Next Generation Spacecraft – Orion

Instructional Objectives
The 5-E’s Instructional Model (Engage, Explore, Explain, Extend and Evaluate) will be used to accomplish the following objectives.

Students will
- decompose composite figures into familiar polygons,
- apply the proper area formulas for various polygons, and
- estimate the area of a complex geometric shape using decomposition method and graphing.

Prerequisites
Prior to this activity, students should have prior experience finding the area of composite figures by decomposition of geometric figures (breaking figures into smaller shapes) and applying area formulas. Students should be familiar with using graphs to estimate area.

Background
This problem applies mathematical principles in NASA’s human spaceflight. Exploration expands human presence into the solar system providing the foundation of our knowledge, technology, resources, and inspiration. It seeks answers to fundamental questions about our existence, responds to recent discoveries, and puts in place revolutionary techniques and capabilities to inspire our nation, the world, and the next generation. Through NASA, we touch the unknown; we learn and we understand. As we take our first steps toward sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future. This is the beginning of a new era in space exploration where NASA will build the transportation system to send humans deeper into space than ever before.

Over the past decade, fifteen nations have come together to design, assemble, occupy, and conduct research inside and outside of the largest and longest inhabited object to ever orbit the Earth—the International Space Station (ISS). Now NASA is working with U.S. industries to develop commercial spaceflight capabilities to the ISS while building America’s new human space exploration vehicle, the Orion Multi-Purpose Crew Vehicle. Using its new space launch system, Orion will have the capability to take astronauts on exploration missions farther than any
previous mission. When paired with additional propulsion and life support systems, Orion will eventually be able to take humans to Mars.

![Figure 1: Components of the Orion Multi-Purpose Crew Vehicle (NASA concept)](image)

Drawing from more than fifty years of NASA spaceflight research and development, the Orion Multi-Purpose Crew Vehicle is designed to meet the evolving needs of our nation's space program for decades to come. Orion is being engineered by NASA as a state-of-the-art spacecraft to support long-duration deep space missions of up to six months. Its flexible design, and its unique life support, propulsion, thermal protection, and avionics systems, will allow future technical innovations to be later incorporated.

The crew module for Orion will be used to transport both astronauts and cargo. In comparison to the Apollo capsule (Figure 2), the Orion crew module will be larger and have a blunt-body shape. While it may resemble its Apollo-era predecessor, the technology and capability between them will be light years apart.

![Figure 2: Shape comparison of the Orion crew module and the Apollo capsule (not to scale)](image)
NCTM Principles and Standards

Number and Operations
- Develop and use strategies to estimate the results of rational number computations and judge the reasonableness of the result
- Develop a deeper understanding of very large and very small numbers and of various representations of them

Geometry
- Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life

Measurement
- Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume
- Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision

Problem Solving
- Solve problems that arise in mathematics and in other contexts
- Apply and adapt a variety of appropriate strategies to solve problems
- Monitor and reflect on the process of mathematical problem solving

Communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Use the language of mathematics to express mathematical ideas precisely

Connections
- Recognize and apply mathematics in contexts outside of mathematics

Common Core Standards

Number and Quantity
- Reason quantitatively and use units to solve problems

Algebra
- Create equations that describe numbers or relationships
- Understand solving equations as a process of reasoning and explain the reasoning
- Solve equations and inequalities in one variable

Geometry
- Experiment with transformations in the plane
- Explain volume formulas and use them to solve problems
- Visualize relationships between two-dimensional and three-dimensional objects
- Apply geometric concepts in modeling situations
Lesson Development

Following are the phases of the 5E’s model in which students can construct new learning based on prior knowledge and experiences. The time allotted for each activity is approximate. Depending on class length, the lesson may be broken into multiple class periods.

1 – Engage (10 minutes)
- Have students read the background section aloud.
- Play the video, Orion MPCV: The Journey Begins (7:08 minutes), accessible at the following link: http://www.nasa.gov/multimedia/videogallery/index.html?media_id=100276411
- If students would like more information about Orion, there is an optional video, Orion: From Factory to Flight (7:42 minutes), accessible at the following link: http://www.nasa.gov/multimedia/videogallery/index.html?media_id=125642591
- With students in groups of three to four, ask them to review and discuss the main points of the background section for several minutes to be sure that they understand the material. Circulate to help facilitate discussion in small groups. Ask if any group needs clarification.

2 – Explore (10 minutes)
- Have the students read the problem setup and directions, and then estimate using the grid in Appendix A.
- Have students work in pairs to answer question 1.

3 – Explain (20 minutes)
- Have student work in pairs to answer questions 2–4.
- Call on students to give their answers and discuss.

4 – Extend (10 minutes)
- Have students work in pairs to answer questions 5–6.
- Encourage student discussion and ask if there are any questions.

5 – Evaluate (5 minutes)
- Have students work in pairs to answer questions 7–8.
- Call students to share their answers with class. Choose groups that have different decomposition methods and discuss and compare the different methods.
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Solution Key (One Approach)

Have students read the background section aloud, then view the video. Encourage students to have a class discussion about the background and video by asking questions about what has been seen and heard.

Some examples of questions for the educator to ask students are:

1. What is the name of the new spacecraft?
   - Orion

2. Why do we need a new spacecraft?
   - A new spacecraft will allow NASA to send humans deeper into space than ever before.

3. What vehicle does the Orion design resemble?
   - The Apollo capsule

4. Name some places where NASA intends to travel using Orion.
   - Orion will eventually be able to take humans to Mars. Students may also mention the Moon and/or further planets in space.

Directions: Read through the problem set-up and work in pairs to complete the following questions. Round all answers to the thousandths place and label with the appropriate units.

Problem
Orion will replace the space shuttle as NASA’s spacecraft for human space exploration. This activity focuses on the Orion crew module, one of Orion’s four functional modules. The vehicle is designed to accommodate four to six astronauts traveling into space.

1. To get a sense of the room inside the crew module, use the model on the graph paper provided in Appendix A to estimate the vertical cross-sectional area by counting squares and multiplying the number of squares by 0.032 m². Record your work on the provided graph.

   Answers may vary. There are approximately 364 squares.
   Estimated area = (0.032 m²)×(number of squares) = 11.648 m²
2. Using the following figure, decompose the model of Orion into familiar geometric shapes and then name the shapes. Use different colored pencils or highlighters for each geometric shape to show the decomposition into smaller parts. Record the shapes and their corresponding area formulas in Table 1.

Using the largest vertical cross-section diagram of the crew module (Figure 4), 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.

All measurements are in meters (unless otherwise noted).

Figure 5: Largest vertical cross-section of the Orion crew module
(This figure shows the student version with decomposition.)
Table 1: Vertical Cross-Section Area Data

<table>
<thead>
<tr>
<th>Figure</th>
<th>Area Formula</th>
<th>Area Formula with Values</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoid</td>
<td>$A = \frac{1}{2}(b_1 + b_2)h$</td>
<td>$A = \frac{1}{2} \times [(2 \times 2.487) + (2 \times 0.912)] \times 2.446$</td>
<td>$A = 8.314$</td>
</tr>
<tr>
<td>Rectangle</td>
<td>$A = lw$</td>
<td>$A = (2 \times 2.487) \times 0.374$</td>
<td>$A = 1.860$</td>
</tr>
<tr>
<td>Triangle</td>
<td>$A = \frac{1}{2}bh$</td>
<td>$A = \frac{1}{2} \times (2 \times 2.360) \times 0.469$</td>
<td>$A = 1.107$</td>
</tr>
</tbody>
</table>

3. Calculate the area of each shape and record your answer in Table 1. Round your answer to the nearest thousandth.

See Table 1

4. What is the total vertical cross-sectional area of the crew module?

$Total\ area = \text{area of trapezoid} + \text{area of rectangle} + \text{area of triangle} = 11.281\ m^2$

5. If the actual largest vertical cross-sectional area of the crew module is 11.665 m², how far off was your estimate from the graphing method in question 1? Express your answer in terms of a percent (percent error). Round your answer to the nearest percent.

$$%\ error = \frac{\text{actual value-estimated value}}{\text{actual value}} \times 100$$

$$%\ error = \frac{11.665 - 11.648}{11.665} \times 100$$

$$%\ error = 0.14\% \ under\ estimated$$

6. If the actual largest vertical cross-sectional area of the crew module is 11.665 m², how far off was your estimate decomposition estimate? Express your answer in terms of a percent (percent error). Round your answer to the nearest percent.

$$%\ error = \frac{\text{actual value-estimated value}}{\text{actual value}} \times 100$$

$$%\ error = \frac{11.665 - 11.281}{11.665} \times 100$$

$$%\ error = 3\% \ under\ estimated$$
Directions: Complete questions 7–8 in your group.

7. Which estimation method was closest to the actual area? Explain.

*Answers may vary.*

8. Discuss your approach and methods used to estimate the area with one other group. Compare your answers.

*Have some of the students share their comparisons aloud to the class.*

Contributors

This problem was developed by the Human Research Program Education and Outreach (HRPEO) team with the help of NASA subject matter experts and high school mathematics educators.

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Appendix A

Next Generation Spacecraft – Orion Grid