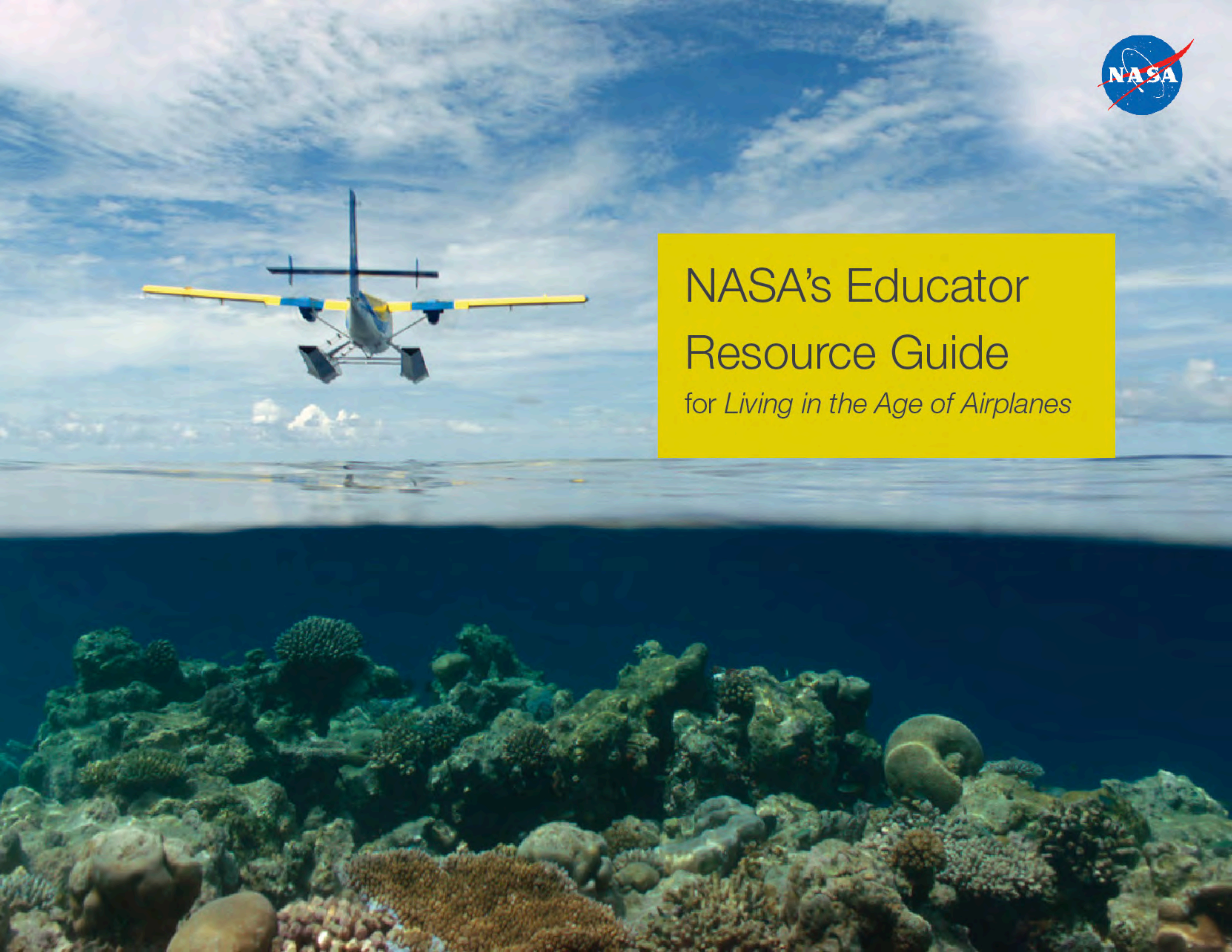


NASA's Educator Resource Guide

for *Living in the Age of Airplanes*

LIVING IN THE AGE OF AIRPLANES
is a story about how the airplane has changed the world. It renews our appreciation for one of the most extraordinary and awe-inspiring aspects of the modern world.

NASA AERONAUTICS
works to solve the many challenges that still exist in our nation's air transportation system: air traffic congestion, safety, efficiency, and environmental impacts.

Presented by National Geographic Studios, ***Living in the Age of Airplanes*** carries audiences across 200,000 years of history and around the globe on an epic journey to 95 locations in 18 countries spanning seven continents to remind us how, in a single century, aviation has changed our world forever. Narrated by actor and pilot Harrison Ford, ***Living in the Age of Airplanes*** began showing in IMAX®, giant screen, 15/70mm dome screens and digital cinemas nationwide on April 10, 2015. For information about the film and the latest list of theatres, visit *www.airplanesmovie.com*

Overview

The invention of aviation has made it possible for people to travel *faster* and *farther* than ever before, and has led to a global increase in *connection* of commerce, people, and ideas.

However, economic growth and social changes have also led to challenges for the aviation industry. NASA's Aeronautics Research Mission Directorate (ARMD) works hand-in-hand with scientists, engineers, industry leaders, and government to solve many of these problems.

The accompanying activities provide students with activities to explore the social and scientific advances in the speed and distance of human travel, as well as NASA ARMD's contributing role to aviation.

Lessons and Activities

Lesson 1 - *Faster*

- Activity 1.a - *Walking Speed*
- Activity 1.b - *Flying Speed*

Lesson 2 – *Farther*

- Activity 2.a - *Flight Paths*
- Activity 2.b – *Smart Skies*
- Activity 2.c - *Round Globe, Flat Map*

Lesson 3 – *Connected*

- Activity 3.a – *Air Cargo Game*
- *Activity 3.b – Friends and Flowers*

Denotes NASA Aeronautics connection.

Resources from NASA Aeronautics

For further classroom resources that describe NASA ARMD's contributions to aviation, please access the following:

NASA Aeronautics: http://www.nasa.gov/topics/aeronautics/index.html

- Aeronautics Education Teacher Resources
  - *Aeronautics for Pre-K* (Pre-K/Early Education)
  - *Museum in a Box* (Elementary – High School)
  - *Aeronautics for Introductory Physics* (High School – Introductory College)
- Lithographs: *NASA's Contributions to Aviation, Parts of an Airplane*
- Videos, News, Updates
- App: *Sector 33* air traffic control game
- e-Books

*"Together, advances in science, engineering, and technology can have—and indeed have had—profound effects on human society, in such areas as agriculture, **transportation**, health care, and **communication**, and on the natural environment. Each system can change significantly when new technologies are introduced, with both desired effects and unexpected outcomes. (NRC, 2012, p. 210)."*

From *Science, Technology, Society, and the Environment and NGSS*: http://goo.gl/n3Xvok

Activity	Content Areas	Next Generation Science Standards	Common Core State Standards
1.a Walking Speed (Middle School/HS)	Science (Physics) Math (Algebra) Social Science	Sci & Eng. Practices: Planning and Carrying out Investigations, Developing and Using Models, Analyzing and Interpreting Data Disciplinary Core Ideas: PS2.A Forces & Motion Crosscutting Concepts: Systems and Models	Algebra: Understand ratio concepts and use ratio reasoning to solve problems, Analyze proportional relationships and use them to solve real-world and mathematical problems.
1.b Flying Speed (Middle School/HS)	Science (Physics) Math (Algebra)	Sci & Eng. Practices: Developing and Using Models Disciplinary Core Ideas: PS2.A Forces & Motion Crosscutting Concepts: Systems and Models	Algebra: Understand ratio concepts and use ratio reasoning to solve problems, Analyze proportional relationships and use them to solve real-world and mathematical problems.
2.a Flight Paths (Middle School/HS)	Geography Math (Geometry, Algebra)	Sci & Eng. Practices: Developing and Using Models Crosscutting Concepts: Systems and Models, Scale, Proportion, and Quantity	Geometry: Analyze, compare, and compose shapes, Reason with shapes and their attributes Algebra: Understand ratio concepts and use ratio reasoning to solve problems.
2.b Smart Skies (Middle School/HS)	Science (Physics) Math (Algebra)	Sci & Eng. Practices: Analyzing and Interpreting Data Disciplinary Core Ideas: PS2.A Forces & Motion, ETS1.A Crosscutting Concepts: Systems and Models	Algebra: Understand ratio concepts and use ratio reasoning to solve problems, Analyze proportional relationships and use them to solve real-world and mathematical problems.
3.a Air Cargo Game (Elementary/Middle)	Engineering Social Science	Sci & Eng. Practices: Designing Solutions Disciplinary Core Ideas: ETS1.A, ETS1.B	--
3.b Friends & Flowers (PreK – Middle School)	Social Science English Language Arts Art	Nature of Science Connection – Science is a human endeavor.	Reading/Listening

Lesson 1 – *Faster*

- Activity 1.a - *Walking Speed*
- Activity 1.b - *Flying Speed*

Airplanes were developed with a primary goal: to take their occupants across the skies at speeds never before imagined. For thousands of years, before the invention of the wheel, humans were limited by the speed of their legs.

In the following laboratory activity 1.a, students will determine their walking speed using an inquiry approach. Although some students might be familiar with the relationship *speed = distance/time*, most will not know where that relationship comes from. Instead of directly applying the equation, students will plot their distance at various waymarks, as well as the time it takes them to get to those points. Students will find that the slope of their graph has a meaning: namely, their speed. Students can compare their own graph to their classmates' graphs. More advanced students can use the simple linear equation to derive the relationship between distance and time: *distance = (speed) * time.* In activity 1.b, students will use a web-based real-time flight viewer and maps to apply the equation derived in activity 1.a, in order to estimate the current speed of an actual plane in the air.

The Legacy of Science, by James Burke:

Change is one of mankind's most mysterious creations. The factors that operate to cause it came into play ***when man produced his first tool****. With it he changed the world forever, and bound himself to the artifacts he would create in order, always, to make tomorrow better than today. But how does change operate? What triggers a new invention, a different philosophy, an altered society? The interactive network of man's activities links the strangest, most disparate elements, bringing together the most unlikely combinations in unexpected ways to create a new world.*

Is there a ***pattern to change*** *in different times and separate places in our history? Can change be forecast? How does society live with perpetual innovation that, in changing the shape of its environment, also transforms its attitudes, morals values? If the prime effect of change is more change, is there a limit beyond which we will not be able to go without anarchy, or have we adaptive abilities, as yet only minimally activated, which will make of our future a place very different from anything we have ever experienced before?*

From *The Impact of Science on Society:* http://history.nasa.gov/sp482.pdf

Activity 1.a – Walking Speed

Goal: Collect distance and time data to determine each student's natural walking speed.

Key Concepts: Distance, Time, Speed, Graphs, Linear Relationships

Grade Level: 5-12

Subjects: Math, Physical Science, Physics

Materials: large classroom/gym/outdoor area, meter stick or tape measure, tape or cones (to mark distances), timer, graph paper, calculator (optional)

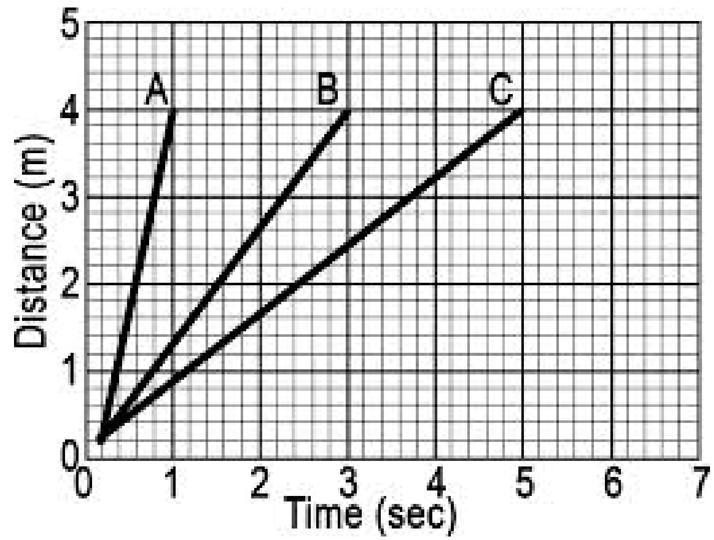
Procedure:

1) Ask a few students to stand against a wall, and to walk – at a normal pace – to the other side of the classroom. Ask the remaining class what the difference is between each student's motion. Students are likely to respond that some students walk faster than others. Discuss how speed could actually be quantified – what things must someone know in order to fairly determine one's speed? (Guide students to recognize that both *distance* and *time* of travel must be known for each student).
2) Split students into pairs or small groups, and ask students to collect data on each individual's *distance* and the *time* it took them to get to that distance. Students should collect at least five different distance and time data sets. In order to make a graph, teachers may provide students with a data table with required distances, or allow students to choose their own distances. (Caution: Some students might want to only do multiple trials of the same distance. To make a proper graph, students must have a wide variety of distance and time values, although multiple trials of the same value are also encouraged to increase accuracy. Also, ensure that students have chosen wide enough distances to get reasonable time values. For example, it would be unreasonable to measure the time it takes for a student to walk one meter. Students should aim for a range of data between five and twenty (or more) meters.)

Photo credit: Tricia Carzoli

Sample Data Table:

Distance (m)	Time (s)
5	4.7
10	9.5
15	15.3
20	21
25	24.9



3) Ask students to each create a dot plot of distance (y-axis) versus time (x-axis) for their own data. (Caution: Ensure that students use a dot plot. Many young students tend to make bar graphs, which are typically appropriate for data categories, not for quantitative data on both axes).
4) Ask students to draw a best-fit line through the data. (Caution: Students often want to simply connect the first and last data point. Encourage students to look for the best fit for all data points).
5) Ask students to compare their graphs, and notice any differences. If necessary, either provide students with axes values to ensure a fair comparison, or ask students to plot their data on a single graph, using a particular color to denote their own data points and best-fit line. Students should notice that although the line goes upward to the right, that the angle (slope) at which it does this is different for some students. Students with significant differences in their slope should be asked to demonstrate their walk. Students should find that students with a steeper slope have a higher natural walking speed.
6) Ask students to quantify how fast each student walks. As students see that the angle (slope) is equivalent to the speed of the walker, students can now determine the slope of their own graph.
7) For more advanced students, students can be asked to determine the relationship – from the graph – between distance and time, using the following method (using C's data, from the graph):
    a. General Equation of a Line: y = mx + b
    b. Substitute Axes Variable Names: Distance = (m) Time + b
    c. Substitute Slope (with Unit): Distance = (0.8 m/s) Time + b
    d. Substitute Y-Intercept (with Unit): **Distance = (0.8 m/s) Time + 0**. (Note: Some students might not get an intercept of 0! This is an important data analysis concept. Students can be asked to describe the meaning of the y-intercept, in this lab (it should represent the starting point). Because students likely assumed that they started at 0 m at 0 s, this value should be 0. If it is not, it is likely the result of experimental error. Teachers can help students discuss possible causes and sources of experimental error).
    e. Generalize the equation for each student to a single equation for the whole class: **Distance = (Speed) Time**.

8) Apply the new equation to a variety of relevant questions:

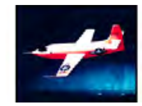
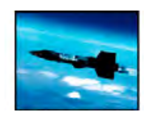
   a. Convert your speed (in m/s) to km/hr, then use that speed to solve the following problems.

   b. How much time would it take **you** to walk the following routes, assuming you never stopped along the way?

Land Routes	Distance to Walk	Time to Walk (Show work)	Time to Fly Non-Stop on Commercial Aircraft
Oregon Trail (MO to OR) 	**3,219 km** (2,000 miles) Immigration route used from 1830's to 1860's for settlers heading west for new land.		**3 hours**
Silk Road (Western China to Constantinople) 	**6,437 km** (4,000 miles) Cultural and commercial trade route used from 200 BC to 1450's AD to connect culture and trade between the East and the West.		**8 hours**
Early Land Migration (Northern Russia to Tierra del Fuego) 	**17,703 km** (11,000 miles) Possible route taken by early civilizations from the Asian continent, beginning about 30,000 years ago to their arrival at the southernmost tip of South America about 15,000 years ago.		**19 hours**

From NASA ARMD's earliest days, it has worked to develop planes to achieve – and exceed – the speed of sound. Visit NASA's *Virtual Skies*, an online learning interface to learn more about airplane design. http://virtualskies.arc.nasa.gov/

c. How long would it take each of the following **NASA planes** to travel the exact same routes above, assuming they were at their maximum speed for the entire duration of the flight?

Land Routes	Distance	NASA Aircraft Speed	Time of Flight (show work)
Oregon Trail (MO to OR) 	**3,219 km** (2,000 miles) Immigration route used from 1830's to 1860's for settlers heading west for new land.	X-1: **1,127 km/hr** Chuck Yeager was the first person to break the speed of sound in 1947 using rockets in conjunction with traditional jet engines.	
Silk Road 	**6,437,376 m** (4,000 miles) Cultural and commercial trade route used from 200 BC to 1450's AD to connect the East and the West.	D-558-2: **2,124 km/hr** Scott Crossfield was the first person to fly more than twice the speed of sound (Mach 2) in 1953.	
Early Land Migration 	**17,702,784 m** (11,000 miles) Possible route taken by early civilizations from the Asian continent, beginning about 30,000 years ago to their arrival at the southernmost tip of South America about 15,000 years ago.	X-15: **7,274 km/hr** William J. "Pete" Knight broke the record for the fastest piloted airplane flight speed ever recorded, at 6.7 times the speed of sound (Mach 6.7) in 1967.	

Activity 1.b – Flying Speed

Goal: Use the equation derived from Activity 1.a, Distance = (Speed) Time, to estimate the speed of an airplane as it travels between any two points across the globe.

Key Concepts: Distance, Time, Speed

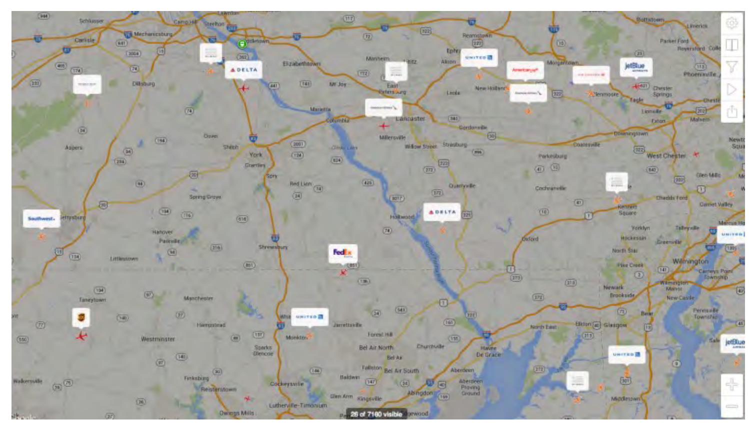
Grade Level: 5-12

Subjects: Math, Physical Science, Physics

Materials: computers or mobile devices with internet access, timer

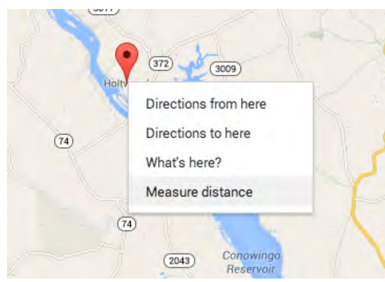
Procedure:

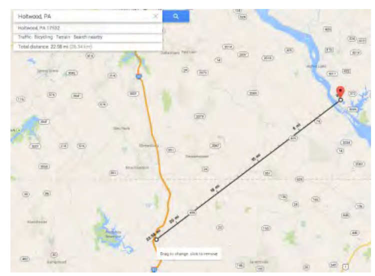
1) Direct students to go to the following website: http://planefinder.net/
2) Ask students to browse the page and to note the greatest concentration of air flights around the world. Students may be provided a map, and asked to mark the countries and areas where there is the most flight activity.
3) Discuss potential reasons for air flight concentrations being where they are. Consider:
    a. Economics
    b. Population Density
    c. Geography (locations of deserts, mountain ranges, remote areas)
    d. Weather (locations of storm systems, hurricanes)
    e. Time of Day (consider that it is night time on the other side of the world)
    f. Cultural Holidays
4) Ask students to zoom in to a particular area where there is a regular amount of air traffic. The goal at this point is to identify an aircraft that is moving from one notable location to another (such as a city, interstate intersection, lake, etc.), so that speed may be determined. (Note: If students zoom in very close to an aircraft, they can get the airline, flight number, origin and destination airports, as well as the speed in knots, or KTS: 1.15 miles per hour, or 1.85 kilometers per hour. However, most



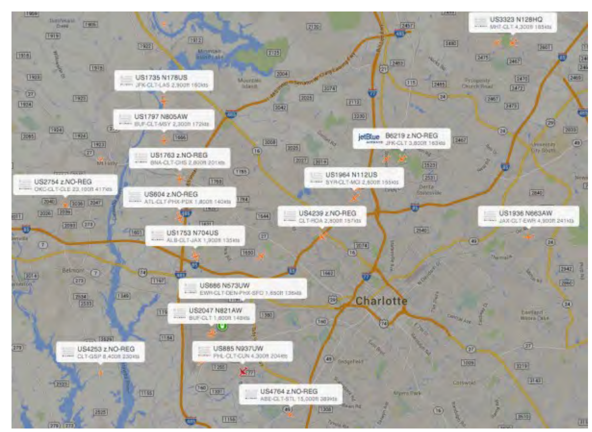
students will not recognize KTS. This value can be used to evaluate the calculated speed, but should not be used directly for this activity).

5) Choose one aircraft, and time it as it goes from one point of interest to the other. Students should choose a range of time somewhere between 1 and 5 minutes to ensure that enough time is collected for accurate calculations. (Caution: Students should not choose planes travelling in significantly curved paths, or near airports, where speeds change).
6) Make sure that students choose recognizable points of interest, because students will next need to determine the distance crossed by re-locating and measuring the distance between the two points using Google Maps.
7) To measure the distance between the points, follow the example procedure below:
    a. Go to www.google.com/maps to get to Google Maps
    b. As an example, a student might have observed a plane (in the pictures below) go from Holtwood, Pa. to Whitehall, Md. in a period of 2.387 seconds.
    c. Students should find, on Google Maps, the initial point of the plane's timing.
    d. Right-click on the initial location to get a menu. Choose "Measure distance." The second point of interest can be clicked, and an estimate given for the distance between the two points. In this example, the distance is 22.58 miles.
    e. To make speeds more relevant, it is suggested that students convert time in seconds to hours. Using a simple conversion, student can find that 2.387 s is equivalent to 0.03978 hr.
    f. Using the equation derived from activity 1.a, Distance = (Speed) Time, and re-arranging for speed, students can get Speed = Distance/Time. In this example, Speed = 22.58 mi / 0.03978 hr, which is equal to 567.6 mi/hr. This is a very reasonable estimate! Most commercial airplanes cruise at about 550 mi/hr.



8) Take a broader look at the flight paths across the United States.
    a. Do you notice any patterns for eastward or westward flights?
    b. How do flight paths change upon entering or leaving airports?



Lesson 2 – *Farther*

- Activity 2.a - *Flight Paths*
- Activity 2.b - *Round Globe, Flat Map*

With increased speed comes the potential for increased distance of travel. People can now – literally – travel to all ends of the earth and back, in the span of a relatively short time. As humans begin to extend their presence to all parts of the globe, remote locations really are no longer remote at all.

Traveling over long distances, however, can require complex navigation. This is made more difficult by the fact that people typically use flat maps to represent a spherical world. Activity 2.a asks students to use a globe and string to help them visualize flight paths for global travel, using the "Great Circle" method. Students transfer their models onto a two-dimensional map of the world to get a better understanding of how pilots choose the most efficient flight routes. Students

Famous Firsts in Aviation

America has a long list of "firsts" in aeronautics:

- Orville and Wilbur Wright - flew the first heavier-than-air machine, 1903
- Harriet Quimby - first U.S. woman pilot, 1911
- Eugene Jacques Bullard – first U.S. black combat pilot – served France in WWI, 1917
- Bessie Coleman – first black female pilot, 1921
- Maj. Frederick Martin – first round-the-world flight, 1924
- Amelia Earhart – first woman's solo transatlantic flight, 1931
- Ruth Rowland Nichols – first airline pilot, 1932
- Capt. Charles Yeager – first pilot to break speed of sound, 1947
- Olga Custodio – first Hispanic female US military pilot, and first Hispanic commercial airline captain, 1988.

Perhaps one of the earliest but least well-known people in aviation research was Pearl Young. She was hired in 1922 as a physicist at the NACA Langley Memorial Aeronautical Laboratory (later renamed NASA Langley Research Center), and soon become the Chief Technical Editor, at a time when there were only a few dozen women physicists in the country, and only one other woman in federal government. She served the NACA through its transition into NASA, over a span of 28 years. Langley also hired women as computers from the 1930s to the 1970s. See "When the Computer Wore a Skirt," for more information, at:
http://crgis.ndc.nasa.gov/historic/Human_Computers

also practice the use of modeling to estimate distances between major flight airports, and then check both their route path and predicted distance by comparing their results to a Web app. Activity 2.b has students study the problems associated with develop a flat world view. Students create their own 2-D models from an orange peel and/or a punching balloon, then build 3-D models to estimate which type of flat map best represents the spherical earth.

Activity 2.a – Flight Paths

Goal: Estimate flight paths for various origins and destinations. Estimate flight distance for various origins and destinations.

Key Concepts: Distance, Time, Speed, Mapping

Grade Level: 5-12

Subjects: Math, Physical Science, Physics, Earth Science

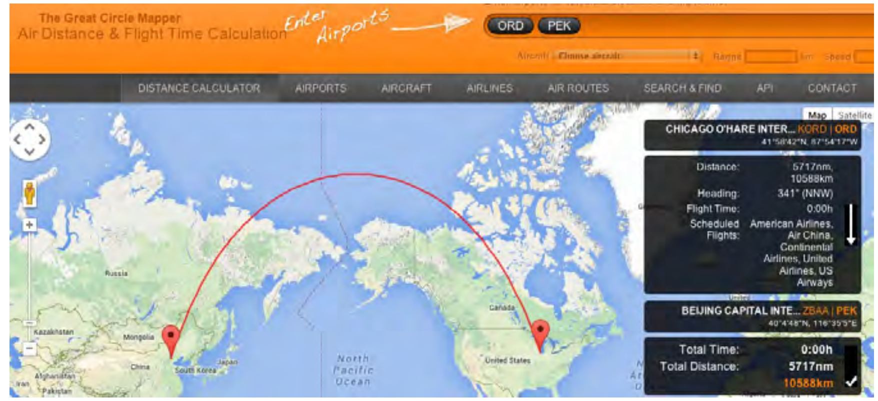
Materials: Globe, string, meter stick or ruler, world map (paper)

Procedure:

1) Split students into small groups, each with a set of their own materials (including a globe).
2) On their map, ask students to draw a straight line from New Delhi to Washington, D.C.
3) Tell students they will now be using a string to actually determine the shortest past from New Delhi to Washington, D.C.
4) Ask students to use their provided piece of string to connect New Delhi to Washington, D.C. (Caution: Students should first let the string lie slack, and then slowly increase the tension so that the string may find the shortest path. This is especially important with globes that might have 3-D surface features.)
5) Discuss the following:
   a. Does the path of the string match with the straight line draw on the map?
   b. What might account for the differences in the two paths?
   c. Which path would a pilot want to fly, in order to save both time and money?
6) The path determined by the string follows what is called "The Great Circle Route," because a plane directed from New Delhi to D.C., without stopping, would pass it by and make a the smallest diameter circle around the world.


Arctic Ocean
Arctic Ocean
Greenland
Iceland
Finland
Sweden
Norway
Russia
Canada
Poland
Germany
Ukraine
France
Kazakhstan
Mongolia
Italy
Spain
Turkey
North Pacific Ocean
United States
North Atlantic Ocean
China
Japan
South Korea
Iraq
Iran
Afghanistan
Pakistan
Algeria
Libya
Egypt
Saudi Arabia
Mexico
India
Thailand
Mali
Niger
Sudan
Chad
Nigeria
Ethiopia
Venezuela
Colombia
DR Congo
Kenya
Indonesia
Papua New Guinea
Tanzania
Brazil
Peru
Angola
Bolivia
Namibia
Madagascar
Botswana
Indian Ocean
South Pacific Ocean
South Atlantic Ocean
Australia
Chile
South Africa
Argentina
New Zealand

7) Next, inform students that the flight path from New Delhi to Washington, D.C. is about 12,080 km. Ask them to determine, based on the required string length, how many km are represented by each centimeter of string on their globe.



8) Ask students to draw the flight paths of the following transits, and to determine the distance between the two points. Put the calculated distance in the "Calculated Distance" column. Give students the Actual Distance only after they have done their calculations, to see if they are correct. Alternatively, allow students to check their answers (flight paths and distances) by using The Great Circle Mapper, found at http://www.greatcirclemapper.net/ or get their app from the iTunes Store. (Caution: The apparent curvature of more vertical flight paths (ex. Los Angeles to Santiago) might not be as evident to students on the globe as on the suggested web site. This has to do with the typically conical nature of the 2-D maps that people are used to seeing. See activity 2.b for more information on this.

Origin	Destination	Calculated Distance (km) (show work)	Actual Distance (km)
London (LGW)	Chicago (ORD)		6,361
Los Angeles (LAX)	Santiago (SCL)		8,963
New Delhi (DEL)	New York (JFK)		11,777
Cape Town (CPT)	Rio de Janeiro (GIG)		6,097
Madrid (MAD)	Washington, DC (IAD)		6,111
Cairo (CAI)	Melbourne (MEL)		13,938
Los Angeles (LAX)	Accra (ACC)		12,204
Toyko (NRT)	Miami (MIA)		12,020

9) Students are likely to find that their calculated distances do not quite match up with all of the actual values, and that realistic flight paths do not always go exactly these distances. Discuss the possible reasons for this, including:
   a. Imperfect spherical shape (Due to rotation and inertia, the diameter of the Earth measured across the equator tends to be wider than that measured from pole to pole, causing the Earth to be a flattened sphere).
   b. Weather conditions
   c. Jet stream location (It is preferable to fly *with* the direction of a jet stream).
   d. Air traffic congestion
   e. Risk when travelling over war zones or areas with heightened political tensions

About NASA Aeronautics

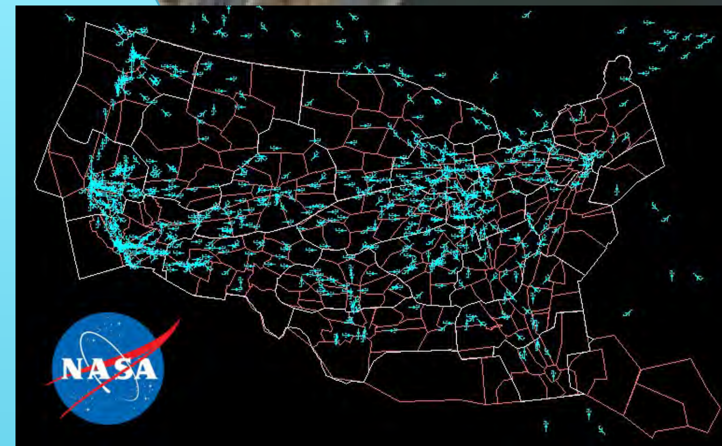
NASA's Aeronautics Research Mission Directorate (ARMD) works to solve the challenges that still exist in our nation's air transportation system: air traffic congestion, safety, and environmental impacts.

Solutions to these problems require innovative technical concepts, and dedicated research and development. NASA's ARMD pursues the development of new flight operation concepts, and new tools and technologies that can transition smoothly to industry to become products. NASA's world-class laboratories and wind tunnels across the country led to fundamental advances in aeronautics that spawned a world-leading civil aviation manufacturing industry, propelled supersonic flight, supported national security during the Cold War and laid the foundation for modern air travel and the space age.

Our focus now includes conceiving new aircraft and engines that burn dramatically less fuel, operate even more quietly and generate far fewer emissions. At the same time, working with our industry and government partners, NASA will continue efforts to improve and modernize the nation's air traffic control system so it can safely handle the additional air traffic and new types of air vehicles expected in the future.

NASA as already made decades of contributions to aviation. We continue to develop solutions to benefit the flying public every day.

A Day in the Life of Air Traffic Control over the US



With the massive increase in passenger and air cargo, the skies have become a very busy place. NASA Aeronautics works hard to solve the problems of air traffic congestion. Modeling air traffic over a span of time to determine problems point is integral to managing the network of highways in the sky. Help students to see how busy the airspace over the U.S. really is by watching the video, “A Day in the Life of Air Traffic Control over the U.S.”

1) Have students go to: http://www.aviationsystemsdivision.arc.nasa.gov/research/modeling/facet.shtml
2) Ask students to read the article about NASA’s work with FACET to manage air traffic across the nation.
    a. What is FACET?
    b. How does it benefit the environment, economy, and education?
3) Ask students to play the linked video (click view Facet Animation) showing 24 hours of air traffic over the continental United States. http://www.aeronautics.nasa.gov/videos/facet24.mov and answer the following questions:
    a. From which direction do most of the flights leave/arrive? (SE, NE, NW) Why don’t they go directly N, S, E, and W?
    b. The simulation begins at 0 UTC (Coordinated Universal Time), which corresponds to 7 p.m. Eastern Standard Time. Describe, in words, what happens to the density of flight traffic, on average, during the 24 hours?
    c. Draw a simple graph showing the average flight density versus time.
    d. What are the three or four busiest airports in the US?
4) What are two or three practical solutions to decreasing traffic congestion in the U.S.?

Activity 2.b – Smart Skies

Goal: Model the difficulties and problems associated with air traffic control using mathematics and simulations. NASA has developed two comprehensive curricular modules, titled *Fly By Math* and *Line Up With Math*, as well as a free app, *Sector 33* that can be used independently of lessons. The fully developed teacher guides, student worksheets, and associated simulations can be found here: http://smartskies.nasa.gov/

Key Concepts: Air Traffic Control, Linear Equations, Kinesthetic Modeling of Motion

Grade Level: 5-12

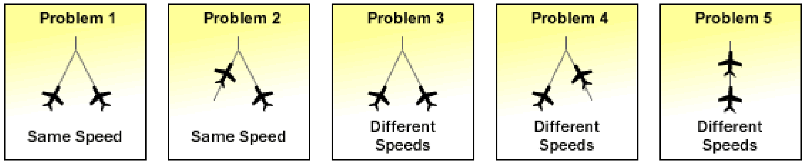
Subjects: Math, Physics

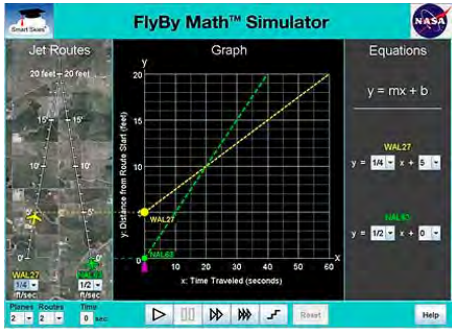
Materials: Computer or mobile device with internet connection

Procedure:

Fly by Math

Fly By Math makes use of 5 different scenarios of airplanes approaching each other. Students are provided with each scenario, and asked to determine a variety of information about the airplanes, including the time it will take for each plane to merge onto the main route (problems 1-4) and the time when the trailing plane will catch up to the leading plane (problem 5).





Students will solve each of the above problems using up to six different calculation methods:

- Counting feet and seconds using a jet route diagram
- Drawing blocks to make a bar graph
- Plotting points on two vertical number lines
- Plotting points on a Cartesian coordinate system
- Deriving and using the distance-rate-time formula
- Graphing two linear equations

In addition, students can use the *Fly By Math Simulator* to plot airplane distance versus time, and see the effects of changing speed and starting distance from the origin by modifying variables in the linear equation.

Line Up With Math

Line Up with Math makes use of six different problems about airplanes that must be carefully aligned to be within three nautical miles of each other upon approach into an air sector – an important, but sometimes difficult feat, to ensure that plane distances are both safe as well as efficient. Students must find solutions to problems involving two-plane and three-plane conflicts resolved with route changes, two-plane and three-plane conflicts resolved with speed changes, and three-plane, four-plane, and five-plane conflicts resolved with speed changes or with speed and route changes. Students use an online air traffic control simulator, supported by student worksheets, to model the movements and placements of airplanes, and to change their speeds and/or routes.

Students and the wider community can access the benefits of *Line Up With Math* with the stand-alone *Sector 33* app for iOS and Android mobile devices.

Sector 33

Sector 33 is an app that allows users of all backgrounds to experience what it is like to manage air traffic control.

Sector 33 can be downloaded, for free, from the Apple iTunes Store and the Google Play Store.

iOS iTunes Store: https://itunes.apple.com/us/app/sector-33/id486953105?mt=8
Android Google Play Store: https://play.google.com/store/apps/details?id=gov.nasa.stem

Sector 33 App Description

It's a stormy Friday evening in Northern California as the evening rush of air traffic fast approaches the San Francisco Bay Area. All the flights going to San Francisco airport from the east pass through "Sector 33" – YOUR sector of the airspace.
As the lead air traffic controller for Sector 33, you must merge the arriving planes into a single traffic stream as they pass over Modesto, California on the western edge of your sector. The planes must be properly spaced and arrive over Modesto as soon as possible. Every

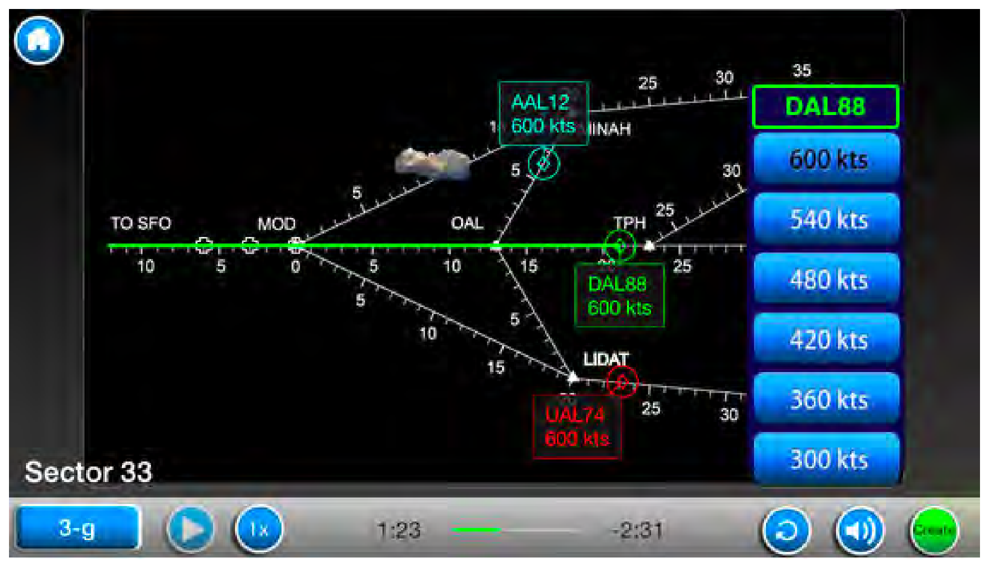
minute you delay a plane during the traffic rush, that delay is passed on to ALL the other planes flying behind it. Although time is of the essence, to assure safety, the planes must NEVER violate minimum spacing requirements.

Can you handle Sector 33?

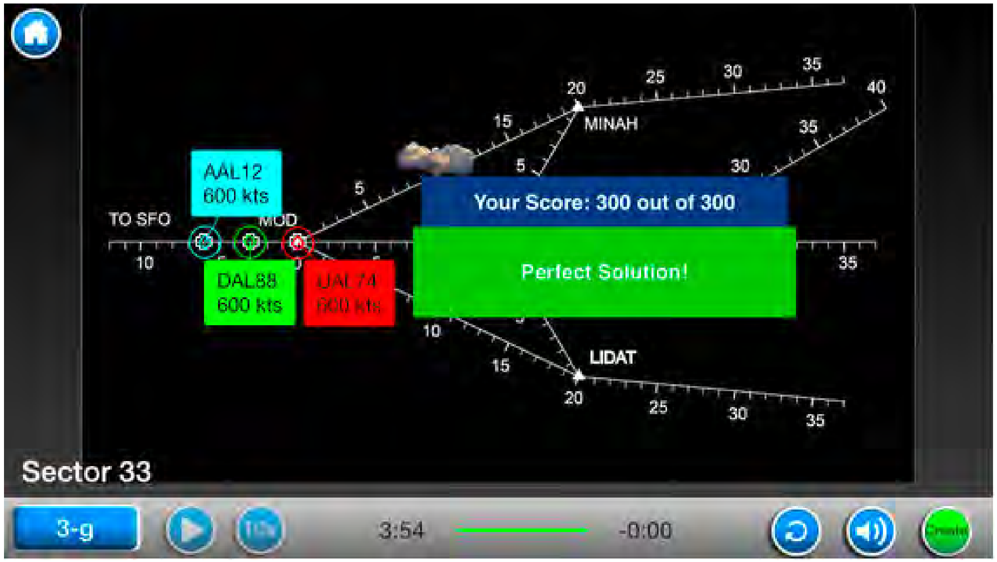
Features:

- 35 problems
- Two to five airplanes
- Speed and route controls
- Thunderstorm obstacles
- Four levels of controller certification
- Locked levels
- Scoring for each problem
- Scoring for each certification level
- In-game introduction
- In-game hints
- Help section
- Extra videos
- Links to related websites
- Links to social websites

In the U.S. Sector 33 airspace, three main air highways merge together over Modesto. In order to ensure that the planes are efficiently trafficked upon arrival at their destination airport – to save fuel and decrease the incidence of delays – all of the planes must be within three nautical miles of each other, but no less than two nautical miles in order to ensure safety. In the scenario, the user must provide instructions to each of the airplanes on their speed and route. The game player must use mathematical strategy, ratios, and time sequencing by thinking ahead. Failing to do so results in a loss of points, and, in the real world, possible tragedy.



As an example, Level 3-g is displayed. Three airplanes, AAL12, DAL88, and UAL74 are approaching Modesto at the same speed of 600 knots. AAL12 is approximately 19 nautical miles from Modesto, while DAL88 is 21 nautical miles away, and UAL74 is 23 nautical miles away if it follows the southern-most path, or 26 miles away from Modesto if it directed to branch off toward OAL (see the previous image). Because all airplanes must achieve a spacing of 3 nautical miles away from each other by the time the last one plane reaches Modesto, there are a variety of possible solutions, as all of the planes' speeds are relative to one another. However, not all solutions are viable, given weather conditions that block certain pathways, and the inability to speed up planes (only decrease speed from a maximum of 600 knots).



Although this may appear quite complex, students are built up from simple to more complex scenarios along the way, and are given a variety of helpful hints:

1) Sending a plane along an intermediary branch (i.e. MINAH to OAL or LIDAT to OAL) adds an addition three nautical miles to the total distance.
2) Speed options decrease by 60 knots each (i.e. from 600 knots to 540 knots). Because the definition of one knot is "one nautical mile per hour," a decrease in speed by 60 knots decreases the distance covered in one hour by one-sixtieth of the distance covered per hour (i.e. the distance covered in one minute).

In reference to the example problem in level 3-g above, one possible solution would require the user to :

1) Decrease DAL88's speed to 540 knots for one minute, to increase distance from AAL12 by one more nautical mile.
2) Send UAL74 from LIDAT to MOD, and decrease speed to 540 knots for two minutes, or 480 knots for one minute, to space UAL74 three nautical miles away from DAL88.

This engaging, educational game demonstrates to students not only the complexities of managing relative speeds and distances, but demonstrates, on a small scale, how difficult it can be to safely and efficiently manage systems of hundreds of plans that might pass through a single air space each day.

NASA ARMD is currently working on a variety of computer-based algorithms that can ease up the burden on traffic controllers. Read about NASA's current research on ASTAR, a prototype tool that allows planes to play "follow-the-leader" instead of relying only on direct traffic control communications: http://www.aviationsystemsdivision.arc.nasa.gov/research/tactical/atd1.shtml

Activity 2.c – Round Globe, Flat Map

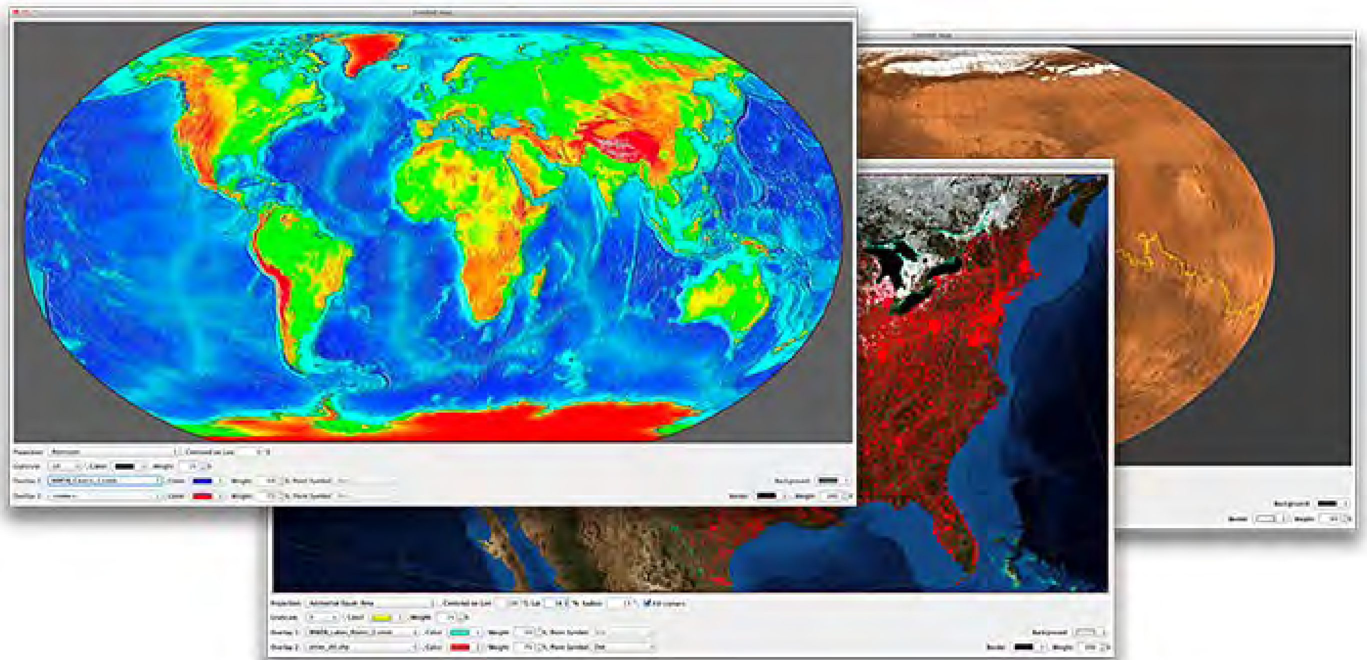
Goal: Create and model a flat map from a spherical shape. Recognize that flat maps are not problematic for air traffic control at the local level, but mapping flights over a long distance onto a flat map is troublesome.

Key Concepts: Mapping, Euclidean versus non-Euclidean Geometry

Grade Level: 5-12

Subjects: Math, Physical Science, Physics, Earth Science

Materials: Large oranges or round citrus fruits, marker, globe, scissors, tape, visuals of different types of map projections (consider downloading the free NASA G.Projector software to display over 100 different types of map projections), map cut-out.

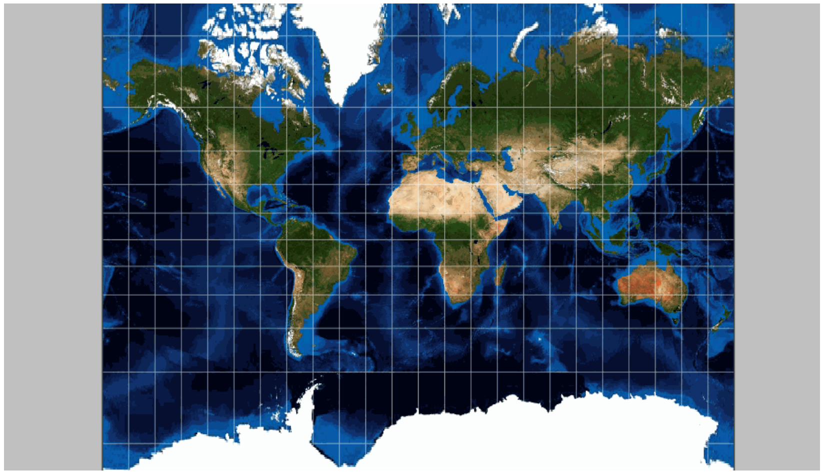


http://www.giss.nasa.gov/tools/gprojector/

Procedure:

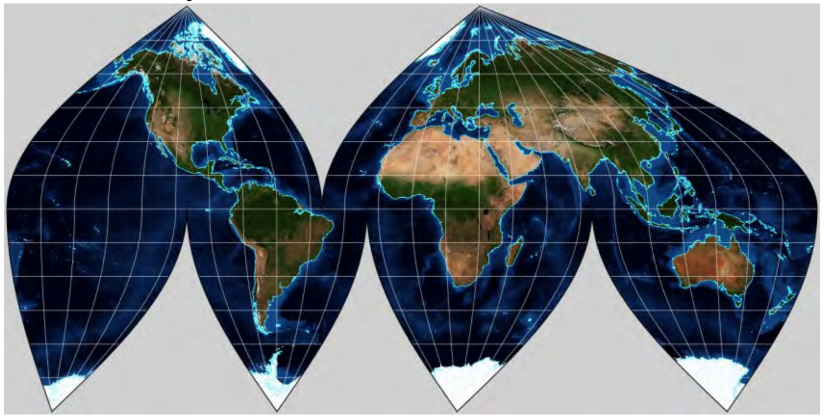
1) Show students a variety of flat maps of the Earth. Ask students why they think scientists prefer to use a variety of different projections. If appropriate, help students to recall that there is a difference when visualizing flight paths, as in the "Great Circle" activity 2.a.

Mercator Projection



Airy Projection

Sinusoidal Projection



Polyconic Projection

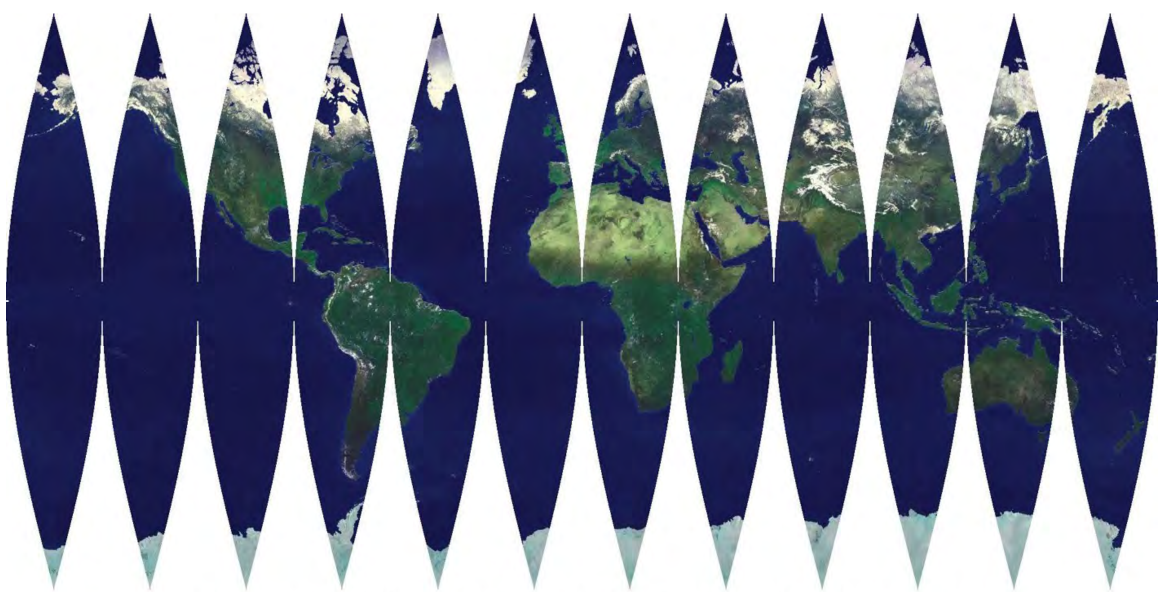
2) If appropriate to the age level, ask students to draw a crude map of the Earth's continents on the outside of an orange (before it is peeled).
3) Ask students to flatten their spherical maps. This can be accomplished by carefully peeling the skin of the orange using a butter knife to make sections. Students should notice that a curved surface cannot be flatted on its own. The orange peel can be carefully flattened, but it is expected that the peel will rip.



4) Once students have flattened their items, ask them to notice where most of the cutting or ripping had to occur, and in which direction. Students should find that most of the cuts or rips occurred near the top and bottom ends of the map, going vertically. (Caution: This is not true if the incision in the globe goes along its "equator," rather than across it).


5) There are a number of important observations teachers can help students to note, in relation to activity 2.a:
    a. Horizontal flight paths experience much more curving on a flat map than do vertical flight paths.
    b. Horizontal flight paths between two distant points experience much more curving on a flat map than between two closer points.
6) Ask students to compare their flattened objects to the maps first introduced to them. Which map appears to be most similar to the flattened balloon or orange peel? Which map likely shows the best visual of the earth in a two-dimensional form?
7) Despite the fact that rectangular, square maps are not ideal, they are most frequently used. Two of the more common non-rectangular maps are the Robinson's Map and the Goode's Map. Discuss with students how these two maps compare.
    a. Robinson's map shows Greenland nearly half the size of the U.S.! Goode's map shows a better proportion.
    b. Robinson's map shows Antarctica as being huge as well!
    c. Both maps show nearly the same proportions near the equator. (As with the balloon and the orange peel, most of the physical problems with converting a spherical shell into a flat plane occur near the edges, in a vertical fashion.
8) The ultimate test of a good flat map is to see if it can be converted into a 3-D sphere. Using an enlarged version of each of the following maps, try to have students make the map into a sphere. Having students rank the following maps for their two-dimensional accuracy. (Students will find that the Mercator map can make a cylinder, which is accurate for the equator, but not for the poles. The Airy projection might be fairly accurate, but it does not allow the whole globe to be viewed on a map. The polyconic projection is somewhere between the Mercator and the Airy projections, but it not quite as accurate as the Sinusoidal Projection.)

9) Perhaps the best visualization of the globe in two dimensions is demonstrated in the map below. Ask students to try building this globe. Discuss with students the benefits – and the drawbacks – of this kind of map. (Consider that it is distracting and splits up important geographical areas that really are connected).

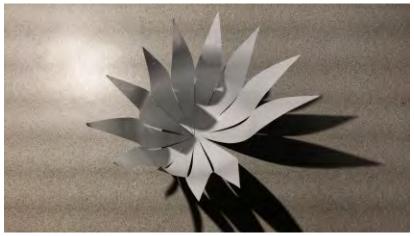


Based on artwork produced by Mitchell N. Charity using NASA & USGS images. Released under Creative Commons/Share Alike

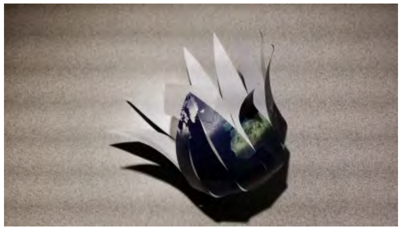
Visual building instructions:

1. Cut out the map cut-out on the following page.
2. Choose one pole, and place a single piece of tape on one of the pole's "petals" to begin gathering up all of the petals for that pole. Add additional tape as necessary.

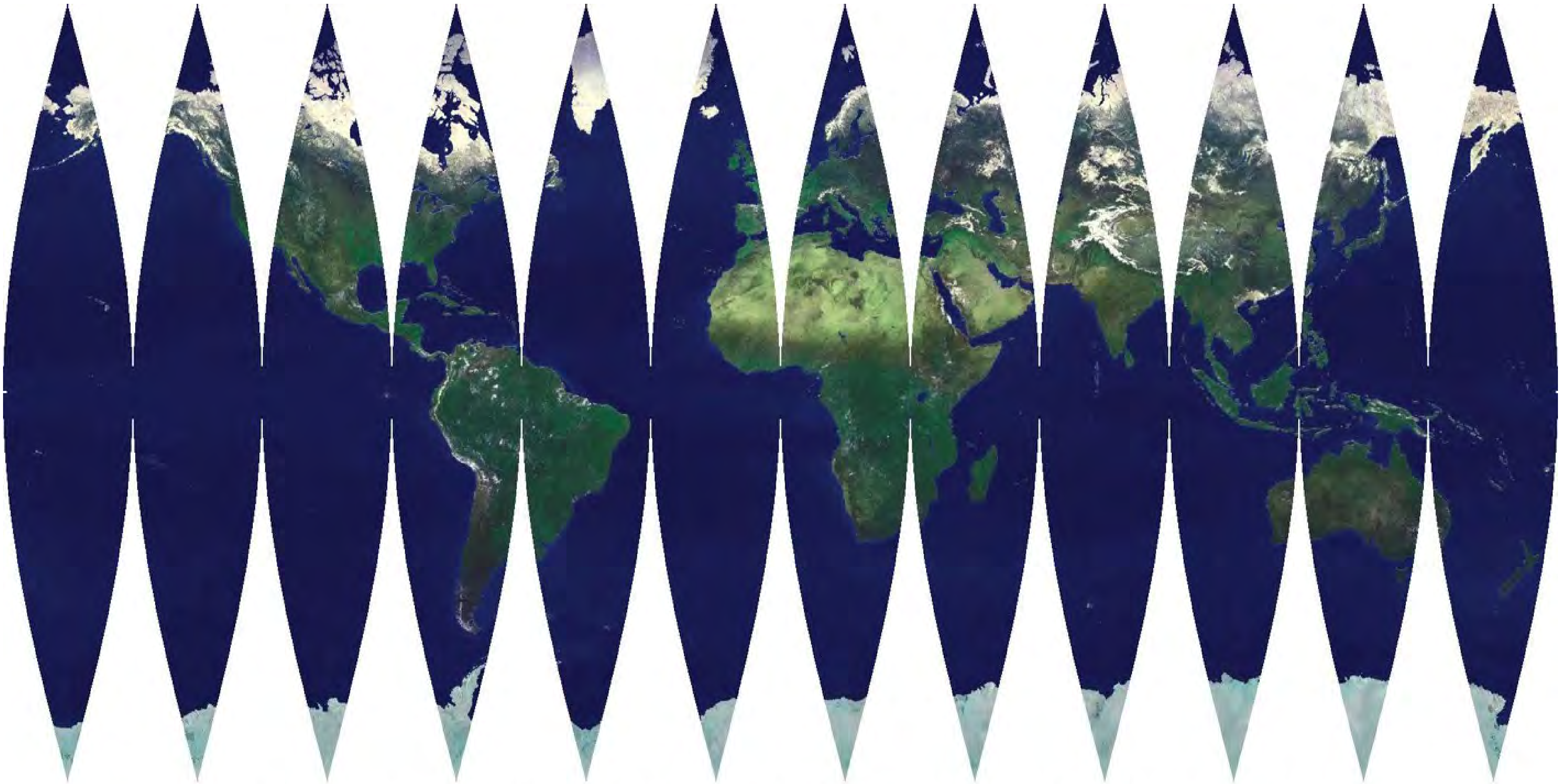




3. Begin collecting up the petals for the opposite pole, and add tape as necessary.




4. The final object should be a very spherical globe.



Lesson 3 – *Connected*

Although we often fail to recognize it, aviation has connected us in ways that deeply impact our daily lives. When you fly to your favorite destination, consider the places you can go, things you can learn, and people you can meet. Before the invention of the airplane, you would likely have been unable to travel very far at all in your lifetime. Even if you do not fly, consider the people and ideas that have come to you! Without airplanes, your world and your life experiences would be very limited indeed.

A visit to your common grocery store is now an international experience brought to you by the power of flight. When you walk into a grocery store, take note of the fruits and vegetables available to you year-round and that could otherwise not be grown in your geographic region. Most of these items transited the air cargo system in order to arrive as fresh as possible and still maintain a reasonable shelf life.

Great Travel in Classic Literature

I travel not to go anywhere, but to go. I travel for travel's sake. The great affair is to move.

- Robert Louis Stevenson, *Travels with a Donkey in the Cevennes*

The Little Prince, Antoine de Saint-Exupery

Written by a famous pioneering French aviator, and based on his own experience after being stranded during a flight, *The Little Prince* is an all time best-selling story of a small boy who falls from the sky to a desert on Earth, and meets a stranded pilot.

Other great travel stories include:

The Chronicles of Narnia, C. S. Lewis

Gulliver's Travels, Jonathan Swift

Hitchhiker's Guide to the Galaxy, Douglas Adams

The Hobbit & *The Lord of the Rings*, J. R. R. Tolkein

Robinson Crusoe, Daniel Defoe

A journey is a person in itself; no two are alike… We find after years of struggle that we do not take a trip; a trip takes us.

- *John Steinbeck,* Travels with Charley: In Search of America

Perhaps surprisingly, even the local farmer's market is not immune to the impact of aviation. Locally grown flowers might have been germinated from seeds flown from South America, and the farmers who sustain the market might make a portion of their income from air-shipping some of their produce around the nation or around the world.

Although not all imported or exported products are shipped by air, most perishable items do travel by plane because of the speed of air cargo in comparison to ground- or water-based transportation. When making purchases of produce that is out of season locally, it can be fairly easy to deduce if a fruit or vegetable has been primarily shipped by air, water, or ground transportation, depending both upon the distance from the item's origin as well as how quickly the produce ripens and spoils. For example, berries, cherries, peppers, and asparagus are among some of the most frequently air-shipped produce because of their short shelf life. Dry onions and coffee beans are more likely to be shipped more cheaply by boat or ground because of their weight, durability, and ability to withstand long transport times.

In the following activities, students are asked to predict which items are most appropriate as air cargo, and to reflect upon how airplanes connect a global economy. In Activity 3.a, students are given a limited amount of time to "air ship" cargo by paper airplane. Points are awarded for correctly identifying and successfully transporting items that are time-sensitive by the deadline, and points are deducted for attempting to transport items that are either unsafe, or for losing cargo during transit. In activity 3.b, students read a storybook about the beauty of flight, learn world geography, and then create tissue paper flowers to attach to a card to remind their friends about the impact of aviation on our everyday life.

Market photo credit: Tricia Carzoli

Activity 3.a – Air Cargo Game

Goal: Identify likely air cargo items from a bank of items that might be shipped by water or air, then rank and deliver as many-time sensitive air cargo items as possible from the point of departure to the destination. Determine the average speed of shipment.

Key Concepts: Air Cargo, Time Sensitivity

Grade Level: 5-12

Subjects: Social Science

Materials: Cargo item cards (printed on card stock – one set per group of 3-5 students), paper, paper clips, masking tape

Procedure:

1) Split students up into groups of 3-5 students. Demonstrate to students the purpose of the game – namely, to ship air cargo, via a paper airplane, from a point of departure (marked on the floor with tape) to a destination (marked on the floor approximately 10-20 feet away from the departure – although this distance can be accommodated for different age groups).
2) Give students about 15 minutes to create a paper airplane from no more than one piece of paper. (Alternatively, to save time, prepare in advance the paper airplanes for students). Provide students with five blank stock cards to simulate the cargo that must be carried on the airplane. Students may use as many paperclips as they want to attach the cargo to the paper airplane. Students may also include as many blank cards as they want in their plane, so long as it flies.
3) Allow students a few minutes to practice sending the blank "cargo" cards via their airplane from the departure to the destination. At least one team member must go to the destination to pick up the airplane, remove the cargo, and return the airplane by flight back to the original point of departure.
4) Once students are ready with their airplanes (and any back-up airplanes), ask students to reconvene in their groups. Provide each group with cargo cards. Give students 5-10 minutes to sort the cards by what they perceive as the MOST IMPORTANT and MOST TIME-SENSITIVE cargo, and to prepare a plan for what cargo they will intend to ship first.
5) Inform students of the rules of the game:
    a. The game is a race to see who can ship the most important and most time-sensitive cargo in an appropriate amount of time.
    b. Only one airplane may be used in the game, per group, at a time. Backup airplanes may only be used if the previous one is taken out of commission.

c. At least one group member must be at the departure and destination in order to send the aircraft back and forth.
d. At the start of the game, all cargo must be at the departure side.
e. As cargo gets shipped, the group member at the destination must place the card in the appropriate time-slot (called out by the teacher).
f. Students may not walk between the departure and destination, unless the airplane crashes. Then, the student should walk the airplane over to the side it was heading.
g. Cargo that successfully gets to the destination will earn points. (More important, more time-sensitive cargo will earn more points if it arrives in time).
h. Cargo that is unshipped at the end of the game, or that crashes between the departure and destination, or that arrives after its time limit, will earn negative points. (More important, more time-sensitive cargo will earn more negative points if it does not arrive in time).
i. Some cargo should not be shipped! Any cargo that is chosen to be shipped, but should not be shipped, and arrives at the destination, earns negative points.
j. Students may ship as much cargo in one airplane ride at a time as they like, but this involves more risk for an airplane crash.
k. The teacher will choose a reasonable amount of time for the game (usually, 10-15 minutes).
l. Students begin to put arrived cargo in time SLOT A. Half-way through the game, teachers will call “SLOT B,” and students will begin to put their cargo in SLOT B.
m. After time is called, students must tally their points according to the rubric to determine which team most successfully delivered their air cargo.

6) After the points are tallied, debrief the game by discussing why certain cargo was valued as high or low importance, and high or low time-sensitivity, as well as some of the potential consequences of cargo not arriving at its destination on time.
7) Discuss how this game is similar to/different from the real-world difficulties of shipping cargo. Consider the following:
    a. Ideally, cargo is transported both ways, so that the return flight is also full.
    b. Cargo placement must be adjusted for stable flights.
    c. There is a pressing need in the aviation industry for more pilots – we are getting to a point where there is more demand than transportation available (check facts…)

TIME SLOT CARD sorter (to be placed at DESTINATION)

	TIME SLOT A	**TIME SLOT B**
When cargo arrives, place the card in the appropriate slot. Your teacher will call out when to switch slots during the transportation time. At the end of the transportation time, match your cards to the scoring rubric to determine your total score.		

Air CARGO Cards

Roses	**Chrysanthemums**	**Greeting Card**	**Car Batteries**	**Dry Onions**
Tulips	**Human Kidney**	**Human Liver**	**Human Lung**	**Fresh Strawberries**
Clothing	**Lumber**	**Fresh Fish**	**Frozen Fish**	**Live Oysters**
Pet Dog	**Tropical Aquarium Fish**	**Potatoes**	**Kerosene**	**Egyptian Antiques**
Refrigerated Blood	**Frozen Ebola Vaccines**	**Lithium Batteries**	**Frozen Blood Plasma**	**Classified Mail**
BLANK	**BLANK**	**BLANK**	**BLANK**	**BLANK**

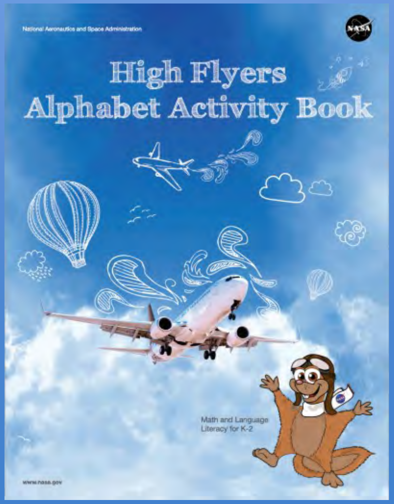
Air CARGO Cards SCORING RUBRIC (Caution: Ensure that students do not forget which time slot the card arrived at!)

Roses **Value: +/-** 2 points **Time:** Slot A **Rationale:** Cut roses have a lifespan of 1-3 weeks.	**Chrysanthemums** **Value: +/-** 2 points **Time:** Slot A or B **Rationale:** Cut chrysanthemums have a lifespan of 1-3 weeks.	**Greeting Card** **Value: +/-** 1 points **Time:** Slot A or B **Rationale:** Minimal impact if it gets lost or arrives late.	**Car Batteries** **Value: -** 5 points **Time:** Should not be air shipped **Rationale:** Liquid batteries pose risk for shortage/leakage.	**Dry Onions** **Value: +/-** 1 points **Time:** Slot A or B **Rationale:** Dried onions do not spoil for 1-2 months.
Tulips **Value: +/-** 2 points **Time:** Slot A **Rationale:** Cut tulips have a lifespan of X to X days.	**Human Kidney** **Value: +/-** 5 points **Time:** Slot A or B **Rationale:** Human kidneys are one of the longest surviving organs.	**Human Liver** **Value: +/-** 5 points **Time:** Slot A **Rationale:** Refrigerated human livers can survive for only 7-18 hours outside of the body.	**Human Lung** **Value: +/-** 5 points **Time:** Slot A **Rationale:** Refrigerated human lungs are one of the shortest surviving organs (5-10 hours).	**Fresh strawberries** **Value: +/-** 2 points **Time:** Slot A **Rationale:** Refrigerated fresh strawberries spoil in 5-7 days.
Clothing **Value: +/-** 2 points **Time:** Slot A or B **Rationale:** Generally not shipped by airplane.	**Lumber** **Value: +/-** 1 points **Time:** Slot A or B **Rationale:** Generally not shipped by airplane.	**Fresh Fish** **Value: +/-** 2 points **Time:** Slot A **Rationale:** Fresh fish typically are not shipped by air.	**Frozen Fish** **Value: +/-** 3 points **Time:** Slot A or B **Rationale:** Frozen fish will not perish easily.	**Live Oysters** **Value: +/-** 2 points **Time:** Slot A **Rationale:** Live oysters can only survive for 1-2 weeks.
Pet Dog **Value: +/-** 4 points **Time:** Slot A **Rationale: Dogs need continuous care and immediate assistance after landing.**	**Tropical Aquarium Fish** **Value: +/-** 4 points **Time:** Slot A **Rationale:** Live fish need continuous care and immediate assistance after landing.	**Potatoes** **Value: +/-** 1 points **Time:** Slot A or B **Rationale:** Potatoes will rot in two to three weeks if stored in cool, dark area.	**Kerosene** **Value: -** 5 points **Time:** Should not be air shipped **Rationale:** Highly flammable.	**Egyptian Antiques** **Value: +/-** 5 points **Time:** Slot A or B **Rationale:** High value.
Refrigerated Blood **Value: +/-** 2 points **Time:** Slot A **Rationale:** Refrigerated whole blood has a shelf life of three to four weeks.	**Frozen Ebola Vaccines** **Value: +/-** 5 points **Time:** Slot A **Rationale:** Although not immediately perishable, could thaw, and is very important.	**Lithium Batteries** **Value: -** 3 points **Time:** Should not be air shipped **Rationale:** Lithium batteries are highly reactive, could be shorted.	**Frozen Blood Plasma** **Value: +/-** 2 points **Time:** Slot A or B **Rationale:** Frozen plasma has a shelf life one year.	**Express Classified Mail** **Value: +/-** 5 points **Time:** Slot A **Rationale:** High importance.
BLANK	**BLANK**	**BLANK**	**BLANK**	**BLANK**

Careers in Aeronautics

With an ever-increasing demand for passenger and cargo air transport, there are many career opportunities within the field of aviation and aeronautics, from engineers who design aircraft and manage air traffic, to pilots who fly the aircraft, to leaders who set industry standards for safety. However, aeronautics includes much more than airplanes; aeronautics is part of a much larger field of study known as aerospace studies, which relate flight science to space travel, and includes topics such as balloons, gliders, parachutes, helicopters, and UAV's and drones, among others.

The NASA High Flyers Alphabet Activity Book introduces even the youngest children to the many topics associated with aeronautics.



Activity 3.b – Friends & Flowers

Goal: Identify the origin of a variety of imported objects, make a paper flower and card to give to a friend or family member.

Key Concepts: Connectivity

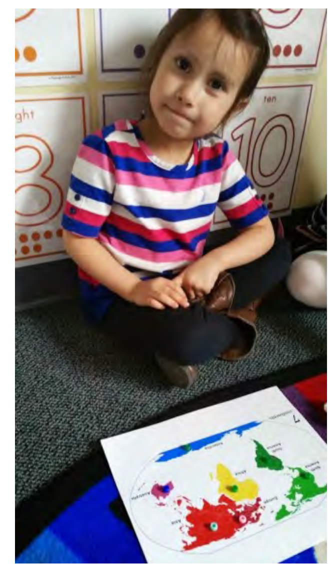
Grade Level: Pre-K – Early Elementary

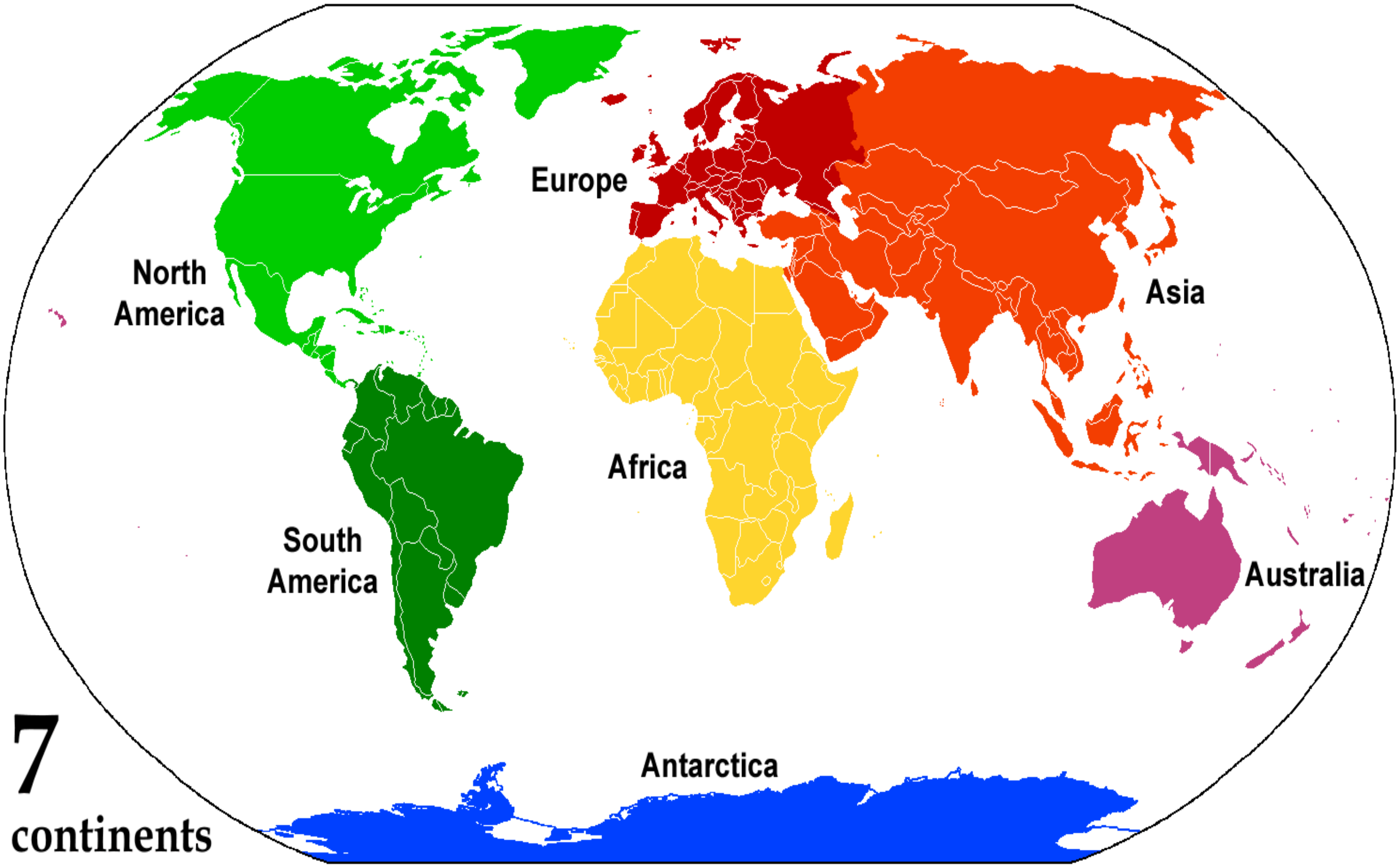
Subjects: Social Science, Geography, Art

Materials: *With You When You Fly* digital book (appended to this document), projector, map of continents, beads or small objects, international objects (ideally, one from each continent – examples provided below), tissue paper, ribbon, scissors, card template, cardstock/paper

Procedure:

1) Read "With You When You Fly" to get children to start thinking about speed, distance, and the things we now get from around the world because of the power of flight.
2) Provide each student (or small group of students) with a map of the continents and seven beads or small objects (buttons, etc.).
3) Show students – one at a time – examples of items that have been imported by aircraft. Depending upon the age, ask students to guess where the object came from. Besides souvenirs from international travel, the following are some examples of items that can be displayed:
    a. North America – any U.S.-made items, preferably perishable or time-sensitive items that are likely to have been flown in an aircraft.
    b. South America – fruits/vegetables, coffee, flowers
    c. Europe – chocolates, specialty foods, flowers
    d. Asia – clothing, specialty foods
    e. Africa – diamonds (i.e. wedding bands), flowers
    f. Australia – diamonds
4) As the nation or continent of origin is identified, ask students to identify the continent by placing a bead or small marker object on the map. Help younger students to identify the continents by referring to both the continent name as well as the color of the continent on the map.

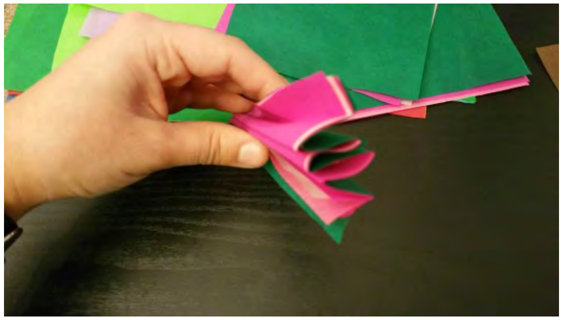


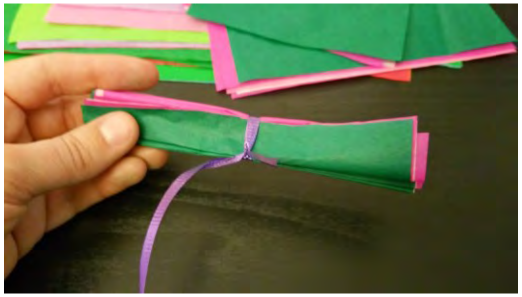


7 continents

Credit: Alex Covarrubius, open source

5) Flowers are one of the most internationally transported perishable items. Explain to students that they will be making tissue paper flowers to attach to a Valentine that they can give to a friend or family member to help them to share what they learned about the importance of air cargo.
6) Cut out tissue paper squares that are approximately 4” x 4”. Stack approximately 5-7 tissue paper squares one on top of the other. (If appropriate, prepare these squares in advance).
7) Fold the tissue paper back and forth multiple times in a folded-fan pattern.
8) Use a piece of ribbon to hold the folds together by tying it tightly in the middle.
9) Use scissors to scallop the edges of the folds to give the paper the appearance of petals.
10) Carefully unfold the folds.
11) Delicately separate each tissue paper layer and fluff it up until it has made the shape of a flower.
12) Use ribbon to attach the tissue paper flower to a card printed on cardstock.





Flower photo Credit: Tricia Carzoli

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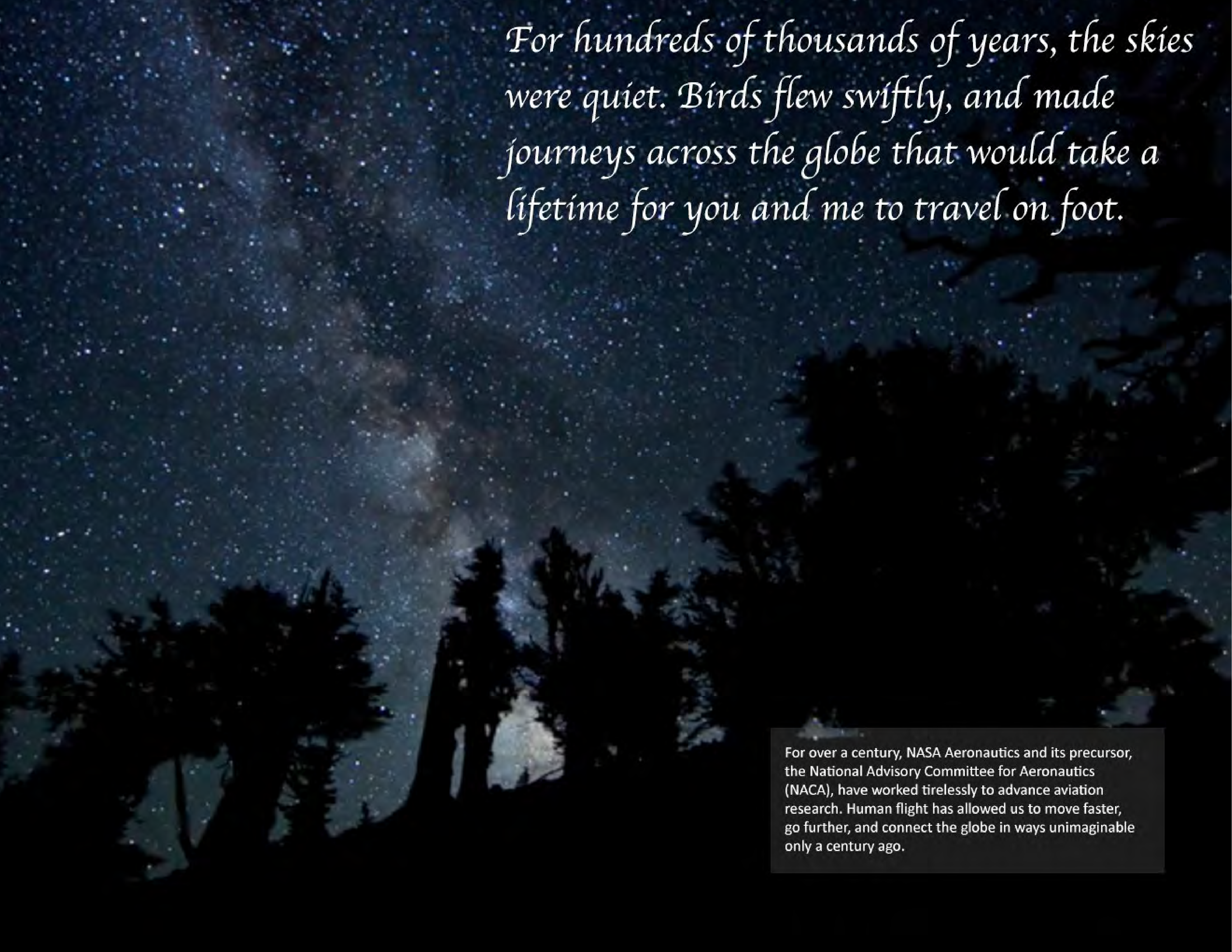
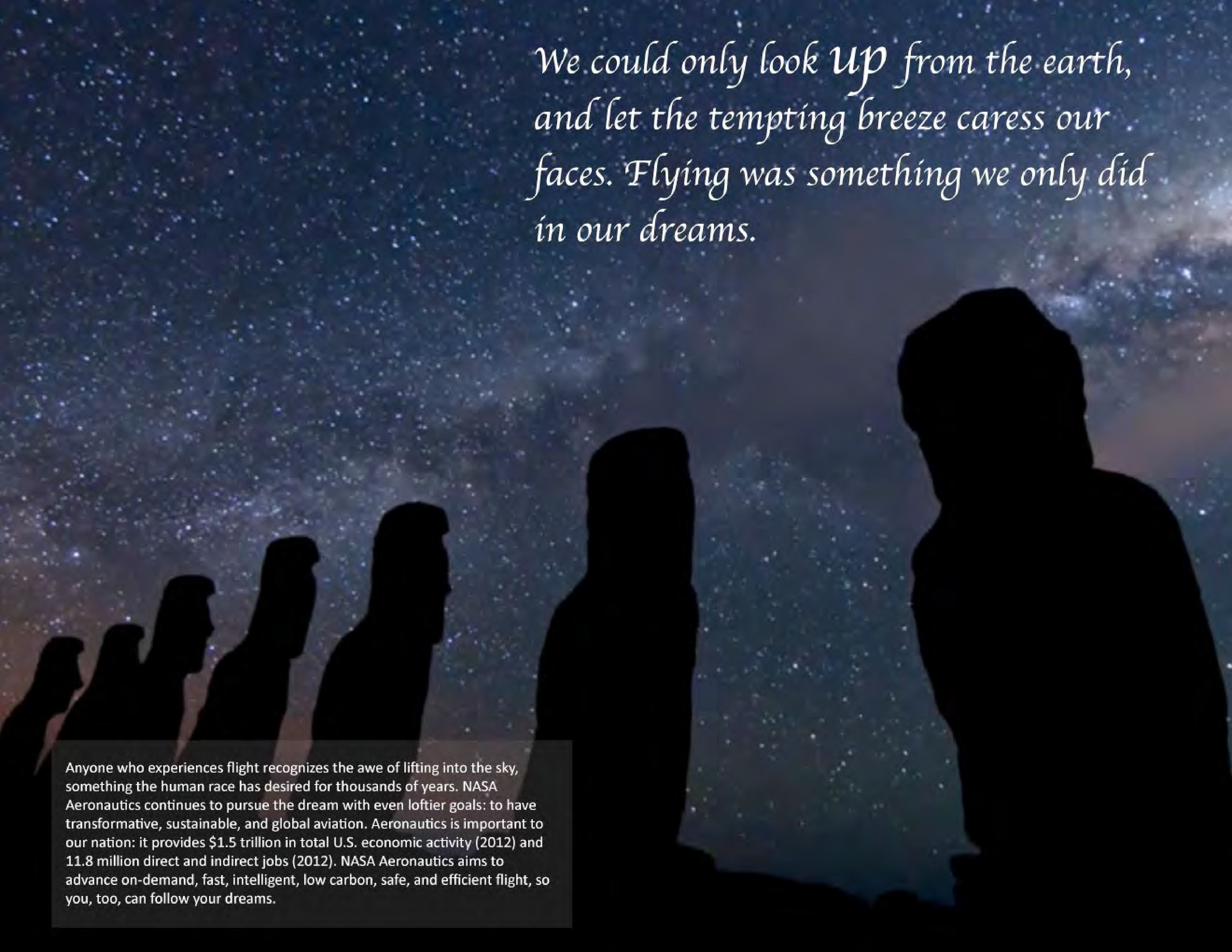
With You When You Fly

A storybook about the wonder of flight.



For hundreds of thousands of years, the skies were quiet. Birds flew swiftly, and made journeys across the globe that would take a lifetime for you and me to travel on foot.

For over a century, NASA Aeronautics and its precursor, the National Advisory Committee for Aeronautics (NACA), have worked tirelessly to advance aviation research. Human flight has allowed us to move faster, go further, and connect the globe in ways unimaginable only a century ago.



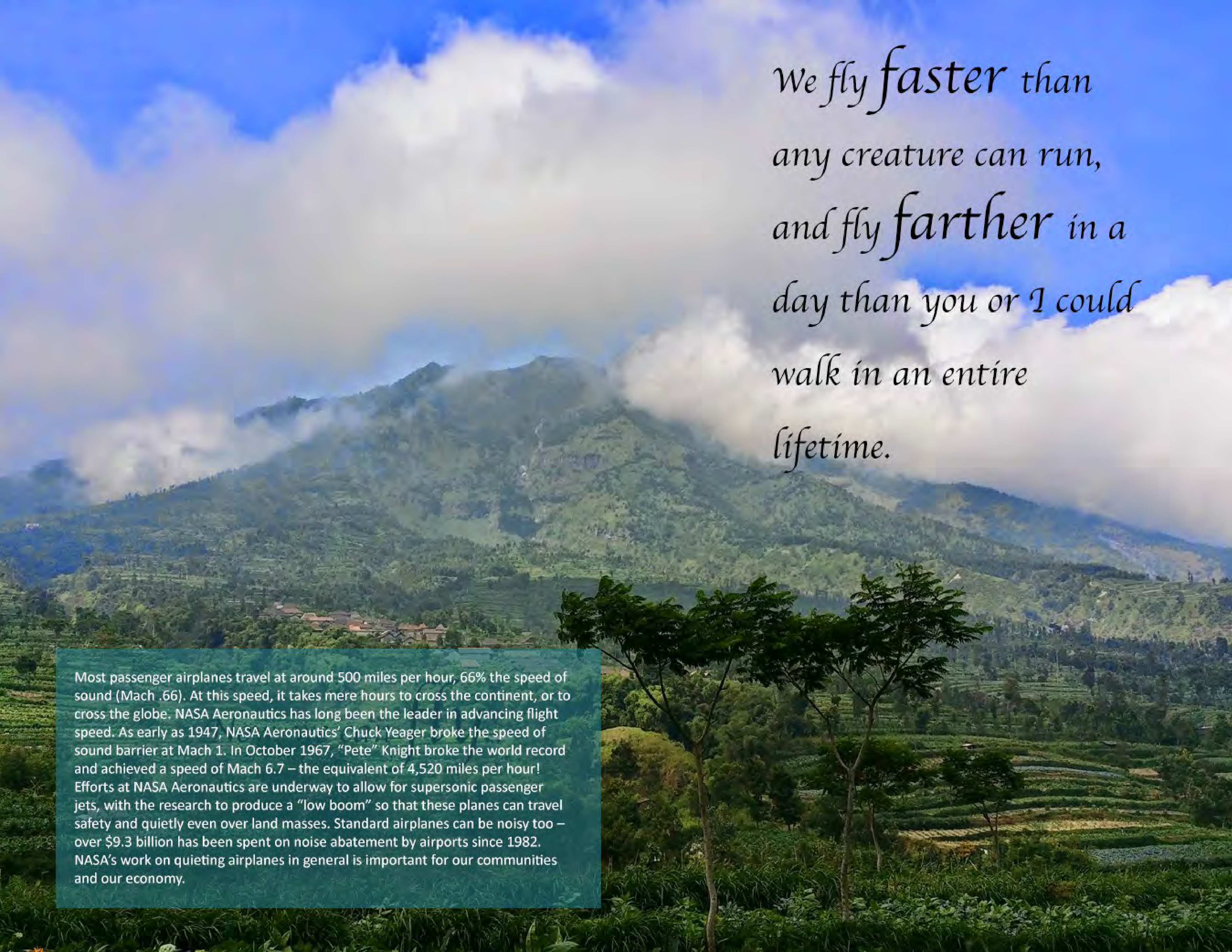
We could only look ***up*** *from the earth, and let the tempting breeze caress our faces. Flying was something we only did in our dreams.*

Anyone who experiences flight recognizes the awe of lifting into the sky, something the human race has desired for thousands of years. NASA Aeronautics continues to pursue the dream with even loftier goals: to have transformative, sustainable, and global aviation. Aeronautics is important to our nation: it provides $1.5 trillion in total U.S. economic activity (2012) and 11.8 million direct and indirect jobs (2012). NASA Aeronautics aims to advance on-demand, fast, intelligent, low carbon, safe, and efficient flight, so you, too, can follow your dreams.

Then, not long ago, fantasy became reality.

Now, we can fly.

We have come a long way since the first heavier-than-air, powered flight by the Wright brothers in 1903. Initially, flight was primarily used to carry correspondence, and the first passenger carriers did not become popular until well after the First World War. Those who did fly were charged hefty fees, exposed to the elements, and the ride was often loud and uncomfortable. In contrast, flight today has become almost commonplace – but no less impressive. Over 741 million passengers fly on U.S. carriers each year (2013). Each day, nearly 1 out of every 100 Americans takes to the skies. NASA Aeronautics works hand-in-hand with federal agencies such as the Federal Aviation Administration (FAA), airlines, and industry to make flight a more convenient, comfortable experience. NASA Aeronautics technologies have allowed airplanes to become quieter and to use trafficking programs that make flight routes faster and more efficient, while decreasing costly and unnecessary delays.



We fly **faster** *than any creature can run, and fly* **farther** *in a day than you or I could walk in an entire lifetime.*

Most passenger airplanes travel at around 500 miles per hour, 66% the speed of sound (Mach .66). At this speed, it takes mere hours to cross the continent, or to cross the globe. NASA Aeronautics has long been the leader in advancing flight speed. As early as 1947, NASA Aeronautics' Chuck Yeager broke the speed of sound barrier at Mach 1. In October 1967, "Pete" Knight broke the world record and achieved a speed of Mach 6.7 – the equivalent of 4,520 miles per hour! Efforts at NASA Aeronautics are underway to allow for supersonic passenger jets, with the research to produce a "low boom" so that these planes can travel safety and quietly even over land masses. Standard airplanes can be noisy too – over $9.3 billion has been spent on noise abatement by airports since 1982. NASA's work on quieting airplanes in general is important for our communities and our economy.

The whole world became a very small place, ...

NASA Aeronautics recognizes that aviation does not come without an impact on the environment. As such, some of NASA's biggest research goals involve the development of green technology. NASA consistently looks for ways to increase fuel efficiency by reducing drag and improving propulsion. Some of NASA's current projects involve redesigning more efficient aircraft body shapes, decreasing aircraft weight through the use of revolutionary composite materials, and testing biofuels with cleaner emissions. NASA's work with Boeing aircraft has resulted in an up to 20% decrease in carbon dioxide emissions, a 30% decrease in nitrous oxide emissions, and a 60% decrease in noise production.

... a very busy place.

Cocooned in a web of invisible highways...

Air traffic has increased dramatically in the last 50 years, and projections estimate that airspace will only become busier, as people seek more connectivity in an increasingly global world. Because of this, air traffic control and safety are of growing importance. NASA Aeronautics continues to revise and develop tools that safely track and communicate with airplanes to ensure the prevention of in-air accidents and to lessen the increasing burden on human air traffic controllers. Better air traffic control will decrease the current annual $8.1 billion loss for U.S. airlines due to delays (2013), and could, ultimately, result in a cheaper airline ticket to your favorite holiday destination.

...we now look ***down*** *from the sky, to the Earth, with the wind beneath our wings.*

Although aviation has been around for over 100 years, aviation technology still has significant room for growth and improvement. Annually, over 16 billion gallons of jet fuel are burned by U.S. airlines (2013), while the cost of fuel rose by 28% from 2010 to 2011. Vertical winglets on the tips of wings, now becoming prevalent on many passenger planes, were invented by NASA Aeronautics in the 1970s. These winglets disturb drag-inducing vortices of air currents, resulting in the need for less fuel, which, in turn, decreases flight cost and environmental pollution.

No place on the Earth is unseen, no continent unconnected.

NASA Aeronautics connects people and societies. NASA collaborates internationally to advance aeronautics research around the world, while working to stay ahead of the curve to keep cutting-edge, fundamental aeronautics research as a national priority. NASA has a long history of developing futuristic X-planes, including lifting bodies, vertical lift aircraft, rocket propulsion, and unmanned aircraft. NASA aims to take futuristic goals and to turn them into real-life, practical technology.

When we fly, we lift our feet off the ground. We share the journey with those same people who helped us place our feet upon the moon.

Before we took to space, we took to the skies. In little over a half century, humans progressed from successfully building a heavier-than-air vehicle to landing on the moon. In partnerships with government and industry, NASA continues to work at the frontier of space and aviation technologies. All commercial passenger aircraft and airport communications towers rely on technology developed by NASA Aeronautics.

Invisible highways in the sky bring us fresh fruits, vegetables, and flowers that could otherwise not be grown in our geographical location. Because of aviation, even our trip to the local grocery story is an international adventure. Many of our most precious belongings come to us by air, including our beloved pets, friends, and family members. Aviation takes us places, too – to our favorite destination to relax and enjoy life with others.

When we fly, we bring together new people, places, and things.


When we fly, we bring more than ourselves.
We bring ideas, and we share them.
We fly faster and farther than ever before, ...


...and we never fly alone.
NASA

NASA is with you when you fly.

- Every U.S. aircraft and U.S. air traffic control tower has NASA-developed technology on board.
- NASA is committed to transforming aviation, as only NASA can, by dramatically reducing its environmental impact, maintaining safety in more crowded skies, and paving the way to revolutionary aircraft shapes and propulsion.
- You may not have flown today but something you needed did.
- The nation's economy needs aviation.
- Aviation generates more than $1.5 trillion in economic activity each year, as well as supports more than 11.8 million direct and indirect jobs, and transports 17.7 billion tons of freight each year.

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