Launch Into

Real-World Modeling with Functions

Florida Connection

Space Shuttle Missions

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On April 8, 1993, Ellen Ochoa became the first Hispanic woman to go into space when she served as a crew member aboard the Space Shuttle *Discovery*. An important goal of her mission was to study Earth's ozone layer. Ochoa would later go on three more shuttle missions in 1994, 1999, and 2002.

In 2013, Ochoa became the first Hispanic and second woman to serve as Director of NASA's Johnson Space Center, a position she held until 2018. In 2017, Ochoa was inducted into the United States Astronaut Hall of Fame, located at the Kennedy Space Center Visitor Complex.

Space Shuttle Facts

- Five fully operational Space Shuttles were built: *Atlantis*, *Challenger*, *Columbia*, *Discovery*, and *Endeavour*.
- *Challenger* and *Columbia* were lost due to in-flight accidents in 1986 and 2003, respectively. *Endeavour* was built in 1991 to replace *Challenger*.
- The Space Shuttle's final mission, by *Atlantis*, ended on July 21, 2011.

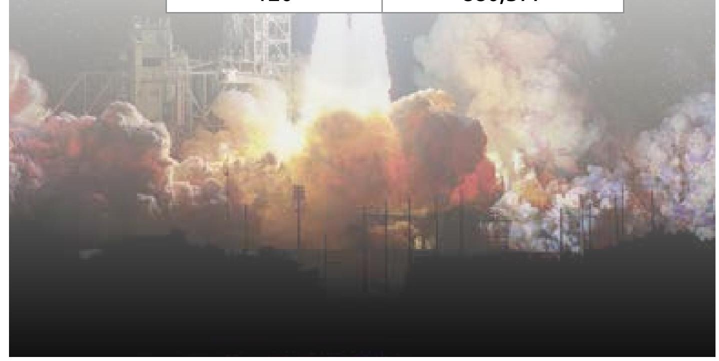
Three Reads

First, read the problem to understand the situation.

Next, read to understand the math. What mathematical questions can you ask about the given quantities?

Most of a Space Shuttle's mass before launch is due to the fuel it carries. After the shuttle is launched, its mass decreases as the fuel is burned. The table shows how the mass of *Discovery* changed during the first two minutes after launch on one of its missions.

Time since launch (s), t	Total mass of shuttle (kg), m
0	2,051,113
20	1,799,290
40	1,567,611
60	1,376,301
80	1,177,704
100	991,872
120	880,377



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Read the problem a third time to formulate a plan for answering the given question.

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What function can you use to model the relationship between the time since launch and the shuttle's mass?

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Think about how the problem can be solved.

Answer the following questions.

A. What information do you know about this problem? How does it relate to the question being asked?

B. How can making a scatter plot of the data help you solve the problem?

C. What types of functions do you know? Do any of these function types seem like good models for the data?

D. How can you use the regression feature of a graphing calculator to find a model? What model do you get? How do you know whether your model fits the data well?

E. Based on your model, what was the mass of *Discovery* 90 seconds after launch?

F. Do you think it is reasonable to use your model to predict the mass of *Discovery* four minutes after launch? Explain.

Discuss with a partner or in a group.

Turn and Talk You may have used a linear function to model the mass m of the Space Shuttle *Discovery* at time t after launch. You can also use an exponential function as a model. An exponential function has the form $m = ab^t$ where a and b are constants. What exponential model does the regression feature of a graphing calculator give for the shuttle data?

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Three Reads Language Routine

First Read The teacher reads the situation aloud. The students listen to understand the situation.

- What is the situation about?
- Can you describe the situation using your own words?

Second Read The students read the situation as a class or with partners. The students read to understand the math.

- What quantities are used in the situation?
- What are the connections between the quantities?
- What mathematical questions could you ask about the situation?

Third Read Each student reads the entire problem on their own, including the question posed on the second page of the lesson. The student reads to formulate a plan for answering the question.

- What plan can you make to solve the problem?

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Introducing Different Types of Models

This Launch Into lesson builds on what students learned in Lesson 6.2, *Residuals and Best-Fit Lines*. Students use a graphing calculator to find a linear function that models a real-world data set. They use their model to make predictions about the situation and consider whether their predictions are reasonable. In the Turn and Talk, students explore how they can also use a graphing calculator to fit an exponential function to the same data set, which foreshadows the work they will do in Lesson 11.1, *Scatter Plots and Fitted Exponential Curves*.

Engage Students

Begin by discussing the opening topic. Invite students to participate by sharing what they know about Space Shuttles and their missions. Students show an increased aptitude for learning if they are actively engaged in some part of the subject matter. Questions might include:

- Have you ever seen a Space Shuttle launch?
- Did you see the launch in person or on TV?
- Can anyone share something the United States has learned from Space Shuttle missions?

Have students work in mixed-ability groups. Give each student a task that they can do well. For instance, in groups of learners with varying abilities, assign each student a specific task, such as leading the group discussion, recording or drawing the work, presenting (but not explaining) the solution, and explaining the models and methods used by the group to solve the problem.

Common Errors made when solving certain problem types can provide valuable teaching opportunities in the classroom. Resolving the cognitive dissonance caused by common errors is one of the most effective methods of improving students' retention of key ideas.

Prompts for Productive Perseverance

For Launch Into lessons, the exploration of math concepts is more critical than finding a solution. Students should be encouraged to think about new math ideas in an atmosphere that is conducive to learning, with minimal pressure. They learn to solve the problem in different ways, and are able to choose the method that works well for them.

What if students can't start or enter into the conversation for this lesson?

Use one or more of these opening prompts:

- *What information do you know about the problem?*
- *What numbers, expressions, or equations are in the problem?*
- *Can a graph help you visualize the situation?*
- *What is given in the problem that might help you answer the question?*

How can I help students who are frustrated?

Ask these leading questions:

- *Think about a starting point. How can you enter into this problem?*
- *What information do you have?*
- *What are you working on? What have you done so far?*
- *What comes next? What are you solving for?*
- *What information do you need to get unstuck? Talk to your partner (or group).*
- *Has someone solved the problem? What question can you ask them to help you solve the problem on your own?*

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ANSWERS

A. Possible answer: I know the total mass of the Space Shuttle *Discovery* at several different times since launch. I can use this information to find a function that models the relationship between time since launch and mass.

B. Possible answer: The shape of the scatter plot suggests the type of function that best fits the data.

C. Possible answer: I know about linear and absolute value functions. A linear function might be a good model because the points in a scatter plot of the data lie close to a line.

D. Possible answer: I can enter the data from the table into a graphing calculator and perform a linear regression. I get the model $m = -9851.698t + 1{,}997{,}426$. I know the model fits the data well because the correlation coefficient is $r \approx -0.9951$, which is very close to -1.

E. Possible answer: about 1,111,000 kg

F. Possible answer: no; My model gives a negative mass at a time of 240 seconds (4 minutes) after launch, which isn't possible.

Turn and Talk: Possible answer: $m = 2{,}076{,}139(0.9928570)^t$