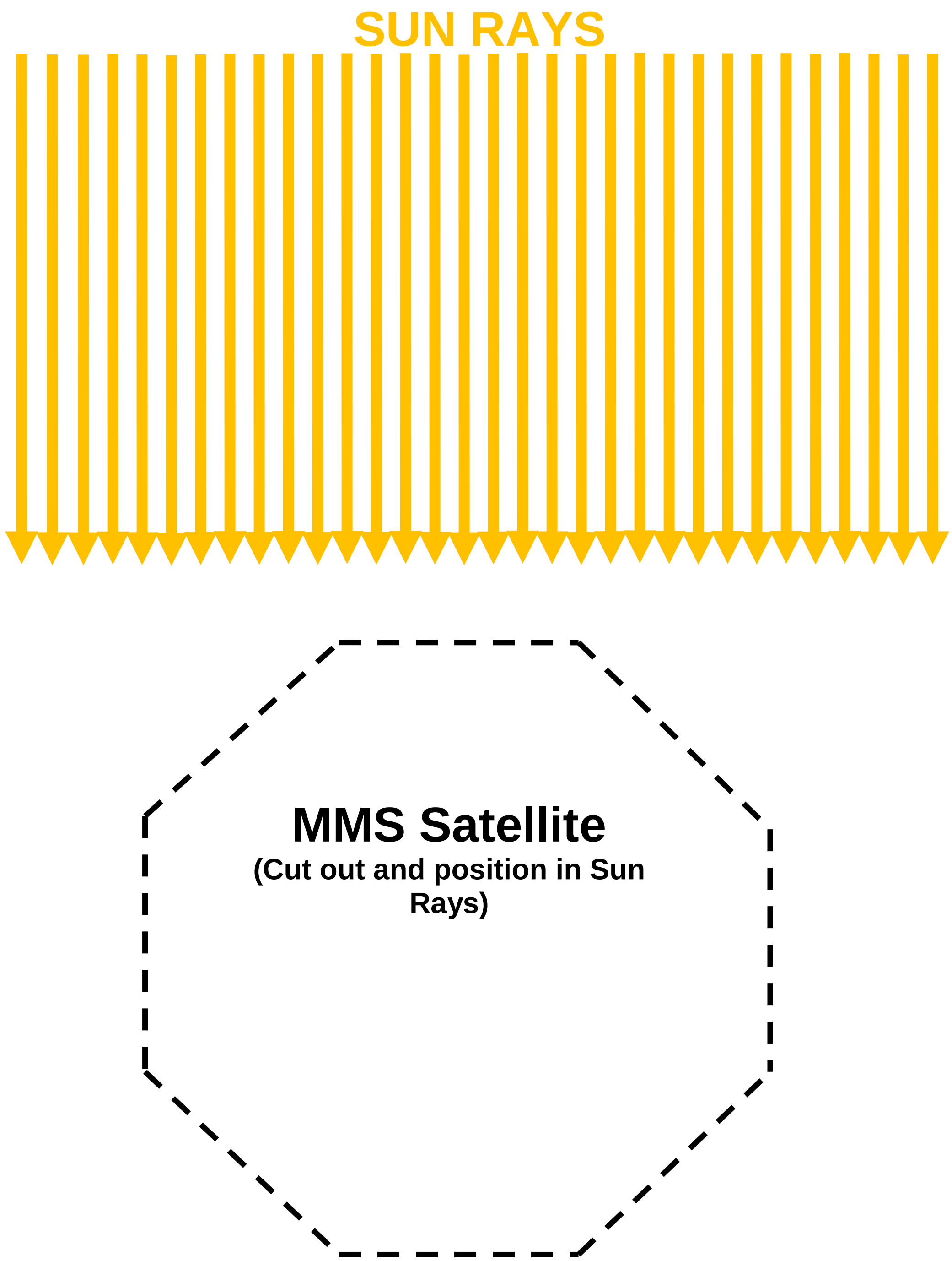
Figure 3: Diagram showing the Octagonal Shape of the Satellite

3. For solar energy to be collected by the panel, it must be facing (or exposed to) the Sun. Use the next page to help you investigate how many solar panels can be facing (or exposed to) the Sun at one time. Note that the number of faces that are exposed to the Sun changes as the satellite rotates. Cut out the octagon that represents the satellite and then place it in the Sun Rays to see how many faces can be directly hit by the rays. Turn the space craft slowly in the Sun Rays to see how many sides can become exposed. If the front of the panel cannot "see" the Sun then the panel does not count.
   a. What is the minimum number of panels that are exposed to the Sun?

   b. What is the maximum number of panels that are exposed to the Sun?

4. How much power is generated when the minimum number of panels is facing the Sun?
Minimum Power = (don't forget the units on your answer)

5. How much power is generated when the maximum number of panels is facing the Sun?
Maximum Power = (don't forget the units on your answer)


SUN RAYS
MMS Satellite
(Cut out and position in Sun Rays)

Appendix J: Answer Keys

Appendix C: Worksheet for Computing the Area of the Top and Bottom of MMS Satellite

1. Octagon
2. Method 1 – Divide the octagon into eight triangular parts
   Method 2 – Divide the octagon into a rectangle and two trapezoids
3. Note for this problem that measurements are approximate; the symbol ~ means "approximately"
   Method 1 – Divide the octagon into eight triangular parts each with base of 1.34 meters and height of 1.75 meters. Each triangle has area of ½ bh = ½ *1.45*1.75 = 1.26875 square meters. Multiply this by 8 for the 8 triangles would be 8*1.26875 = 10.15 square meters.

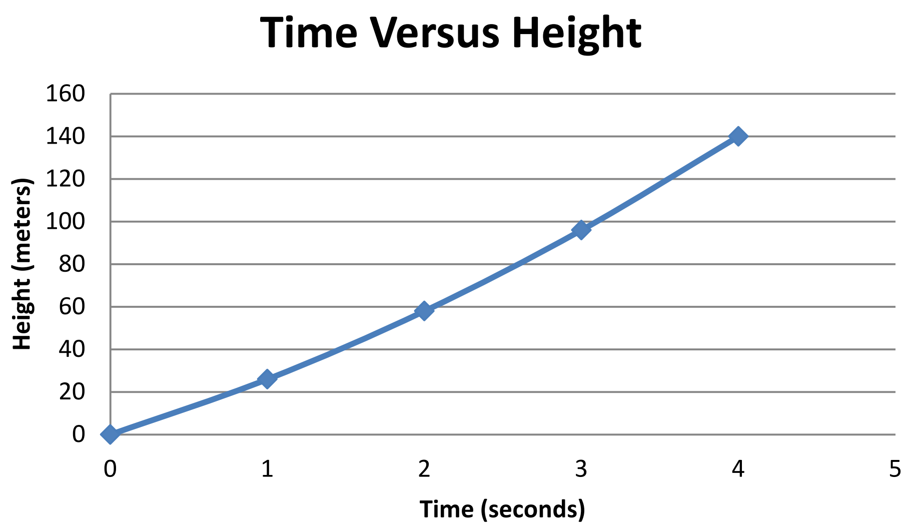
   Method 2 – Divide the octagon into a rectangle and two trapezoids. The rectangle has length 3.5meters and width 1.34 meters. L*W = 5.075 square meters. For the trapezoid, base 1 = 3.5 and base 2 = 1.45. The height is (3.5-1.45)/2 = 1.025. The area of the trapezoid is (h/2)(b1+b2) = (1.025/2)(3.5+1.45) = 2.537 square meters. Add the areas of all three shapes 5.075 + 2.537 + 2.537 = 10.15 square meters.
4. If the apothem (length from the center of the octagon to the middle of a side) is 1.75 meters, then the radius (length from the center of the octagon to one of the vertices) is ~1.8942 meters. The radius of a circle that circumscribes the octagon mush have radius greater than 1.8942 meters.

Appendix D: Rocket Worksheet

1. Satellites
2. a million
3. 6,000
4. 22,000
5. the desired orbit or on its desired trajectory
6. 860,000 lbs.
7. Liquid oxygen/liquid kerosene
8. 4 meters
9. In the upper part of the second stage.
10. Short, medium, and large

Appendix E:

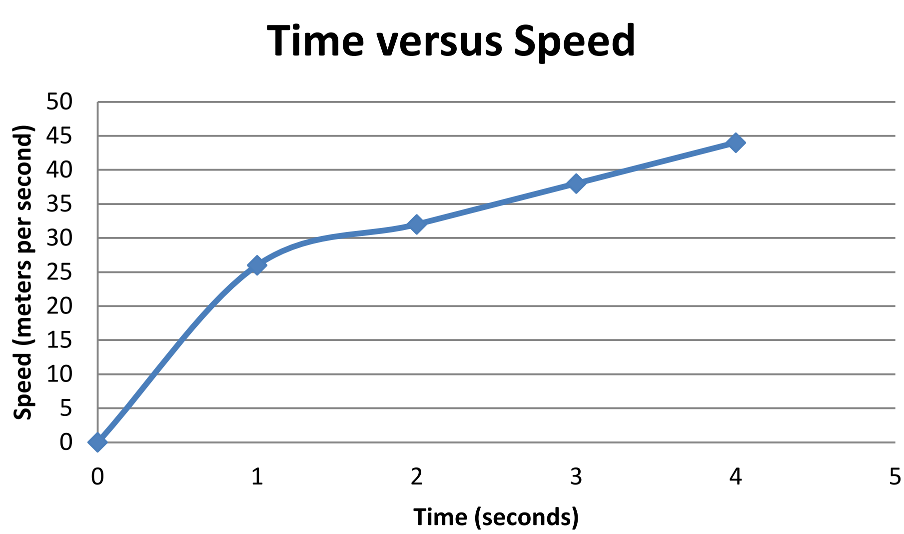
1.



2.

Time (sec)	Height (m)	Speed (m/sec)
0	0	0
1	26	26
2	58	32
3	96	38
4	140	44

3.



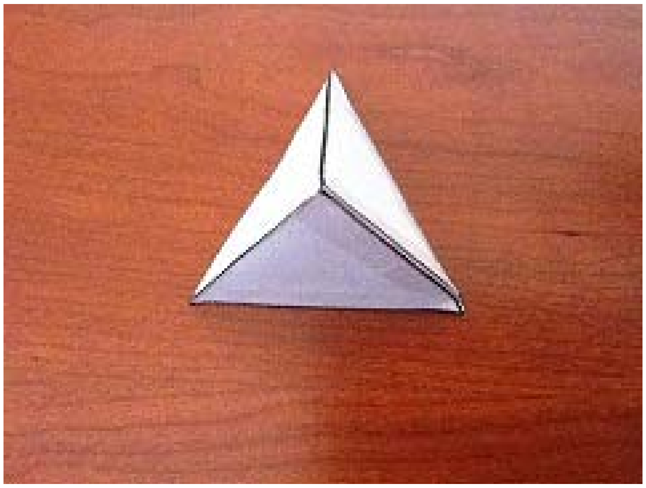
4. At approximately 9 to 10 seconds.

Appendix F: Formation Flying Worksheet

1. Geese
2. Satellite formation flying is the concept were multiple satellites work together in a group to accomplish an objective.
3. The Earth Observing Satellites (this is one example, but there are others)
4. The EOS collects data about the Earth for researchers and practitioners to use.
5. Landsat 7, CALIPSO, CloudSat, Terra, Aqua

Appendix G: Directions for Computing the Volume of the Flight Configuration

1. The picture shows the assembled tetrahedron



2. The height of the triangle is 2.5 inches and the base is 3 inches. The area is ½ *2.5*3 = 3.75 square inches.
3. The height of the tetrahedron is approximately 2.5 inches.
4. V = 1/3 * 3.75 square inches * 2.5 inches = 3.125 inches cubed.

Appendix H: Spacecraft Solar Power Worksheet

There will be various answers depending on mission.

Appendix I: Worksheet for Computing the Electrical Power Generated by the Solar Panels

1. 850
2. 25.5 watts
3. a. 2 panels
   b. 3 panels
4. 51 watts
5. 76.5 watts

Appendix L: Lesson Summary and Standards Mapping

Lesson	Objectives	NCTM Standards	Common Core Standards
1: Model of the MMS Satellite	Build a three dimensional scale paper model of one of the MMS satellites. Calculate the octagonal area of the top and bottom of the satellite, given the measurements from the satellite. Compare the octagonal cross section area of the satellite with the circular cross section area of the launch vehicle to determine if the space craft will fit the cargo bay.	GEOMETRY: Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships • precisely describe, classify, and understand relationships among types of two- and three-dimensional objects using their defining properties ADD SPECIFIC STATE STANDARDS HERE.	GEOMETRY: 5.G.3. Understand that attributes belonging to a category of two-dimensional figures also belong to all subcategories of that category. For example, all rectangles have four right angles and squares are rectangles, so all squares have four right angles. 6.G.1. Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes; apply these techniques in the context of solving real-world and mathematical problems. 7.G.1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale. 7.G.2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle. 7.G.4. Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle. 7.G.6. Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.
2: Launch of the Satellites	Compute the speed of the launch rocket, given a data chart of time vs. distance data	ALGEBRA: Understand patterns, relations, and functions • represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic	5.NF.3. Interpret a fraction as division of the numerator by the denominator ($a/b = a \div b$). Solve word problems involving division of whole numbers leading to answers in the form of fractions or mixed numbers, e.g., by using visual fraction models or equations to represent the problem. For example, interpret 3/4 as the result of dividing 3 by 4, noting that 3/4 multiplied by 4 equals 3, and that when 3

	from lift-off.	rules • identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations ALGEBRA: <u>Analyze change</u> in various contexts • use graphs to analyze the nature of changes in quantities in linear relationships. ADD SPECIFIC STATE STANDARDS HERE.	wholes are shared equally among 4 people each person has a share of size 3/4. If 9 people want to share a 50-pound sack of rice equally by weight, how many pounds of rice should each person get? Between what two whole numbers does your answer lie? 6.EE.6. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. 6.EE.9.Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation d = 65t to represent the relationship between distance and time. 7.RP.1. Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. For example, if a person walks 1/2 mile in each 1/4 hour, compute the unit rate as the complex fraction 1/2/1/4 miles per hour, equivalently 2 miles per hour. 8.F.3. Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. For example, the function A = s2 giving the area of a square as a function of its side length is not linear because its graph contains the points (1,1), (2,4) and (3,9), which are not on a straight line. 8.F.4. Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.
3: The Satellites Flight Config-uration	Visualize the three dimensional tetrahedral flight configuration	GEOMETRY: Use visualization, spatial reasoning, and geometric modeling to solve problems • draw geometric objects with	5.G.2. Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation. 6.G.2. Find the volume of a right rectangular

	of the four satellites in the mission using graphing techniques and models. Analyze, by graphing techniques, the changing shape of the tetrahedron as the satellites change position. Compute the volume of the tetrahedron based on the positions of the four satellites.	specified properties, such as side lengths or angle measures • use two-dimensional representations of three-dimensional objects to visualize and solve problems such as those involving surface area and volume; ADD SPECIFIC STATE STANDARDS HERE.	prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying the edge lengths of the prism. Apply the formulas V = l w h and V = b h to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems. 6.G.4. Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems. 7.G.1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale. 7.G.2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle. 7.G.6. Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms. 8.G.9. Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.
4: Powering the Satellites	Calculate the surface area of the panels that are exposed to the sun for various positions of the satellite, given the dimensions of the solar panels. Calculate the power generated by the solar panels for various	GEOMETRY: Use visualization, spatial reasoning, and geometric modeling to solve problems • use two-dimensional representations of three-dimensional objects to visualize and solve problems such as those involving surface area and volume • use geometric models to represent and explain numerical and algebraic relationships • recognize and apply geometric ideas and relationships in	8.G.2. Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent figures, describe a sequence that exhibits the congruence between them.

	positions of the satellite, given the dimensions of the panels. Organize and write a report about the satellites in the MMS Mission that contains information from the fours lessons, after completing the exercises for the unit.	areas outside the mathematics classroom, such as art, science, and everyday life ADD SPECIFIC STATE STANDARDS HERE.	