Activity One: Analyze the Geometry of a Spacecraft

Educator Notes

Challenge

Students (individually or in small groups) will use geometry to find the area of the horizontal and vertical cross sections of a crew module.

Suggested Time

45 to 60 minutes

Learning Objectives

Students will

- Decompose a complex geometric shape into more basic geometric shapes.
- Approximate the total area of a complex geometric shape by using measurements and geometric formulas to find the summation of the areas of the more basic geometric shapes.
- Learn about careers at NASA.

Curriculum Connection

Science and Engineering (NGSS)	
Crosscutting Concepts • Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. *Science and Engineering Practices* • Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.	*Science and Engineering Practices (continued)* • Using Mathematics and Computational Thinking: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.
Technology (ISTE)	
Standards for Students • Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions. – 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem solving.	
Mathematics (CCSS)	
Content Standards by Domain • CCSS.MATH.CONTENT.6.NS.B.3: Fluently add, subtract, multiply, and divide multidigit decimals using the standard algorithm for each operation. • CCSS.MATH.CONTENT.6.G.A.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. • CCSS.MATH.CONTENT.7.NS.A.3: Solve real-world and mathematical problems involving the four operations with rational numbers. • CCSS.MATH.CONTENT.7.G.A.3: Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.	*Content Standards by Domain (continued)* • CCSS.MATH.CONTENT.7.G.B.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. • CCSS.MATH.CONTENT.8.G.C.9: Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems. *Mathematical Practices:* • CCSS.MATH.PRACTICE.MP2: Reason abstractly and quantitatively. • CCSS.MATH.PRACTICE.MP4: Model with mathematics. • CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically. • CCSS.MATH.PRACTICE.MP6: Attend to precision.

Preparation Time

15 minutes

- Read the Introduction and Background, Educator Notes, and Student Handout to become familiar with the activity.
- Determine if students will be working independently or in small groups.
- Gather and prepare all supplies listed on the materials list.
- If presenting videos or web-based resources, test the links and the classroom technology ahead of time.

Materials

- ☐ Copies of Student Handout and blank paper
- ☐ Metric rulers with straight edge
- ☐ Colored pencils or thin markers
- ☐ Grid paper (optional)

Introduce the Challenge

- Show students the Orion: Expanded View diagram and explain the purpose of the crew module.
- Define **vertical and horizontal cross sections** and ask students to sketch what they think the vertical and horizontal cross sections of the crew module might look like.
- Show students the diagram that depicts the seven structural components of the Orion crew module. Discuss how NASA uses friction stir welding to assemble this complex geometric shape from multiple components composed of simple shapes.
- Explain how complex geometric shapes can be decomposed or broken into multiple simple shapes. Identify examples in the classroom.
- Discuss how to approximate the total area of a complex shape by finding the sum of the areas of each of the simple shapes.
- Review the mathematical formulas for finding the area of basic geometric shapes.
- Distribute the Student Handout and explain the challenge.

Facilitate the Challenge

Ask and Imagine

- Provide examples of shapes in the classroom that are symmetric and demonstrate how symmetry can help in decomposing a complex shape.
- Discuss different approaches for finding area of curved surfaces in a complex shape. One option is for students to trace the shape onto grid paper to approximate the area. Ask how the size of the squares on the grid paper impacts the estimation.
- Remind students that if the shape is already simple, it does not need to be decomposed.

Create

- Students will work individually or in small groups to find the area of the largest vertical and horizontal cross sections of a crew module. Students will record their work on the tables provided.
- Encourage students to use different-colored pencils or highlighters for each geometric shape to show how they are decomposing the figure into smaller parts. For example, using the largest vertical cross section diagram of the crew module, students will likely see the top part of the figure as a trapezoid. The next area is rectangular, but students may select different segments for their length estimate. The bottom of the diagram might be decomposed into a triangle.
- The largest horizontal cross section will be a circle, so students will not need to further decompose this shape.

Share

- Once the exercise is completed, have students form pairs or small groups to discuss and evaluate the various approaches taken to decompose the crew module into smaller shapes, and how symmetry was used in their approaches.
- Have students identify the types of geometric shapes that were found within the crew module.

Share With Students

Brain Booster

Starting with the formation of NASA in October 1958, intense efforts were undertaken to create a manned space vehicle that could fly a human in orbit around the Earth. The plans for this vehicle were based on the blunt reentry body proposed earlier by Harvey Allen and Max Faget. These efforts would eventually result in the Mercury spacecraft.

Learn more: https://history.nasa.gov/SP-350/ch-2-2.html

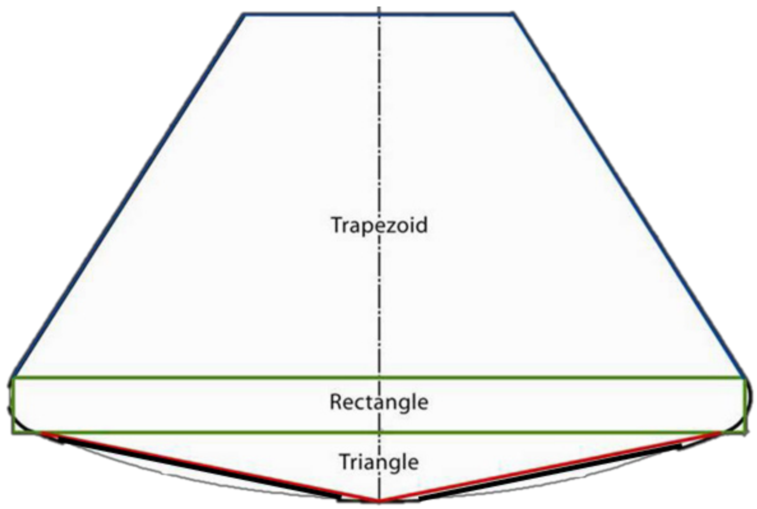
On Location

Mathematics and physics models need to be expressed and translated in a language computers can understand and work with, which often requires thousands of lines of computer code. NASA Ames Research Center in Mountain View, California, provides supercomputing capabilities for more than 1,500 users across the United States who rely on high-end computing to help them visualize and solve mathematical problems every day.

Learn more: https://www.nasa.gov/centers/ames/areas-of-ames-ingenuity-supercomputing

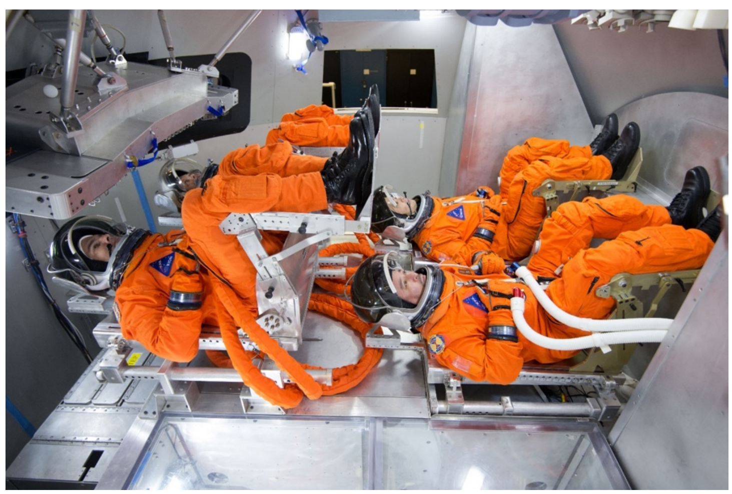
Crew Transportation With Orion

- Discuss why different approaches resulted in different areas.
- Give students an opportunity to see one solution for the decomposition of the crew module.
- Share photos of horizontal and vertical cross sections showing astronauts inside the crew modules.

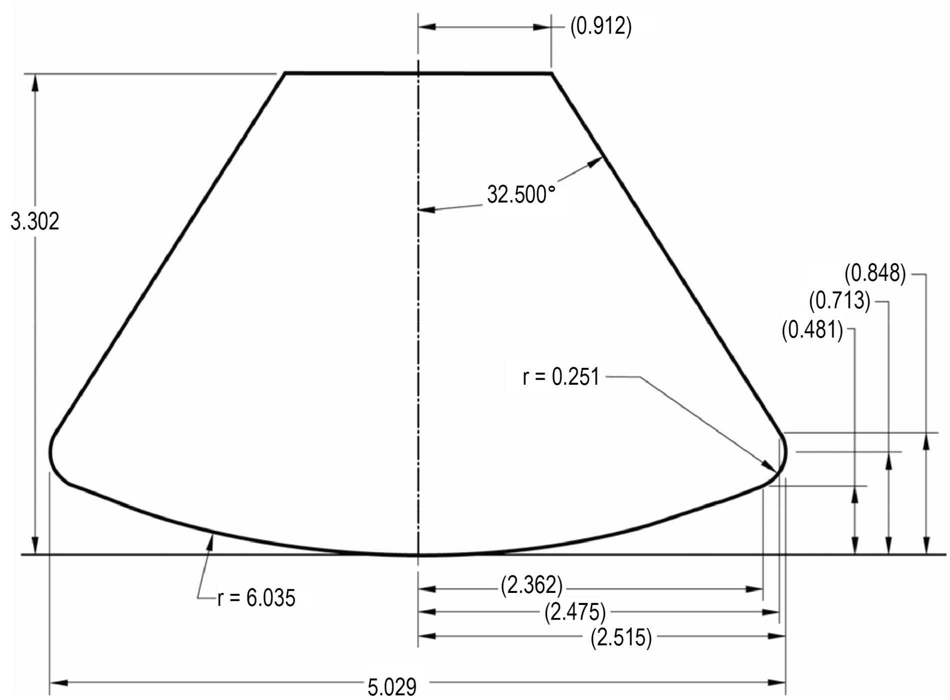


One solution for the decomposition of the crew module (vertical cross section).

(a) 

(b) 

Four astronauts in the Orion module. (a) Horizontal cross section (birds-eye view). (b) Vertical cross section (side view). (NASA)



Largest vertical cross section of the Orion crew module. All measurements in meters unless otherwise noted.

Extensions

- Use the measurements in the diagram above to find the scale factor of the diagram compared to the actual life-size crew module.
- Compare the size of the actual crew module to the size of your classroom.
- Identify the three-dimensional shapes that make up the actual crew module (e.g., truncated cone sitting on a disc or cylinder with an inverted dome). Refer to the diagram in the Introduction and Background section that shows the seven components of Orion's primary structure.

Reference

Modified from Exploring Space through Algebra. https://er.jsc.nasa.gov/seh/264011main_Algebra_Stu_Orion.pdf

Additional Resources

- Video: Final Friction Stir Weld Completed on Orion. https://www.youtube.com/watch?v=m3pOe8gk0Jo
- Video: NASA Now: Engineering: Friction Stir Welding (features welding engineer at Marshall Space Flight Center). https://www.youtube.com/watch?v=XM825iLaPvU
- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

Activity One: Analyze the Geometry of a Spacecraft

Student Handout

Your Challenge

Use geometry to find the area of the vertical and horizontal cross sections of a crew module.

Ask and Imagine

- How does decomposing a complex geometric shape help you find the area?
- How does symmetry aid in decomposing a complex geometric shape into simple shapes?
- When decomposing the crew module into multiple simple shapes, you will eventually have curved surfaces that do not fit with the shapes you draw. What can you do to minimize this and keep your calculation of the crew module's area as accurate as possible?

Create

1. Using a different colored pencil for each geometric shape, begin decomposing the vertical cross section of the crew module on the following page into individual simple shapes. Create as many shapes as necessary to fill in as much of the crew module cross section as possible.
2. Measure and record the dimensions of each shape in the accompanying chart.
3. Calculate the area of each shape you created and record it on the chart.
4. Find the sum of all your area measurements for the module cross section to determine its total area.
5. Find the area of the horizontal cross section of the crew module.

Share

When you finish finding the areas, answer each of the following questions with a partner or small group:

- What steps did you take to decompose the crew module into smaller shapes? How was symmetry used?
- What types of geometric shapes were found within the crew module?
- Did each person or group calculate the same area? Why or why not?

Fun Fact

The Orion heat shield is composed of a titanium skeleton and carbon fiber skin that gives the crew module its rounded shape on the bottom. The outer-most layer chars away during the intense heat of reentry and is removed and replaced by 180 individual blocks for each launch.

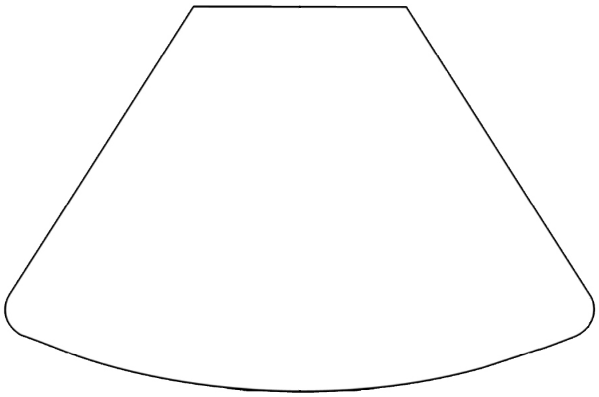
Learn more: https://www.nasa.gov/feature/nasa-applies-insights-for-manufacturing-of-orion-spacecraft-heat-shield

Career Corner

Katherine Johnson is a retired mathematician who worked for NASA from 1953 until 1986. Johnson and other women were hired as "human computers" to calculate the trajectory, or flight path, for the rocket that would put the first American in space in 1961. NASA is always looking for the brightest mathematicians, and there are many other rewarding careers that involve numbers, problem solving, and mathematical modeling.

Learn more: https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/who-is-katherine-johnson-5-8

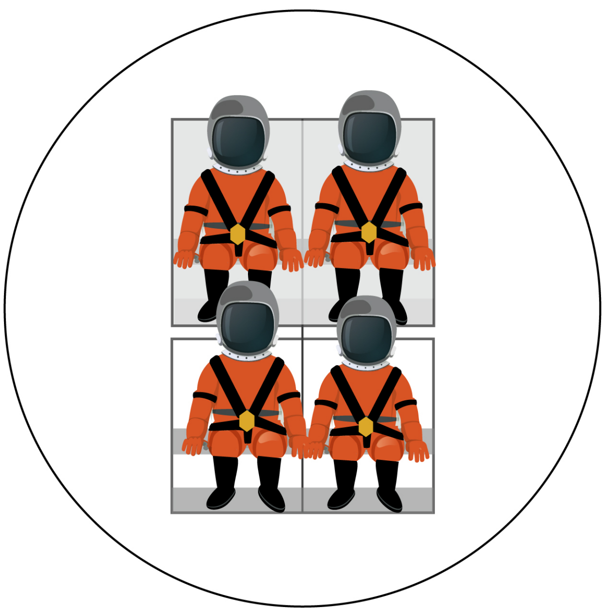
Vertical Cross Section



Vertical cross section (side view) of a crew module.

Shape name	Dimensions, cm (length, width, height, diameter, etc.)	Formula for area of shape	Area of shape, cm^2
			Total area, cm^2 ___________

Horizontal Cross Section



Horizontal cross section (bird's-eye view) of a crew module.

Shape name	Dimensions, cm (length, width, height, diameter, etc.)	Formula for area of shape	Area of shape, cm^2
			Total area, cm^2 ___________