CLASSROOM TEACHER'S GUIDE

GRADES 6–8

ABOVE AND BEYOND℠

THE ULTIMATE INTERACTIVE FLIGHT EXHIBITION

PRESENTED BY BOEING

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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 and the Smithsonian's National Air and Space Museum.

This Teacher's Guide is created by TurnKey Education, Inc., for Evergreen Exhibitions. Education advisors include NASA and the Museum of Flight.

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. Boeing Centennial education collaborative partners include The Documentary Group, WGBH, PBS LearningMedia, Iridescent, Teaching Channel. The Museum of Flight is an education collaborator.

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 math (STEAM) 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 . . . farther . . . higher . . . smarter! Today, these goals propel aerospace innovators to apply the principles of STEAM learning 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 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 farther 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, FARTHER, 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 won't 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. Exhilarating 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, airship, glider, fixed-wing aircraft, rotorcraft, and 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 real barrier when he blazed past it at 700 mph 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 7,000 mph. 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 10 feet 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.

FARTHER

Across the Atlantic, around the world, to the Moon, and beyond! Since we first got off the ground, we've always wanted to fly even farther. For aircraft, the current focus is on going farther with less – using less fuel and creating less pollution. In space, we're shooting for Mars and the stars! What will it take to fly humans to Mars? Can we "sail" to the stars? FARTHER 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 farther 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 program 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 honors 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 STEAM 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 comprehensive Teacher's Guide for Middle School has been created to complement your classroom instructions and make the most of your school field trip. This Teacher's Guide contains original, assessable, STEAM-related classroom lesson plans for you to use and share.

The Teacher's Guide for Middle School contains dynamic activities and assignments for students in grades six through eight. There is also a Teacher's Guide for Elementary 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 Instruction pages, which include answer keys for those activities. At the top of the Teacher Instructions 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 "Modeling the Future." Students will explore the dimensions of several experimental aircraft under development by NASA and Boeing, such as the Blended Wing Body X-48. Students will then practice calculating proportions, ratios, and scale modeling using the measurements of both the test models and their real counterparts.

"Swept for Speed," the second lesson plan, combines history, geometry, and physical science into a fascinating activity on the development of swept-wing technology in the mid-twentieth century. Students will begin with a firsthand account of secret research discovered in Germany at the end of World War II and end by calculating wing angles for today's subsonic and supersonic aircraft.

In the next lesson plan, "Beyond Biology," engineers and biologists cross paths to create innovations in aerospace inspired by biomimicry. From noise-dampening engine housing on jet engines based on the silent flight of a hunting owl to ideas from the animal kingdom on how to get humans to Mars, students will see how biomimicry has already advanced the possibilities of human flight.

The fourth lesson plan is "Logical Careers." Generally, students might think of airplane mechanics and rocket scientists when they imagine a career in the aerospace industry. However, this vibrant workforce – located all over the world – also moves forward on the shoulders of physicians, accountants, and interior designers, just to name a few. 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!

The next section contains two Games and Puzzles related to themes in ABOVE AND BEYOND. One is a word search and the second is a cryptogram. These are excellent activities for your bus ride to and from the exhibition or to assign for extra credit as you see fit. Under "Additional Resources," you will find a recommended reading list, "Milestones of Aviation" timeline, glossary of terms and acronyms, and extensions to the education materials provided by the many contributors to ABOVE AND BEYOND and The Boeing Company's centennial celebration.

We know how important it is to be able to justify field trips and document how instructional time is spent outside of your classroom. To that end, this Teacher's Guide is directly correlated to the Common Core State Standards for Mathematics and English Language Arts along with the Next Generation Science Standards and the C3 Framework for Social Studies State Standards. In addition you will find specific state requirements for your local area to assist with your planning needs. The correlations are organized by grade level and content. You can readily see how they fit into your required curriculum, making it easy to connect a field trip to ABOVE AND BEYOND with your classroom instruction.

All of 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 STEAM instruction. Let's get ready for takeoff!

LESSON PLAN 1: MODELING THE FUTURE OF FLIGHT

Teacher Instructions

MATHEMATICS

PROPORTIONAL RELATIONSHIPS, SCALE MODELS

Across the Atlantic, around the world, to the Moon, and beyond! Since humankind got off the ground, we have worked to fly faster, higher, farther and smarter. For aircraft, the focus is now all about going farther with less – less fuel and less pollution. There are three cutting-edge, experimental aircraft – several featured in ABOVE AND BEYOND – that have moved from inspired ideas to workable models: the X-48, SUGAR Volt, and Phantom Swift.

From the Wright Flyer of 1903 to the most experimental spaceplanes of today, every craft your students encounter during their field trip to ABOVE AND BEYOND started out as an idea and a model. Scale models save both resources and lives. Engineers gather valuable information by trying out their ideas on smaller models that use fewer materials and don't require a human pilot. If they discover that part of their design, such as the angle of a wing or the placement of an engine, makes the aircraft less efficient or unsafe, changes can be made.

THE X-48/BWB-450

Conventional tube-and-wing aircraft produce drag because the wings stick out from the body. NASA and Boeing are experimenting with blending the wings and body of an aircraft into a single, smooth surface in order to reduce drag and improve fuel efficiency. The X-48 is a blended wing body, or BWB, craft. It is called the BWB-450 because someday, it could seat up to 450 passengers! The prototypes proved that this new shape is aerodynamic, fuel-efficient, and can reduce noise, making it a good candidate for an ultra-green flying machine in the future. During 2012 and 2013, different size models were flown many times. You will see one of the test models in ABOVE AND BEYOND.

SUGAR VOLT

Another experimental green aircraft currently in development by Boeing is SUGAR Volt. It is a hybrid electric and jet fuel plane, similar to the hybrid cars we drive today that use both electricity and gasoline. SUGAR stands for Subsonic Ultra-Green Aircraft Research, a group that helps design airplane technologies needed 20 years from now to meet green aviation requirements, including fuel efficiency.

PHANTOM SWIFT

Helicopters can take off and land just about anywhere, but they don't fly very quickly. Fixed-wing aircraft, like airplanes, can fly quickly but need runways to take off and land. A VTOL (vertical takeoff and landing) aircraft combines the best of both worlds! The Phantom Swift experimental aircraft began as Boeing's entry for a competition led by the US military's Defense Advanced Research Projects Agency (DARPA) to develop a new VTOL. In fact, DARPA competitions are behind the development of several cutting-edge technologies featured in ABOVE AND BEYOND. Sounds like the ultimate Science Fair!

In this lesson, your students will discover more about these three flights of the future designed to carry us faster, higher, farther and smarter than ever before. First, they will calculate the full-size dimensions and scale model measurements for the X-48C, SUGAR Volt, and Phantom Swift. Then, to help them get a perspective on the sizes of both the scale models used in tests and their full-scale counterparts, they will compare these proportions to several locations in and around your school.

LESSON PLAN 1: MODELING THE FUTURE OF FLIGHT

Answer Key

PART 1

1.

	Full Size	8.5% Model	5% Model
Width	**240 ft**	20.5 ft	12 ft
Weight	5,882.4 lbs	**500 lbs**	294.1 lbs

2.

	Full Size	15% Model
Width	173.3 ft	**26 ft**
Weight	89.3 lbs	**13.4 lbs**

3.

	Full Size	17% Model
Width	**50 ft**	8.5 ft
Length	**44 ft**	7.48 ft
Weight	**12,000 lbs**	2,040 lbs

PART 2

1. **(a.)** Average middle school desk: 1.5 ft by 2 ft;
   (b.) none
2. **(a.)** Average/minimum middle school classroom: 660 ft^2, roughly 25.5 ft by 25.5 ft if square;
   (b.) all;
   (c.) none
3. **(a.)** Average/minimum middle school gym: 90 ft by 54 ft;
   (b.) Phantom Swift
4. Answers will vary depending on the size of your school's largest parking lot.
5. SUGAR Volt
6. X-48
7. Phantom Swift
8. X-48 at the 5% scale model size
9. Phantom Swift
10. Answers will vary depending on each student's opinion on which vehicle should be developed.

GO BEYOND!

To further explore the work of the Boeing model builders, direct students to view the video clip Model Citizens: Inside Boeing's Wind Tunnel Model Shop, www.youtube.com/watch?v=9MFWnHkG6YU.html. Who knew that playing with model airplanes could lead to such a cool career?

NAME______________________________ CLASS ______________________ DATE__________

MODELING THE FUTURE OF FLIGHT

Student Activity

TERMS TO KNOW:	dimension, hybrid, prototype, subsonic, unmanned, wingspan

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Discover more about these three flights of the future designed to carry us faster, higher, farther and smarter than ever before. First, you will calculate the full-size dimensions and scale model measurements for the X-48, SUGAR Volt, and Phantom Swift. Then, to help you get a perspective on the sizes of both the scale models used in these important tests and their full-scale counterparts, you will compare these proportions to several locations in and around your school.

NAME____ CLASS ____________________________ DATE_________

PART 1: SCALE MODELS

Student Activity

1. Models of the X-48, or BWB-450, were created in more than one size. One model used for unmanned flying tests in California is 8.5% of the actual size. An earlier version was a wind test model built at 5% of its actual size. Complete this chart for the measurements of the full-size aircraft and two of its scale models. Round your calculations to the nearest tenth.

	Full Size	8.5% Model	5% Model
Width	**240 ft**		
Weight		**500 lbs**	

2. The prototype for the SUGAR Volt used in wind tunnel testing was a 15% scale model. In the wind tunnel tests, only a semi-span, or half of the craft, was used. This half model was 13 feet wide, which means a completed 15% model is 26 feet wide. Complete this chart for the measurements of both the full-size aircraft and its scale model. Round your calculations to the nearest tenth.

	Full Size	15% Model
Width		**26 ft**
Weight		**13.4 lbs**

3. Phantom Swift only exists as a scale model, built at 17% of what will be its actual size. With advanced prototyping technology, engineers at The Boeing Company conceived and created the remote-controlled model in less than a month. Look for other rapid prototypes in the SMARTER gallery at ABOVE AND BEYOND. Complete this chart for the measurements of both the full-size aircraft and its scale model. Round your calculations to the nearest tenth.

	Full Size	17% Model
Width	**50 ft**	
Length	**44 ft**	
Weight	**12,000 lbs**	

NAME________________________ CLASS ________________ DATE________

PART 2: RELATIVE SIZE

Student Activity

For perspective on the sizes of both the scale models used in experimental aircrafts and their full-scale counterparts, compare their dimensions to several locations in and around your school.

1. (a.) Measure your desk: ____________ ft long ____________ ft wide

(b.) Which scale models would fit on your desk? ________________________

2. (a.) Measure your classroom: ____________ ft long ____________ ft wide

(b.) Which scale models might fit in your classroom? ________________________

(c.) Which full-scale versions would fit in your classroom? ________________________

3. (a.) Measure your gymnasium: ____________ ft long ____________ ft wide

(b.) Which full-scale versions might fit in your gymnasium? ________________________

4. (a.) Measure the school's largest parking lot: ____________ ft long ____________ ft wide

(b.) Which full-scale versions might fit in this parking lot? ________________________

5. Which experimental aircraft scale model is widest? ________________________

6. Which full-scale craft will have the widest wingspan? ________________________

7. Which of the scale model crafts is the smallest in size, but the closest to its full-sized counterpart? ____________

8. Which of the models is built on the smallest scale? ________________________

9. Which full-scale craft will weigh more, the Phantom Swift or the X-48? ________________________

10. If it were up to you to select one of these three models to be built full-sized and fully functioning, which one would you choose? Why?

____

____

____

LESSON PLAN 2: SWEPT FOR SPEED

Teacher Instructions

MATHEMATICS, SCIENCE, SOCIAL STUDIES

GEOMETRY, PHYSICAL SCIENCE, HISTORY, PRIMARY SOURCE

One of the highlights of a class field trip to ABOVE AND BEYOND is the fighter jet design challenge in the FASTER gallery. Your students' mission at the Full Throttle Virtual Jet Design and Test Facility is to design a maneuverable jet capable of supersonic flight. Their plans will focus on a jet's fuselage, wings, and tail shapes.

Since the wings of a jet provide lift, their shape is key to creating the speed and maneuverability needed in this challenge. Therefore, your designers will want to select the type of wings that give them both. Which wing shape is best for a supersonic fighter jet?

STRAIGHT WINGS

Straight wings are perpendicular to the fuselage. They provide excellent lift and stability at slow speeds. However, they cause significant buildup of shock waves making the aircraft unstable at supersonic speeds.

SWEPT WINGS

Swept wings are angled to reduce drag. Drag is the force that opposes forward thrust. Swept wings reduce the buildup of shock waves near supersonic speeds and offer good maneuverability. However, they produce less lift and are less stable than straight wings at slow speeds.

DELTA WINGS

Delta wings are triangular-shaped, like the Greek letter "delta." The extreme angle of their sweep greatly reduces the buildup of shock waves as the jet approaches the speed of sound. They also offer excellent maneuverability. However, similar to swept wings, they do not provide much lift at slow speeds.

So, where does this information leave your class of student jet designers? Ask them one more critical question: What do abandoned, top-secret research centers in Nazi Germany have to do with the shape of jet wings today? During World War II, aerospace engineers were trying to figure out how to use new, powerful jet engines with the aircraft they already had. Existing airplanes – with straight wings – tended to fall apart when they reached the high speeds possible with the new jet engines.

Some scientists, like Boeing engineer George Schairer, had just started to experiment with an idea called "swept wings." At the end of War World II, Schairer went to Germany with a group of American scientists and engineers. They were sent to find and collect any aeronautical research developed by the Nazis during the war.

In this activity, your students will begin by reading and analyzing a primary source from Schairer. It is a memo he sent hurriedly to Boeing after the Americans discovered secret German documents hidden in an old well. The reports demonstrated that angled, swept-back wings really did work. Boeing then used this information on the B-47 for the Air Force and on the first passenger jet, the 707. Next, students will find out what "angled" means geometrically by measuring and calculating the angles of swept wings on jets today.

SUPPLIES

- **Protractors**

LESSON PLAN 2: SWEPT FOR SPEED

Answer Key

PART 1

1. 20 May 1945
2. 1509 29th Ave. Seattle, Wash
3. Within a few miles of the front line, in the middle of a forest
4. Quiet; excellent quarters including lights, hot water, heat
5. The Germans were ahead in a few items
6. Sweepback or sweepforward has a very large effect on critical Mach number
7. ME163
8. Control and stability problems
9. **(a.)** Answers will vary and may mention that because it was wartime, sharing the information with other plane builders would help America as a whole.
   (b.) Answers will vary and may mention that it might not happen today because of competition among the companies.
10. His razor

PART 2

1. 90 degrees; right angle
2. The wing line and the fuselage line should be at right angles to each other
3. Lines should be drawn on diagram.
4. 125 degrees, obtuse
5. **(b.)** approximately 35 degrees
6. Subtraction; subtract the 90 degrees of the straight wing from the 125 degrees of the angle of swept wing from the line of symmetry: 125-90=35
7. Lines depicting new wings should be added at a 45-degree angle.
8. They will be harder to control at slower speeds (during takeoff and landing, for example).

GO BEYOND!

To learn more about George Schairer's historic swept-wing design and its wind tunnel testing, watch Boeing Wind Tunnel Blows Strong for Nearly 70 Years at www.boeing.com/features/2013/10/bca-wind-tunnel-history-10-28-13.page. You'll be blown away!

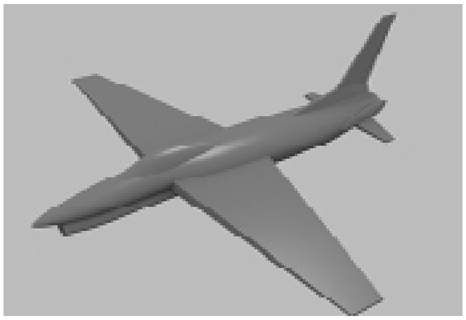
NAME________________________________ CLASS ____________________ DATE__________

SWEPT FOR SPEED

Student Activity

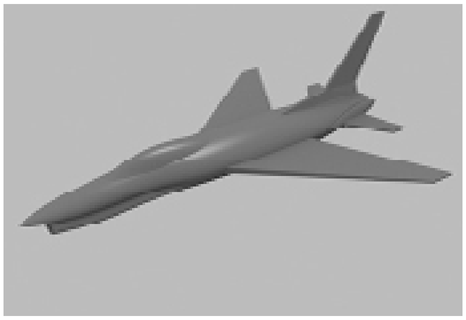
One of the highlights of a class field trip to ABOVE AND BEYOND is the fighter jet design challenge in the FASTER gallery. At the Full Throttle Virtual Jet Design and Test Facility your mission will be to design a maneuverable jet capable of supersonic flight. Your design will focus on a jet's fuselage, wings, and tail shapes. Since the wings of a jet provide lift and their shape is key to speed and maneuverability, you will want to select the type of wings that give you both. Which wing shape do you think is best for a supersonic fighter jet?

STRAIGHT WINGS



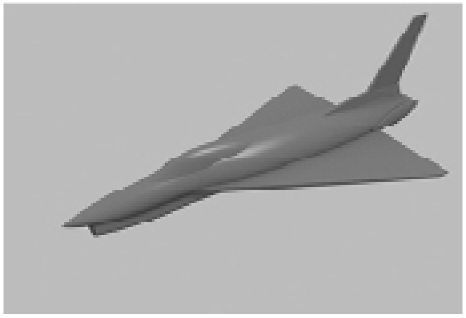
Straight wings are perpendicular to the fuselage and typically have more surface area than other wing shapes. They provide excellent lift and stability at slow speeds. However, they cause significant buildup of shock waves making the craft unstable at supersonic speeds.

SWEPT WINGS



Swept wings are angled to reduce drag. Drag is the force that opposes forward thrust. Swept wings reduce the buildup of shock waves near supersonic speeds and offer good maneuverability. However, they produce less lift and are less stable than straight wings at slow speeds.

DELTA WINGS



Delta wings are triangular-shaped, like the Greek letter "delta." The extreme angle of their sweep greatly reduces the buildup of shock waves as the jet approaches the speed of sound. They also offer excellent maneuverability. However, similar to swept wings, they do not provide much lift at slow speeds.

To begin your research, ask yourself this critical question: What do abandoned, top-secret research centers in Nazi Germany have to do with the shape of jet wings today? During World War II, aerospace engineers were trying to figure out how to use new, powerful, jet engines with the aircraft they already had. Existing airplanes – with straight wings – tended to fall apart when they reached the high speeds possible with the new jet engines.

Some scientists, like Boeing engineer George Schairer, had just started to experiment with an idea called "swept wings." At the end of World War II, Schairer went to Germany with a group of American scientists and engineers. They were sent to find and collect any aeronautical research developed by the Nazis during the war.

In this activity, you will begin by reading and analyzing a primary source from Schairer. It is a memo he sent hurriedly to Boeing after the Americans discovered secret German documents, hidden in an old well. The reports demonstrated that angled, swept-back wings really did work. Boeing then used the information on the B-47 for the Air Force and on the first passenger jet, the 707. Next, you will find out what "angled" means geometrically by measuring and calculating the angles of swept wings on jets today.

TERMS TO KNOW: **aerodynamics, aeronautical, airfoil, drag, fuselage, lift, Mach, maneuverable, perpendicular, supersonic, symmetry, thrust**

NAME______________________________ CLASS ______________________ DATE__________

PART 1

Student Activity

After the secret German research on swept wings was discovered, Schairer sent a seven-page letter to his friend and coworker, Benedict Cohn. Read the excerpt below and answer the questions that follow.

20 May 1945

To: Mr. Benedict Cohn
1509 29th Ave.
Seattle, Wash
USA

Dear Ben,

It is hard to believe I am in Germany within a few miles of the front line. Everything is very quiet and I am living very normally in the middle of a forest. We have excellent quarters including lights, hot water, heat, electric razors, etc.

We are seeing much of German aerodynamics. They are ahead of us in a few items which I will mention. Here the Germans have been doing extensive work on high-speed aerodynamics. This has led to one very important discovery. Sweepback or sweepforward has a very large effect on critical Mach number[1]*. This is quite reasonable on second thought. The flow parallel to the wing cannot affect the critical Mach number and the component normal to the airfoil is the one of importance. Thus the critical M [Mach] is determined by the airfoil section normal to the wing and by the sweepback....*

A certain amount of experimental proof exists for this sweepback effect. Only the ME163[2] *has used it in so far as I can find out. Naturally many control and stability problems are to be encountered in using large amounts of sweep here.*

I do not know how soon this info will get around to other manufacturers so will you write letters to Ozzie, C.L. Johnson, R. Bayless, E. Horky, E. Sheafer, & Darby quoting pages 2 – 5 for their information.

I am having a fine time. I even use my electric razor wherever I go. ...Hope things are going well for you. My best to all the gang. They are sure tops in all comparisons.

Sincerely,
George

Notes:

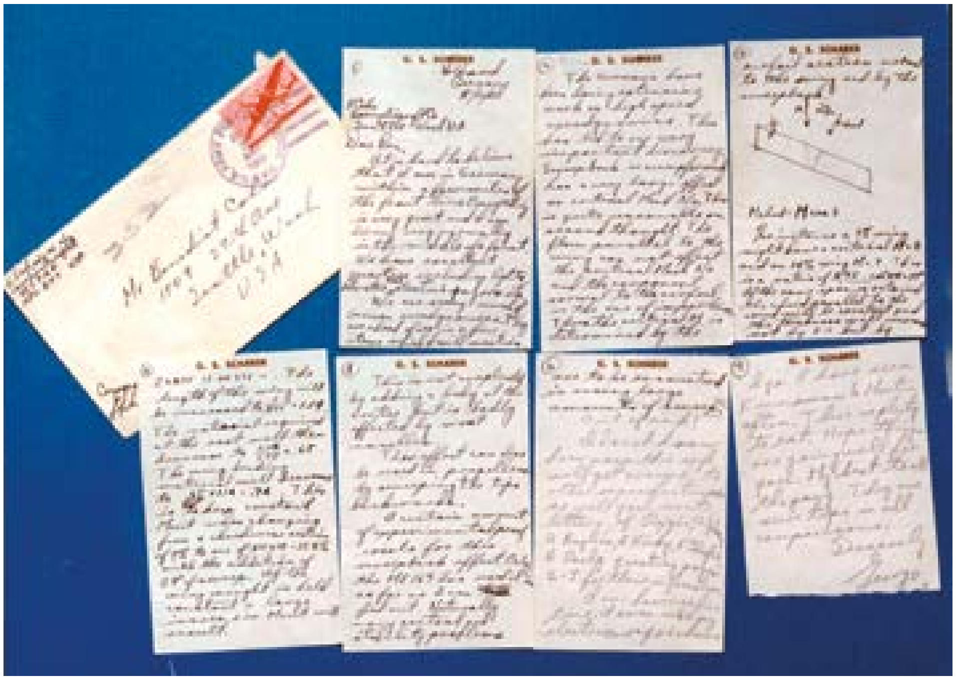
[1]The “critical Mach number” is the speed at which air flowing over any part of an aircraft gets close to, but does not pass, the speed of sound. You will see examples of how the speed of the airflow is tracked in the sample wind tunnel test at ABOVE AND BEYOND.

[2]ME163: The Messerschmitt ME163 Komet was a German rocket-powered fighter aircraft. It was the only rocket-powered fighter actually used in the war.

NAME CLASS DATE

PART 1

Student Activity



Schairer sent this letter describing swept-back wings from Germany

1. On what date does George Schairer write the letter?

2. Where did Benedict Cohn live?

3. Where in Germany is Schairer located when he writes the letter?

4. How does Schairer describe their living conditions?

NAME______________________________ CLASS ______________________ DATE__________

PART 1

Student Activity

5. How do the German aerodynamics compare to American?

6. What is one very important discovery made by the Germans?

7. At that point in history, what is the only aircraft to have used swept wings?

8. What kinds of problems can be expected if the angle is swept too far back?

9. The names listed toward the end of his letter are fellow aeronautical engineers at companies other than Boeing.

(a.) Why do you think Schairer wanted to pass this discovery on to his competitors?

(b.) Do you think companies would still share such information today? Why or why not?

10. What electric appliance does Schairer mention twice in this letter?

NAME______________________ CLASS ______________________ DATE__________

PART 2

Student Activity

You will need a protractor to complete this section.

1. Because straight wings are perpendicular to the fuselage, what is the measurement of the angle formed by the leading, or front, edge of a straight wing and a line of symmetry drawn through the fuselage? Which kind of angle is formed: right, acute, or obtuse?

---

2. Sketch a diagram of an aircraft with straight wings in the space below.

3. On the diagram of the 787, draw a line of symmetry through the fuselage. Next, extend the line from the leading, or front, edge of a wing until it intersects the line of symmetry.

NAME________________________________ CLASS ____________________ DATE__________

PART 2

Student Activity

4. Measure the angle formed by the two lines you drew on the diagram. What size is the angle? Which kind of angle is it: right, acute, or obtuse?

____

____

5. When describing swept wings on aircraft, the angle is actually measured from what would be an invisible, perpendicular straight wing.

(a.) Draw a line on the diagram of the 787 to show where straight wings would go. This line is your new 0 degrees!

(b.) Now measure the angle for the swept wings on this jet. How many degrees are they swept back from your new 0 degree line??

____

6. Based on your answer to questions #3 and #4, explain another way you can find the answer to question #5, without using your protractor.

____

____

____

7. Fighter jets and other high-speed aircraft have wings swept back an additional 10 degrees. Measure and draw in wings at this new angle to turn the 787 on the previous page into a supersonic jet.

8. At ABOVE AND BEYOND, you will see ideas for low-boom, supersonic passenger jets of the future, featuring highly swept-back delta wings. These wings delay the onset of the loud “sonic boom” that is heard when jets break the sound barrier. Based on Schairer’s letter and what you learned about wing angles during the Full Throttle challenge, what is one disadvantage that needs to be considered when designing jets for high speed?

____

____

____

SCIENCE, TECHNOLOGY

BIOLOGY, BIOMIMICRY, ENGINEERING

LESSON PLAN 3: BEYOND BIOLOGY

Teacher Instructions

While ABOVE AND BEYOND is an exhibition full of high-tech engineering, supersmart computers, and cutting-edge technology, it also features the study of plants and animals – life sciences – if you know where to look! In the UP gallery, for example, your students can spread their wings to join birds in flight heading south.

In SMARTER, they will see unmanned aerial vehicles named after the creatures that inspire them, like the Raven. Even the small satellites featured in SMARTER will flock together like their namesakes, Doves. These designs are all examples of biomimicry, where imitation really is the sincerest form of flattery!

Biomimicry introduces engineers and biologists to each other in order to explore problems in one area that could have solutions in another. Often the answers to difficult technological questions can be found outside in the world around us, perfected by millions of years of trial and error. One of the most famous examples of biomimicry is the hook and loop fastener now best known as Velcro®. It was invented by George de Mestral, a Swiss electrical engineer, after he noticed how tiny hooks on burrs stuck to the loops in the fabric of his clothing and in his dog's fur.

The fact that birds first inspired humans to take to the skies is not news. Aerospace engineers have often looked to Mother Nature with questions about how to take flight farther, higher, faster, and smarter. The Boeing Company even has teams who study biological topics such as bird evolution or sound sensors on rainforest insects in Costa Rica! In fact, the carpet on the floor in many airplanes has roots in biomimicry. Inspired by the patterns of fallen leaves on the forest floor, carpet tiles are designed to be removed, repaired, or replaced at random. This way, they can be maintained without disturbing the pattern or wasting time, resources, and money to take out the entire carpet.

Biomimicry has applications far beyond aerospace. For example, robots that can move like snakes are being created to assist in search and rescue missions when it is too difficult for people to look amongst the rubble of a fallen building. In medicine, the ways that fish are able to stay alive in icy cold waters may someday inspire a form of antifreeze to keep human organs viable longer for transplants. Architectural engineers are studying termite towers in Africa to learn how to design tall buildings that stay cool in the heat.

In this activity, your students will see how some of the latest advances in flight are based in nature. Ten examples of biomimicry in aerospace engineering are featured. Some innovations are either already in use or in development, while others are realistic possibilities for future generations. If your class has access to the internet, direct them to the website www.asknature.org to learn more about the practical applications of these and other examples of biomimicry.

Students should understand the "Terms to Know" listed in the box on their Student Activity page. Keep a dictionary nearby to help them use the context clues in this matching activity. For a further challenge, use these examples of biomimicry as prompts for research projects and design challenges. Imagine hosting a Biomimicry Science Fair at your school or creating a picture book series on life sciences in space for your local elementary school!

LESSON PLAN 3: BEYOND BIOLOGY

Answer Key

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

GO BEYOND!

For a closer look at how The Boeing Company studies birds to learn how to reduce fuel burning in their aircraft, check out the video clip Saving Energy in Flight at www.youtube.com/watch?v=srNTtuTqUBE Biomimicry and aerospace make good science!

NAME______________________________ CLASS ______________________ DATE__________

BEYOND BIOLOGY

Student Activity

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TERMS TO KNOW:	**albatross, biomimicry, chevron, dormancy, hover, maneuverable, nanotubes, primate, serrated, transonic, viable, unfurl**

NAME______________________________ CLASS ____________________ DATE__________

PART 1

Student Activity

Match the example from nature on this page with the photo and description of the technology it inspires in the list on the next two pages.

a. Hummingbird: Hummingbirds are small, lightweight, and very maneuverable. They can change directions quickly, hover, and fly sideways.

b. Bird migrations: Groups of birds fly in a V formation to go farther on less energy. The air currents created by one bird help lift the one behind it, so it doesn't have to work as hard.

c. Hibernation: Bears, like many animals, spend their winters hibernating. Recently, scientists have discovered that the fat-tailed dwarf lemur from Madagascar can lower its body temperature, decrease its heart rate, and require less oxygen in a form of primate hibernation.

d. Honeycomb: The six-sided cells of the honeycomb have been known for centuries as being strong yet lightweight structures.

e. Plant buds: Large flower blossoms and leaves unfurl from inside small buds.

f. Owl feathers: Serrated feathers on the edges of owl wings allow the birds to fly silently. The sawtooth pattern dampens sounds the bird makes while swooping toward its prey.

g. Spider webs: Scientists know that spider silk is one of the strongest materials on Earth. It is five times stronger than both piano wire and Kevlar, the material used in bullet-proof vests.

h. Bumblebees: Many plants on Earth, including our food crops, rely on the pollinating powers of bees and other flying insects.

i. Eagle wingtips: The feathers on the end of a steppe eagle's wings curl up at the ends, until they are almost vertical. The shape of these wingtips allows the eagle to maximize lift, without having unnecessarily long wings.

j. Albatross: Birds with long wingspans are able to soar efficiently over incredibly long distances. An albatross can spend weeks, or even months, at sea before returning to land.

NAME______________________________ CLASS ____________________ DATE__________

PART 1

Student Activity

1. ___________ Large solar panels and antennae on satellites have to be folded and packed into very small spaces in order to be launched on rockets. Once in orbit, however, they must be able to safely open up to their full size.

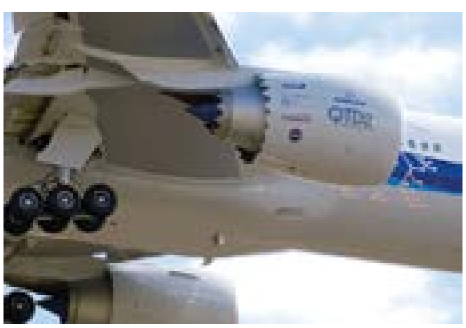
Satellites like this Tracking and Data Relay Satellite (TDRS) have large antennae and solar panels that deploy once they are in orbit.

2. ___________ Swarms of tiny RoboBees with flapping wings could be shipped to Mars. Once released inside greenhouses built there, their sensors will be able to identify flower types and where to land on a flower in order to pollinate food crops.

3. ___________ Aerospace engineers study the benefits of commercial or military aircraft flying together in order to conserve energy. NASA recently demonstrated a 5% to 10% fuel saving by flying aircraft up to a kilometer (over half a mile) apart, which eliminates many of the fears of having commercial aircraft fly too close to each other.

4. ___________ Before an elevator to space can become a reality, a material must be found that is strong enough for the cable car to stretch 62,000 miles above the Earth. So far, scientists and engineers are betting on carbon nanotubes, but biomimicry might have the solution hidden in a web.

5. ___________ Engineers developed a jagged, chevron nozzle that fits onto the back of jet engines. The shape of the nozzle reduces the amount of noise created by the jet.



Testing on this All Nippon Airways 777-300ER showed that the chevron shape of the engine nozzle helps reduce noise.

NAME____________________ CLASS ____________________ DATE__________

PART 1

Student Activity

6. __________ The SUGAR Volt is an experimental aircraft. Its exceptionally wide wingspan combined with composite materials and a hybrid electric engine should allow it to fly for long periods of time without refueling.

This drawing shows how a full-sized SUGAR Volt would look in flight.

7. __________ This tiny, unmanned aerial vehicle is a remote-controlled, undercover aircraft. It has flapping wings, can change directions quickly, and navigate tight spaces. Even though it carries a small camera, it still weighs less than an AA battery.

8. __________ Scientists are studying the genetic mechanisms of dormancy as a way of suspending animation in humans. It could be used to safely transport astronauts on the long-distance journey to Mars, or beyond.

9. __________ The benefits of winglets on the tips of airplane wings were first explored by NASA and Boeing in 1977. With wingtips curled upward at the ends, airplanes fly more efficiently and with fewer emissions.

This 737-MAX features the latest in winglet technology.

10. __________ Hexagons have been used for years on projects big and small in aeronautical research and construction. They are featured in everything from floor panels to wind tunnels to nanotubes.

This honeycomb installation is from a Boeing transonic wind tunnel in the 1960s.

LESSON PLAN 4: LOGICAL CAREERS

Teacher Instructions

MATHEMATICS, CRITICAL THINKING

ALGEBRA, EQUALITIES & EQUATIONS

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 three fictitious students to the STEAM-related careers they hope to have someday. 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 or location. 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 Cora does not want to live in the southern hemisphere. Therefore, Australia cannot be the location for her future career. This first clue has been marked on the 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 be inspired to join them some day!

LESSON PLAN 4: LOGICAL CAREERS

Answer Key

Paul - Australia - Accountant

Cora - USA - Biofuel chemist

Ruby - Saudi Arabia - F-15 technician

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 STEAM in real life!

NAME______________________________ CLASS ______________________ DATE__________

LOGICAL CAREERS

Student Activity

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TERMS TO KNOW:	accountant, deduction, financial, grid, renewable

NAME______________________________ CLASS ____________________ DATE__________

LOGICAL CAREERS

Student Activity

The Story

On the bus ride back to school from their field trip to ABOVE AND BEYOND, three students talk about careers they have been inspired to pursue after learning so much about the aerospace industry. One student is fascinated by fighter jets like the F-15 and hopes to work on them in Saudi Arabia. Another student is concerned about the environment and would like to become a biofuel chemist at a research laboratory in the USA. The third student has always wanted to live in Australia and will consider applying for an accounting job at an aerospace company's office in Melbourne after college.

Students
- Cora
- Paul
- Ruby

Country
- Saudi Arabia
- Australia
- USA

Careers
- F-15 Maintenance Technician
- Accountant
- Biofuel Chemist

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

The Clues

1. Cora does not want to live in the southern hemisphere.

2. Ruby expects her career choice will bring her to Saudi Arabia someday.

3. The student who wants to stay in the USA hopes to create new kinds of jet fuel from renewable resources, like plants.

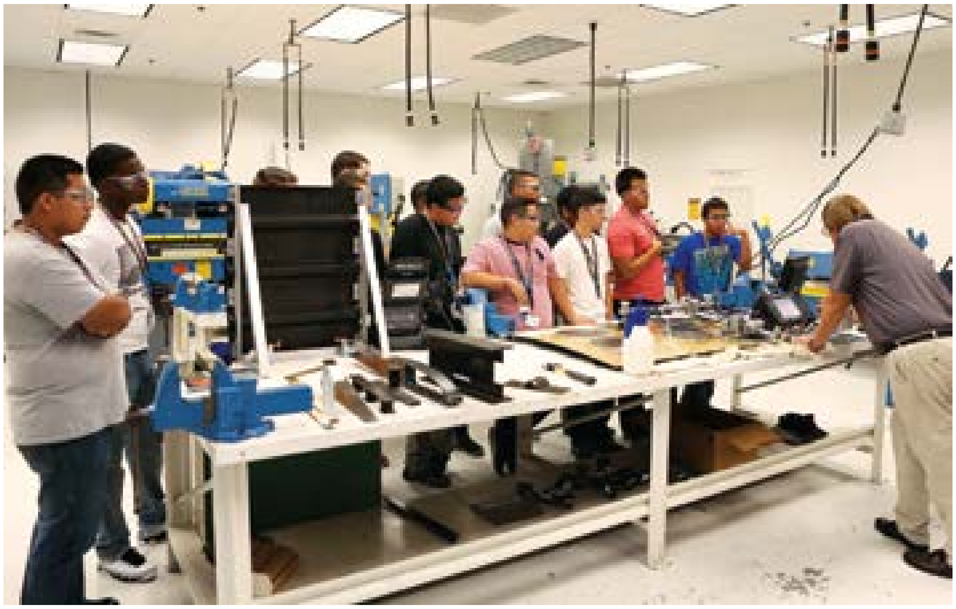
4. The student whose dream job is in Australia loves finance and aeronautics, which is perfect for becoming an accountant at an aerospace company.

		Career			Country		
		Accountant	F-15 Technician	Chemist	Australia	USA	Saudi Arabia
Student	Ruby						
	Paul						
	Cora				x		
Country	Australia						
	USA						
	Saudi Arabia						

NAME______________________________ CLASS ______________________ DATE__________

LOGICAL CAREERS

Student Activity



Occasionally, companies like Boeing host Career Expos for students like this one in Miami where students got hands-on experience with aircraft maintenance tools.

F-15s are flown all over the world, which means that qualified technicians are needed to work on them in locations across the globe.

Boeing and South African Airways are working together to help farmers grow crops, like this sorghum, that can be used for biofuel.

Write the solution to the puzzle here.

Student	Country	Career

NAME________________________________ CLASS ____________________ DATE__________

THE SEARCH IS ON: WOMEN PIONEERS IN AVIATION

Student Activity

These fascinating women are responsible for many key advancements in the history of flight, including those who achieved significant “firsts” in aviation.

For example, do you know which of these innovators…

- was the first woman in America to get a pilot’s license?
- was the first American to make a solo flight in an aircraft?
- was the first woman to break the sound barrier?

Search for the women’s last names, shown in all capital letters, in the list below. You might be inspired to research the biographies of some of these early STEAM champions. They set the bar pretty high!

Willa Brown was the first African-American woman to receive a commission as a lieutenant in the US Civil Air Patrol. US National Archives and Records

Jacqueline **AURIOL**
Florence “Pancho” **BARNES**
Willa **BROWN**
Jacqueline **COCHRAN**
Bessie **COLEMAN**
Amelia **EARHART**

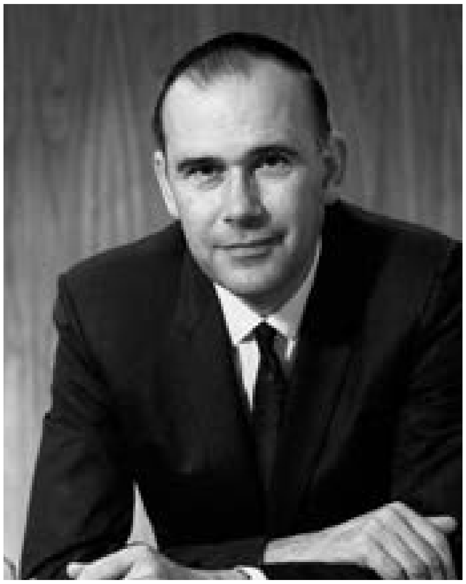
Harriet **QUIMBY**
Bessica **RAICHE**
Mary **RIDDLE**
Betty **SKELTON**
Elinor **SMITH**
Katherine & Marjorie **STINSON**

C	O	C	H	R	A	N	N	R	C	Y	R	B
O	G	U	J	S	A	U	R	Q	U	F	E	A
L	O	S	F	V	O	I	R	O	D	D	I	R
E	E	N	Z	H	D	K	C	I	C	G	C	N
M	K	M	T	A	C	O	M	H	O	D	M	E
A	Z	I	M	R	I	D	D	L	E	L	I	S
N	M	H	P	J	A	S	G	O	D	N	K	Q
S	E	Y	B	M	I	U	Q	N	N	E	O	W
L	B	B	R	J	U	M	I	N	L	A	Y	E
I	C	N	O	I	T	R	S	T	G	R	Y	N
O	T	L	W	E	K	S	O	B	Y	H	P	R
S	T	I	N	S	O	N	X	A	M	A	F	E
D	S	N	R	I	E	I	O	B	S	R	I	A
N	H	X	E	Y	T	U	A	C	H	T	T	H

NAME______________________________ CLASS ______________________ DATE__________

ENGINEERING A CRYPTOGRAM

Student Activity



John E. "Jack" Steiner, the father of the 727.

How did John E. Steiner, chief engineer on the Boeing 727, define his work? You might be surprised!

This puzzle is a cryptogram, a code in which letters have been replaced by numbers. You will decipher the sentence to reveal his quote. Hints are provided and one has been filled in to get you started. Do you agree with Mr. Steiner?

A	B	C	D	E	F	G	H	I	J	K	L	M
						23		24				

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
9	10				17	11						

___	___	___	___	___	___	___	___	___	___	___	
8	9	23	24	9	8	8	19	24	9	23	
___	___		T	___	___						
24	17		11	2	8						
___	___	___	___	___	___	___		___	___		
17	18	24	8	9	18	8		10	6		
___	___	___	___	___		T	___	___	___	___	___
14	10	24	9	23		11	2	24	9	23	17
___	___	___	___		___	___	___	___	___ .		
10	15	8	19		5	23	5	24	9		

THE SEARCH IS ON: WOMEN PIONEERS IN AVIATION AND ENGINEERING A CRYPTOGRAM

Answer Key

Word Search

AURIOL (6,1,SE)
BARNES (13,1,S)
BROWN (4,8,S)
COCHRAN (1,1,E)
COLEMAN (1,1,S)
EARHART (11,8,S)
QUIMBY (8,8,W)
RAICHE (5,1,SE)
RIDDLE (5,6,E)
SKELTON (13,6,SW)
SMITH (1,8,NE)
STINSON (12,1,E)

C	O	C	H	R	A	N	N	R	C	Y	R	B
O	G	U	J	S	A	U	R	Q	U	F	E	A
L	O	S	F	V	O	I	R	O	D	D	I	R
E	E	N	Z	H	D	K	C	I	C	G	C	N
M	K	M	T	A	C	O	M	H	O	D	M	E
A	Z	I	M	R	I	D	D	L	E	L	I	S
N	M	H	P	J	A	S	G	O	D	N	K	Q
S	E	Y	B	M	I	U	Q	N	N	E	O	W
L	B	B	R	J	U	M	I	N	L	A	Y	E
I	C	N	O	I	T	R	S	T	G	R	Y	N
O	T	L	W	E	K	S	O	B	Y	H	P	R
S	T	I	N	S	O	N	X	A	M	A	F	E
D	S	N	R	I	E	I	O	B	S	R	I	A
N	H	X	E	Y	T	U	A	C	H	T	T	H

Cryptogram: "Engineering is the science of doing things over again."

A	C	D	E	F	G	H	I	N	O	R	S	T	V
5	18	14	8	6	23	2	24	9	10	19	17	11	15

BEYOND THE GUIDE: LEARNING EXTENSIONS FOR TEACHERS, STUDENTS AND FAMILIES

Take advantage of these special learning extensions, created to align with ABOVE AND BEYOND exhibition content and themes.

IRIDESCENT: STUDENT AND FAMILY ENGINEERING DESIGN CHALLENGES

www.curiousitymachine.org

Iridescent's Curiosity Machine is a community of scientists, engineers, and children who create, invent, and engineer together. Their design challenges are open-ended and appropriate for children in grades K-12. With the support of a parent or mentor, even your youngest students can navigate the Curiosity Machine website, complete and upload their engineering designs, receive feedback from an online engineer-mentor and become the next generation of aerospace explorers. In addition, the design challenges are grouped into units and align with next generation science standards with new curriculum being added regularly. Through a special grant from Boeing, Iridescent has created design challenges based on the educational themes explored in ABOVE AND BEYOND. Use them all!

THE DOCUMENTARY GROUP

The Documentary Group's multipart documentary series, *The Age of Aerospace*, tells the story of the last 100 years of aviation through the lens of an aerospace giant, The Boeing Company, which today is the largest aerospace company in the world, having acquired or merged with many of the most important aerospace companies of the last century: McDonnell, Douglas, North American Aviation, Rockwell, Piaseki/Vertol and Hughes Satellites Systems. The story of these companies is the story of men and women whose intelligence and imagination were focused on engineering the future and thereby transforming our lives.

PBS LEARNINGMEDIA

www.pbslearningmedia.org

In addition to the documentary series, The Documentary Group has partnered with WGBH Boston, America's preeminent public broadcaster, to create a suite of educational resources that will be distributed on PBS's educational service, PBS LearningMedia. Using video and interactive media, these resources will give students a window into what it takes to make something fly, the scientific concepts that make flight possible, the history of aviation, as well as introduce them to some of the people who build the machines that take us into the sky. These resources support the middle and high school Engineering Design ideas and practices of the Next Generation Science Standards and state standards.

TEACHING CHANNEL: PROFESSIONAL DEVELOPMENT

www.teachingchannel.org

Teaching Channel is a thriving online community where educators can watch, share, and learn diverse techniques to help every student grow. It is a nonprofit video showcase of inspiring and effective teaching practices. Their resources provide a unique opportunity to offer professional development to your local educators as part of their experience at ABOVE AND BEYOND. Developed through a special grant with the support of Boeing, Teaching Channel engaged 20 Boeing engineers and 10 teachers to create 10 science units for grades 4-8 that align with the exhibition content, national standards and the educational themes featured in Above and Beyond.

NASA: "MUSEUM IN A BOX"

www.aeronautics.nasa.gov/mib.htm

The "Museum in a Box" program brings the physical sciences of flight to students in grades pre-K-12. These self-contained activities provide hands-on/minds-on lessons with an aeronautics theme to inspire future scientists, mathematicians and engineers. This group of exercises provided by NASA is perfectly suited for add-on programming at your venue. Think about which of these topics you want to highlight, where they best fit in to your overall plan, and how you can use them – singularly or collectively – to maximize the learning potential of ABOVE AND BEYOND.

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.

GO THE EXTRA MILE: ADDITIONAL RESOURCES

THE ULTIMATE FLIGHT LIBRARY: RECOMMENDED READING

Check this out – of your school or community library! Before or after a class trip to ABOVE AND BEYOND, you will want to use these lists as a starting point to create your own "Ultimate Flight Library." Explore the inspirational people, mind-boggling science, real-life math, and fascinating history that come together to make dreams take flight. To capitalize on individual student interests, these lists are divided by grade level based on reading abilities: Elementary School (Grades 3 – 5) and Middle School (Grades 6 – 8).

ELEMENTARY SCHOOL

Grades 3 – 5

Arnold, Nick. *Flying Machines.* Candlewick Press, 2014.

Baggett, Denise. *Smithsonian Discover: Space.* Silver Dolphin Books, 2014.

Basher, Simon. *Basher Basics: Space Exploration.* Kingfisher, 2013.

Becker, Helaine. *Zoobots: Wild Robots Inspired by Real Animals.* Kids Can Press, 2014.

Buckley, Jr., James. *Who Were the Wright Brothers? (Who Was...?).* Grosset & Dunlap, 2014.

Fleming, Candace. *Amelia Lost: The Life and Disappearance of Amelia Earhart.* Schwartz & Wade, 2011.

Gates, Phil. *Nature Got There First: Inventions Inspired by Nature.* Kingfisher Second Edition, 2010.

Hardesty, Von. *Flight (Insiders).* Simon & Schuster Books for Young Readers, 2011.

Lee, Pascal. *Mission: Mars.* Scholastic Inc., 2013.

Murphy, Pat. *Air Power: Rocket Science Made Simple.* Klutz, 2014.

Nahum, Andrew. *Flight (DK Eyewitness Books).* DK Children, 2011.

Parker, Steve. *Tabletop Scientist –The Science of Air: Projects and Experiments with Air and Flight.* Dover Publications, 2013.

Portman, Michael. *Fighter Jets (Military Machines).* Gareth Stevens Publishing, 2013.

Prior, Jennifer. *Take Off! All About Airplanes (TIME for Kids Nonfiction Readers).* Teacher Created Materials, 2011.

Rice, William B. *Blast Off to Space Camp (TIME for Kids Nonfiction Readers).* Teacher Created Materials, 2011.

Scholastic. *Drones: From Insect Spy Drones to Bomber Drones.* Scholastic Paperback Nonfiction, 2014.

Stine, Megan. *Who Was Sally Ride?* Grosset & Dunlap, 2013.

The Exploratorium. *Exploralab.* Weldon Owen, 2013.

MIDDLE SCHOOL

Grades 6 – 8

Aguilar, David A. *Space Encyclopedia: A Tour of Our Solar System and Beyond.* National Geographic Kids, 2013.

Bortz, Fred. *Seven Wonders of Space Technology.* 21st Century, 2011.

Case, Betsy. *Trailblazers: The Women of The Boeing Company.* Ironwood Lithographics, 2014.

Collins, John M. *The New World Champion Paper Airplane Book: Featuring the World Record-Breaking Design, with Tear-Out Planes to Fold and Fly.* Ten Speed Press, 2013.

Gibson, Karen Bush. *Women Aviators: 26 Stories of Pioneer Flights, Daring Missions, and Record-Setting Journeys (Women of Action).* Chicago Review Press, 2013.

Gibson, Karen Bush. *Women in Space: 23 Stories of First Flights, Scientific Missions, and Gravity-Breaking Adventures (Women of Action).* Chicago Review Press, 2014.

Gregory, Josh. *Aircraft Pilot (Cool Military Careers).* Cherry Lake Publishing, 2012.

Hardesty, Von. *Epic Adventure: Epic Flights.* Kingfisher, 2011.

Holden, Henry M. *The Coolest Job in the Universe: Working Aboard the International Space Station (American Space Missions-Astronauts, Exploration, and Discovery).* Enslow Publishing Inc., 2012.

McMahon, Peter. *Space Tourism (Machines of the Future).* Kids Can Press, 2011.

Mercer, Bobby. *The Flying Machine Book: Build and Launch 35 Rockets, Gliders, Helicopters, Boomerangs, and More (Science in Motion).* Chicago Review Press, 2012.

Mooney, Carla. *Rocketry: Investigate the Science and Technology of Rockets and Ballistics (Build It Yourself).* Nomad Press, 2014.

Nardo, Don. *Drones (Military Experience: In the Air).* Morgan Reynolds Publishing, 2013.

Rooney, Anne. *Aerospace Engineering and the Principles of Flight (Engineering in Action).* Crabtree Publishing Co., 2013.

Rusch, Elizabeth. *The Mighty Mars Rovers: The Incredible Adventures of Spirit and Opportunity (Scientists in the Field Series).* HMH Books for Young Readers, 2012.

Skurzynski, Gloria. *This Is Rocket Science: True Stories of the Risk-taking Scientists who Figure Out Ways to Explore Beyond Earth.* National Geographic Children's Books, 2010.

Waxman, Laura Hamilton. *Aerospace Engineer Aprille Ericsson (STEM Trailblazer Bios).* Lerner Publications, 2015.

TIME CAPSULE: MILESTONES OF AVIATION

Use this detailed timeline of significant moments in aerospace innovation to incorporate the science, technology, engineering, art, and math of flight into your daily lesson plans. These achievements are connected to the wide variety of themes, events, people, and topics featured in this Teacher's Guide and within the galleries at ABOVE AND BEYOND.

This information can be used in your classroom:

- As a resource for biographies of key people involved in the evolution of flight.
- For exercises in historical geography, by mapping specific locations over time.
- To develop group study aids such as trivia contests and game or quiz shows.
- As writing prompts and research project topics across the curriculum.

Be as creative as you like. Remember, the sky is NOT the limit!

Theme	Date	Event
HIGHER	1783	**Hot Air Balloon:** First flight – the Montgolfier Brothers' balloon.
HIGHER	1783	**Hydrogen Balloon:** Jacques Charles' balloon flies with hydrogen, which is lighter but also more flammable.
HIGHER	1794	**Observation Balloon:** Jean-Marie-Joseph Coutelle uses balloons for spying and intimidation during the French Revolution.
HIGHER	1852	**Dirigible:** Steam power now allows balloons to be steered.
HIGHER	1858	**Pictures From the Sky:** French photographer and balloonist Gaspard-Félix Tournachon, known as "Nadar," photographs Paris from the air.
FASTER	1896	**Unpiloted Airplane:** Samuel Pierpont Langley conducts a semi-successful early airplane flight, powered by a steam engine.
FASTER	1903	**Piloted Airplane:** The Wright Brothers fly an internal-combustion-powered plane at Kitty Hawk, NC.
SMARTER	1903	**First Cockpit Instruments:** The Wright Brothers' 1903 flyer uses an anemometer and a tachometer.
SMARTER	1908	**Accident Investigation:** An aircraft piloted by Orville Wright crashes, killing Thomas Selfridge and prompting an investigation.
FASTER	1909	**Air Races:** France holds the first international flying competition at Reims.
FARTHER	1909	**Across the Channel:** Louis Charles Joseph Blériot's hydrogen balloon successfully flies across the English Channel.

FARTHER	1910	**Seaplanes:** Henri Fabre invents the seaplane, or hydroplane, called the "Hydravion."
SMARTER	1910	**Air-to-Ground Radio:** James McCurdy uses air-to-ground radio.
FASTER	1912	**Single Shell Aircraft:** An early racing aircraft has a single shell fuselage of hollow wood that reduces drag.
FASTER	1914	**Fighter Planes:** Aerial dogfighting begins in World War I.
SMARTER	1914	**Early Autopilot:** Lawrence Sperry uses gyroscopes to make the first autopilot.
HIGHER	1914-1918	**Bombs Away:** Nations demonstrate the early use of aircraft bombers in World War I.
SMARTER	1915	**NACA:** Congress creates the National Advisory Committee for Aeronautics (NACA), the organization from which NASA was created in 1958.
HIGHER	1917	**Supercharged:** Sanford Moss invents the turbo supercharger for pressurizing air in engines to adjust to high altitudes.
SMARTER	1918	**Remotely Piloted Aircraft:** The Curtiss-Sperry Flying Bomb combines autopilot with radio, resulting in a remotely piloted aircraft.
FARTHER	1919	**International Airmail:** Bill Boeing and Eddie Hubbard fly from Seattle to Victoria, Canada.
FARTHER	1919	**Across the Atlantic:** The NC-4 sea planes complete transatlantic flights, followed by the flight of John Alcock and Arthur Brown.
SMARTER	1921	**Lighting the Way:** US Postal Service installs rotating lights on towers to guide planes (aerodrome beacon).
FARTHER	1923	**Fuel Station in the Sky:** Lowell H. Smith and John P. Richter set new record for time spent in the sky, thanks to aerial refueling.
FARTHER	1924	**Around the World:** Two Douglas World Cruisers make it around the globe.
HIGHER	1926	**Liquid Rocket Fuel:** Rockets switch from solid to liquid fuel, which allows engines to throttle up and down and stop and start mid-flight.
FARTHER	1927	**Pan American World Airways:** Juan Trippe starts Pan Am, first with mail flights around the Caribbean and then adding passenger service.
FARTHER	1927	**Solo Across the Atlantic:** Charles Lindbergh flies solo from New York to Paris.
FASTER	1929	**Women Racers:** Louise Thaden wins the first all-women's air race from Santa Monica, CA, to Cleveland, OH.
SMARTER	1929	**Flight Instruments:** Jimmy Doolittle makes the first "blind" (instrument-only) flight.
FASTER	1930	**Toward the Modern Airliner:** The Boeing Monomail plane is a more streamlined craft with retractable landing gear.
FASTER	1930s	**Jet Engine:** Frank Whittle and Hans von Ohain develop the jet engine independently.

SMARTER	1930s	**Radar Tracking:** British refine use of radar leading up to WWII, which is then used by both sides in the war.
HIGHER	1931	**To the Stratosphere:** Beginning with Swiss physicist Auguste Piccard, humans visit the stratosphere – including a woman (1934).
HIGHER	1934	**Pressure Suit:** Wiley Post invents the pressure suit. Using it, he discovers the Jet Stream.
FASTER	1935	**Swept Wing:** Research shows that an angled wing design makes near-supersonic flight easier by changing air resistance.
FARTHER	1935	**Sleeper Transport:** The DC-3 Douglass Skysleeper, a hardy, but luxurious, aircraft, makes commercial air transport profitable.
SMARTER	1935	**Air Traffic Control:** Airlines group together to start air traffic control in New Jersey.
FARTHER	1938-1945	**Bigger Bombers:** World War II spurs development of bigger long-range bombers.
FARTHER	1939	**Luxury Flying Boat:** First flight – Boeing 314-Clipper.
FASTER	1939-1945	**WWII Propeller Planes:** More powerful engines and streamlined designs make propeller planes faster.
HIGHER	1940	**Pressurized Cabin:** First commercial aircraft with a pressurized cabin is the Boeing 307 Stratoliner.
FASTER	1944	**Fighter Jet:** Jets join the battle at the end of World War II.
FASTER	1946	**Speed of Sound:** Chuck Yeager goes supersonic.
FASTER	1947	**Swept-Wing Fighter:** Jet fighters with swept wings come into play, especially during the Korean War.
FASTER	1947	**Swept-Wing Bomber:** The B-47 Stratojet debuts, the first long-range jet with swept wings.
FARTHER	1949	**Nonstop Around the World:** James Gallagher flies around the world in the *Lucky Lady II*, refueling four times along the way.
SMARTER	1950s	**Air Traffic Computers:** Computers come into use in air traffic control.
FARTHER	1950s	**Cold War Bombers:** Demands of the Cold War and nuclear arms race result in bigger bombers, like the Boeing B-52 Stratofortress.
FASTER	1952	**The Jetliner:** DeHavilland Comets fly from London to Johannesburg in 23 hours.
FASTER	1953	**Mach 2:** A. Scott Crossfield goes twice the speed of sound in the D-558-2 Skyrocket.
FASTER	1956	**Mach 3:** Milburn Apt reaches Mach 3, only to be killed minutes later when the X-2 goes out of control.
HIGHER	1957	**Artificial Satellite:** Sputnik launches the satellite race!

HIGHER	1957	**Cold War Spy Planes:** The high-altitude Lockheed U-2 spy plane is introduced.
FASTER	1958	**The Jet Age:** Boeing 707 launches regular intercontinental jet travel.
FARTHER	1958	**Intercontinental Ballistic Missile:** First flight – Atlas missile.
SMARTER	1958	**Black Box:** Crash-proof flight recorders come into use.
FASTER	1959	**Escape Velocity:** Soviet Luna-1 is launched toward the moon (it misses and winds up in solar orbit).
SMARTER	1960	**Communications Satellite:** Echo 1, a passive communications satellite, lays the groundwork for future communications tech.
HIGHER	1961	**Humans in Space:** Yuri Gagarin (first human), Alan Shepard (first American), and Valentina Tereshkova (in 1963, first woman) are the first people in space.
HIGHER	1963	**Spaceplane:** Launched from a B-52, the X-15 can go to the edge of space.
FARTHER	1968	**Around the Moon:** Apollo 8 goes around the moon.
SMARTER	1968	**Apollo Guidance Computer:** A computer with less capability than your mobile phone takes 10 crews of astronauts to the moon and back.
FASTER	1969	**Fastest Humans in Flight:** Apollo 10 astronauts return to Earth.
FARTHER	1969	**Moon Landing:** Apollo 11 lands on the moon.
FARTHER	1970	**The Jumbo Jet:** The first jumbo jet, the Boeing 747, flies commercially.
SMARTER	1972	**Digital Fly-By-Wire:** F-8 Crusader demonstrates the new computer technology.
SMARTER	1975	**Heads-Up Display:** Displays projected on windscreens allow for safer flying.
FASTER	1976	**Supersonic Jet Age:** The European Concorde and Soviet Tupolev bring supersonic flight to commercial transportation.
FASTER	1976	**Fastest Human-Made Object:** First flight – Helios-B, a deep-space probe developed by the Federal Republic of Germany with NASA.
FASTER	1976	**Fastest Crewed Jet:** First flight – Lockheed SR-71 Blackbird.
FARTHER	1976	**Flight to Mars:** Viking 1 reaches Mars.
FARTHER	1977	**Sustained Human-Powered Flight:** Bryan Allen flies the *Gossamer Condor*, the first human-powered aircraft capable of controlled flight, built by Paul MacCready.

FARTHER	1977	**Wingtip Device:** Research proves that wingtip devices, like winglets, improve efficiency.
HIGHER	1981	**Space shuttle:** First Flight – Columbia, the first reusable space shuttle.
SMARTER	1982	**Glass Cockpit:** Boeing 767 integrates flat-panel digital displays into flight deck.
HIGHER	1984	**"Jet Pack" in Space:** The MMU lets astronauts move outside of a shuttle without tethers.
FARTHER	1986	**Unrefueled Nonstop Around the World:** The Rutan Model 76 Voyager, piloted by Jeana Yeager and Richard Rutan, sets a flight endurance record.
SMARTER	1993	**GPS:** Global positioning systems come into use.
SMARTER	1994	**Designed on Computer:** The new Boeing 777-200 is designed entirely on computers.
HIGHER	1998	**International Space Station:** ISS becomes the biggest manmade object in space.
FARTHER	1999	**Nonstop Around the World by Balloon:** Breitling Orbiter 3 circles the globe in 19 days.
SMARTER	2000s	**Satellite Aircraft Tracking:** Automatic Dependent Surveillance Broadcast (ADSB) goes into use.
HIGHER	2001	**Vacation in Space:** American businessman Dennis Tito takes the Soyuz up to the ISS as the world's first space tourist.
HIGHER	2001	**Solar High Flyer:** With wings covered in solar cells, remote-control pilots on the ground fly the Helios Prototype to a height of 96,863 ft.
HIGHER	2003	**Private Spaceplane:** SpaceShip One becomes the first private spacecraft and wins the Ansari X Prize after taking two trips to the edge of space in a week.
FARTHER	2005	**Longest Range Airliner:** A Boeing 777-200LR flies nonstop from Hong Kong to London.
FASTER	2006	**Fastest Launch:** NASA New Horizons probe is launched to explore Pluto in 2015.
FASTER	2010	**Hypersonic Milestone:** First flight – Boeing X-51 Waverider, an unmanned scramjet designed to fly faster than Mach 5.
FARTHER	2010	**To the Asteroids and Back:** Hayabusa, an unmanned Japanese spacecraft, returns to Earth from its trip to the asteroid Itokawa and back, begun in 2003.
SMARTER	2013	**Pilotless Jets:** A 16-seater, unmanned Jetstream is tested over UK.
SMARTER	2014	**Smart Helmets:** Lockheed-Martin adds a helmet-mounted display for fighter-jet pilots.
FARTHER	Today	**Voyager 1:** Voyager 1 leaves our solar system.

SPACE AGE: GLOSSARY OF KEY TERMS AND ABBREVIATIONS

TEACHERS: Keep this list handy for both you and your class. You might encounter some space-age words and out-of-this-world acronyms during your epic journey ABOVE AND BEYOND!

accountant	person whose job it is to keep track of money and finances
additive manufacturing	3D printing; used to make all kinds of objects, layer by layer, using materials like plastic, metal, or glass
aerodrome	airport or airfield
aerodynamics	the way air flows around an object in flight
aeronautics	the science of airplanes and flying
aerospace	the businesses that deal with travel in and above the Earth's atmosphere, and with the production of vehicles to go to such places
ailerons	the part of an airplane wing that can be moved up or down to make the airplane turn by rolling to the left or the right
airfoil	the shape of a wing as seen in a cross-section
albatross	a large white ocean bird with long wings that travels very long distances
aluminum	type of metal that is strong, light, and silvery
anemometer	an instrument that measures wind speed
beamed energy propulsion	form of thrust created when spacecraft are launched by lasers or microwaves, instead of chemical rockets
BWB	Blended Wing Body
cambered airfoil	a special wing shape that generates lift, the airplane wing has an arched upper surface similar to a bird
carbon fiber composite	a type of plastic reinforced with stiff strands of carbon that enables the construction of aircraft that are lightweight, yet superstrong
career	job or profession
CFD	Computational Fluid Dynamics; a way to conduct wind tunnel tests on computer
chevron	shape or pattern in the form of a V
composites	made of different parts

CST	Crew Space Transport
CUBESATS	10cm (4-in) satellites that can be customized and combined to perform a variety of missions
cured charge	hardened result when a raw charge is pressed over a mold to form it into a shape with pressure and/or heat applied to bond the layers of carbon fiber tape together
DARPA	US Defense Advanced Research Projects Agency
deduction	something that is taken away
delta	shaped like a triangle
dimensions	sizes or measurements
dormancy	no activity, not doing anything
drag	when air molecules push and rub against your body or the body of a vehicle, causing a resistant force; opposes thrust
efficient	making good use of resources available, without wasting materials, time, or energy
elimination	getting rid of something
emissions	producing or sending out something, like energy or gas
epoxy	a glue-like resin, seals the fibers of carbon fiber tape
ESA	European Space Agency
fuselage	the body of an airplane, usually shaped like a long, cylindrical tube
grid	chart
hover	stay in one place in midair
hybrid	a combination of different things, such as an engine that uses gasoline and electricity
hypersonic	beyond five times the speed of sound

industry	type of business
ISS	International Space Station
lift	an opposing force, greater than an aircraft's weight, that must be generated in order for the craft to ascend, or go up
Mach	used to measure the speed of sound; for example Mach 2 = twice the speed of sound
maneuverable	easy to control
metallic microlattice	a new material that is 100 times lighter than Styrofoam, yet strong and springy to the touch, invented with a new process that uses 3D printing and ultraviolet (UV) light
MMU	manned maneuvering unit
nanotubes	long, tiny, hollow structures formed by graphene, which is sheets of carbon that are only one atom thick, 100 times stronger than steel
NASA	National Aeronautics and Space Administration
orbital debris	anything human-made found in the orbit of the Earth that has no way to adjust its own orbit; space junk
originate	start from, place of beginning
ornithopter	a human-powered, wing-flapping aircraft
perpendicular	at right angles to another surface; as opposed to parallel
photovoltaic cells	solar panels
primate	an animal in the group of mammals that includes apes, monkeys, lemurs, and humans
prototype	the first working version or model of something
Proxima Centauri	nearest star other than the Sun, 40 trillion km (25 trillion mi) away
rapid prototype	a model that is 3D printed, turning ideas for new aircraft and spacecraft into physical articles quickly and inexpensively
raw charge	a sheet of material created by laying carbon fiber tape down layer by layer
resin	a glue-like substance
scramjet	a supersonic combusting ramjet; while rocket engines carry the oxygen needed for combustion, scramjets scoop up oxygen in Earth's atmosphere as they move
SEP	solar electric propulsion; using solar power to electrically charge xenon gas, which is expelled to produce thrust and is more efficient than chemical propulsion

serrated	jagged, like the edge of a knife
shock cone	the shape formed at supersonic speeds when shock waves bend back
shock wave	the pressure waves that build up as an aircraft approaches the speed of sound, in front of its nose and wings; can cause wing flutter and vibrations
SLS	Space Launch System
SMALLSATS	highly capable small satellites
sonic boom	when a shock cone created by an aircraft going faster than the speed of sound reaches the ground, the change in pressure causes a loud noise
subsonic	less than the speed of sound (< Mach 1)
SUGAR	Subsonic Ultra-Green Aircraft Research
supersonic	above the speed of sound (> Mach 1)
symmetry	having two sides or halves that are the same
tachometer	instrument that measures rotations, or turns, per minute
tether	a cable, long cord
thrust	the force opposing drag and the one that moves an aircraft forward
transonic	getting near the speed of sound (Mach .75-Mach 1)
UAV	unmanned aerial vehicle; a drone, an aircraft without a pilot on board
unfurl	to unfold, unroll, or open something
unmanned	uncrewed, without humans on board
viable	possible, capable of being done
VTOL	vertical takeoff and landing
weight	a measurement of Earth's gravitational pull on you
Whipple Shield	a shield invented by astronomer Fred Whipple featuring multiple thin layers of aluminum as a way to protect against orbital debris
wingspan	the length of the wings on an aircraft or bird, from tip to tip

AIM HIGH: CURRICULUM CORRELATIONS

We know how important it is for you to be able to justify field trips and document how instructional time is spent outside of your classroom. With that in mind, the activities in this Teacher's Guide and the experience your class will have during their field trip to ABOVE AND BEYOND have been directly correlated to national curriculum requirements.

Below, you will find the recommended content standards for Grades 6 through 8 set forth by the Next Generation Science Standards, Common Core State Standards for both Mathematics and English Language Arts, and C3 Framework for State Social Studies Standards.

NATIONAL CONTENT STANDARDS

Next Generation Science Standards, Grades 6 – 8

Physical Sciences

MS-PS2-4. Motion and Stability: Forces and Interactions. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

· Science and Engineering Practices: Engaging in Argument from Evidence

· Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence

· Disciplinary Core Idea: PS2.B: Types of Interactions

· Crosscutting Concepts: Systems and System Models

MS-PS4-2. Waves and Their Applications in Technologies for Information Transfer. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

· Science and Engineering Practices: Developing and Using Models

· Disciplinary Core Ideas: PS4.A: Wave Properties; PS4.B: Electromagnetic Radiation

· Crosscutting Concepts: Structure and Function

Life Sciences

MS-LS2-5. Ecosystems: Interactions, Energy, and Dynamics. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

· Science and Engineering Practices: Engaging in Argument from Evidence

· Disciplinary Core Ideas: LS2.C: Ecosystem Dynamics, Functioning, and Resilience; LS4.D: Biodiversity and Humans; PS4.B: ETS1.B: Developing Possible Solutions

· Crosscutting Concepts: Stability and Change

· Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World

· Connections to Nature of Science: Science Addresses Questions About the Natural and Material World

Earth and Space Sciences

MS-ESS1-2. Earth's Place in the Universe. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

· Science and Engineering Practices: Developing and Using Models

· Disciplinary Core Ideas: ESS1.A: The Universe and Its Stars; ESS1.B: Earth and the Solar System

MS-ESS1-3. Earth's Place in the Universe. Analyze and interpret data to determine scale properties of objects in the solar system.

· Science and Engineering Practices: Analyzing and Interpreting Data

· Disciplinary Core Idea: ESS1.B: Earth and the Solar System

· Crosscutting Concepts: Scale, Proportion, and Quantity

· Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology

MS-ESS3-3. Earth and Human Activity. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

· Science and Engineering Practices: Constructing Explanations and Designing Solutions

· Disciplinary Core Idea: ESS3.C: Human Impacts on Earth Systems

· Crosscutting Concepts: Cause and Effect

· Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World

Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

· Science and Engineering Practices: Asking Questions and Defining Problems

· Disciplinary Core Idea: ETS1.A: Defining and Delimiting Engineering Problems

· Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

· Science and Engineering Practices: Engaging in Argument from Evidence

· Disciplinary Core Idea: Developing Possible Solutions

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

· Science and Engineering Practices: Analyzing and Interpreting Data

· Disciplinary Core Ideas: ETS1.B: Developing Possible Solutions; ETS1.C: Optimizing the Design Solution

Common Core State Standards for Mathematics

Grade 6: CCSS.Math.Content.6.RP.A.1, CCSS.Math.Content.6.RP.A.3; CCSS.Math.Content.6.NS.B.3; CCSS.Math.Content.6.EE.A.2, CCSS.Math.Content.6.EE.A.4, CCSS.Math.Content.6.EE.B.6

Grade 7: CCSS.Math.Content.7.RP.A.2, CCSS.Math.Content.7.RP.A.3; CCSS.Math.Content.7.NS.A.3; CCSS.Math.Content.7.EE.A.2, CCSS.Math.Content.7.EE.B.4; CCSS.Math.Content.7.G.A.1, CCSS.Math.Content.7.G.A.2, CCSS.Math.Content.7.G.B.5

Grade 8: CCSS.Math.Content.8.EE.C.7, CCSS.Math.Content.8.G.A.5

Standards for Mathematical Practice: CCSS.Math.Practice.MP1, CCSS.Math.Practice.MP2, CCSS.Math.Practice.MP4, CCSS.Math.Practice.MP5, CCSS.Math.Practice.MP6

Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects, Grades 6 - 8

Anchor Standards: CCSS.ELA-Literacy.CCRA.R.1, CCSS.ELA-Literacy.CCRA.R.4, CCSS.ELA-Literacy.CCRA.R.7, CCSS.ELA-Literacy.CCRA.R.10

History/Social Studies: CCSS.ELA-Literacy.RH.6-8.1, CCSS.ELA-Literacy.RH.6-8.2, CCSS.ELA-Literacy.RH.6-8.4, CCSS.ELA-Literacy.RH.6-8.7

Science and Technical Subjects: CCSS.ELA-Literacy.RST.6-8.1, CCSS.ELA-Literacy.RST.6-8.3, CCSS.ELA-Literacy.RST.6-8.4, CCSS.ELA-Literacy.RST.6-8.7, CCSS.ELA-Literacy.RST.6-8.9, CCSS.ELA-Literacy.RST.6-8.10

Writing: CCSS.ELA-Literacy.WHST.6-8.1, CCSS.ELA-Literacy.WHST.6-8.2, CCSS.ELA-Literacy.WHST.6-8.7, CCSS.ELA-Literacy.WHST.6-8.9

C3 Framework for Social Studies State Standards, Grades 6 - 8

D1.2.6-8., D2.Civ.14.6-8., D2.Eco.2.6-8., D2.Geo.7.6-8., D2.His.1.6-8., D2.His.3.6-8., D2.His.14.6-8.,