Illinois Mathematics & Science Academy

# Take to the Air


PBL

Problem-Based Learning

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The internationally recognized Illinois Mathematics and Science Academy® (IMSA) develops creative, ethical leaders in science, technology, engineering and mathematics. As a teaching and learning laboratory created by the State of Illinois, IMSA enrolls academically talented Illinois students (grades 10-12) in its advanced, residential college preparatory program, and it serves thousands of educators and students in Illinois and beyond through innovative instructional programs that foster imagination and inquiry. IMSA also advances education through research, groundbreaking ventures and strategic partnerships. (www.imsa.edu)

## Acknowledgments

This PBL Design manual consists of materials conceived and developed by numerous individuals affiliated with IMSA's PBL Network over the past two decades. Whether internal IMSA faculty, educators from our partner schools, participants in Problem-Based Learning initiatives, or PBLNetwork staff, we acknowledge their participation and contributions to the conceptual and developmental process. We have all learned from one another.
This manual and professional development in problem-based learning at IMSA is grounded in the work of our former colleagues in their book:

Torp, L. & Sage, S. (2002). *Problems as Possibilities: Problem-Based Learning for K-16 Education.* Alexandria, VA: The Association for Supervision and Curriculum Development.

## Copyright Policy


Think of some of the "big ideas" from your entire curriculum. What are some of the themes you focus on during the year? What are some outcomes you and your school value enough to spend quality time on during the school year?

Notes

# Unit Overview

**Title:** Take to the Air
**Focus:** Technology and Business

**Embedded Problem:** Plan a new airline, based in Chicago
**Overarching questions:**

- How does an airline attract customers?
- How does it decide which aircraft to buy?
- What economic factors are important to success?
- What impacts will a new airline have on the surrounding community?

**Role and Situation:** Chicago Skies Initiative asks students to create a plan for their new airline.

**Grade Level/s and Content Area/s:** Grades 7-9
**Science**: Sound, experimental techniques, data analysis
**Math:** Algebra, geometry, statistics
**Language Arts:** Research, writing, presentation skills
**Additional Possible Resources:**

**People and Places:**

- Chamber of Commerce
- Universities
- Illinois Department of Transportation
- Federal Aviation Administration

**Curriculum Outcomes:** Throughout this PBL experience, learners are actively engaged in learning the content, developing self-directed learning dispositions and applying thinking and reasoning skills.

Notes

# Standards

**Next Generation Science Standards:**

**MS ESS3-3***: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment*

**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*

**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*

**MS-ETS1-4** *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be reached*

**MS-PS4-1** *Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave*

**MS-PS4-2** *Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials*

**Crosscutting Concepts: Cause and effect: Mechanism and explanation.**

*Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.*

**Crosscutting Concepts: Scale, proportion, and quantity**

*In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.*

**Crosscutting Concepts: Systems and system models**

*Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering*.

**Science and Engineering Practices**:

**SEP1**: *Asking questions and defining problems*

**SEP2**: *Developing and using models*

**SEP3**: *Planning and carrying out investigations*

**SEP4**: *Analyzing and interpreting data*

**SEP5**: *Using mathematics and computational thinking*

**SEP6**: *Constructing explanations and designing solutions*

**SEP7**: *Engaging in argument from evidence*

**SEP8**: *Obtaining, evaluating, and communicating information*

**Next Generation Science Standards Reference:**

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Notes

## Mathematics Common Core Standards

**CCSS.Math.Content.5.OA.B** *Analyze patterns and relationships*

**CCSS.Math.Content.6.EE.A** *Apply and extend previous understandings of arithmetic to algebraic expressions*

**CCSS.Math.Content.6.EE.A.2** *Write, read, and evaluate expressions in which letters stand for numbers*

**CCSS.Math.Content.6.EE.B** *Reason about and solve one-variable equations and inequalities*

**CCSS.Math.Content.6.EE.C.9** *Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation*
*d = 65t to represent the relationship between distance and time.*

**CCSS.Math.Content.6.NS.C.8** *Solve real world and mathematical problems by graphing points in all four quadrants of the coordinate plane*

**CCSS.Math.Content.6.RP.A** *Understand ratio concepts and use ratio reasoning to solve problems*

**CCSS.Math.Content.6.SP.B** *Summarize and Describe Distributions*

**CCSS.Math.Content.7.G.A.1** *Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale*

**CCSS.Math.Content.7.EE.B** *Solve real-life and mathematical problems using numerical and algebraic expressions and equations*

**CCSS.Math.Content.7.NS.A.3** *Solve real-world and mathematical problems involving the four operations with rational numbers*

**CCSS.Math.Content.7.G.B** *Solve real-life and mathematical problems involving angle measure, area, surface area, and volume*

**CCSS.Math.Content.7.RP.A** *Analyze proportional relationships and use them to solve real-world and mathematical problems*

**CCSS.Math.Content.7.RP.A.2** *Recognize and represent proportional relationships between quantities*

**CCSS.Math.Content.7.SP.C** *Investigate chance processes and develop, use, and evaluate probability models*

**CCSS.Math.Content.HSN.Q.A.1** *Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays*

## Mathematical Practices:

**CCSS.Math.Practice.MP1** *Make sense of problems and persevere in solving them*

**CCSS.Math.Practice.MP2** *Reason abstractly and quantitatively*

**CCSS.Math.Practice.MP3** *Construct viable arguments and critique the reasoning of others*

**CCSS.Math.Practice.MP4** *Model with mathematics*

**CCSS.Math.Practice.MP5** *Use appropriate tools strategically*

**CCSS.Math.Practice.MP6** *Attend to precision*

**CCSS.Math.Practice.MP7** *Look for and make use of structure*

Notes

## Common Core English Language Arts (ELA) Standards

**6.RI.7** *Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue*

**6-8.RH.7** *Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts*

**6-8.SL.1** *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly.*

**6-8.SL.4** *Present claims and finding, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details*

**SL.6-8.6** *Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate*

**6-8.RST.3** *Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks*

**6-8.RST.7** *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually*

**6-8.RST.9** *Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic*

**6-8.W.1** *Write arguments to support claims with clear reasons and relevant evidence*

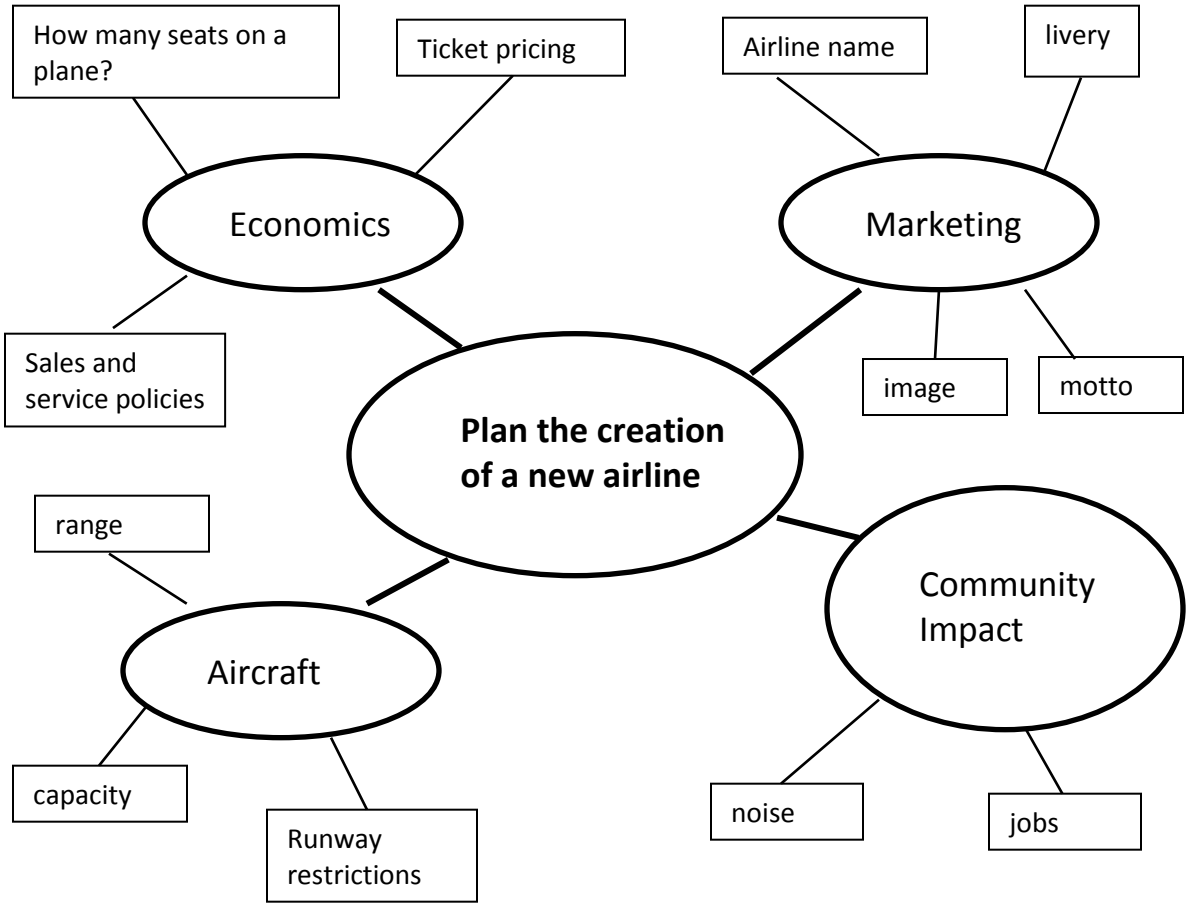
**6-8.WHST.2** *Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content*

**6-8.WHST.7** *Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of*

**6-8.WHST.9** *Draw evidence from informational texts to support analysis, reflection, and research*

Notes

# Map of the Problem



Notes

# Meet the Problem

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- Letter

Time: 15 minutes
Location: Classroom

**Introduction:**

The students will meet the problem through a letter from Chicago Skies Initiative:

Dear Students,

I represent a group of entrepreneurs with an interest in starting a new airline, based in Chicago. We know that O'Hare Airport is planning to expand. It is also likely that an entirely new airport will be built in the south suburbs. This is a golden opportunity to start a new business and create more jobs here in Chicago.

The existing airlines will no doubt plan to expand, using the newly available airport facilities. We believe that a new, smaller airline, with the ability to make more rapid business decisions can beat them to the punch. To help us stand out from the competition, we will target a younger generation of flyers, who may not feel they are being well served by the older, more traditional airlines.

For this reason, we need the advice of young people like you. We would like your input on everything related to starting a new airline including:

- Marketing our airline
- Choosing which aircraft to purchase
- Resolving potential problems in getting those aircraft delivered
- Seating arrangements
- Ticket pricing
- Customer satisfaction
- Community impact

Please assist us in designing a next-generation airline to serve the people who live in, and fly through, the city of Chicago.

Best Regards,
Renaya Barton
Director of Research
Chicago Skies Initiative

**Coaching Questions:**

- What problem factors do we need to consider?
- What issues connect to this problem?

**Assessment:**

- Are the students aware that the situation is problematic, did they get "hooked?"
- Can learners participate in a team discussion of the problem situation?

Notes

# Know/Need to Know

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- Chart Paper
- Markers
- K/NK

Time: 45 minutes
Location: Classroom
Safety: No known issues

**Objectives:**

- *Students will list their prior knowledge and pose questions which may help them solve the problem.*

**Introduction:**

In this lesson students will develop a list of Know and Need to Know items relating to the problem. The purpose of the activity is to have students think deeply about what they will need to know in order to solve the problem, and to provide a guide for their investigations. Student engagement is increased when they can see the connections between learning activities and questions they have about the problem. The list should be posted in the classroom, and as the questions are addressed, they can be crossed off of the Need to Know list and added to the Know list. Need to Know items can be added to the list as they arise, and the students should refer to the list before and after learning activities. It may be necessary to coach students to particular Need to Know items relating to learning activities.

**Activity/Activities**:

1) Using the handout, the students will individually fill out Know and Need to Know items. Remind students that it is all right if there are more items on the Need to Know list than the Know list.
2) Pairs of students will compare their lists and add as needed.Small groups (4-6) of students will compare their lists. The groups will come to a consensus as to which items are the top 3 on each list.
3) As a whole class, generate a master K/NK list on chart paper that will be posted in the classroom.
4) As an extension, or as an initial activity, students could draw concept maps of the problem, individually or in small groups.

Notes

**Coaching Questions:**

- What do you know about the problem? How do you know that information?
- What questions do you still have? Why do you need to know?
- Are there other areas that you should consider? Why do you think so?

**Assessment:**

- Can learners identify key elements from the letter? Can they identify key areas of investigation?
- Concept maps and K/NK lists—for breadth and depth of understanding
- Do the students validate and respect the contributions of all individuals

**Anticipated Needs to Know items addressed by unit:**

What are brands, logos, mottos, and livery? How do they help a business?
How and why are aircraft painted (or left bare)?
What is the most profitable arrangement of seats on an aircraft?
What are the different "classes" of seating?
Will it take long to get our aircraft delivered? Should we expect delays?
Will our aircraft be able to use the runways at Chicago's airports?
What size should our aircraft be?
How far should our aircraft be able to fly?
How loud will our aircraft be?
Will noise bother residents near the airport?
Can we reduce the noise made by our aircraft?
What makes air travelers unhappy about the experience of flying?
How should we decide on ticket prices?
What types of jobs will be created by our airline?
Who is our competition?

Notes

# Problem Statement

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- Chart Paper
- Markers
- Problem Statement handouts

Time: 45 minutes
Location: Classroom

**Objectives:**

- *Students will define the problem that will guide their investigation.*

**Introduction:**

The Problem Statement is the key document that will guide the students through the problem. It consists of an overall task, and the factors to be considered in successful completion of the task. The students should carefully consider the information given in the Meet the Problem documents when writing their Problem Statement. Having the students draw concept maps, with the problem in the middle and the factors around it, can help the student clarify their thinking. The Problem Statement should be posted, and can be changed if the need arises.

**Activity/Activities**:

1. The students will draw a concept map of the problem.
2. Distribute the Problem Statement handouts.
3. The students will fill in the columns individually, then with a partner, and then with a small group of 4-6 students.
4. Each group of students will present their proposed Problem Statement to the class. The teacher will then work with the class to develop a whole class Problem Statement.
5. The Problem Statement will be revisited on a daily basis to guide the class' investigations.

Notes

The stem for the Problem Statement is:
"How can we as (role) [overall task], in such a way that we consider [factors]

**Coaching Questions:**

- What have we been asked to do? (overall task)
- Are there other areas to consider? (factors)
- Who else could be affected by this problem?
- Are there other problem conditions to consider?

**Assessment:**

- Does the problem statement identify most of the key issues of the problem? (individual and group)
- Do they have a working problem statement?
- Do the students validate and respect the contribution of all individuals?
- The Problem Statement worksheet can be used to assess the learners' overall understanding of the "big picture" of the problem and key factors for solutions.

**Final Anticipated Problem Statement:**

How can we, as young residents of Chicago, develop a plan for the creation of a new airline

… in such a way that we consider:

- Marketing
- Aircraft selection
- Aircraft delivery
- Seating arrangements
- Ticket pricing
- Customer satisfaction
- Community impact

Notes

# Plan for Information Gathering

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- Chart Paper
- Markers
- K/NK handouts, Problem Statement Handouts from previous sessions

Time: 15 minutes
Location: Classroom

**Objectives:**

- *Students will design a plan for answering their need to know items and solving the problem.*

**Introduction:**

In this lesson students will develop a plan for gathering information. The students will usually come up with the Internet as the first option. They key understanding is that there are other sources of information, such as experts, lab activities, books, surveys, etc. that can be used. The students may need some coaching to get to these ideas.

**Activity/Activities**:

- The students will brainstorm ideas for gathering information to address the Need to Know items and the Problem Statement. The teacher will capture the ideas on chart paper.
- The students will develop a plan for gathering information at the teacher's discretion. Options include assigning individual students or groups of students to address particular items, investigating as a whole class, etc.
- The Need to Know list and the Problem Statement will be revisited on a daily basis, with completed items being checked off, and new items added as needed.

Notes

**Coaching Questions:**

- Is the information important? Why?
- Where can you obtain the information?
- Is the information relevant to the problem? How do you know?

**Assessment:**

- Are students able to identify information critical to the problem?
- Can learners find, evaluate, and use information effectively?
- Do learners make valid connections between needed information and possible resources?
- Do learners work collaboratively and share resources?

Notes

# Livery Design

**Logistics**
Class age/size: 7-9th grade in pairs
Materials:

- Aircraft template
- Colored pencils or markers
- Computer with internet access

Time: 120 Minutes
Location: Classroom
Safety: None

**Objectives/Standards**
Students will:

- Design a custom livery for a fictional commercial airliner and research the importance of a recognizable brand.
- Learn about reasons why commercial airlines spend time and money on developing a brand
- Investigate the process of painting or polishing an aircraft fuselage
- Design a personal aircraft livery
- 7.RP.A; 6.RI.7; 6-8.SL.4; 6-8.WHST.7

**Need to Know Items Addressed**

- What are brands, logos, mottos, and livery?
- How do they help a business?
- How and why are aircraft painted (or left bare)?

**Introduction**
Airline companies can spend millions of dollars to paint a fleet of aircraft to support their marketing brand. Additionally, complex paint schemes add weight to an aircraft, contributing to the fuel consumption during flight. Companies compare the costs associated with various paint schemes to the income generated from the customer's association with the brand. What many airlines are trying to accomplish is the creation of an emotional attachment to their particular brand. American Airlines was noted for decades for its shiny, polished fuselage exteriors with the AA eagle tail logo. A major rebranding in 2013 saw this airline depart with its long-held brand in hopes of revitalizing the image of the airline. Also, the shiny, polished exterior would be impossible to reproduce on newer, composite-based aircraft and, while saving fuel due to less aircraft weight, resulted in higher maintenance costs to both polish the exterior of the fuselage and apply anti-corrosives to the exposed surfaces which paint naturally provides.

Notes

In the first activity, students will investigate the importance of an aircraft's livery in representing the brand of an airline as well as consider design choices related to the weight of painted aircraft fuselages versus polished metal's anti-corrosive maintenance requirements. Also, students will have an opportunity to design their own custom livery to represent their "brand" for this curriculum.

**Activity/Activities**

***Activity 1: Introduction and online research***
*Estimated Time: 60 Minutes*

**Materials:**

- Computer with internet access

**Instruction:**

1. Ask students if they can name any commercial airline companies either United States carriers or International carriers. Record on the board or chart paper any student responses.
2. Follow up by asking what they "know" about each of the airlines listed. Place a star or mark any of the responses that describe what the aircraft "looks like" or its paint scheme or logo but do not tell students why you are highlighting those points.
3. As a class, have fun with the airline logo quiz found at http://airlinelogos.aero/quiz
4. Students will work in pairs for the next part of this activity. Provide each student team with at least one computer with internet access. Allow students 25-30 minutes for research and to organize their response and then have each partner team share their research.
5. Important questions to ask students at this point are as follows:
    - What are the various types of aircraft livery that have been used on different aircraft?
    - Why is spending millions of dollars on designing an aircraft livery important to an airline company?
    - What is the impact of painting the fuselage (the aircraft's main body section that holds crew and passengers or cargo)?
    - How might an airline counteract the fuel consumption issues due to painting the aircraft?
    - What problems might an airline have if they decide to polish the fuselage instead of painting?

Notes

***Activity 2: Design and Share***
*Estimated Time: 60 Minutes*

**Materials:**

- Aircraft template
- Colored pencils or markers

**Instruction:**

1. Student teams will generate a corporate name for a new, start-up commercial airline and will design a logo and livery for their new fleet of aircraft. An aircraft template is provided for students to design and color their new livery scheme. Students should also prepare a written explanation of the message their brand should send to potential customers, in the form of a motto or slogan.

**Debrief:**

- What message will your brand and livery send to potential customers?
- What design considerations did you and your partner discuss in order to reach a decision on your company name, logo, and livery design?

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Great Circle Routes

**Logistics**
Class age/size: 7-9th grade
Materials:
***For each group of students***

- 1 inflated globe of the Earth
- 1 meter string (approximate)
- Computer with Internet access
- 1 ruler (30 cm/12 in.)
- 5" x 8" index card

***For each student***

- Student pages
- World study map (Map A)
- Copy of Map B

Time: 90 Minutes
Location: Classroom
Safety: None

**Objective/Standard:**
Students will:

- Prepare flight plan itineraries for two different maps of the earth
- Use a two-dimensional Mercator Projection Map and a three-dimensional globe to determine the shortest route between two points on Earth
- Describe the differences between itineraries created from two different *maps*
- Use an online great circle mapper to analyze the routes of two-dimensional latitudinal flight paths
- Determine which aircraft have the range to reach every major city in the continental US from Chicago.
- 7.G.A.1; SL.6-8.1; RH.6-8.7; WHST.6-8.9
  SEP5; SEP6; SEP8

**Need to Know Items Addressed**
How far should our aircraft be able to fly?

**Introduction**
Determining the shortest distance between two points on a two-dimensional Mercator projection map turns out to be a visibly curved line if the path crosses several longitudinal lines and is significantly north or south of the equator. On a three dimensional globe of the Earth the shortest path is a "Great Circle Route". A "Great Circle Route" viewed from a position directly above it looks like a straight line and it is the shortest distance between the two points.

While a great circle route may be the shortest distance between two points on a sphere, pilots do not automatically fly a great circle route when flying between two points. Wind along the great circle route may increase the travel time compared to a route with a longer distance but shorter travel time. Airspace restrictions over various countries may make following a great circle route impossible. Also, a great circle route involves following a continuously changing heading. From a pilot's viewpoint, that is quite difficult to accomplish. Rather, aircraft tend to follow quite defined routes, especially over oceans. Waypoints along the great circle route are selected and a constant heading between these points is followed.

**Inquiry Overview:**
This lesson helps students gather and analyze information about the shortest distance between two points on the surface of the Earth from two different perspectives. When a map of the approximately spherical three-dimensional Earth is spread out into a flat Mercator two-dimensional projection the relative positions among places on the Earth change.

Students will be asked to determine an airplane flight path beginning in Springfield, Illinois, and ending in Ankara, Turkey. The reason for the choice of these two locations is that they span several longitudinal lines, or meridians, and they are both at approximately 40 degrees north latitude (same parallel). They will plot the flight path on the labeled side of a world study pad map.


**Figure 2:** Shortest flight path

After the students have determined what they believe the shortest flight path between the two cities on the Mercator projection map, they will plot out the shortest flight path between the cities on a globe of the Earth. The shortest flight path on the globe should look something like the path shown in Figure 2. Students will then expand their knowledge of great circle routes by examining several routes at different latitudes, both north and south of the equator. Actual flight paths will also be investigated to determine if pilots always fly along great circle routes.

Notes

**Suggested Inquiry Approach:**

*Part 1: (45 minutes)*

Before class begins inflate each of the globes and cut enough string for each team. Students should be divided into groups of 3 students with 2 groups using one globe. If students are unfamiliar with the terms "latitude" and "longitude" please review these with students. More information can be found at: http://www.learner.org/jnorth/tm/LongitudeIntro.html

**Instruction:**

To begin the lesson:

- Tell the students that this activity involves determining the shortest route between two cities.
- Read the first three paragraphs on the student pages to the students.
- Distribute the materials and student work pages to teams of students.
- Have the students read the rest of the instructions for the activity.
- Make it clear that the team of students is to cooperatively gather and analyze information for their group.
- Provide access to the Internet or atlases as needed by the students.
- Once all of the landmarks are recorded on the maps and Flight Plans, encourage each team of students to discuss and write responses to the prompts in the Discussion/Conclusions section on the student pages.

**Debrief: Part 1**

When the students have had the chance to look over the Flight Plans and the maps and the teams of students have completed their responses as they were directed:

- Ask some of the students to read their responses and their reasons.
- Have the students plot Flight Plan # 2 on the two-dimensional Mercator projection map alongside Flight Plan # 1.
- Allow the students a few minutes to make sense of the two Flight Plan diagrams.
- Engage the students in a large group dialogue that looks at the reasons for the two differently shaped flight paths.

Students' responses should indicate that a path which follows along a latitude line at latitudes above or below the equator on a globe is not the shortest distance between the two points. The shortest path between two such points is actually a curve on a two-dimensional Mercator Projection Map. It is the shortest distance between the two points as measured across the curved surface of a globe – a "Great Circle Route". Use the transparency of **Map C** to show this to the students.

It would be interesting to note if any student recognizes the fact that the distance between two points spanning longitude lines along the 0 Degree latitude line (the Earth's equator) is a minimum for any two points on the equator.

Notes

*Part 2: (45 minutes)*
Students will continue in their teams looking at different pairs of cities at roughly the same latitudes and plotting the great circle routes. Students should notice that the higher latitude cities exhibit more of a curve in the path, while closer to the equator the path follows truer to the parallel. Also, they should note that below the equator in the southern hemisphere the great circle routes are inverted.

Students will then use an online great circle mapper (www.gcmap.com) to investigate a flight between Chicago, IL and San Francisco, CA. They will plot the great circle route.

The website at http://www.greatcirclemapper.net/ is a very nice online tool to both map the great circle routes and look at airlines that may fly that route. This site will also allow the user to input various aircraft and look at their operating ranges.

Using any combination of tools available, students will determine which commercial aircraft can reach any city in the continental US from Chicago. They may find helpful information about commercial airlines at http://www.airlines-inform.com/commercial-aircraft/

**Debrief: Part 2**

- How are great circle routes shown on two-dimensional projections for route along the same meridian?
- Which commercial aircraft can reach every major city in the continental US from Chicago?

Following the completion of Part 2, ask student teams to write two or three questions related to the activity on individual 5" x 8" index cards. On the reverse side of the card, teams should record the answer to their questions. Collect the cards and debrief using the student-generated questions and answers.

**Extension:**
For each of the routes, have students also record the distances in nautical miles. Based on airspeeds of various aircraft, students can estimate the time it would take to fly the route. Some typical cruising airspeeds are as follows:

| Aircraft | Cruising speed |
|---|---|
| Airbus A380-800 | 587 KTS |
| Boeing 737-600 | 446 KTS |
| Boeing 747-8 | 563 KTS |
| Boeing 787-8 Dreamliner | 510 KTS |
| Bombardier CRJ-700 | 473 KTS |

Source: planes.axlegeeks.com

Notes

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# FAA Airport Diagrams

**Logistics**
Class age/size: 7-9th grade
Materials:

- FAA airport diagrams for MDW and ORD
- 1 – C-THRU navigational protractor
- Computer with Internet Access

Time: 60 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will: Determine which aircraft are capable of operating from runways at Midway and O'Hare.

SEP 4 – 8, 6-8.RH.7, 6-8.SL.4

**Need to Know Items Addressed**

- Will our aircraft be able to use the runways at Chicago airports?

**Introduction**

The Federal Aviation Administration publishes Airport Diagrams/Facility Directories every 28 days. These resources are essential for pilots to get the latest information on runway construction, new runways or taxiways, new control towers, and radio frequency changes. Airport Diagrams can be viewed and downloaded from http://www.faa.gov/airports/runway_safety/diagrams/ using an airport identifier such as the three-letter FAA format or the four-letter ICAO (International Civil Aviation Organization) airport code.

**Instruction:**

Students will learn to read runway diagrams and use this knowledge to see which aircraft can operate from which runways in Chicago's airports.

Students will receive a copy of the FAA Airport Diagrams for Midway and O'Hare. They will investigate various features of the Airport Diagram. Then, they will organize data taken from the Airport Diagrams, and use this information and information on takeoff/landing distances and weight for different models of aircraft. They will determine which aircraft are capable of operating from which runways at Chicago's main airports.

Provide each team with a set of FAA Airport Diagrams. Allow students to investigate the information on the Airport Diagram to record in the table on their student pages. Each team may decide to work together, or to distribute the work among the team members.

Notes

Students may have some questions related to the weight-bearing capacity information for runways as indicated on the Airport Diagrams. Let them know that the codes are based on how much weight different configurations of landing gear can handle. You may want to collect some images of different aircraft during the landing phase to illustrate how different-size aircraft need different wheel configurations to handle the weight of the aircraft safely on landing.

Using the Aircraft Data Table and Landing Wheel Configuration Chart, students will investigate which aircraft they believe can land at the given airports in Chicago. If students have access to the internet, they can navigate to planes.axlegeeks.com to view examples of the various aircraft types.

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Assembly and Delivery

**Logistics**
Class age/size: 7-9th grade
Materials:

- 1 – game board and directions
- 30 – ORDER cards
- 30 – MANUFACTURE cards
- 30 – DELIVER cards
- 30 – ASSEMBLY cards
- 4 – Two-color counters
- 1 – Color-coded die
  4 – different colored planes
- 4 – different colored cut-apart plane templates
- Student Pages

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will: Use a board game to learn about the manufacturing and delivery process for a large, commercial jet aircraft.

NGSS Crosscutting Concept: Cause and Effect,
Systems and System Models, SEP 8, 6-8.RH.7, 6-8.SL.4

**Need to Know Items Addressed**
Will it take long for our aircraft to be delivered? Should we expect delays?

**Introduction**
Students will play a board game designed to teach them about the supply chain and manufacturing process and all of the potential problems that engineers and production planners face in assembling such a complex product for their customer.

**Instruction:**
Students will form teams of four and will receive a game board, directions, playing pieces, a die, four two-color counters, and cards to play the game of **So You Want to Build a Jet?**. Review the directions to the game with students and answer any questions that students may have about playing the game.

Allow students to play the game, recording on their student sheets various problems that could occur (as well as potential positive developments) as the seven parts of the plane they will be building are assembled. Students should also be encouraged to discuss potential solutions to some of the problems as they arise.

Notes

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Design an Aircraft Cabin

**Logistics**
Class age/size: 7-9th grade
Materials:

- Computer with internet access
- Access to Dia Template

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will:

- Create a seating arrangement for an aircraft cabin that maximizes profit subject to design constraints.
- Use the engineering design process to create a seating arrangement for a commercial airliner
- Derive an algebraic equation to express the profitability of their design
- MS-ETS 1; 6.EE.A; MP1 – 6

**Need to Know Items Addressed**

- What is the most profitable arrangement of seats on an aircraft?
- What are the different "classes" of seating?

**Introduction**

Shortly after the Wright Brother's first flight, Igor Sikorsky built the first commercial airliner with seating for 16 passengers. It boasted a bedroom, toilet, and electric lighting. The year was 1913. It would be another 20 years, however, before airliners became efficient enough to make a profit without government subsidies. The Douglas DC3 carried 21 passengers on its inaugural flight in 1935. The aircraft was so successful that some are still in service as cargo carriers. By 1947 jet airliners had seating for 100 passengers. Today, the Airbus A380 carries 555 passengers.

Not all seats are created equal. Most airlines use a three-tier system of seating including the basic economy class, a business class, and the luxurious first class. Designing the perfect combination and arrangement of seats is critical to the success of an airliner. Airlines operate on a very thin profit margin, often netting less than $5 profit per passenger on a typical flight

In this lesson students will use software design the cabin seating arrangement for a 10-meter long segment of an airliner. They will be given various design constraints and asked to arrive at a design which yields the greatest possible profit to the airline.

# Take to the Air

Notes

Students will derive an algebraic expression for calculating profit which can be used for evaluating designs. Students will share designs and try modifications to arrive at the best possible design.

**Advanced Preparation:**
Each computer will need to have Dia Diagram Editor installed. Download the Windows version here: http://dia-installer.de/ or the Mac OSX version here: http://dia-installer.de/download/macosx.html.

**Instruction:**

1. Ask the class to see how many of the students have actually flown on an airliner. See if they understand that some flights can exceed ten hours in duration. Ask them what the cabin must have to ensure that customers are safe and happy at the end of their trip. They can make lists and share with the class.
2. Explain that students, working in pairs, will use computers or laptops to design a seating layout for a 10-meter section of cabin.
3. Open the document "Aurora 500 Cabin Seating" and show students how to move the aisles and how to duplicate, delete, and move seats.
4. Pass out student data sheets.
5. Discuss the monetary aspects of the challenge and ask students to derive an algebraic expression to determine the profitability of any particular design based on the number of Economy, Business, and First Class seats.

   On a typical four-hour flight from Chicago to San Francisco:
   - Tickets for a First Class seat sell for $660 each
   - Tickets for a Business Class sell for $490 each
   - Tickets for an Economy Class seat sell for $315 each
   - The operating cost of this flight (for your section of the aircraft) is $37,500

6. Ask students to read the design constraints on their data sheets, or present them as follows:

   *Welcome to School Airlines! Our activity today will take place aboard the Aurora 500 wide-body passenger jet. As we begin this activity I do want to remind you of certain rules regarding the design of your cabin section:*
   1. *You have two aisles running the length of your cabin section to position as you choose. For safety reasons, no passenger can be required to sit more than two seats from an aisle.*
   2. *At this time I'd like to welcome our First Class Passengers! You must have at least four First Class seats in your cabin section.*
   3. *No Business or Economy Class seats may be placed alongside First Class seats unless separated by an aisle.*

4. *I would now like to welcome our Business Class travelers aboard! You must have at least six Business Class seats in your cabin section.*
5. *No Economy Class seats may be placed alongside Business Class seats unless separated by an aisle.*
6. *Economy Class seats must account for at least half of the total seats in your cabin section.*
7. *FAA regulations prohibit tampering with the size of any object in your activity.*

*On behalf of the entire crew I would like to thank you for participating in this engineering design activity.*

7. Help students start the Dia software by opening "Aurora 500 Cabin Seating".

8. As students complete their designs, have them write their name and profit (if it is positive!) on the board. Encourage other groups to look at the current best designs to see what works and what does not.

***Alternative Activity: Design an Aircraft Cabin (without a computer)***

If computers running Windows or Mac OS are not available, the activity can be done by using paper cardstock cutouts. Differences are:

- There is only one aisle to position in the cabin
- The operating cost of this flight (for your section of the aircraft) is $6,000
- There must be at least two first class seats
- There must be at least three business class seats

Separate Student Pages are provided for classes doing the activity without

**Debrief:**

Discuss with students which designs worked best. Is there anything the designs had in common? Many aspects of cabin design and seat pricing are not simulated in this activity. Have students name some other things which might be manipulated by an airline to increase profits. Whenever possible discuss how this would change the equation they derived for calculating profit.

**Conclusion:**

*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# BUMP You Up or Out?

**Logistics**
Class age/size: 7-9th grade
Materials:

- One computer with Internet access for each pair of students
- Calculators

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will:

- Calculate the opportunity cost of flying with empty seats
- Investigate the economic advantages of overbooking
- Examine the relationship between overbooking and customer satisfaction
- 7.EE.B; 7.SP.C; MP1, MP2, MP3, MP4, MP5, MP6; 6-8.RST.3, 6-8.SL.4, 6-8.WHST.2; SEP4, SEP5, SEP6, SEP7

**Need to Know Items Addressed**

- What makes air travelers unhappy about the experience of flying?
- How should we decide on ticket prices?

**Introduction**
Students will adopt the role of an airline executive and formulate their own policy on overbooking based on what they learn from guided internet research. Students will investigate the often controversial practice of commercial airlines to "overbook" flights by selling more seats for a given flight than there actually are on an aircraft. Students will mathematically examine why this practice makes sense to certain airlines, and will examine reports indicating whether the practice impacts their customers' satisfaction with their airline.

Overbooking is the practice of selling more tickets to fly on a flight than the aircraft can really hold. Airlines are not the only companies which do this. Hotels and automobile rental agencies oversell as well. Making a reservation for services seldom gives one an exclusive right to the service reserved. Although some consider overselling to be unethical, it is generally not illegal.

Nearly all airlines overbook their tickets. Failure to do so would result in serious economic losses. On average, roughly 10% of all booked passengers do not show up for their flight. Some make last minute changes or cancellations. Regardless of the reasons, if 10% of the seats are empty at take-off the airline is losing the opportunity to sell those seats to customers who would pay for them. In economic terms, failure to take advantage of a potential profit is effectively a loss. The "opportunity cost" of not overbooking is equal to the additional income that could be made by choosing to overbook.

Notes

Airlines track the rate of no-shows for different flights, times, destinations, and seasons. A complex formula will guide the airline in deciding how much overbooking to do on each flight. In this activity, only the simplest factors will be considered.
Regardless of how much research informs the overbooking decision, the possibility exists that more passengers will show-up at the gate than the aircraft can hold. In this case the airline is required to offer passengers incentives to skip this flight in favor some later option. Incentives can include upgrades, discounts, or even cash. In most cases enough passengers choose the incentive, take a later flight, and everyone goes away happy.

If, however, not enough volunteers step forward, the airlines will require some passengers to give up their reserved seats. US law requires certain monetary compensation be given to the unfortunate passengers. Passengers who are bumped in this fashion may be resentful and no airline wants to have a reputation for bumping more often than necessary. This question of reputation is another factor to be considered in calculating the costs and benefits of overbooking.

**Instruction:**

*Suggested Inquiry Approach:*

Students should work in pairs to encourage discussion, but having more than two working at a computer screen should be avoided if possible.

You can prime students' interest in the concept of overbooking by asking them some questions:

- Have you ever played "musical chairs"? How does it feel to be left without a seat?
- Have you attended a movie or concert with general admission and been unable to find a seat? What do you think *general admission* means?
- Suppose you purchased an airline ticket for seat 12B on flight 583 to Atlanta for a 9:00 am departure next Tuesday. Would you be surprised if you tried to board and were told that it was impossible because the plane is full?

The Student Pages will explain the concept of overbooking from the perspective of the airline industry. The final step asks students to develop a policy on overbooking for their airline. This could be done as a written report or a presentation to the class. Their policy should address questions such as:

- How does our policy ensure that we make enough profit to grow?
- How does our policy help us compete against other airlines?
- How will we determine how many extra tickets to sell?

Notes

- If more passengers show up than can fit on the plane, what incentives will be offered to get some to accept a later flight?
- What explanation will be given to passengers who must be involuntarily bumped?

Press students to justify their decisions with mathematical reasoning and numerical examples from their research.

**Debrief:**
Nobody likes the idea of overbooking. It violates our sense of basic fairness. The economic incentives, however, make it irresistible in an industry that operates with notoriously slim profit margins. Overbooking can allow airlines to pass on savings to consumers in the form of lower airfares.

Travelers complain about airlines all the time but less than 4% of those complaints are related to overbooking. Why? Because airlines understand probability and statistics well enough to sell an appropriate number of extra tickets. Mistakes are relatively uncommon. On average, only 0.1% of passengers will get bumped on a flight. Of those, less than 10% will be involuntary.

Often our gut instincts tell us one thing while the data indicates just the opposite. Being able to sift through data and use mathematics to get at the truth is a powerful skill.

**Extensions:**
Take another look at the October 2014 Air Travel Consumer Report. Identify which airline does the best job of satisfying its customers. Which is the worst? Justify your answers using numerical data.

Students can investigate many additional economic impacts such as the cost of jet fuel. Labor relations are a critical aspect for most airlines which must negotiate salary and benefits with labor unions.

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Culture and Image

**Logistics**
Class age/size: 7-9th grade
Materials:

- Computers with access to the internet
- Student pages

Time: 60 Minutes
Location: Classroom
Safety Concerns: None

**Objectives:**
Students will examine examples of corporate culture, image, and customer service policies within five different airlines that operate in Chicago.

**Need to Know Items Addressed**
Who is our competition?

**Introduction**
Students will use the internet to research the corporate culture and image of five airlines which operate from Chicago airports. They will examine what these airlines promise their customers. Finally they will suggest what culture, image, and policies might help a new airline to succeed and distinguish itself from the competition.

**Instruction:**
Form students into groups of two. Each group should be assigned two of the following airlines to investigate:

- American Airlines
- United Airlines
- Delta
- Southwest Airways
- JetBlue Airways

Be sure that every airline is being investigated by at least one student group.

Students begin their investigation at the TrackStar website:
http://trackstar.4teachers.org/trackstar/
View Track # 458728
The password is: FUSION
Choose: View in Text

Notes

They are looking for information about

1. Corporate culture and image
2. Promises made to customers

Give students 30 minutes to find what they can about their assigned airlines. Then lead a class discussion for students to share that they learned.

- What do these airlines have in common?
- Is there room for a new airline to establish itself as unique and attractive?

Working in pairs again, have students create a statement of corporate culture for a new airline which includes specifics about how they demonstrate their dedication to customer satisfaction.

In a class discussion, have each group share their work.

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Delay, Delay, Go Away!

**Logistics**
Class age/size: 7-9th grade
Materials:

- Per team of three students:
- 1 – US Time Zone map
- 1 – green dry erase pen
- 1 – blue dry erase pen
- 1 – red dry erase pen
- 1 – set polyhedra dice
- 3 – two-color counters
- 3 – 11" x 17" copies of data tables
- Computer with Internet access
- Paper towels (to erase maps)

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will:

- Discuss the impact of flight delays on airlines, passengers, and other industries
- Simulate a multi-leg journey through US airspace incorporating delay probabilities to determine travel times
- Seek to find alternate routes that reduce travel time to a particular destination
- 6.RP.A, 7.NS.A.3, 7.SP.C; MP1, MP2, MP4, MP5, MP6, 6-8.RST.7; 6-8.SL.4

**Need to Know Items Addressed**
What makes air travelers unhappy about the experience of flying?

**Introduction**

Image courtesy of Carolina K. Smith M.d.|Dreamstime.com

Flight delays are a serious and widespread problem in the aviation industry. On average, it is estimated that over 25% of all flights arrived more than 15 minutes late (15 minutes is the threshold to be considered "delayed" by the FAA). According to data released by the FAA, Chicago's airports at Midway and O'Hare experience delays in excess of 25% annually.

# Take to the Air

Notes

An obvious reason for passenger delays is atributed to weather issues. However, that is only a small part of the overall picture. Airspace congestion due to lack of capacity accounts for at least 1/3 of all possible delays. Mechanical problems, problems boarding passengers, severe weather, compounded delays due to late-arriving aircraft, crew scheduling issues, and other issues all contribute to the unpredictability in air travel for passengers. As a result, many aircraft have increased their "schedule padding" in publishing scheduled departure and arrival times thus prompting passengers to add additional time to their travel itineraries in order to increase the probability of reaching a destination on time.

In order to cost-efficiently provide services, many airlines fly to large "hubs" – airports often in major metropolitan areas – and require passengers to seek out connecting flights to arrive at a destination. The theory is that flying to hubs results in fuller flights. Offering non-stop service between two destinations is riskier for airline carriers since the demand for travel between these locations, especially if they are considered "secondary" markets, may not be consistent. Thus, non-stop flights are usually more expensive to the traveler. However, nonstop itineraries are shorter overall and less likely to experience delays. Thus, the traveler is paying for a better chance of arriving on time.

**Inquiry Overview:**
In this inquiry, students will select a four-leg travel itinerary from an airport on the West coast to one on the East coast. They will select destinations in at least three different time zones, and will use a data table to determine if a flight is available between locations and the corresponding flight time for that leg of the journey. Next, students will use a table of probabilities for delay for that particular leg, and will use polyhedral dice to set up a simulation strategy to model the likelihood of delay. Students will then run their simulations several times and record their total flight time for the four-leg journey. They will analyze the data, and compare to a non-stop flight.

**Instruction:**
Students will be working in teams of three for this activity. Pass out the student pages for the activity

Begin this activity by asking students to discuss what they know about flight delays. Possible questions to pose to students are as follows:

- When a flight is delayed, who or what is impacted by the delay?
- What variables may contribute to flight delays in the United States and globally?
- How might airlines attempt to decrease the number of delays for its scheduled flights?

Notes

Next, hand students a copy of the 11" x 17" data tables. Encourage students to spend a few minutes discussing with their teammates the format and data contained within the tables. Also, point out the table of airport identifiers contained on the student pages. Students may have noticed these 3-letter IATA (International Air Transport Association) codes on luggage tags if they have traveled by air.

Now provide student teams with 3 different colored dry erase pens, one US Time Zone map, and a paper towel to erase marks. Students will be selecting four segments (legs) of a journey from an airport located at a city on the West coast to an airport in a city on the East coast according to their map.
Using their colored dry erase pens, students will mark along the US Time Zone map four segments (legs) between cities of their choice starting with a location on the West coast of the United States and ending at a location on the East coast. They must choose cities in at least **three different time zones** indicated by the different shades on the map.

Students will use the **Flight Schedule** data table to determine if there are flights between the selected cities. If there are not, they will choose alternative legs from the available flights.

Provide each team with a set of five different polyhedral dice. These dice are six-sided, eight-sided, ten-sided, twelve-sided, and twenty-sided. Students will use these dice to model the probability of delay for each leg of their journey. The likelihood of a delay for a given flight is given as a fraction, decimal, or percent value in the **Delay Probabilities** data table. As an example, if the likelihood of a delay is given as **1/20**, a student may select the 20-sided polyhedral die to model this likelihood by stating that "rolling a 1 represents a delay; rolling 2 – 20 represents no delay." Likewise, for a delay probability of 25% (1/4) students may select the eight-sided die and state "rolling a 1 or 2 represents a delay; rolling 3, 4, 5, 6, 7, or 8 represents on-time."

If a flight experiences a delay, students will then toss the two-colored counter. If the counter lands on yellow, add one additional hour to the flight time for that leg; two additional hours will be added to the flight time for red.

Ask students to run the simulation three times and record the total travel time for the four-leg itinerary for each of their trials. They will be calculating an average flight time, and then determining their local arrival time for a 9:00 A.M. West coast departure.

Notes

**Debrief:**
Following student completion of this activity, debrief this activity with the following questions:

Working with your team, did any team member experience delays along your routes? If so, what do you notice about the airports with higher delay probabilities? If not, what observations can you make about the airports you "flew" into along your route?

- Why do you think airlines fly into airports with higher probabilities of delay?
- What are the advantages and disadvantages of a non-stop route for both airlines and passengers? Are there any disadvantages?

**Extensions:**
If time permits, allow students to choose another 4-leg route between their departure and destination cities and try to reduce their overall flight time.

Students may research the "hub and spoke" system used by many airline carriers versus the point-to-point system in use by many of the low-cost carriers such as Southwest Airlines. What are the advantages of each approach? What are the differences? The US Department of Transportation's website has a graphic of air traffic hubs from 2012 at http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/geographic_information_services/maps/hub_maps/2012/html/map.html

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Noise Reduction

**Logistics**
Class age/size: 7-9th grade
Materials:

- One or more smart phones with a free app that allows measuring sound levels.
- Party favors (paper horns)
- Pipe cleaners, foam, paper, cotton balls, and other materials to make improvised sound baffles
- Graph paper

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will:

- Design and build structures to minimize noise pollution from jet engines.
- Understand the impact of aviation noise on the industry and on people living near airports.
- Students will understand the basics of sound level measurement.
- Students will use the engineering design process to reduce the noise from a party favor (paper horn).
- MS-PS4-1, MS-PS4-2, MS-ESS3-3, SEP1, SEP2, SEP3, SEP4, SEP5, SEP6, SEP7, SEP8, 6-8.W.1, 6.RI.7, MP-7, 6.SP.B

**Need to Know Items Addressed**

- How loud will our aircraft be?
- Will noise bother residents near the airport?
- Can we reduce the noise made by our aircraft?

**Introduction**
Aircraft produce noise levels which can be annoying to people living along the flight path near an airport. Although there is no evidence that aviation noise is dangerous to the general public it certainly can impact the quality of life. Operations at most airports are constrained by rules to reduce this impact. Such rules reduce the efficiency of airport operations so noise reduction is always a consideration in new aircraft designs.

**Activity/Activities**
**Instruction:**
Sound is a physical phenomenon consisting of vibrations travelling through a medium, such as air. These vibrations can best be described as waves. Sound can be detected by the ear and processed by the brain. If it is found to be annoying or unwanted, the sound may be labelled as noise. Aircraft engines tend to make a lot of noise.

# Take to the Air

There are many different aspects of sound that may be measured. The intensity level of a sound is a measure of how much power is carried by a sound wave. Intensity level may be measured by instruments. The unit used to describe sound intensity is the decibel (dB). Because the human ear can comfortably handle sound intensities over an immensely wide range, the use of a linear scale would be inconvenient. The decibel scale is logarithmic. It begins at 0 dB which is barely at the threshold of human hearing. Every 3dB increase represents a doubling of the sounds intensity. Human conversation is typically around 60 dB. At 120 dB sound becomes uncomfortable and at 130 to 140 dB it becomes painful. The term "loudness" refers to how the human ear and brain perceive the intensity of sound.

Frequency is a measure of how many sound waves pass by each second and has units of cycles/sec or Hertz (hz). Our ears perceive high frequencies as high-pitched and lower frequencies as a low-pitched. Sound waves of different frequencies are usually moving with the same speed. The higher pitched sound waves reach the listener with higher frequency because the length of those waves is short. Lower pitched sound waves arrive with lower frequency because the waves are relatively long.

Since the sensitivity of the human ear depends somewhat on frequency, a weighted scale of sound level, called dBA, is often used. In fact most sound meters measure dBA even if they do not explicitly say so.

Typical Sound Levels in dBA

| | | | |
|---|---|---|---|
| 0 | hearing threshold | 100 | motorcycle engine |
| 10 | pin dropping | 110 | rock concert |
| 20 | rustling leaves | 120 | thunderclap |
| 30 | whisper | 125 | balloon popping |
| 60 | conversational speech | 135 | tornado siren |
| 70 | shower | 140 | jet engine (at takeoff) |
| 80 | garbage disposal | 160 | gunshot |
| 90 | lawn mower | 180 | rocket launch |

Measuring noise is a complicated task. What qualifies as noise to one person may not be perceived as noise by another. Three aspects of sound contribute to its perception as noise: the sound intensity, frequency, and duration. The FAA uses computer models to analyze these quantities and assign noise ratings. Aircraft are restricted in how much noise they are allowed to create. Over the years jet engine designs have made progress in reducing noise but there is still an interest in additional reduction. Airports are often required to modify their operations to minimize their overall noise impact on local communities. That cuts into profits so there remains a financial incentive for developing engines that produce less noise.

Notes

Recent engine design innovations include serrations or chevrons. These structures, at the rear end of the engine, allow exhaust gases to mix with each other and surrounding air more rapidly. The points of the serrations are curved very slightly inward toward the exhaust flow. Various tests have shown 2dB sound level reductions with minimal loss of thrust (less than 0.25%).

Pictured below is the engine of a Boeing 787 Dreamliner displaying chevrons for noise reduction.

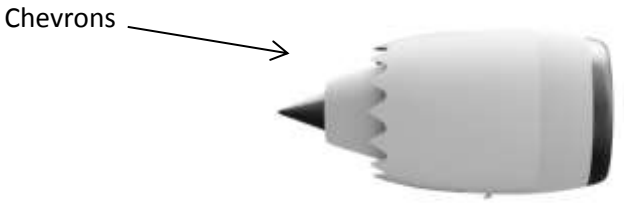



Photo licensed to IMSA by Iulius Costache|Dreamstime.com

**Inquiry Overview:**
In this activity students will study the sound produced by a party favor and modify its design in an attempt to reduce the sound levels it produces. They will gain experience with the engineering design cycle and statistical analysis of experimental data.

**Suggested Inquiry Approach**
Give each pair of students a straw on which to practice. Their goal is to develop a technique of forcing a short burst of air (lasting less than one second) through the straw in a very repeatable manner. They will eventually use this technique with their paper horn.

Once they have a plan for repeatability, give them their horns. Each team must measure the baseline sound level from their horn. Depending on the number of smart phones and test areas available, develop a plan such that only one team is testing at a time in each available area.

Only allow those teams which are making actual test measurements to make noise with their horn. Others can discuss and plan their design modifications while awaiting their opportunity to test.

Free apps are available for most, if not all smart phone operating systems for measuring sound levels. A good app for the iPhone is Decibel 10$^{th}$ by SkyPaw Co Ltd. A good choice for Android is Sound Meter by Smart Tools Co.

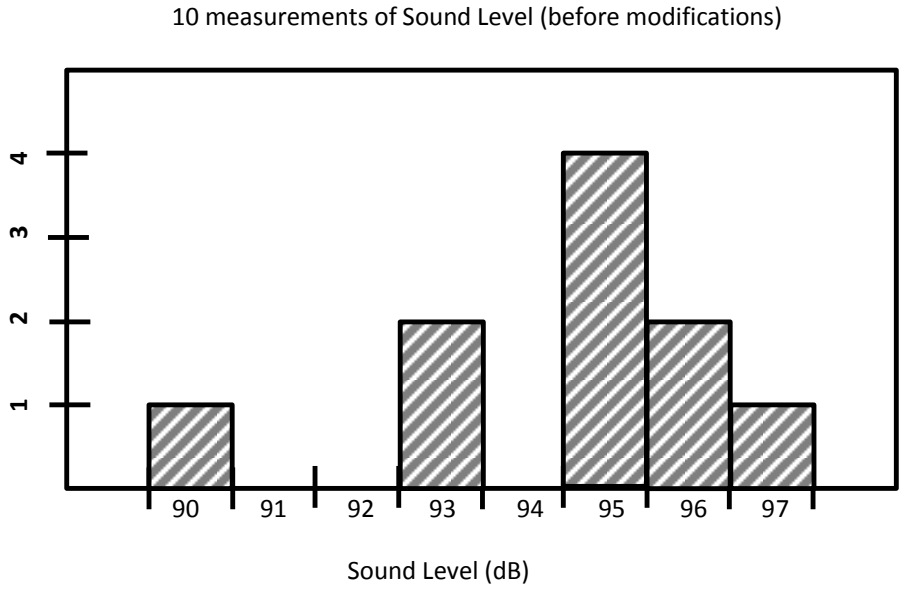
Notes

Establish a standard system for making measurements. The position and angle of the phone and horn should be consistent between measurements. Establish a convenient standard distance between horn and phone. At four meters, horns typically produce 90 to 105 dB.

Students should make ten measurements of sound level for their horn to establish a baseline.

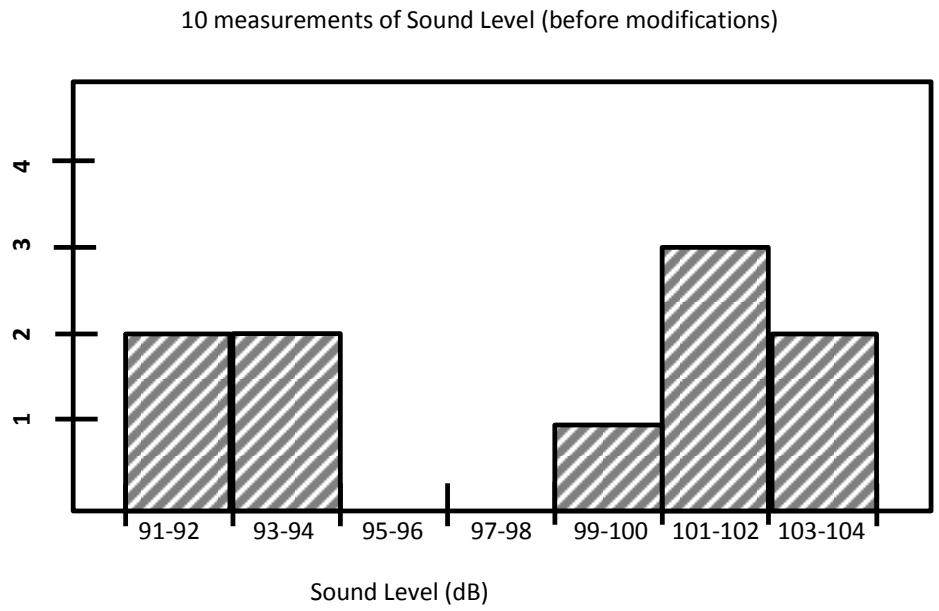
Students will plot a histogram of their data, looking for outliers, bimodal distributions, or any other indication that their experimental procedure has produced questionable data. Once they are satisfied that their data is valid they will calculate the mean sound level for their horn.

Here is one example of a histogram:




It shows a typical distribution of measured values. A student may reasonably wonder if the single measurement at 90 dB is a valid data point or an "outlier" that happened as a result of procedural error. Was this measurement taken while they were laughing? Should it be included in subsequent calculations?

Here is another example:



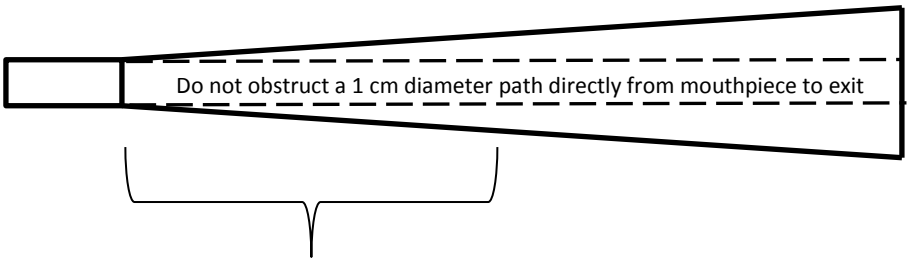

This is known as a bimodal distribution and suggests that something may have changed during the course of the experiment. Perhaps students took turns using their horns? Any change in technique could reveal itself in this way. Should students use only part of the data, repeat the experiment, or just go ahead and find the mean sound level using all ten measurements?

After calculating the mean sound level, students will modify their horn in an attempt to reduce its sound level.

Design Constraints:

- The white plastic mouthpiece may not be modified.
- The paper cone within 8 cm of the mouthpiece may not be modified.
- There must be a straight, unobstructed passage at least 1 cm wide running the length of the cone from the mouthpiece to the exit.

Notes




After making their modifications students will repeat their sound level measurements, analyze their data, and comment on the effectiveness of the modifications. Time permitting, another round of design modifications may be possible.

**Debrief:**

The smartphone apps are not science-grade instruments and give only an approximation of sound levels. Sometimes when repeating measurements many times, students will record a measurement that seems "off". Histograms can help them decide if the odd measurement is due to a momentary procedural error or represents something real and unusual. There are advanced mathematical techniques for analyzing such situations but ultimately the researcher will have to make a decision on whether or not to discard the "outlier". Science is a human process and relies on human judgment. Even if an outlier is omitted from subsequent calculations, its existence should be documented in the laboratory notebook. Others who examine this data later must be allowed to make their own judgments.

**Extension:**

1. The engineering design process is an iterative cycle. Allow students to continue making modifications if they feel they can make further progress.

2. Most students would correctly predict that perceived loudness decreases as one gets farther from a source of sound. But how quickly does it decrease? Will doubling the distance result in half the sound level? Challenge students to design an experiment to collect data at different distances from a sound source. Have them plot their data on a graph of dB vs. distance. Do any other natural phenomena share this relationship with distance?

Notes

3. Ask students what room or location in their school is the loudest. Use your smartphone app to make measurements in various locations to verify their predictions. Suggest modification that might reduce noise in these areas.

4. Visit the Midway Airport Noise Management website at http://www.flychicago.com/midway/en/AboutUs/NoiseManagement/default.aspx to learn about the steps Midway is taking to reduce their noise footprint.

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Careers in the Aviation Industry

**Logistics**
Class age/size: 7-9th grade
Materials:

- Computer with Internet access
- 11" x 17" cardstock
- Post-it notes
- Markers or colored pencils

Time: 90 Minutes
Location: Classroom
Safety Concerns: None

**Objective/Standard:**
Students will:

- Brainstorm a list of possible aviation careers
- Research two possible careers
- Create a "Help Wanted" poster outlining the necessary duties, skills, salary, and educational requirements for an aviation industry career
- SEP1; 6-8.RI.7; 6-8.RH.7; 6-8.WHST.7

**Need to Know Items Addressed**
What types of jobs will be created by our airline?

**Introduction**
While the aviation industry as a whole suffered a recession following the 9/11 terrorist attacks, the outlook for careers in the industry is currently optimistic. While the job most associated with aviation is that of the pilot, the flight crew is only a small part of what keeps an airplane flying and flight schedules on track. To stay in business, airlines and airports rely on many individuals such as baggage handlers, airport ground crew, ticket agents, and avionics technicians.

**Activity/Activities**

*Activity 1: Online research*
*Estimated Time: 35Minutes*

Notes

**Instruction:**

*Inquiry Overview:*

In this inquiry, students will brainstorm a list of jobs in the aviation sector and will then create an organizational scheme for the job listings. Students will share their strategies, and will generate a large class data set of possible jobs and careers in commercial aviation. Next, student teams will research a specific career and will create a "Help Wanted" poster to highlight the job description for that career.

**Suggested Inquiry Approach**

Provide each student with about 5 small post-it notes. Ask students to write down what jobs or careers are available in the commercial aviation industry. Next, have students form teams of four students and organize their careers by category. Examples of categories students may choose are as follows:

| | |
|---|---|
| **Pilot Jobs** | **Aircraft Manufacturers** |
| **Airline Company Jobs** | **Airport Operations** |
| **Air Traffic Control/Safety** | **Environmental** |

Ask each student team to share their categories. Place categories on the board and then have students come up and place their post-it notes job/career under the category in which they feel it best fits. Summarize the class data, and ask if any additional jobs can be generated.

Students will work in pairs for the next part of this activity. Provide each student team with at least one computer with internet access. Have each team come to the board and select a job or career post-it to research and write a job description for a "Help Wanted" poster.

Student teams will research their selected career and will use their student page to record the information they find. Pass out an 11" x 17" piece of cardstock for students to use to create their "Help Wanted" poster.

Students begin their investigation at the TrackStar website:
http://trackstar.4teachers.org/trackstar/
View Track # 456034
The password is: FUSION
Choose: View in Frames

Notes

**Debrief:**
Allow students to host a "Job Fair" to describe their jobs to prospective employees, namely the other students in the class.

**Conclusion:**
*Estimated Time: 5 Minutes*

Revisit the Know/Need to Know list and answer any Needs to Know and add any new ones that may have arisen from this activity.

Notes

# Generate Possible Solutions

Class age/size: 7-9th grade/whole group
Materials:

- K/NK Charts
- Final Problem Statement
- Generating Solutions sheets or post-it notes
- Information from activities and research

Time: 20 minutes
Location**:** Classroom

**Objectives:** *Students brainstorm solutions to the problem.*

**Introduction:**

Brainstorming solutions is the next step towards developing the ultimate solutions to the problem. At this stage, students should not be trying to choose solutions, the goals is to generate a large list of solutions for students to consider in the next lesson.

**Activity/Activities**

The students will brainstorm ideas for the ultimate solution to the problem by writing them on either the Generating Solutions handouts or post-it notes. They will then hang their solutions on the wall. As a class, or as small groups, the students will categorize the solutions according to common themes.

**Coaching Questions:**

- Have you investigated all of the areas of the Problem Statement?
- Do you have enough information?
- Have you investigated all of the Need to Know items?
- What options are you considering?

**Assessment:**

- Do the proposed solutions address the overall task and factors to consider in the Problem Statement?
- Do the proposed solutions show evidence of sufficient content knowledge to support the learners' case?
- Do they actively consider a broad range of solution elements?
- Do they offer valid support for their solution elements?
- Do all learners participate?

Notes

# Determine Best Fit Solution

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- K/NK Charts
- Final Problem Statement
- Generating Solutions sheets or post-it notes
- Information from activities and research
- Decision matrix or similar (if desired)

Time**:** 20 minutes
Location: Classroom

**Objectives/Standards:** *Students will determine the best solution to the problem.*

**Introduction:** The students will develop criteria for evaluating which solutions best fit the problem, and determine which solution(s) are a best fit. The key understanding is that there is seldom a perfect solution for a messy problem, just solutions that are a better or worse fit. The students may come up with one solution for the class, a solution with several components, or several solutions.

**Activity/Activities**
By referring to the Meet the Problem letter and the Problem Statement, the students will develop a list of criteria to judge the proposed solutions. Teachers may have the students use a decision matrix, SWOT analysis, or other methods for evaluating the solutions.

**Coaching Questions:**

- What is at stake in the problem? Have you considered all of the stakeholders/factors?
- What are the pros and cons of each possible solution?
- What solutions or combination of solutions seems most reasonable? Why or why not?
- What is the best-fit solution? How do you know?
- What are the potential consequences of this solution?
- What is the hardest question that you might be asked when you present this solution?
- Have you reached consensus?
- Is the solution realistic?

Notes

**Assessment:**

- Does the solution incorporate the information and content that learners have gained throughout this problem?
- Does the best-fit solution address all the factors in the problem statement?
- Do the learners work cooperatively to reach consensus on their shared vision?
- Do they set criteria for establishing priorities?
- Do they analyze the factors by means such as: feasibility, ethics/morals, cost benefit and risk analysis, consequences?
- Do they consider the consequences of their decisions?

Notes

# Present the Solution

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- K/NK Charts
- Final Problem Statement
- Generating Solutions sheets or post-it notes
- Information from activities and research
- Decision matrix or similar (if desired)

**Time:** 2 hours (1 hour for preparation, 1 hour for presentations)
**Location:** Classroom

**Safety:** No known issues

**Objectives/Standards:** *Students will design a presentation of their solution and give the presentation to poser of the problem.*

**Introduction/Activity/Activities:**

The students will develop presentations of the solution(s) to the problem. There may be multiple solutions within the class, or one solution with multiple parts presented by different groups. This is an especially powerful experience if the students are able to present their solutions to the problem poser.

**Coaching Questions:**

- Do you know what your role in the presentation is?
- Are your presentation materials ready?
- Have you considered and prepared for questions from the audience?

**Assessment:**

- Do the presentations communicate learners' solutions effectively, accurately, and clearly?
- Do learners ask appropriate questions of other presenters?
- Do learners engage with all of the presentations?

Notes

# Final Debrief

**Logistics**
Class age/size: 7-9th grade/whole group
Materials:

- Chart Paper
- Markers

Time: 30 minutes
Location: Classroom

**Objectives/Standards:** *Students will reflect on what the learned from the presentations and from the problem as a whole.*

**Introduction and Activity/Activities**:

The learners will reflect up their learning. This can be done through journaling small group discussion, whole class discussion, or any combination of these activities. Students sometimes don't realize how much they have learned until they are asked to reflect and make connections.

**Coaching Questions:**

- Guide learners to critically analyze their groups' presentation and those of other groups for effectiveness and completeness of the solution.
    - What elements worked and what didn't? How did you know?
    - What did you see in other presentations that was different from yours?
    - What content did other teams find that your team did not?
    - What would you leave out or add to your presentation if you were to do it again?
    - What would be the best solution to the problem?
- Guide learners to critically analyze their processing and group skills.
    - What skills worked for you as you gathered information, and what did not?
    - How effective did you think you were in solving the problem?
    - How effective did you think your group was in solving the problem?
    - How would you change your research tactics for another problem?
    - What helped you most to understand the problem?

- Guide learners to critically analyze their learning throughout the problem.
    - What new content knowledge did you gain through this problem?
    - How did that content knowledge help you to understand the problem?
    - What questions do you still have about the content of this problem?
    - Did your beliefs change after listening to others?
    - How did your thinking change during this problem?

Notes

**Assessment:**

- Can learners articulate the problem and solution in an individual journal entry?
- Do learners engage in whole group sharing about the presentation, the process, and the learning?

Dear Students,

I represent a group of entrepreneurs with an interest in starting a new airline, based in Chicago. We know that O'Hare Airport is planning to expand. It is also likely that an entirely new airport will be built in the south suburbs. This is a golden opportunity to start a new business and create more jobs here in Chicago.

The existing airlines will no doubt plan to expand, using the newly available airport facilities. We believe that a new, smaller airline, with the ability to make more rapid business decisions can beat them to the punch. To help us stand out from the competition, we will target a younger generation of flyers, who may not feel they are being well served by the older, more traditional airlines.

For this reason, we need the advice of young people like you. We would like your input on everything related to starting a new airline including:

- Marketing our airline
- Choosing which aircraft to purchase
- Resolving potential problems in getting those aircraft delivered
- Seating arrangements
- Ticket pricing
- Customer satisfaction
- Community impact

Please assist us in designing a next-generation airline to serve the people who live in, and fly through, the city of Chicago.

Best Regards,
Renaya Barton
Director of Research
Chicago Skies Initiative

# Take to the Air

***Name*** _____ ***Date*** _____

| Know | Need to Know | Need to Do |
|---|---|---|
| | | |

Name_____ Team _____ Date _____

## Problem Statement

| | Here's what I think… | Here's what we (pair) think… | Here's what our group thinks… |
|---|---|---|---|
| **Overall Task** | | | |
| **Factors to Consider** | | | |

**How can we . . .**

**in such a way that**

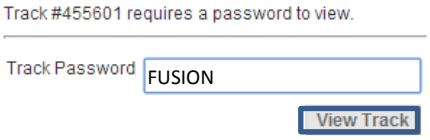
# Livery Design

***Problem:*** What is an aircraft livery and why is it important to an airline?

***Materials:*** Computer with internet access
Colored pencils and markers

***Procedure***:

1. With a partner, navigate to trackstar.4teachers.org and enter the following

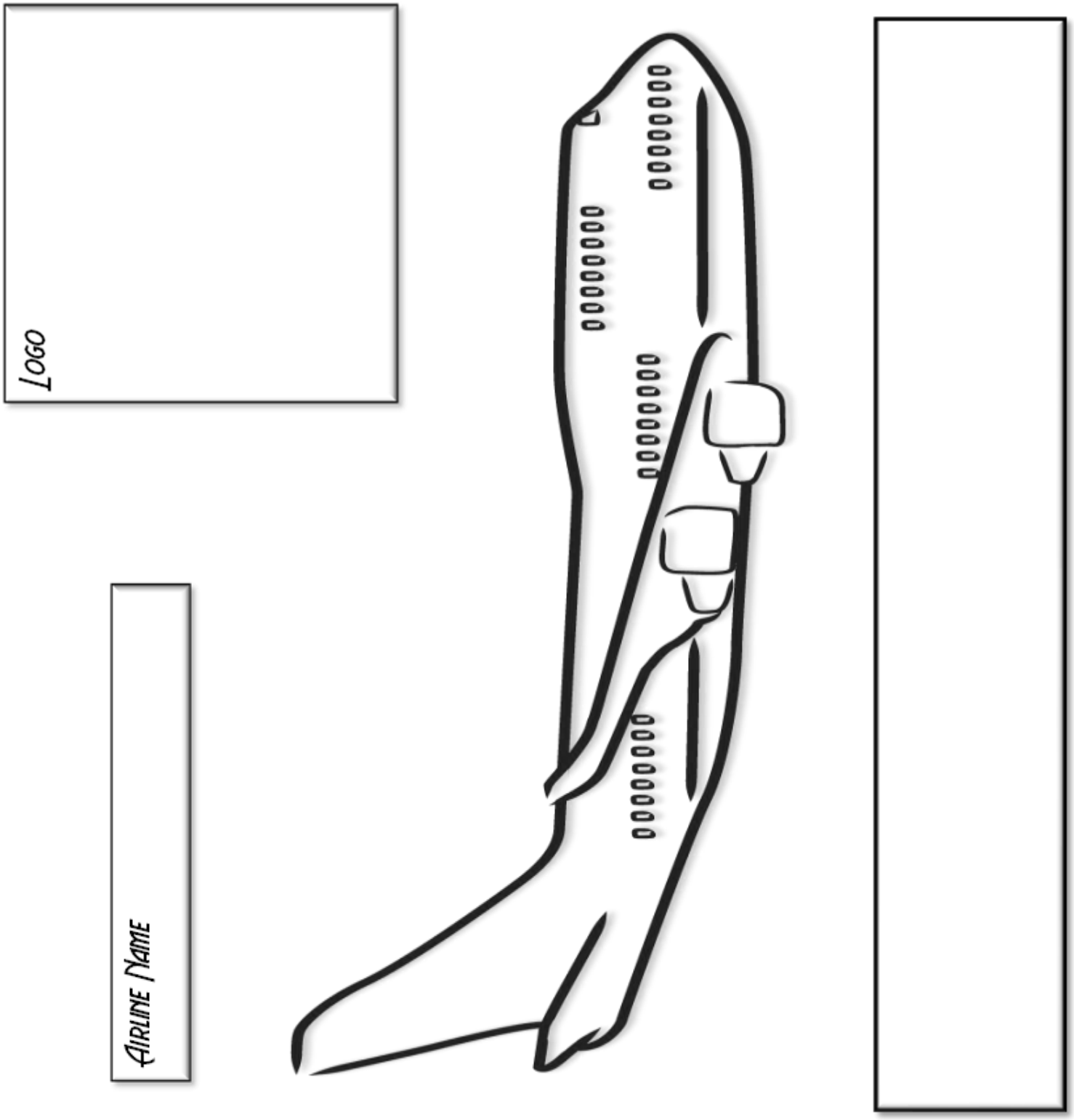




2. Select the "View in Frames" button upon opening the track.


Record any notes or other information to help with your response to the problem.

# Take to the Air

***Problem***: Design your custom logo and livery for your airline. Describe how your design choices will influence customers to try your airline.



# Great Circle Routes

Traveling to different places by car may involve going around mountains, lakes, or other obstacles. However, if you are traveling by air, these obstacles are not as problematic and there appear to be many choices for the path of your flight.

It would seem logical that pilots would choose the shortest path between two points. This would be economical in saving both time and jet fuel. However, other factors often come into play when determining the ultimate path a pilot will choose.

Imagine that you are at the controls of a large commercial jetliner. You are plotting a course between two locations an ocean apart. You would like to travel the shortest possible distance. How will you get there?

***Problem Part 1*:**

Determine the flight path that will yield the shortest distance between two points and plot on a two-dimensional world map.

***Materials*:**

1 – World study map (**Map A**)
1m kite string
Computer with internet access
1 – inflatable globe (per 2 teams)
1 – ruler
Colored pencils

***Procedure*:**

1. On your world study map (**Map A**), draw the shortest flight path between Springfield, Illinois, and Ankara, Turkey. Springfield, IL can be approximated on the map by drawing a point 2mm down and 1 mm left of the circle indicating Chicago, IL. Ankara, Turkey is identified on the map.
2. Once you have drawn the flight path on the map, use Flight Plan #1 to make a list of 5–10 major Earth features or landmarks over which the plane will fly. You may need a more detailed map to help identify some of these locations. An atlas or the Internet (http://go.hrw.com/atlas/ or http://www.atlapedia.com/) can supply this information. Save Flight Plan # 1.

***Flight Plan #1***
***Using World Study Map (Map A)***

***Landmarks:***

1. ***Springfield, Illinois***
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. ***Ankara, Turkey***

A globe of the Earth offers a different perspective of intercontinental travel.

3. Use an inflatable globe of the Earth and a piece of kite string about 1 meter in length to map out the shortest flight between Springfield, Illinois, and Ankara, Turkey.
4. Locate Springfield, Illinois, and Ankara, Turkey on the globe.
5. Pinch one end of the string between your thumb and first finger and hold it down over Springfield, Illinois on the globe.
6. Stretch the string tightly, holding it between your other thumb and first finger. Slide your thumb and first finger along the string until you reach Ankara, Turkey on the globe and hold it down there.
7. While you are holding the stretched string over the two cities, have another member of your team mark 5-10 Earth features or landmarks on **Map B** over which the string passes.
8. Use an atlas or the Internet to get the names of the locations marked on **Map B** write them down on the Flight Plan #2.

***Flight Plan #2***
***Using a Globe and* Map B**
***Landmarks:***

1. ***Springfield, Illinois***
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. ***Ankara, Turkey***

9. Connect the locations marked on **Map B** with a smooth, continuous line.
10. Mark on **Map A** the locations to be flown over as recorded on Flight Plan #2.

Now that you have completed Flight Plans # 1 and # 2 and **Maps A** and **B** take a look at them and compare the Earth features or landmarks over which the plane is scheduled to travel on both maps. Write down your answers to the following directions and be ready to discuss them with your classmates and your teacher.

- Describe how the two flight paths are the same and how they are different.

- Explain which flight path is the shortest and give reasons for your choice.

***Part 2***


The shortest distance between two points on a sphere is referred to as a ***great circle route***. In this part of the activity, you will further explore the relationship between the great circle route and the two-dimensional map projection of the routes and begin to investigate the relationship between these routes and the actual flight paths of commercial aircraft.

***Problems Part 2*:**

- How are great circle routes mapped in two-dimensions?
- Do actual flight paths always follow great circle routes?

***Materials*:**

1 – Two-dimensional world study map
1m kite string
Computer with internet access
1 – inflatable globe (per 2 teams)
1 – ruler
Colored pencils

***Procedure*:**

1. Using the inflatable globe, you and your partners will continue using the kite string to determine great circle routes for the pairs of cities in the table below. Be sure to accurately plot the Earth features or landmarks on the two-dimensional world map that accurately represents the great circle route.

| | |
|---|---|
| **Barrow, Alaska, US** | **Murmansk, Russia** |
| **Seattle, Washington, US** | **Paris, France** |
| **Atlanta, Georgia, US** | **Jerusalem, Israel** |
| **Bogota, Columbia** | **Columbo, Sri Lanka** |
| **Buenos Aires, Argentina** | **Sydney, Australia** |

2. What observations can you make when looking at the paths of great circle routes on the two-dimensional world map?

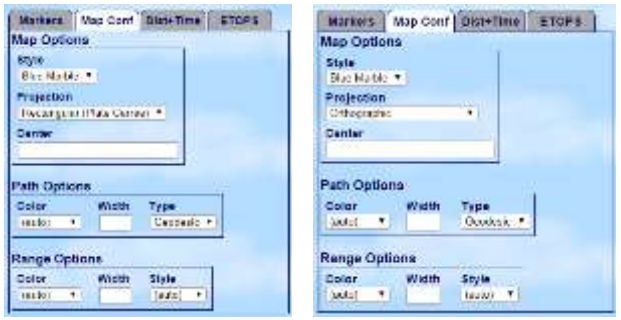
**3.** Using a computer with internet access, navigate to http://www.gcmap.com/ which is an online Great Circle Mapper tool. Using the online tool, you will search the city of "Chicago", and record the IATA (International Air Transport Association) 3-letter airport code. Searching "Chicago" gives the following data:


Location codes **1-20** of **31** for **chicago**

| ICAO | IATA | Other | Location |
|---|---|---|---|
| KORD | ORD | ORD | ***Chicago*** *[Chicago O'Hare Intl], IL, US* |
| KMDW | MDW | MDW | ***Chicago*** *[Chicago Midway Intl], IL, US* |
| | CHI | | ***Chicago*** *[Metro Area], IL, US* |

**4.** Select **ORD** as the code for Chicago's O'Hare International Airport. If **SFO** is selected for San Francisco International Airport, then mapping the Great Circle Route is done by typing in ORD-SFO and clicking the (MAP) button.


**5.** To go between the two-dimensional projection (Plate Carrée) and the globe view, use the following menu choices:




Click on the


button to change views.

**6.** Draw the route on the map below.

Of course not every aircraft could reach San Francisco from Chicago. A nice website which lists maximum ranges of different commercial aircraft can be found here: http://www.airlines-inform.com/commercial-aircraft/

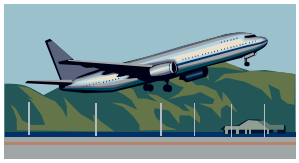
The website at http://www.greatcirclemapper.net/ is a very nice online tool to both map the great circle routes and look at airlines that may fly that route. This site will also allow the user to input various aircraft and look at their operating ranges.

**7.** Using any of the available tools and resources, determine which commercial aircraft have a sufficient range to fly from Chicago to every other major city in the continental US. This would be useful information for anyone starting a new Chicago-based airline. List at least five suitable aircraft below:

# Map B


Springfield
Ankara
km
0 1000 2000
GMT 2004 Feb 6 21:23:18
GMC - Martin Weinelt

# FAA Airport Diagrams



The Federal Aviation Administration (FAA) publishes Airport Diagrams that give essential information to pilots and other aviation specialists. It is highly advised that pilots completely familiarize themselves with the layout of the airport they will be taking off and landing at so they have a visual reference to rely upon. Even large commercial jets have been known to land at the wrong airport! In this activity, you will view various features of an FAA Airport Diagram and compare the runway design of actual airports in Chicago.

***Materials***:

1 – C-THRU navigational protractor
FAA Airport Diagrams for Midway and O'Hare
Computer with Internet Access

***Procedure***:

You will be working with a partner. Your teacher will provide your team with a set of FAA Airport Diagrams.

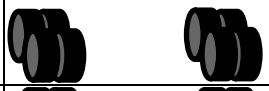
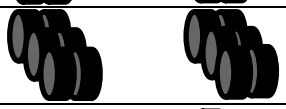
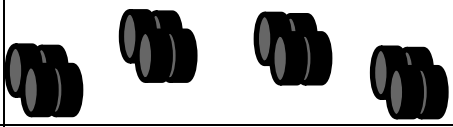
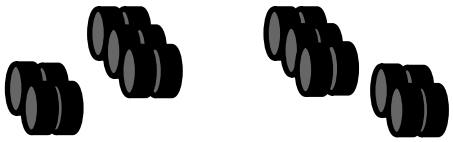
Identify and name all 13 runways at ORD and MDW.

Based on a runway's design, certain aircraft may not be able to use a specific runway to takeoff or land. What variables should be considered by pilots when determining the ground distance it will take their aircraft to takeoff or land?

You will be viewing data in a table and comparing it to the various runways in Chicago. Based on the information provided, you will determine which aircraft can operate from which runways. Navigate to http://planes.axlegeeks.com/ to view examples of the various aircraft types so you can associate the name with what it actually looks like. On the Airport Diagrams, the **Runway Weight Bearing Capacity** for landing is determined by the landing wheel configurations of the aircraft. On the diagrams they read:
RWY 14-32 S – 75, D – 140, 2S – 175, 2D – 200 where the letters are the wheel configurations and the numbers are the weight in thousands of pounds.

| Aircraft Type | Takeoff Length (MTOW) (feet) | Landing Length (MTOW) (feet) | Max Takeoff Weight (pounds) | Max Landing Weight (pounds) | Wheel Configuration Symbol |
|---|---|---|---|---|---|
| Airbus A320 | 5,600 | 5,052 | 172,000 | 145,500 | 2D |
| Airbus A340 | 9,842 | 6,318 | 609,000 | 423,300 | 2D-2D1 |
| Airbus A380 | 9,020 | 5,000 | 1,268,000 | 869,000 | 2D-3D2 |
| Boeing 737-700 | 6,300 | 5,906 | 154,500 | 128,000 | D |
| Boeing 747-400 | 9,901 | 7,545 | 875,000 | 574,000 | 2D-2D2 |
| Boeing 777-200ER | 7,998 | 5,098 | 656,000 | 470,000 | 3D |
| Boeing 787 | 4,986 | 4,986 | 502,000 | 380,000 | 2D |
| Bombardier CRJ-900 | 5,833 | 5,257 | 80,500 | 73,500 | D |

Source: http://planes.axlegeeks.com/ Assume: Zero Wind, Zero Gradient, Stand. Temp +27° F, Max takeoff weight

| Landing Gear Wheel Configuration Symbol | Wheel Arrangement |
|---|---|
| S – Single Wheel |  |
| D – Double Wheel |  |
| 2D – Double Wheel in Tandem |  |
| 3D – Double Wheel/Tandem 3 |  |
| 2D – 2D1 |  |
| 2D – 2D2 |  |
| 2D – 3D2 |  |

For each aircraft, determine how many of Chicago's 13 runways are useable.

What seems to be the determing factor in the type of landing wheel configuration of a particular aircraft? _____

Why do you think runways have different weight limits for different landing wheel configurations?

Why do you think some airports do not allow larger planes to takeoff/land even though the runway can accommodate the distance and weight?

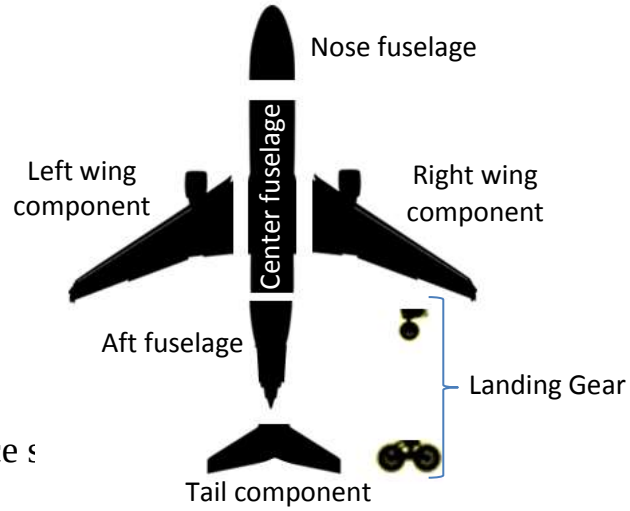
# Assembly and Delivery

***Background Information*:**
Manufacturing engineers direct and coordinate the processes for making things—from the beginning to the end. With a complex product such as a commercial jet aircraft, there are thousands of component parts and dozens of systems, including electrical, plumbing, flight control, propulsion, and cabin pressurization, that are integrated into one final product. In this activity, you will explore many of the issues that arise through the supply chain – from ordering specific components through manufacturing, delivery, and final assembly.

***Problems*:**

- What concerns do manufacturing engineers address when assembling a commercial jet aircraft for delivery to a customer?
- How likely is it that an aircraft can be delivered to the customer without delays?

***Materials (per team)***
1 – ***So You Want to Build a Jet?***
Game board and Instructions
1 – Color-coded game die
4 – Two –color counters
30 – Orange ORDER cards
30 – Yellow MANUFACTURE cards
30 – Red DELIVER cards
30 – Green ASSEMBLY cards
4 – Different colored planes
4 – Different colored cut-apart airplane game piece s




***Procedure:***

1. Please read aloud all of the instructions prior to playing the game ***So You Want to Build a Jet?***

2. As you play the game, record on your data sheet observations related to **Ordering**, **Manufacturing**, and **Delivering** components, and final **Assembly** of your jet to deliver to your customer.

| Order | Manufacture |
|---|---|
| | |
| **Deliver** | **Assembly** |
| | |

When assembling a jet aircraft, manufacturers want to use Just-in-Time delivery methods (parts are scheduled to arrive at assembly to "slide in" without needing storage). Why do you think aircraft manufacturers would not want to store large inventories of aircraft components?

Suppose you are a new airline purchasing aircraft. If a manufacturer tells you he should be able to deliver an aircraft within six months if no problems arise, how long do you think it might *actually* take?

# Design an Aircraft Cabin

***Problem*:**
How can the cabin seating arrangement in an airliner be designed to maximize profits?

***Materials*:**
Computer with internet access
Dia software template "Aurora 500"

***Procedure*:**

1. Create a formula which calculates how much profit your airline would make assuming you can fill every seat. Use the information below:

   On a typical four-hour flight from Chicago to San Francisco:
   - Tickets for a First Class seat sell for $660 each
   - Tickets for a Business Class sell for $490 each
   - Tickets for an Economy Class seat sell for $315 each
   - The operating cost of this flight (for your section of the aircraft) is $37,500

   Show your formula below:

2. Now use the Dia software provided to try different seating designs.

   Design Constraints:
   - You have two aisles running the length of your cabin section to position as you choose. For safety reasons, no passenger can be required to sit more than two seats from an aisle.
   - You must have at least four First Class seats in your cabin section.
   - No Business or Economy Class seats may be placed alongside First Class seats unless separated by an aisle.
   - You must have at least six Business Class seats in your cabin section. No Economy Class seats may be placed alongside Business Class seats unless separated by an aisle.

- Economy Class seats must account for at least half of the total seats in your cabin section.
- You may not change the size of any object in your activity.

3. Once you have a design that seems to make sense, and follows the rules, use your formula to calculate your profit.

4. If your profit is a negative number, try again! If it is positive, share your results with others.

5. See who can create the most profitable design in the time you are given.

**What other design elements would your aircraft cabin contain?**

# Take to the Air

## *(No Computer)*

***Problem*:**
How can the cabin seating arrangement in an airliner be designed to maximize profits?

***Materials*:**
Aircraft Cabin and Aisle Template
Cabin Seat Templates

**Procedure:**

1. Create a formula which calculates how much profit your airline would make assuming you can fill every seat. Use the information below:

   On a typical four-hour flight from Chicago to San Francisco:
   - Tickets for a First Class seat sell for $660 each
   - Tickets for a Business Class sell for $490 each
   - Tickets for an Economy Class seat sell for $315 each
   - The operating cost of this flight (for your section of the aircraft) is $6,000

   Show your formula below:

2. Now use the paper templates provided to try different seating designs. Cut out the aisle and a few seats and begin positioning them within the cabin outline.
   Design Constraints:
   - You have one aisle running the length of your cabin section to position as you choose. For safety reasons, no passenger can be required to sit more than two seats from an aisle.
   - You must have at least two First Class seats in your cabin section.
   - No Business or Economy Class seats may be placed alongside First Class seats unless separated by an aisle.
   - You must have at least three Business Class seats in your cabin section.

- No Economy Class seats may be placed alongside Business Class seats unless separated by an aisle.
- Economy Class seats must account for at least half of the total seats in your cabin section.

3. Once you have a design that seems to make sense, and follows the rules, use your formula to calculate your profit.

4. If your profit is a negative number, try again! If it is positive, share your results with others.

5. See who can create the most profitable design in the time you are given.

**What other design elements would your aircraft cabin contain?**

# Bump You Up or Out?

***Problem*:**
What is "overbooking" and how do airlines use it to increase their profits?

***Materials*:**
- Calculators
- Computer with Internet access

***Procedure*:**
1. Form groups of two. You and your partner own an airline which operates trans-pacific flights. You wish to make as much profit from this business as possible.

2. There are several aircraft which your company could use for flying across the pacific such as the **Airbus A340** or the **Boeing 747**. Select one of these aircraft and search the internet to find out how many passengers your aircraft can seat. There are many versions of these two aircraft with different seating capacities. Select any version you wish and record the seating capacity below:

   Aircraft: _____ with _____ seats

3. This aircraft will be used to fly a route between Los Angeles and Tokyo. How much you charge your customers for a ticket, known as the *airfare*, would depend on many factors including your operating costs. As a new company you may want to offer the lowest rates available just to get people's attention. Use the internet to discover what your competitors are charging for round-trip airfare between Los Angeles and Tokyo. There are many internet sites that compare what different airlines are charging. You could use one of the following:
   - www.expedia.com
   - www.airfare.com
   - www.travelocity.com

You are looking for the lowest airfare for one traveler, flying round trip from any airport in **Los Angeles** to any airport in **Tokyo**. The departure date should be one month from today with a return one week after departure. Assume this is an **economy class** ticket. You should not need to enter any other information. **Do not** give the website any real information such as your name or contact information.
Record the lowest airfare below:

Lowest airfare available from competitors: _____

4. Now subtract one dollar to arrive at your airline's introductory rate.

   Your airline's airfare: _____

5. This is what you will charge for each ticket. Assume your introductory rate catches the public's attention and you are able to sell as many tickets as your aircraft has seats. In the space below, calculate how much money you will take in from ticket sales.

   This is not all profit. Most of this money (over 95%) must be spent on aircraft, crew, fuel, and other costs.

6. That may still seem like a lot of profit but you notice something interesting when passengers board the aircraft on your company's inaugural flight. There are several empty seats. Some passengers changed their plans and did not use the tickets they bought.

   On average, about 10% of passengers will not show up to use their tickets. If 10% of your passengers are no-shows, calculate the number of empty seats on your flight in the space below. Round your answer to the nearest whole number.

7. Is this a problem for you, the airline owner? You may not think so at first. After all, these people have already paid you for the tickets. But had you sold some extra tickets, you would have made an additional profit. Selling more tickets than you have seats is perfectly legal and almost every airline does it. The process is called *overbooking*.

   Failure to do what would have given you more profit is an example of an *opportunity cost*. If you don't sell extra tickets you are essentially paying a cost equal to what you would have made from selling those extra tickets. In the space below, estimate the **opportunity cost** you paid by not overbooking the flight.

8. Now you can see why airlines overbook. The actual opportunity cost is probably even higher than what you estimated as we will see. There is a lot of potential money that can be earned by selling more than one ticket per seat. How many extra tickets should you put on sale for your flight from Los Angeles to Tokyo?

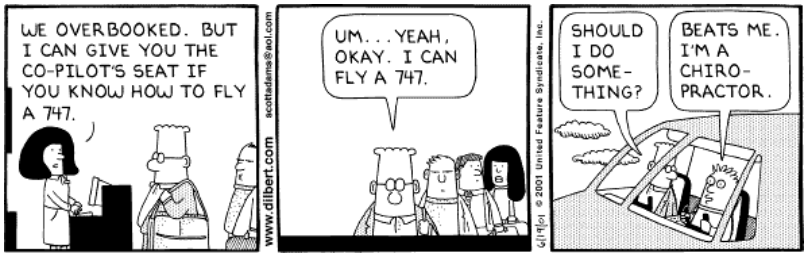
9. If your answer was less than or equal to the number of empty seats you had (your answer to question 6) then you are still losing potential income. Remember that, on average, 10% of the people buying these extra tickets will not actually use them. You could have sold more!

   So how can an airline decide how many extra tickets to sell? If you want a full plane and expect 10% of the people to not show up, you should sell enough tickets so that 90% of the total tickets sold equals the number of seats. Write this as an algebraic equation in the space below:

10. Using your equation, calculate the total number of tickets you should sell.

11. Subtract the number of seats from the total number of tickets to see how many extra tickets you should sell. Show your work below.

Actual airlines use a similar process but they include a lot more variables in their calculations and let computers do the math. Even the most powerful computers, however, cannot change one fact. You can never predict exactly how many people will not show up for their flight. Ten percent is just an average and it is possible that everyone your airline sold a ticket to will show up at the gate expecting to fly.




Airlines handle this uncomfortable event by offering passengers incentives to postpone their travel to a later flight. The incentives might include free upgrades from economy to first class (bumping-up) or discount coupons for future air travel. In most cases enough volunteers step forward to alleviate the problem. Sometimes, nobody volunteers to postpone their flight and the airlines must pick some passengers who will be denied boarding. They have been involuntarily bumped from the flight and will be given some money in compensation.

12. How would you feel if an airline told you that you could not fly on a flight for which they sold you a ticket? Would you use that airline again?

Obviously an airline does not want to obtain a bad reputation for bumping passengers off of their flights and this must be considered when deciding how to manage overbooking.

13. The U.S. Department of Transportation maintains statistical records of how often airlines bump their passengers and how often passengers complain about the airlines. Visit this website: http://www.dot.gov/airconsumer/air-travel-consumer-reports and open the October 2014 Air Travel Consumer Report.

14. Use the data on page 37 to determine how many air passengers were denied boarding during the first half of 2014. Select the statement below which is the best approximation of your answer and then justify your choice using numerical data.
    a) one in a million
    b) one tenth of one percent
    c) most
    d) 99%

15. Of those who were denied boarding, how many were bumped involuntarily? Select the statement below which is the best approximation of your answer and then justify your choice using numerical data.
    a) one percent
    b) 10%
    c) most
    d) 99%

16. Use data from page 37 to fill-in the first empty column in the following data table:

| Airline | Involuntary bumps (involuntary DB's) | Customer complaints about oversales | Total customer complaints |
|---|---|---|---|
| Delta Air Lines | | | |
| Expressjet Airlines | | | |
| United Airlines | | | |
| US Airways | | | |

17. It would be nice to know how many customers complained about overbooking (also called overselling) during this same time period. Unfortunately the Department of Transportation only reported on complaints for the month of August in 2014. You will find that data on page 41. Use it to complete your data table.

18. Do you see any obvious relationships in the data? Do you see anything which surprises you?

19. In steps 5 through 11 you examined the economic benefits of overbooking. In steps 12 through 18 you examined the possible negative effects of overbooking on passengers. As an airline owner what would be your policy on overbooking? Justify your policy decisions based on numerical data.

# Culture and Image

***Background Information*:**
Many companies adopt a Statement of Values or a Code of Ethics to help guide their activities. These documents become part of their identity and culture. For businesses such as airlines, there are often specific goals related to customer service. This information is generally posted on corporate websites and reflects the image which an airline presents to the public.

***Problems*:**

- What airlines operate in the Chicago area?
- How do these airlines portray themselves to the public?
- How might a new airline portray itself to gain attention?

***Materials (per team)***
Computer with internet access

***Procedure:***
Find a partner. Your teacher will assign you two Chicago-based airlines to research on the internet.

Begin your investigation at the TrackStar website:
http://trackstar.4teachers.org/trackstar/
View Track # 458728
The password is: FUSION
Choose: View in Text
Read whatever you can find on the airline's website to discover how they view themselves and what they promise to potential customers. Take notes in the tables that follow:

# Airline:

| Corporate Culture: How they view themselves | Customer Service: What they promise to the customer |
| --- | --- |
| | |

# Airline:

| Corporate Culture: How they view themselves | Customer Service: What they promise to the customer |
| --- | --- |
| | |

In a class discussion, you will share your findings. Take notes on any unique aspects of the airlines researched by other groups below:

# Take to the Air

Suppose you were to start a new airline. How could you establish a successful corporate culture? How would you portray your airline to the public? What would you promise to customers? How could you set your airline apart from the competition? After discussing with your partner, record your ideas below. Be prepared to share your work with the class.

# Delay, Delay, Go Away!

***Background Information*:**


Have you ever traveled on a commercial aircraft? If so, did your flight arrive later than scheduled? Millions of travelers every year experience flight delays. In fact, it is estimated that flight delays cost in excess of $30 BILLION dollars annually. Who is impacted by these delays? What variables might contribute to flight delays? How might airlines try to reduce flight delays in the future? Discuss these questions with your team, and be prepared to share your ideas with the class.

***Problem:***

Can I fly a four-leg journey without experiencing a flight delay using simulation?

***Materials*:**

- 1 – US Time Zone map
- 1 – green dry erase pen
- 1 – blue dry erase pen
- 1 – red dry erase pen
- 1 – set polyhedra dice
- 3 – two-color counter chips
- 3 – 11” x 17” copies of data tables
- Computer with Internet access
- Paper towels (to erase maps)

***Procedure*:**

1. Your team of three will each select a different colored pen to use during the simulation. Using your colored dry erase pen, mark along the US Time Zone map four segments (legs) between cities of your choice starting with a location on the West coast of the United States and ending at a location on the East coast. You must choose cities in at least **three different time zones** indicated by the different shades on the map. Then, pass the map to a teammate for their selections until you have all selected four segments.

2. Spend a few minutes looking over the table below. Notice that the airports that appear in the cities on your US Time Zone map are identified using a three-digit alphabetic code. Use the table below to assist in identifying the locations.

| City/Airport | Code | City/Airport | Code |
|---|---|---|---|
| Seattle, WA/Seattle-Tacoma INTL Airport | SEA | Milwaukee, WI/General Mitchell INTL APT | MKE |
| Portland, OR/Portland International Airport | PDX | Des Moines, IA/Des Moines INTL Airport | DSM |
| San Francisco, CA/San Fran. INTL Airport | SFO | Minneapolis, MN/Minneapolis-St. Paul INTL | MSP |
| Los Angeles, CA/Los Angeles INTL Airport | LAX | Detroit, MI/Detroit Metro. Wayne County | DTW |
| Las Vegas, NV/McCarran INTL Airport | LAS | Indianapolis, IN/Indianapolis Regional APT | IND |
| Boise, ID/ Boise Airport | BOI | Columbus, OH/Port Columbus INTL Airport | CMH |
| Cheyenne, WY/Cheyenne Regional Airport | CYS | Frankfort, KY/Capital City Airport | FFT |
| Billings, MT/Billings Logan INTL Airport | BIL | Atlanta, GA/Jackson-Hartsfield INTL Airport | ATL |
| Salt Lake City, UT/Salt Lake City INTL Airport | SLC | Orlando, FL/Orlando International Airport | MCO |
| Denver, CO/Denver International Airport | DEN | Miami, FL/Miami International Airport | MIA |
| Phoenix, AZ/Phoenix Sky Harbor INT Airport | PHX | Charleston, SC/Charleston INTL Airport | CHS |
| Albuquerque, NM/Albuquerque INT Sunport | ABQ | Charlotte, NC/Charlotte-Douglas INTL APT | CLT |
| Bismarck, ND/Bismarck Municipal Airport | BIS | Richmond, VA/Richmond International APT | RIC |
| Sioux Falls, SD/Sioux Falls Regional Airport | FSD | Charleston, WV/Yeager Airport | CRW |
| Omaha, NE/Eppley Airfield | OMA | Washington, DC/Wash. Dulles INTL APT | IAD |
| Wichita, KS/Wichita Mid-Continent Airport | ICT | Annapolis, MD/Balt.-Wash. INTL | BWI |
| Oklahoma City, OK/Will Rogers World APT | OKC | Dover, DE/ Dover Air Force Base | DOV |
| Dallas, TX/Dallas-Ft. Worth INTL Airport | DFW | Trenton, NJ/Trenton-Mercer Airport | TTN |
| San Antonio, TX/ San Antonio INTL Airport | SAT | Philadelphia, PA/Philadelphia INTL Airport | PHL |
| New Orleans, LA/Louis Armstrong INTL APT | MSY | New York, NY/John F. Kennedy INTL APT | JFK |
| Jackson, MS/Jackson-Medgar Wiley Evers | JAN | Hartford, CT/Bradley International Airport | BDL |
| Montgomery, AL/Montgomery Regional | MGM | Providence, RI/Theodore Francis Green APT | PVD |
| Memphis, TN/Memphis INTL Airport | MEM | Boston, MA/Boston-Logan INTL Airport | BOS |
| Little Rock, AR/Bill and Hillary Clinton INTL | LIT | Montpelier, VT/Burlington INTL Airport | BTV |
| St. Louis, MO/Lambert St. Louis INTL Airport | STL | Concord, NH/Manchester-Boston Regional | MHT |
| Chicago, IL/O'Hare International Airport | ORD | Augusta, ME/Augusta State Airport | AUG |

3. You will each receive an 11" x 17" copy of two data tables. The data table titled "**Flight Schedule**" is a list of available flights from one airport to another airport. Listed in the body of the table are the flight times (in h:mm format). On the other side of the sheet titled "**Delay Probabilities**", you will find the probability of experiencing a delay for a particular flight. You will use these tables to simulate a four-leg journey from an airport on the West coast of the U.S. to a destination on the East coast of the United States.

4. Now, use the **Flight Schedule** data table to determine if there are flights between your selected cities. If there are not, use a paper towel to erase your selections and select from the available flights.

   Why might there not be direct flights between two locations on the map?

5. Now view your polyhedra dice. Write down some observations you have about the dice.

6. You will use the dice to design a simulation for the probability that you will experience a delay along the leg of the journey you have chosen. The data table **Delay Probabilities** lists the chance of a delay along any particular leg. As an example, if the likelihood of a delay is given as **1/20**, you may use the 20-sided polyhedra die to model this likelihood by stating that "rolling a 1 represents a delay; rolling 2 – 20 represents no delay."

7. If your flight experiences a delay, you must then toss the two-colored counter.

   - If the counter lands on yellow, add one additional hour to your flight time for that leg.

   - If the counter lands on red, add two additional hours to the flight time for that leg.

8. You may record your data in the table below. Run the simulation three times and record the total travel time for your four-leg itinerary for each of your trials.

| **Itinerary from _____ to _____** | | | | | |
|---|---|---|---|---|---|
| **Flight Segments** | Leg 1: _____ to _____ | Leg 2: _____ to _____ | Leg 3: _____ to _____ | Leg 4: _____ to _____ | |
| **Flight Time** | | | | | |
| **Delay Probability** | | | | | |
| **Probability Model** | | | | | Total Time |
| **Trial 1** | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | |
| **Trial 2** | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | |
| **Trial 3** | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | Delay? Y N<br>Time? 1hr 2hr<br>Total: Leg Flight Time (h:mm) | |

9. What was the average total flight time for your itinerary?

10. Using the US Time Zone map, if you depart from the West coast at 9:00 A.M. local time, what time would it be on the East coast (local time) when you reach your destination?

11. Working with your team, did any team member experience delays along your routes? If so, what do you notice about the airports with higher delay probabilities? If not, what observations can you make about the airports you "flew" into along your route?

12. Why do you think airlines fly into airports with higher probabilities of delay?

13. If your team has access to a computer, you may navigate to http://www.travelmath.com/flights/ and determine the flight time if you flew non-stop between your starting and ending locations.

14. Compare the advantages and disadvantages of a non-stop route for both airlines and passengers.

15. If time permits, choose another 4-leg route between your departure and destination cities and try to reduce your overall flight time. Were you successful?

# Noise Reduction

***Problem*:**
How can we modify a machine to reduce the amount of noise it creates?

***Materials*:**

- party favor (paper horns)
- wood glue or craft glue
- straw
- graph paper
- Sound APP
- pipe cleaners
- cotton balls
- craft foam
- hole punch

***Procedure:***

1. Using a straw for practice, develop a technique that will allow you to make short (less than a second) blasts of air through your horn. The goal is not to be as loud as possible but to develop a technique which is highly repeatable.

2. Go to the designated area with your horn and a smart phone. Be sure you know the proper distance to use between the horn and meter. Be mindful of how you are doing these measurements because you will need to come back in a while and do more measurements in exactly the same way.

3. Use the smartphone app to measure the sound level of your horn. Record the peak value then reset the meter for your next test. Record ten measurements.

4. Calculate the range in your data (max dB value – minimum dB value). Hopefully your range is small which indicates that your technique was consistent. Are you concerned that any of your data might be invalid because of mistakes in your procedure or measuring technique?

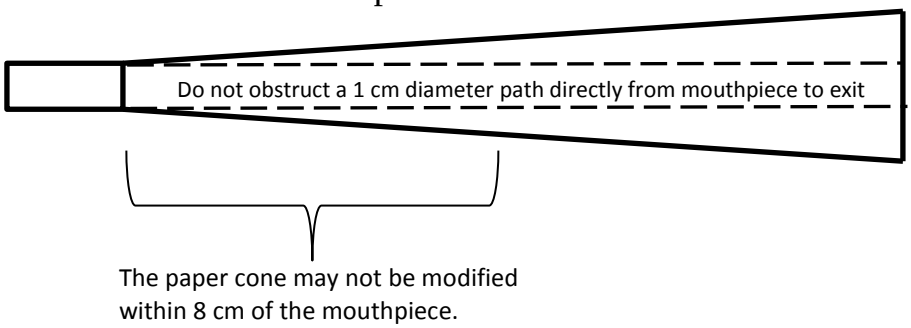
5. Construct a histogram of your data on a sheet of graph paper. A histogram is a graph that can visually display the consistency of your measurements. Your range of data can be divided into a number of "bins". The size of your bins could be 1dB each or 2 dB each. Your teacher can show you examples. Put a bar in each bin to indicate how many of your ten measurements fell within that bin.

6. After constructing your histogram you may suspect that one of your measurements was the result of an error in your technique. Should you consider that point valid? Should you ignore that measurement? What is the potential danger of each choice?

7. Using all of your valid measurements, calculate the mean.

8. Next you will modify your horn but your modifications must not violate the following design constraints:

- The white plastic mouthpiece may not be modified.
- The paper cone within 8 cm of the mouthpiece may not be modified.
- There must be a straight, unobstructed passage at least 1 cm wide running the length of the cone from the mouthpiece to the exit.




9. Once you have made your modifications, test your horn's sound level just as you did before, repeating steps 2 through 7. Did you achieve a reduction in sound level? Explain your results by referring to your numerical data.

# Careers in the Aviation Industry

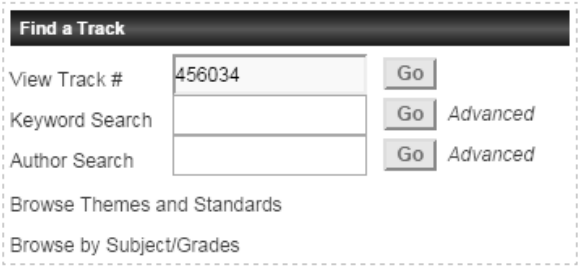
***Problem*:**
What careers are available in the aviation industry?

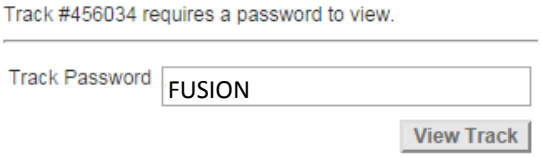
***Materials*:**

- 11" x 17" piece cardstock (per partner team)
- Post-it note sheets
- Markers or colored pencils
- Computer with Internet Access

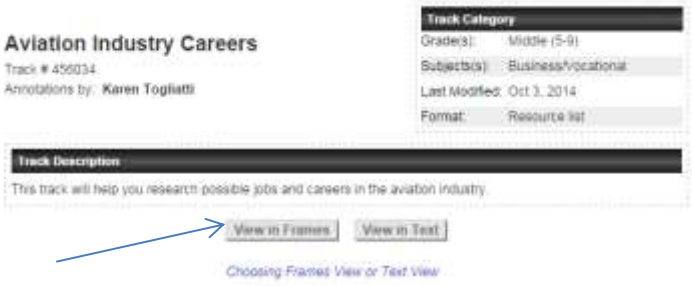
***Procedure*:**

1. Navigate to trackstar.4teachers.org and enter the following:




2. Select the "View in Frames" button upon opening the track.




3. With your partner, research the job or career that you have selected. Also look for jobs that may have similar titles. On the back side of this sheet, record information that you will use to make a "Help Wanted" poster using 11" x 17" cardstock. Your poster should be attractive and should include all the information necessary to attract a quality candidate for the job! Be sure to include the "company" that the candidate would work for with this job.

| | |
|---|---|
| **Job Title and Related Job Titles** | |
| **What companies would require this job?** | |
| **Job Overview** | |
| **Main job tasks/responsibilities** | |
| **Education/Training Required** | |
| **Working Conditions/Physical Requirements** | |
| **Salary** | |
| **Interests and Abilities related to the job** | |

# Generate Possible Solutions

***Name*** _____ ***Date*** _____

What possible elements of a solution do you see emerging?

Why do you think those elements help resolve the problem?

What other elements have you considered and rejected?

Why did you reject them?

# Take to the Air

***Name*** _____ ***Date*** _____

**Task:**

| Factors to Consider | Solution Element A | Solution Element B | Solution Element C |
|---|---|---|---|
| **Factor 1** | | | |
| **Factor 2** | | | |
| **Factor 3** | | | |
| **Factor 4** | | | |
| **Pros** | | | |
| **Cons** | | | |
| **Long-term effects** | | | |

**Our best-fit solution includes:**