

CLASSROOM TEACHER'S GUIDE

YEARS 4 - 5 - 6

ABOVE AND BEYONDSM

THE ULTIMATE INTERACTIVE FLIGHT EXHIBITION

PRESENTED BY





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TABLE OF CONTENTS

WELCOME TO ABOVE AND BEYOND!	1
Experiencing ABOVE AND BEYOND: The Field Trip	2
Using This Teacher's Guide	4
TAKE FLIGHT: CLASSROOM LESSON PLANS	6
1. Map It! Partners Around the World – <i>Geography, Data Collection, Graphing</i>	6
2. When Drag Isn't a Drag – <i>Science, Mathematics</i>	14
3. Better Suited for Mars – <i>Science, Engineering</i>	21
4. Logical Careers – <i>Mathematics, Logic</i>	29

ABOVE AND BEYOND – THE ULTIMATE INTERACTIVE FLIGHT EXHIBITION is made possible by Boeing. The exhibition is produced by Evergreen Exhibitions in association with Boeing, in collaboration with NASA.

This Teacher's Guide is created by TurnKey Education, Inc., for Evergreen Exhibitions.

Education resources and programming for ABOVE AND BEYOND are made possible by Boeing in celebration of its centennial and its ongoing commitment to prepare and inspire the next generation to dream, design and build something better for the next century.

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WELCOME TO ABOVE AND BEYOND!

Looking back at the history of flight, one thing is abundantly clear: the sky was never the limit. ABOVE AND BEYOND is a multisensory flight and aerospace exhibition that invites you and your students to experience what it takes to make the “impossible” possible in and above the sky.

This unique learning opportunity is brought to you by The Boeing Company and developed in collaboration with a host of renowned aviation specialists, aerospace experts, historians, archivists, teachers and educational programming professionals. These skilled partners bring science, technology, engineering, the arts and maths instruction to new heights in your classroom. ABOVE AND BEYOND offers your students direct access to immersive simulations, interactive design challenges, iconic historical touchstones, visionary concepts for the future and inspiring stories from game-changing innovators past and present. Imagine the teachable moments!

From the time humans first got off the ground, the race was on to go above and beyond. Faster . . . further . . . higher . . . smarter! Today, these goals propel aerospace innovators to apply these learning principles to new discoveries and expand the boundaries of our universe. ABOVE AND BEYOND will engage your students and fellow teachers across the curriculum with its thought-provoking content. What if we could . . .

- *Get airborne wherever and whenever we wanted?*
- *Fly faster than the speed of sound with supersonic flights that don't make a lot of noise or burn too much fuel?*
- *Design ultra-green flying machines to carry more people to more places and, at the same time, treat the planet better?*
- *Invent supersmart flying robots to assist us in our daily lives, such as delivery-bots, eco-bots and more?*
- *Build a new generation of reusable space vehicles to make trips to Earth's orbit as common as air travel?*

ABOVE AND BEYOND is more than a visit to the museum. It is a way to inspire your students to aim higher and go further in their studies. Maybe someone you know will take us all above and beyond in the near future!

EXPERIENCING ABOVE AND BEYOND: THE FIELD TRIP

During your field trip to ABOVE AND BEYOND, you can experience five interactive galleries in any order: UP, FASTER, HIGHER, FURTHER and SMARTER. Each one features simulations and design activities related to real-life engineering challenges in the aerospace industry. Here are some of the highlights your students will not want to miss!

A field trip to ABOVE AND BEYOND celebrates the power of innovation to make dreams take flight. An expansive, multitouch timeline where students can explore the innovations and innovators that transformed our world introduces them to the history of flight. Next, a short film called Beyond the Limits immerses students into the spirit and power of aerospace innovation. Exciting imagery and soaring music will build anticipation for what comes next.

UP

UP gets everyone into the action as they discover what it takes to get off the ground. Learn about the breakthroughs that enabled us to join the birds in the sky. Then check out some bold new concept vehicles designed to give us more freedom of mobility in the future.

The concepts of lift, drag, thrust and weight come to life with a group flying game called Spread Your Wings. Here, students become birds and follow their leader heading south in a V formation. These four principles

of flight are further explored through a comparison of how a balloon, an airship, a glider, a fixed-wing aircraft, a rotorcraft and a rocket each reach the skies. A look at the amazing aircraft of the future shows your students how faster and greener models are already in development.

FASTER

In 1947, test pilot Chuck Yeager proved the speed of sound wasn't a barrier when he blazed past it at 1,100 KPH in a Bell X-1 rocket plane. In 2004, NASA's unpiloted X-43A broke the speed record for an air-breathing aircraft when it flew 11,000 KPH. Whether to get "there" quicker, to gain an advantage over an opponent, or for the pure adrenalin rush, the quest for speed has inspired innovative advances in flight. FASTER immerses you in the exhilarating thrills of high-speed flight.

To understand what is meant by "high-speed," your students will design and test-fly a jet in a virtual competition called Full Throttle. This supersonic fighter jet challenge demonstrates the effects of various shapes of the fuselage, wings and tail on how well the craft flies, how fast it can go and how easy it is to maneuver. A simulated wind tunnel test reveals how other aspects of an aircraft's shape determine where its top speed will be reached in the range from subsonic to supersonic. Students will also see small-scale aircraft models that Boeing and NASA have used in actual wind tunnel tests.

HIGHER

Just 58 years after Wilbur Wright “soared” to 3 metres in the Wright Flyer, Soviet cosmonaut Yuri Gagarin became the first person to orbit Earth. Today, astronauts regularly live and work aboard the International Space Station (ISS). However, it is still difficult and expensive to reach space. Few people can experience its wonders . . . for now! HIGHER explores high-altitude flight and the innovations that might soon make it easier to get into orbit.

The highlight of this gallery is the International Space Elevator. Your class will explore the layers of the atmosphere and the possibilities of high-altitude flight. This experience is a visually stunning, simulated ascent in a space elevator loosely inspired by concepts that might one day transport cargo and people to the orbit around Earth.

FURTHER

Across the Atlantic, around the world, to the Moon and beyond! Since we first got off the ground, we have always wanted to fly even further. For aircraft, the current focus is on going further with less – using less fuel and creating less pollution. In space, we are shooting for Mars and the stars! What will it take to fly humans to Mars? Can we “sail” to the stars? FURTHER reveals the power of innovation to help us go the distance, on Earth and in space.

Marathon to Mars asks your students the very same questions aerospace engineers ponder about

the challenges inherent in a months-long journey to Mars. How long will it take? What will you pack? What will you wear? Models of the future spacecraft that might someday get us to Mars – and beyond – are also on display. Students can then experiment with superstrong, lightweight composite materials that already help aircraft and spacecraft fly further using less fuel.

SMARTER

In aerospace, there is no battle of “brains vs. brawn.” You need both! SMARTER invites your students to discover what happens when flight and smart technologies unite. See how aerospace innovators are applying advances in computers, electronics and robotics to invent more capable aircraft and spacecraft. Learn how smart technologies are transforming the way we build and operate these amazing, intelligent flying machines.

Real objects and multimedia displays tell the story of space junk – its dangers and potential solutions. Your students will see how smarter aircraft will make spaceflight safer for everyone in Space Junk. This challenge presents three out-of-this-world solutions to cleaning up orbital debris.

SMARTER also features an assortment of real unmanned aerial vehicles. Students will have an opportunity to programme their own virtual UAV (unmanned aerial vehicle) to carry out a specific mission. In this Roboflyers activity, they will compare several design possibilities

to evaluate the best solution based on the parameters of their mission. Mission options include flying into the eye of a storm, pollinating a green house on Mars, or tracking an endangered species. Students will also want to check out the Smart Skies video to discover how smart technologies will transform our airspace by improving efficiency, reducing pollution, decreasing weather delays and lowering costs.

DREAMS ALOFT

At the conclusion of the field trip, you virtually “meet” young Boeing employees who will share some of the exciting projects they are working on now, their personal inspirations and how they followed a path from the classroom to outer space. Students can then contribute their own vision of the future of flight to a collaborative wall of dreams. Cool!

ABOVE AND BEYOND is designed to ignite a passion for the greatest adventure of all: our journey of flight in the air and in space. In doing so, it honours past world-changing innovations while looking ahead and demonstrating the impact of aerospace breakthroughs in our everyday lives. This exhibition inspires your students to imagine future careers in aerospace and helps you build Science and Technology awareness in your classroom. Your field trip to ABOVE AND BEYOND is, simply put, out of this world!

USING THIS TEACHER'S GUIDE

As a companion to your experience at ABOVE AND BEYOND this Teacher's Guide for Elementary School has been created to complement your classroom instruction and make the most of your school field trip. This Teacher's Guide contains original, assessable, Science and Technology classroom lesson plans for you to use and share.

The Teacher's Guide for Primary School contains dynamic activities and assignments for students in years 4 - 6. There is also a Teacher's Guide for Secondary School. Both of these Guides are created to be flexible; use them to best meet the needs and capabilities of your class. You know your students better than anyone else!

Following this Introduction, you will find the section containing four interdisciplinary Classroom Lesson Plans designed to correlate with your curriculum standards. The lesson plans begin with Teacher Instructions pages, which include answer keys for those activities. At the top of the Teacher Instruction page, you will find the appropriate content areas and skills addressed by the activities in the lesson. Each lesson continues with complete, ready-to-copy, Student Activity worksheets that center on key topics featured in the exhibition.

The first lesson plan is "Map It! Partners Around the World." Students will combine their geography and statistics skills while working with a diagram that shows the origins of various parts of a Boeing 787 Dreamliner. They will see how the global world of science, technology, engineering and maths came together to create an airplane of the future that is ready to fly today!

"When Drag Isn't a Drag," the second lesson plan, combines geometry and physical science in an enquiry-based activity. Students will create and test rectangular and circular parachutes to figure out which shapes are used to safely land some of aircraft and spacecraft they will see on their visit to ABOVE AND BEYOND.

In the next lesson plan, "Better Suited for Mars," students will be introduced to the steps of the engineering design process as they participate in a spacesuit simulation. After attempting a series of tasks and exercises in a simulated suit, their goal is to decide what would work well in a spacesuit for a future Mars mission and to make recommendations for improvements.

The fourth lesson plan is “Logical Careers.” Generally, students might think of commercial airplanes when they imagine a career with a company in the aerospace industry. However, The Boeing Company – a vibrant workforce located all over the world – also designs and builds everything from satellites to underwater manned vehicles! The logic puzzle in this lesson plan opens your students’ eyes to the diversity of careers available in a company like Boeing while they practice making deductions and establishing equalities without using any numbers!

All these education resources can be used before or after your field trip. They will help prepare students for the teachable moments found throughout ABOVE AND BEYOND as well as when you return to school to further explore connections between the themes of the exhibition and your classroom Science and Technology instruction. Let’s get ready for takeoff!

LESSON PLAN 1: MAP IT! PARTNERS AROUND THE WORLD

Teacher Instructions

Boeing's 787 Dreamliner is proof of what happens when the best aerospace engineers from around the world work together. During your class field trip to ABOVE AND BEYOND, your students will learn about the many new ways airplanes and spacecraft are designed and built. Some of these methods, like 3D printing, creative wing shapes and lighter materials, were used to create the newest 787 passenger jet.

The 787 is a smart airplane from the inside out. Instead of aluminium, special materials called “composites” are used in the wings and body of the plane. Composite materials are much lighter than the metals that are usually used to make airplanes. The structure of Boeing's 787 Dreamliner is more than 50% carbon composite. Lighter planes need less fuel to fly, which is better for the environment.

Teams from four continents contributed parts and expertise to this new kind of airplane. In this activity, your students will practice their geography and graphing skills to see how the global world of science, technology, engineering and maths came together to create an airplane of the future that is ready to fly today!

In Part 1, your students will identify individual parts of the Dreamliner. In Part 2, they will answer questions using a diagram of the 787 that illustrates these various parts along with their countries of origin. In Part 3, they will create a bar graph to compare the number of parts for the 787 Dreamliner that are made in each country. Finally, they will locate the countries where the Dreamliner is made on maps of the world. If your Social Studies textbook does not already provide blackline master maps for you to copy for your class, there are many options online including:

www.eduplace.com/ss/maps/, www.worldatlas.com/webimage/testmaps/maps.htm, and www.clickandlearn.cc/FreeBlacklineMaps/FreeBlacklineMaps.htm.

SUPPLIES

- **World map**
- **Colouring pencils or markers**



LESSON PLAN 1: MAP IT! PARTNERS AROUND THE WORLD

Answer Key

PART 1

1. b
2. e
3. a
4. g
5. c
6. d
7. f
8. h

PART 2

1. Wing tips
2. Chengdu, China
3. Foggia, Italy and Salt Lake City, Utah/US
4. 3: Italy (centre), Japan (forward), USA (aft/SC, forward/KS)
5. Wichita, Kansas and Nagoya, Japan
6. California, Kansas, Ohio, Oklahoma, South Carolina, Utah, Washington
7. **(a.)** US, Canada; **(b.)** Australia; **(c.)** France, UK, Italy, Sweden; **(d.)** Korea, China, Japan
8. **(a.)** $2/10=1/5$; **(b.)** $1/10$; **(c.)** $4/10=2/5$; **(d.)** $3/10$

PART 3

Australia							
Canada							
China							
France							
Italy							
Japan							
Korea							
Sweden							
UK							
US							

3. 6
4. USA
5. Japan

GO BEYOND!

To realize the breakthrough innovations found in the 787 Dreamliner, Boeing had to rethink the way it makes airplanes. Introduce this revolutionary jetliner to your students by showing them the video *787: Game Changing Innovation* at www.boeing.com/features/2012/02/787-game-changing-innovation-02-6-12.page. Can you think of other ways these new materials and methods can be used?

MAP IT! PARTNERS AROUND THE WORLD

Student Activity

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The 787 is a smart airplane from the inside out. Instead of aluminium, special materials called "composites" are used in the wings and body of the plane. Composite materials are much lighter than the metals that are usually used to make airplanes. As you see in SMARTER, the structure of Boeing's 787 Dreamliner is more than 50% carbon composite. Lighter planes need less fuel to fly, which is better for the environment.

Teams from four continents contributed parts and expertise to this new kind of airplane. In this activity, you will practice your geography and graphing skills to learn about how the global world of science, technology, engineering and math came together to create an airplane of the future that is ready to fly today!



This is carbon fiber. It is used in the 787's fuselage and wings. © Boeing. All Rights Reserved.

SUPPLIES

- **World map**
- **Colouring pencils or markers**

TERMS TO KNOW:

aluminium, composites, expertise

PART 1: THE PARTS

Student Activity

Match each of these terms to their definitions. Use their positions on the Boeing 787 in the diagram to help you.

- | | |
|-------------------------------|-----------------------|
| 1. _____aft | 5. _____nacelle |
| 2. _____fuselage | 6. _____rudder |
| 3. _____horizontal stabiliser | 7. _____trailing edge |
| 4. _____leading edge | 8. _____wing box |

- a. part of the tail that keeps the airplane level and keeps it from moving up and down too much
- b. rear, or back end
- c. part of an airplane that holds the engines, attached to the wings
- d. part of the tail that keeps the airplane's nose from swinging from side to side, sometimes called a "vertical stabiliser"
- e. body of the airplane, shaped like a long tube
- f. rear edge of a wing or propeller
- g. front edge of a wing or propeller
- h. section under the fuselage where the wings attach to the body of the airplane

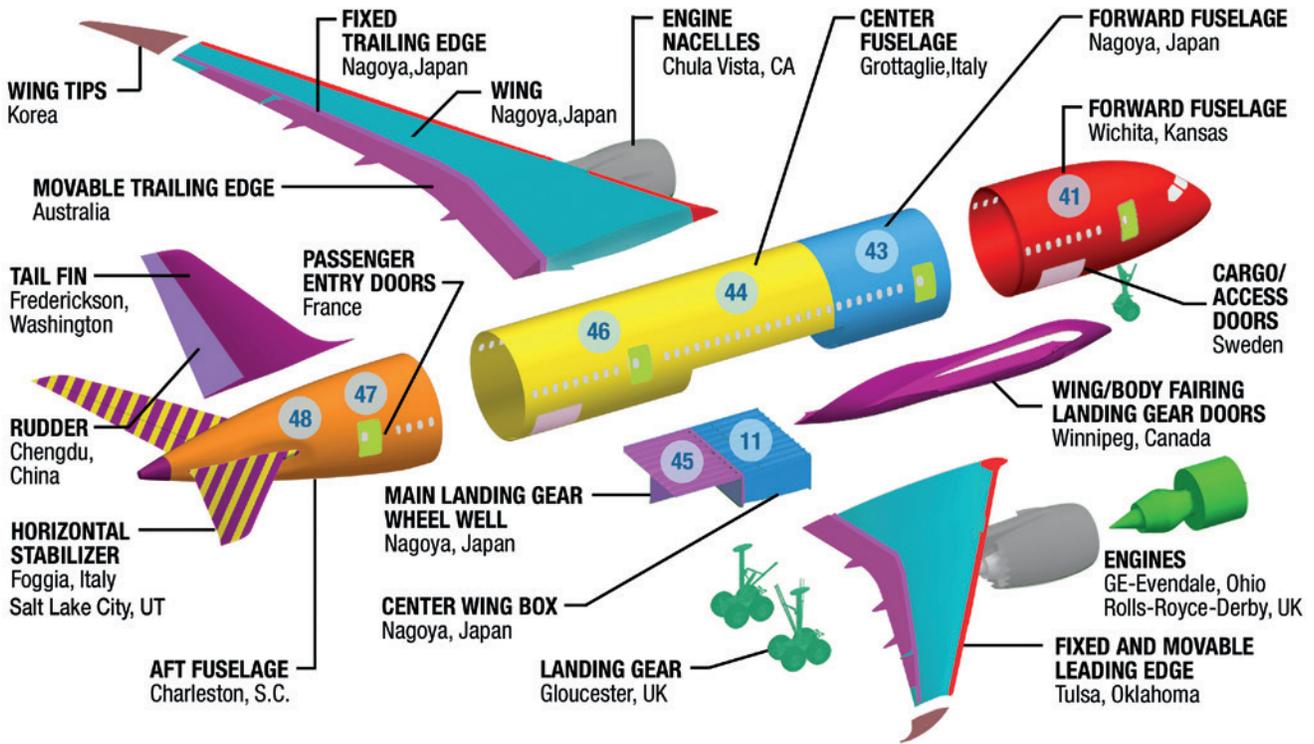
PART 2: THE DIAGRAM

Student Activity

This diagram shows where different parts of the Boeing 787 are made. Answer the questions below the diagram.

THE COMPANIES

U.S.	CANADA	AUSTRALIA	ASIA	EUROPE
Boeing	Boeing	Boeing	Kawasaki	Messier-Dowty
Spirit	Messier-Dowty		Mitsubishi	Rolls-Royce
Vought			Fuji	Latecoere
GE			KAL-ASD	Alenia
Goodrich			Chengdu Aircraft Industrial	Saab



1. Which part of the 787 is made in Korea? _____

2. Where is the rudder made? _____

3. Where is the horizontal stabiliser made? _____

4. How many countries make parts for the fuselage of the 787? Name these countries.

PART 2: RELATIVE SIZE

Student Activity

5. Where are the two forward (front) fuselage sections made? _____

6. Name the seven American states on the diagram. _____

7. There are four continents represented on the diagram. Name the countries that are on each of these continents.

(a.) North America: _____

(b.) Australia: _____

(c.) Europe: _____

(d.) Asia: _____

8. Write a fraction that represents how many of the total number of countries from the diagram are on each continent.
Reduce to equivalent fractions when possible.

(a.) North America: _____

(b.) Australia: _____

(c.) Europe: _____

(d.) Asia: _____

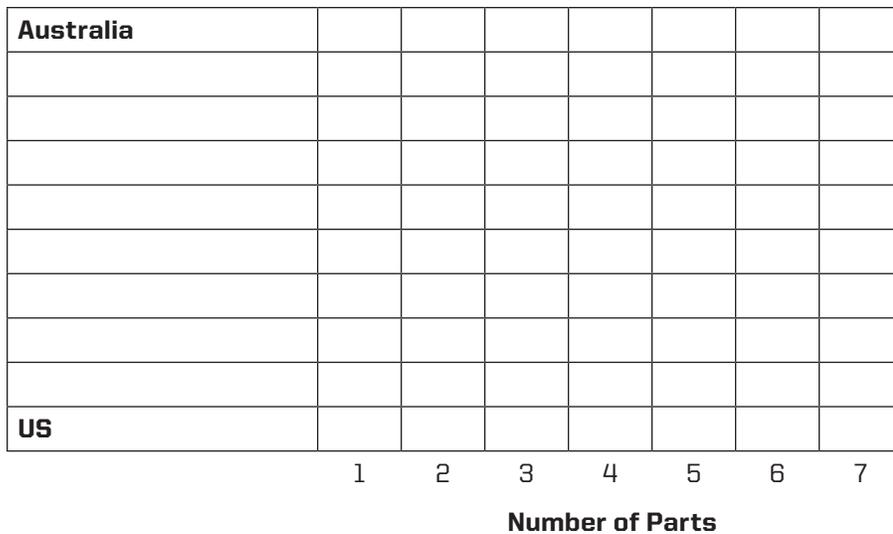
PART 3: THE BAR GRAPH

Student Activity

Use the information from Part 2 to compare the number of parts for the Boeing 787 Dreamliner that are made in each country.

1. Label each row of the bar graph below with the names of the ten countries where parts are built for the 787. Write them in alphabetical order. The first one and last one have been done for you.

2. Count the number of parts made in each country and fill in the bar graph.



3. How many countries produce one part for the 787? _____

4. Which country produces the most parts for the 787? _____

5. Which country produces five parts for the 787? _____

PART 4: THE MAPS

Student Activity

Use your Social Studies textbook, a computer, or an atlas to complete this section using the maps from your teacher.

1. **(a.)** Label the continents and oceans on the world map.
(b.) Locate, label and colour the ten countries where parts of the 787 are made on the world map.

2. Explain why you think this sentence is either true or false:

The Dreamliner is an example of international cooperation.

LESSON PLAN 2: WHEN DRAG ISN'T A DRAG

Teacher Instructions

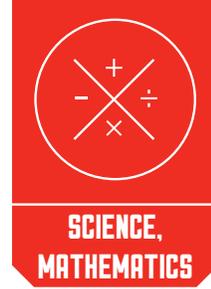
If we keep going UP, FASTER, HIGHER, FURTHER and SMARTER, do ever you wonder how we are going to get back down? One way that might come to mind is a parachute. A parachute is a canopy that fills with air in order to slow down the speed of an object as it is pulled down by gravity. The greater the mass of an object, the faster it falls through air and the harder it lands. Parachutes are used to safely bring down everything - and everyone - from high-speed jets to Mars rovers to sky divers who leap out of airplanes just for fun!

As you will learn during your class visit to ABOVE AND BEYOND, parachutes are part of some of the most high-tech aerospace craft built today. They are used on the CST-100, the Boeing Crew Space Transportation vehicle featured in FURTHER. Someday soon, NASA will use this capsule to transport people and cargo to the International Space Station. The parachutes will help it land safely after returning to Earth. Parachutes are also used sideways! They help supersonic fighter jets slow down quickly on a short runway. Sometimes these are called “drogue parachutes.”

A parachute uses air resistance, or drag, to slow something down. Usually, aerospace engineers want to overcome the force of drag in order to go forward or upward. However, a parachute uses the force of drag for a safe landing.

The parachutes used in the aerospace industry to land jets and space capsules are almost always round or dome-shaped. However, those used by skydivers are usually rectangular or square. Why are there different shapes? What difference does the shape of the parachute make in the job it is supposed to do? In this activity, your students will work in groups to make and test model parachutes to discover the connection between form and function.

After trials with both a circular and a rectangular canopy, students should come to the conclusion that the round ones fall more slowly, which is why they are used to slow the landings and descents of heavy aircraft and spacecraft. The supplies listed are for each group of students working together. For younger ages, you can pre-cut the 12 pieces of string or yarn. For older students, the activities in this lesson plan can be used to introduce the concepts of opposing force and Newton's Laws, which they will begin learning about in Secondary School.



PHYSICAL SCIENCE,
GEOMETRY

SUPPLIES

- Scissors
- 26.8 cm x 27.3 cm plastic bag
- Ruler
- Permanent marker
- Sticky Tape
- Hole punch
- 16 pieces of string or lightweight yarn, 30.5 cm long each
- 2 wooden clothespins
- Balcony, stairwell, or stepladder
- Stopwatch

LESSON PLAN 2: WHEN DRAG ISN'T A DRAG

Answer Key

PART 3

1. Answers will vary based on the height from which the parachutes are dropped.
2. Answers will vary based on the height from which the parachutes are dropped.
3. **(a.)** rectangle; **(b.)** circle
4. Answers will vary based on the student's hypothesis from Part 2.
5. **(a.)** 322.58 square centimetres. **(b.)** Answers will vary and may mention that if one was bigger or smaller than the other, the surface area could have a greater effect on the speed of the descent than the shape does.
6. Answers will vary and may include the weight the materials, height for the drop, or the length of the strings.
7. Answers will vary and may mention that the path of the rectangular one was straighter while the circular one seemed to veer off course.
8. Circle. The purpose of the parachute is to slow the descent for a gentler landing and round canopies land more slowly than rectangular ones.
9. Answers will vary and may include other large items such as cargo/ supplies.
10. "Velocity" means speed and a low-velocity chute would descend slowly.

GO BEYOND!

Show your students how the CST-100 uses its three massive parachutes to safely land from 3,048 metres above the Nevada desert in the video Boeing CST-100 Parachute Drop Test: www.youtube.com/watch?v=ZZ-D3HPyBYU. The capsule's three main parachutes deploy to slow its descent before it lands on six airbags. Did you notice their shape?

WHEN DRAG ISN'T A DRAG

Student Activity

If we keep going UP, FASTER, HIGHER, FURTHER and SMARTER, do ever you wonder how we are going to get back down? One way that might come to mind is a parachute. A parachute is a canopy that fills with air in order to slow down the speed of an object as it is pulled down by gravity. The greater the mass of an object is, the faster it falls through air and the harder it lands. Parachutes are used to safely bring down everything - and everyone - from high-speed jets to Mars rovers to sky divers who leap out of airplanes just for fun!

As you will learn during your class visit to ABOVE AND BEYOND, parachutes are part of some of the most high-tech aerospace craft built today. They are used on the CST-100, the Boeing Crew Space Transportation vehicle featured in FURTHER. Someday soon, NASA will use this capsule to transport people and cargo to the International Space Station. The parachutes will help it land safely after returning to Earth.

Parachutes are also used sideways! They help supersonic fighter jets, like the one you can design at the Full Throttle challenge in FASTER, slow down quickly on a short runway. Sometimes these are called “drogue parachutes.”



In the 1950s, this F-86 Sabre Jet used a drogue parachute to help it land. © Boeing. All Rights Reserved.

A parachute uses air resistance, or drag, to slow something down. Usually, aerospace engineers want to overcome the force of drag in order to go forward or upward. However, a parachute uses the force of drag for a safe landing.

The parachutes used in the aerospace industry to land jets and space capsules are almost always round or dome-shaped. However, those used by skydivers are usually rectangular or square. Why are there different shapes? What difference does the shape of the parachute make in the job it is supposed to do? Your group will make and test model parachutes with different shapes to find out why!

SUPPLIES

- Scissors
- 26.8 cm x 27.3 cm plastic bag
- Ruler
- Permanent marker
- Sticky tape
- Hole punch
- 16 pieces of string or lightweight yarn, 30.5 cm long each
- 2 wooden clothespins
- Balcony, stairwell, or stepladder
- Stopwatch

TERMS TO KNOW:

canopy, capsule, counteract, descend, dome, drag, drogue, velocity

PART 1

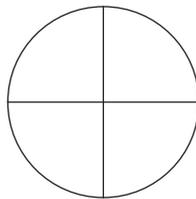
Student Activity

1. Use the scissors to cut open the seams of the plastic bag on all three sides. Cut off the strip with the zipper closure, too. You will have two square pieces of plastic after you cut the bag apart.

2. With the ruler and marker, measure and draw a rectangle on one piece of plastic that is 25.4 cm long by 12.7 cm inches wide.



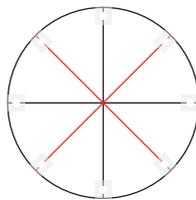
3. With the ruler and marker, make a circle with an a 20.32 cm diameter on the second piece of plastic. To make the circle, start by drawing an 20.32 cm by 20.32 cm cross.



4. Cut out the rectangle and the circle you drew on the plastic. These are the canopies for your parachutes.

5. Fold a piece of tape over each of the four corners of your rectangle. Fold a piece of tape at the midpoint of each side of your rectangle. Punch a hole in each of the four corners and the four midpoints, through the tape and plastic. The tape will keep the yarn from ripping through your parachute.

6. With the ruler and marker, add an X to your circle. Fold a piece of tape over at each of the eight points where your lines meet the edge of the circle. Punch a hole in each of the eight pieces of tape.



7. Tie one 30.5 cm piece of string or yarn with a double knot through each of the holes you made in your canopies.

8. For both the rectangle and the circle, knot the ends of the parachute strings together. Attach a wooden clothespin at the end.

PART 2

Student Activity

1. First, form your hypothesis for this experiment. Which parachute shape do you think will fall faster, rectangular or circular? Which do you think will fall more slowly? Why?

2. Your teacher will climb to the top of the stepladder or a member of your group will climb to the top of the stairwell or balcony with the two parachutes. You or another member of the group will stand at the bottom with the stopwatch.

3. The person at the top of the ladder will release the rectangular parachute while the other person times how many seconds it takes to reach the ground. Record the length of time in the chart below for Trial 1.

4. Repeat step 2 for the round parachute.

5. Drop each parachute two more times and record their times in the chart for Trial 2 and Trial 3.



A member of the US Navy Parachute Demonstration Team, the "Leap Frogs" returns to earth after a successful jump. US Air Force photo, released.

	Rectangle	Circle
Trial 1		
Trial 2		
Trial 3		

PART 3

Student Activity

1. To calculate the average time it took the rectangular parachute to fall, add its three trial times together. Divide that total by 3. What was the average fall time for the rectangular canopy?

2. To calculate the average time it took the circular parachute to fall, add its three trial times together. Divide that total by 3. What was the average fall time for the circular canopy?

3. **(a.)** Which shape fell more quickly? **(b.)** Which shape fell more slowly?

4. Was your hypothesis correct? Why or why not?

5. The surface areas of the two parachutes are constant, which means they are the same for both even though the shapes are variable, or different. **(a.)** Based on what you know about the dimensions of the rectangular parachute, what are their surface areas? **(b.)** Why does the area of the parachutes matter in this experiment?

PART 3

Student Activity

6. Name at least one other constant, or condition that is the same, for the two parachutes in this experiment.

7. Did you observe any other differences in the way the two parachutes descended?

8. Which shape would provide a softer and safer landing for an air craft or spacecraft? Why?

9. What other situations can you think of where a circular parachute would be a better choice than a rectangular one?

10. Why do you think large, round parachutes are sometimes called "low-velocity" parachutes?

LESSON PLAN 3: BETTER SUITED FOR MARS

Teacher Instructions

After decades of innovations and inventions in science, technology, engineering and maths, humans will be able to travel above and beyond the Earth - all the way to Mars. But getting there is only half the battle! Once they land, people will need places on Mars that mimic living conditions here on Earth. Mars has enough gravity to keep people on the surface, but it does not have an atmosphere like ours. It is much colder than Earth, has too much carbon dioxide in its air and gets dangerous levels of radiation from the sun. We will need to protect ourselves from these elements in order to survive on the Red Planet.

During your field trip to ABOVE AND BEYOND, your students can plan their own missions to see if they have what it takes to complete the Marathon to Mars featured in the FURTHER gallery. Meanwhile, there are people already practicing in simulated Martian environments right here on Earth! Settings like a desert or a volcano serve as a pretend Mars. "Astronauts" spend anywhere from a week to a few months living and working there as though they truly are on Mars. They hope to learn about the best ways to grow plants, use solar energy and live with strangers in very small spaces.

They can also try out different types of spacesuits to use on Mars.

If the humans of the future want to go out for a walk on Mars, they will need special outerwear to protect them. Some new options like flexible, "second-skin" suits are featured at ABOVE AND BEYOND. Hopefully, these will be more comfortable and user-friendly than traditional, bulky astronaut suits.

What do you think a Mars mission suit will look like? What capabilities and tools will it need? Would the spacesuits we have today work on Mars? Ask your students to keep these questions in mind as they complete several tasks while wearing a simulated spacesuit and then make recommendations to improve it.

The supplies listed are for one simulated spacesuit per group. Groups should have four to six members. The garments are to be donned over the students' own clothes, except for their shoes. Most of the supplies can be found at a local thrift store or perhaps in your own or a colleague's closet! Use the disinfecting wipes for the head items after each student. If you prefer, the head gear can be omitted entirely without affecting the outcome of the activity.

Feel free to improvise, omit, or substitute tasks and activities to best suit your class. For example, you can reduce the number of safety pins or use paper clips to make it easier. Instead of attaching the nuts and bolts, students can pick up a specific



SCIENCE,
ENGINEERING

EARTH & SPACE
SYSTEMS,
DESIGN PROCESS

number of toothpicks or marbles to test their dexterity. Toothpicks or skewers can also be used for stringing large beads together. Look around your school at the supplies readily available. Get inspired! Remind students to move carefully once they are suited up, in case they lose their balance or overheat. One of the roles in each group is that of a Safety Engineer, who will spot the “astronaut” during his or her mission.

For younger children, or to reduce the number of supplies needed, you can create stations around the room that can be visited in any order. Each group will go to a station to test a component of the suit, one at a time: torso, hands, lower body, feet and head. In this scenario, the students will choose amongst the members of their own group to decide who gets to try each challenge.

After experiencing some of the limitations inherent in an astronaut suit, students will make recommendations on how to build a better one. Finally, each team will present their design to the class, who will then vote on the best one. You can tell your students that even NASA used a voting process to help select a suit for Mars: www.nasa.gov/content/nasa-s-next-prototype-spacesuit-has-a-brand-new-look-and-it-s-all-thanks-to-you/#.VOZTQy7lxWQ. The “Z-2” suit was chosen by the public after it beat out two other designs by 63% of the vote!

SUPPLIES

For each group's simulated Martian suit:

- **1 pair of large, elastic-waist trousers (like track-suit bottoms)**
- **2 sections of 10.2 cm diameter (standard) dryer vent hose**
- **2 large pairs of thick socks (in addition to student's own socks)**
- **1 pair of large welly boots**
- **2 large jumpers**
- **1 large winter puffy coat**
- **2 pairs of gloves, one extra-large pair of garden or work gloves and one smaller pair of any kind to fit inside the larger pair**
- **1 motorcycle helmet**
- **1 pair of sunglasses or safety goggles (if the helmet already has a visor, you can omit this)**

Additional, for each group:

- **Disinfecting wipes**
- **Duct tape**
- **Scissors**
- **Stopwatch or clock with second hand**
- **8 closed safety pins in a small zipped bag**
- **Nuts and bolts, 3 different sizes, separated**
- **Play tunnel (1 per class, groups can rotate)**

LESSON PLAN 3: BETTER SUITED FOR MARS

Answer Key

PART 3

1. Answers will vary by group but should reflect their results in the table from Part 2.
2. Answers will vary by group but should reflect their results in the table from Part 2.
3. Answers will vary by group depending on their astronaut's experience, but may include a better-fitting suit, tools to use, or no gloves.
4. Answers will vary by group and may include oxygen source, different ways to use the bathroom, cooling system/temperature control, adjusting the size of the suit, communication systems, or a way to eat.

PART 4

Each group's final product will vary based on their own ideas and experiences. Assess for completion against the checklist provided in the Student Activity pages.

GO BEYOND!

Kavya Manyapu is a Boeing engineer who dreams of becoming an astronaut. For insight on the two weeks she spent at a simulated Martian environment, show your class Mars Attracts: www.boeing.com/features/2014/07/bds-mars-attracts-07-02-14.page. That is some science camp!

BETTER SUITED FOR MARS

Student Activity

After decades of innovations and inventions in science, technology, engineering and maths, humans will probably be able travel to Mars. But getting there is only half the battle! People need places on Mars that mimic living conditions here on Earth. Mars has enough gravity to keep people on the surface, but it does not have an atmosphere like ours. It is much colder than Earth, has too much carbon dioxide in its air and gets dangerous levels of radiation from the sun. We will need to protect ourselves from these elements in order to survive on the Red Planet.

During your field trip to ABOVE AND BEYOND, you can plan your own mission and see if you have what it takes to complete the Marathon to Mars when you get to the FURTHER gallery. Meanwhile, there are people already practicing in simulated Martian environments right here on Earth! Settings like a desert or a volcano serve as a pretend Mars. "Astronauts" spend anywhere from a week to a few months living and working there as though they truly are on Mars. They hope to learn about the best ways to grow plants, use solar energy and live with strangers in very small spaces.



This illustration shows how Boeing's and NASA's space launch system and Orion crew capsule might look on their way to Mars - a journey that will take about six months. © Boeing. All Rights Reserved.

They can also try out different spacesuits to use on Mars. If the humans of the future want to go out for a walk on Mars, they will need special outerwear to protect them. Some new options like flexible, "second-skin" suits are featured at ABOVE AND BEYOND. Hopefully, they will be more comfortable and user-friendly than traditional, bulky astronaut suits.

What do you think a Mars mission suit will look like? What capabilities and tools will it need? Would the spacesuits we have today work on Mars? Keep these questions in mind as your group completes several tasks while wearing a simulated spacesuit and then makes recommendations for how to improve it.

TERMS TO KNOW:

capabilities, hardware, innovations, mimic, prototype, radiation, simulated, tasks, torso

PART 1: GET READY

Student Activity

In Mars simulations and real space missions, people work together as a team. Assign the following roles to the members of your group.

Position	Job	Name(s)
Safety Engineer (1 or 2 students)	Makes sure the astronaut is safe during tasks and exercises	
Equipment Engineer (1 or 2 students)	Helps dress the astronaut, sets up equipment	
Astronaut	Wears the suit, performs tasks and exercises	
Data Engineer	Collects and records results	

Equipment Engineers: Use this check list to make sure your team has all the supplies necessary to complete this mission. The items below might not look much like the parts of a spacesuit, but they will mimic the way it feels to move and work in one!

Lower Body & Feet	Torso & Hands	Head & Face
2 pairs of socks 1 pair of trousers 2 sections of hose 1 pair of boots	2 jumpers 1 winter coat 2 pairs of gloves	1 helmet 1 pair of sunglasses or safety goggles

Additional Supplies: duct tape, scissors

Astronaut: Begin fully dressed in your own clothes but remove your shoes. Your Equipment Engineers will assist you. Spacesuits are made of many layers!

1. Pull on the socks over your socks.
2. Put on the trousers over your trousers.
3. Slide a piece of hose over each leg and up past the knee. Secure the hose to the trousers with tape.
4. Step into the boots.
5. Wear the jumpers over your own shirt.
6. Put on the winter coat and zip/button it closed.
7. Wear the sunglasses or goggles.
8. Put the helmet on.
9. Put on the two pairs of gloves, beginning with the smaller pair.

PART 2: TESTING

Student Activity

An Equipment Engineer dressed in his or her own clothes will perform the same tasks and exercises alongside the Astronaut, for comparison. The Data Engineer will record the results in the “Mars” column for the Astronaut and in the “Earth” column for the Engineer in the data chart below. Use the stopwatch to time how long each task takes.

Safety Engineer: Stay next to the Astronaut at all times.

Task 1: Star jumps
Complete 15 star jumps.

Task 2: Press-ups
Begin in standing position. Complete 15 press-ups. Return to standing.

Task 3: Tunnel
Crawl through the tunnel, which is similar in size to the entrance to a spacecraft. Begin and end in a standing position.

Task 4: Safety pins
Open the bag of safety pins, open each pin, link the pins together like a bracelet, return them to the bag and seal it.

Task 5: Writing
Write the following information from NASA, as dictated by the Equipment Engineer: The temperature on Mars may range from a high of about 21 degrees Celsius at noon at the equator in the summer, or a low of about -143 degrees Celsius at the poles.

Task 6: Bolts
Begin with the nuts and bolts separated and lying on the floor. Pick up all the pieces and connect the nuts to their bolts.

Data Engineer: Record the time results here.

Tasks	Mars	Earth
1. Star jumps		
2. Press-ups		
3. Tunnel		
4. Safety pins		
5. Writing		
6. Bolts		



On Mars, astronauts will not need to move around with an MMU, or manned maneuvering unit, attached to their suits like the one seen here. © Boeing. All Rights Reserved.

SUPPLIES

- **Stopwatch or clock with a second hand**
- **Tunnel**
- **8 closed safety pins in a small zipped bag**
- **Paper and pencil**
- **3 nut and bolt sets, separated**

PART 3: ASSESS

Student Activity

Once the Astronaut has removed the suit, your team will discuss the mission's results and answer these questions.

1. Which task had the greatest time difference between Mars and Earth?

2. Which task had the least time difference between Mars and Earth?

3. Which was the most uncomfortable or difficult task to complete in the Mars suit? Why? What could have helped?

4. What else might an astronaut need to do while exploring Mars in a spacesuit? List two additional tools or pieces of equipment that would be useful.

PART 4: REDESIGN

Student Activity

Now that you have experience conducting experiments in a spacesuit, your group will make recommendations for how to build a better one – a prototype suit to be worn by the first Mars explorers!

You will need to include the basic equipment used for research in space. Remember that your design must also provide warmth (but not too much!), oxygen and protection from radiation while still allowing astronauts to move around on Mars. Begin your planning with the basic requirements listed under Research Tools, below. Use the checklist as you add them.

Based on the results of your earlier spacesuit mission, complete the following steps on separate paper.

Step 1: Sketch the front and back view of your design. Label the diagram to show where each of its features will be and where your equipment will be stored.

Step 2: Write out an explanation for each feature on your suit, describing how it will work.

Be prepared to present your new and improved Mars suit to the class as a team. Each group will then vote on the best design. Are you ready to suit up for this challenge?



Once on Mars, geologists will study its rocks. They hope to learn more about any resources that might be useful and whether other life forms were ever there. © Boeing. All Rights Reserved.

RESEARCH TOOLS

- **A camera**
- **Binoculars**
- **A way to bring rock samples back to a laboratory**
- **Navigation system**
- **Communication system**
- **Torch**
- **Way to record observations**
- **Tools (hammer, wrench, screwdriver, pliers, etc.)**

LESSON PLAN 4: LOGICAL CAREERS

Teacher Instructions

In this lesson, your class will read a short story about a field trip to ABOVE AND BEYOND, then solve a logic puzzle that matches four fictitious students to the Science and Technology related careers they hope to have some day at aerospace companies. Logic puzzles are a fun way to practice mathematical skills without using any numbers! Your students will be making deductions and establishing equalities similar to those used in algebra: if $A = B$ and $B = C$, then $A = C$.

To solve the puzzle, read each clue carefully. Use the chart to help you keep track of what you do and do not know about each student's career plans. Because each student in the puzzle can only have one career and each career can only have one student, you will use the process of elimination to solve the mystery.

If a clue tells you that a person does NOT like something, then place an X in the box for that person and that career. When you are able to match a student to his or her career choice, put a checkmark in that box.

For example, the first clue says that Lorraine has no interest in working with submarines because she does not like the ocean. Because we now know that Lorraine's career choice cannot involve the Echo Ranger submarine, there should be an X in the box where the row with her name meets the column for the Echo Ranger. This first clue has been marked on the answer grid for you.

Keep reading the clues. Write an X on the answer grid for what you know is not true and use a checkmark for what you know is true until you have matched all the students with their future aerospace careers. Perhaps one of your own students will enjoy a career like these one day!



MATHEMATICS

**EQUALITIES
AND EQUATIONS,
LOGIC**

LESSON PLAN 4: LOGICAL CAREERS

Answer Key

Ann = CST-100

Mike = 777

Lorraine = Chinook

Jim = Echo Ranger

GO BEYOND!

For an inside look at the inspiring innovations dreamed and manufactured by committed Boeing employees all over the world, watch *Who We Are: In the Words of Boeing Employees*: <https://www.youtube.com/watch?v=gdu05M3LnPY>.

There may be a Boeing volunteer in your area available to speak to your class about Science and Technology in real life!

LOGICAL CAREERS

Student Activity

In this lesson, you will read a short story about a field trip to ABOVE AND BEYOND, then solve a logic puzzle that matches four students to the careers they hope to have some day at aerospace companies.

To solve the puzzle, read each clue carefully. Use the chart to help you keep track of what you do and do not know about each student's career plans. Because each student in the puzzle can only have one career and each career can only have one student, you will use the process of elimination to solve the mystery.

If a clue tells you that a person does NOT like something, then place an X in the box for that person and that career. When you are able to match a student to his or her career choice, put a checkmark in that box.

For example, the first clue says that Lorraine has no interest in working with submarines because she does not like the ocean. Because we now know that Lorraine's career choice cannot involve the Echo Ranger submarine, there should be an X in the box where the row with her name meets the column for the Echo Ranger. This first clue has been marked on the answer grid for you.

Keep reading the clues. Write an X on the answer grid for what you know is not true and use a checkmark for what you know is true until you have matched all the students with their future careers. Are you inspired to join them?

TERMS TO KNOW:

aerospace, career, elimination, emissions, grid, industry

LOGICAL CAREERS

Student Activity

The Story

A class is on the bus, returning to school from a field trip to ABOVE AND BEYOND. After learning so much about the future of the aerospace industry, four students talk about the careers they hope to have in the aerospace industry when they grow up.

One student wants to help design the CST-100 in Location 1, which will take astronauts to the International Space Station. Another student wants to be a test pilot in Location 2 for the Chinook helicopters. The third student loves the ocean and wants to work with Echo Ranger, which is a robotic submarine tested in Location 3. The final student wants to become an environmental engineer and reduce carbon dioxide emissions by working with the next generation of eco-friendly 777 jets built in Location 4.

Students

- Lorraine
- Ann
- Mike
- Jim

Careers and locations

- CST-100 space capsule in Location 1
- Chinook helicopter in Location 2
- Echo Ranger submarine in Location 3
- 777 jet in Location 4

Use the clues below to match each student to her or his future career.

The Clues

1. Lorraine has no interest in submarines because she does not like the ocean.
2. Jim does not want to live in Location 4.
3. Lorraine either wants to live in Location 3 or be a Chinook test pilot in Location 2.
4. Ann, who has always been fascinated by space travel, hopes to work on the CST-100 in Location 1.

	777	CST-100	Chinook	Echo Ranger
Lorraine				X
Ann				
Mike				
Jim				