Pre-Visit Prep and Extension Activities

Level 2: 6th - 8th Grade
<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>About the ALC</td>
</tr>
<tr>
<td>Welcome Letter</td>
</tr>
<tr>
<td>How to Use this Extension Packet</td>
</tr>
<tr>
<td>- Big Ideas</td>
</tr>
<tr>
<td>Preparing For Your Visit</td>
</tr>
<tr>
<td>- Your Day at The Museum of Flight</td>
</tr>
<tr>
<td>- Chaperone Info</td>
</tr>
<tr>
<td>- Museum Map</td>
</tr>
<tr>
<td>Assigning Teams</td>
</tr>
<tr>
<td>- Learning Lab Workstations</td>
</tr>
<tr>
<td>- Aviation Learning Center Student Roster</td>
</tr>
<tr>
<td>Extension Activities</td>
</tr>
<tr>
<td>- Don’t Be Fuel-ish (Mathematics)</td>
</tr>
<tr>
<td>- Airplanes! Stat! (Language Arts)</td>
</tr>
<tr>
<td>- Roll with Newton’s Laws of Motion (Science)</td>
</tr>
<tr>
<td>Standards Supported</td>
</tr>
<tr>
<td>- Extension Activities Standards Supported</td>
</tr>
<tr>
<td>- Aviation Learning Center Standards Supported</td>
</tr>
</tbody>
</table>
Welcome to the Aviation Learning Center. Your students are about to embark upon a two-hour immersive pilot training and ground school inspired program in which they will experience aeronautical science, piloting protocols and the thrill of flight.

Engaging hands-on lessons connect classroom content (sciences, math, technical reading) and real world skills (problem solving, teamwork) to the aviation world. The Aviation Learning Center encourages students to find their place in that world and gives them the tools to get there.

The program is geared toward three academic age groups; upper elementary (4-5), middle (6-8), and high school (9-12). Each level is designed with age appropriate challenges and learning, and supports current educational standards (Common Core State Standards, Next Generation Science Skills, & 21st Century Skills).

On the day of your visit, your class will be divided into two groups. (Within the groups, students will work in pairs throughout the entire Aviation Learning Center experience.) The two groups will rotate through three different areas of the ALC: Rajpaul Learning Laboratory, Cirrus Hangar and Flight Simulator Bay.

- In the Rajpaul Learning Laboratory, students explore aeronautical topics and concepts that pilots study in ground school.

- In the Cirrus Hangar, students plan a course and create a flight plan. They also perform a pre-flight safety inspection of an actual Cirrus SR-20 aircraft.

- Finally, in the Flight Simulator Bay, students put their new skills to use—when they step into the simulators and fly the route they charted in the Hangar.

The Aviation Learning Center combines STEM topics, real world skills and fun for an inspiring and memorable experience for all participants.

If you have any questions or comments about your upcoming Aviation Learning Center experience, please do not hesitate to contact us at alc@museumofflight.org or at 206.768.7188.

Happy Flying,
The Aviation Learning Center Staff
The Museum of Flight
How to use this Extension Packet:

This Aviation Learning Center Extension Packet sets the stage for your exciting program in the Aviation Learning Center. You will find information about your day-of field trip experience, how to organize your students for their ALC program, and Extension Activities to use in your classroom.

The materials are targeted for use by teachers and students in Middle School (Grades 6-8). Suggestions and extensions for different ages are included in the activity instructions.

The activities in this packet are designed to enhance your students’ understanding of the concepts that will be explored during the ALC program and should be included as part of your preparation to visit The Museum of Flight.

The lessons are designed for age appropriate challenges and learning, and support current educational standards (Common Core State Standards, Next Generation Science Standards and 21st Century Skills).

All of the activities offer opportunities to integrate science, mathematics and other subjects into the lessons.

Additionally, these activities are adaptable, multi-disciplinary, and inclusive enough to meet the needs of individual learning and teaching styles.

We hope you and your students enjoy the activities in this Extension Packet and your time in the Aviation Learning Center.

If you have any questions or comments about your upcoming Aviation Learning Center experience, please do not hesitate to contact us at alc@museumofflight.org or at 206.768.7188.
About the Aviation Learning Center
OVERVIEW

Students will learn about the science of flight and experience what it takes to be a pilot. They will perform a pre-flight safety inspection on a real airplane, create a flight plan, and fly the route in flight simulators.

BIG IDEAS

• Forces of Flight
• Navigation and Map Reading
• Parts of a Plane
• Flight Controls

OUTCOMES - What will students know or be able to do by the end of the lesson?

• Identify the preparations a pilot must undertake before flying.
• Appreciate the value of math and science skills in the real world.

VOCABULARY

• Force
• Aileron
• Elevator
• Rudder
• Nautical Mile
• Knots
• Latitude & Longitude
• Simulator

Program: Aviation Learning Center - Level I, II, III
Grade Level: 4-12
Group Size: Max. 36
Length: 2 hours
Location: The Museum of Flight
PREPARING FOR YOUR MUSEUM VISIT

• Please arrive at the Museum 15 -30 minutes before the program start time. This allows time for lunch storage, bathroom breaks, check-in, and group organization.
• All programs must end at the original end time, regardless of when the program starts.
  Headcount - # of students _______
  # of chaperones _______
• Please leave backpacks at school or on the bus.
• Bring lunches in a box with school name on it. These will be stored adjacent to the Alaska Airlines Aerospace Education Center.

ARRIVAL AT THE MUSEUM

• Students should wait on the bus or outside until a MOF representative greets the group and stamp the students’ hands.
• Please wait for students whom arrive separately in the Museum Lobby.
• Teachers will check in at the Alaska Airlines Aerospace Education Center (AEC), at the nose of the MD-21 Blackbird. Student and chaperone headcounts are needed at this time.
• Upon check in, groups can reserve a lunch time for one of the Museum’s indoor lunch areas. Reservations are made on a first-come, first-served basis.
• Lunches will be stored adjacent to the AEC.
• After students are dropped off at the Museum, buses are parked in the West campus, behind the Charles Simonyi Space Gallery. After parking, drivers are welcome to get a chaperone nametag from the AEC and tour the museum.
• If you will be late, please call the AEC at (206) 768-7239.

YOUR DAY AT THE MUSEUM

Program name(s) ___________________________________________________________

Program start time(s) _______________________________________________________

Program end time(s) _______________________________________________________

Location (where to meet) ___________________________________________________
FOR YOUR VISIT

PREPARING FOR A MUSEUM TRIP

Student Names

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

ARRIVAL AT THE MUSEUM

If you arrive separately from your teacher, please wait for them in the Museum Lobby.

All students must follow the Museum’s TREES:

T - Toe rails - stay outside the gray and black striped barriers around the aircraft
R - Running - use your walking feet in the Museum
E - Eating - eat only in the designated lunch area
E - Elevator - save the elevator for visitors who need it - take the stairs
S - STICK - students must AT ALL TIMES stick with their chaperone (including bathroom breaks and while in the gift shop)

YOUR DAY AT THE MUSEUM

Program: ____________________________

Time: ____________________________

Location: ____________________________

Departure Time: ____________________________

Chaperones
FOR YOUR VISIT

FURTHER EXPLORATION

• Check out the future of space travel in the Charles Simonyi Space Gallery
• Explore the evolution of technology from WWI through WWII in the J. Elroy McCaw Personal Courage Wing
• Board the Concorde and Airforce One in the Aviation Pavilion
• Celebrate Washington State history and the Boeing story in the original Boeing factory, the William E. Boeing Red Barn
• Go back in time and explore the history of space exploration in the Lear Gallery and the APOLLO Exhibit
• See the transformation of aviation over the ages in the T.A. Wilson Great Gallery
• Watch movies in the William M. Allen theater- tickets available at an additional charge
• Ride one of the flight simulators in the T.A. Wilson Great Gallery- tickets available at an additional charge
Assigning Teams
PRIOR TO ARRIVING AT THE MUSEUM OF FLIGHT

• Use the Aviation Learning Center Roster to divide your class evenly into two groups, Alpha Flight and Bravo Flight.
• Assign partner teams within the groups; students will work in these pairs throughout the entire program.
• If your class has an odd number of students, a student may work alone or in a group of three.

Alpha and Bravo Flights will rotate through three different areas of the ALC: the Rajpaul Learning Laboratory, the Cirrus Hangar, and the Flight Simulator Bay.

In the Learning Lab, student pairs will work with one of six topics. Each team will become topic specialists and report back to the entire group at the end of their time in the lab.

• Familiarize yourself with the different stations using the Aviation Learning Center Learning Laboratory Workstations description.
• Assign teams to a workstation using the Aviation Learning Center Roster.
• Bring two copies of the roster to The Museum of Flight.
• Give a copy to the Educator at the beginning of the program.
Use the following descriptions to assist as you assign students to Learning Lab Stations.

**FLIGHT DYNAMICS**
Through hands-on experiments, students explore the basic physics of flight and the four forces of flight and learn how these physical principles make flight possible.

**INSTRUMENT FLIGHT**
Students learn how flight instruments— the compass, altimeter, and attitude indicator-work, and how pilots utilize them to draw conclusions about an airplane’s position and motion.

**NAVIGATION**
Students explore the fundamental concepts of navigation— latitude, longitude, and compass directions, while they practice using a pilot’s chart and other navigation tools to plot a local flight.

**WEATHER**
Analyze the current weather conditions at Boeing Field to understand how weather affects flight and determine if it is safe to fly.

**WEIGHT AND BALANCE**
Working with a variety of model airplanes, students explore the concepts of load weight and center of gravity, and how they affect the flight of a Cirrus SR-20.

**WIND TUNNEL**
Using a wind tunnel and wind tunnel app, students focus on basic aerodynamic theory and the mechanics of lift.
AVOID FLIGHT Begins in Learning Lab

Flight Dynamics
1. __________________________
2. __________________________

Instrument Flight
1. __________________________
2. __________________________

Navigation
1. __________________________
2. __________________________

Weather
1. __________________________
2. __________________________

Wind Tunnel
1. __________________________
2. __________________________

Flight Dynamics (team 2)
1. __________________________
2. __________________________

Instrument Flight (team 2)
1. __________________________
2. __________________________

Navigation (team 2)
1. __________________________
2. __________________________

BRAVO FLIGHT Begins in Cirrus Hangar

Flight Dynamics
1. __________________________
2. __________________________

Instrument Flight
1. __________________________
2. __________________________

Navigation
1. __________________________
2. __________________________

Weather
1. __________________________
2. __________________________

Wind Tunnel
1. __________________________
2. __________________________

Flight Dynamics (team 2)
1. __________________________
2. __________________________

Instrument Flight (team 2)
1. __________________________
2. __________________________

Navigation (team 2)
1. __________________________
2. __________________________
Extension Activities
OVERVIEW

As environmental concerns increase in the scientific and political communities, airplane manufacturers are working to minimize the environmental effects of air travel. In this activity, students will calculate the fuel consumption of various historic and modern aircraft.

VOCABULARY

- **Range**- The distance an airplane can travel before needing to refuel.
- **Nautical mile (nm)**- A unit of distance measurement used by airplane pilots and sailors. One nautical mile is 6,076 feet.
- **Knots (kts)**- A unit of speed measurement. One knot is one nautical mile per hour.
- **Statute mile**- A unit of distance measurement, commonly referred to as a mile. One statute mile is 5,280 feet.
- **Mission fuel**- The fuel available for a trip. This is calculated by subtracting a 10% fuel reserve from the total fuel capacity.
- **Gallons per hour (gph)**- A unit of rate of fuel consumption.
- **Cruising**- The part of an airplane’s trip not including takeoff and landing.
- **Cruising speed**- The speed of an airplane during the cruising part of the trip.

MATERIALS

- Aircraft Specifications Chart (provided, one per student/group)
- Student worksheet (provided, one per student)

SET-UP

- Gather all materials.

INTRODUCTION

When planning a trip, it is important to consider one’s impact on the environment.
Imagine if 300 people wanted to travel from Seattle to New York City. Would it be more fuel efficient for each person to drive their own car or fly in a plane? What type of plane would be the most efficient?

EXTENSION

1. Add in take-off and landing in fuel calculations.
2. Compare and contrast the pros and cons of each plane in different situations such as- long haul flights, local flights, etc.
## AIRCRAFT SPECIFICATION CHART

Refer to the chart for specific aircraft information.

<table>
<thead>
<tr>
<th></th>
<th>BOEING 787-8</th>
<th>BOEING 747-100</th>
<th>DOUGLAS DC-3</th>
<th>CIRRUS SR 20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range (nautical miles)</strong></td>
<td>7355 nm</td>
<td>5214 nm</td>
<td>2125 nm</td>
<td>785 nm</td>
</tr>
<tr>
<td><strong>Cruise Speed (knots)</strong></td>
<td>566 kts</td>
<td>482 kts</td>
<td>168 kts</td>
<td>155 kts</td>
</tr>
<tr>
<td><strong>Max Speed (knots)</strong></td>
<td>510 kts</td>
<td>516 kts</td>
<td>199 kts</td>
<td>161 kts</td>
</tr>
<tr>
<td><strong>Ceiling (feet)</strong></td>
<td>43,000 ft</td>
<td>45,000 ft</td>
<td>23,200 ft</td>
<td>17,500 ft</td>
</tr>
<tr>
<td><strong>Cruising Altitude (feet)</strong></td>
<td>35,000 ft</td>
<td>34,000 ft</td>
<td>6,000 ft</td>
<td>8,000 ft</td>
</tr>
<tr>
<td><strong>Fuel Capacity (gallons)</strong></td>
<td>33,384 gal</td>
<td>48,445 gal</td>
<td>822 gal</td>
<td>60.5 gal</td>
</tr>
<tr>
<td><strong>Weight Empty (lbs)</strong></td>
<td>259,500 lbs</td>
<td>370,816 lbs</td>
<td>16,600 lbs</td>
<td>2,050 lbs</td>
</tr>
<tr>
<td><strong>Weight Full (lbs)</strong></td>
<td>502,500 lbs</td>
<td>735,000 lbs</td>
<td>25,200 lbs</td>
<td>2,900 lbs</td>
</tr>
<tr>
<td><strong>Passengers</strong></td>
<td>290</td>
<td>336</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td><strong>Engines</strong></td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Type of Engine</strong></td>
<td>jet</td>
<td>jet</td>
<td>propeller</td>
<td>propeller</td>
</tr>
<tr>
<td><strong>Wing Area (sq ft)</strong></td>
<td>3880 sq ft</td>
<td>5500 sq ft</td>
<td>987 sq ft</td>
<td>135 sq ft</td>
</tr>
</tbody>
</table>
DEFINITIONS

- **kts** = Knots (speed)
- **nm** = Nautical Miles (distance)
- **Statute mile** = A unit of distance on land in the United States. Equal to 5280 feet, or 1760 yards, commonly referred to as a mile

FORMULAS

<table>
<thead>
<tr>
<th>distance</th>
<th>time it takes to travel given distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>fuel capacity (gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 10% safety reserve (gal)</td>
</tr>
<tr>
<td>mission fuel (gal)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>mission fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>total flight time</td>
</tr>
</tbody>
</table>

= fuel consumed per hour (gph)

1 kts = 1.15078 mph
kts x 1.15078 = statute miles

kts = \[ \frac{\text{mph}}{1.15078} \]

1 nm = 1.15078 statute miles
nm x 1.15078 = statute miles

nm = \[ \frac{\text{statute miles}}{1.15078} \]

SOLVE

Use the aircraft specification chart and formulas provided to answer the following questions:

**A)** A Douglas DC-3 has a range of 2,125 nm and a cruising speed of 168 kts.

1. What is the range in statute miles?
2. What is the speed in miles per hour?
3. How long will it take the DC-3 to fly 2,125 nm?
4. What is the fuel capacity of DC-3?

Don’t Be Fuel-ish!
5. If the pilot keeps 10% of the fuel as safety reserves, how much fuel is available for a flight (mission fuel)?

6. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel used?

B) A Boeing 747-100 is flying from King County International Airport/Boeing Field in Seattle (BFI) to Hong Kong International Airport (HKG), a trip of 6,500 statute miles.

1. What is the length of that route in nautical miles?

2. Will the 747-100 reach HKG without refueling along the way or will the pilot have to stop and refuel?

3. Will the 747-100 reach Tokyo Narita International Airport (NRT), a route of 4,138 nm, to refuel?

4. What is the cruising speed of the 747-100?

5. Assuming consistent cruising speed, how long will the flight between BFI and NRT take?

6. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel used?

C) A Boeing 787-8 is flying the same route from King County International Airport/Boeing Field (BFI) to Hong Kong International Airport (HKG).

1. Would it be able to make the trip from BFI to HKG without stopping to refuel?

2. What is the cruising speed of the 787-800?

3. Assuming consistent cruising speed, how long will the flight take?

4. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel is consumed?
D) A Cirrus SR-20 is flying from King County International Airport/Boeing Field (BFI) to Felts Field Airport (SFF) in Spokane, Washington at a cruising speed of 155 kts. The total flight distance is 194 nm, and the plane is already flying over Wenatchee, Washington 82 nm east of Seattle.

1. How long will the remainder of the flight take?

2. If the fuel burn rate is consistently 11.9 gallons per hour, how much fuel was used on the flight between BFI and SFF?

3. How much mission fuel is left?

4. If the flight continues from Felts Field Airport (SFF) to Salt Lake City International Airport (SLC) in Salt Lake City, Utah, 478 nm away, assuming consistent cruising speed and fuel burn rate, will the pilot need to refuel or is there enough mission fuel for the journey? How much mission fuel is left?
Use the aircraft specification chart and formulas provided to answer the following questions:

A) A Douglas DC-3 has a range of 2,125 nm and a cruising speed of 168 kts.
   1. What is the range in statute miles? (2,125 nm)(1.15078) = 2,445.5 miles
   2. What is the speed in miles per hour? (168 kts)(1.15078) = 193.33 mph
   3. How long will it take the DC-3 to fly 2,125 nm?
      \( \frac{2,125 \text{ nm}}{168 \text{ kts}} = 12.64 \text{ hours or 12 hours & 38 minutes} \)
   4. What is the fuel capacity of DC-3? 822 gallons
   5. If the pilot keeps 10% of the fuel as safety reserves, how much fuel is available for a flight (mission fuel)?
      \( 822 \text{ gal} \times 0.10 = 82.2 \text{ gal} \)
      822 gal - 82.2 gal = 739.8 gal mission fuel
   6. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel used?
      \( \frac{739.8 \text{ gal}}{12.64 \text{ hours}} = 58.53 \text{ gph} \)

B) A Boeing 747-100 is flying from King County International Airport/Boeing Field (BFI) in Seattle to Hong Kong International Airport (HKG), a trip of 6,500 statute miles.
   1. What is the length of that route in nautical miles?
      \( \frac{6,500 \text{ m}}{1.15078} = 5,648.34 \text{ nm} \)
   2. Will the 747-100 reach HKG without refueling along the way or will the pilot have to stop and refuel?
      Stop & refuel. The range of a 747-100 is 5,214 nm.
   3. Will the 747-100 reach Narita International Airport (NRT) in Tokyo, Japan, a route of 4,138 nm, to refuel?
      Yes
   4. What is the cruising speed of the 747-100? 482 kts
   5. Assuming consistent cruising speed, how long will the flight between BFI and NRT take?
      \( \frac{4,138 \text{ nm}}{482 \text{ kts}} = 8.59 \text{ hours or 8 hours & 35 minutes} \)
   6. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel used?
      \( \frac{48,445 \text{ gal} \times 0.10}{8.59 \text{ hours}} = 5,075.73 \text{ gph} \)

C) A Boeing 787-8 is flying the same route from King County International Airport/Boeing Field (BFI) to Hong Kong International Airport (HKG).
   1. Would it be able to make the trip from BFI to HKG without stopping to refuel?
      Yes, the range of a 787-8 is 7,355 nm
   2. What is the cruising speed of the 787-800? 566 kts
3. Assuming consistent cruising speed, how long will the flight take?

\[
\frac{5,648.34 \text{ nm}}{566 \text{ kts}} = 9.98 \text{ hours or 9 hours & 59 minutes}
\]

4. What is the hourly rate of fuel consumed, assuming a consistent cruising speed and all mission fuel is consumed?

\[
\begin{align*}
(33,384 \text{ gal})(10\%) &= 3,338.4 \text{ gal} \\
33,384 \text{ gal} - 3,338.4 \text{ gal} &= 30,045.6 \text{ gal} \\
(30,045.6 \text{ gal}) / (9.98 \text{ hours}) &= 3,010.58 \text{ gph}
\end{align*}
\]

D) A Cirrus SR-20 is flying from King County International Airport/Boeing Field (BFI) to Felts Field Airport (SFF) in Spokane, Washington at a cruising speed of 155 kts. The total flight distance is 194 nm, and the plane is already flying over Wenatchee, Washington 82 nm east of Seattle.

1. How long will the remainder of the flight take?

\[
(194 \text{ nm}) - (82 \text{ nm}) = 112 \text{ nm} \\
(112 \text{ nm}) / (155 \text{ kts}) = 0.72 \text{ hour or 43 minutes}
\]

2. If the fuel burn rate is consistently 11.9 gallons per hour, how much fuel was used on the flight between BFI and SFF?

\[
(194 \text{ nm}) / (155 \text{ kts}) = 1.25 \text{ hour or 1 hour & 15 minutes} \\
(11.9 \text{ gph})(1.25 \text{ hours}) = 14.88 \text{ gallons}
\]

3. How much mission fuel is left?

\[
54.45 \text{ gal} - 14.88 \text{ gal} = 39.59 \text{ gallons}
\]

4. If the flight continues from Felts Field Airport (SFF) to Salt Lake City International Airport (SLC) in Salt Lake City, Utah 478 nm away, assuming consistent cruising speed and fuel burn rate, will the pilot need to refuel or is there enough mission fuel for the journey? How much mission fuel is left?

\[
(478 \text{ nm}) / (155 \text{ kts}) = 3.08 \text{ hour or 3 hours & 5 minutes} \\
(11.9 \text{ gph})(3.08 \text{ hours}) = 36.65 \text{ gallons} \\
39.59 \text{ gallons} - 36.65 \text{ gallons} = 2.64 \text{ gallons}
\]

There is enough mission fuel to make the journey.

Don’t Be Fuel-ish!
OVERVIEW

As environmental concerns increase airplane manufacturers are working to minimize the environmental effects of air travel. In this activity, students will investigate several different historic and modern aircraft, comparing and contrasting their environmental impacts.

VOCABULARY

Both Texts

• **Composite**- Material made from two or more different materials.
• **Fuselage**- The body of an airplane, not including the wings or tail.
• **Aerodynamics**- The way air moves around an airplane.

Museum Exhibits

• **Predecessor**- Something that came immediately before.
• **Carbon-fiber**- A fabric-like material made of carbon atoms bonded together.
• **Aspect ratio**- A measurement of a wing’s length versus its width.
• **Pneumatic**- Equipment that uses pressurized air.
• **Control surfaces**- The parts of an airplane’s wings and tail that are moved to control the plane’s direction.
• **Livery**- The paint colors and symbols on an airplane that show which airline it belongs to.

AOPA Article

• **Kit airplane**- An airplane that is bought in pieces and assembled.
• **Mainstream-certificated**- An airplane that has been approved by an organization like the Federal Aviation Administration.
• **Mock-up**- A full-scale example of a proposed design.
• **Leading edge**- The front edge of a wing.
• **Ailerons**- The part of an airplane’s wing that is moved to turn the airplane.
• **Fiberglass**- A composite material made of glass and plastic.

Plane Specs Chart

• **Range**- The distance an airplane can travel before needing to refuel.
• **Nautical mile (nm)**- A unit of distance measurement often used by airplane pilots, sailors and astronauts.
• **Cruising**- The part of an airplane’s trip not including takeoff and landing.
• **Cruise speed**- The speed of an airplane during the cruising part of the trip.
• **Knots (kts)**- A unit of speed measurement, one knot is one nautical mile per hour.

Airplanes! Stat!
LESSON PLAN

SET-UP
Before visiting the Museum, review any necessary vocabulary.

READING (recommended before Museum visit)
Have students read the AOPA article about the Cirrus SR-20: take notes on the article using the attached graphic organizer, an organizer you provide, or student-selected method.

AT THE MUSEUM
Have Students
• Look at the exhibits about the Boeing 747 (Aviation Pavilion), Boeing 787 (Aviation Pavilion), and Douglas DC-3 (T.A. Wilson Great Gallery).
• Take notes on the exhibits using the attached graphic organizer, an organizer you provide or student-selected method.
• If students did not attend the Museum field trip or were unable to look at all the exhibits, have them read the attached exhibit text.

MATERIALS (provided)
• Graphic organizer or note-taking materials (one per student)
• AOPA article about Cirrus SR-20- provided (one per student)
• Museum exhibit text
• Aircraft Specifications Chart from “Don’t Be Fuel-ish” activity (one per student)

Altitude- Height above sea level, typically measured in feet.
Ceiling- The highest altitude an airplane can safely fly.
Cruising altitude- The altitude an airplane typically flies during the cruising part of its trip.

Altitude- Height above sea level, typically measured in feet.
Ceiling- The highest altitude an airplane can safely fly.
Cruising altitude- The altitude an airplane typically flies during the cruising part of its trip.
**WRITING**

- Provide students with the Plane Specification Comparison chart from the “Don’t Be Fuelish” activity.
- Scaffolding:
  - Pair-share things they notice about differences between planes.
- Ask students: given the information from your readings and the chart, which of these four planes is the most environmentally friendly? Write an essay defending their position.
- Scaffolding:
  - Pro/con list for each plane as class, small groups, or individuals.
  - Pair-share thoughts.
  - Provide basic outline (Intro, Paragraph 1, Paragraph 2, Conclusion) for students to fill in.
  - Provide sentence frames/starters for topic/transitional sentences.
  - Provide sentence frames/starters for citation of evidence.
  - Peer edits.

**EXTENSION**

Have students conduct additional research about at least one of the airplanes before writing their essay and include their additional research in the essay.

**Debate**

- Facilitate a debate between teams or individuals about which plane is the most environmentally friendly.
- Scaffolding:
  - Students discuss their reasons in groups of 2-3 with same opinion before the debate.
  - Provide sentence frames/starters to use in debate (“I agree with __, and I’d like to add . . .” “I disagree because . . .”).

**SCIENCE EXTENSION**

**Monitoring Methods**

- Divide students into groups.
- Assign each group a potential environmental impact of airplanes (see Intro for list of ideas) or have the whole class work on the same potential impact.

**Groups**

- Brainstorm possible ways to monitor/track the environmental impact.
- Conduct research to see if any of those possible methods are already in use, and what those methods have found.
- Identify potential difficulties with monitoring impact.
- Design a monitoring method that addresses potential difficulties identified.
- Present their method to the class.
• Scaffolding:
  o Provide specific questions to answer in their presentation. What are you monitoring? How does your proposed method work? What are the difficulties with monitoring that impact? How does your proposed method address those difficulties, etc.?
  o Provide sentence frames/starters to use in presentation.
• Extension: Use technology in their presentation (video, slide-show, etc.)
First of the Twenty-First Century

The first 787 Dreamliner rolled out in 2007, 13 years after its predecessor, the 777. The new aircraft included many new design features intended to improve the passenger experience. The extensive use of carbon-fiber composites allowed for larger windows and higher cabin pressure at altitude. A newly designed interior resulted in a spacious, more attractive cabin.

Dreamliner ZA003

This aircraft was the third Dreamliner off the production line (note the 003 on the front nose wheel door). It served as a test aircraft and made its first flight in 2010. It was also the first 787 to be partially outfitted with the new passenger cabin interior. After certification, this aircraft flew around the world as part of a promotional tour. It made 40 stops in 23 countries and was displayed at three air shows.

Building the 787 Dreamliner

The 787 is the first production airliner to make extensive use of composite materials. These composites are used on the fuselage, wings, tail, doors and interior. The aircraft includes one-piece barrel fuselage sections instead of multiple riveted aluminum panels. This reduces material waste and material needed.

Composite materials such as the carbon-fiber reinforced plastic on the 787 have a higher strength-to-weight ratio than traditional airplane materials. With lighter-weight materials, modern systems, improvements in aerodynamics, and new jet engines, the 787 Dreamliner is 20 percent more fuel-efficient than similarly sized airplanes.

In 2003, Boeing announced the 787 would be assembled in its production facility in Everett, Washington. In June 2011, Boeing added a second final assembly facility in North Charleston, South Carolina. Workers join together completed subassemblies built by Boeing partners located around the world.

Building for Efficiency

Four key technologies on the 787 Dreamliner family contribute to an impressive 20 to 25 percent improvement in fuel efficiency and emissions compared with the airplanes they will replace.

Next Gen Engines: On April 6, 2004, Rolls Royce and General Electric won contracts to develop new engines for the Boeing 787 Dreamliner. The new engines represented a generational jump in technology allowing for 20-25 percent lower fuel use and emissions, and a 60 percent reduced noise footprint on the ground than comparable airplanes.

Advanced Systems: At the heart of the 787 design is a modern systems architecture that is simpler, more functional and more efficient than that of comparable airplanes. For example, the airplane can self-monitor its systems and report maintenance requirements to ground-based monitoring centers.

Modern Aerodynamic Design: The use of composite materials allows the 787 to have a higher aspect ratio (long, narrow wings) than previous airplanes. This, along with raked wing tips, allows the 787 to maintain Mach .85 (650 mph) cruise speed while consuming less fuel than comparable airliners today.

Carbon Composite Material: The 787 fuselage is made of a series of one-piece barrel sections made from carbon fiber reinforced plastic (CFRP). Fifty percent of the 787 Dreamliner by weight is made from composite material, which
eliminates 1,500 aluminum sheets and 40,000 to 50,000 fasteners per section.

Continuing Progress
The Boeing Company launched the 787 Dreamliner program in April 2004 with a record order of 50 airplanes from All Nippon Airways (ANA). As of August 2015, nearly 60 customers from six continents have ordered more than one thousand 787’s, making it the fastest selling twin-aisle commercial airplane in Boeing history.

The 787-8 Dreamliner can carry 242 passengers up to 7,355 nautical miles (13,620 km), while the longer 787-9 can carry 290 passengers 7,635 nautical miles (14,410 km). The third and longest 787, the 787-10, will fly 330 passengers up to 6,430 nautical miles (11,910 km) or more than 90 percent of the world’s twin-aisle routes, when deliveries begin in 2018.

Electric Airplane: The 787 Dreamliner is the first nearly all-electric airliner. The electric architecture of the 787 replaced complex pneumatic systems of previous airplanes. The electric system improves efficiency by using on the power actually needed during each phase of flight.

Smart Surfaces: Sensors on the 787 Dreamliner are designed to counter the effects of turbulence by automatically adjusting certain control surfaces (ailerons, flaperons, elevator, and flaps).

747 PROTOTYPE

The First Jumbo Jet

The growing worldwide demand for air travel during the 1960s led to the development of the 747 – the first wide-body jet. The 747-100 could carry 374-490 passengers, nearly four times as many as its largest predecessors. It is taller than a six-story building and heavier than nine fully-loaded 18-wheel trucks. With its signature humped fuselage and mammoth size, the 747 is one of the most recognizable aircraft in the world. Despite its success, the 747 began its career as a placeholder for the Boeing Super Sonic Transport (SST). The SST program eventually lost funding and ended in 1971, allowing the 747 to emerge as the premier commercial transport.

The Incredibles

Boeing constructed the world’s largest building (by volume) in Everett, Washington, for the purpose of fabricating the 747. An impressive team of 50,000 people, dubbed “The Incredibles,” worked behind the scenes and in the manufacturing plant for 16 months building this enormous, history-making airliner.

The Museum’s Boeing 747

The Museum’s aircraft was the first 747 ever built; it first flew on February 9, 1969 over western Washington. Later, this aircraft served as a test bed for 747 systems improvements and new engine developments for the Boeing 777. It was retired and flown one last time to the Museum in 1996.

Queen of the Skies: the world’s first “Jumbo Jet”

The 747’s size and transport capability marked an amazing achievement in aviation history. It was called the “jumbo jet” due to its unprecedented size – more than twice as large as The Boeing Company’s second largest jetliner, the 707.

A revolution in air travel: Airline passenger capacity immediately tripled when the 747 first flew commercially for
Pan American World Airways on January 21, 1970. The 747 offered people around the world faster and farther travel options and shorter shipping times for international goods. Its increased range and cargo capacity reduced transportation costs considerably, impacting the global economy. The 747’s design and construction is one of the greatest aviation achievements of the 20th century.

DC-3

Faithful Gooney Bird

The first versions of the DC-3, called Douglas Sleeper Transports, began service with American Airlines in 1936. Demand for the unique airliner was high – by 1938, DC-3s were flying an amazing 95 percent of the United States’ and 90 percent of the world’s airline traffic. During World War II, the DC-3 design became a troop and cargo carrier called the C-47. Douglas built over 10,600 of the rugged and reliable planes and many are still flying today. The Museum’s DC-3 was built in 1940 for American Airlines. It has seen service with various companies and flown over 60,000 hours. Today, it wears the livery of Alaska Airlines, which operated many DC-03s and C-47s after World War II.

Time Flies

Compare the DC-3 with the three-engined Boeing Model 80A-1 parked below it in the Great Gallery. Seen together, they show a rapid progression of aircraft design. The Model 80’s first flight was in 1928. The DC-3 followed just seven years later. The fabric and wood-covered biplane 80A looks like an antique compared to the all-metal monoplane hanging above. The bottom line for airlines? In just seven years, the new DC-3-series was much faster, had over twice the range, and could carry almost twice as many passengers as the first Boeing Model 80s.

Donald Wills Douglas (1892-1981)

Engineer Donald Douglas created his own company in 1920. His Cloudster was the first aircraft to lift a payload equal to its own weight and the Douglas World Cruisers were the first to fly around the world. The Douglas name became associated with commercial transport through the “Douglas Commercial” or “DC”-series. Douglas also built military transports, bombers, and attack airplanes. Donald Douglas was inducted into the National Aviation Hall of Fame in 1969 for his design of both military and commercial aircraft.

CIRRUS SR20

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Unless you are brand-new to general aviation or have been under a rock for the past decade, you know by now the Cirrus Design story. Wisconsin brothers Dale and Alan Klapmeier started building kit airplanes, but soon recognized that the real market was for a new-generation mainstream-certificated airplane. In 1995, they announced, with much fanfare, that they were going to produce just such an airplane. The airframe would be composite and incorporate the latest thinking in aerodynamics and survivability. Unusual doors that lift upward and forward (actually, in the mock-up they were sliding doors like your minivan has), opening to a wide and comfortable cabin. The plan was to incorporate the latest avionics and engine management systems to reduce pilot workload and improve situational awareness. And deliver it all at a higher “value” than was then available in the market.

Safety

At first, Cirrus planned to offer a unique rocket-powered parachute as an option. Later, the Klapmeiers decided that the parachute would be standard equipment. The parachute is designed to lower the aircraft to the ground in such a way that those inside would survive. However, the 1,800-foot-per-minute descent rate beneath the deployed parachute
will most likely damage or destroy the aircraft upon impact in the worst case scenario. Still, as a last-ditch effort in the event of a loss of control, it’s not a bad safety net. “In 2002, the Cirrus Airframe Parachute System™ made aviation history with the first safe landing by a private pilot after deploying the parachute.” (Cirrus Design Corp.)

Development and certification of the parachute system took many months and many tests. Eventually, the system, dubbed CAPS, for Cirrus Airframe Parachute System, earned FAA approval.

Hidden in an area in the aft fuselage, the parachute and its rocket, along with the extra structure to accommodate the system, weigh less than 80 pounds. A pull forward and down on the handle ignites the rocket motor and propels it out through the skin of the aircraft, pulling the parachute with it. Wide straps buried just below the composite exterior skin of the fuselage, running beneath the door openings, are ripped free by the force. In the end, the fuselage is suspended by the straps, which are attached to the firewall and the aft cabin. The system requires almost no maintenance, just an inspection and repacking of the chute every 10 years and perhaps replacement of the rocket motor.

The Klapmeiers believe that the aircrafts’ avionics and navigation systems will improve situational awareness. On Cirrus Aircraft, the Avidyne Multi Function Display has always been standard. Later models are equipped with the Avidyne Entegra Integrated Flight Deck, providing the pilot with a new level of situational awareness and safety.

**SR20- Handling and Performance**

The SR20 has a very solid, stable feel to it in flight. At slow speeds, the unusual leading edge cuff comes into play to prevent the aircraft from easily entering a spin. Cirrus certified the SR20 in the “spin resistant” category, thanks to the cuff. The cuff causes the air flowing over the ailerons to remain “attached” to the wing at very high angles of attack. As a result, the ailerons remain effective even after the inboard portions of the wing have stalled. Because of this, you can easily fly the airplane, feet on the floor, despite much of the wing’s being stalled. You’ll be descending at several hundred feet per minute, but with complete aileron control. The intent is to prevent the common base-to-final-turn stall-spin accident by allowing the pilot to simply roll wings-level even in a stall. There is plenty of natural buffeting to alert even the most distracted pilot that the aircraft is entering a stall. It’s a good system and a significant safety enhancement.

Part of the reason for the SR20’s stellar cruise speeds on such a small, efficient engine is the composite fuselage. The fiberglass material allowed the designers to carefully shape the fuselage to be aerodynamically efficient. In the beginning, the airplane was to be all composite, but Cirrus engineers discovered fairly early in the process that it was difficult to make strong and stiff flight control surfaces out of fiberglass because of the tight spaces inside, particularly at the trailing edges. As a result, the SR20 has aluminum ailerons, flaps, rudder, and elevator.

The engine itself delivers other efficiencies. The Continental IO-360-ES utilizes both tuned induction and tuned exhaust to efficiently extract every horsepower while keeping fuel flows down. A tuned induction system delivers an equal amount of air at the same velocity to each cylinder, allowing efficient and consistent combustion from cylinder to cylinder. A tuned exhaust system, evidenced by the long parallel stacks along the belly, decreases exhaust back pressures, allowing the engine to efficiently deliver rated horsepower with minimal fuel burn.

Overall, the SR20 combines a unique blend of tried-and-true systems married to many advances in safety and avionics, all bundled into a robust and efficient airframe.
OVERVIEW

Using these three quick and simple activities, your students will become familiar with Newton’s three laws of motion and some of the basic forces that affect all objects in motion, including airplanes. This activities can be accomplished as demonstrations before the class, or in small student groups, depending on the availability of materials.

VOCABULARY

- **Acceleration**: A measure of how fast a moving object speeds up.
- **Aerodynamics**: A science that studies how moving object interact with air.
- **Force**: A push or pull on an object.
- **Gravity**: The force that pulls towards the center of the Earth.
- **Inertia**: The resistance of an object to any change in its motion.
- **Mass**: A measure of the amount and density of matter in an object.
- **Newton’s Laws of Motion**: Three laws that describe how things move.
- **Velocity**: A measure of how fast something moves.

MATERIALS

- Ping-pong ball
- Hair dryer with low & high speed settings
- Balloon
- “Newton’s Laws Observations” datasheet
- “Observations Answer Key”

SET UP

- Prepare to present the three demonstrations in a location easily visible by all students.
- Distribute one copy of the data sheet to each student.

PROCEDURE

For each of these activities:

1. Review relevant Law of Motion and explain the activity.
2. Have students record predictions on the “Newton’s Laws Observations” datasheet.
3. Demonstrate activity so that all students can see/ have students perform activity.
4. Have students record results on data sheet.
5. Discuss what they observed.
OVERVIEW

- Brainstorm about what forces are and what they do.
  - A force is a push or a pull on an object.
- Discuss examples of forces.
  - Push/Pull, Gravity, Electromagnetism.
- List the four forces of flight and discuss how they affect aircraft in flight.
  - Lift – The upward force created by difference in pressure. In aircraft, this pressure difference is created by the difference in speed of airflow over and under the airfoil shape of the wings.
  - Weight/Gravity - The force that acts in a downward direction towards the center of the Earth.
  - Thrust - The force that propels an airplane in the direction of motion. For aircraft, the engine produces thrust.
  - Drag – The force that acts opposite to the direction of motion. It is caused by friction and differences in air pressure.

BALL DROP (NEWTON’S FIRST LAW OF MOTION)

Supplies: ball, “Newton’s Laws Observations” datasheet
- Review Newton’s first law of motion.
- Activity: Hold ball where all can see, let go of ball.
- Discussion Questions:
  - What would happen if you perform this same demonstration in the microgravity environment of space?
  - What happens to a baseball when it is thrown? How do forces, such as gravity and drag act upon the ball to slow it down and cause it to come to rest?
  - Examples that illustrate Newton’s first law of motion.

SPEEDING BALL (NEWTON’S SECOND LAW OF MOTION)

Supplies: hair dryer, ping pong ball, Newton’s Laws Observations” datasheet
- Review Newton’s second law of motion.
- Activity: Set a Ping-Pong ball on top of a table and plug in the hair dryer, then turn the hair dryer on low-speed. Repeat on high-speed.
- Discussion:
  - What would change if we used a tennis ball? A bowling ball? Why?
  - Examples from everyday life that illustrate Newton’s second law of motion.

Roll With Newton’s Laws of Motion
BALLOON ROCKET (NEWTON’S THIRD LAW OF MOTION)

Supplies: balloon
- Review Newton’s third law of motion.
- Activity: Blow up a balloon and hold the opening shut (do not tie off the end), hold where all can see, let go of balloon.
- Discussion:
  - What vehicles use this method for propulsion? (jets, rockets, fan boats)
  - Examples from everyday life that illustrate Newton’s third law of motion.

RELATE NEWTON’S LAWS OF MOTION TO AN AIRCRAFT

Discussion:
- How do Newton’s three laws of motion relate to the motion of an aircraft through the air.
- How do the various forces act on an airplane in order to make it fly or while it is in flight.

Newton’s First Law
- An aircraft has four major forces acting on it—lift, weight (or gravity), thrust and drag.
- When an airplane is cruising (flying at constant airspeed) at a constant altitude, lift and weight are in balance and the thrust will exactly balance the drag.
- The forces cancel each other out and there is no net force resulting from unbalanced forces acting on the airplane so it travels at a constant velocity in a straight line.
- If the pilot increases or decreases the thrust of the engine by shifting the throttle setting, the thrust and drag are no longer in balance and some change in the aircraft’s previously constant motion will occur.
- If the thrust is increased, the forces of thrust and drag are no longer in balance and the airplane will accelerate and the velocity will increase.
- The drag of the aircraft increases with increasing velocity (drag is basically the frictional force between a moving object and the air around it). Drag will begin to increase until it is equal to the new thrust level. Once that happens, the forces will again be in balance and the airplane will fly at a new constant speed.

Newton’s Second Law
- The motion of an aircraft resulting from unbalanced forces can be computed by using the second law of motion.
- In the example above, the aircraft cruised at a constant altitude and speed until the pilot changed the thrust of the engine.
- When the thrust increased, the constant motion of the airplane changed according to Newton’s first law.
- The amount of change in velocity, or the aircraft’s acceleration as a result of the force, can be calculated by the second law.
- If the airplane’s mass remains constant, an increase in thrust causes an increase in acceleration.
Newton’s Third Law

- Newton’s third law helps to explain how an aircraft engine works.
- A jet engine produces hot exhaust gases that flow out of the back of the engine.
- The action of the gases flowing out causes a reaction of the aircraft moving forward in the opposite direction.

ACTIVITY EXTENSIONS

- Try using the hair dryer to keep the ping-pong ball in the air, or see how the size of the ball affects the experiment.
- Experiment with different sizes and shapes of balloons to see if they fly the same or differently or stay aloft longer.
- Challenge students to come up with their own investigations using the materials.
Demonstration 1: Ball Drop

First Law of Motion: An object at rest stays at rest, and an object in motion stays in motion with the same speed and direction, unless acted upon by an unbalanced force.

Hypothesis:

Observations:

Draw a diagram of your observations. Label the ball and all forces acting on the ball. Highlight all parts of your diagram that demonstrate Newton’s First Law of Motion.

How did your hypothesis compare to the actual results?
Demonstration 2: Speeding Ball

Second Law of Motion: Unbalanced forces create acceleration (change of speed or direction). The relationship between a force and the resulting acceleration can be described by the equation Force = Mass x Acceleration.

Hypothesis:

Observations, slow speed:

Observations, fast speed:

Draw a diagram of your observations for both speeds. Label the ball and all forces acting on the ball. Highlight all parts of your diagram that demonstrate Newton’s Second Law of Motion.

How did your hypothesis compare to the actual results?
Demonstration 3: Balloon Rocket

Third Law of Motion: For every action, there is an equal and opposite reaction.

Hypothesis:

Observations:

Draw a diagram of your observations. Label the balloon, the “action,” and the “reaction.”

How did your hypothesis compare to the actual results?
Standards
EXTENSION ACTIVITIES SUPPORTED STANDARDS

**Don’t Be Fuel-ish (Math)**
- Common Core State Standards – English Language Arts
  RST.6-8.3, RST.6-8.4

- Common Core State Standards – Math
  6.RPA.1, 6.RPA.3, 6.NS.B.2, 6.NS.B.3
  7.NS.A.3, 7.EE.B.3

- Next Generation Science Standards
  MS-ESSS3-4
  Practice 4 & 5

- Social Studies EALRs
  6.3.2.1, 6.3.3.1

**Airplanes! Stat! (English Language Arts)**
- Common Core State Standards – English Language Arts
  W.7.1, W.7.7, W.7.9 (SL.7.1, SL.7.4, SL.7.5)
  W.8.1, W.8.7, W.8.9 (SL.8.1, SL.8.4, SL.8.5)
  RST.6-8.1, RST.6-8.7

- Next Generation Science Standards
  MS-ESSS3-3

- Social Studies EALRs
  6.3.2.1

**Roll With Newton’s Laws of Motion (Science)**
- Common Core State Standards – English Language Arts
  SL.6.1, SL.7.1, SL.8.1
  RST.6-8.3, RST.6-8.4
  WHST.6-8.2-D, WHST.6-8.4
• Next Generation Science Standards
  MS-PS@-1, MS-PS2-2 (MS-PS3-1)
  Practice 2, 4, 6, 7, 8

AVIATION LEARNING CENTER SUPPORTED STANDARDS L2

Overview Rajpaul Learning Lab:
Individual workstation supported standards available upon request
• Common Core State Standards- English Language Arts
  Reading Informational Texts: RI.6.4, RI.6.7
  Writing: W.6.4
  Language: L.7.4, L.7.4.A, L.7.6
  Reading Informational Texts: RI.7.4
  Speaking and Listening: SL.7.1, SL.7.1.C, SL.7.1.D, SL.7.4
  Writing: W.7.4
  Reading Informational Texts: RI.8.4
  Speaking and Listening: SL.8.1, SL.8.1.C, SL.8.4
  Writing: W.8.4
  Reading Science and Technical Subjects: RST.6-8.3, RST.6-8.4, RST.6-8.7

• Common Core State Standards- Math
  Number Systems: 6.NS.B.2, 6NS.C.6.C
  Number Systems: 7.NS.A.2, 7.NS.A.3
  Expressions and Equations: 7.EE.B.3

• Next Generation Science Standards
  Earth’s Systems: MS-ESS2-5, MS-ESS2-6
  Energy: MS-PS3-1
  Motion and Stability: Forces and Interactions: MS-PS2-2
  Practices 2,3,4,5,7,8
• 21st Century Skills
  Work Creatively with Others: 1.A.3, 1.B.1, 1.B.2, 1.B.4
  Reason Effectively: 2.A.1
  Use Systems Thinking: 2.B.1
  Make Judgements and Decisions: 2.C.1, 2.C.3, 2.C.4, 2.C.5
  Solve Problems: 2.D.1, 2.D.2
  Collaborate with Others: 3.B.1, 3.B.2, 3.B.3
  Use and Manage Information: 4.B.2
  Apply Technology Effectively: 6.A.1
  Adapt to Change: 7.A.1
  Be Flexible: 7.B.1, 7.B.2
  Manage Goals and Time: 8.A.3
  Work Independently: 8.B.1
  Work Effectively in Diverse Teams: 9.B.1
  Manage Projects: 10.A.1
  Guide and Lead Others: 11.A.1

Overview Cirrus Hangar:

• Common Core State Standards- English Language Arts
  Reading Informational Texts: RI.6.7
  Speaking and Listening: SL.6.1, SL.7.1, SL.8.1
  Reading Science and Technical Subjects: RST.6-8.4, RST.6-8.7

• Common Core State Standards- Math
  Number Systems: 6.NS.B.3, 7.NS.A.3

• Next Generation Science Standards
  Practices: 4, 8
• 21st Century Skills
  Make Judgements and Decisions: 2.C.4
  Communicate Clearly: 3.A.1
  Collaborate with Others: 3.B.1, 3.B.2, 3.B.3
  Use and Manage Information: 4.B.2
  Adapt to Change: 7.A.1
  Work Independently: 8.B.1
  Produce Results: 10.B.1.F

Simulators:
• 21st Century Skills
  Work Creatively with Others: 1.B.4
  Collaborate with Others: 3.B.1
  Apply Technology Effectively: 6.A.1
  Adapt to Change: 7.A.1, 7.A.2
  Be Flexible: 7.B.2
  Interact Effectively with Others: 9.A.2
  Work Effectively in Diverse Teams: 9.B.2
  Guide and Lead Others: 11.A.1