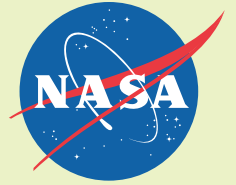


National Aeronautics and Space Administration



Calculator-Controlled Robots:

Hands-On Mathematics and Science Discovery



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Controlled Robots
Hands-On Math and
Science Discovery*

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Introduction

The Calculator Controlled Robots activities are designed to engage students in hands-on inquiry-based missions. These activities address National science and technology standards, as well as specifically focusing on mathematics content and process standards. There are ten missions and three exploration extensions that provide activities for up to one semester.

These activities are geared towards using a graphing calculator with a Norland Research calculator robot. Best results for student engagement have been obtained with each student having her/his own CalcBot (calculator + robot) to use in class. The curriculum is suited for mathematics, science, technology, or after-school classes.

Students create programs in TI-BASIC (<http://en.wikipedia.org/wiki/TI-BASIC>) to run their robots. Missions are sequentially built upon the knowledge of previous activities. Step-by-step programming instructions are provided in the first missions, gradually leading students to create their own programs in later missions. Students use and apply mathematics and science concepts to direct their robots through a variety of challenges.

In addition to the detailed activities, teachers are given opportunities to draw on their students' hands-on experience to reach a deeper understanding of mathematical concepts. Several open-ended questions and extension activities are included to encourage potential scientists, engineers, mathematicians, and computer programmers to explore their fields.

Missions

Each mission starts with a brief introduction, materials list, and an illustration of a robot challenge. Student programming instructions are at the end of the activities. "Teacher Notes" are located at the end of the booklet (pg 58). These notes should be removed from students' activities before duplicating them for students. Using a different color of paper for each mission is helpful for distinguishing one assignment from another.

Preface and Credits

This manual was created using the Texas Instruments TI-83 graphing calculator as a model, and can be directly applied to the following TI models: TI-73, TI-82, TI-83, TI-83Plus, TI-83Plus Silver Edition, TI-84Plus, TI-84Plus Silver Edition, TI-85(CBL model), TI-86, TI-89, TI-89 Titanium, TI-92, TI-92 Plus, and Voyage 200 (will not mount on base).

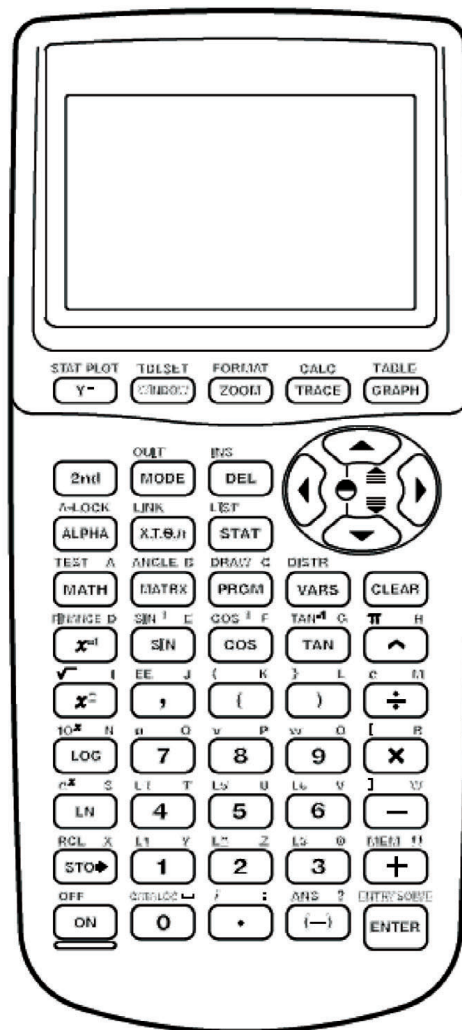
PLEASE NOTE that the basic concepts and instructions in this manual can be applied with modification to any standard graphing calculator and hardware. Users are responsible for determining and implementing these modifications.

The Calculator-Controlled Robot curriculum was developed with support from Texas Instruments Incorporated, Norland Research, Lake County School District #7 in Oregon, and the National Aeronautics and Space Administration (NASA) Office of Education. The curriculum was classroom field-tested for four years at Daly Middle School in Lakeview, Oregon and further developed during at NASA Headquarters in Washington, DC. The activities are designed to lead students to discover mathematical concepts through robotics, programming, and science challenges. Mathematics content and process standards are embedded throughout the curriculum. In many activities math is used as a practical tool for understanding science.

Calculator-Controlled Robots was written by Tyson Tuchscherer. Illustrations in *Calculator-Controlled Robots* were created by Todd Tuchscherer. For their encouragement and support, the author would like to extend a special THANK YOU to: Judy Graham, Superintendent, Lake County School District #7 Will Cahill, Principal, Daly Middle School, Peg Steffen, Former Program Manager, NASA Explorer Schools.

About the Author

Tyson Tuchscherer has taught mathematics and science at both middle and high school levels for over 18 years, including three years in Australia. As a teacher, he coached MATHCOUNTS and mentored students entering international science and engineering fairs. He has provided math problems for state mathematics assessments and for the MATHCOUNTS National School Handbook. As a tier-one candidate for NASA's Educator Astronaut Program, Tyson was invited to become a select member of the Network of Educator Astronaut Teachers. In 2005, he was honored with an Albert Einstein Distinguished Educator Fellowship and selected by NASA to work with the NASA Explorer Schools Program as a math specialist. Tyson is married and has three children. He is currently a Research Fellow at LMI Government Consulting working on science, technology, engineering and mathematics (STEM) education and workforce development for the Director of the National Defense Education Program.



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Name:		Date:
MISSION	1	Measure
		Materials & Instructions
Your first mission is to measure the width of the hallway outside your classroom using only a robot and a graphing device.		

You need:

- 1 Norland Calculator Robot
(Your “wheels” for this mission)
- 1 Graphing Calculator (Robot brains)
- 1 Meter Stick



Instructions

Write a simple program (see Programming Instructions if needed) for your robot on your graphing calculator. Name your program **GO**.

```
PROGRAM: GO
: Send ({222})
: Get (R)
: Disp R
: Stop
```

These commands instruct the robot to move forward until its bumper runs into something. Attach your graphing calculator to the robot and run GO. You have fifteen minutes to experiment using the robot and a meter stick in the classroom before you measure the hallway. Remember, the meter stick cannot leave the classroom and the width of the hallway must be measured using the movement of the robot. Time will be displayed in centiseconds (1/100 second) on the graphing calculator’s screen after each run, i.e. 524=5.24 seconds. On the following page are tables to help you record your data. Decide ahead of time how to label the columns and rows.

Accuracy of Measurement Grading Scale:

Within 0 to ≤ 10 cm	A
>10 to ≤ 20 cm	B
>20 to ≤ 30 cm	C
>30 cm	Try again

Name:		Date:
MISSION	1	Measure
		<i>Data</i>

Inside the classroom:

Trials		
Total		
Average		

Outside the classroom:

(No meter sticks allowed)

Trials		
Total		
Average		

Name:		Date:
MISSION	1	Measure
		Results

1. What is your estimate of the width of the hallway in centimeters?

.....

.....

2. What was the speed or rate of your robot?

.....

.....

3. The bumper is at the front of the robot. How did you account for this in your measurement of the hallway?

.....

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.....

.....



4. What calculations did you use to determine the width of the hallway?

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.....

Extension:

Using the speed of the robot, determine your height in centimeters. Write your results with initials on the board. When the entire class has their measurements displayed, determine the mean, mode, median, and range for the data.

- Convert your height to feet and inches. How tall are you?
- Design an advanced robot program to automatically measure distance.

Name:			Date:
MISSION	1	Measure	Programming Instructions

Turn on your graphing calculator. Press **PRGM**, use the arrow to highlight NEW. Press **ENTER**, then spell out [GO] by pressing the appropriate keys. Press **ENTER**. You're ready to enter the first command for the program.

Line 1: Press **PRGM**, use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send**. Press **ENTER**. Press **2nd** and then press **[]** for an open brace. Type in **222**. Close the braces and parentheses by pressing **2nd**, **[]**, then **[]**. Press **ENTER**. The first line should appear as:

```
:Send ({222})
```

Line 2: Press **PRGM**, use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get**. Press **ENTER**. Press **ALPHA**, then **[R]**. Press **[]**, then **ENTER**. The second line should appear as:

```
:Get (R)
```

Line 3: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press **ENTER**. Press **ALPHA**, then press **[R]**. Press **ENTER**. The third line should appear as:

```
:Disp R
```

Line 4: Press **PRGM** and **CTL** will be highlighted. Use the arrow to scroll down to **F: Stop**. Press **ENTER**. The fourth line should appear as:

```
:Stop
```

Press **2nd**, then **[QUIT]**.

To run the program, attach the graphing calculator to your robot and connect the link cable. Make sure the robot and calculator are both switched on. Press **PRGM** and use the arrow to scroll down to **: GO**. Press **ENTER**. Place the robot on the floor, then press **ENTER** again and the robot will move forward until the bumper hits something.

Calibration for Straight Line Travel

The following program enables you to correct wheel speed so that your robot goes straight.

- Run the **CALI** program. (Press **PRGM** and use the arrow to scroll down to **: CALI**. Press **ENTER**. Place the robot on the floor, then press **ENTER** again.) Press **ZOOM**. Note which way the robot veers and press the bumper to stop the robot.
- Slow down the faster wheel of the two wheels by pressing the button under the DN on that side. Due to the design of the electronics, you may have to change this 70-100 units to see much speed change.
- Press **ZOOM** and the speed of the wheel should change. Press the bumper and continue adjusting the speed until the robot goes straight. For simplicity, it's best to change the speed of just one wheel.
- Once your robot is going straight make a note of which wheel was adjusted and the correction number. To leave the **CALI** program press **ON**, then **1**, then **CLEAR**.
- Edit the **CORRECT** program. (Press **PRGM**, then use the arrow to highlight **EDIT**. Use the arrow to scroll down to **: CORRECT**. Press **ENTER**.) If you had to slow the left wheel, change "255" in the program Line 1 to the appropriate value. If you slowed the right wheel, change the "0" in program Line 4 to the appropriate value. To insert numbers, press **2nd**, then **[INS]**. To finish, Press **2nd**, then **[QUIT]**.
- Run the **CORRECT** program and press the bumper to stop the robot. Your correction is now set in the robot's memory until the power switch is turned off. Whenever you switch on the robot, run the **CORRECT** program to reestablish the wheel correction.

Calculating Speed (Rate) of Your Robot

After your robot is running as straight as possible, do some trial runs using a meter stick or ruler. Use the front bumper as a starting and ending point reference. Run several trials. Use page 3 of Mission 1 to record your data.

- For a meter stick, run 100 cm trials.
- Average the trials.

Background:

DEFT Formula: **D**istance **E**quals **R**ate \times **T**ime or $d=rt$ or $rt=d$

If you are traveling in a car at a constant speed of 60 mph (rate) for 3 hours (time), you'll cover a distance of 180 miles, $rt=d$ or $60 \times 3 = 180$ miles.

If you know the distance traveled (d) and you know elapsed time (t), you can calculate the rate (r) or speed using the same formula. By algebraic transformation, $d/t=r$. If you travel 200 miles in 4 hours, what is your average speed (rate)? If your robot travels 100 cm in 5 seconds, what is its speed (rate)?

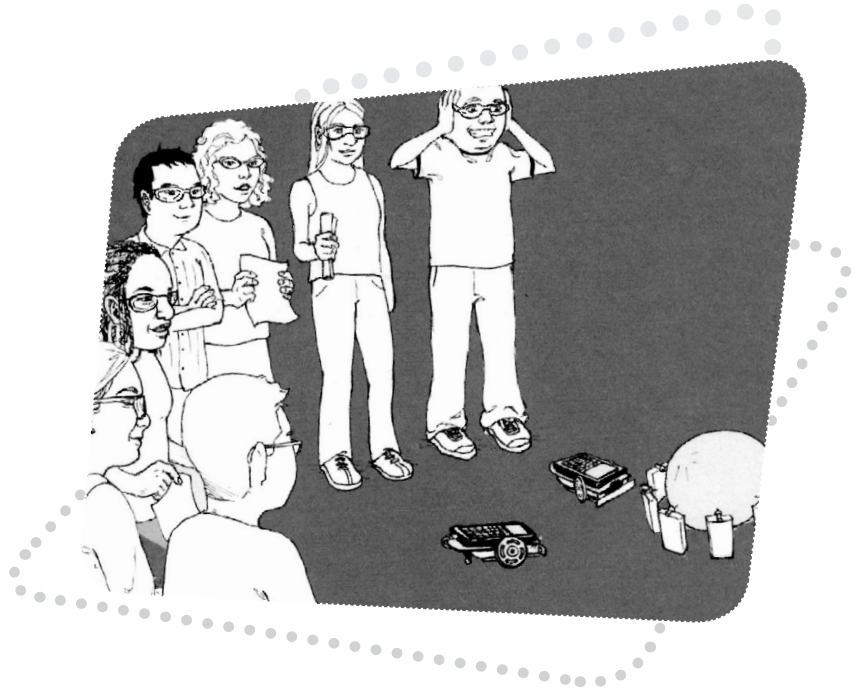
- Divide the distance traveled by the average time to obtain the speed of your robot ($d/t=r$). For example, $100 \text{ cm}/5.67 \text{ sec} =$ a speed or rate of approximately 17.64 cm/sec. Your robot travels 17.64 cm every second.

$$\frac{\text{distance}}{\text{average time (sec.)}} = \text{rate or speed (cm/sec.)}$$

Name:			Date:	
MISSION	2	Graph and Predict	Materials	
Your second mission, should you decide to take it (and you know you will), is to come as close to crashing your robot into an object as possible, without actually hitting the object.				

You need:

- 1 Norland Calculator Robot
- 1 Graphing Calculator
- 1 Meter Stick
- Graph Paper
- Safety Goggles



Name:		Date:	
MISSION	2	Graph and Predict	<i>Instructions</i>

Use a meter stick with your robot and the **GO** program from **Mission 1** to obtain data for the table below:

Table 1

Time (In seconds)	Distance (In centimeters)
	50
	100
	150
	200
	250

Graph the data as points on graph paper with TIME on the horizontal or x-axis and DISTANCE on the vertical or y-axis. Draw the best-fitting line that most closely follows the pattern shown by your data points.

How Good Is Your Graph?

Write a simple program (see PROGRAMMING INSTRUCTIONS if needed) for your robot on a graphing calculator name your program **MISSION2**:

PROGRAM: MISSION2

: randInt (1,10)->X

: Disp X

: Pause

: X*100->T

: Send ({122,T})

: Get (R)

: Stop

Name:		Date:	
MISSION	2	Graph and Predict	<i>Instructions</i>

This program will randomly pick a number from 1 to 10. This number represents the time in seconds the robot will be instructed to travel forward. The program will pause while you use your graph to predict the distance the robot will travel. Record your prediction in the table below, then press **ENTER** on the graphing device and measure the actual distance. Record your degree of error.

Table 2

Time (In seconds)	Prediction (In centimeters)	Actual	Error

Name:		Date:
MISSION	2	Graph and Predict
		<i>Advanced</i>

Using your graph will let you predict how far the robot will travel forward for a given time. What if a time is given that exceeds the limitations of your graph?

.....

.....

.....

Is there a more accurate way to predict or calculate the expected distance?

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.....

Find the slope of your best-fitting line on the graph. What does the slope represent?

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Write an equation for your line using the slope-intercept form $y=mx+b$. What does b equal?

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.....

Graph this equation on your calculator. Press **TRACE** and confirm your values from table one. For any given Y value (distance) there will be a corresponding X value (time).

Rewrite your slope-intercept equation above, substituting d for y, r for m, and t for x. Does it look familiar? This equation can be used to predict the time needed for the robot to travel any given distance.

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.....

Name:		Date:
MISSION	2	Graph and Predict
		<i>Challenge</i>

The mission is to instruct your robot to move as close as possible to a teacher designated object without actually hitting it. You may measure from the starting point to the object and then you must predict the time that your robot will need to complete the task. Using the **GO** program from **Mission 1** change code line 1 from “:Send ({{222}})” TO “:Send ({{122,xxx}})” where xxx represents the time in centiseconds you want your robot to travel forward, i.e. 850=8.5 seconds. (See EDITING INSTRUCTIONS on page 14 if needed.)

Imagine that you are sending a \$125 million satellite to Mars and not doing a trial and error exercise. You have only one shot. Make sure your estimates are accurate and that you have accounted for all variables.

Accuracy of Prediction Grading Scale:

- Within 0 to ≤ 10 cm **A**
- >10 to ≤ 20 cm **B**
- >20 to ≤ 30 cm **C**
- >30 cm **Try again**

Name:		Date:
MISSION	2	Graph and Predict
		<i>Results</i>

1. In centimeters, how close did you get?

.....

2. What could you do to improve your results?

.....

3. What other designated object would be interesting to use in this mission besides the one given by your teacher? (Perhaps one that would show a definite reaction if a robot hit it.)

.....

4. How did you predict the travel time needed for the robot?

.....

Name:		Date:	
MISSION	2	Graph and Predict	Programming Instructions

Turn on your graphing calculator. Press **[PRGM]**, then use the arrow to highlight **NEW**. Press **[ENTER]**, then spell out **MISSION2** by pressing the appropriate keys. (Press **[ALPHA]** to switch from letters back to numbers for the **[2]**.) Press **[ENTER]** and you're ready to enter the first command for the program.

Line 1: Press **[MATH]**, then use the arrow to highlight **PRB**. Use the arrow to scroll down to **5: randInt(**. Press **[ENTER]**. Type in **[1],[10]** and **[,]**. Press **[STO▶]**. Press the **[X,T,θ,n]** button. Press **[ENTER]**. The first line should appear as:
:randInt (1, 10) -> X

Line 2: Is blank

Line 3: Press **[PRGM]**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press **[ENTER]**. Press the **[X,T,θ,n]** button. Press **[ENTER]**. The third line should appear as:
:Disp X

Line 4: Press **[PRGM]** and **CTL** will be highlighted. Use the arrow to scroll down to **: Pause**. Press **[ENTER]** twice. The fourth line should appear as:
:Pause

Line 5: Press **[X,T,θ,n]**. Press **x** and then type in **[1][0][0]**. Press **[STO▶]**. Press **[ALPHA]**, then press **[T]**. Press **[ENTER]**. The fifth line should appear as:
X*100->T

Line 6: Press **[PRGM]**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send(**. Press **[ENTER]**. Press **[2nd]** and then press **[{]**. Type in **[1][2][2]**, then press **[,]**. Press **[ALPHA]**, then press **[T]**. Close by pressing **[2nd]**, the **[}]** button, and then **[,]**. Press **[ENTER]**. The seventh line should appear as:
:Send ({122,T})

Line 7: Press **[PRGM]**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (**. Press **[ENTER]**. Press **[ALPHA]**, then press **[R]**. Press **[,]** then **[ENTER]**. The second line should appear as:
:Get (R)

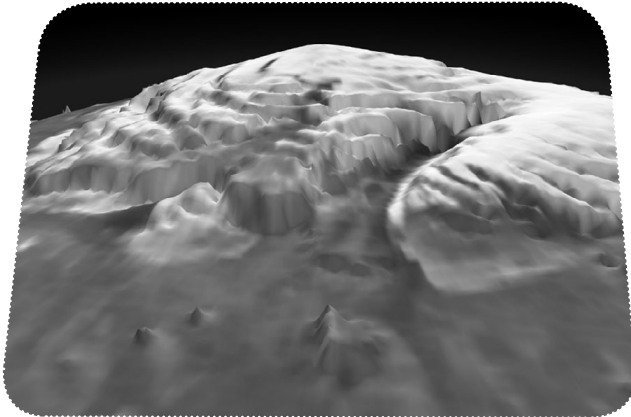
Line 8: Press **[PRGM]** and **CTL** will be highlighted. Use the arrow to scroll down to **F: Stop**. Press **[ENTER]**. The fourth line should appear as:
:Stop
Press **[2nd]**, then **[QUIT]**.

To run the program, attach the calculator to your robot and connect link cable. Make sure the robot and calculator are both switched on. Press **[PRGM]** and use the arrow to scroll down to **: MISSION2**. Press **[ENTER]**. Press **[ENTER]** again and the program will randomly pick a number from 1 to 15. This number represents the time in seconds the robot will be instructed to travel forward. The program will pause while you predict the distance the robot will travel. Place the robot on the floor, then press **[ENTER]** and robot will travel forward for the displayed number of seconds.

Editing Instructions:

Press **[PRGM]**, then use the arrow to highlight **EDIT**. Use the arrow to scroll down to **:GO**. Press **[ENTER]**. Change 222 to 122 then press **[,]**. Enter the number of centiseconds you want the robot to run. Close the braces and parentheses by pressing **[2nd]**, the **[}]** button, and then **[,]**. The new first line (if you want the robot to run 8.5 seconds) should appear as:
:Send ({122,850})
Press **[2nd]**, then **[QUIT]**. Follow instructions above to run the program; after the second **[ENTER]** the robot will move forward.

Name:		Date:
EXPLORATION EXTENSION	1	Laser Altimeter
		Background & Instructions



First 3-D view of the north pole of Mars from MOLA
(Image credit: MOLA science Team/NASA/GSFC SVS)

Background

A laser altimeter is a device used aboard planet-orbiting satellites to map a planet's terrain. The elevations of surface features can be calculated by comparing how long it takes a laser pulse to echo back at different locations.

On NASA's Earth-orbiting ICESat satellite, a laser altimeter (Geoscience Laser Altimeter System) is used to obtain data on the elevation or thickness of ice sheets. This is relevant to understanding global climate change.

NASA's Mars Orbiter Laser Altimeter (MOLA) is currently in orbit around Mars on the Mars Global Surveyor satellite.

Spacecraft name = Mars Global Surveyor
Instrument name = Mars Orbiter Laser Altimeter (MOLA)
Instrument ID = MOLA
Target = Mars

MOLA's laser altimeter bounces laser pulses off of the surface of Mars at the speed of light and records return times. Laser light returns faster from the top of a volcano than from the lowlands around it because the top of the volcano is closer to the satellite than the lowlands. Three-dimensional mapping of Mars surface features can be done by analyzing the data (as was done to get the image above).

Instructions

To calculate the one-way distance from the satellite to a surface feature, a computer divides the elapsed time of a returning laser pulse by two and then multiplies the quotient by the speed of light. Like a laser pulse, your robot travels at a constant rate. It can "bounce" off the walls of unknown terrain and return data that helps to give a picture of the topography of a vertical surface. The program below will automatically calculate the distance to a vertical surface once you enter the speed of your robot in centimeters per second.

Write the program ECHO:

(If needed, see PROGRAMMING INSTRUCTIONS on pages 18,19.)

PROGRAM: ECHO

```
:Disp "SPEED CM/  
S="  
:Input S  
:Lbl A  
:Pause  
: Send ({{222}})  
: Get (R)  
: Send ({{100, R}})  
: Get (R)  
: Disp S*R/100  
:Disp "CM"  
:Goto A
```

Name:		Date:	
EXPLORATION EXTENSION	1	Laser Altimeter	Challenge

Your mission is the exploration of Planet X. Your robot is in orbit around the planet on a spacecraft and will be sent to explore the surface. Unfortunately, cameras won't work in this environment because of a constant thick fog. You'll need to use the echo feature of your robot to analyze the topography of the steep cliffs on the planet's surface. These may be similar to those seen in the 3-D image of Mars's north pole on the previous page.

1. Describe what type of spacecraft your robot is on and how your robot will get to the planet's surface without damage.

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Fill out the following:

SPACECRAFT NAME

INSTRUMENT NAME

INSTRUMENT ID

TARGET

You are on an important mission to map the fog-hidden, vertical cliff face on Planet X. Position a transect line (a line along which measurements are taken at intervals), marked with 10-centimeter increments, parallel to the cliff face. Use your robot to measure the distance from the transect line to the cliff face at each increment. Record your data below.

Table 1

TEST INTERVAL (In centimeters)	DISTANCE (In centimeters)
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Graph the data from Table 1 as points on graph paper with TEST INTERVAL on the horizontal or x-axis, and DISTANCE on the vertical or y-axis. Draw a line connecting the points to picture what the vertical surface of the cliff face looks like.

Name:		Date:	
EXPLORATION EXTENSION	1	Laser Altimeter	<i>Results</i>

2. If you were going to land a spacecraft in the region near the cliff face, are there any areas you might want to avoid? Why?

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3. If you discovered any rocky outcroppings jutting out from the cliff face give their approximate area in square centimeters. (Show all work for calculations.) How can you change your data gathering techniques to get a more accurate picture of the outcroppings?

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Name:		Date:	
EXPLORATION EXTENSION	1	Laser Altimeter	Results

On missions to the Moon, crews from NASA's Apollo 11, 14, and 15 left behind retroreflector arrays that could reflect laser light back to Earth. The distance to the Moon can be accurately determined by "Laser Ranging" or measuring the time it takes a laser pulse (traveling at the speed of light) to go from Earth to the Moon and back again.

4. It takes a laser pulse 2.5 seconds to go to the Moon and echo back to Earth. Given the speed of light as approximately 300,000 kilometers per second, how many kilometers away is the Moon at that point in time? (Show all work for calculations.)

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5. In a sense you have a "robot ranger" or distance finder. A robot travels 22.32 centimeters per second and pings off an unknown object in the elapsed time of 3.04 seconds. How many centimeters away is that object? Express your answer to the nearest whole centimeter. (Show all work for calculations.)

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Name:		Date:
EXPLORATION EXTENSION	1	Laser Altimeter
		<i>Programming Instructions</i>

Turn on your graphing calculator. Press **PRGM**, then use the arrow to highlight **NEW**. Press **ENTER**, then spell out ECHO by pressing the appropriate keys. Press **ENTER** and you're ready to enter the first command for the program.

Line 1&2: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press **ENTER**. Press **2nd**, then **ALPHA**. Press **+** and then spell [SPEED CM] (For the blank space, press **0**). Press **ALPHA** then **÷**. Press **ALPHA**, then **S**. Press **2nd**, then press **TEST**, **ENTER** for the = sign. Press **ALPHA**, then press **[**. Press **ENTER**. The first and second line should appear as:
:Disp "SPEED CM/
S="

Line 3: Press **PRGM**, then use the arrow to highlight **I/O**. Press **ENTER** at **1: Input**. Press **ALPHA**, then **S**. Press **ENTER**. The third line should appear as:
:Input S

Line 4: Press **PRGM** and **CTL** will be highlighted. Use the arrow to scroll down to **9: Lbl**. Press **ENTER**. Press **ALPHA**, then press **A**. Press **ENTER**. The fourth line should appear as:
:Lbl A

Line 5: Press **PRGM** and **CTL** will be highlighted. Use the arrow to scroll down to **8: Pause**. Press **ENTER** twice. The fifth line should appear as:
:Pause

Line 6: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send (**. Press **ENTER**. Press **2nd** and then press **[{** for an open brace. Type in **222**. Close the braces and parentheses by pressing **2nd**, the **}]** button, and then **]**. Press **ENTER**. The sixth line should appear as:
:Send ({222})

Line 7: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (**. Press **ENTER**. Press **ALPHA**, then press **R**. Press **]** then **ENTER**. The seventh line should appear as:
:Get (R)

Line 8: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **B: Send (**. Press **ENTER**. Press **2nd** and then press **[{**. Type in **100**, then press **,**. Press **ALPHA**, then press **R**. Press **2nd** and then **]**. Press **2nd** and then **]**. Press **ENTER**. The eighth line should appear as:
:Send ({100,R})

Line 9: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get(**. Press **ENTER**. Press **ALPHA**, then press **R**. Press **)** then **ENTER**. The ninth line should appear as:
:Get (R)

Line 10: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press **ENTER**. Press **ALPHA** and then **S**. Press **×** and then press **ALPHA** and then **R**. Press **÷** and then type in **100**. Press **ENTER**. The tenth line should appear as:
: Disp S*R/100

Line 11: Press **PRGM**, then use the arrow to highlight **I/O**. Use the arrow to scroll down to **3: Disp**. Press **ENTER**. Press **2nd** and then press **ALPHA**. Spell **[CM]**. Press **ENTER**. The eleventh line should appear as:
: Disp "CM"

Line 12: Press **PRGM** and **CTL** will be highlighted. Use the arrow to scroll down to **0: Goto**. Press **ENTER**. Press **ALPHA**, then press **A**. Press **ENTER**. The twelfth line should appear as:
:Goto A
Press **2nd**, then **[QUIT]**.

To run the program:

Attach the calculator to your robot and connect link cable. Make sure the robot and calculator are both switched on. Press **PRGM** and use the arrow to scroll down to **: ECHO**. Press **ENTER**. Press **ENTER** again. Enter robot speed in centimeters per second. Press **ENTER**.

Name:		Date:	
EXPLORATION EXTENSION	1	Laser Altimeter	<i>Programming Instructions</i>

Position robot on the transect line facing the hidden cliff face.

Press **[ENTER]** again and the robot will start.

(It will travel until the bumper hits and then return. The one-way distance in centimeters will be displayed.)

Reposition robot along the transect line.

Press **[ENTER]**.

Repeat until the distance is determined for each TEST INTERVAL.

To stop the program:

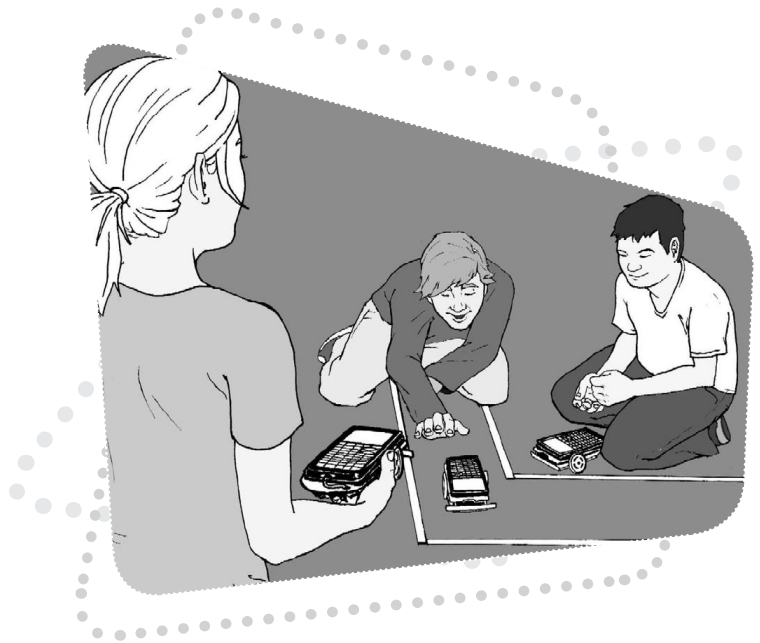
Press **[ON]**, then **[ENTER]**.

Press **[CLEAR]** to clear the screen.

Name:		Date:	
MISSION	3	Turns and Mazes	Materials
The third mission is to program your robot to navigate a maze, retrieve a secret package, and return to the original starting point. As always should your robot be discovered or captured, your teacher will disavow any knowledge of your mission. Good luck.			

You need:

- 1 Norland Calculator Robot
- 1 Graphing Calculator
- Several Meter Sticks
- Graph Paper



Name:		Date:
MISSION	3	Turns and Mazes
		<i>Instructions</i>

Discuss how many different ways you can program your robot to turn. Which ways might be best for navigating a maze? How can you make a 90° turn? Layout a practice maze with meter sticks on each side about one foot apart. Start with two straight runs with a right angle turn in between them. Create the new program **MAZE** (see PROGRAMMING INSTRUCTIONS if needed). When programming your robot, recall the following numbers used in a Send command. For example, Send ({ABC,xxx}):

A-Time or Bumper	B-Left Wheel	C-Right Wheel
1=timed movement only	0=backwards	0=backwards
2=move until bumper hits	1=no motion	1=no motion
3=time or until bumper hits	2=forwards	2=forwards

xxx is the number of seconds of run time in centiseconds.

For example: Send ({122,600})

Get (R) (Always needed to close a Send command.)

The robot will move forward for 6 seconds.

You'll need to know how fast your robot travels. For example, if your robot takes 5.27 seconds to travel the distance of one meter stick or 100 cm, it's traveling at approximately 18.98 cm per second ($r=d/t$ or $r=100/5.27$).

When you've discovered how to make your robot rotate for a turn, you'll need to determine how many seconds the rotation must last for a 90 degree turn.

Name:		Date:
MISSION	3	Turns and Mazes
		Challenge

The official test maze will have four straight runs and three turns. At the end of the maze there will be a secret message cube that must be recovered. Attach something to the robot so that the message cube can be retrieved.

The chart that follows can help you plan your strategy for completing the maze.

Maze Chart

Run 1 (In centimeters)	Time Needed (In centiseconds)	Commands
Turn 1 (Left or Right)		
Run 2 (In centimeters)		
Turn 2 (Left or Right)		
Run 3 (In centimeters)		
Turn 3 (Left or Right)		
Run 4 (In centimeters)		

Grading Scale:

- Robot retrieves message cube and returns it to start: **A+**
- Robot retrieves message cube and spins in circle for joy: **A**
- Robot makes it through, but misses message cube: **B**
- Robot makes it halfway through the maze: **C**

Name:		Date:
MISSION	3	Turns and Mazes
		Results

1. List five different environments where it might be too dangerous for humans to explore, but a robot could go and send back valuable information.

1.
2.
3.
4.
5.

2. Describe three situations where humans couldn't reach and you would need a small robot to explore.

1.
2.
3.

3. Have you seen the movie, *Fantastic Voyage*? Could miniature robots be used to explore the human body? Draw a picture of miniature robot below and explain what devices it might have to explore the human body?

Name:		Date:
MISSION	3	Turns and Mazes
		<i>Extension</i>

1. Place a small piece of tape labeled Point A on the floor. Place another piece of tape five feet (feet: primitive units of measure) away and label it Point B. Program your robot to get from Point A to Point B, but your journey must include one right angle (90°) turn at a point we'll call Point C. Measure the distances your robot travels before and after Point C. Below, draw the right triangle formed by points A, B, and C. Label the distances between each point to the nearest whole foot.

2. If points A and B in the description above were 10 feet apart, what would the lengths of the other segments be? Draw and label the new triangle formed.

3. If Point A and B were 13 feet apart, what would be the shortest distance your robot would travel before making a 90° turn at Point C?

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Name:		Date:
MISSION	3	Turns and Mazes
		<i>Programming Instructions</i>

Turn on your graphing calculator. Press **PRGM** and arrow to highlight **NEW**. Press **ENTER**, then spell out [MAZE] by pressing the appropriate keys. Press **ENTER** and you're ready to enter the first command for the program.

Line 1: Press **PRGM**, then use arrow to highlight **I/O**. Use arrow to scroll down to **B: Send (** and press **ENTER**. Press **2nd** and then press **[]** for an open brace. Type in **122,600**. Close the braces and parentheses by pressing **2nd**, **[]**, then **[]**. Press **ENTER**. The first line should appear as:
:Send({122,600})

(**Line 2:** Is blank)

Line 3: Press **PRGM**, then arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (** and press **ENTER**. Press **ALPHA**, then **[R]**. Press **[]** then **ENTER**. The third line should appear as:
:Get(R)

Line 4: Press **PRGM**, then use arrow to highlight **I/O**. Use arrow to scroll down to **B: Send (** and press **ENTER**. Press **2nd** and then press **[]**. Type in **120,42**. Close the braces and parentheses by pressing **2nd**, **[]**, then **[]**. Press **ENTER**. The fourth line should appear as:
:Send({120,42})

Line 5: Press **PRGM**, then arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (** and press **ENTER**. Press **ALPHA**, then **[R]**. Press **[]** then **ENTER**. The fifth line should appear as:
:Get(R)

Line 6: Press **PRGM**, then use arrow to highlight **I/O**. Use arrow to scroll down to **B: Send (** and press **ENTER**. Press **2nd** and then press **[]**. Type in **122,600**. Close the braces and parentheses by pressing **2nd**, **[]**, then **[]**. Press **ENTER**. The sixth line should appear as:
:Send({122,600})

(**Line 7:** Is blank)

Line 8: Press **PRGM**, then arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (** and press **ENTER**. Press **ALPHA**, then **[R]**. Press **[]** then **ENTER**. The eighth line should appear as:
:Get(R)

Adjust command times as necessary. Add forward motion and turns as needed. A sample left turn is,
:Send({102,42}).

Name:		Date:
EXPLORATION EXTENSION	2	Crawler-Transporter
		<i>Background, Materials & Instructions</i>

Background

The Crawler-Transporter is used by NASA to transport the Space Transportation System (the Space Shuttle and fuel tanks) from the Vehicle Assembly Building (VAB) to the launch pad on a Mobile Launcher Platform (MLP). It travels at approximately 1 mph and has to negotiate turns and an uphill incline of five percent and still keep the Space Transportation System steady. It's approximately 4.2 miles from the VAB to launch pad 39B, which is commonly used for Shuttle launches.

Your mission will be to construct a rocket, design and create a MLP, and transport your rocket safely from the VAB through the **Mission 3** maze to the launch pad on your own Crawler-Transporter (robot).

Materials

Same as **Mission 3** plus:

- 1 Estes Alpha Rocket or Similar Rocket
- Popsicle Sticks, Straws, Foam Meat Trays (unused)
- Glue or Glue Gun

Instructions

Build a rocket according to your teacher's and manufacturer's instructions.

On graph paper, design a mobile launch platform that will support your rocket and fit on the robot. The design must keep your "multimillion dollar rocket" secure through turns and rises in elevation. It must also allow for access to the calculator buttons needed to run the robot. Use your design to build a mobile launch platform from materials provided by your teacher.

Name:		Date:
EXPLORATION EXTENSION	2	Crawler-Transporter
		<i>Challenge & Results</i>

Challenge

The maze from **Mission 3** will represent the “Crawlerway” at Kennedy Space Center (KSC) which connects the VAB to the launchpad. Use your Crawler-Transporter (robot+MLP) and the **MAZE** program to transport a rocket from the beginning of the Crawlerway to the end. Your successful transport of the rocket determines the types of rocket engines you can use as follows:

- Two straight-aways and a curve: Eligible for A engine
- Three straight-aways and two curves: Eligible for A or B engine
- Four straight-aways and three curves: Eligible for A, B, or C engine

Results

1. Did you have to change the time durations in the **MAZE** program for the successful transport of the rocket? If so, why did that occur?

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2. When NASA’s Crawler-Transporter is loaded with the MLP and the Space Transportation System, it weighs about 17 million pounds and creeps along at only one mile per hour. Calculate which is faster the Crawler-Transporter or a robot that travels at 20 centimeters per second?

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By how many centimeters per second?

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3. The Crawler-Transporter has to keep the Space Transportation System vertical as it goes up a 5% incline ramp at the launchpad. On a separate sheet of paper, draw a design of how you would keep your rocket vertical if the robot had to go up a 5% incline. Label all parts of your diagram.

(For more information about the Crawler-Transporter, see your teacher for Web sites.)

Name:		Date:
MISSION	4	Circles
		Materials
Your fourth mission is to draw circles using the robot. Sounds simple enough, but you'll need to draw three different diameter circles using three different wheel motions. Good luck.		

You need:

- 1 Norland Calculator Robot and 1 Graphing Calculator
- 1 Clothes Peg or Norland Research Pen Holder (www.smallrobot.com)
- 1 Marker
- 1 Meter Stick
- String
- Drawing Paper 18" x 24"



Name:		Date:
MISSION	4	Circles
		<i>Instructions & Challenge</i>

Instructions

Write a simple program for the robot on your calculator named **CIRCLE** (see PROGRAMMING INSTRUCTIONS on page 33 if needed):

```
PROGRAM:CIRCLE
:Send({120,200})
:Get(R)
:Disp R
:Stop
```

This program will instruct the robot to spin in a circle for a given amount of time. Attach a clothes peg or pen holder at the underside, rear of the robot with tape or Velcro. Place your robot, with wheels centered, at the middle of a sheet of 18" x 24" drawing paper. Use the clothes peg to hold and position a marker on to the paper. Run the **CIRCLE** program and draw a circle. Adjust the time (i.e. 200) in the **Send** command as needed to draw a complete circle.

Save your best circle drawing for the next mission. Cut a piece of string the same length as the diameter of your circle. Trace around the circle with your length of string. Be as accurate as possible.

Challenge

1. About how many string lengths or diameters does it take to go around the circle?

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You should have a small gap in between the initial starting point and the end of the last string length. Measure the distance of the gap and divide it by the length of the diameter.

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2. Using this new information, about how many diameters does it take to make a circle?

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Your mission is to instruct your robot to draw an additional, three circles: small, medium, and large. The circle above doesn't count. You must use three different types of wheel movements to create the circles:

- A one wheel stopped one moving,
- B wheels moving in opposite directions, and
- C both wheels moving forward.

For each circle, carefully cut a string the same length as the diameter and measure how many diameters it takes to go around the circle. Fill in the Mission Data chart.

Name:		Date:
MISSION	4	Circles
		Results

Mission Data:

Circles	Diameter (cm)	Diameters Around
A		
B		
C		
Total		
Average		

3a. What is the diameter of a robot wheel?

.....

3b. Given the average above, how many centimeters around is a robot wheel?

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4. How far would your robot travel forward with one complete turn of its wheels?

.....

5. How many complete circles or revolutions would a robot's wheels make to travel the length of a meter stick or 100cm? (Show how you calculated your answer.)

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.....

.....

6. Define in your own words the following:

Diameter:

.....

.....

.....

Name:			Date:
MISSION	4	Circles	Results

6. (Continued) Define in your own words the following:

Circumference:

.....

.....

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Pi:

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7. How are diameter, circumference, and pi related? If you know any two, can you find the third? Show an example.

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8. Determine the area of a circle with a diameter of 7 cm.

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Name:		Date:
MISSION	4	Circles
		<i>Extension</i>

On my home planet of Libathonkey our pies are always baked in square pans. Therefore, all the little Libathonkians know that pies are squared and they can easily remember the formula for the area of a circle.

9. On Libathonkey the flying saucers are circular. What is the approximate diameter of flying saucer that has an underside surface area of 12.56 m^2 ?

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10. If the value of pi is the same on Libathonkey, Earth, and other planets, then could it be used as a “common known” to communicate with intelligent beings from other worlds? How?

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Would we want to do that?

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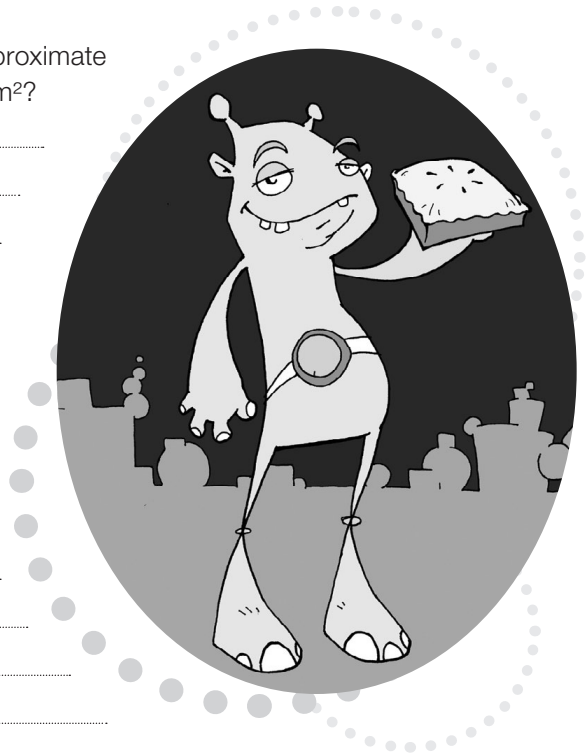
.....

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Name:		Date:
MISSION	4	Circles
		<i>Programming Instructions</i>

Turn on your graphing calculator. Press the **PRGM** and arrow to highlight **NEW**. Press **ENTER**, then spell out [CIRCLE] by pressing the appropriate keys. Press **ENTER** and you're ready to enter the first command for the program.

Line 1: Press **PRGM**, then use arrow to highlight **I/O**. Use arrow to scroll down to **B: Send (** and press **ENTER**. Press the **2nd** button and then press [1]. Type in **120,000**. Close the braces and parentheses by pressing **2nd**, [1], then **]**. Press **ENTER**. The first line should appear as:
:Send({120,200})

Line 2 is blank

Line 3: Press **ç**, then arrow to highlight **I/O**. Use the arrow to scroll down to **A: Get (** and press **ENTER**. Press **ALPHA**, then type [R]. Press **]** then **ENTER**. The third line should appear as:
:Get(R)

Line 4: Press **PRGM**, then arrow to highlight **I/O**. Arrow down to **3: Disp** and press **ENTER**. Press **ALPHA**, then type [R]. Press **ENTER**. The fourth line should appear as:
:Disp R

Line 5: Press **PRGM** and **CTL** will be highlighted. Use the arrow key to scroll down to **F: Stop**, and press **ENTER**. The fifth line should appear as:
:Stop

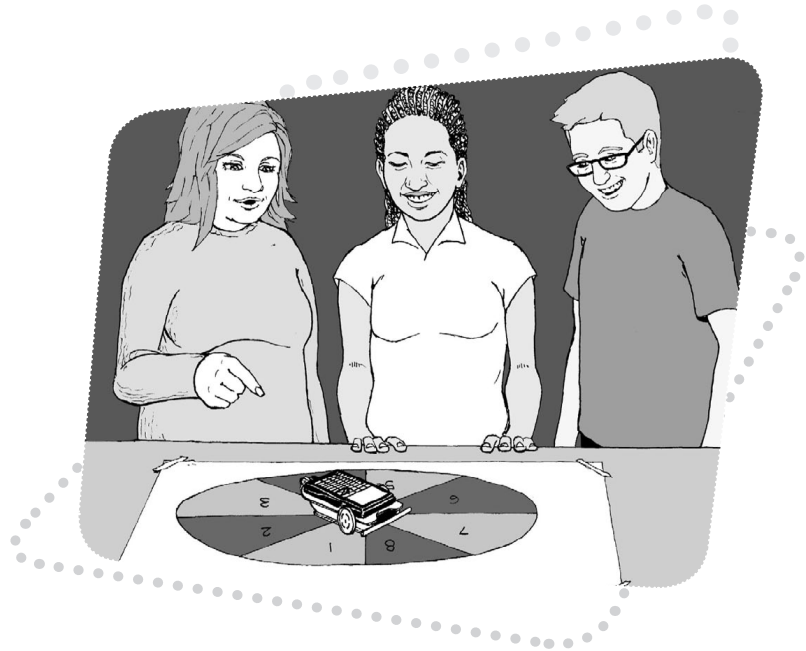
Press **2nd**, then [QUIT].

Adjust the time (i.e. 200) in the **Send** command as needed to draw a complete circle.

Name:		Date:
MISSION	5	Game Spinner
		Materials
What are the chances that you can write your own program on a graphing calculator that instructs your robot to spin and randomly land on numbers 1 to 8? If the probability of that is low, can you write the program on the next page without looking at the detailed programming instructions? Try.		

You need:

- 1 Norland Calculator Robot
- 1 Graphing Calculator
- 1 Robot Circle from Mission 4
- Markers and Colored Pencils



Name:		Date:
MISSION	5	Game Spinner
		<i>Instructions</i>

Instructions:

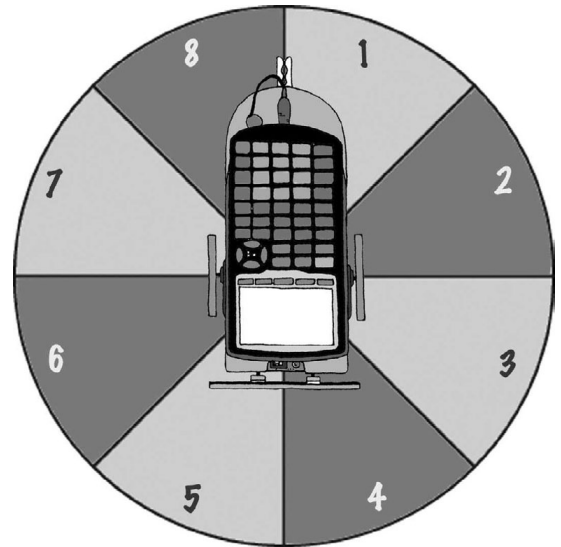
Use a robot drawn 32 to 40 cm circle from mission 4. With a marker, divide the circle into eight equal pieces and number 1 to 8 clockwise. Color odd numbered spaces red and the even numbered spaces black. Use your graphing calculator to write the program **SPINNER** (see PROGRAMMING INSTRUCTIONS if needed):

PROGRAM:SPINNER

```

:randInt(1,8)->X
:Disp X
:If X=1
:Then
:X+209->T
:Disp T
:Send({120,T})
:Get(R)
:Else
:210+(X-1)25->T
:Disp T
:Send({120,T})
:Get(R)

```



This program will randomly pick a number from 1 to 8, display that number, and instruct the robot to spin in one full circle, then stop at that number. The clothes peg attached at the back of the robot from the previous exercise makes a good pointer or you can make a cardboard pointer.

The program is designed for the robot to be placed at the center of the spinner with its pivot point (located half way between the two large wheels) directly over the intersection of the four lines used to divide the spinner. The robot's pointer should be set on the line between the 1 and the 8. You may need to adjust the duration of spin times in the program depending on your robot's turn speed or the size of your spinner board.

Name:			Date:
MISSION	5	Game Spinner	Challenge

The Largest Sum Wins!

Odd or red numbers are negative. Even or black numbers are positive. What are your chances of spinning a negative number? Test it out.

Use your “robot spinner” to randomly select four numbers. Remember red numbers are negative. Record your numbers and find their sum. You have three trials. Circle your largest sum and write it on the board with your initials. If it’s over 10 you get 1 point, if it’s over 20 you get 2, over 30 is 3. What are your chances of getting a sum over 30?

Table 1

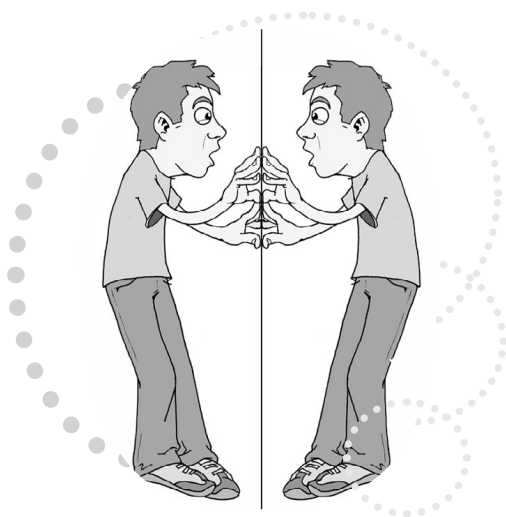
Spins	Number Value	Spins	Number Value	Spins	Number Value
1		1		1	
2		2		2	
3		3		3	
4		4		4	
Total					

What’s Missing?

For Table 2, use your “robot spinner” to randomly select three numbers. Record the numbers, (red, negative and black, positive) and then determine what the fourth number would have to be to arrive at the total given. Again, there are three trials. Have your teacher check your answers. If they are all correct, put +1 by your initials on the board.

Table 2

Spins	Number Value	Spins	Number Value	Spins	Number Value
1		1		1	
2		2		2	
3		3		3	
X=		X=		X=	
Total					



Chance and the Parallel Universe

Scientists theorize that there are only so many ways matter can be arranged in our observable universe (between 2 to 10^{118} arrangements) before things must repeat. They view space as infinite and that probability dictates that you have an exact twin somewhere 10 meters to 10^{28} meters away from where you are standing right now and that between 10 meters to 10^{118} meters away is a totally identical parallel universe.

Name:			Date:
MISSION	5	Game Spinner	Challenge & Results

Challenge:

Spin a random number and record it across from Spin 1 in Table 3 below. How many more spins would you predict will be required before the number is repeated? Given enough spins, will the number always repeat itself? Test it out and record the randomly selected numbers until your initial number is repeated. Show your teacher your results and the answers to the adjacent questions and he/she will award points accordingly.

Table 3

Spins	Number	Spins	Number	Spins	Number
1		6		11	
2		7		12	
3		8		13	
4		9		14	
5		10		15	

Results:

1. What is the theoretical probability of the robot pointing to an even number and then an odd number?

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2. What are the chances of the robot pointer landing on a prime number?

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3. In space if you exhaust all possible arrangements of matter, what would happen after that? (Your opinion)

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.....

4. Do you have an identical twin in another universe? Why or why not?

.....

.....

.....

.....

Name:		Date:
MISSION	5	Game Spinner
		<i>Extension</i>

Somebody Give Me a Number

Randomly pick five numbers with the robot spinner and, using the basic operations (add, subtract, multiply, or divide), make the largest number possible. You have to use all five numbers, but only once, and each operation may only be used once.

Table 4

Spins	Number	Calculations
1		
2		
3		
4		
5		
Largest Number:		

Spins	Number	Calculations
1		
2		
3		
4		
5		
Largest Number:		

Name:		Date:	
MISSION	5	Game Spinner	Programming Instructions

Turn on your graphing calculator. Press the **PRGM** and arrow to highlight **NEW**. Press **ENTER**, then spell out [SPINNER] by pressing the appropriate keys. Press **ENTER** and you're ready to enter the first command for the program.

Line 1: Press **MATH**, then use arrow to highlight **PRB**. Use the arrow to scroll down to **5: randInt (**. Press **ENTER**. Type in **1**, **8** and close the parentheses by pressing **)**. Press **STO►**. Press **X,T,θ,n** and **ENTER**. The first line should appear as:
:randInt(1,8)->X

Line 2: Press **PRGM**, then use the arrow key to highlight **I/O**. Arrow down to **3: Disp**, and press **ENTER**. Press **X,T,θ,n** and **ENTER**. The second line should appear as:
:Disp X

Line 3: Press **PRGM** and **CTL** will be highlighted as well as **1: If**. Press **ENTER**. Press **X,T,θ,n**. Press **2nd** and **MATH** and **TEST** will be highlighted as well as **1: =**. Press **ENTER** and then type the number **1** followed by **ENTER** again. The third line should appear as:
:If X=1

Line 4: Press **PRGM** and **CTL** will be highlighted. Arrow down to **2: Then**. Press **ENTER** twice. The fourth line should appear as:
:Then

Line 5: Press **X,T,θ,n**. Press **+** and then type in **209**. Press **STO►**. Press **ALPHA** [T]. Press **ENTER**. The fifth line should appear as:
:X+209->T

Line 6: Press **PRGM**, then use the arrow key to highlight **I/O**. Arrow down to **3: Disp**, and press **ENTER**. Press **ALPHA** T. Press **ENTER**. The sixth line should appear as:
:Disp T

Line 7: Press **PRGM**, then use the arrow key to highlight **I/O**. Arrow down to **B: Send (** and press **ENTER**. Press **2nd** and **[t]**. Type in **120,** (including the comma). Press **ALPHA** [T]. Close the braces and parentheses by

pressing **2nd** [**]**, and then **)**. Press **ENTER**. The seventh line should appear as:
:Send({120,T})

Line 8: Press **PRGM**, then arrow to highlight **I/O**. Arrow down to **A: Get (**. Press **ENTER**. Press **ALPHA** [R], press **)** then **ENTER**. The eighth line should appear as:
:Get(R)

Line 9: Press **PRGM** and **CTL** will be highlighted. Arrow down to **3: Else**. Press **ENTER** twice. The ninth line should appear as:
:Else

Line 10: Type in the number **210** then press **+**. Press **(**, then press **X,T,θ,n**. Press **-**, then type **1**. Press **)** and then type **25**. Press **STO►**. Press **ALPHA** [T]. Press **ENTER**. The tenth line should appear as:
:210+(X-1)25->T

For lines 11 through 13, repeat lines 6 to 8, that is:
:Disp T
:Send({120,T})
:Get(R)

Line 14: Press **PRGM** and **CTL** will be highlighted. Arrow down to **F: Stop**. Press **ENTER**. The fourth line should appear as:
:Stop

Press **2nd**, then **[QUIT]**.

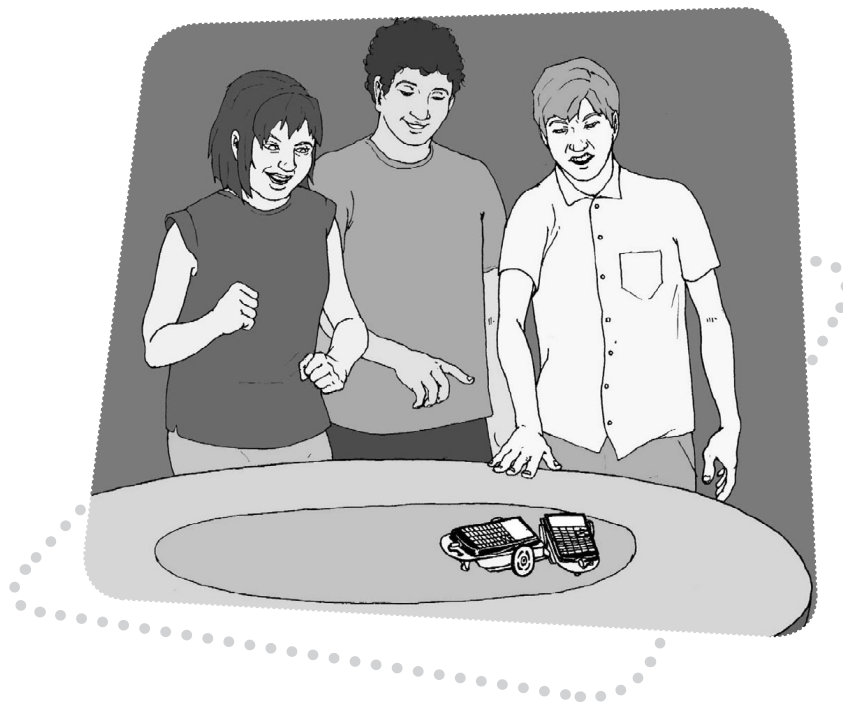
Name:		Date:
MISSION	6	Game Day!
		Materials & Instructions
Congratulations! You've made it to Game Day! If you've gone ahead and skipped the previous lessons, your calculator will not have the necessary programs to make your robot perform these activities. Go back to Mission 1 and start over. If you've completed the previous five missions, Great Job! You're ready to start.		

You need:

- 1 Norland Calculator Robot
- 1 Graphing Calculator
- Varying items, depending which games you play.

Instructions:

Your teacher will divide you into groups and show you which game to start with. Each group will have a chance to play all six games.



Name:			Date:
MISSION	6	Game Day!	<i>Games</i>

1. King Of The Ring On a large table, use tape to lay out a circular ring approximately one meter in diameter. Remove rubber bands from the robots' wheels and, if appropriate, cover the ring with graphite to reduce friction.

Place two robots, with bumpers facing each other at the center of the ring, about 40-cm apart. Start the contest. The first robot to push any two wheels (back roller included) of his opponent's robot out of the ring WINS!

2. Robot Race Use the **GAME1** program on page 50 to randomly cause good and bad things to happen to your robot's forward progress. Start a number of robots three meters away from a wall and see which robot reaches the wall first. Switch the game around and make the last robot to arrive the winner.

Separate into two groups on either side of a room with robots facing each other. All start at **GO**. The group that has the most robots reach the opposing team's wall WINS!

3. Robot Bowling Set up ten markers in a triangular shape, one meter away from the robot. Program the robot to knock them down. For more of a challenge, have the robot hit a ball and knock the markers down.

4. Robot Jousting With straws and paper, fashion a jousting lance for each robot. Also make a straw flag that sets on the front of the robot and is attached by a piece of clay.

Two robots face each other about one meter away, then charge! The first robot to knock its opponent's flag off WINS!

5. Topple The Imperial Walker Obtain a Moon Walker or similar robot. Start your robot one-meter away from the Moon Walker. Start the Moon Walker. The object is to charge after the Moon Walker and topple it in the shortest possible time.

6. Relay Race This is a four-meter relay race. Instead of passing a baton, robots tag their partners' bumpers. Use four robots per team, place them one meter apart with the finish line one meter away from the last robot. After the first robot is started, no other robots may be touched. The remaining robots must all be activated by another robot hitting (tagging) their bumpers. The first team to get their fourth robot across the finish line WINS!

Name:			Date:
MISSION	6	Game Day!	Results

How Did You Do?

Team Members	King of the Ring	Race	Bowling	Jousting	Topple	Relay

Name:		Date:
MISSION	6	Game Day!
		<i>Programming Instructions</i>

PROGRAM:GAME1

:Lbl A

:randInt(1,10)->X

:Disp X

:If X=3

:Then

:Disp "WAIT"

:Send({111,300})

:Get(R)

:GoTo A

:Else

:If X=5

:Then

:Disp "BACK"

:Send({100,300})

:Get(R)

:GoTo A

:Else

:If X=7

:Then

:Disp "SPIN"

:Send({120,235})

:Get(R)

:Send({102,235})

:Get(R)

:GoTo A

:Else

:Disp "GO"

:X*100->T

:Disp T

:Send({322,T})

:Get(R)

:If R<T

:Then

:Disp "YOU FINIS

H"

:STOP

:END

:GoTo A

Name:		Date:
EXPLORATION EXTENSION	3	Mission Patches and Demos
		<i>Background, Materials & Instructions</i>

Background:

Mission patches are designed by NASA's astronaut crews to symbolize the goals and objectives of their missions. They're personalized with the astronaut's names and represent the crew's mission.

Materials:

- Tag Board
- Colored Markers

Instructions:

Working with a partner, prepare a demonstration of a robot mission or exploration extension activity. Design a mission patch for that activity and create a poster that illustrates what you've learned. Your teacher will provide further instructions. Present your demonstration in front of the class.



Name:		Date:
MISSION	7	$E=mc^2$
		Materials
<p>In Albert Einstein's famous 1905 equation $E=mc^2$, the speed of light, c, in meters per second is a very large number. If you square the speed of light, the product is huge. Multiply that times a small amount of mass and the amount of energy produced is hard to imagine. The equation seems as far-fetched as "Parallel Universes" from Mission 5.</p>		

You need:

- 6 or more Norland Calculator Robots
- 6 or more Graphing Calculators
- 1 2-3" Rubber Ball (Neutron)



Name:			Date:
MISSION	7	E=mc²	Background & Instructions

Background:

The speed of light in a vacuum is 299,792,458 meters per second. Use your graphing calculator to calculate what happens to the speed of light when it is “squared.” You will get an answer in scientific notation. Write this number in standard form below.

Think of this as a conversion factor for changing mass into energy. If any mass is pushed back across the = sign and multiplied times the number above, the resulting energy can be enormous.

During the early stages of World War II, governments began to realize that the equation, $E=mc^2$, offered a potential to harness massive power in the form of a nuclear bomb. Because of this potential, individuals were asked to go to great lengths for their country and the common good. In efforts to prevent Nazi Germany from developing a nuclear device, a member of the Norwegian underground was asked to kill his fellow countrymen who were aboard a ferry carrying materials needed for the German nuclear effort. He did it, ultimately based on the potential of the equation above.

On August 6, 1945, the power of the equation was realized in the atomic bomb dropped on Hiroshima, Japan, by America. Neutrons were sent into the nucleus of an enriched uranium atom splitting it and releasing two neutrons that in turn struck other uranium atoms. In the resulting chain reaction, two became four, four split into eight, and so on until approximately 2^{80} atoms were split. Energy equivalent to 13-15 kilotons of TNT was released and temperatures in excess of 300,000°C (540,000°F) were produced.

Instructions:

Simulation of Nuclear Fission Chain Reactions

The following program is a progressive doubling program. The numbers, like atoms being split, will double before your eyes from 4 to 8 to 16 to a VERY LARGE number.

PROGRAM:ATOMSPLT

```

:ClrHome
:0->X
:2->Y
:Input "2*2^X:
";Z
:Z-1->Z
:Lbl A
:Y*2->Y
:X+1->X
:Disp Y
:If X<Z:GoTo A

```

Start the program and key in 2^{10} (2^{20}) and press **ENTER**, try 4^{10} , finally key in 8^{10} (2^{80}) and press **ENTER**. You will get an answer in scientific notation. Round the decimal to the hundredth place and write this number in standard form below.

Write the program for a robot chain reaction, NEUTONB or NEUTONL. Half the robots need NEUTRONB and the other half need NEUTRONL. The programs can be written easily by first creating the program names and then recalling the **RELAY** program from Mission 6.

Name:			Date:
MISSION	7	E=mc²	<i>Instructions</i>

From the new NEUTONB or NEUTONL program press y, then K. Press c, then scroll over to **EXEC** and select **RELAY**. Press Í twice and the instructions from **RELAY** will be added to NEUTONB or NEUTONL. Edit the commands and times as necessary.

PROGRAM:NEUTRONB

```
:Send({211})
:Get(R)
:Send({100,120})
:Get(R)
:Send({120,82})
:Get(R)
:Send({222})
:Get(R)
```

In the program NEUTONB, the “B” is for back. After the bumper is hit, the robot backs up, turns around, and then heads the opposite direction until it hits other robots or some other object.

PROGRAM:NEUTRONL

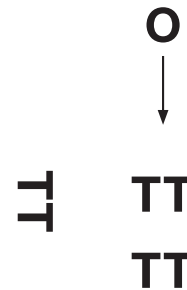
```
:Send({211})
:Get(R)
:Send({111,70})
:Get(R)
:Send({102,40})
:Get(R)
:Send({222})
:Get(R)
```

In the program NEUTONL the “L” is for left. After the bumper is hit, the robot pauses, turns 90° left and then moves forward until it hits other robots or some other object.

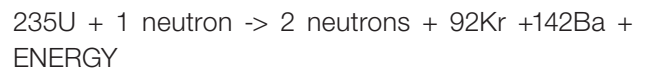
Make an initial “uranium atom” by placing an “L” programmed robot to the left and wheel to wheel with a “B” programmed robot. This first pair of robots can be positioned with the bumper of the “B” robot touching and slightly behind the bumper of the “L” robot. Both robots will be activated when the bumper of the “L” robot is struck.

Set additional pairs of robots (“uranium atoms”) about one foot apart with bumpers together and in position

to be hit (split) by incoming single robots (“neutrons”). Add as many pair as you can. In the diagram below **TT** represents two robots together with bumpers touching and **O** is the rubber ball (“neutron bullet”) coming in to start the chain reaction.



Roll the rubber ball (“neutron bullet”) towards the “L” robot in your first robot pair and a chain reaction will start with energy being released as each pair (uranium atom) is split apart. One neutron becomes two, two becomes four and so on. As shown by the equation:



Different products like ${}_{92}\text{Kr}$ and ${}_{142}\text{Ba}$ can be produced in this reaction, but are not shown in this simulation.

Radioisotope Thermoelectric Generators

Radioactive elements, such as plutonium, decay according to $E=mc^2$. Mass is converted to energy and heat is given off. This heat can be used to make electricity. Radioisotope Thermoelectric Generators (RTGs) use bimetallic thermocouples to convert heat to electricity. These types of generators have no moving parts and produce electricity for long periods of time, making them ideal for satellites and space probes.

Recent spacecrafts that have used RTGs include Cassini and New Horizons. There are RTGs on the Moon left by Apollo missions 12-17 to run scientific experiments. Units similar to RTGs, that just use the heat from radioisotope decay, keep the Mars Exploration Rovers warm on Mars.

Name:			Date:
MISSION	7	$E=mc^2$	Questions

1. Besides atomic weapons and RTGs, what are some other applications of nuclear decay, nuclear fission, and $E=mc^2$?

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2. How does the equation $E=mc^2$ apply to the energy being generated by the sun?

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3. If it were possible to change a one kilogram text-book (mass) completely into energy, it would produce enough electricity to light 47,000 60-watt light bulbs for one year. In metric energy units this equivalent to 90,000,000,000,000,000 joules. Write this number in scientific notation and explain why scientific notation is useful.

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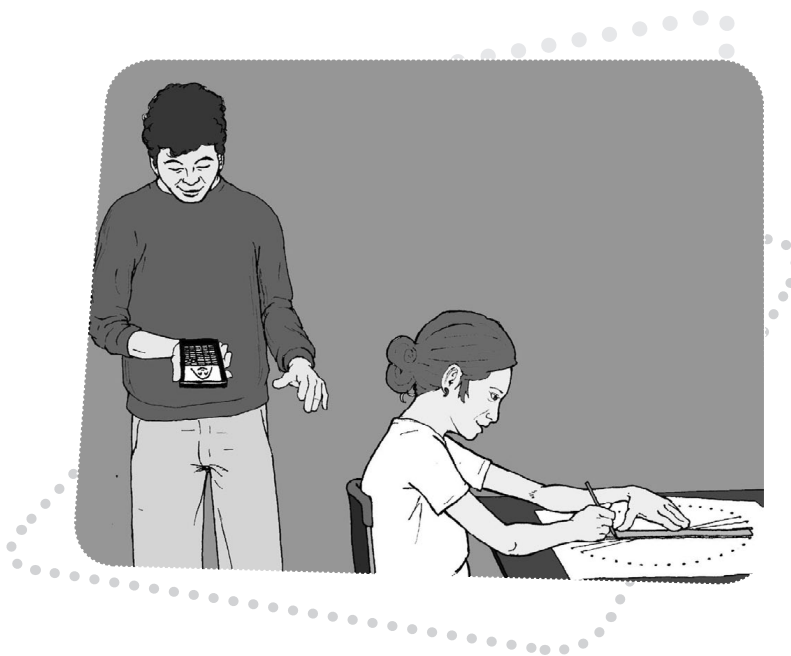
"Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."
 —Einstein

4. On a separate sheet of paper, make up your own famous equation (like $E=mc^2$) that will change the way we view the universe. Explain the meaning of each part of the equation and how understanding the equation will benefit the world.

Name:		Date:
MISSION	8	Cool Stuff
		Materials
There is more to your robot and graphing calculator than meets the eye. "Alfred" and "George" live inside the calculator along with an Exploding Star. A new DaVinci, Escher, or Picasso may also be discovered with the help of your calculator robot.		

You need:

- 1 Norland Calculator Robot and 1 Graphing Calculator
- 1 Clothes Peg, Marker
- Graph Paper
- Drawing Paper 18" x 24"



Name:		Date:
MISSION	8	Cool Stuff
		<i>Instructions</i>

Alfred:

On your graphing calculator press the $\boxed{2\text{nd}}$ key and then press $\boxed{\text{ZOOM}}$ for format. Scroll down with the arrow keys and highlight **AxesOff**. Press $\boxed{\text{ENTER}}$.

Press $\boxed{\text{Y=}}$ key and enter the following equations:

```

Plot1 Plot2 Plot3
\Y1= -.5X^2+10
\Y2= -\sqrt{(16-X^2)}-5
\Y3= -4+\sqrt{(1-(X+3)
2)}
\Y4= -4+\sqrt{(1-(X-3)
2)}
\Y5= -\sqrt{(1-X^2)}-6

```

All keys are visible on the face of your graphing calculator. Be sure and distinguish between a negative and a subtraction sign. Don't leave out the 2) at end of equations three and four. Press $\boxed{\text{GRAPH}}$ to see Alfred.

George:

Leave the setting as above. Press $\boxed{\text{Y=}}$ and enter the following equations, then press $\boxed{\text{GRAPH}}$. Meet George.

```

Plot1 Plot2 Plot3
\Y1= -2\sqrt{(X-2)}+1
\Y2= -2\sqrt{(-X-2)}+1
\Y3= \sqrt{(25-X^2)}+5
\Y4= -\sqrt{(25-X^2)}+5
\Y5= -\sqrt{(16-X^2)}+6
\Y6= -4+\sqrt{(1-(X+3)
2)}+10
\Y7= -4+\sqrt{(1-(X-3)
2)}+10
\Y8= -\sqrt{(1-X^2)}+6
\Y9= -X^2-.25
\Y0=

```

Exploding Star:

Leave format setting as above. Press the $\boxed{2\text{nd}}$ key and then press $\boxed{\text{ZOOM}}$. Scroll down with the arrow keys and highlight **5:ZSquare**. Press $\boxed{\text{ENTER}}$. Press $\boxed{\text{MODE}}$ and then scroll down with the arrow keys and highlight **Pol**. Press $\boxed{\text{ENTER}}$. Press $\boxed{\text{Y=}}$ and enter the following equations, then press $\boxed{\text{GRAPH}}$ to view the explosion.

```

Plot1 Plot2 Plot3
\r1=6
\r2=8sin(11.5\theta)
\r3=5tan(5.4\theta)
\r4=
\r5=
\r6=

```

Name:		Date:
MISSION	8	Cool Stuff
		<i>Instructions</i>

Make Your Own:

Press $\boxed{2\text{nd}}$ and then press $\boxed{\text{ZOOM}}$. Scroll down with the arrow keys and highlight **6:ZStandard**. Press $\boxed{\text{ENTER}}$. Press $\boxed{\text{MODE}}$ and then scroll down with the arrow keys and highlight **Func**. Press $\boxed{\text{ENTER}}$. Press $\boxed{2\text{nd}}$ and then press $\boxed{\text{ZOOM}}$ for format. Scroll down with the arrow keys and highlight **AxesOn**. Press $\boxed{\text{ENTER}}$.

Press $\boxed{\text{Y=}}$, delete any other entries, and then enter the following equations. When finished, press $\boxed{\text{GRAPH}}$. On graph paper, draw what happens to the parabola as 3 is added and subtracted. Use different colors to draw the graphs for each equation.

$$\begin{aligned} Y_1 &= X^2 \\ Y_2 &= X^2 + 3 \\ Y_3 &= X^2 - 3 \end{aligned}$$

Insert parentheses around the second and third equations. Instead of squaring just X, square the whole expression. First predict what the graphs will look like, then press $\boxed{\text{GRAPH}}$ and draw what happens to the parabola on graph paper.

$$\begin{aligned} Y_1 &= X^2 \\ Y_2 &= (X+3)^2 \\ Y_3 &= (X-3)^2 \end{aligned}$$

Graph the following and draw what happens to the parabola:

$$\begin{aligned} Y_1 &= X^2 \\ Y_2 &= .5X^2 \\ Y_3 &= .25X^2 \\ Y_4 &= -X^2 \end{aligned}$$

For straight lines, graph and draw the following linear equations:

$$\begin{aligned} Y_1 &= X \\ Y_2 &= X+3 \\ Y_3 &= X-3 \end{aligned}$$

Predict what the following absolute value equations will look like, then graph and draw them. (For absolute value, press $\boxed{\text{MATH}}$, arrow over to **NUM**, and select number **1**. Press $\boxed{\text{ENTER}}$.)

$$\begin{aligned} Y_1 &= \text{abs}(X) \\ Y_2 &= \text{abs}(X)+3 \\ Y_3 &= \text{abs}(X)-3 \end{aligned}$$

Try:

$$\begin{aligned} Y_1 &= \text{abs}(X) \\ Y_2 &= \text{abs}(X+3) \\ Y_3 &= \text{abs}(X-3) \end{aligned}$$

For a circle, press $\boxed{2\text{nd}}$ and then press $\boxed{\text{ZOOM}}$. Scroll down with the arrow keys and highlight **5:ZSquare**. Press $\boxed{\text{ENTER}}$. Graph and draw the following circles and determine their radii and diameters:

$$\begin{aligned} Y_1 &= \sqrt{(100-x^2)} \\ Y_2 &= -\sqrt{(100-x^2)} \\ Y_3 &= \sqrt{(16-x^2)} \\ Y_4 &= -\sqrt{(16-x^2)} \end{aligned}$$

Name:			Date:
MISSION	8	Cool Stuff	Challenge

Make your own creation on your graphing calculator using variations of the function equations above. Write down your equations for a partner and see if they can duplicate your design.

Circular Lines

Using the robot, paper, and marker draw a circle with the circumference of approximately 36 inches. This can be accomplished by attaching a marker 5.75 inches from the robot's pivot point. On most robots, a marker taped to the back is very close. (If necessary, see **Mission 4** for more on robot circle drawing.)

After you've made your circle, put 36 dots evenly spaced (one inch apart) around the circumference. Number the dots from zero to 35. Also, place the number 36 above the zero.

Make a solution table for the equation $Y=X+21$.

X	0	1	2	3	...
Y	21	22	23	24	...

On your "circle graph," use a straight line to connect 0 with 21, 1 with 22, 2 with 23, etc. Extend the solution table to $X=36$. In order to connect larger numbers, continue the number pattern around the outside of the circle. Your efforts will be rewarded by an intricate symmetrical pattern that can be enhanced by shading it with colored pencils.

The Robot Does the Work

Enter the following program into your calculator. Place your robot on a large sheet of paper with a marker on the back and have it ready to draw. Start the program. Hit the bumper to stop the robot when you're satisfied with your design.

```
PROGRAM:SCORPIO
:Lbl A
:Send({321,10})
:Get (R)
:If R<10:Goto B
:Send ({320, 10})
:Get (R)
:If R<10: Goto B
:Goto A
Lbl B
```


Name:		Date:	
MISSION	9	Mission to Mars	Materials
Your robot has been selected for the next mission to Mars. All initial robot movements after landing have to be preprogrammed. After that, if you've successfully completed all previous missions, you're now ready to take full direct control of your robot to explore Mars.			

You need:

- 1 Norland Calculator Robot and 1 Graphing Calculator
- 1 Submini Coupler
- 1 84-inch Data Cable



Name:		Date:	
MISSION	9	Mission to Mars	<i>Instructions</i>

Upon landing, your robot needs to be preprogrammed to drive off the Mars landing vehicle and lay out a two-meter long transect line. At the end of the line, the robot needs to trace out the perimeter of a one-meter-square rock sampling area. Place a marker at each corner of this sample area.

You are now ready to convert your robot to explorer mode. You have your choice of two programs. EXPLORE below uses the arrow keys on the calculator and allows remote wire-control of four motions: forward, backward, left, and right. EXPLORE2 (page 69) uses the number pad and controls nine different motions. Enter one of the two programs into your calculator.

Program:EXPLORE

```

ClrHome
Lb1 A
getKey->X
If X=24: Goto 2
If X=25: Goto 1
If X=26: Goto 3
If X=34: Goto 4
If X=105: Goto 5

Goto A
Lb1 1
ClrHome
Output (4,5, "FOR
EWARD")
Send ({122,100})

Get (R)
Goto A
Lb1 2
ClrHome
Output (4,7, "LEF
T")
Send ({102,42})
Get (R)
Goto A
Lb1 3
ClrHome
Output (4,6, "RIG

```

```

HT")
Send ({120,42})
Get (R)
Goto A
Lb1 4
ClrHome
Output (4,5, "BAC
KWARD")
Send ({100,100})

Get (R)
Goto A
Lb1 5
Stop

```

Remove the calculator from the robot. Use the submini coupler to connect the 84-inch data cable to the cable coming from the robot. Connect your calculator to the other end of the 84-inch data cable. To move forward press the up arrow (or [8] for EXPLORE2). To repeat a movement, simply press the key again. To end either program press **[ENTER]**. Practice driving and maneuvering your Mars robot rover.

Add simulated equipment and sensors to the top of your robot: high gain antenna, solar array, sundial, instrument deployment device, low gain antenna, pancam, etc. Attach a Velcro strip to the front of the robot for retrieving Mars rocks.

Name:		Date:
MISSION	9	Mission to Mars
		Challenge & Questions

Challenge:

Mars is millions of miles away from Earth and even at the speed of light a command takes several minutes to reach the Mars Rovers. Likewise, to learn the results of a command takes several minutes.

Your teacher will place rocks in the Mars rock sample area and you will need to avoid obstacles and retrieve rock samples without looking. (Mission controllers on Earth can't instantly "see" the reaction of the Mars Rover when they give a command.) Have a partner direct you where to navigate your robot. Return the rock samples to the Mars landing vehicle. Rocks that are the furthest away are worth more points. Record your results below.

Mission Data:

Trails	Points for Rocks Recovered
A	
B	
C	
Total	
Average	

Questions:

1. The Spirit and Opportunity Mars rovers have six wheels. What are the advantages and disadvantages of this configuration compared to your robot?

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2. When the Spirit rover first moved off of the Mars Lander, it traveled 3 meters in 78 seconds. Compare this speed to the speed of your robot in meters per second.

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3. The satellite, Voyager I, is beyond our solar system. When it was 7.555×10^9 miles away from Earth, how long did it take for a signal to reach Voyager and an acknowledgement signal to be received back on Earth? Answer in hours and use 186,000 miles per second as the speed of light.

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Name:			Date:
MISSION	10	PopBots!	Materials & Questions
This contest is a very exciting, single elimination battle between two opposing robots. But before you can change your robot into a PopBot and challenge another robot to a match, you must prove yourself worthy by a test of knowledge and imagination.			

You need:

- 1 Norland Calculator Robot and 1 Graphing Calculator
- 1 84-inch Data Cable and 1 Submini Coupler
- Safety Goggles and Water Balloons

Are you worthy?

(Show all work on a separate sheet. Diagrams will help you visualize and solve some problems.)

1. A robot travels at the constant speed of 17.45 cm/second. How many seconds will it take this robot to travel 205 centimeters? (Round your answer to the second decimal place.)
2. A robot draws a circle that is 47.1 inches around. What is the diameter of this circle in inches? (Use $\pi = 3.14$)
3. On the planet Libathonkey they play ROBOT SHUFFLEBOARD, which is similar to shuffleboard here on Earth, except you use a robot and points are received when the robot stops on a numbered section of a circular court. The court has a diameter of 2 meters. What is its area? (Use $\pi = 3.14$)
4. This same circular ROBOT SHUFFLEBOARD court is divided equally into eighths. One section is 10 points, two are 8 points, two are 7 points, two are 6 points, and one is 10 points off. If a robot randomly lands on the court once, what are the chances of getting more than 7 points?
5. If you were trying to pop a balloon on another robot only using a pencil, where would you place that pencil on your robot and at what angle? In the EXPLORE2 program the \cdot key is open for a free movement command. What command would best help you pop the balloon on an opposing robot?
6. Suppose that a recycling machine is invented that completely changes matter into energy. How much energy would be produced by putting a 2 kilogram math textbook into the machine? Give your answer in joules and in scientific notation. (Use 300,000,000 meters/second as the speed of light.)
7. The entrance to a cave has collapsed and your friend is trapped inside. He needs food and medical supplies, but there is only a narrow opening that winds between granite boulders. Program your robot to carry a lifeline to your friend. It needs to travel 2.25 seconds north, 2.50 seconds northeast, and then back due north 5 seconds to reach your friend. Show your teacher your answer.
8. Imagine your robot in the middle of an open floor made of square vinyl floor tiles, one foot on a side. The robot travels 5 squares north, 12 square east. In feet, how long is the shortest distance back to the start?
9. Describe the movement of the calculator graph of each equation when it is changed as shown:
 - a. $Y=2X \rightarrow Y=2X+5$
 - b. $Y=\text{abs}(X) \rightarrow Y=\text{abs}(X+3)$
 - c. $Y=X^2 \rightarrow Y=(X-3)^2$
10. If there were intelligent life forms somewhere in our universe, what characteristics would you image them to have? How could we communicate with them?

Name:			Date:
MISSION	10	PopBots!	<i>Instructions</i>

Use the EXPLORE2 program from the last mission. You may want to adjust your robot's response to the · key. This is an open keystroke to put in any defensive or offensive movement you feel necessary.

Use the 84-inch data cable with your robot. Practice your driving and maneuvering skills to prepare for battle. When your turn for a match comes, your teacher will provide you with an air-inflated water balloon to attach to your robot. Balloons must be securely attached (large end forward) with tape to the calculator cover on top of the robot. Wear safety goggles.

You are allowed either one mechanical or regular pencil to use as a balloon lance. Attach the pencil in the best position to pop the balloon on an opposing robot. Use a round table or designate a round contest ring. If a robot starts to fall off the table or has two wheels (back roller included) out of the ring, it is disqualified and the other robot automatically wins. Otherwise, the first robot to pop its opponent's balloon WINS the match and remains in the ring until defeated. (Current record: 7 consecutive wins.)

If a balloon comes loose during a match, the contest is stopped. The balloon is reattached, and then the match is restarted.

Let the games begin!

Measure the hallway yourself with a metric tape measure or meter stick. Students work well in pairs for this activity. If robots veer to one side or the other, adjust the rubber bands on the wheels or see instructions on page 5 along with the Calibrate Program at <http://www.smallrobot.com/speed/htm> (Also see HELP SHEET on next pages.)

Data tables are partially blank for students to choose their own labels and methods. A more directed approach would be to label the first table across the top with TRIALS, 100 CENTIMETERS, 200 CENTIMETERS. Number of trials could be listed down the first column. TRIALS, TIME, and DISTANCE could be used in the second table with the first column again labeled with number of trials.

Students can be left to invent ways to solve this problem on their own or they can be given some review on proportions or the DERT formula (distance = rate \times time or $d=rt$). Also see the HELP SHEET on page 6. After the initial use of the meter sticks, it's helpful to store them away to avoid less mathematical solutions.

When measuring the hallway, the length of the robot (from the front bumper to the back) needs to be taken into account. This can be measured beforehand, calculated out in the hallway by running the robot the short distance of its own length, or sometimes an adjusted starting point can be used.

In the extension activity, one way to measure height is to have students lie on the floor with their feet against the wall and use the robots to measure how many seconds tall they are. Then use the DERT formula to convert to distance/height.

Height data can be organized in a stem-and-leaf plot.

Transfer a Program

To transfer a program from one calculator to another:

- Securely connect a link cable between the two calculators.
- RECEIVE Calculator: Press **[2nd]**, then **[LINK]**. Use the arrow to highlight **RECEIVE**. Press **[ENTER]**. Wait for the other calculator to be set up and to send you the program/s.
- TRANSMIT Calculator: Press **[2nd]**, then **[LINK]**. Use the arrow to scroll down to **3:Prgm...** Press **[ENTER]**.
- Using the scroll arrow move the indicator arrow to the program/s to be transferred. Press **[ENTER]**. A program is selected if it has a black square in front of it.
- Use the scroll arrow to highlight "TRANSMIT". Press **[ENTER]**. The programs should be transmitted to the RECEIVE calculator.

The use of this function is suggested for transferring large programs (like CALI) only and not to eliminate programming practice for students.

The graph of TIME versus DISTANCE for this exercise should be a straight line that can be modeled by a linear equation. Students can make predictions by reading from the graph. Algebra 1 students or higher can use the slope formula and the slope–intercept model ($y=mx+b$) to find an equation for the best-fitting line. The y-intercept point (b) is zero. The slope of the line is determined by the speed or rate of the robot. From their slope–intercept equation, students can discover the formula for distance, $d=rt$.

The object that student robots come close to, but never touch, could be many things. For example: a wall, a house of cards, a small board with a tack that can fall and pop a balloon, or a line of dominos. The board and balloon challenge is exciting and works well. Students come to a testing area with only their robots and graphs. They are tested individually and given a randomly picked distance to start from in front of the board. Grades are given according to the scale on page 11. Whoever gets closest to the board for the class period can pop the balloon at the end. Participants should wear safety goggles.

Another approach is to simulate a Mars Rover doing planetary exploration. The robot has to go to the edge of a crater rim (tabletop) and peer down with a mock up bumper mounted camera to take pictures. The bumper must hang over the edge without the robot falling.

EXPLORATION EXTENSION	1	Laser Altimeter	Teacher Notes
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For more information on the Mars Orbiter Laser Altimeter see:

<http://ftpwww.gsfc.nasa.gov/tharsis/mola.html>

<http://ftpwww.gsfc.nasa.gov/tharsis/mola.top10.html>

A Planet X cliff face could be set up against a wall hidden from view with a curtain. Allow enough room for robots to travel underneath the curtain. A book or similar object could be used to simulate a rocky outcropping along the cliff face. Robots will reflect back more quickly from this region. Have the transect line (a meter stick works well) set parallel to the wall outside the curtain, but not more than 50 cm away. See CHALLENGE SET-UP diagram.

For **question one**, information from the Mars Exploration Rover Mission might be helpful: <http://marsrovers.nasa.gov/home/index.html>

For **question two**, you may want to avoid the newly discovered rocky outcropping region to avoid damage to your spacecraft.

For **question three**, answers will vary for part 1. In part 2, one way to improve accuracy is to shorten the increments along the transect line and take more samples. The MOLA emits 10 laser pulses per second.

For **question four**: $2.5 \text{ seconds} \div 2 = 1.25 \text{ seconds}$ for the one-way trip and $300,000 \times 1.25 = \mathbf{375,000 \text{ km}}$ (rate \times time = distance) yields the distance from Earth to the Moon at that time.

Question five is similar: $3.04 \div 2 = 1.52 \text{ seconds}$, $22.32 \times 1.52 = 33.9264$ or approximately **34 centimeters**. Also see: http://en.wikipedia.org/wiki/Lunar_laser_ranging_experiment

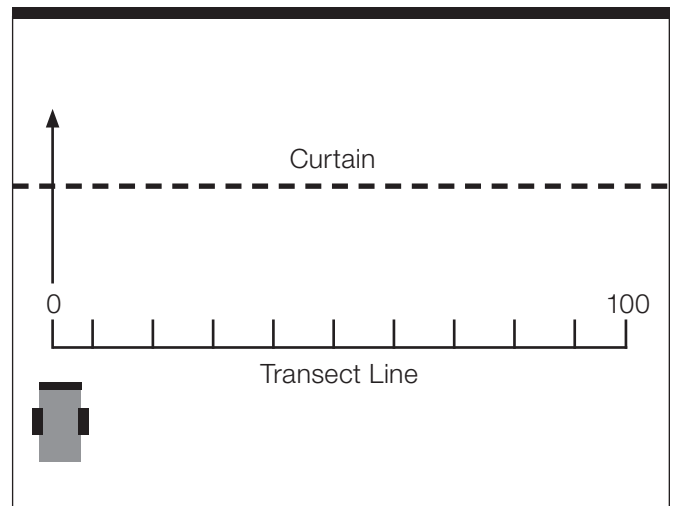
From Planetary Features to Microscopic Creatures

Amazingly, the tapping atomic force microscope (AFM) uses the same basic principles that are at work on the MOLA and the robot exercise above. It has a cantilever that oscillates over extremely small surfaces and can make 3D images of bacteria, viruses, or even DNA. For more information see:

http://en.wikipedia.org/wiki/Atomic_force_microscope

http://en.wikipedia.org/wiki/Tapping_AFM

Challenge Set-up:



Because of the size of the bumper, the robot senses too large of an area. Another challenge for students could be to design a removable probe that could be attached to the bumper to sample a narrower area.



There are several ways to make the robot turn: one wheel stopped and the other moving forward or backward, one wheel moving forward and the other moving backward, et cetera. A sample right turn would be: Send ({120,42}) followed by Get (R). Hopefully by now most students are becoming comfortable programming robot movements on the calculator. However, if needed, a starter program that includes two straight runs with a right angle turn in between can be found in the PROGRAMMING INSTRUCTIONS. An alternative programming method is to use two programs and the recall command.

For example, first have students experiment with programming turns in their **GO** program from **Mission 1**, then have them program a straight run and a right turn. They can then create the new program **MAZE** and repeatedly recall sets of instructions from the **GO** program as follows.

From the new **MAZE** program press $\boxed{2nd}$, then $\boxed{[RCL]}$. Press PRGM, then scroll over to **EXEC** and select **GO**. Press \boxed{ENTER} twice and the instructions from **GO** will be added to **MAZE**. Edit commands and times as necessary. This process can be repeated as many times as needed.

Sometimes just getting through the maze is challenging enough. One way to create a maze is to use meter sticks about a foot apart and included left and right turns. Place a paper cube (templates available on Internet) with a message inside at the end. A rolled piece of tape on the robot's bumper works for "picking up" the cube or Velcro strips or dots can be used.

For questions 1-3 answers will vary. The extension activity involves right triangles, the Pythagorean Theorem, and Pythagorean Triples. For **question 1**, the sides should be labeled 3 and 4 with a hypotenuse of 5. For **question 2**, the sides are 6 and 8. For **question 3**, the answer is 5. A linoleum floor composed of one-foot square tiles is helpful to visualize the right triangles formed by the robots' movements.

Another extension is to have students use their maze programming skills and have their robots duplicate the first iteration of the Jurassic Park fractal. See: <http://math.rice.edu/~lanius/frac/real.html>. *

* Used with permission of Cynthia Lanus

EXPLORATION EXTENSION	2	Crawler-Transporter	<i>Teacher Notes</i>
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Estes Alpha Rocket bulk pack is useful for this exercise. When students are creating their mobile launch platform use all appropriate safety precautions. In this exercise, the MLP is only for transporting the rocket and not for launching

Follow all manufacturer's recommendations and the NAR's Model Rocket Safety Code when building and launching rockets. The early portions of the movie *October Sky* is informative as to what NOT to do when building and launching rockets.

As an added challenge, a 5% incline ramp could be added to the end of students' Crawlerways.

For **question 1**, the weight and placement of the MLB and rocket may change the traveling and turning characteristics of the robot. For **question 2**, at one mph NASA's Crawler-Transporter is traveling at 44.7 cm/s. It's faster by 24.7 cm/s. For **question 3**, answers will vary. The Crawler-Transporter uses hydraulic lifts to keep the Space Transportation System vertical as it goes up the incline at the launch pad.

The following Web sites may be helpful:

<http://www.nar.org/NARmrsc.html>

<http://science.ksc.nasa.gov/facilities/crawler.html>

<http://en.wikipedia.org/wiki/Crawler-Transporter>

http://www.cdli.ca/CITE/sts_rollout.htm

<http://www-pao.ksc.nasa.gov/nasafact/count3teaf.htm>

The first part of the lesson leads students to discover or reconfirm that the diameter of any circle fits around its circumference three and a bit times or pi (approx. 3.14):

By attaching a marker to different positions on the robot, various size circles can be created using wheel motions A or B as described on page 35. For wheel motion C (both wheels moving forward) attach a piece of string to the robot and secure the other end to a center point. As the robot travels around the center point, a circle can be drawn with a radius equal to the length of the string. An alternative method is to hold the robot on its side or to slide a small piece of pencil lead under the rubber band of one wheel and then hold the robot against a piece of paper.

For **question 3**, the diameter of a robot wheel is about 6.7 cm which makes the circumference of the wheel ($C = \pi d$, $C = 3.14 \times 6.7$) approximately 21 cm. **Question 4** is approximately 21 cm. For **question 5**, the wheels need about 4.76 revolutions forward for the robot to travel 100 cm. **Question 7** is intended to lead students to the equation: circumference equals pi times diameter ($C = \pi d$).

Question 8 and **question 9** use the area of circle formula: area equals pi times the radius squared ($A = \pi r^2$). Using 3.14 for pi gives a rounded answer of 38.47 cm² for question eight and 4 m for question nine. For **question 10**, answers will vary. In the book *Contact*, prime numbers were used as a basis for communication.

A clearly drawn circle about 32 to 40 cm in diameter will be needed for **Mission 5**.

The parallel universe information is based on the article “Parallel Universes” by Max Tegmark in the May 2003 *Scientific American* magazine, page 40.

Award points as you see fit for the Table 3 activity. At the end of the activity, one way to reward the top individuals or teams with the highest total is allow them to pick a prize box. Three mystery prize boxes can be made ahead of time, one with 2-3 pencils, one with one pencil, and a dud prize. Similar to the game show *Let's Make a Deal*, the teacher can offer to “buy” a box back after it has been chosen. Probability can be discussed as each box is chosen.

For **questions 1** and **2** treat the numbers on the spinner board as being all positives. The answer to number one is $\frac{1}{4}$ and the answer to number two is $\frac{1}{2}$. Many other types of probability questions can be asked such as, asking for the probability of landing on a multiple of 2 or 3, a perfect square, etc.

For game 5, a Moon Walker or similar walking robot is available at a variety of scientific supply stores.

For the Relay Race the following program might be helpful:

PROGRAM:RELAY

:Send({211})

:Get(R)

:Send({100,50})

:Get(R)

:Send({120,92})

:Get(R)

:Send({222})

:Get(R)

This program is for a robot waiting to be tagged. Start the program and the robot will wait until its bumper is hit, backup, then turn 180° (as always adjust the time of the turn as necessary), and run forward until it tags the next robot or crosses the finish line. See if students can write a program that cuts time off their run. For instance, the second through fourth robot can simply back up when “tagged.” The starting robot in the relay only needs the commands:

PROGRAM:START

:Send({222})

:Get(R)

King of the Ring was the most popular game with students. They used strategies of charging, withdrawing, charging again, and turning to knock opponents out of the ring. The Relay Race was also very exciting for the students and graphically demonstrated why scientists test and test again. There are many opportunities for Murphy’s Law to sneak into this activity.

EXPLORATION EXTENSION	3	Mission Patches and Demos	<i>Teacher Notes</i>
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For mission patches see:

Activity

http://nasaexplores.nasa.gov/show_58_teacher_st.php?id=040526104107

Students may need encouragement to pick different activities for their reports. In addition to missions and exploration extensions, consider topics such as:

Murphy's Law and Robotics - Whatever can go wrong will go wrong

Basics Robotics - How to Operate a Calculator Robot

Synchronized Robot Dance

Robot Art

Rescue Robots



Besides showing what they've learned, there is an opportunity for students to demonstrate communication standards in this activity. You may want to invite parents, other teachers, and your principal to see the patches, posters, and presentations.

How to create a spectacular chain reaction demonstration using ping-pong balls can be found at: http://www.ap.stmarys.ca/demos/content/modern/mousetrap_reactor/mousetrap_reactor.html

ThinkQuest's Nuclear Processes home site has links to student level information on this topic: <http://library.thinkquest.org/17940/index.html>

Book reference: *E=mc²: A Biography of the World's Most Famous Equation*, by David Bodanis. For more information on the Norwegian Resistance and Germany's nuclear efforts during World War II see: <http://www.pbs.org/wgbh/nova/hydro/>

For more information on Radioisotope Thermoelectric Generators see: http://en.wikipedia.org/wiki/Radioisotopic_Thermoelectric_Generator

In standard form, $299,792,458^2$ equals:
89,875,517,870,000,000

With the scientific notation decimal rounded to the second places, 2^{80} in standard form equals:
1,210,000,000,000,000,000,000,000,000.

For **question 1**, other applications of $E=mc^2$ include: nuclear submarines, nuclear power plants, smoke detectors with radioactive americium inside, red-glowing emergency exit signs with radioactive tritium inside, some medical diagnostic devices, radiation treatment of cancer, carbon-14 dating, and our sun. See pages 192-194 in Bodanis' book.

For **question 2**, the energy produced by the sun makes our planet habitable. This energy is produced by nuclear fusion where hydrogen atoms are combined to make helium. Also see nuclear fusion at the ThinkQuest Web site.

For **question 3**, in scientific notation
90,000,000,000,000,000 equals 9.0×10^{16} .

For **question 4**, answers will vary.

This activity provides a fun way to explore functions and an opportunity to extend concepts while encouraging artistic design.

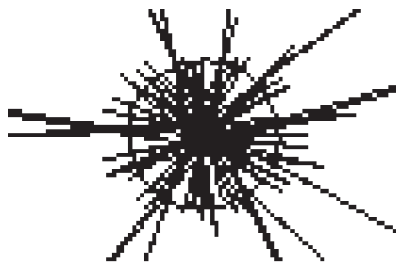
Alfred:



George:



Exploding Star:



You'll need to have some students make a cardboard Mars landing vehicle and some fuzzy "rock" that can be picked up by Velcro. For information on the Mars Exploration Rover Mission, see: <http://marsrovers.jpl.nasa.gov/home/> and http://en.wikipedia.org/wiki/Mars_Exploration_Rover.

For **questions 1**, six wheels generally make a vehicle more stable and in the case of the Mars Exploration Rovers, with extra steering motors front and rear, they enable the Rovers to turn in place, a full 360 degrees. (Also see Drive system at the Web site above.) For **question 2**, answers will vary. For **question 3**, the answer is approximately 22.57 hours.

```

Program: EXPLORE2
  ClrHome
  Lbl 1 A
  getKey->X
  If X=73: Goto 1
  If X=93: Goto 2
  If X=82: Goto 3
  If X=84: Goto 4
  If X=74: Goto 5
  If X=94: Goto 6
  If X=72: Goto 7
  If X=92: Goto 8
  If X=83: Goto 9
  If X=105:Goto 1
  0
  Goto A
  Lbl 1 1
  ClrHome
  Output (4,5, "FORE
  WARD")
  Send ({122,99})
  Get (R)
  Goto A
  Lbl 3
  ClrHome
  Output (4,7, "LEF
  T")
  Send ({102,43})

```

```

  Get (R)
  Goto A
  Lbl 4
  ClrHome
  Output (4,6, "RIG
  HT")
  Send ({120,42})
  Get (R)
  Goto A
  Lbl 2
  ClrHome
  Output (4,5, "BAC
  KWARD")
  Send ({100,99})
  Get (R)
  Goto A
  Lbl 5
  ClrHome
  Output (4,5, "FOR
  RIGHT")
  Send ({120,22})
  Get (R)
  Goto A
  Lbl 6
  ClrHome
  Output (4,4, "BAC
  KRIGHT")
  Send ({120,67})

```

```

  Get (R)
  Goto A
  Lbl 7
  ClrHome
  Output (4,5, "FOR
  LEFT")
  Send ({102,22})
  Get (R)
  Goto A
  Lbl 8
  ClrHome
  Output (4,5, "BAC
  KLEFT")
  Send ({102,67})
  Get (R)
  Goto A
  Lbl 9
  ClrHome
  Output (4,6, "DEF
  ENCE")
  Send ({120,99})
  Get (R)
  Send ({102,99})
  Get (R)
  Goto A
  Lbl 10
  Stop

```

For the CHALLENGE activity, two 84-inch cables connected together are useful for extended range. The 84-inch data cable (7.5 foot CBR **I/O** cable) can be found at:

<http://epsstore.ti.com>

Follow links to TI-83 or TI84 accessories

Test Questions:

1. Time=11.75 seconds (rounded):

$D=rt$, $205=17.45t$, solve for t .

2. Diameter=15 inches: $C=\pi d$, $47.1=3.14d$, solve for d .

3. Area=3.14 square meters: $A=\pi r^2$, $A=3.14(1^2)$, solve for A .

4. Probability=3/8: One 10 and two 8's out of eight possible choices or $P(A)=n(A)/n(S)$, $P(A)=3/8$.

5. Answers will vary: Open ended questions.

6. Energy= 1.8×10^{17} joules: $E=mc^2$, $E=2(300,000,000^2)$, solve for E .

7. The program should look something like this:

PROGRAM:LIFELINE

:Send({122,225})

:Get(R)

:Send({120,21})

:Get(R)

:Send({122,250})

:Get(R)

:Send({102,21})

:Get(R)

:Send({122,500})

:Get(R)

:Stop

8. Hypotenuse=13 feet: $a^2+b^2=c^2$, $5^2+12^2=c^2$, solve for c .

9. Questions:

a. Moves straight-line graph five units up the y-axis.

b. Moves an absolute value graph three unit to the left on the x-axis.

c. Moves parabola three units to the right on the x-axis.

10. Answers will vary: Open ended question.

PopBots is an exciting activity and a fun way to finish the class. A small pump to inflate balloons is useful and the safety issue of sharp pencils needs to be addressed before the activity begins. Safety goggles should be worn by all involved.

Mission 1 - Measure: Discover and use a function, solve for a variable, metric measurement, inequalities, time, mean, mode, median, and range

Mission 2 - Graph and Predict: Make a table, graph and interpret a linear function equation, slope-intercept model, y-intercept, best fitting line, interpret random events, metric measurement, and time

EXPLORATION EXTENSION 1 - Laser Altimeter:

Make a table, graph and interpret a graph, area of a polygon, solve for a variable, metric measurement, and time

Mission 3 - Turns and Mazes: Application of DERT formula, metric measurement, time, Pythagorean Theorem, degrees in triangle, and fractals

EXPLORATION EXTENSION 2 - Crawler-Transporter: Measurement and conversion

Mission 4 - Circles: Pi, diameter, radius, chord, tangent line, circumference, area, translation, rotation, reflection, and use a formula

Mission 5 - Game Spinner: Probability, interpret data from events, integers, order of operation, and multiple calculations

Mission 6 - Game Day: Fun applications and experimentation with the above

Mission 7 - $E=mc^2$: Standard and scientific notation, exponents, apply and interpret a formula

EXPLORATION EXTENSION 3 - Mission Patches and Demos: Measurement

Mission 8 - Cool Stuff: Graph linear, quadratic, absolute value, and radical equations, and create a solution table

Mission 9 - Mission to Mars: Functions and estimations

Mission 10 - Popbots: Final assessment

APPENDIX

National Content Standards for Mathematics: Grades 6-8

Content Standard	Objectives	Correlating Mission(s)
Number and Operations Understand numbers, ways of representing numbers, relationships among numbers, and number systems.	<ul style="list-style-type: none"> Work flexibly with fractions, decimals, and percents to solve problems. 	Mission 1 and 2
	<ul style="list-style-type: none"> Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation. 	Mission 7
	<ul style="list-style-type: none"> Develop meaning for integers and represent and compare quantities with them. 	Mission 5
Number and Operations Understand meanings of operations and how they relate to one another.	<ul style="list-style-type: none"> Understand and use the inverse relationships of addition and subtraction, multiplication and division, and squaring and finding square roots to simplify computations and solve problems. 	Missions 1-5, 7-10, Exploration Extensions 1, 2
Number and Operations Compute fluently and make reasonable estimates.	<ul style="list-style-type: none"> Select appropriate methods and tools for computing with fractions and decimals from among mental computation, estimation, calculators or computers, and paper and pencil, depending on the situation, and apply the selected methods. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> Develop and use strategies to estimate the results of rational-number computations and judge the reasonableness of the results. 	Missions 1-10, Exploration Extensions 1-3
Algebra Understand patterns, relations, and functions	<ul style="list-style-type: none"> Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic rules. 	Missions 1-10, Exploration Extension 1
	<ul style="list-style-type: none"> Relate and compare different forms of representation for a relationship. 	Missions 1-4, 7, 8, and 10, Exploration Ext. 1
	<ul style="list-style-type: none"> Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations. 	Missions 1, 2, 8, and 10
Algebra Represent and analyze mathematical situations and structures using algebraic symbols	<ul style="list-style-type: none"> Develop an initial conceptual understanding of different uses of variables. 	Missions 1-5, 7, 8, and 10, Exploration Ext. 1
	<ul style="list-style-type: none"> Explore relationships between symbolic expressions and graphs of lines, paying particular attention to the meaning of intercept and slope. 	Mission 2
	<ul style="list-style-type: none"> Use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships. 	Missions 1, 2, 4, and 8
	<ul style="list-style-type: none"> Recognize and generate equivalent forms for simple algebraic expressions and solve linear equations. 	Missions 1, 2, 4, and 8
Algebra Use mathematical models to represent and understand quantitative relationships.	<ul style="list-style-type: none"> Model and solve contextualized problems using various representations, such as graphs, tables, and equations. 	Missions 1-5, 7, 8, and 10, Exploration Ext. 1, 2

APPENDIX

National Content Standards for Mathematics: Grades 6-8

Content Standard	Objectives	Correlating Mission(s)
Algebra Analyze change in various contexts.	<ul style="list-style-type: none"> Use graphs to analyze the nature of changes in quantities in linear relationships. 	Missions 2 and 8
Geometry Use visualization, spatial reasoning, and geometric modeling to solve problems.	<ul style="list-style-type: none"> Use geometric models to represent and explain numerical and algebraic relationships. 	Mission 3
	<ul style="list-style-type: none"> Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life. 	Mission 3
Measurement Understand measurable attributes of objects and the units, systems, and processes of measurement.	<ul style="list-style-type: none"> Understand both metric and customary systems of measurement. 	Missions 1 and 10
	<ul style="list-style-type: none"> Understand relationships among units and convert from one unit to another within the same system. 	Missions 1, 2, 4, 7, and 10, Exploration Ext. 1, 2
	<ul style="list-style-type: none"> Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume. 	Missions 4 and 10
Measurement Apply appropriate techniques, tools, and formulas to determine measurements.	<ul style="list-style-type: none"> Use common benchmarks to select appropriate methods for estimating measurements. 	Missions 1-4, and 9, Exploration Ext. 1, 2
	<ul style="list-style-type: none"> Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision. 	Missions 1-4, and 10, Exploration Ext. 1, 2
	<ul style="list-style-type: none"> Develop and use formulas to determine the circumference of circles and the area of triangles, parallelograms, trapezoids, and circles and develop strategies to find the area of more-complex shapes. 	Missions 4 and 10
	<ul style="list-style-type: none"> Solve simple problems involving rates and derived measurements for such attributes as velocity and density. 	Missions 1-3, and 10, Exploration Ext. 1, 2
Data Analysis and Probability Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them	<ul style="list-style-type: none"> Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population. 	Mission 1
	<ul style="list-style-type: none"> Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots. 	Mission 1
Data Analysis and Probability Select and use appropriate statistical methods to analyze data.	<ul style="list-style-type: none"> Find, use, and interpret measures of center and spread, including mean and interquartile range. 	Mission 1

APPENDIX

National Content Standards for Mathematics: Grades 6-8

Content Standard	Objectives	Correlating Mission(s)
Data Analysis and Probability Select and use appropriate statistical methods to analyze data.	<ul style="list-style-type: none">• Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots.	Mission 1
Data Analysis and Probability Understand and apply basic concepts of probability.	<ul style="list-style-type: none">• Use proportionality and a basic understanding of probability to make and test conjectures about the results of experiments and simulations; compute probabilities for simple compound events.	Mission 5

Selected from *Principles & Standards for School Mathematics* sponsored by the National Council of Teachers of Mathematics
<http://standards.nctm.org/document/chapter6/index.htm>

APPENDIX

National Process Standards for Mathematics: Grades 6-8

Process Standard	Objectives	Correlating Mission(s)
Problem Solving Standard	<ul style="list-style-type: none"> • Build new mathematical knowledge through problem solving. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Solve problems that arise in mathematics and in other contexts. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Apply and adapt a variety of appropriate strategies to solve problems. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Monitor and reflect on the process of mathematical problem solving. 	Missions 1-10, Exploration Extensions 1-3
Communication Standard	<ul style="list-style-type: none"> • Organize and consolidate their mathematical thinking through communication. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Communicate their mathematical thinking coherently and clearly to peers, teachers, and others. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Analyze and evaluate the mathematical thinking and strategies of others. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Use the language of mathematics to express mathematical ideas precisely. 	Missions 1-10, Exploration Extensions 1-3
Connection Standard	<ul style="list-style-type: none"> • Recognize and use connections among mathematical ideas. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Understand how mathematical ideas interconnect and build on one another to produce a coherent whole. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Recognize and apply mathematics in contexts outside of mathematics. 	Missions 1-10, Exploration Extensions 1-3
Representation Standard	<ul style="list-style-type: none"> • Create and use representations to organize, record, and communicate mathematical ideas. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Select, apply, and translate among mathematical representations to solve problems. 	Missions 1-10, Exploration Extensions 1-3
	<ul style="list-style-type: none"> • Use representations to model and interpret physical, social, and mathematical phenomena. 	Missions 1-10, Exploration Extensions 1-3

Selected from *Principles & Standards for School Mathematics* sponsored by the National Council of Teachers of Mathematics
<http://standards.nctm.org/document/chapter6/index.htm>

APPENDIX

National Content Standards for Science: Grades 5-8

Content Standard	Objectives	Correlating Mission(s)
Science as Inquiry Abilities necessary to do scientific inquiry	<ul style="list-style-type: none"> Identify questions that can be answered through scientific investigations. 	Missions 1 and 2, Exploration Extension 1
	<ul style="list-style-type: none"> Design and conduct a scientific investigation. 	Missions 1 and 2, Exploration Extension 1
	<ul style="list-style-type: none"> Use appropriate tools and techniques to gather, analyze, and interpret data. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Develop descriptions, explanations, predictions, and models using evidence. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Think critically and logically to make the relationships between evidence and explanations. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Recognize and analyze alternative explanations and predictions. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Communicate scientific procedures and explanations. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Use mathematics in all aspects of scientific inquiry. 	Missions 1-5, 7-10, Exploration Extensions 1, 2
Science as Inquiry Understandings about scientific inquiry	<ul style="list-style-type: none"> Mathematics is important in all aspects of scientific inquiry. 	Missions 1-5, 7-10, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations. 	Missions 1-5, 7-9, Exploration Extensions 1, 2
	<ul style="list-style-type: none"> Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. 	Mission 7, Exploration Extensions 1
Science and Technology Abilities of technology design	<ul style="list-style-type: none"> Design a solution or product. 	Exploration Extension 2
	<ul style="list-style-type: none"> Implement a proposed design. 	Exploration Extension 2
	<ul style="list-style-type: none"> Evaluate completed technological designs or products. 	Exploration Extension 2
	<ul style="list-style-type: none"> Communicate the process of technological design. 	Exploration Extensions 2, 3

APPENDIX

National Content Standards for Science: Grades 5-8

Content Standard	Objectives	Correlating Mission(s)
Science in Personal and Social Perspectives: Personal Health	* The potential for accidents and the existence of hazards imposes the need for injury prevention.	Missions 1-10, Exploration Extensions 1-3
Science in Personal and Social Perspectives: Science and Technology in Society	* Science influences society through its knowledge and world view.	Mission 7
	* Technology influences society through its products and processes.	Mission 7
Selected from <i>National Science Education Standards</i> authored by The National Committee on Science Education Standards and Assessment, National Research Council http://www.nap.edu/readingroom/books/nses/6d.html		

APPENDIX

National Educational Technology Standards for Students

Technology Standard	Grades 6-8 Performance Indicators	Correlating Mission(s)
<p>Standard 1 - Basic Operation and Concepts: Students demonstrate a sound understanding of the nature and operation of technology systems. Students are proficient in the use of technology.</p>	<p>1. Apply strategies for identifying and solving routine hardware and software problems that occur during everyday use.</p> <p>9. Demonstrate an understanding of concepts underlying hardware, software, connectivity, and of practical applications to learning and problem solving.</p>	<p>Missions 1-10, Exploration Extensions 1 and 2</p>
<p>Standard 3 - Technology Productivity Tools: Students use technology tools to enhance learning, increase productivity, and promote creativity. Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.</p>	<p>4. Use content-specific tools, software, and simulations (e.g., environmental probes, graphing calculators, exploratory environments, Web tools) to support learning and research.</p>	<p>Missions 1-10, Exploration Extensions 1 and 2</p>
<p>Standard 5 - Technology Research Tools: Students use technology to locate, evaluate, and collect information from a variety of sources. Students use technology tools to process data and report results. Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.</p>	<p>7. Collaborate with peers, experts, and others using telecommunications and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products for audiences inside and outside the classroom.</p> <p>8. Select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems.</p>	<p>Missions 1-10, Exploration Extensions 1 and 2</p>
<p>Standard 6 - Technology Problem-Solving and Decision-Making: Students use technology resources for solving problems and making informed decisions. Students employ technology in the development of strategies for solving problems in the real world.</p>	<p>8. Select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems.</p> <p>9. Demonstrate an understanding of concepts underlying hardware, software, connectivity, and of practical applications to learning and problem solving.</p>	<p>Missions 1-10, Exploration Extensions 1 and 2</p>

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APPENDIX

Standards for English Language Arts

Standards	Correlating Mission(s)
1. Students read a wide range of print and non-print texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.	Missions 1-10, Exploration Extensions 1-3
3. Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics).	Missions 1-10, Exploration Extensions 1-3
4. Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.	Exploration Extensions 3
7. Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.	Missions 1-10, Exploration Extensions 1-3
8. Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.	Missions 1-10, Exploration Extensions 1-3
11. Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.	Missions 1-10, Exploration Extensions 1-3
12. Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).	Missions 1-10, Exploration Extensions 1-3

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