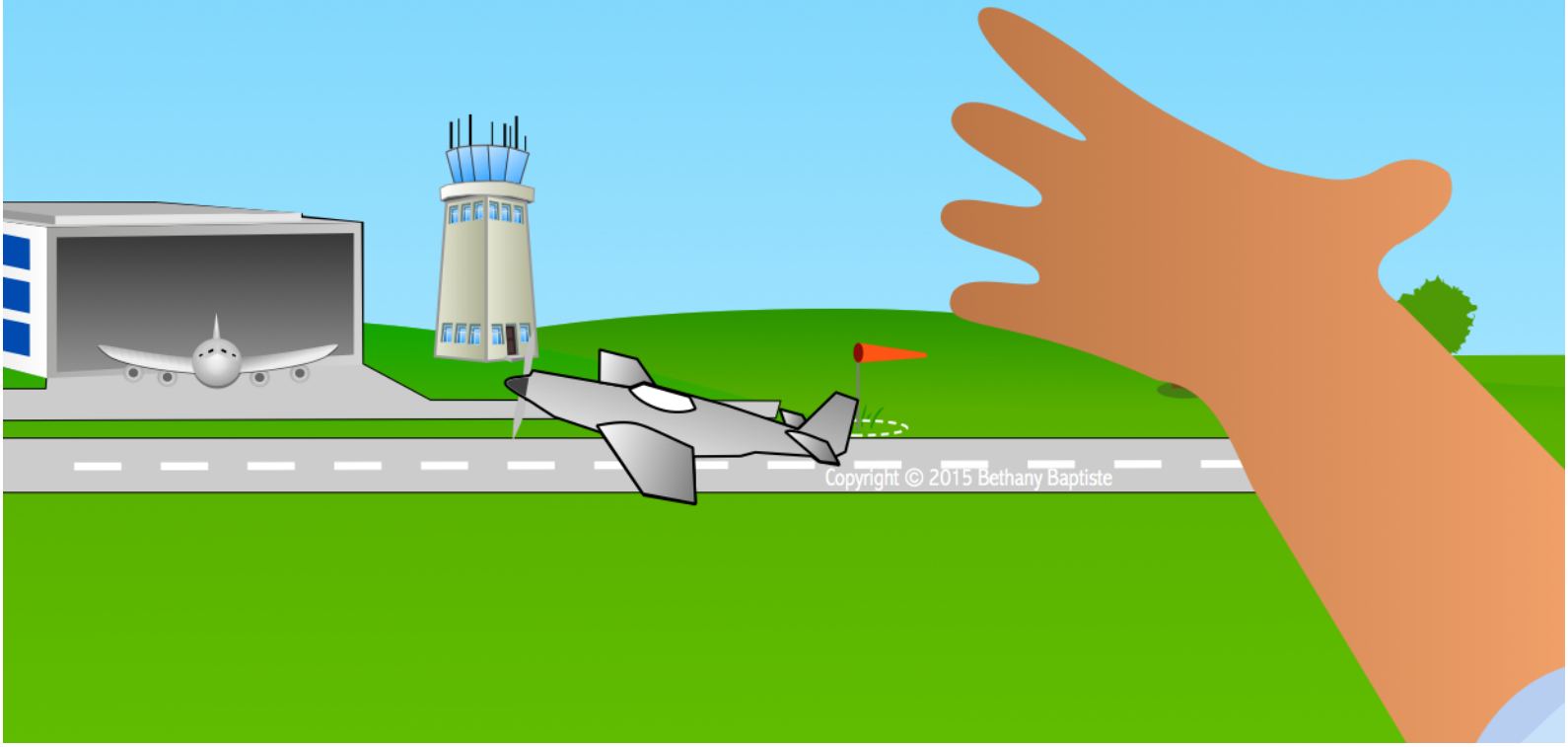
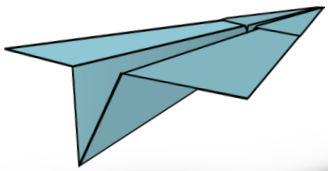
Time For Takeoff!

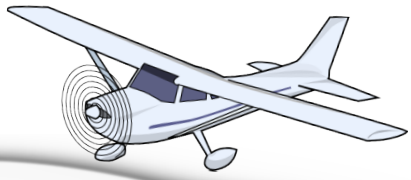
STEM Activity:
Paper Airplane Challenge

Appropriate for Grades 3-5
5 Sessions
Aligned to CCSS





TIME FOR TAKEOFF!
STEM Activity



OVERVIEW

Time for Takeoff! is a **STEM** lesson (integrates science, technology, engineering, and mathematics) that introduces aerodynamics and the forces of flight. Students will apply these concepts to design and construct a paper airplane that will fly as far as possible. Students assume the roles of aerospace engineers throughout the challenge and work in collaborative teams while following an engineering design process. Final paper airplanes and team conclusions will be presented. The challenge is intended to last five sessions and introduce students to the engineering design process.

TEACHER PROCESS

Grade Levels: 3rd-5th grades
Subject Areas: Science, Technology, Engineering, Mathematics, Literacy
Standards Addressed: (3rd grade standards listed but can be adapted to meet many grade level standards)
CCSS: 3.MD.4; 3.RI.10, 3.W.8, 3.SL.1, 3.SL.4; *Science Framework* PS2.A Forces and Motion
Objective: Students will design and construct a paper airplane that flies as far as possible by using aerodynamic principles. Students will be guided through using the Engineering Design Process.

Materials Needed:

- all posters and worksheets included
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, weights) for airplane folding
- stickers, markers, colored pencils, crayons, or other decorating materials (for planes and presentations)
- one poster board or poster paper for each team
- measuring sticks or measuring tape
- variety of materials to modify/improve flight: scissors, paperclips, stapler, staples, tape
- masking tape for airplane throwing line
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, and/or aerospace engineering for student learning center (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

Duration: 5-10 days (Younger students may need more time.)

Preparations: (Detailed descriptions are included for each session.)

- Copy all print outs included as instructed in each session plan.
- Display *Collaborative Conduct Expectations*, *Engineering Design Process*, and *Design Challenge* posters.
- Assign students to engineering teams and assign each student a role. *See the role descriptions in the *Session 1 Preparations*.
- Cut out *Aerospace Engineer Role Assignment Cards* for each student assignment. (I recommend printing these on card stock or laminating them. Then punch a hole and make a necklace for students to wear their assignment cards.)
- Fill in student names on the *Teacher Observation Sheet*.
- Set up at least one "Test Fly Zone". *See the instructions in Session 2 Preparations.
- Provide a safe place to store paper airplanes.
- *Optional: Set up a learning center with books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, and/or aerospace engineering (see included resource list for suggestions).

PROCEDURE: Each step in this procedure may be completed in 1-2 days. See the detailed description of each session included in this unit.

Session 1: Introduction and Brainstorm

- Post and read the *Design Challenge* poster: How far can you fly a paper airplane designed and constructed by your aerospace engineering team?
- Brainstorm: Students record ideas on the *Brainstorm* sheet
- *Aerospace Engineering Training*: Students individually research aerodynamics using provided information card or through available websites, books, or articles (see resource list for suggestions) to fill in their training sheet.
- Build and Test: Students explore folding and flying a paper airplane with the *Try It Yourself* worksheet.
- Team Up and *Brainstorm*: Assign students to teams and engineering roles. Establish management expectations. As a team, students share training ideas and brainstorm possible solutions to the design challenge.
- *Team Brainstorm and Plan:* Display and discuss the *Engineering Design Process* poster. Teams imagine and plan possible solutions to the design challenge and record ideas on the *Team Brainstorm and Plan* sheet.

Session 2: Research and Plan

- Research: Each team member will gather information and fill out a basic report about an assigned force of flight by researching and experimenting. Students may use provided information cards or other available resources (see resource list for suggestions).
- Team Meeting Minutes Sheet 1: Students will share individual findings with their team and record the team ideas from discussions.
- Team Meeting Minutes Sheet 2: Teams reflect, plan, and design a paper airplane to test fly.
- Create and Test: Teams fold and fly their paper airplane in the *Test Fly Zone*.

Session 3: Create, Test, Reflect

- *Time to Fly*: Teams follow the Engineering Design Process by fulfilling assigned tasks on the *Time to* Fly worksheets while creating and test flying their paper airplanes.
- Teams repeat the Engineering Design Process until satisfied or as time allows.
- *Post Flight Reflection Page:* Students record and reflect on results to improve their designs.

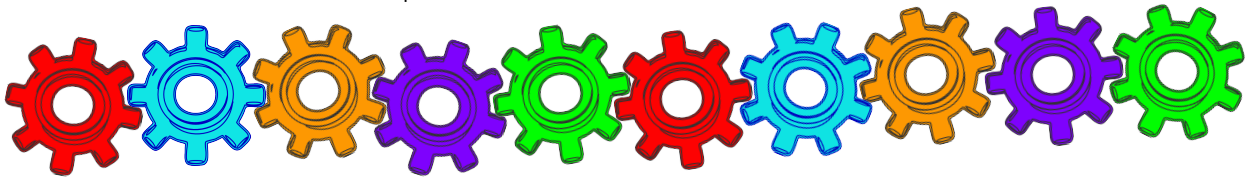
Session 4: Improve, Test, Reflect

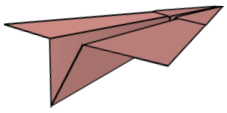
- *Ask and Imagine:* Each team member will gather information about different features of paper airplanes by completing assigned challenges and record their findings on the *Ask and Imagine* worksheets.
- *Final Modifications Log:* Team members will share what was learned from their *Ask and Imagine* sheets. Teams will modify or create new paper airplanes to test while filling out the *Final Modifications Log*.
- Final Design: Students will decorate and name their final airplane. They must test fly the final airplane to be sure the decorations did not alter the flight characteristics.

Session 5: Final Presentation

- Plan Final Presentation: Read through and answer any questions on the *Final Presentation Instructions* and *Scoring* Rubric. Each team will use a *Presentation Planner* to prepare final presentations.
- Present: Teams will be scored based on the scoring rubric as they present.
- Student Evaluation Form: Students fill out the *Student Evaluation Form* to reflect on using the Engineering Design Process while working on a cooperative team.
- Extensions: Optional learning opportunities and activity ideas are included.

Assessment: Students will be evaluated on their individual and team efforts throughout the process. Each student will receive a score from a performance-based rubric.





SUGGESTED RESOURCE LIST

**Optional:* Set up a student learning center during this unit to allow students a place to further research topics. Enjoy this FREE page of websites and books I have found helpful for students to use for research. These websites are included for your convenience. You may choose to reference them or use your own resources along with the provided information cards. These websites were active as of August 27, 2015 and may change at any time.

WEBSITES

www.howthingsfly.si.edu

www.paperplane.org

www.funpaperairplanes.com

www.amazingpaperairplanes.com

www.thepaperairplaneguy.com

BOOKS

Kids' Paper Airplane Book by Ken Blackburn and Jeff Lammers, 1996.

The World Record Paper Airplane Book by Ken Blackburn and Jeff Lammers, 2006.

The New World Champion Paper Airplane Book by John Collins, 2013.

The Flying Machine Book: Build and Launch 35 Rockets, Gliders, Helicopters, Boomerangs, and More by Bobby Mercer, 2012.

Tabletop Scientist-The Science of Air: Projects and Experiments with Air and Flight by Steve Parker, 2005.

The Paper Airplane Book by Seymour Simon,1976.

Session 1
Introduction and Brainstorm

MATERIALS NEEDED:

- 8.5 X 11" copy paper for airplane folding
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **1 Copy:**
  Collaborative Conduct Expectations
  Teacher Observation Sheet
  Aerospace Engineer Teams
  Aerospace Engineer Assignment Cards
  Engineering Design Process
  Design Challenge
- **Class Set:**
  Brainstorm sheet
  Aerospace Engineer Training
  Try It Yourself
  Aerodynamics information card
- **1 Copy per Team:**
  Team Brainstorm and Plan sheet

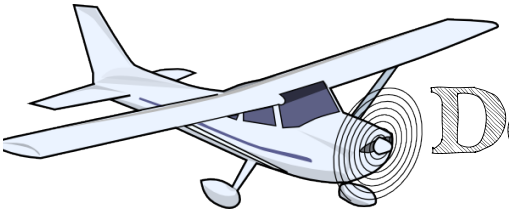
PREPARATIONS:

- Print and display *Engineering Design Process*, *Design Challenge*, and *Collaborative Conduct Expectations* posters.
- Print and fill in student names on the *Teacher Observation Sheet*.
- Group students into engineering teams of 4 students and assign roles. Record student roles on the *Aerospace Engineer Teams* sheet. When assigning each student a role, consideration of student strengths and student special needs is encouraged.
  Engineering Manager: leads group discussions, organizes the group presentation
  Aircraft Designer: draws and describes each airplane design idea
  Airplane Mechanic: folds and modifies the paper airplanes tested
  Test Pilot: test flies each paper airplane and records measured data
  * If there is an odd number of students, assign 2 students to 1 role.
- Cut out *Aerospace Engineer Assignment Cards* for each student assignment. (I recommend printing these on card stock or laminating them. Then punch a hole and make a necklace for students to wear their assignment cards.)
- Copy the print outs listed above as directed.
- *Optional: Arrange desks in pods (one work station for each group).
- *Optional: Set up a learning center with books/pictures about airplanes, history of flight, and/or paper airplanes. Leave this center set up and accessible for the duration of this 5 session activity.

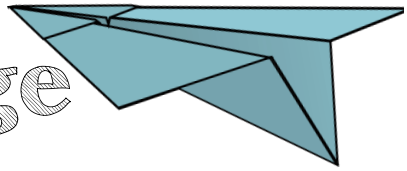
PROCEDURE:

1. Read the *Design Challenge* poster aloud and distribute the *Brainstorm* sheet for students to complete.
2. Distribute *Aerodynamics Information Card* for students to read. Distribute *Aerospace Engineering Training* sheet for students to record notes about aerodynamics. *Optional: Allow students to research additional facts through available websites, books, or articles (see resource list for suggestions).
3. Build and Test: Distribute the *Try It Yourself* worksheet and one sheet of copy paper to each student. Demonstrate and guide students through folding the paper airplane shown. Line students up in an unobstructed area. Everyone will throw on your count. Students reflect on the *Try It Yourself* sheet.
4. Team Up: Distribute *Aerospace Engineer Assignment Cards* and break students into assigned groups. Remind students they are a team. Every job is important to successfully complete the final project.
   - Remind students you will be watching what they are doing and how well they work together by following the *Collaborative Conduct Expectations* (on displayed poster).
   - Tell students they will be scored on their work habits and their results throughout this challenge.
5. Read and discuss the *Engineering Design Process* poster. Explain that this process is used by engineers and will be used during this entire challenge.
6. Team Brainstorm and Plan: Engineering teams will imagine and plan possible solutions to the design challenge while filling out the *Team Brainstorm and Plan* sheet together.

ENGINEERING DESIGN PROCESS



Design Challenge



Problem

Airplanes are wasting too much time and money stopping for fuel before reaching their final destination. This problem will soon make plane tickets cost too much money for travelers. Boeing is asking students across the nation for airplane designs that will fly farther.

Challenge

How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

Criteria

Each airplane must include a unique design that demonstrates forces of flight.

Constraints

To stay under budget, you will be limited to using paper or other classroom supplies.

COLLABORATIVE CONDUCT EXPECTATIONS

Teacher Observation Sheet **Date** _____

~ Collaboration Skills ~

Student	Strong in All Areas	Needs Improvement With…
1.		
2.		
3.		
4.		
5.		
6.		
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31.		
32.		

AEROSPACE ENGINEER TEAMS

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

Team ______________

Engineering Manager: ______________________

Aircraft Designer: ______________________

Airplane Mechanic: ______________________

Test Pilot: ______________________

AEROSPACE ENGINEER ASSIGNMENT CARDS

Copy on cardstock or laminate the cards and give to each team member.
I recommend punching a hole and attaching a string for students to wear as a necklace.

Engineering Manager

- leads group discussions
- records group ideas
- researches *weight*; connects forces of flight to aerodynamics of paper airplanes
- organizes presentation and assigns speaking parts to team members
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Aircraft Designer

- draws, describes, and reflects on paper airplane designs created
- researches *lift*; explores successful design ideas
- spots where each paper airplane lands and helps measure distance traveled on 1st touchdowns
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Airplane Mechanic

- folds or modifies (changes) paper airplane designs
- researches *drag*; experiments with modifications that make paper airplanes fly better
- spots where each paper airplane lands and helps measure distance traveled on 1st touchdowns
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Test Pilot

- test flies each airplane three times with equal force each time
- records measured distance data from each flight
- records any factors that may have changed the distance of flight
- researches *thrust*; experiments with using various materials
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

BRAINSTORM

CHALLENGE:
How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

1. What do I know about flying paper airplanes?

_____
_____
_____
_____
_____

2.

What do I think would make my paper airplane fly farther?	What do I think would shorten the flight of my paper airplane?
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

3. What do I think would be the perfect paper airplane design?

Drawing of Design	I think this design will work well because
	_____
	_____
	_____
	_____
	_____
	_____
	_____
	_____

4. Write down any more ideas you have to complete the challenge.

_____
_____
_____

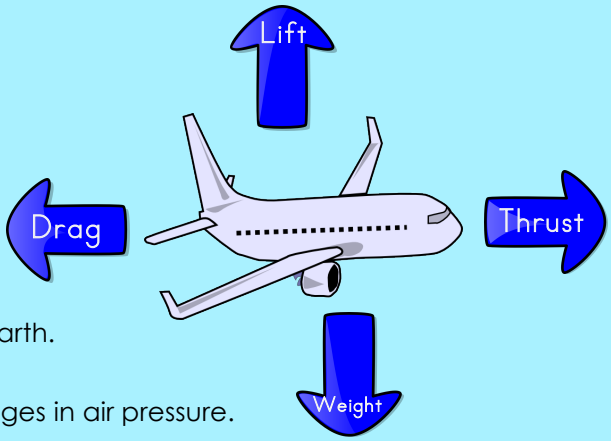
INFORMATION CARD – AERODYNAMICS

Aerodynamics

Aerodynamics explains how objects fly. The air that moves around an object is described through four forces of flight – weight, lift, thrust, and drag. These forces make up the rules of aerodynamics. Balls, Frisbees, kites, airplanes, rockets, and even birds all react to the rules of aerodynamics when moving through air.

Four Forces of Flight

A **force** is a push or pull that changes an object's speed, direction, or shape. An object flies faster, slower, up, or down depending on how much of each force there is. When all four forces are balanced, an object flies.



Weight

Weight is the force of gravity pulling down toward Earth.

Lift

Lift is the force that moves objects higher from changes in air pressure.

Thrust

Thrust is the force that moves objects forward, such as an engine or throw.

Drag

Drag is the force that slows objects down by pulling against thrust with friction or air pressure.

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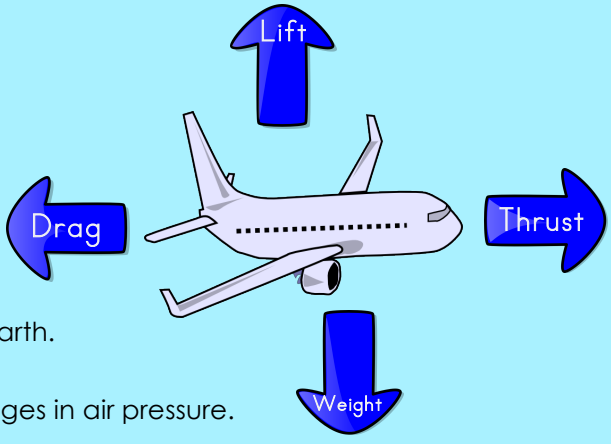

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Drag

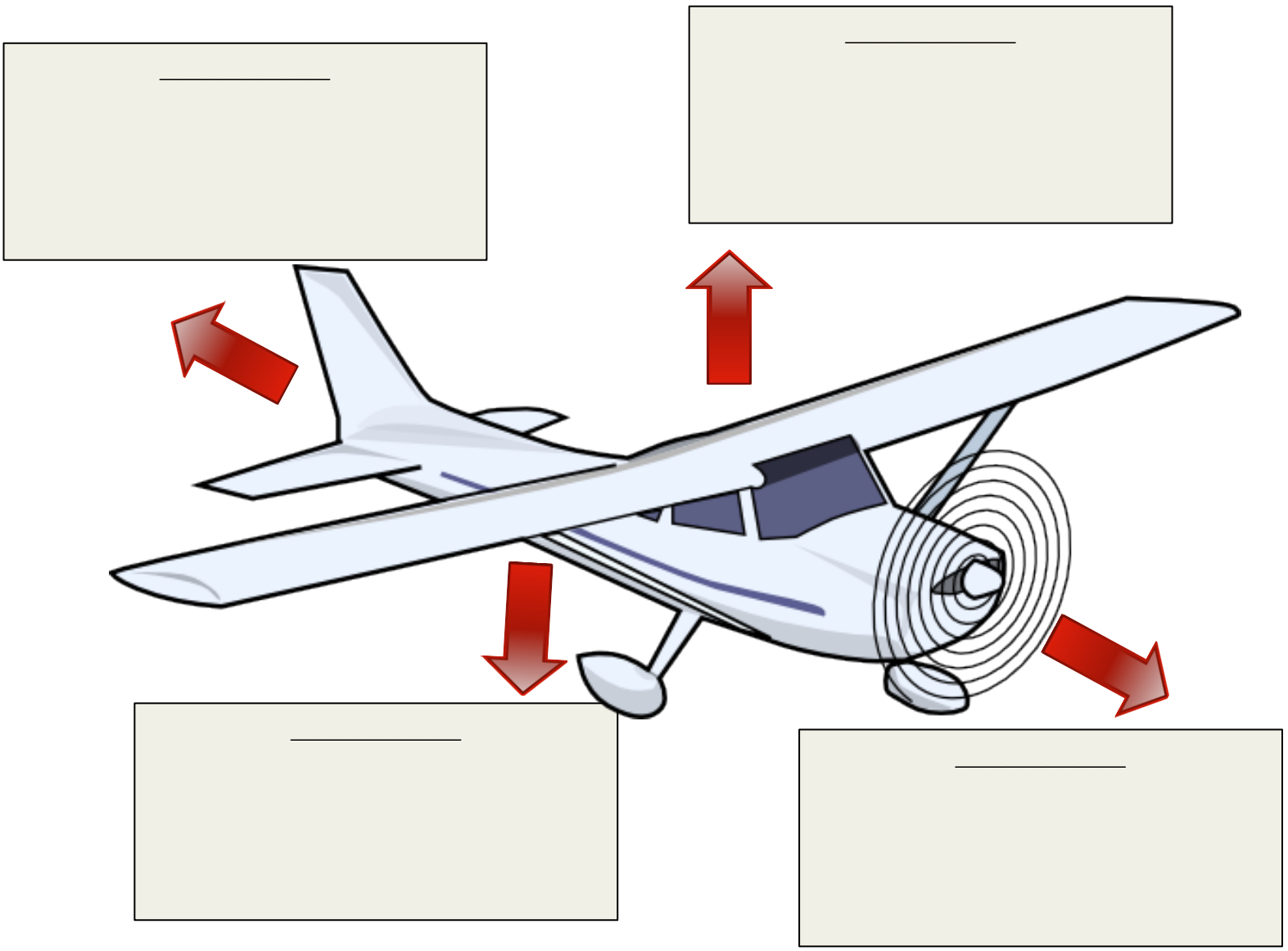
Drag is the force that slows objects down by pulling against thrust with friction or air pressure.

AEROSPACE ENGINEER TRAINING

It's time to begin your training! Find information about aerodynamics. You may include definitions, explanations, examples, or any other interesting facts you want to remember or share with your aerospace engineering team.

AERODYNAMICS NOTES

Research, label, and explain the four forces of flight on the airplane below. Record any other interesting findings on the back of this sheet.



TRY IT YOURSELF

CHALLENGE

How far can you fly a paper airplane?

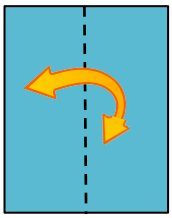
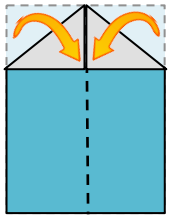
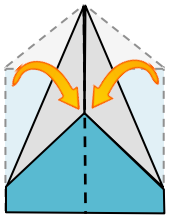
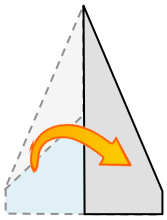
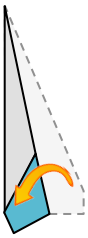
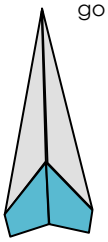
CRITERIA

You must fold a paper airplane out of a piece of copy paper.
Write your name on your airplane before flying it.

CONSTRAINTS

You many only use one piece of copy paper.

TIPS: Follow the instructions provided to fold a basic design or use your own folding method.
Have fun and good luck!

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
fold and unfold paper in half	fold in corners	fold bent corners in to center	fold in half	fold wings down	flip up wings and go fly!
					

REFLECT

What I Liked About My Airplane	What I Didn't Like About My Airplane
Next Time, I would…	**Next time, I would not…**

TEAM BRAINSTORM AND PLAN

MANAGER: _____ **AIRCRAFT DESIGNER:** _____

TEST PILOT: _____ **AIRPLANE MECHANIC:** _____

CHALLENGE:

How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

1. **Think:**

What do we think would make our paper airplane fly farther?	What do we think would shorten the flight of our paper airplane?
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

2. **Plan:** Describe the materials you plan to use and why you chose to use them.

Material:	How/Why it will be used:

3. **Decide:** What do we think would be the perfect paper airplane design?

Drawing of Design	I think this design will work well because
	_____
	_____
	_____
	_____
	_____
	_____

4. Write down any more ideas you have to complete the challenge.

_____

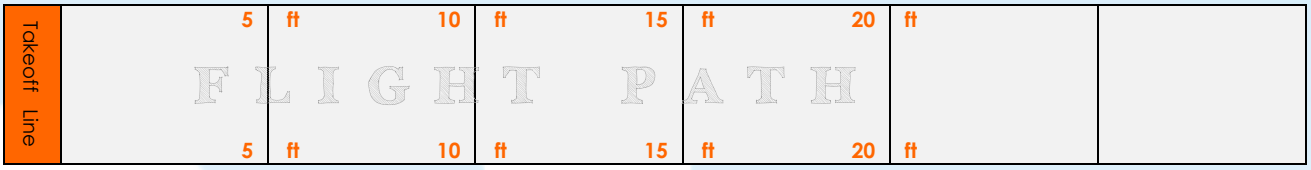
_____

Session 2
Research and Plan

MATERIALS NEEDED:
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips
- masking tape
- measuring sticks or measuring tape
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):
- **Test Fly Zone Posters and Markers (at least one set)**
- **1 Copy per Team:**
  - Thrust Information Card
  - Drag Information Card
  - Weight Information Card
  - Lift Information Card
  - Thrust Report
  - Drag Report
  - Weight Report
  - Lift Report
  - Team Meeting Minutes Sheet 1
  - Team Meeting Minutes Sheet 2

PREPARATIONS:
- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points.
    Use the blank markers to modify marked measurements to best fit your students' needs.



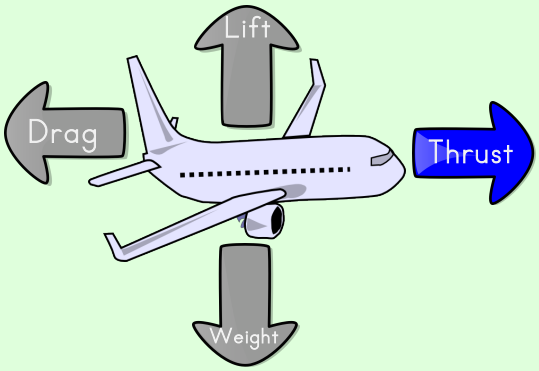
- Copy the print outs listed above as directed.
- Provide safe place to store paper airplanes in progress.

PROCEDURE:
1. Explain the rules of the "Test Fly Zone":
   - Do not cross the flight path (where paper airplanes will be thrown).
   - Test Pilots must stand behind the takeoff line to throw paper airplanes & take turns with other pilots.
   - After paper airplanes land, measure distance from the takeoff line to the *first* touchdown.
2. Explain Team Assignment: Your first team assignment is to explore the four forces of flight. Think about how these forces could improve a paper airplane flight. Each team member will fill out a basic report about an assigned force of flight by researching and experimenting.
   *Optional: Allow students to research additional facts through available websites, books, or articles (see resource list for suggestions).
   - Distribute *Information Cards* and *force report sheets* to assigned engineers.
     Engineering Manager: Research and experiment with weight.
     Aircraft Designer: Research and experiment with lift.
     Airplane Mechanic: Research and experiment with drag.
     Test Pilot: Research and experiment with thrust.
3. *Team Meeting Minutes Sheet 1:* Call engineer teams together to share individual findings. Engineering Managers lead team discussions and record notes on *Team Meeting Minutes Sheet 1*.
4. *Team Meeting Minutes Sheet 2:* Teams reflect, plan, and design a paper airplane to test fly.
5. Create and Test: Airplane Mechanics fold their team paper airplane. Teams may help with folding if needed. Students who are ready may fly their planes in the Test Fly Zone. Teams may adjust and fly their paper airplanes as time allows.




INFORMATION CARD – THRUST

Forces of Flight: Thrust



Thrust is the force that moves a flying object in a direction, usually forward. To move forward, the force of thrust must be stronger than the force of drag.

Most aircraft use an engine to control a propeller, a jet, or a rocket to create thrust. More or less power from the engine will move the aircraft forward faster or slower.

Flying objects without power, such as paper airplanes or water balloons, are supplied with thrust by how the object is thrown. The harder or lighter the throw, the faster or slower the force of thrust will move the object. What other objects have you thrown with more or less thrust?

TRY IT!

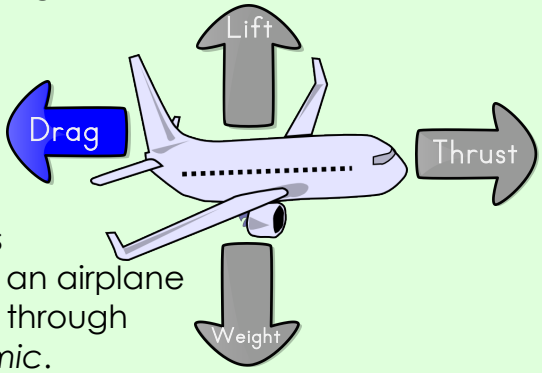
Can you change the force of thrust?

Fold a basic paper airplane. How does the flight change when throwing the airplane with hard or light force?

INFORMATION CARD – DRAG

Forces of Flight: Drag

Drag is the force that slows down forward motion. It pulls against thrust. The shape of an object as it moves through the air can create more or less drag.



Airplanes are designed with a shape that moves through the air more easily. The front, or *nose*, of an airplane is narrow to create less drag. Objects that move through the air with little drag are considered *aerodynamic*.

Drag can also be felt on the ground. If you try running into the wind on a breezy day, you may become more tired. The force of drag slows you down, making you work harder. Drag can also be very helpful. Skydivers are thankful for the drag that slows down their parachutes before landing. Where else have you felt drag?

TRY IT!

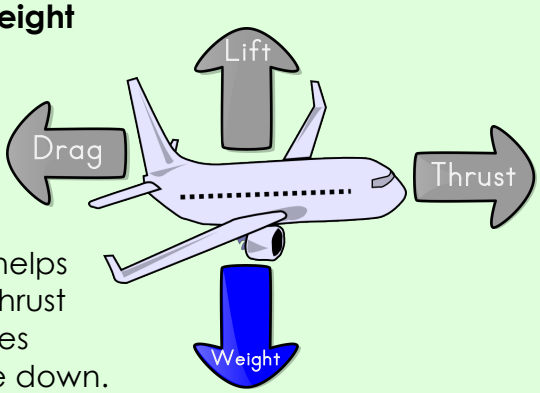
How do different shapes change the force of drag?

Find a clear area. Throw a crumbled and a flat piece of paper at far as you can. What happened? Why?

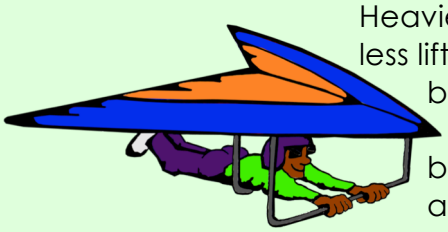
INFORMATION CARD – WEIGHT

Forces of Flight: Weight

Weight is the force of gravity pulling down on an object. The amount of downward pull is equal to how heavy the object is. To fly, the force of weight must be less than the force of lift.



When a pilot is finished flying, the force of weight helps the airplane land. The pilot lowers the amount of thrust and less lift is created. The force of weight becomes stronger than the force of lift, bringing the airplane down.



Heavier planes need more lift. When a plane is lighter it needs less lift to fly. A paper airplane that weighs less will fly farther because there is less gravity pulling it down. Weight also changes how an object flies. Weight must be equally balanced for controlled flight. What flying objects or animals can you think of with balanced weight?

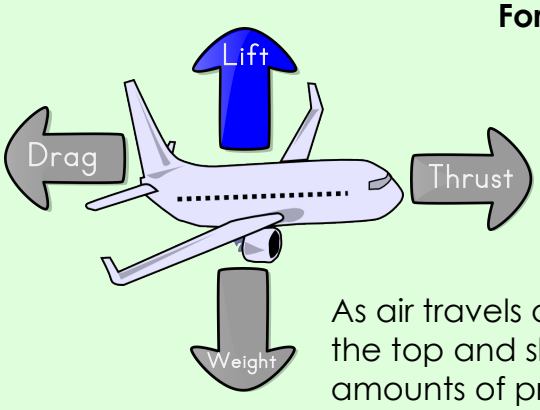
TRY IT!

How does unbalanced weight affect flight?

Fold a basic paper airplane and fly it. Change the weight by attaching a paperclip to one wing. Move the paper clip for each flight. What do you notice?

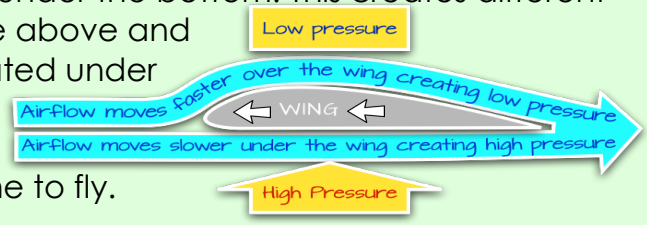
INFORMATION CARD – LIFT

Forces of Flight: Lift



Lift is the force that pulls objects up from the ground. The air moving past the shape and angle of a flying object creates lift. The force of lift must be greater than the force of weight, for an object to fly.

As air travels around an airplane wing, it moves faster over the top and slower under the bottom. This creates different amounts of pressure above and below the wing. The higher pressure created under the wing is stronger than the lower pressure over the wing. This high pressure acts as a lifting force allowing the airplane to fly.



Paper airplanes have a different shaped wing but still use the force of lift. Both the size and angle of the wing can create more or less lift to fly the plane farther.

TRY IT!

How could the angle of the wing change the amount of lift?

Fold and fly a basic paper airplane. Bend the angle of the wings down and then bend them up. Try folding the wings at different angles. What do you notice?

AEROSPACE TEST PILOT

TEST PILOT: _____

TEAM: _____ , _____ , _____

THRUST REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How thrust is applied to actual airplanes:

How thrust can be applied to paper airplanes:

AEROSPACE AIRPLANE MECHANIC

AIRPLANE MECHANIC: _____

TEAM: _____ , _____ , _____

DRAG REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How drag is applied to actual airplanes:

How drag can be applied to paper airplanes:

AEROSPACE ENGINEERING MANAGER

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

WEIGHT REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How weight is applied to actual airplanes:

How weight can be applied to paper airplanes:

AEROSPACE AIRCRAFT DESIGNER

AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

LIFT REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How lift is applied to actual airplanes:

How lift can be applied to paper airplanes:

AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

TEAM MEETING MINUTES SHEET 1

Boeing called! They want to check in on your progress. Collect and record research and ideas from your team about the four forces of flight. Draw arrows between the two pairs of forces that affect each other most in flight.

Weight

Drag

Lift

Thrust

AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

TEAM MEETING MINUTES SHEET 2

Use what you have learned about the four forces of flight to imagine and plan your first team paper airplane design. Agree on a plan and record it below.

Materials Needed

Procedure (Steps to Follow)

Sketch

What We Think Will Happen

Session 3
Create, Test, Reflect

MATERIALS NEEDED:

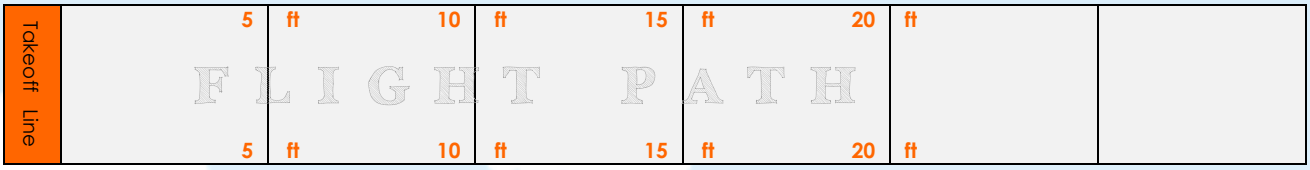
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips, stapler, staples, scissors
- masking tape, clear tape
- measuring sticks or measuring tape
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **Test Fly Zone Posters and Markers (at least one set)** (in Session 2 print outs)
- **1 Copy per Team**
  Engineer Design Process (in Session 1 print outs)
- **2 Copies per Team**
  Aerospace Engineering Manager: Time to Fly
  Aerospace Aircraft Designer: Time to Fly
  Aerospace Airplane Mechanic: Time to Fly
  Aerospace Test Pilot: Time to Fly
  Post Flight Reflection

PREPARATIONS:

- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.
    Use the blank markers to modify marked measurements to best fit your students' needs.



- Set out supplies to be used for airplane modifications: paperclips, stapler, tape, scissors, etc.
- Copy the print outs listed above as directed.
- Provide safe place to store paper airplanes in progress.

PROCEDURE:

1. Explain Team Assignment: Today you will work together with your engineering team to create and test fly your designs. Each of you will have a different job while working through the Engineering Design Process. (Briefly explain each job assignment. Guide students through the process as needed. Monitor team progress.)
   - Distribute *Engineering Design Process* and *Time to Fly* worksheet assignments.

Engineering Manager	Leads the team through the process by following steps on the instructions sheet; Keeps team on task and helps team members.
Aircraft Designer	Draws a sketch of the paper airplane the team wants to build; Lists materials needed and records predictions of how it will fly.
Airplane Mechanic	Folds paper airplanes; Describes how the paper airplane was constructed; Records reflections on how the plane flew.
Test Pilot	Throws paper airplane 3 times; Records the measured distances and how the plane flew; Fills in a bar graph with intervals appropriate for the results.

2. After reflection and discussion, teams may begin the design process again (until the team is satisfied…or as time allows).
3. Post Flight Reflection: Teams reflect on flights and how they wish to improve their designs.

TIME TO FLY!
AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

PREPARING FOR FLIGHT
INSTRUCTIONS FOR AEROSPACE ENGINEER TEAM

1. Ask team: What should be included in the design of our paper airplane? Agree on a design everyone is happy with.
2. Ask the **Aircraft Designer** to sketch and describe the airplane being created on the *Time to Fly Aircraft Designer* planning worksheet. Make sure the team approves the design.
3. Ask the **Airplane Mechanic** to fold the paper airplane while team looks on to check that the folds match the design. Fill in the *create* section of the Airplane Mechanic's *Time to Fly* worksheet. Once the team is satisfied, take your plane to the test flight area.
4. Ask the **Aircraft Designer** and **Airplane Mechanic** to stand along either side of the test flight area to spot where the airplane touches down. (If the floor is slick enough to allow your plane to glide after landing, measure from where the plane *first* touches down.) **If** the plane goes out of bounds, the flight is not measured and must be thrown again.
5. Remind your **Test Pilot** to stand behind the Takeoff Line and try to throw with the same force each time. After the test pilot throws the plane, ask the Aircraft Designer and the Airplane Mechanic to measure from the Takeoff Line to the spot where the airplane first touched down. The team should assist with measuring. The test pilot must record the distance of the flight to the nearest ¼ inch on the recording sheet.
6. Repeat step 5 two more times.
7. Next fill in the *improve* section of the Test Pilot's *Time to Fly* worksheet. Reflect and fill in the *improve* section of the Airplane Mechanic's *Time to Fly* worksheet.
8. Next, repeat steps 1-6 with a new or modified design using new worksheets and reflect on it again. Continue the Engineering Design Process until your team is satisfied with a design.

TIME TO FLY!
AEROSPACE AIRCRAFT DESIGNER

Challenge
How far can you fly a paper airplane?

AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

PLAN
Draw a diagram. Make a list of materials you will need and steps you will take.

This is a diagram of our paper airplane!

Materials Needed to Construct this Design

-
-
-
-

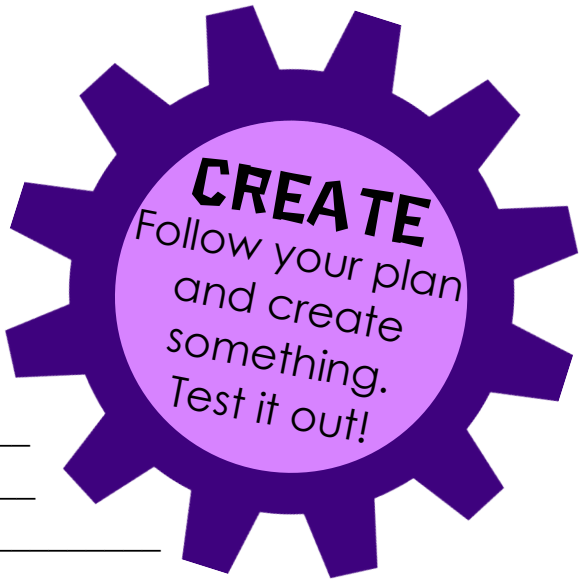
When test flying, this is what we think will happen:

TIME TO FLY!
AEROSPACE AIRPLANE MECHANIC

Challenge
How far can you fly a paper airplane?

AIRPLANE MECHANIC: _____

TEAM: _____ , _____ , _____



While constructing our paper airplane,

☐ I was able to follow our plan!

☐ I was not able to follow our plan because

_____

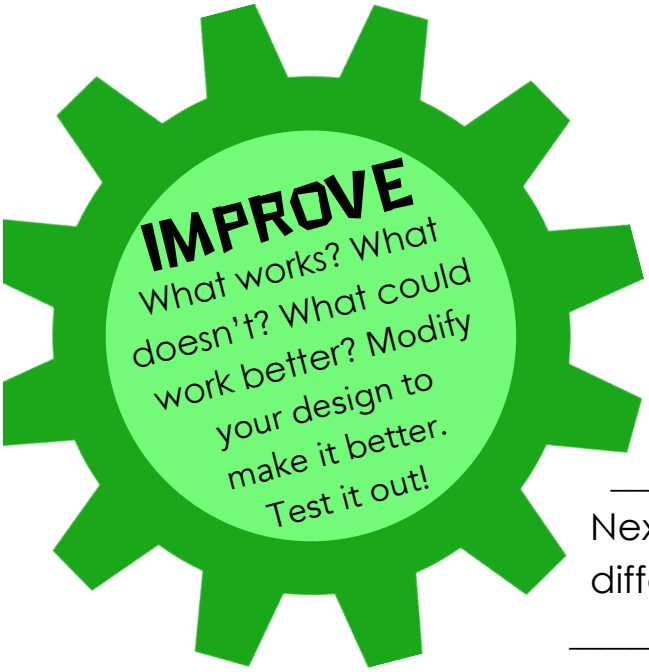
_____

_____

Instead, we decided to _____

_____

_____



REFLECT:

After the test flights, we thought _____

_____

_____

_____

We decided to _____

_____

_____

Next time, we will construct our paper airplane differently by (describe improvements)

_____

_____

_____

TIME TO FLY!
AEROSPACE TEST PILOT

Challenge
How far can you fly a paper airplane?

TEST PILOT: _____

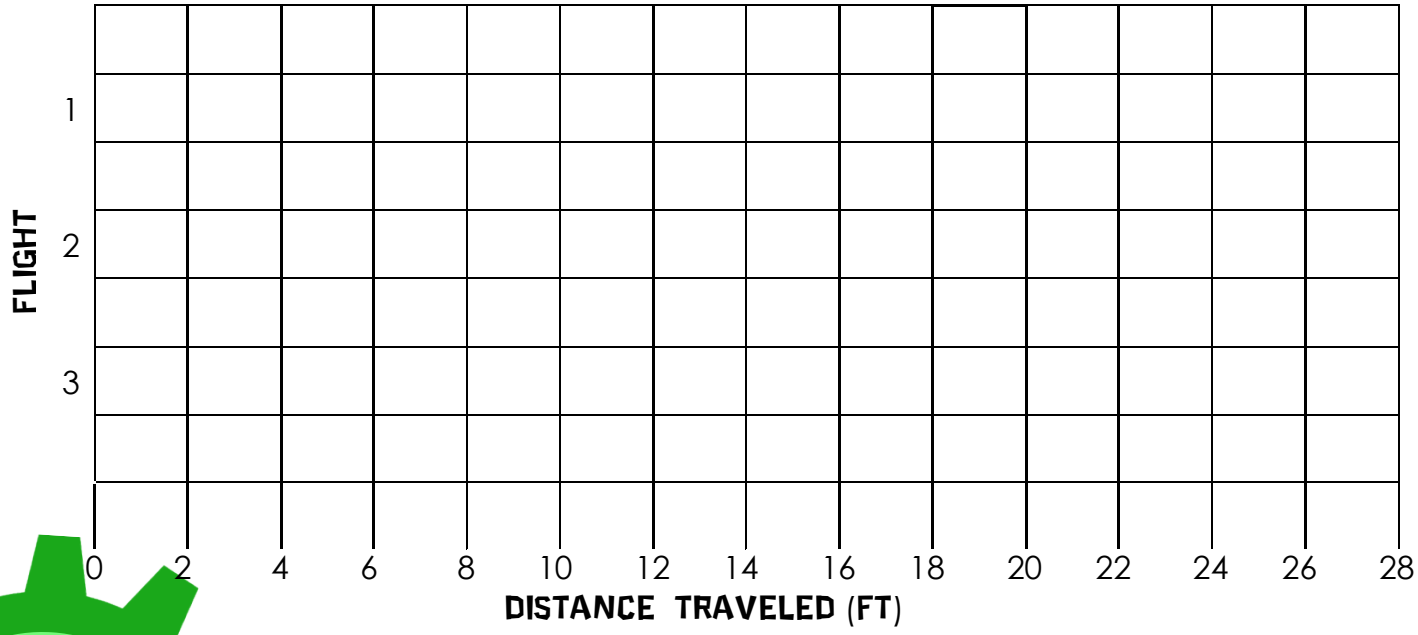
TEAM: _____ , _____ , _____

Time to test fly! Fly your paper airplane three times using the same force. Measure the distance it flew from the Takeoff Line to touch down. Record each measurement in feet and inches to the nearest ¼ inch. Record any unusual or interesting things that happen during each flight.

CREATE
Follow your plan and create something. Test it out!

	Distance Traveled	Notes
1st Flight		
2nd Flight		
3rd Flight		

Display this data on the bar graph below. Round each measurement to the nearest ½ foot to display on the bar graph. Make sure your team agrees that the graph is correct.



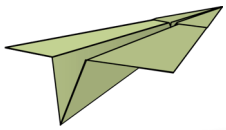
IMPROVE
What works? What doesn't? What could work better? Modify your design to make it better.

What was the distance of the farthest flight? _____

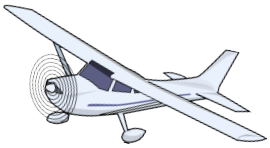
Why was this flight more successful?

_____

_____



POST-FLIGHT REFLECTION



Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

What happened? Describe your results.

_____

_____

_____

Are you happy with your design?

Yes, because…

_____

_____

_____

_____

_____

Not yet, because…

_____

_____

_____

_____

_____

Did you try different solutions?Why or why not?

_____

_____

_____

_____

_____

_____

_____

_____

How did you decide which solution was best?

_____

_____

_____

_____

_____

_____

_____

_____

What will you try differently next time?

_____

_____

_____

_____

_____

_____

_____

_____

What did you learn?

_____

_____

_____

_____

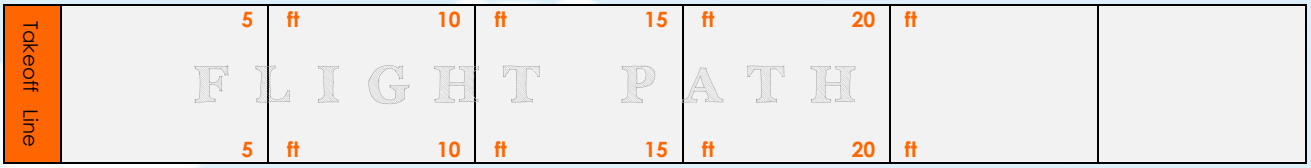
_____

Session 4
Improve, Test, Reflect

MATERIALS NEEDED:
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips, stapler, staples, scissors
- masking tape, clear tape
- measuring sticks or measuring tape
- stickers, markers, colored pencils, crayons, other decorating materials
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):
- **Test Fly Zone Posters and Markers (at least one set)** (in Session 2 print outs)
- **1 Copy per Team**
  Engineer Design Process (in Session 1 print outs)
  Ask and Imagine: Aerospace Engineering Manager
  Ask and Imagine: Aerospace Aircraft Designer
  Ask and Imagine: Aerospace Airplane Mechanic
  Ask and Imagine: Aerospace Test Pilot
  Final Modifications Log

PREPARATIONS:
- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.



- Set out supplies for airplane modifications: variety of paper, paperclips, stapler, tape, scissors, etc.
- Copy the print outs listed above as directed
- Provide safe place to store paper airplanes in progress

PROCEDURE:
1. Explain Team Assignment: Boeing has sent your next team assignment. Your challenge is to find an even better way to design and construct your paper airplane. Each team member will discover techniques that may be used to modify or redesign your paper airplanes. Today you will begin with the *Ask* and *Imagine* steps of the Engineering Design Process. (Briefly explain each job assignment. Guide students through the process as needed. Monitor progress.)
   - Distribute *Engineering Design Process* and *Ask and Imagine* worksheet assignments.

Engineering Manager	Change the forces of flight in new ways on a paper airplane.
Aircraft Designer	Fold and fly a variety of paper airplane designs.
Airplane Mechanic	Experiment with paper airplane modifications to change flight.
Test Pilot	Explore how different building materials can change flight.

2. *Final Modifications Log*: You may use your paper airplane from Session 3 and improve it with what you learned today or start fresh with a new paper airplane. Follow the Engineering Design Process to create your final paper airplane. Use the parts of the process needed until you and your team are satisfied with your design. Use the *Final Modifications Log* to record distances, changes made, and any additional notes as you complete your design.
3. Final Design: Decorate and name your final airplane. Be creative and artistic! Test-fly your final airplane to be sure the decorations did not alter the flight.

ASK & IMAGINE
AEROSPACE ENGINEERING MANAGER

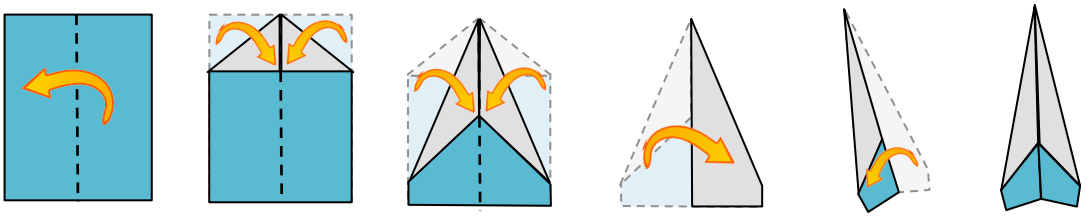
ASK
How can I change the forces of flight to make a paper airplane fly differently?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

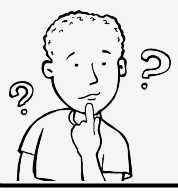
CHALLENGE:

Consider how the four forces of flight work together and affect each other. Most airplanes, both real and paper, need some adjusting for the best flight possible. Fold and fly a paper airplane and try to find the perfect balance of the four forces of flight. Use a simple paper airplane design, such as the one below.



Force	Hints	Affect on Flight	
		What I Tried	What Happened
Thrust	Try throwing your plane in different ways.		
Drag	Try folding the tail up different amounts.		
Lift	Try folding the wings bigger or smaller.		
Weight	Try adding or taking away weight.		

Consider the forces that would affect the distance of flight. What will you try to make your team's paper airplane fly the farthest?



IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

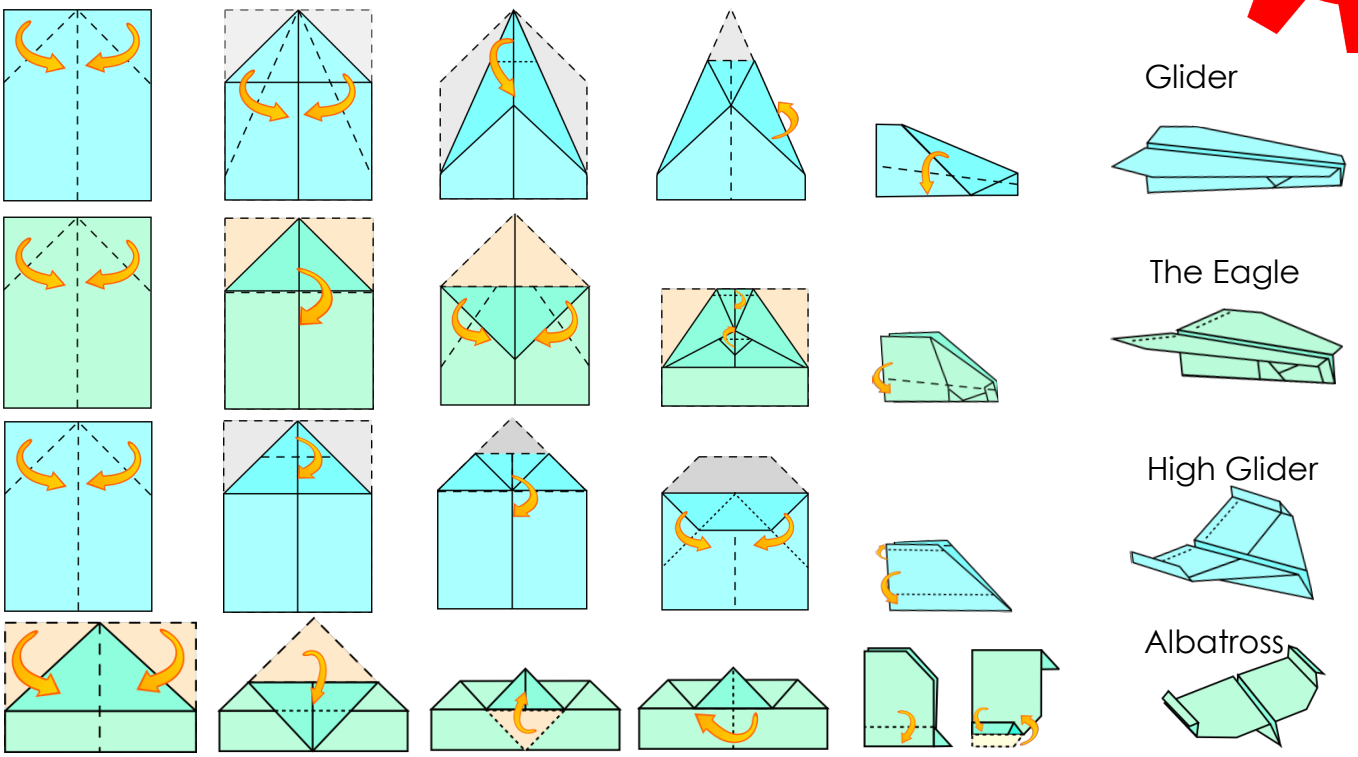
ASK & IMAGINE
AEROSPACE AIRCRAFT DESIGNER

ASK
How have others created successful designs? What are some design ideas and how do they fly?

AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

CHALLENGE: Consider successful paper airplane designs and try them out. Choose at least 2 paper airplane designs to fold and fly. Here are some samples:



Name & Sketch	Distance	Features Causing Farther Flight

What features can you try on your team's paper airplane to make it fly the farthest?

ASK & IMAGINE
AEROSPACE AIRPLANE MECHANIC

ASK
How have others modified designs? What are some modifications and how do they affect flight?

AERONAUTIC MECHANIC: _____

TEAM: _____ , _____ , _____

CHALLENGE: Most airplanes, paper and real, need some adjusting to allow for the best flight possible. Experiment with a basic paper airplane to see how different modifications affect the flight. Below are some flying tips others have tried. Add your own tips too!

Flying Tip: Bend the tail tabs up or down to straighten flight.

Flying Tip: Symmetry! Make sure each side is the same.

Flying Tip: Place a paperclip on the bottom. Slide it back or forward.

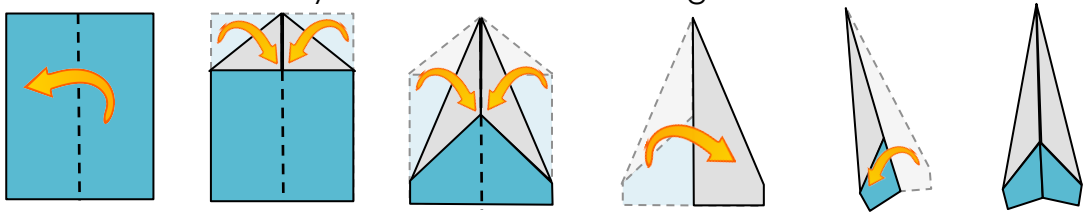
Flying Tip: Make tight, crisp folds at every step.

Flying Tip: Bend the wing angles slightly up.

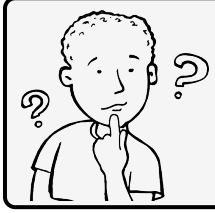
Flying Tip:

Flying Tip:

Hint: Throw the same way and use the same design each time such as this:



Describe Original Flight	Modification	Affect on Flight



Which modifications are you most likely to try to make your team's paper airplane fly farther? Why?

IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

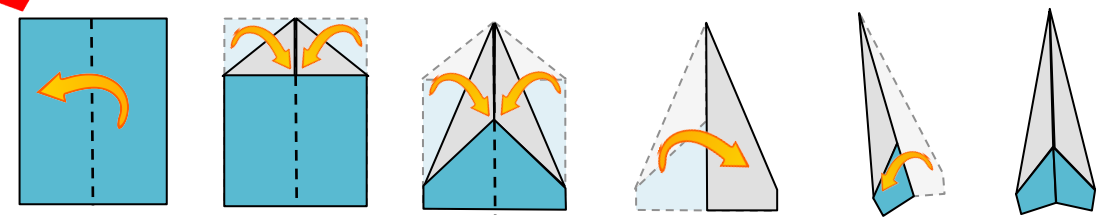
ASK & IMAGINE
AEROSPACE TEST PILOT

ASK
What types of paper might work best? What size or shape paper would fly farthest?

TEST PILOT: _____

TEAM: _____ , _____ , _____

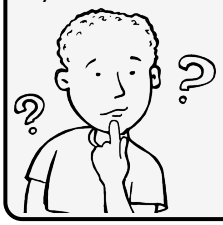
CHALLENGE: Do you think paper airplanes would fly different if they were made out of different types of paper or differently sized paper? Explore how different building materials can affect flight. Use the same paper airplane design, such as the one below, to best compare different materials or shaped paper.



When trying different sized paper, you may need to modify the folds to work.
Paper ideas: loose leaf notebook paper, card stock, construction paper, newspaper, etc.

Materials Used/ Paper Shape	Affect on Flight

Consider the paper choices or paper shapes you could use in constructing your paper airplane. What choices might make your team's paper airplane fly farther? Why do you think so?



IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

Challenge
How far can you fly a paper airplane?

FINAL PAPER AIRPLANE DESIGN

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

Improve your paper airplane from Session 3 or start fresh with a new paper airplane. Follow the Engineering Design Process to create your final paper airplane until all team members are satisfied. Record distances, changes made, and any additional notes as you complete your design. Decorate and name your final airplane. Be creative and artistic! Test-fly your final airplane to be sure the decorations did not alter the flight.

You're finished when all team members are satisfied with the flight. Name and decorate your final paper airplane!

FINAL MODIFICATIONS LOG

FLIGHT 1
distance: _____

FLIGHT 2
distance: _____

FLIGHT 3
distance: _____

FLIGHT 4
distance: _____

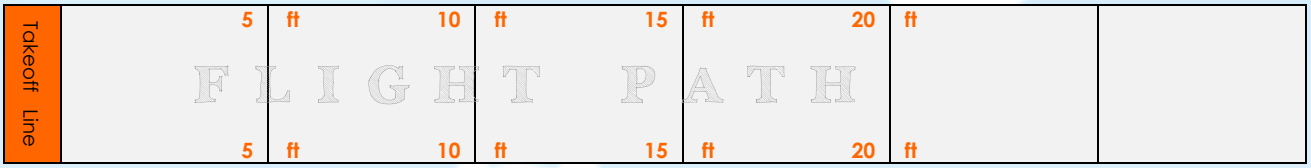
FLIGHT 5
distance: _____

Session 5
Final Presentation

MATERIALS NEEDED:
- poster board or poster paper for each team
- markers or any other art supplies available to create final presentation poster
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):
- **Test Fly Zone Posters and Markers (at least one set)**
- **Class Set:**
  Final Presentation Instructions
  Scoring Rubric
  Student Evaluation Form
- **1 Copy per Team:**
  Presentation Planner

PREPARATIONS:
- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.



- Set out poster boards and art supplies available for students to create final presentations.
- Provide a clear area for team presentations.
- Copy the print outs listed above as directed.
- Complete *Teacher Observation Sheet* to assist with student final scores.

PROCEDURE:
1. Distribute *Final Presentation Instructions* and *Scoring Rubric*: Read through and answer any questions on *Final Presentation Instructions* and *Scoring Rubric*.
2. Preparation Time: Distribute a *Presentation* Planner to each team. Allow teams time to plan and prepare for final presentations. You many want to set a time limit. Monitor progress and guide students to stay on track.
3. Presentations: As each team presents, score students on individual rubrics (consider notes from *Teacher Observation Sheet* for contributions and responsibilities). Evaluate students on individual and team efforts according to the provided rubric.
4. *Optional *Student Evaluation Form:* Students fill out the *Student Evaluation Form* to reflect on using the Engineering Design Process while working in a cooperative team.
5. *Optional *Extensions:* Additional learning opportunities and activity ideas are included.

FINAL PRESENTATION INSTRUCTIONS

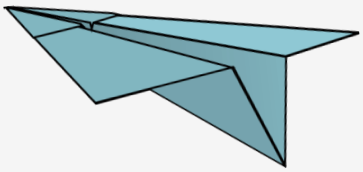
You made it! Now it's time to share your results with your fellow aerospace engineer teams and create a final presentation for Boeing!

Each team must present their final conclusions on a poster and fly their final paper airplanes on one demonstration flight. Look back through any team notes together to fill in the *results, results process, and conclusions*.

Presentations must include:

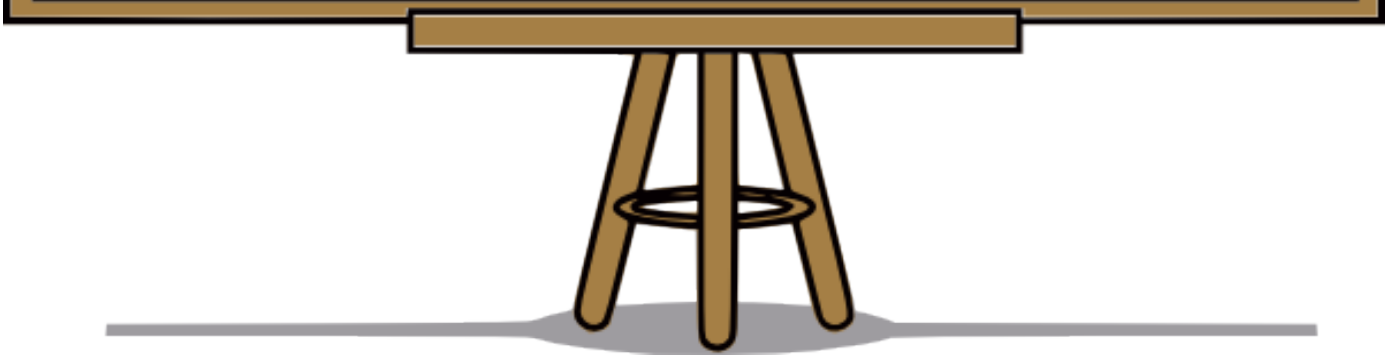
1. Results:
   Describe your paper airplane and how far it went when tested.

2. Results Process:
   First, we tried _____. _____ happened.
   So we _____. ____happened.
   Finally, when we ____, ____ happened.



3. Conclusions:
   We learned _____

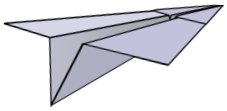
4. Demonstration Flight:
   Share throwing technique used and fly paper airplane on one demonstration flight.



Use the *Presentation Planner* sheet to organize your presentation. Make sure to:

- display results and conclusions in an organized presentable way on your poster.
- name and decorate your paper airplane for the demonstration flight.
- plan what every team member will say (everyone must speak).
- PRACTICE before presenting.

HINT: Compare your presentation to the scoring rubric to be sure it is complete.



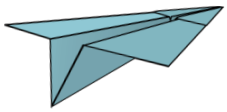
Name _____

SCORING RUBRIC

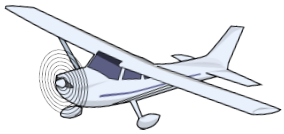
This is how your work will be evaluated.

	Exemplary 4	Accomplished 3	In Training 2	Novice 1	Score
Engineer Contributions					
Researches and Records Information	collects and records information beyond the basics – relates to topic	collects and records basic information – most relates to topic	collects and records minimal information – some relates to topic	does not collect or record any information related to topic	
Shares Information	shares a great deal of information – all relates to topic	shares some basic information – most relates to topic	shares very little information – some relates to topic	does not share any information related to topic	
Engineer Team Responsibilities					
Fulfills Assigned Job	performs all duties of assigned job	performs nearly all duties of assigned job	performs very little duties of assigned job	does not perform duties of assigned job	
Participates in Presentation	contributes extensively to presentation – all information is relevant	contributes some information during presentation – most is relevant	contributes little or irrelevant information during presentation	does not contribute during presentation	
Teamwork	always does the assigned work without having to be reminded	usually does the assigned work – rarely needs reminding	rarely does the assigned work – often needs reminding	always relies on others to do the work	
Quality of Paper Airplane and Final Presentation					
Attention to Detail and Creativity	presentation was neat, well organized and showed creativity	presentation was neat and well organized	presentation was neat but not well organized	presentation was messy and not well organized	
Content Required is Complete	presentation includes detailed results, result process, and conclusion	presentation includes results, result process, and conclusion	presentation includes 2 out of 3 requirements (results, result process, conclusion)	presentation includes 0-1 of the requirements (results, result process, conclusion)	
Distance of Flight	20 feet or more	10-19 feet	5-9 feet	0 feet	
Measurement of Flight	accurately and precisely measures and records data	measurements are usually accurate and recorded	measurements are sometimes accurate and recorded	measurements are not accurate and/or recorded	
Uses Aerodynamics Principles	plane indicates a clear and accurate understanding of aerodynamic principles in construction and modifications	plane indicates a fair understanding of aerodynamic principles in construction and modifications	plane indicates a minimal understanding of aerodynamic principles in construction and modifications	plane indicates no understanding of aerodynamic principles in construction and modifications	

TOTAL ___ ÷ 10 = FINAL SCORE ____



PRESENTATION PLANNER



Decide what information each team member will share. Plan the order of speakers. List any materials that need to be created or speeches that need to be prepared. PRACTICE!

Engineering Manager	Aircraft Designer
Airplane Mechanic	Test Pilot

STUDENT EVALUATION FORM

Name _____

Team Members: _____ , _____ , _____

Being able to work with a team is important for success. How did you do? Circle the best response.

1. When I knew an answer or had an idea, I shared it.

   Always Sometimes Never

2. I encouraged others in my group.

   Always Sometimes Never

3. I felt encouraged by people in my group.

   Always Sometimes Never

4. When my answer was different than others, I tried to find out why.

   Always Sometimes Never

5. When I did not understand something, I asked my group for help.

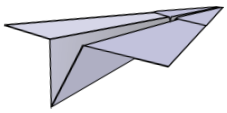
   Always Sometimes Never

6. If another group member did not understand something, I helped them understand.

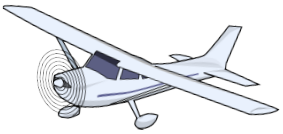
   Always Sometimes Never

7.

Write what you could do to make your group better.	
Did you enjoy using the Engineering Design Process?	What was most difficult? Why?
What did you learn?	



PAPER AIRPLANE CHALLENGE EXTENSION ACTIVITIES



Can't get enough?

TRY THIS!
Line up all the final paper airplanes from the shortest to the longest flights. Compare the design choices. What aerodynamic features do you think were responsible for the different flight distances?

TRY THIS!
Learn from the expert himself! Read about "The Paper Airplane Guy" who broke the world record for the farthest flying paper airplane on February 26, 2012. Find out how far his plane flew, which paper airplane he used, and watch how he did it on his website www.thepaperairplaneguy.com.

TRY THIS!
Design an airplane out of materials other than paper. If you were not limited to paper for a main material, what would you use to fly an aerodynamic aircraft that flies even farther than a paper airplane? Try it!

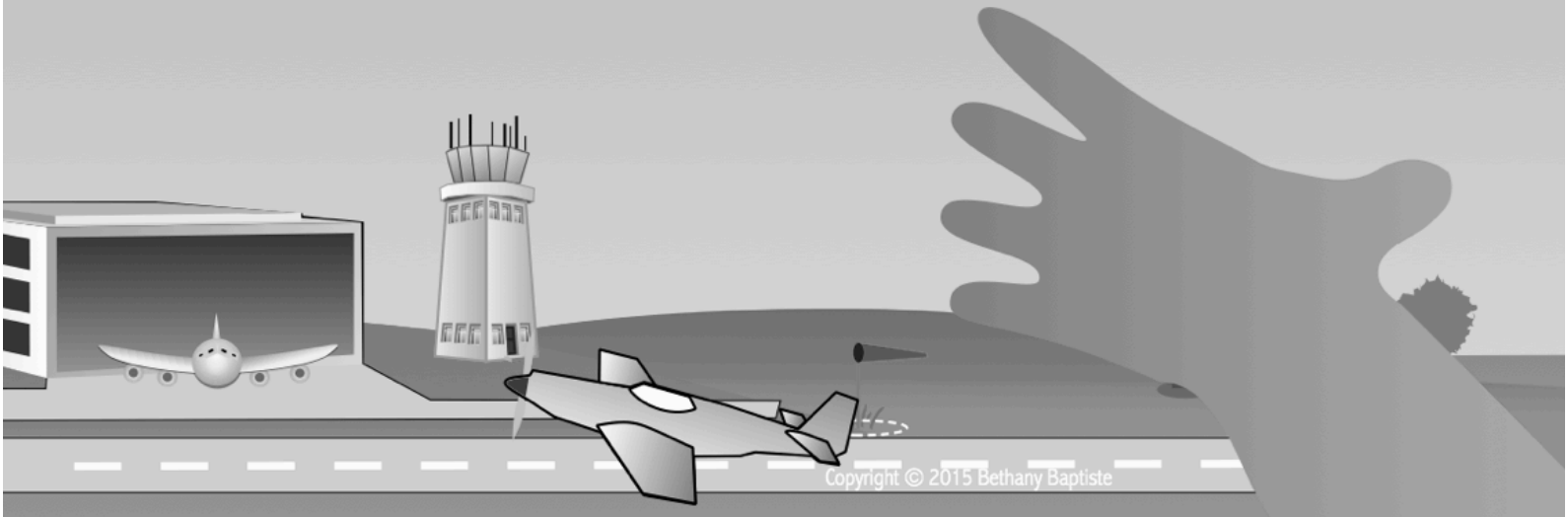
TRY THIS!
Are you interested in aerospace engineering? Explore what jobs are currently available for aerospace engineers at www.engineerjobs.com/jobs/aerospace-engineering. List the jobs you would like to do.

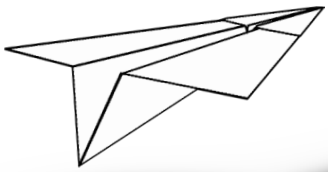
TRY THIS!
Research famous aerospace engineers. What are they most well known for? What do they do or what did they do? Where do they work today?

Time For Takeoff!

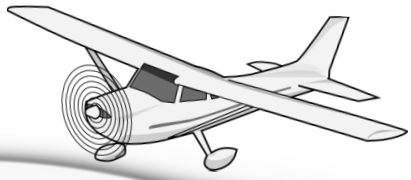
STEM Activity:
Paper Airplane Challenge

Appropriate for Grades 3-5
5 Sessions
Aligned to CCSS





TIME FOR TAKEOFF!
STEM Activity



OVERVIEW

Time for Takeoff! is a **STEM** lesson (integrates science, technology, engineering, and mathematics) that introduces aerodynamics and the forces of flight. Students will apply these concepts to design and construct a paper airplane that will fly as far as possible. Students assume the roles of aerospace engineers throughout the challenge and work in collaborative teams while following an engineering design process. Final paper airplanes and team conclusions will be presented. The challenge is intended to last five sessions and introduce students to the engineering design process.

TEACHER PROCESS

Grade Levels: 3rd-5th grades
Subject Areas: Science, Technology, Engineering, Mathematics, Literacy
Standards Addressed: (3rd grade standards listed but can be adapted to meet many grade level standards)
CCSS: 3.MD.4; 3.RI.10, 3.W.8, 3.SL.1, 3.SL.4; *Science Framework* PS2.A Forces and Motion
Objective: Students will design and construct a paper airplane that flies as far as possible by using aerodynamic principles. Students will be guided through using the Engineering Design Process.

Materials Needed:

- all posters and worksheets included
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, weights) for airplane folding
- stickers, markers, colored pencils, crayons, or other decorating materials (for planes and presentations)
- one poster board or poster paper for each team
- measuring sticks or measuring tape
- variety of materials to modify/improve flight: scissors, paperclips, stapler, staples, tape
- masking tape for airplane throwing line
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, and/or aerospace engineering for student learning center (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

Duration: 5-10 days (Younger students may need more time.)

Preparations: (Detailed descriptions are included for each session.)

- Copy all print outs included as instructed in each session plan.
- Display *Collaborative Conduct Expectations*, *Engineering Design Process*, and *Design Challenge* posters.
- Assign students to engineering teams and assign each student a role. *See the role descriptions in the *Session 1 Preparations*.
- Cut out *Aerospace Engineer Role Assignment Cards* for each student assignment. (I recommend printing these on card stock or laminating them. Then punch a hole and make a necklace for students to wear their assignment cards.)
- Fill in student names on the *Teacher Observation Sheet*.
- Set up at least one "Test Fly Zone". *See the instructions in Session 2 Preparations.
- Provide a safe place to store paper airplanes.
- *Optional: Set up a learning center with books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, and/or aerospace engineering (see included resource list for suggestions).

PROCEDURE: Each step in this procedure may be completed in 1-2 days. See the detailed description of each session included in this unit.

Session 1: Introduction and Brainstorm

- Post and read the *Design Challenge* poster: How far can you fly a paper airplane designed and constructed by your aerospace engineering team?
- Brainstorm: Students record ideas on the *Brainstorm* sheet
- *Aerospace Engineering Training*: Students individually research aerodynamics using provided information card or through available websites, books, or articles (see resource list for suggestions) to fill in their training sheet.
- Build and Test: Students explore folding and flying a paper airplane with the *Try It Yourself* worksheet.
- Team Up and *Brainstorm*: Assign students to teams and engineering roles. Establish management expectations. As a team, students share training ideas and brainstorm possible solutions to the design challenge.
- *Team Brainstorm and Plan:* Display and discuss the *Engineering Design Process* poster. Teams imagine and plan possible solutions to the design challenge and record ideas on the *Team Brainstorm and Plan* sheet.

Session 2: Research and Plan

- Research: Each team member will gather information and fill out a basic report about an assigned force of flight by researching and experimenting. Students may use provided information cards or other available resources (see resource list for suggestions).
- Team Meeting Minutes Sheet 1: Students will share individual findings with their team and record the team ideas from discussions.
- Team Meeting Minutes Sheet 2: Teams reflect, plan, and design a paper airplane to test fly.
- Create and Test: Teams fold and fly their paper airplane in the *Test Fly Zone*.

Session 3: Create, Test, Reflect

- *Time to Fly*: Teams follow the Engineering Design Process by fulfilling assigned tasks on the *Time to* Fly worksheets while creating and test flying their paper airplanes.
- Teams repeat the Engineering Design Process until satisfied or as time allows.
- *Post Flight Reflection Page:* Students record and reflect on results to improve their designs.

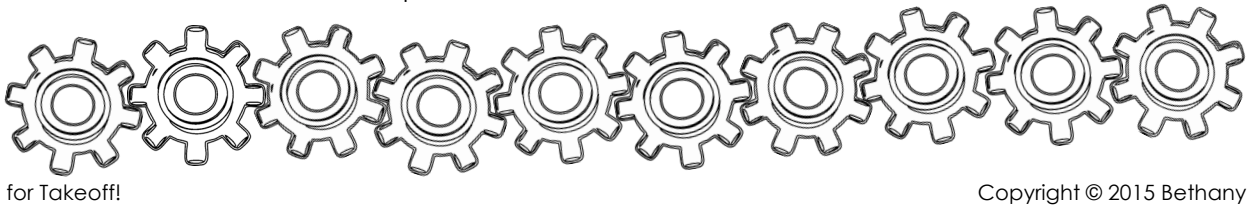
Session 4: Improve, Test, Reflect

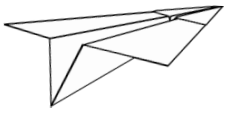
- *Ask and Imagine:* Each team member will gather information about different features of paper airplanes by completing assigned challenges and record their findings on the *Ask and Imagine* worksheets.
- *Final Modifications Log:* Team members will share what was learned from their *Ask and Imagine* sheets. Teams will modify or create new paper airplanes to test while filling out the *Final Modifications Log*.
- Final Design: Students will decorate and name their final airplane. They must test fly the final airplane to be sure the decorations did not alter the flight characteristics.

Session 5: Final Presentation

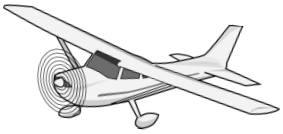
- Plan Final Presentation: Read through and answer any questions on the *Final Presentation Instructions* and *Scoring* Rubric. Each team will use a *Presentation Planner* to prepare final presentations.
- Present: Teams will be scored based on the scoring rubric as they present.
- Student Evaluation Form: Students fill out the *Student Evaluation Form* to reflect on using the Engineering Design Process while working on a cooperative team.
- Extensions: Optional learning opportunities and activity ideas are included.

Assessment: Students will be evaluated on their individual and team efforts throughout the process. Each student will receive a score from a performance-based rubric.





SUGGESTED RESOURCE LIST



**Optional:* Set up a student learning center during this unit to allow students a place to further research topics. Enjoy this FREE page of websites and books I have found helpful for students to use for research. These websites are included for your convenience. You may choose to reference them or use your own resources along with the provided information cards. These websites were active as of August 27, 2015 and may change at any time.

WEBSITES

www.howthingsfly.si.edu

www.paperplane.org

www.funpaperairplanes.com

www.amazingpaperairplanes.com

www.thepaperairplaneguy.com

BOOKS

Kids' Paper Airplane Book by Ken Blackburn and Jeff Lammers, 1996.

The World Record Paper Airplane Book by Ken Blackburn and Jeff Lammers, 2006.

The New World Champion Paper Airplane Book by John Collins, 2013.

The Flying Machine Book: Build and Launch 35 Rockets, Gliders, Helicopters, Boomerangs, and More by Bobby Mercer, 2012.

Tabletop Scientist-The Science of Air: Projects and Experiments with Air and Flight by Steve Parker, 2005.

The Paper Airplane Book by Seymour Simon,1976.

Session 1
Introduction and Brainstorm

MATERIALS NEEDED:

- 8.5 X 11" copy paper for airplane folding
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **1 Copy:**
  Collaborative Conduct Expectations
  Teacher Observation Sheet
  Aerospace Engineer Teams
  Aerospace Engineer Assignment Cards
  Engineering Design Process
  Design Challenge
- **Class Set:**
  Brainstorm sheet
  Aerospace Engineer Training
  Try It Yourself
  Aerodynamics information card
- **1 Copy per Team:**
  Team Brainstorm and Plan sheet

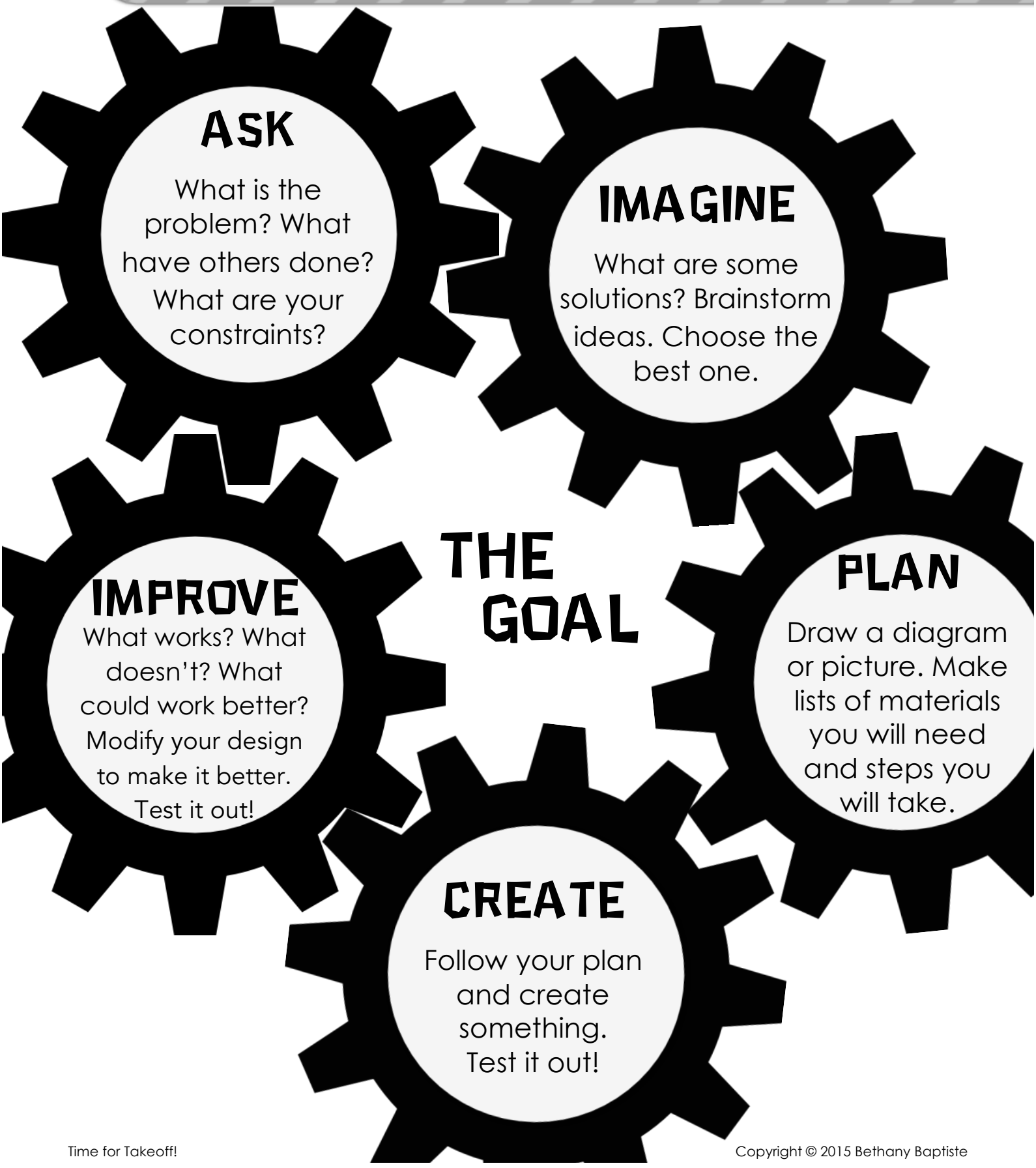
PREPARATIONS:

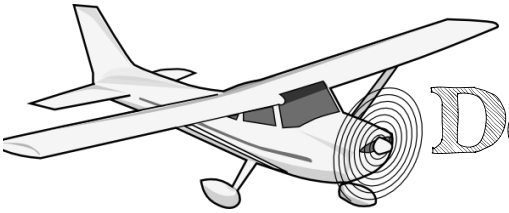
- Print and display *Engineering Design Process*, *Design Challenge*, and *Collaborative Conduct Expectations* posters.
- Print and fill in student names on the *Teacher Observation Sheet*.
- Group students into engineering teams of 4 students and assign roles. Record student roles on the *Aerospace Engineer Teams* sheet. When assigning each student a role, consideration of student strengths and student special needs is encouraged.
  Engineering Manager: leads group discussions, organizes the group presentation
  Aircraft Designer: draws and describes each airplane design idea
  Airplane Mechanic: folds and modifies the paper airplanes tested
  Test Pilot: test flies each paper airplane and records measured data
  * If there is an odd number of students, assign 2 students to 1 role.
- Cut out *Aerospace Engineer Assignment Cards* for each student assignment. (I recommend printing these on card stock or laminating them. Then punch a hole and make a necklace for students to wear their assignment cards.)
- Copy the print outs listed above as directed.
- *Optional: Arrange desks in pods (one work station for each group).
- *Optional: Set up a learning center with books/pictures about airplanes, history of flight, and/or paper airplanes. Leave this center set up and accessible for the duration of this 5 session activity.

PROCEDURE:

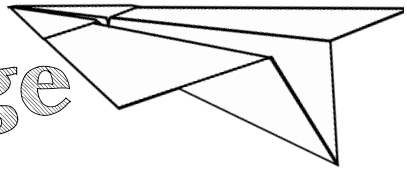
1. Read the *Design Challenge* poster aloud and distribute the *Brainstorm* sheet for students to complete.
2. Distribute *Aerodynamics Information Card* for students to read. Distribute *Aerospace Engineering Training* sheet for students to record notes about aerodynamics. *Optional: Allow students to research additional facts through available websites, books, or articles (see resource list for suggestions).
3. Build and Test: Distribute the *Try It Yourself* worksheet and one sheet of copy paper to each student. Demonstrate and guide students through folding the paper airplane shown. Line students up in an unobstructed area. Everyone will throw on your count. Students reflect on the *Try It Yourself* sheet.
4. Team Up: Distribute *Aerospace Engineer Assignment Cards* and break students into assigned groups. Remind students they are a team. Every job is important to successfully complete the final project.
   - Remind students you will be watching what they are doing and how well they work together by following the *Collaborative Conduct Expectations* (on displayed poster).
   - Tell students they will be scored on their work habits and their results throughout this challenge.
5. Read and discuss the *Engineering Design Process* poster. Explain that this process is used by engineers and will be used during this entire challenge.
6. Team Brainstorm and Plan: Engineering teams will imagine and plan possible solutions to the design challenge while filling out the *Team Brainstorm and Plan* sheet together.

ENGINEERING DESIGN PROCESS





Design Challenge



Problem

Airplanes are wasting too much time and money stopping for fuel before reaching their final destination. This problem will soon make plane tickets cost too much money for travelers. Boeing is asking students across the nation for airplane designs that will fly farther.

Challenge

How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

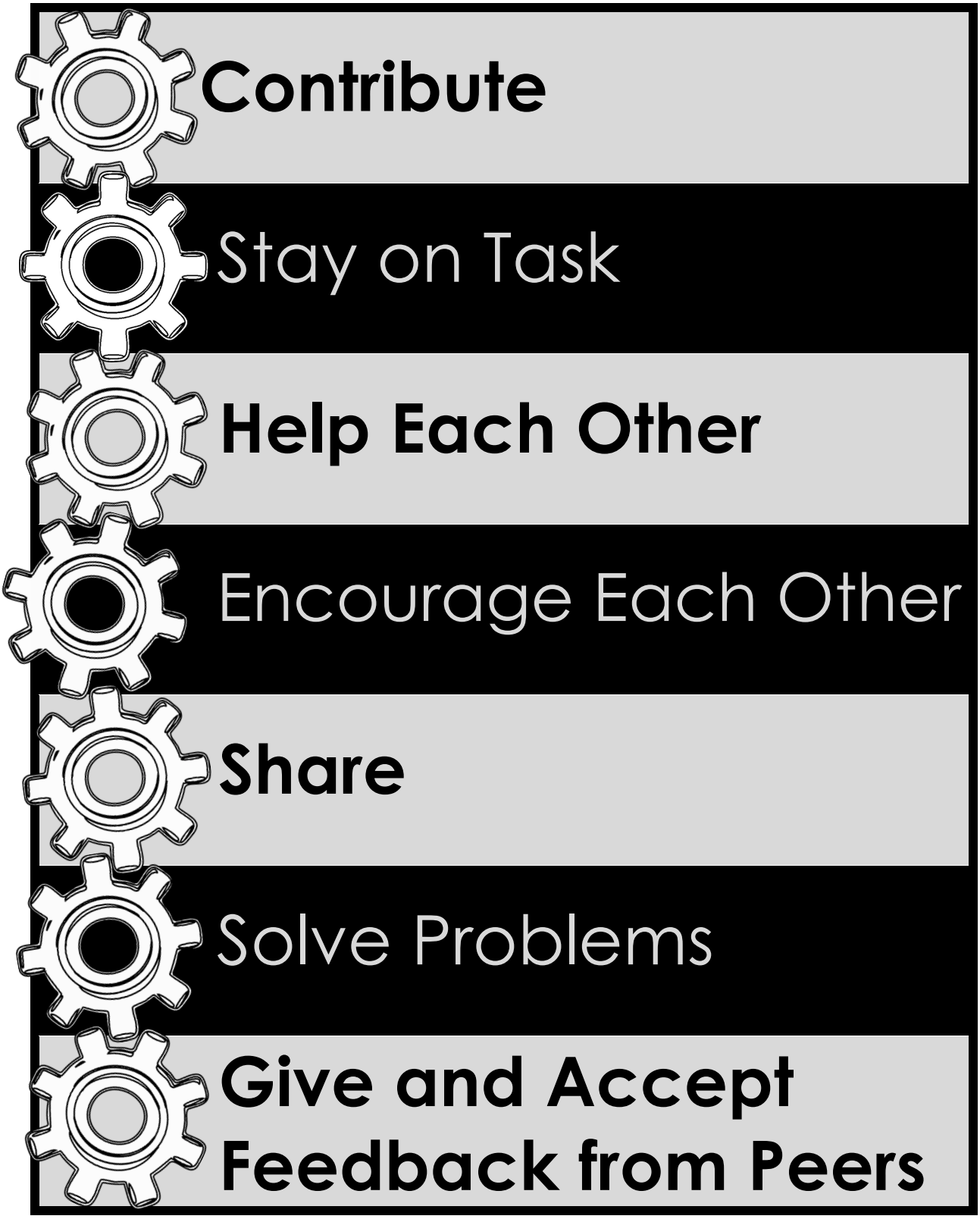
Criteria

Each airplane must include a unique design that demonstrates forces of flight.

Constraints

To stay under budget, you will be limited to using paper or other classroom supplies.

COLLABORATIVE CONDUCT EXPECTATIONS



Teacher Observation Sheet **Date** _____

~ Collaboration Skills ~

Student	Strong in All Areas	Needs Improvement With…
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
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16.		
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21.		
22.		
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27.		
28.		
29.		
30.		
31.		
32.		

AEROSPACE ENGINEER TEAMS

Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________	Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________
Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________	Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________
Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________	Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________
Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________	Team ______________ Engineering Manager: ____________________ Aircraft Designer: ____________________ Airplane Mechanic: ____________________ Test Pilot: ____________________

AEROSPACE ENGINEER ASSIGNMENT CARDS

Copy on cardstock or laminate the cards and give to each team member.
I recommend punching a hole and attaching a string for students to wear as a necklace.

Engineering Manager

- leads group discussions
- records group ideas
- researches *weight*; connects forces of flight to aerodynamics of paper airplanes
- organizes presentation and assigns speaking parts to team members
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Aircraft Designer

- draws, describes, and reflects on paper airplane designs created
- researches *lift*; explores successful design ideas
- spots where each paper airplane lands and helps measure distance traveled on 1st touchdowns
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Airplane Mechanic

- folds or modifies (changes) paper airplane designs
- researches *drag*; experiments with modifications that make paper airplanes fly better
- spots where each paper airplane lands and helps measure distance traveled on 1st touchdowns
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

Test Pilot

- test flies each airplane three times with equal force each time
- records measured distance data from each flight
- records any factors that may have changed the distance of flight
- researches *thrust*; experiments with using various materials
- **gives input**
- **helps team members who need assistance**
- **presents conclusions with group**

BRAINSTORM

CHALLENGE:
How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

1. What do I know about flying paper airplanes?

_____
_____
_____
_____
_____

2.

What do I think would make my paper airplane fly farther?	What do I think would shorten the flight of my paper airplane?
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

3. What do I think would be the perfect paper airplane design?

Drawing of Design	I think this design will work well because
	_____
	_____
	_____
	_____
	_____
	_____
	_____
	_____

4. Write down any more ideas you have to complete the challenge.

_____
_____
_____

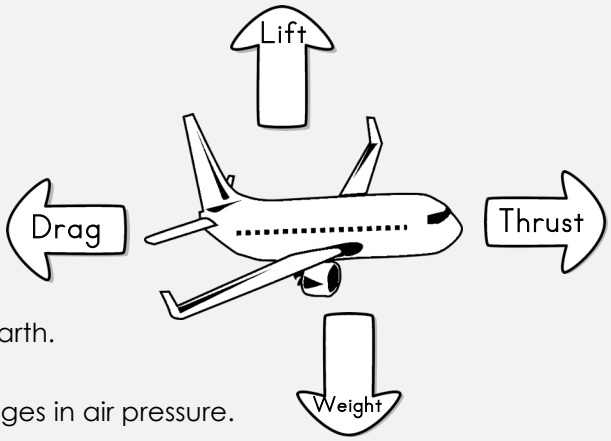
INFORMATION CARD – AERODYNAMICS

Aerodynamics

Aerodynamics explains how objects fly. The air that moves around an object is described through four forces of flight – weight, lift, thrust, and drag. These forces make up the rules of aerodynamics. Balls, Frisbees, kites, airplanes, rockets, and even birds all react to the rules of aerodynamics when moving through air.

Four Forces of Flight

A **force** is a push or pull that changes an object's speed, direction, or shape. An object flies faster, slower, up, or down depending on how much of each force there is. When all four forces are balanced, an object flies.



Weight

Weight is the force of gravity pulling down toward Earth.

Lift

Lift is the force that moves objects higher from changes in air pressure.

Thrust

Thrust is the force that moves objects forward, such as an engine or throw.

Drag

Drag is the force that slows objects down by pulling against thrust with friction or air pressure.

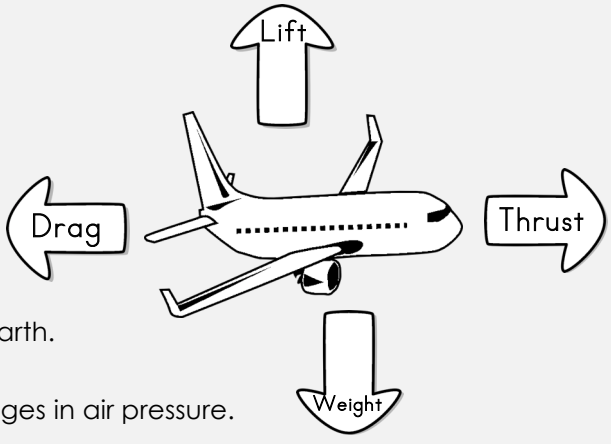
INFORMATION CARD – AERODYNAMICS

Aerodynamics

Aerodynamics explains how objects fly. The air that moves around an object is described through four forces of flight – weight, lift, thrust, and drag. These forces make up the rules of aerodynamics. Balls, Frisbees, kites, airplanes, rockets, and even birds all react to the rules of aerodynamics when moving through air.

Four Forces of Flight

A **force** is a push or pull that changes an object's speed, direction, or shape. An object flies faster, slower, up, or down depending on how much of each force there is. When all four forces are balanced, an object flies.



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Drag

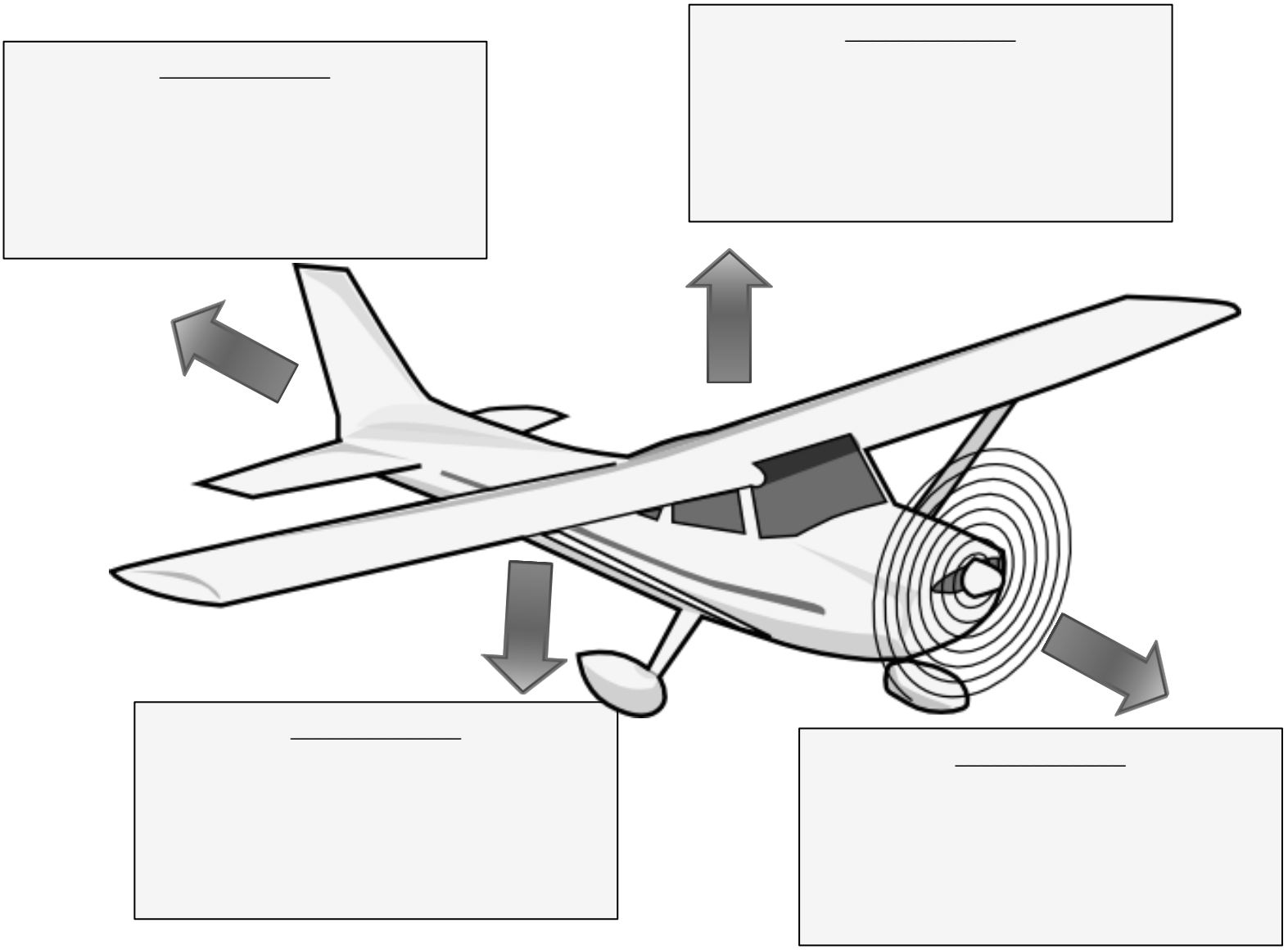
Drag is the force that slows objects down by pulling against thrust with friction or air pressure.

AEROSPACE ENGINEER TRAINING

It's time to begin your training! Find information about aerodynamics. You may include definitions, explanations, examples, or any other interesting facts you want to remember or share with your aerospace engineering team.

AERODYNAMICS NOTES

Research, label, and explain the four forces of flight on the airplane below. Record any other interesting findings on the back of this sheet.



TRY IT YOURSELF

CHALLENGE

How far can you fly a paper airplane?

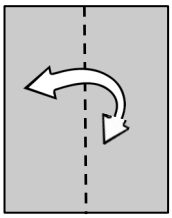
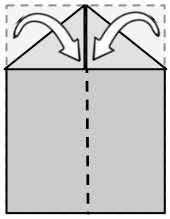
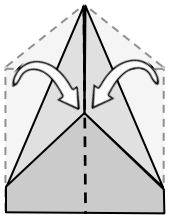
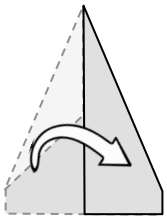
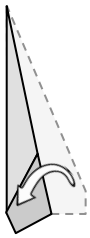
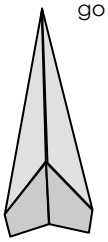
CRITERIA

You must fold a paper airplane out of a piece of copy paper.
Write your name on your airplane before flying it.

CONSTRAINTS

You many only use one piece of copy paper.

TIPS: Follow the instructions provided to fold a basic design or use your own folding method.
Have fun and good luck!

STEP 1 fold and unfold paper in half	**STEP 2** fold in corners	**STEP 3** fold bent corners in to center	**STEP 4** fold in half	**STEP 5** fold wings down	**STEP 6** flip up wings and go fly!
					

REFLECT

What I Liked About My Airplane	**What I Didn't Like About My Airplane**
Next Time, I would…	**Next time, I would not…**

TEAM BRAINSTORM AND PLAN

MANAGER: _____ **AIRCRAFT DESIGNER:** _____

TEST PILOT: _____ **AIRPLANE MECHANIC:** _____

CHALLENGE:

How far can you fly a paper airplane designed and constructed by your aerospace engineering team?

1. **Think:**

What do we think would make our paper airplane fly farther?	What do we think would shorten the flight of our paper airplane?
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

2. **Plan:** Describe the materials you plan to use and why you chose to use them.

Material:	How/Why it will be used:

3. **Decide:** What do we think would be the perfect paper airplane design?

Drawing of Design	I think this design will work well because
	_____
	_____
	_____
	_____
	_____
	_____

4. Write down any more ideas you have to complete the challenge.

_____

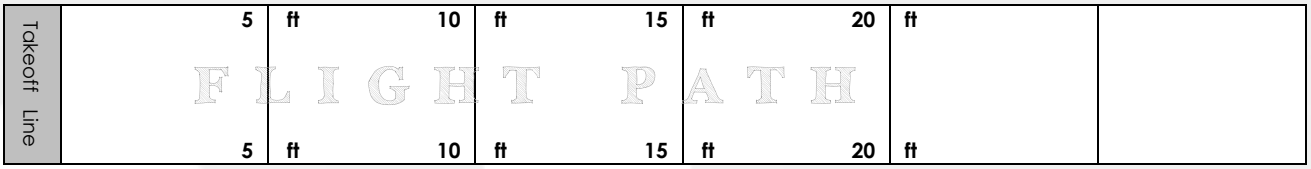
_____

Session 2
Research and Plan

MATERIALS NEEDED:
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips
- masking tape
- measuring sticks or measuring tape
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

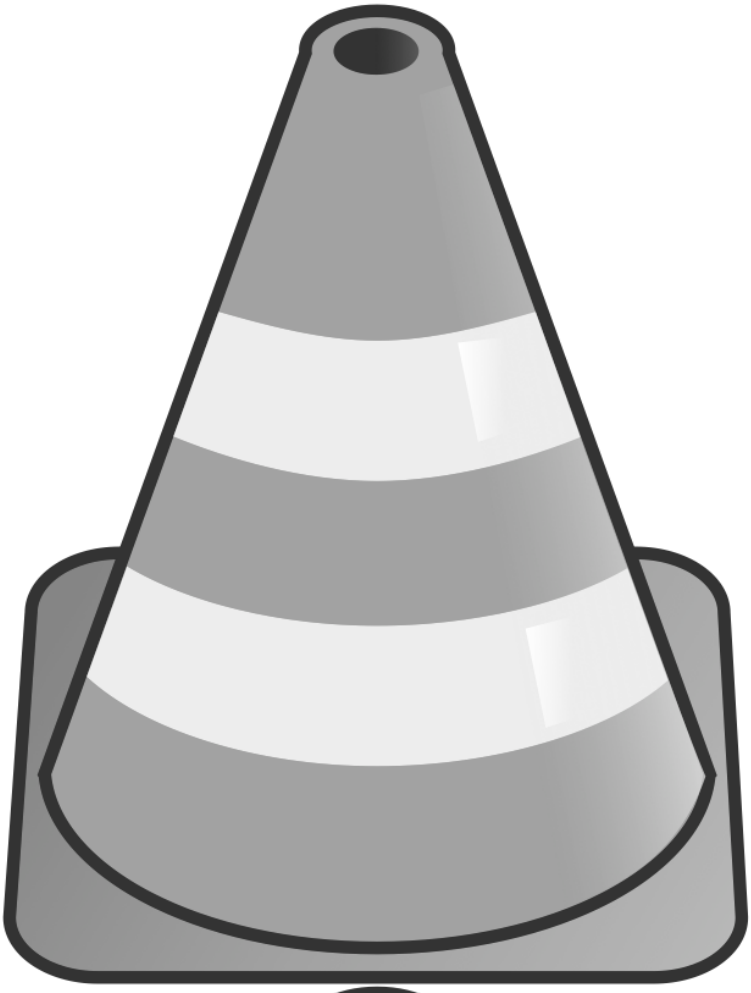
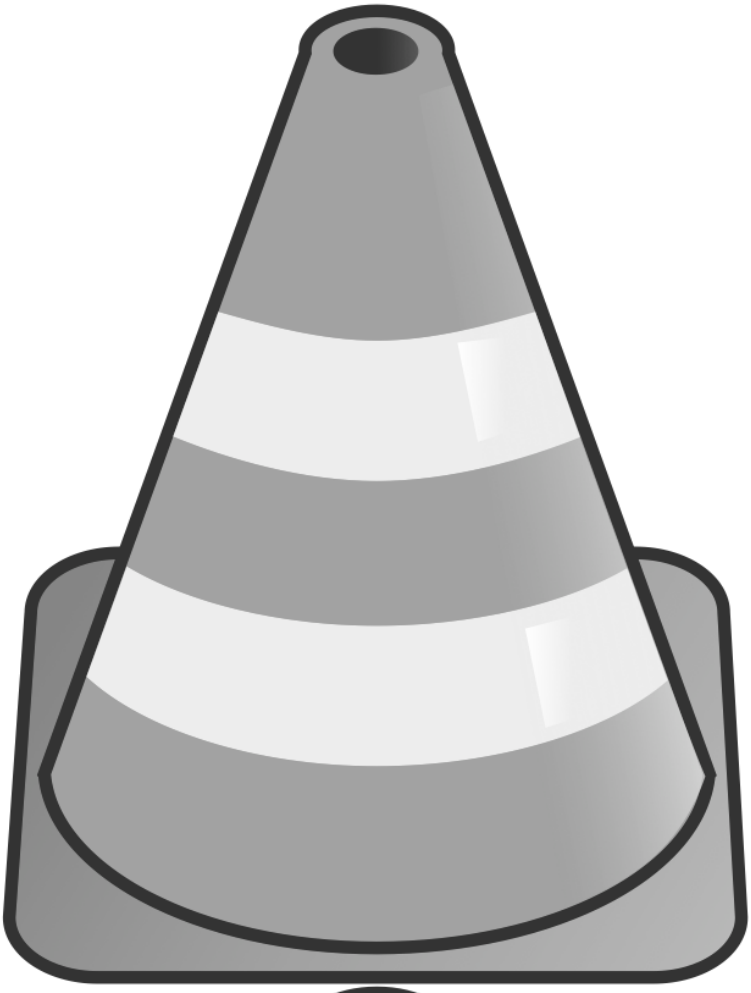
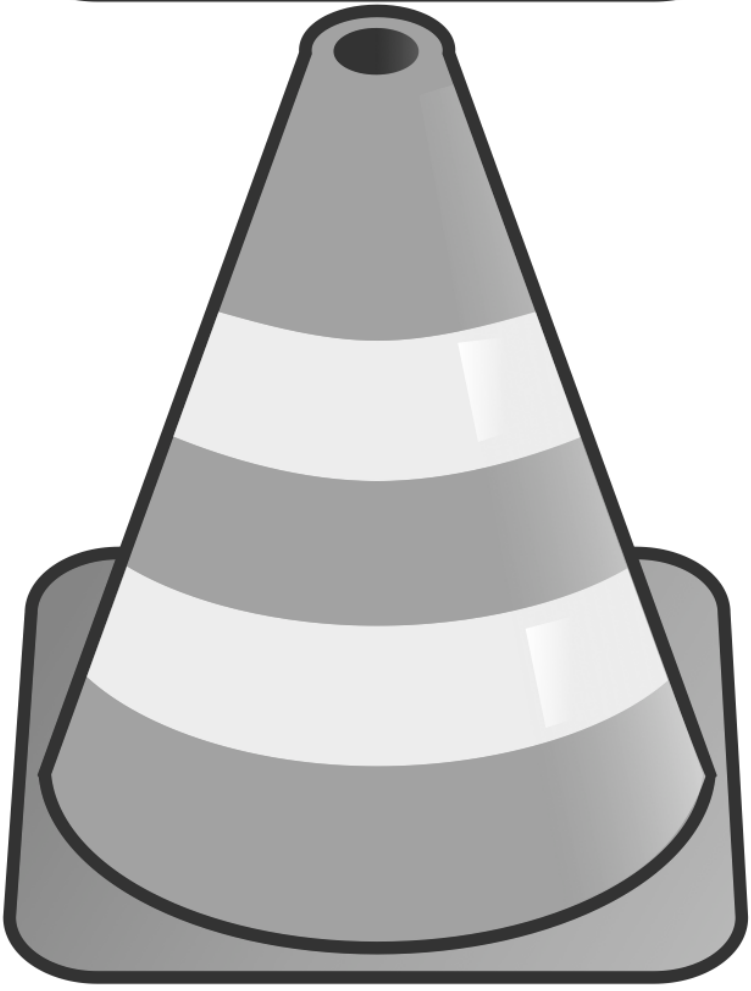
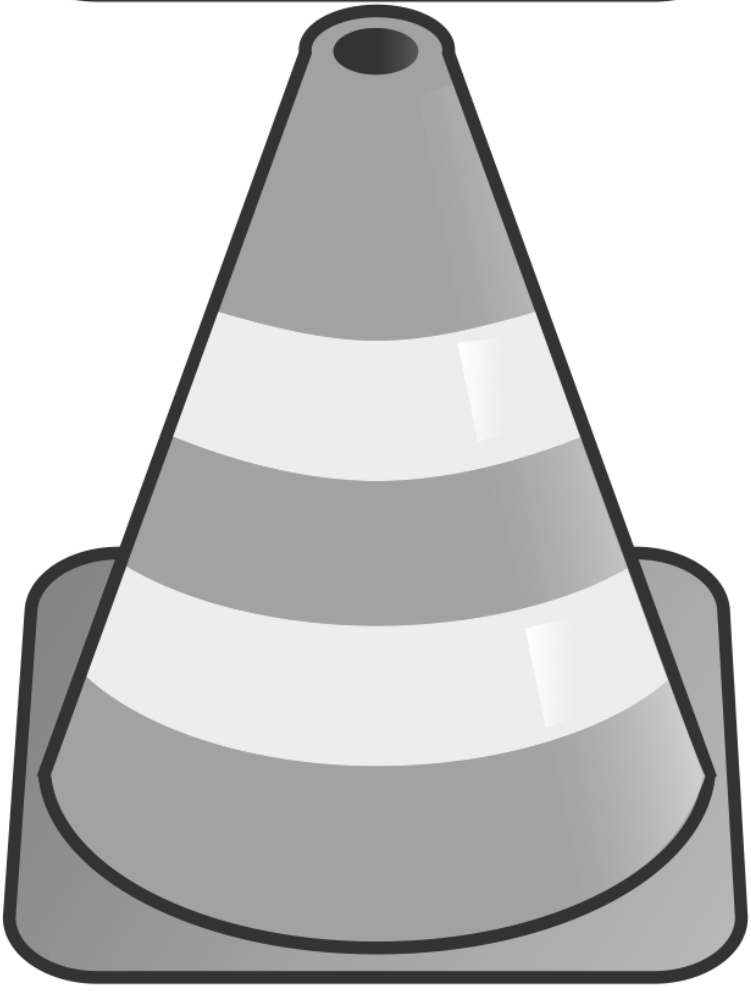
PRINT OUTS NEEDED (all included):
- **Test Fly Zone Posters and Markers (at least one set)**
- **1 Copy per Team:**
  - Thrust Information Card
  - Drag Information Card
  - Weight Information Card
  - Lift Information Card
  - Thrust Report
  - Drag Report
  - Weight Report
  - Lift Report
  - Team Meeting Minutes Sheet 1
  - Team Meeting Minutes Sheet 2

PREPARATIONS:
- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points.
    Use the blank markers to modify marked measurements to best fit your students' needs.



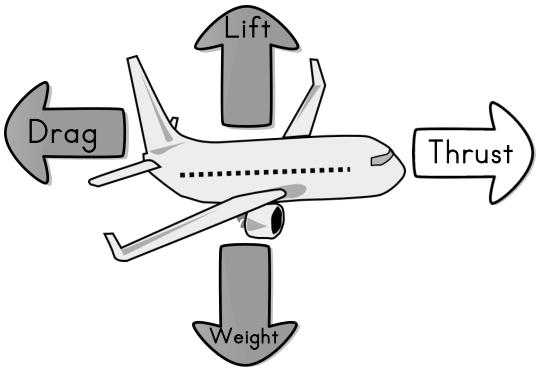
- Copy the print outs listed above as directed.
- Provide safe place to store paper airplanes in progress.

PROCEDURE:
1. Explain the rules of the "Test Fly Zone":
   - Do not cross the flight path (where paper airplanes will be thrown).
   - Test Pilots must stand behind the takeoff line to throw paper airplanes & take turns with other pilots.
   - After paper airplanes land, measure distance from the takeoff line to the *first* touchdown.
2. Explain Team Assignment: Your first team assignment is to explore the four forces of flight. Think about how these forces could improve a paper airplane flight. Each team member will fill out a basic report about an assigned force of flight by researching and experimenting.
   *Optional: Allow students to research additional facts through available websites, books, or articles (see resource list for suggestions).
   - Distribute *Information Cards* and *force report sheets* to assigned engineers.
     Engineering Manager: Research and experiment with weight.
     Aircraft Designer: Research and experiment with lift.
     Airplane Mechanic: Research and experiment with drag.
     Test Pilot: Research and experiment with thrust.
3. *Team Meeting Minutes Sheet 1:* Call engineer teams together to share individual findings. Engineering Managers lead team discussions and record notes on *Team Meeting Minutes Sheet 1*.
4. *Team Meeting Minutes Sheet 2:* Teams reflect, plan, and design a paper airplane to test fly.
5. Create and Test: Airplane Mechanics fold their team paper airplane. Teams may help with folding if needed. Students who are ready may fly their planes in the Test Fly Zone. Teams may adjust and fly their paper airplanes as time allows.

INFORMATION CARD – THRUST

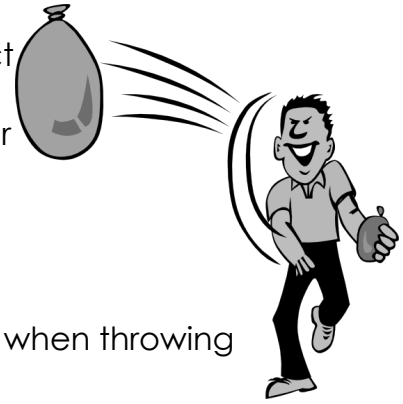
Forces of Flight: Thrust



Thrust is the force that moves a flying object in a direction, usually forward. To move forward, the force of thrust must be stronger than the force of drag.

Most aircraft use an engine to control a propeller, a jet, or a rocket to create thrust. More or less power from the engine will move the aircraft forward faster or slower.

Flying objects without power, such as paper airplanes or water balloons, are supplied with thrust by how the object is thrown. The harder or lighter the throw, the faster or slower the force of thrust will move the object. What other objects have you thrown with more or less thrust?



TRY IT!

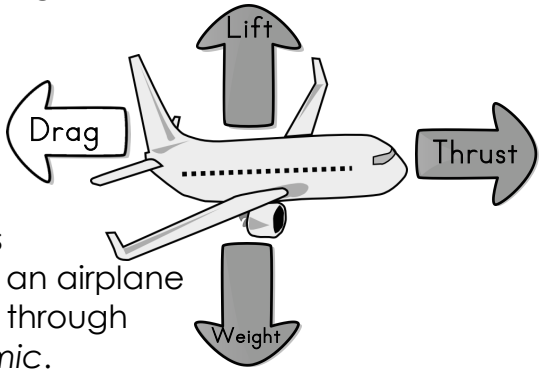
Can you change the force of thrust?

Fold a basic paper airplane. How does the flight change when throwing the airplane with hard or light force?

INFORMATION CARD – DRAG

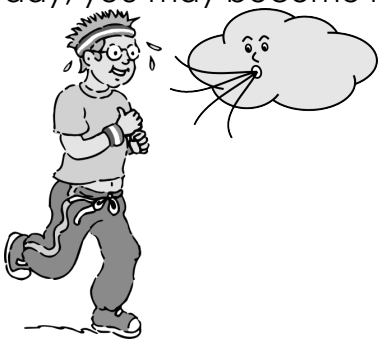
Forces of Flight: Drag

Drag is the force that slows down forward motion. It pulls against thrust. The shape of an object as it moves through the air can create more or less drag.



Airplanes are designed with a shape that moves through the air more easily. The front, or *nose*, of an airplane is narrow to create less drag. Objects that move through the air with little drag are considered *aerodynamic*.

Drag can also be felt on the ground. If you try running into the wind on a breezy day, you may become more tired. The force of drag slows you down, making you work harder. Drag can also be very helpful. Skydivers are thankful for the drag that slows down their parachutes before landing. Where else have you felt drag?



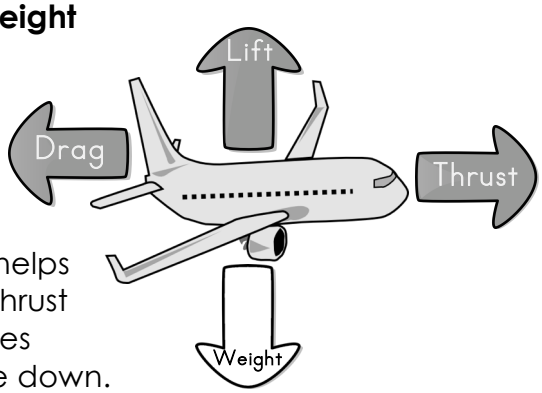
TRY IT!

How do different shapes change the force of drag?

Find a clear area. Throw a crumbled and a flat piece of paper at far as you can. What happened? Why?

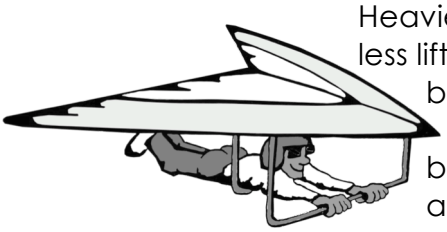
INFORMATION CARD – WEIGHT

Forces of Flight: Weight



Weight is the force of gravity pulling down on an object. The amount of downward pull is equal to how heavy the object is. To fly, the force of weight must be less than the force of lift.

When a pilot is finished flying, the force of weight helps the airplane land. The pilot lowers the amount of thrust and less lift is created. The force of weight becomes stronger than the force of lift, bringing the airplane down.



Heavier planes need more lift. When a plane is lighter it needs less lift to fly. A paper airplane that weighs less will fly farther because there is less gravity pulling it down. Weight also changes how an object flies. Weight must be equally balanced for controlled flight. What flying objects or animals can you think of with balanced weight?

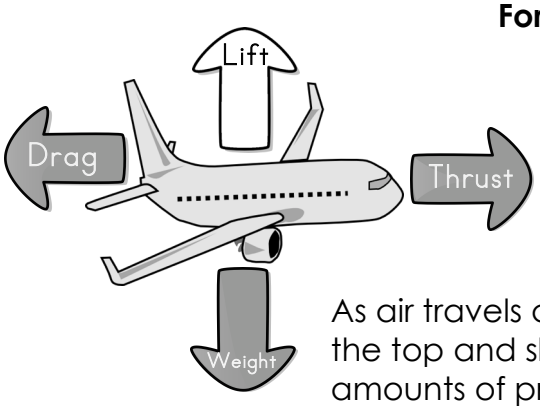
TRY IT!

How does unbalanced weight affect flight?

Fold a basic paper airplane and fly it. Change the weight by attaching a paperclip to one wing. Move the paper clip for each flight. What do you notice?

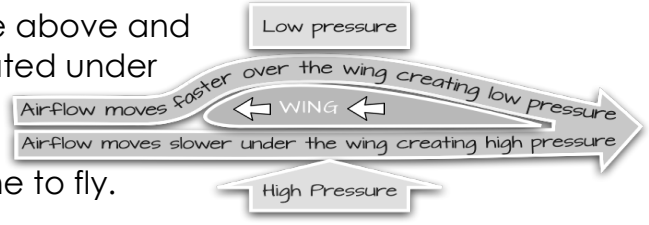
INFORMATION CARD – LIFT

Forces of Flight: Lift



Lift is the force that pulls objects up from the ground. The air moving past the shape and angle of a flying object creates lift. The force of lift must be greater than the force of weight, for an object to fly.

As air travels around an airplane wing, it moves faster over the top and slower under the bottom. This creates different amounts of pressure above and below the wing. The higher pressure created under the wing is stronger than the lower pressure over the wing. This high pressure acts as a lifting force allowing the airplane to fly.



Paper airplanes have a different shaped wing but still use the force of lift. Both the size and angle of the wing can create more or less lift to fly the plane farther.

TRY IT!

How could the angle of the wing change the amount of lift?

Fold and fly a basic paper airplane. Bend the angle of the wings down and then bend them up. Try folding the wings at different angles. What do you notice?

AEROSPACE TEST PILOT

TEST PILOT: _____

TEAM: _____ , _____ , _____

THRUST REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How thrust is applied to actual airplanes:

How thrust can be applied to paper airplanes:

AEROSPACE AIRPLANE MECHANIC

AIRPLANE MECHANIC: _____

TEAM: _____ , _____ , _____

DRAG REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How drag is applied to actual airplanes:

How drag can be applied to paper airplanes:

AEROSPACE ENGINEERING MANAGER

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

WEIGHT REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How weight is applied to actual airplanes:

How weight can be applied to paper airplanes:

AEROSPACE AIRCRAFT DESIGNER

AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

LIFT REPORT

Notes, diagrams, interesting facts…

My experiment taught me…

How lift is applied
to actual airplanes:

How lift can be applied
to paper airplanes:

AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

TEAM MEETING MINUTES SHEET 1

Boeing called! They want to check in on your progress. Collect and record research and ideas from your team about the four forces of flight. Draw arrows between the two pairs of forces that affect each other most in flight.

Weight

Drag

Lift

Thrust

AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

TEAM MEETING MINUTES SHEET 2

Use what you have learned about the four forces of flight to imagine and plan your first team paper airplane design. Agree on a plan and record it below.

Materials Needed

Procedure (Steps to Follow)

Sketch

What We Think Will Happen

Session 3
Create, Test, Reflect

MATERIALS NEEDED:

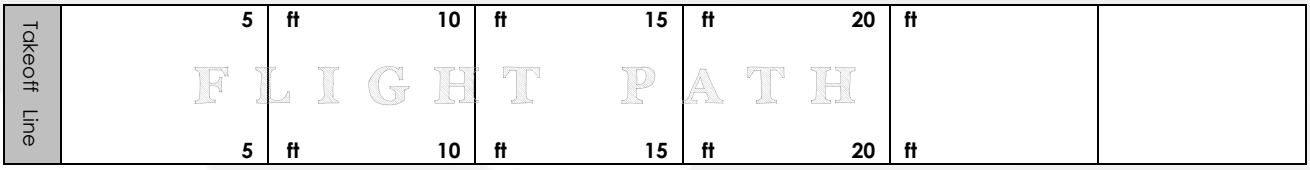
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips, stapler, staples, scissors
- masking tape, clear tape
- measuring sticks or measuring tape
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **Test Fly Zone Posters and Markers (at least one set)** (in Session 2 print outs)
- **1 Copy per Team**
  Engineer Design Process (in Session 1 print outs)
- **2 Copies per Team**
  Aerospace Engineering Manager: Time to Fly
  Aerospace Aircraft Designer: Time to Fly
  Aerospace Airplane Mechanic: Time to Fly
  Aerospace Test Pilot: Time to Fly
  Post Flight Reflection

PREPARATIONS:

- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.
    Use the blank markers to modify marked measurements to best fit your students' needs.



- Set out supplies to be used for airplane modifications: paperclips, stapler, tape, scissors, etc.
- Copy the print outs listed above as directed.
- Provide safe place to store paper airplanes in progress.

PROCEDURE:

1. Explain Team Assignment: Today you will work together with your engineering team to create and test fly your designs. Each of you will have a different job while working through the Engineering Design Process. (Briefly explain each job assignment. Guide students through the process as needed. Monitor team progress.)
   - Distribute *Engineering Design Process* and *Time to Fly* worksheet assignments.

Engineering Manager	Leads the team through the process by following steps on the instructions sheet; Keeps team on task and helps team members.
Aircraft Designer	Draws a sketch of the paper airplane the team wants to build; Lists materials needed and records predictions of how it will fly.
Airplane Mechanic	Folds paper airplanes; Describes how the paper airplane was constructed; Records reflections on how the plane flew.
Test Pilot	Throws paper airplane 3 times; Records the measured distances and how the plane flew; Fills in a bar graph with intervals appropriate for the results.

2. After reflection and discussion, teams may begin the design process again (until the team is satisfied…or as time allows).
3. Post Flight Reflection: Teams reflect on flights and how they wish to improve their designs.

TIME TO FLY!
AEROSPACE ENGINEERING MANAGER

Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

PREPARING FOR FLIGHT
INSTRUCTIONS FOR AEROSPACE ENGINEER TEAM

1. Ask team: What should be included in the design of our paper airplane? Agree on a design everyone is happy with.
2. Ask the **Aircraft Designer** to sketch and describe the airplane being created on the *Time to Fly Aircraft Designer* planning worksheet. Make sure the team approves the design.
3. Ask the **Airplane Mechanic** to fold the paper airplane while team looks on to check that the folds match the design. Fill in the *create* section of the Airplane Mechanic's *Time to Fly* worksheet. Once the team is satisfied, take your plane to the test flight area.
4. Ask the **Aircraft Designer** and **Airplane Mechanic** to stand along either side of the test flight area to spot where the airplane touches down. (If the floor is slick enough to allow your plane to glide after landing, measure from where the plane *first* touches down.) **If** the plane goes out of bounds, the flight is not measured and must be thrown again.
5. Remind your **Test Pilot** to stand behind the Takeoff Line and try to throw with the same force each time. After the test pilot throws the plane, ask the Aircraft Designer and the Airplane Mechanic to measure from the Takeoff Line to the spot where the airplane first touched down. The team should assist with measuring. The test pilot must record the distance of the flight to the nearest ¼ inch on the recording sheet.
6. Repeat step 5 two more times.
7. Next fill in the *improve* section of the Test Pilot's *Time to Fly* worksheet. Reflect and fill in the *improve* section of the Airplane Mechanic's *Time to Fly* worksheet.
8. Next, repeat steps 1-6 with a new or modified design using new worksheets and reflect on it again. Continue the Engineering Design Process until your team is satisfied with a design.

TIME TO FLY!
AEROSPACE AIRCRAFT DESIGNER

Challenge
How far can you fly a paper airplane?

AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

PLAN
Draw a diagram. Make a list of materials you will need and steps you will take.

This is a diagram of our paper airplane!

Materials Needed to Construct this Design

-
-
-
-

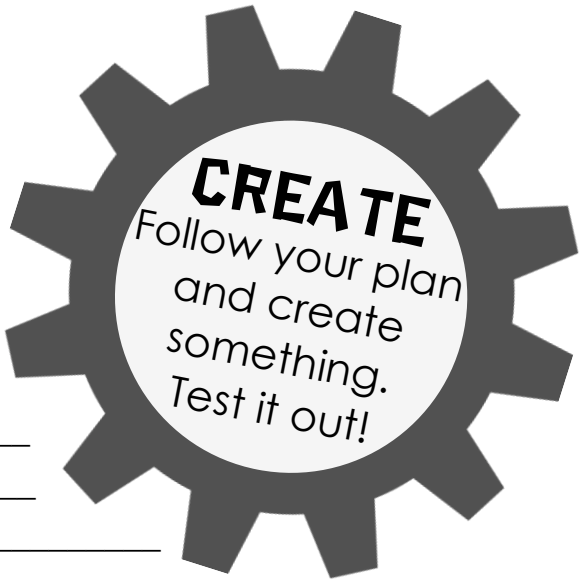
When test flying, this is what we think will happen:

TIME TO FLY!
AEROSPACE AIRPLANE MECHANIC

Challenge
How far can you fly a paper airplane?

AIRPLANE MECHANIC: _____

TEAM: _____ , _____ , _____



While constructing our paper airplane,

☐ I was able to follow our plan!

☐ I was not able to follow our plan because

_____

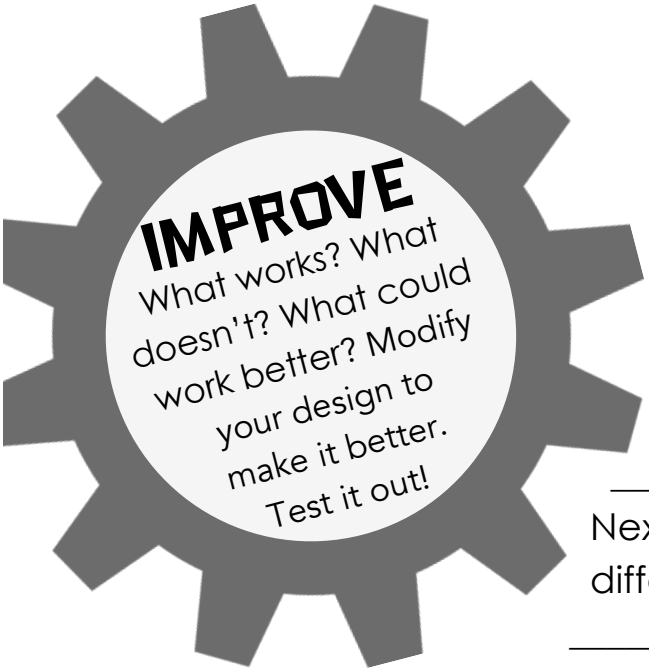
_____

_____

Instead, we decided to _____

_____

_____



REFLECT:

After the test flights, we thought _____

_____

_____

_____

We decided to _____

_____

_____

Next time, we will construct our paper airplane differently by (describe improvements)

_____

_____

_____

TIME TO FLY!
AEROSPACE TEST PILOT

Challenge
How far can you fly a paper airplane?

TEST PILOT: _____

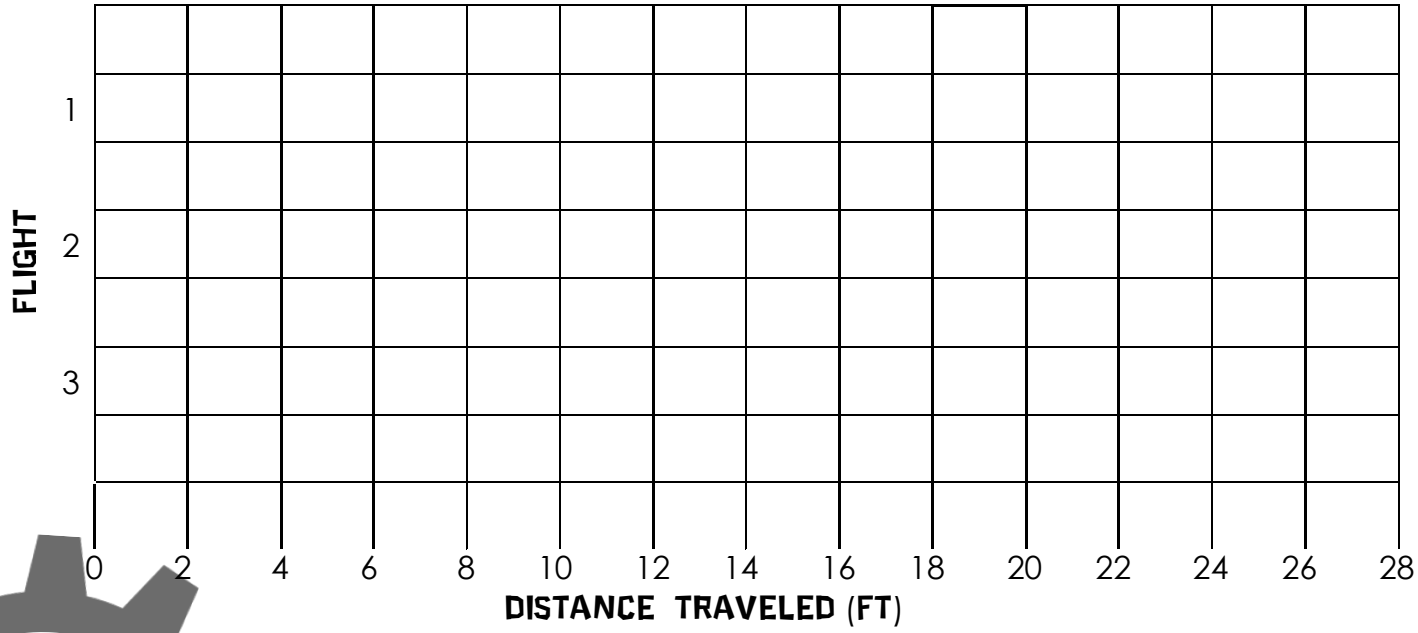
TEAM: _____ , _____ , _____

Time to test fly! Fly your paper airplane three times using the same force. Measure the distance it flew from the Takeoff Line to touch down. Record each measurement in feet and inches to the nearest ¼ inch. Record any unusual or interesting things that happen during each flight.

CREATE
Follow your plan and create something. Test it out!

	Distance Traveled	Notes
1st Flight		
2nd Flight		
3rd Flight		

Display this data on the bar graph below. Round each measurement to the nearest ½ foot to display on the bar graph. Make sure your team agrees that the graph is correct.



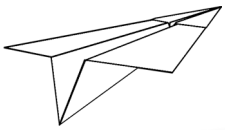
IMPROVE
What works? What doesn't? What could work better? Modify your design to make it better.

What was the distance of the farthest flight? _____

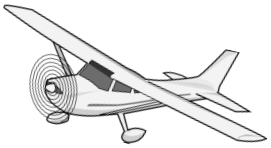
Why was this flight more successful?

_____

_____



POST-FLIGHT REFLECTION



Challenge
How far can you fly a paper airplane?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

What happened? Describe your results.

_____

_____

_____

Are you happy with your design?

Yes, because…

_____

_____

_____

_____

_____

Not yet, because…

_____

_____

_____

_____

_____

Did you try different solutions? Why or why not?

_____

_____

_____

_____

_____

_____

_____

_____

How did you decide which solution was best?

_____

_____

_____

_____

_____

_____

_____

_____

What will you try differently next time?

_____

_____

_____

_____

_____

_____

_____

_____

What did you learn?

_____

_____

_____

_____

_____

Session 4
Improve, Test, Reflect

MATERIALS NEEDED:

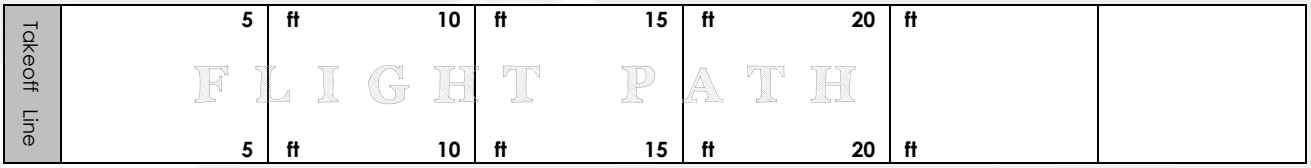
- 8.5 X 11" copy paper for airplane folding
- variety of paper (different colors, sizes, and weights) for airplane folding
- paper clips, stapler, staples, scissors
- masking tape, clear tape
- measuring sticks or measuring tape
- stickers, markers, colored pencils, crayons, other decorating materials
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **Test Fly Zone Posters and Markers (at least one set)** (in Session 2 print outs)
- **1 Copy per Team**
  Engineer Design Process (in Session 1 print outs)
  Ask and Imagine: Aerospace Engineering Manager
  Ask and Imagine: Aerospace Aircraft Designer
  Ask and Imagine: Aerospace Airplane Mechanic
  Ask and Imagine: Aerospace Test Pilot
  Final Modifications Log

PREPARATIONS:

- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.



- Set out supplies for airplane modifications: variety of paper, paperclips, stapler, tape, scissors, etc.
- Copy the print outs listed above as directed
- Provide safe place to store paper airplanes in progress

PROCEDURE:

1. Explain Team Assignment: Boeing has sent your next team assignment. Your challenge is to find an even better way to design and construct your paper airplane. Each team member will discover techniques that may be used to modify or redesign your paper airplanes. Today you will begin with the *Ask* and *Imagine* steps of the Engineering Design Process. (Briefly explain each job assignment. Guide students through the process as needed. Monitor progress.)
   - Distribute *Engineering Design Process* and *Ask and Imagine* worksheet assignments.

Engineering Manager	Change the forces of flight in new ways on a paper airplane.
Aircraft Designer	Fold and fly a variety of paper airplane designs.
Airplane Mechanic	Experiment with paper airplane modifications to change flight.
Test Pilot	Explore how different building materials can change flight.

2. *Final Modifications Log*: You may use your paper airplane from Session 3 and improve it with what you learned today or start fresh with a new paper airplane. Follow the Engineering Design Process to create your final paper airplane. Use the parts of the process needed until you and your team are satisfied with your design. Use the *Final Modifications Log* to record distances, changes made, and any additional notes as you complete your design.
3. Final Design: Decorate and name your final airplane. Be creative and artistic! Test-fly your final airplane to be sure the decorations did not alter the flight.

ASK & IMAGINE
AEROSPACE ENGINEERING MANAGER

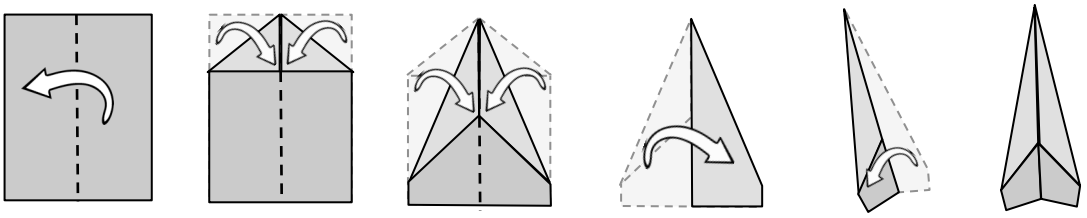
ASK
How can I change the forces of flight to make a paper airplane fly differently?

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

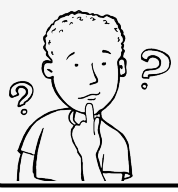
CHALLENGE:

Consider how the four forces of flight work together and affect each other. Most airplanes, both real and paper, need some adjusting for the best flight possible. Fold and fly a paper airplane and try to find the perfect balance of the four forces of flight. Use a simple paper airplane design, such as the one below.



Force	Hints	Affect on Flight	
		What I Tried	What Happened
Thrust	Try throwing your plane in different ways.		
Drag	Try folding the tail up different amounts.		
Lift	Try folding the wings bigger or smaller.		
Weight	Try adding or taking away weight.		

Consider the forces that would affect the distance of flight. What will you try to make your team's paper airplane fly the farthest?



IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

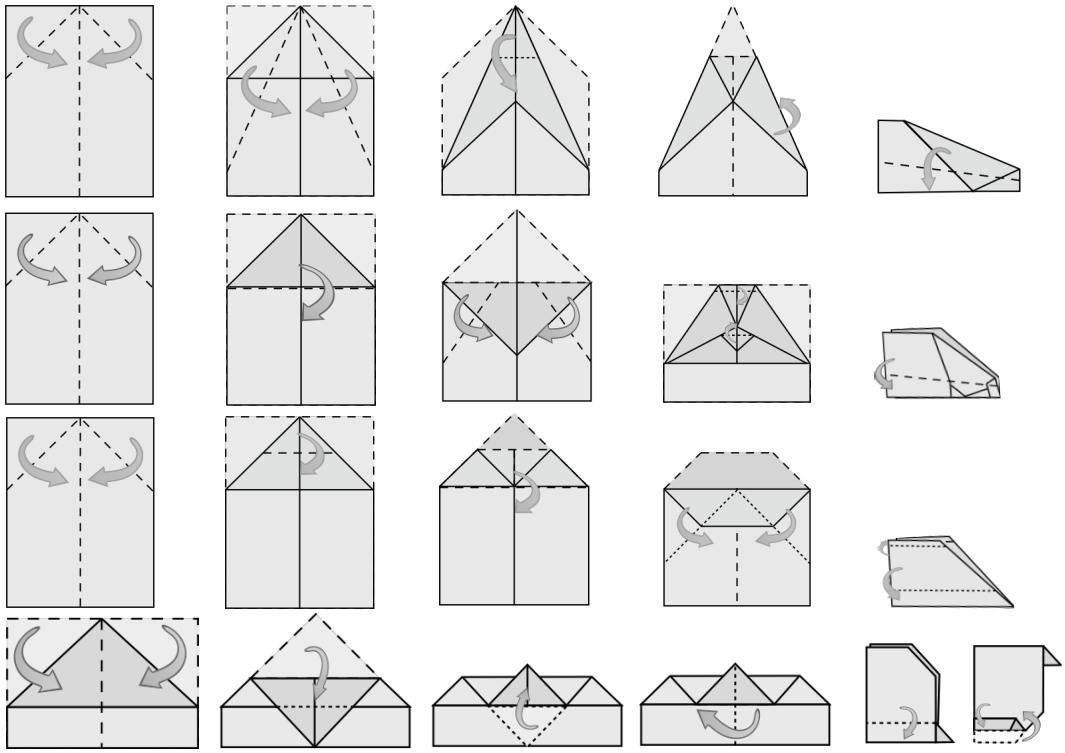
ASK & IMAGINE
AEROSPACE AIRCRAFT DESIGNER

ASK
How have others created successful designs? What are some design ideas and how do they fly?

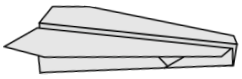
AIRCRAFT DESIGNER: _____

TEAM: _____ , _____ , _____

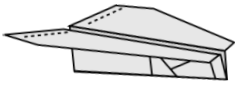
CHALLENGE: Consider successful paper airplane designs and try them out. Choose at least 2 paper airplane designs to fold and fly. Here are some samples:



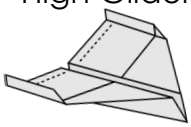
Glider



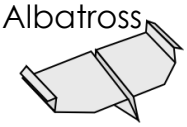
The Eagle



High Glider



Albatross



Name & Sketch	Distance	Features Causing Farther Flight

What features can you try on your team's paper airplane to make it fly the farthest?

ASK & IMAGINE
AEROSPACE AIRPLANE MECHANIC

ASK
How have others modified designs? What are some modifications and how do they affect flight?

AERONAUTIC MECHANIC: _____

TEAM: _____ , _____ , _____

CHALLENGE: Most airplanes, paper and real, need some adjusting to allow for the best flight possible. Experiment with a basic paper airplane to see how different modifications affect the flight. Below are some flying tips others have tried. Add your own tips too!

Flying Tip: Bend the tail tabs up or down to straighten flight.

Flying Tip: Symmetry! Make sure each side is the same.

Flying Tip: Place a paperclip on the bottom. Slide it back or forward.

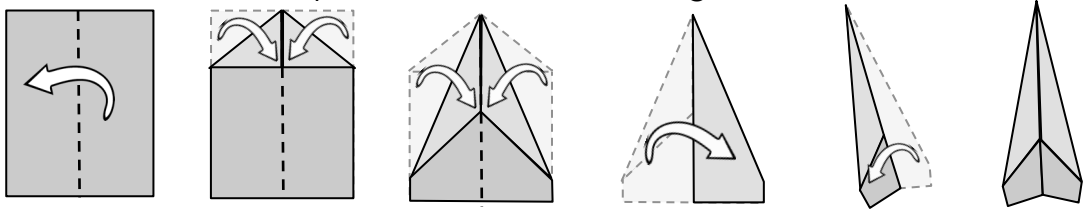
Flying Tip: Make tight, crisp folds at every step.

Flying Tip: Bend the wing angles slightly up.

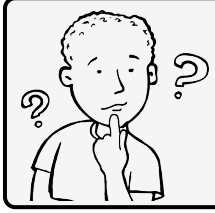
Flying Tip:

Flying Tip:

Hint: Throw the same way and use the same design each time such as this:



Describe Original Flight	Modification	Affect on Flight



Which modifications are you most likely to try to make your team's paper airplane fly farther? Why?

IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

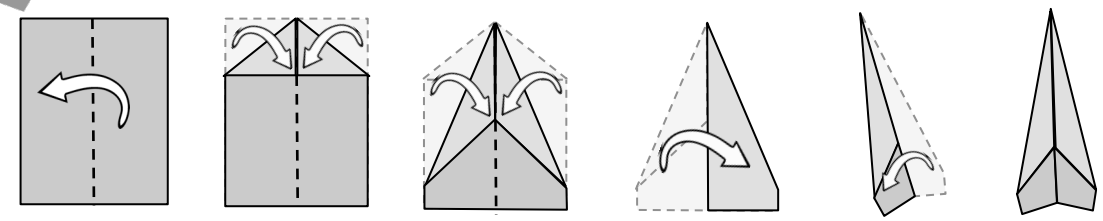
ASK & IMAGINE
AEROSPACE TEST PILOT

ASK
What types of paper might work best? What size or shape paper would fly farthest?

TEST PILOT: _____

TEAM: _____ , _____ , _____

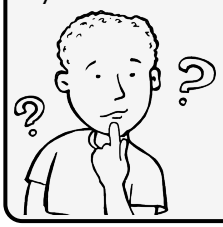
CHALLENGE: Do you think paper airplanes would fly different if they were made out of different types of paper or differently sized paper? Explore how different building materials can affect flight. Use the same paper airplane design, such as the one below, to best compare different materials or shaped paper.



When trying different sized paper, you may need to modify the folds to work.
Paper ideas: loose leaf notebook paper, card stock, construction paper, newspaper, etc.

Materials Used/ Paper Shape	Affect on Flight

Consider the paper choices or paper shapes you could use in constructing your paper airplane. What choices might make your team's paper airplane fly farther? Why do you think so?



IMAGINE
What are some solutions? Brainstorm ideas. Choose the best one.

Challenge
How far can you fly a paper airplane?

FINAL PAPER AIRPLANE DESIGN

ENGINEERING MANAGER: _____

TEAM: _____ , _____ , _____

Improve your paper airplane from Session 3 or start fresh with a new paper airplane. Follow the Engineering Design Process to create your final paper airplane until all team members are satisfied. Record distances, changes made, and any additional notes as you complete your design. Decorate and name your final airplane. Be creative and artistic! Test-fly your final airplane to be sure the decorations did not alter the flight.

You're finished when all team members are satisfied with the flight. Name and decorate your final paper airplane!

FINAL MODIFICATIONS LOG

FLIGHT 1
distance: _____

FLIGHT 2
distance: _____

FLIGHT 3
distance: _____

FLIGHT 4
distance: _____

FLIGHT 5
distance: _____

Session 5
Final Presentation

MATERIALS NEEDED:

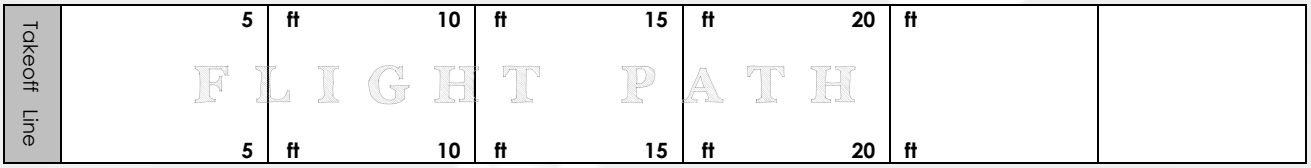
- poster board or poster paper for each team
- markers or any other art supplies available to create final presentation poster
- *optional: books/pictures/articles about airplanes, history of flight, paper airplanes, aerodynamics, aerospace engineering (see resource list for suggestions)
- *optional: computers/iPads with internet access (see resource list for suggestions)

PRINT OUTS NEEDED (all included):

- **Test Fly Zone Posters and Markers (at least one set)**
- **Class Set:**
  Final Presentation Instructions
  Scoring Rubric
  Student Evaluation Form
- **1 Copy per Team:**
  Presentation Planner

PREPARATIONS:

- Set up at least one "Test Fly Zone" in a large unobstructed area:
  - Display copies of *Test Fly Zone* posters to mark the area.
  - Place masking tape on the floor for students to stand behind when throwing airplanes.
  - Measure and tape provided markers at the 5, 10, 15, and 20 foot marks to provide a throwing line (Takeoff Line) and measuring points. Set out measuring sticks or measuring tape.



- Set out poster boards and art supplies available for students to create final presentations.
- Provide a clear area for team presentations.
- Copy the print outs listed above as directed.
- Complete *Teacher Observation Sheet* to assist with student final scores.

PROCEDURE:

1. Distribute *Final Presentation Instructions* and *Scoring Rubric*: Read through and answer any questions on *Final Presentation Instructions* and *Scoring Rubric*.
2. Preparation Time: Distribute a *Presentation* Planner to each team. Allow teams time to plan and prepare for final presentations. You many want to set a time limit. Monitor progress and guide students to stay on track.
3. Presentations: As each team presents, score students on individual rubrics (consider notes from *Teacher Observation Sheet* for contributions and responsibilities). Evaluate students on individual and team efforts according to the provided rubric.
4. *Optional *Student Evaluation Form:* Students fill out the *Student Evaluation Form* to reflect on using the Engineering Design Process while working in a cooperative team.
5. *Optional *Extensions:* Additional learning opportunities and activity ideas are included.

FINAL PRESENTATION INSTRUCTIONS

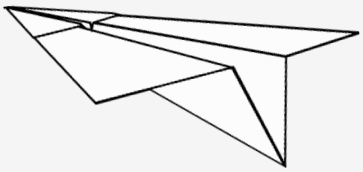
You made it! Now it's time to share your results with your fellow aerospace engineer teams and create a final presentation for Boeing!

Each team must present their final conclusions on a poster and fly their final paper airplanes on one demonstration flight. Look back through any team notes together to fill in the *results, results process, and conclusions*.

Presentations must include:

1. Results:
   Describe your paper airplane and how far it went when tested.

2. Results Process:
   First, we tried _____. _____ happened.
   So we _____. ____happened.
   Finally, when we ____, ____ happened.



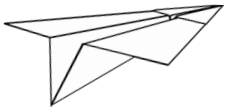
3. Conclusions:
   We learned _____

4. Demonstration Flight:
   Share throwing technique used and fly paper airplane on one demonstration flight.

Use the *Presentation Planner* sheet to organize your presentation. Make sure to:

- display results and conclusions in an organized presentable way on your poster.
- name and decorate your paper airplane for the demonstration flight.
- plan what every team member will say (everyone must speak).
- PRACTICE before presenting.

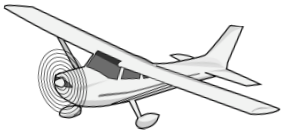
HINT: Compare your presentation to the scoring rubric to be sure it is complete.



Name _____

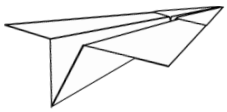
SCORING RUBRIC

This is how your work will be evaluated.

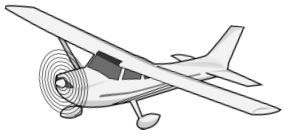


	Exemplary 4	Accomplished 3	In Training 2	Novice 1	Score
Engineer Contributions					
Researches and Records Information	collects and records information beyond the basics – relates to topic	collects and records basic information – most relates to topic	collects and records minimal information – some relates to topic	does not collect or record any information related to topic	
Shares Information	shares a great deal of information – all relates to topic	shares some basic information – most relates to topic	shares very little information – some relates to topic	does not share any information related to topic	
Engineer Team Responsibilities					
Fulfills Assigned Job	performs all duties of assigned job	performs nearly all duties of assigned job	performs very little duties of assigned job	does not perform duties of assigned job	
Participates in Presentation	contributes extensively to presentation – all information is relevant	contributes some information during presentation – most is relevant	contributes little or irrelevant information during presentation	does not contribute during presentation	
Teamwork	always does the assigned work without having to be reminded	usually does the assigned work – rarely needs reminding	rarely does the assigned work – often needs reminding	always relies on others to do the work	
Quality of Paper Airplane and Final Presentation					
Attention to Detail and Creativity	presentation was neat, well organized and showed creativity	presentation was neat and well organized	presentation was neat but not well organized	presentation was messy and not well organized	
Content Required is Complete	presentation includes detailed results, result process, and conclusion	presentation includes results, result process, and conclusion	presentation includes 2 out of 3 requirements (results, result process, conclusion)	presentation includes 0-1 of the requirements (results, result process, conclusion)	
Distance of Flight	20 feet or more	10-19 feet	5-9 feet	0 feet	
Measurement of Flight	accurately and precisely measures and records data	measurements are usually accurate and recorded	measurements are sometimes accurate and recorded	measurements are not accurate and/or recorded	
Uses Aerodynamics Principles	plane indicates a clear and accurate understanding of aerodynamic principles in construction and modifications	plane indicates a fair understanding of aerodynamic principles in construction and modifications	plane indicates a minimal understanding of aerodynamic principles in construction and modifications	plane indicates no understanding of aerodynamic principles in construction and modifications	

TOTAL ___ ÷ 10 = FINAL SCORE



PRESENTATION PLANNER



Decide what information each team member will share. Plan the order of speakers. List any materials that need to be created or speeches that need to be prepared. PRACTICE!

Engineering Manager	Aircraft Designer
Airplane Mechanic	Test Pilot

STUDENT EVALUATION FORM

Name _____

Team Members: _____ , _____ , _____

Being able to work with a team is important for success. How did you do? Circle the best response.

1. When I knew an answer or had an idea, I shared it.

   Always Sometimes Never

2. I encouraged others in my group.

   Always Sometimes Never

3. I felt encouraged by people in my group.

   Always Sometimes Never

4. When my answer was different than others, I tried to find out why.

   Always Sometimes Never

5. When I did not understand something, I asked my group for help.

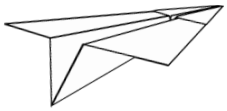
   Always Sometimes Never

6. If another group member did not understand something, I helped them understand.

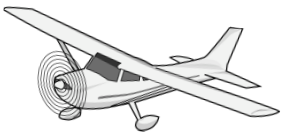
   Always Sometimes Never

7.

Write what you could do to make your group better.	
Did you enjoy using the Engineering Design Process?	What was most difficult? Why?
What did you learn?	



PAPER AIRPLANE CHALLENGE EXTENSION ACTIVITIES



Can't get enough?

TRY THIS!
Line up all the final paper airplanes from the shortest to the longest flights. Compare the design choices. What aerodynamic features do you think were responsible for the different flight distances?

TRY THIS!
Learn from the expert himself! Read about "The Paper Airplane Guy" who broke the world record for the farthest flying paper airplane on February 26, 2012. Find out how far his plane flew, which paper airplane he used, and watch how he did it on his website www.thepaperairplaneguy.com.

TRY THIS!
Design an airplane out of materials other than paper. If you were not limited to paper for a main material, what would you use to fly an aerodynamic aircraft that flies even farther than a paper airplane? Try it!

TRY THIS!
Are you interested in aerospace engineering? Explore what jobs are currently available for aerospace engineers at www.engineerjobs.com/jobs/aerospace-engineering. List the jobs you would like to do.

TRY THIS!
Research famous aerospace engineers. What are they most well known for? What do they do or what did they do? Where do they work today?