Spacewalking

Instructional Objectives

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

Students will

- write a regression equation and interpret the meaning of the slope and *y*-intercepts in the context of the problem;
- make predictions based on the correct mathematical models; and
- solve linear equations.

Teacher Prep Time

15 minutes

Prerequisites

Students should have prior knowledge of linear regression, the properties of linear functions, and the different representations of a linear function.

Background

This problem applies algebraic principles in NASA's human spaceflight.

The International Space Station (ISS) Mission Control Center (MCC) uses some of the most sophisticated technology and communication equipment in the world. Teams of highly qualified engineers, scientists, doctors, and technicians (known as flight controllers) monitor the systems and activities aboard the ISS. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support each mission and crew during both normal operations and any unexpected events. Aspects of spacewalks performed from the ISS are monitored by the Extra-Vehicular Activities (EVA) Officer. This flight controller monitors the technical operation of the spacesuits and the activities to be carried out before, during, and after a spacewalk.

The pressurized spacesuit worn by astronauts during a spacewalk is officially known as an Extra-vehicular Mobility Unit (EMU). An EMU is worn anytime a crewmember is required to step outside of a pressurized vehicle (i.e., the ISS) to work in the vacuum of space. The key features of the EMU are breathable air, habitable pressure, temperature control, and protection from the harsh space environment.

Suppose an astronaut were to leave a pressurized vehicle without wearing a pressurized suit. Without oxygen, he or she would quickly lose

Key Concepts
Slope, linear regression, linear equations, and *y*-intercept

Problem Duration
65–70 minutes

Technology
Computer with Internet access and projector, TI-Nspire™ handhelds

Materials
- TI-Nspire Student Edition: *Alg-ST_Nspire_Spacewalking.pdf*
- TI-Nspire Student document: *Alg-ST_Spacewalking.tns*
- Video: *The Making of a Spacewalk*
- Student computers with Adobe® Flash® Player and Internet access

Skills
Identify slope, identify *y*-intercept, and solve linear equations

NCTM Principles
- Algebra
- Problem Solving
- Communication
- Connections
- Representation

Common Core Standards
- Algebra
- Functions
- Eighth Grade Statistics and Probability
- High School Statistics

consciousness. Without pressurization, the astronaut would not be expected to survive longer than fifteen seconds. Temperature fluctuations in orbit are caused by the rising and setting of the sun, and temperatures can fluctuate from 120° C (248° F) in sunlight to -100° C (-148° F) in darkness, cycling every forty-five minutes. This means that, during an EVA that lasts for hours, an unprotected person would experience extreme temperatures, potentially causing his or her own body fluids to boil from the heat or freeze from the cold. In addition to the lack of oxygen and pressurization, and exposure to fluctuating temperatures, an unsuited individual would also be exposed to radiation and cosmic rays, and could risk fatal bodily injury from orbiting space debris (e.g. micrometeoroids) moving at high rates of speed.

Figure 1: An astronaut on the robotic arm of the ISS

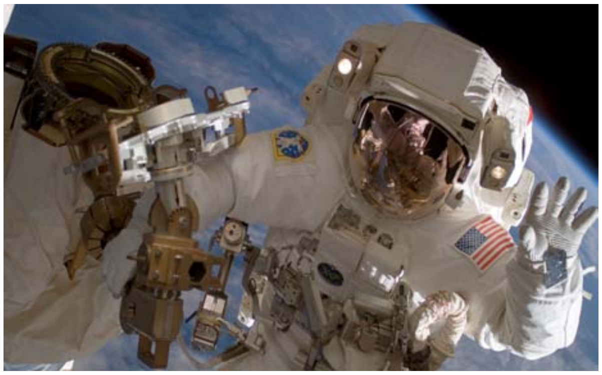


Figure 2: An astronaut on EVA

Along with protecting humans on spacewalks, the EMU also allows astronauts to move around with a comfortable range of motion for arms and legs, provides good visibility, and allows communication with the crew and the MCC. Like a personal spaceship, the EMU allows crewmembers to perform scheduled activities and planned spacewalks for up to seven hours at a time.

NCTM Principles and Standards

Algebra

- Understand relations and functions, and select, convert flexibly among, and use various representations of them.
- Write equivalent forms of equations, inequalities, and systems of equations, and solve them with fluency—mentally or with paper and pencil, simple cases, and using technology in all cases.
- Use symbolic algebra to represent and explain mathematical relationships.

Problem Solving

- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.

Communication

- Organize and consolidate their mathematical thinking through communication.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Analyze and evaluate the mathematical thinking and strategies of others.
- Use the language of mathematics to express mathematical ideas precisely.

Connections

- Recognize and apply mathematics in contexts outside of mathematics.

- Recognize and use connections among mathematical connections.

Representation

- Select, apply, and translate among mathematical representations to solve problems.

Common Core Standards

Algebra

- Create equations that describe numbers or relationships.

Functions

- Construct and compare linear, quadratic, and exponential models and solve problems
- Interpret expressions for functions in terms of the situation they model.

Eighth Grade Statistics and Probability

- Investigate patterns of association in bivariate data.

High School Statistics

- Reason quantitatively and use units to solve problems.
- Create equations that describe numbers or relationships.
- Understand the concept of a function and use function notation.
- Interpret expressions for functions in terms of the situation they model.
- Summarize, represent, and interpret data on two categorical and quantitative variables.
- Interpret linear models.

Lesson Development

Following are the phases of the 5–E's Instructional 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 (15–20 minutes)

- Play the video, *The Making of a Spacewalk* (2:50 minutes). Access the video by following this link and scrolling down until you find the correct title. http://www.nasa.gov/multimedia/videogallery/Video_Archives_Collection_archive_18.html
- Have students read the background section aloud to the class, and pause occasionally to check for understanding.
- Optional: Play the video, *STS-126 Spacewalkers at Work* (4:07 minutes). Access the video by following this link and scrolling down until you find the correct title. http://www.nasa.gov/multimedia/videogallery/Video_Archives_Collection_archive_22.html

2 – Explore (10 minutes)

- After watching the video, *The Making of a Spacewalk*, ask students to describe and discuss the features that would be necessary in a spacesuit. Answers will vary, but should include: breathable air, protective gear, communication, heating/cooling, habitable pressure, mobility, and visibility.
- Open the TI-Nspire document, *Spacewalking,* and answer questions 1.2–1.4.
- Follow the link below to access *The Clickable Spacesuit*. A description is provided with each part of the spacesuit. Have students compare their ideas to this actual suit. http://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html

3 – Explain (15 minutes)

- Review the terms, slope, and *y*-intercept. Discuss the terms in real world problem situations; i.e., slope is the rate of change; *y*-intercept is the starting condition.
- All of the questions in this lesson are embedded in the TI-Nspire document, *Spacewalking.* Have students work in cooperative groups to answer questions 1.7–1.13.
- Facilitate student discussion and answer questions.
- Call on students to give their answers to the class and discuss.

4 – Extend (5 minutes)

- Have students work in the same cooperative groups to answer question 2.3.
- Allow students to discuss answers to this question.
- Lead the class in a discussion to check for understanding.

5 – Evaluate (20 minutes)

- Have students complete questions 2.4–2.10 independently. This may be done in class or assigned as homework.

Pre-AP Extension

- Have students complete questions 3.2 and 3.3 independently. This is optional to extend the statistical concept.

Spacewalking

Solution Key

Note to teacher: Instruct students to open TI-Nspire document, Alg-ST_Spacewalking.tns on their handhelds. You may choose to have students record their work directly in their handhelds or on their worksheets in the provided spaces. A solution key is provided below, as well as in the educator's version of the TI-Nspire document, Alg-ED_Spacewalking.tns.

Directions: On the TI-Nspire handheld, open the document, Alg-ST_Spacewalking. Complete the embedded questions on pages 1.2–1.4.

1.2 Imagine that you are an astronaut. What would you need to survive and successfully complete a spacewalk?

Answers may vary, but may include protective suit, breathable air, communication equipment, air conditioning for the suit, tools, mobility, and visibility.

1.3 What would happen to your oxygen supply as you perform a spacewalk?

Oxygen supply would deplete.

1.4 Explain why your oxygen usage might be different from another astronaut's oxygen usage during a spacewalk.

Oxygen usage is dependent upon how each astronaut breathes; i.e., respirations (or breaths) per minute and amount of oxygen consumed with each breath.

Directions: Read the problem set up on page 1.5. Answer questions 1.7–1.13 in your group. Discuss answers to ensure everyone understands and agrees on the solutions. Round all answers to three decimal places, and label with the appropriate units.

Problem

The EVA Officer is preparing for an upcoming mission in which two astronauts will install solar panels on the International Space Station (ISS). The spacewalk will last about seven hours. In order to ensure that the first astronaut (Astronaut A) can complete the mission with a normal oxygen supply, the EVA Officer is reviewing Astronaut A's oxygen usage data from a previous EVA (as shown in Table 1).

Oxygen usage data is measured by oxygen (O_2) tank pressure using pounds per square inch (psi), and EVA duration (or time) data is measured in hours (hrs).

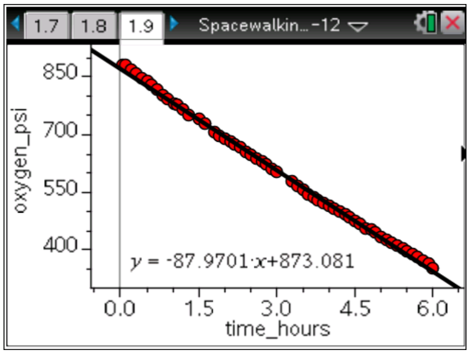
Table 1: Astronaut A's oxygen usage data during previous EVA

O_2 Tank Pressure (psi)	EVA Time (hrs)	O_2 Tank Pressure (psi) *(continued)*	EVA Time (hrs) *(continued)*
880.000	0.033	576.728	3.300
880.000	0.100	565.714	3.400
868.718	0.200	554.701	3.500
857.973	0.300	545.031	3.600
849.109	0.400	536.972	3.700
841.319	0.500	529.988	3.800
828.156	0.600	523.004	3.900
817.143	0.700	516.020	4.000
803.443	0.800	507.961	4.100
791.624	0.900	499.365	4.200
780.611	1.033	492.918	4.300
776.044	1.100	484.591	4.400
766.911	1.200	476.264	4.500
750.000	1.300	467.937	4.600
742.198	1.500	457.998	4.700
730.916	1.600	451.551	4.800
706.203	1.800	444.567	4.900
698.144	1.900	435.971	5.000
689.817	2.000	427.912	5.100
682.564	2.100	421.465	5.200
674.506	2.200	411.526	5.300
656.777	2.400	405.885	5.400
647.106	2.500	399.438	5.500
638.510	2.600	391.111	5.600
629.377	2.700	381.172	5.700
621.050	2.800	372.576	5.800
612.723	2.900	363.712	5.900
604.664	3.000	354.310	6.000

1.7 Analyze the data on page 1.6. What type of correlation would you predict best fits this data?

- o **linear**
- o quadratic
- o cubic

1.8 On page 1.9, plot the oxygen tank pressure (psi) vs. the time (hrs). Determine an appropriate mathematical model to fit the data.



$p = -87.970t + 873.081$

1.10 Interpret the slope and *y*-intercept of your model in the context of the problem.

The slope indicates that Astronaut A will use an average of 87.970 psi of oxygen tank pressure for every hour of the EVA. The y-intercept indicates that the regression model predicts Astronaut A's starting oxygen tank pressure is 873.081 psi.

1.11 Use the model to determine if Astronaut A can perform a seven-hour spacewalk before depleting his or her oxygen.

$$p = -87.970t + 873.081$$
$$p = -87.970(7) + 873.081$$
$$p = 257.291\,psi$$

Since the model predicts there is still 257.270 psi of oxygen left before depletion, Astronaut A can perform a seven-hour spacewalk.

1.12 Determine the *x*-intercept, and explain what it means in this scenario.

$$p = -87.970t + 873.081$$
$$0 = -87.970t + 873.081$$
$$t = \frac{-873.081}{-87.970}$$
$$t = 9.925\,hours$$
$$(9.925, 0)$$

The x-intercept is the number of hours an astronaut can be on a spacewalk before his or her oxygen is depleted.

1.13 What type of association (or correlation) between time and oxygen usage is displayed by the plotted data?

A strong, negative association

Directions: Read the problem set up on page 2.1. Answer question 2.3 in your group. Discuss answers to ensure everyone understands and agrees on the solutions.

Astronaut B will be accompanying Astronaut A to assist with the solar panel installation. The EVA Officer is evaluating previous oxygen usage data for Astronaut B (as shown in Table 2).

Table 2: Astronaut B's oxygen usage during a previous EVA

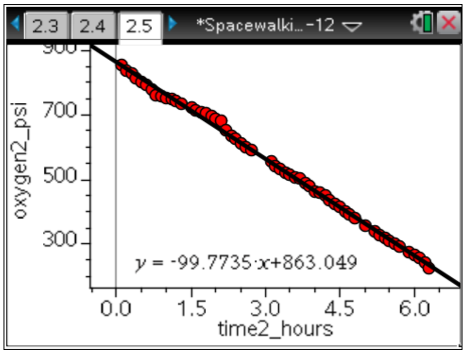
O_2 Tank Pressure (psi)	EVA Time (hrs)	O_2 Tank Pressure (psi) *(continued)*	EVA Time (hrs) *(continued)*
853.138	0.100	531.600	3.300
838.633	0.200	520.049	3.400
826.007	0.300	515.751	3.500
812.845	0.400	508.767	3.600
801.294	0.500	501.514	3.700
790.818	0.600	489.695	3.800
778.462	0.700	479.756	3.900
763.956	0.800	462.564	4.000
758.315	0.900	456.923	4.100
753.480	1.000	449.939	4.200
749.719	1.100	437.045	4.300
744.078	1.200	425.226	4.400
735.214	1.300	414.481	4.500
720.977	1.500	402.393	4.600
715.067	1.600	390.574	4.700
707.546	1.700	381.441	4.800
703.785	1.800	359.145	5.000
696.264	1.900	338.999	5.200
687.668	2.000	327.985	5.300
680.684	2.100	318.046	5.400
652.210	2.200	310.256	5.500
635.018	2.300	301.661	5.600
624.811	2.400	290.110	5.700
611.917	2.500	272.918	5.900
597.949	2.600	263.785	6.000
588.816	2.700	255.727	6.100
554.432	3.100	241.221	6.200
543.150	3.200	226.716	6.300

2.3 What is different about the oxygen usage data of Astronaut B?

Answers will vary. Astronaut B appears to use oxygen more quickly than Astronaut A. The starting pressures in the tank are also different.

Directions: Complete questions 2.4–3.3 independently. Round all answers to three decimal places, and label with the appropriate units.

2.4 On page 2.5, create a scatter plot for Astronaut B's oxygen usage vs. time and determine the mathematical model that fits the data.



$p = -99.774t + 863.049$

2.6 What can be determined from the slope of Astronaut B's model, when comparing the slopes from both models?

Astronaut B uses more oxygen per hour than Astronaut A.

Three hours into the spacewalk, Astronaut B has become exhausted. Since Astronaut A is using less oxygen than Astronaut B, Astronaut A is asked to perform the more strenuous EVA tasks. The Extra-Vehicular Activities (EVA) Officer recommends that the two astronauts switch duties.

2.8 How much oxygen tank pressure can we predict that each astronaut has left at this point?

Astronaut A

$p_A = -87.970t + 873.081$

$p_A = -87.970(3) + 873.081$

$p_A = 609.171 \text{ psi}$

Astronaut B

$p_B = -99.774t + 863.049$

$p_B = -99.774(3) + 863.049$

$p_B = 563.727 \text{ psi}$

2.9 Write two new equations to represent the oxygen tank pressure for each astronaut after switching roles. Astronaut B now has a lighter workload, and is using oxygen at a rate of 87.970 psi/hr. Astronaut A now has the more strenuous workload, and is using oxygen at a rate of 99.774 psi/hr. Use *p* to represent oxygen tank pressure (in psi) and *t* to represent EVA time (in hrs).

Astronaut A: $p_A = -99.774t + 609.171$

Astronaut B: $p_B = -87.970t + 563.727$

2.11 The EVA Officer has recommended that the spacewalk be aborted if either astronaut reaches an oxygen tank pressure of 150 psi before the mission is complete. If four more hours are required to complete the EVA, will the astronauts be able to finish the spacewalk?

Astronaut A	Astronaut B
$p_A = -99.774t + 609.171$	$p_B = -87.970t + 563.727$
$p_A = -99.774(4) + 609.171$	$p_B = -87.970(4) + 563.727$
$p_A = 210.075 \text{ psi}$	$p_B = 211.847 \text{ psi}$

The spacewalk can be completed because neither astronaut will reach 150 psi.

Pre-AP Extension

3.2 In Statistics, the actual value minus the predicted value is called a residual. What is the oxygen tank pressure residual when Astronaut A has been on the spacewalk for five hours?

Actual – predicted = residual

435.971 – 433.231 = 2.740 psi

3.3 Is this an overestimate or an underestimate? Explain.

Since the residual is positive, this is an underestimate.

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.

NASA Expert

Lisa B. Shore – Extravehicular Activities Officer, Mission Operations Directorate, NASA Johnson Space Center, Houston, Texas

Math Educators

Curtis Brown – Mathematics Coordinator, National Math and Science Initiative

Paulette Granger – Education Specialist, Human Research Program Education and Outreach Team, NASA Johnson Space Center, Houston, Texas