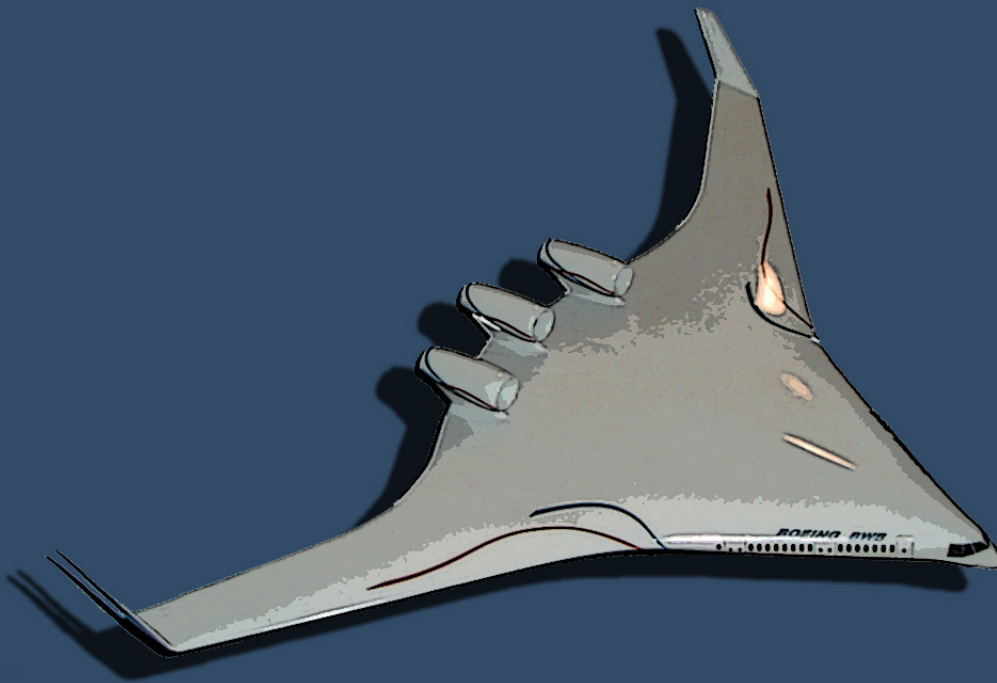


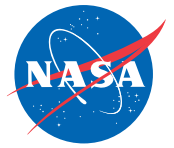
National Aeronautics and Space Administration



# Flying Circus

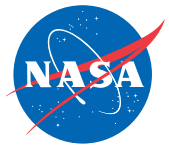
A classroom design challenge for students





## Table of Contents

Lesson Objectives, Concepts, and Standards	2
Materials List	3
Background	4
The Challenge	5
Mini Evaluations	7
Extend & Evaluate	9
Teacher Transparencies	10
Student Worksheets	12
Rubrics	15



# Flying Circus!



*Students apply their knowledge of the four forces and engineering design process to create rubber band powered aircraft. Aircraft are evaluated for their ability to stay in the air longest or carry the most passengers.*

**Grades: 5–8**

**Time: 2–3 hours**

## Objectives

Students will demonstrate mastery of:

- application of the four forces of flight to aircraft design.
- how to apply the engineering design process.
- the importance of reproducibility and reliability.
- experimentation as a means of learning from non-successful trials.

## Main Concept

Engineers use the engineering and the scientific design and experimentation processes when creating new aircraft technologies.

## Education Standards

### California Science Content Standards

Grade 5

- Investigation and Experimentation: 6e, 6f, 6g, 6h

Grade 6

- Investigation and Experimentation: 6b

Grade 7

- Investigation and Experimentation: 7a

Grade 8

- Forces: 2a, 2c, 2d, 2e
- Investigation and Experimentation: 9a, 9b, 9c, 9e, 9f

### National Science Education Standards

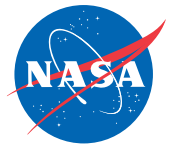
Grades 5–8

Science and Technology, Content Standard E

- Abilities of Technological Design: a, b, c, d, e
- Understanding About Science and Technology: d, e

Physical Science, Content Standard B

- Motions and Forces: b, c



## ~ Materials List ~

- **Hang Time Mission** overhead transparency (with copies for the students, p.10)
- **Passenger Capacity Mission** overhead transparency (with copies for the students, p.11)

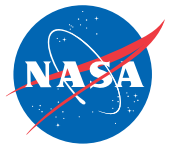
Each team of 2–3 students will need:

- Fuselage and propeller materials, including: (see box below for sources)
  - Propeller assembly
  - Fuselage stick
  - Landing gear
  - Vertical stabilizer
  - Rubber motor material or rubber bands (size #117B)

*\* Do not include horizontal stabilizer or wings \**
- Various materials to create wings such as:
  - Balsa wood
  - Tissue paper
  - Foam sheets/plates/trays
  - Cardstock or file folder material
  - Tongue depressors
  - Popsicle sticks
  - Other craft items as available
- 10 pennies
- Scissors
- Glue
- Stopwatch for hang time measurements
- Clear tape
- Aircraft Design and Evaluation sheets (pp.12–13; Multiple copies per team for each tested design)
- Final Aircraft Design Solution sheet (p.14)
- Rubric for Hang Time Mission (p.15)
- Rubric for Passenger Capacity Mission (p.16)
- Rubric for Final Design Presentation (p.17)

Possible sources for the rubber band powered propeller airplane kits and parts include:

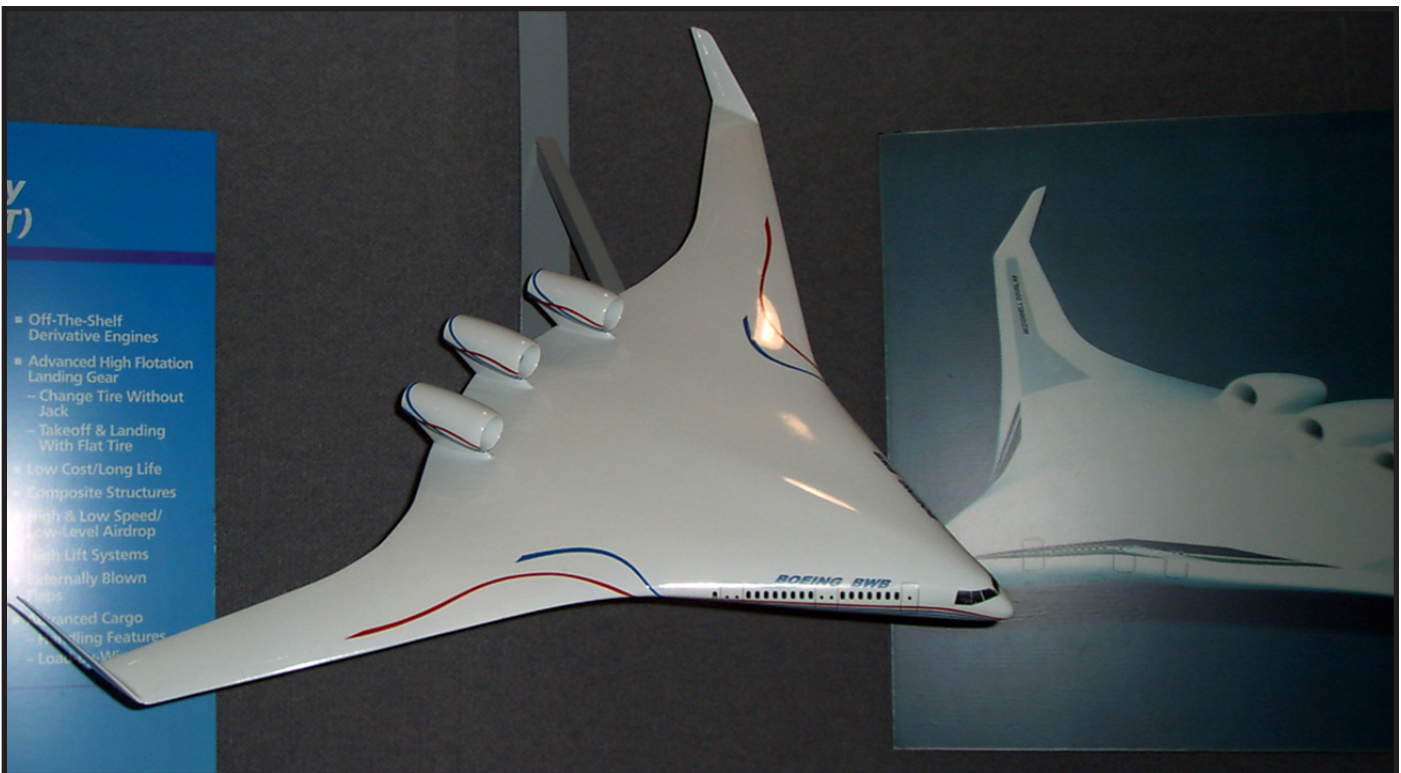
- Paul K. Guillow <http://www.guillow.com>
- Midwest Products <http://www.midwestproducts.com>
- Pitsco <http://www.pitsco.com>
- Quest Aerospace <http://www.questaerospace.com>

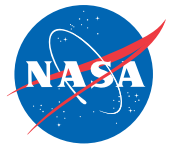


## Background

This challenge brings together all that students have learned about the forces of flight, the experimentation and investigation process, and the engineering design process. The focus of this activity will be wing design. Share NASA's work on researching future aircraft designs with students as they work on the design process.

NASA Dryden is a leader in the creation of the next generation of military and civilian aircraft. NASA scientists and engineers have created a new aircraft that utilizes what is called a "blended body design". NASA is interested in the potential benefits of the aircraft, which include increased volume for carrying capacity, efficient aerodynamics for reduced fuel burn, and, possibly, significant reductions in noise due to propulsion integration options. More information about the blended body design can be found at: [http://www.aeronautics.nasa.gov/releases/07\\_26\\_07\\_release.htm](http://www.aeronautics.nasa.gov/releases/07_26_07_release.htm)





## The Challenge

### 1. Introduce the missions.

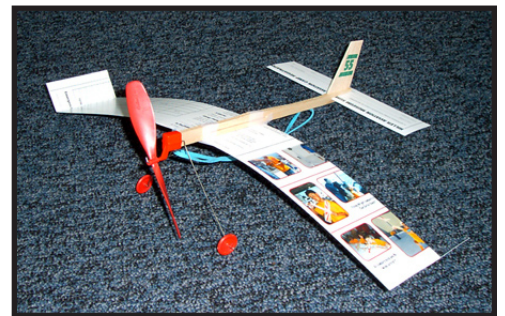
- Divide students into groups of 2 or 3.
- Hand out two mission sheets to the students: one for *Hang Time* (p.12) and the other for *Passenger Capacity* (p.13).
- Set the stage:

*NASA needs your help in the design of two new aircraft. Over the next few days, you and your team will be engineers for NASA, and you will select one of these two challenges to complete. Engineers design solutions to real-life problems. Engineers also have criteria they have to meet, which are like rules that they must follow. Here are your criteria.*

- Go over the criteria of the *Hang Time Mission* overhead transparency (p.10) and then the *Passenger Capacity Mission* overhead transparency (p.11) with the students.

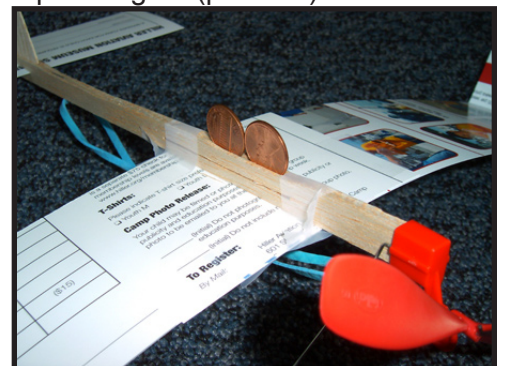
#### Hang Time Mission

- Your job is to design an aircraft that stays in the air the longest when launched from your hand.
- You must be in a design team of 2 or 3 people.
- Each person must contribute to the team effort.
- Your team must build a rubber band powered airplane.
- Your team may only use the materials provided by the teacher.
- You must be able to explain your design decisions and how the design works in terms of the forces of flight.

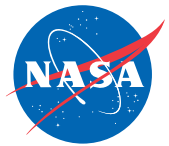


#### Passenger Capacity Mission

- Your job is to design an aircraft that can take off carrying the most passengers (pennies).
- You must be in a design team of 2 or 3 people.
- Each person must contribute to the team effort.
- Your team must build a rubber band powered airplane.
- Your team may only use the materials provided by the teacher.
- You must be able to explain your design decisions and how the design works in terms of the forces of flight.







2. Introduce the final evaluation criteria.

- Hand out the 3 grading rubrics to the students (pp.15–17).
- Say:

*This activity is the culmination of our studies into the science of aeronautics and aeronautical engineering. Your team will be evaluated on a set of criteria. I want to go over these criteria with you so that you will know exactly what you must do to succeed. If you were a scientist or engineer with NASA or a large aeronautics firm, there would be similar criteria used to evaluate the work that your team created. The results of these evaluations would determine if your team would continue the project.*

- Go over the rubrics with the students.
- Explain that to demonstrate their engineering process, each team will also be required to create research books where they document their process and keep all of their design evaluation sheets (pp.12–13) and their final design evaluation sheet (p.14).

The image shows three overlapping worksheets from the 'Four To Soar: Flying Circus' project. The top-left worksheet is titled 'Aircraft Design and Evaluation Sheet: Hang Time' and includes a table for recording hang time in seconds. The middle worksheet is titled 'Aircraft Design and Evaluation Sheet: Passenger Capacity' and includes a table for recording the number of passengers and lift-off time. The bottom-right worksheet is titled 'Final Aircraft Design Solution' and contains four numbered questions for reflection on the design process.

**Aircraft Design and Evaluation Sheet: Hang Time**

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 Team Members: \_\_\_\_\_

1. Sketch a front and side view of the aircraft.

2. Test your design and record the results in the table. (Flight must be launched by hand and land on a level surface.)

Trial	Hang Time in Seconds
1	
2	
3	

3. What have you learned from this test that will help you design the next version?

Four To Soar: Flying Circus 12

**Aircraft Design and Evaluation Sheet: Passenger Capacity**

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 Team Members: \_\_\_\_\_

1. Sketch a front and side view of the aircraft showing placement of the passengers.

2. Test your design and record the results in the table.

Trial	Number of Passengers	Liftoff (Y/N)
1		
2		
3		
4		
5		
6		

3. What have you learned from this test that will help you design the next version?

Four To Soar: Flying Circus 13

**Final Aircraft Design Solution**

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 Team Members: \_\_\_\_\_

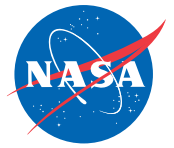
1. Sketch a front view of the aircraft you recommend for future research.

2. Why should this aircraft be further studied? What makes it the best design?

3. How did you determine that this was the best design? What process did you use?

4. How did you make sure that your results are reliable and reproducible?

Four To Soar: Flying Circus 14



## Mini Evaluations

The following are guidelines for questions that can be used for informal oral evaluation as students are working on their designs or finishing them up to assess each members' understanding of the main concepts of focus in this unit. Alternatively, these questions might be used as a discussion once students have completed their designs and are presenting to the rest of the class.

### 1. Reliability and Reproducibility

During the course of the challenge observe the students' experimental process. Stop the groups and ask:

- *How do you know your results are reliable?*

Students should discuss that trials are done multiple times to minimize the chance for experimental error affecting results. This is called **reliability**.

- *What steps would you take to ensure your results are reproducible?*

Students should discuss that they would record, or document, how they did their test to have their experiment repeated by many different scientists and engineers, in many locations around the world, to see if the results can be replicated. This is called **reproducibility**.

### 2. Four Forces of Flight

As you meet with each design team ask:

- *What are the four forces of flight?*

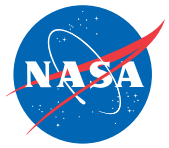
The four forces of flight are lift, weight, drag, and thrust.

- *Please show me your design and discuss how each force will affect it?*

Students should be able to speak about their designs and explain how each of the four forces has been addressed.

- **Thrust** is the force generated by an airplane's engines that moves an airplane forward. Thrust can be changed by changing the speed, size, shape, angle, or number of rotations of a propeller.
- **Drag** is a force that resists the forward motion of an airplane due to the resistance of air molecules that are pushed aside as an airplane travels through the air. Designs might minimize drag by having as little surface area facing into the air flow as possible.



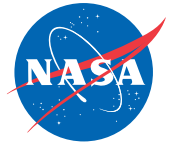


- **Lift** is the upward force that causes an object to fly. In an airplane, it is generated primarily by airflow over the wings. Lift can be changed in these designs by changing the shape or angle of the wings or possibly by curving the wings to create an airfoil.
- **Weight** is a measure of the force of gravity acting on the mass of an aircraft. Weight can be minimized by making aircraft parts out of the lightest materials.
- *In order for an aircraft to fly, what relationship must exist between the four forces?*  
In order for an aircraft to remain in flight, lift must be equal to or greater than weight and thrust must be equal to or greater than drag.
- *How did you create your designs in order to make sure that the four forces were in the best balance to fulfill the mission criteria?*  
Students should explain their designs. They must understand and use the vocabulary lift, thrust, weight, and drag. They should also use phrases like “angle of attack” to describe their wings and “air resistance” when they talk about minimizing drag.

### 3. Engineering Design Process

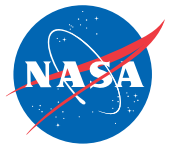
Ask each design team:

- *Are there design criteria for this mission? If so, what are they?*  
Students should answer with the mission criteria for the project they have selected.
- *How did your team go about the engineering design process?*  
Students should describe the process they used to design and test their ideas.
- *Is the engineering design process your team used the “right” one?*  
Students need to explain that there is not one “right” order to this process. Many tests and changes are made before a final design is completed.
- *Did your team encounter any failures? Does failure play a role in the engineering design process?*  
Failure is very important to the engineering process. Often we learn more from failure than from success. It is important that we learn what doesn’t work during modeling rather than after the actual full-sized design is built.



## Extend & Evaluate

1. Attend a museum-hosted *Family Flight Night* or host one at your school.
  - Have students create project display boards to display their project design process and results. Depending on the school, these boards can either be in English only or one side can be in English and one side in another language. **Note:** *This is a great way to involve parents who do not speak English.*
  - Have students share their research books documenting their process.
  - Have students take on tasks such as decorating, music, set up of demonstrations, refreshments, making signs, and cleaning up.
  - Have students demonstrate their designs for their parents in a spectacular air show. They can demonstrate both their final aircraft designs as well as the propeller designs developed as part of the “Propeller Palooza” pre-visit activity.
2. Evaluate students’ work.
  - Use the rubrics provided on pp.15–17.
  - You may also want students to give a formal presentation of their final projects if they are not participating in a Family Night.



# Hang Time Mission

## NASA PROBLEM

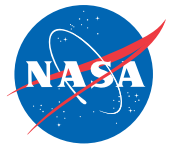
NASA is working to improve aircraft design so that future aircraft can fly further using less fuel. NASA needs your help to design a better aircraft. Your mission is to find the materials and determine the best shape and size of wings and stabilizer to make your aircraft stay in the air longest.

## YOUR CHALLENGE

Design a rubber band propeller powered airplane that stays in the air the longest when launched by hand.

## YOUR CRITERIA

- Design an aircraft that stays in the air the longest when launched by hand.
- You must be in a design team of 2 or 3 people.
- Each person must contribute to the team effort.
- Your team must design and build a rubber band powered airplane.
- Your team may only use the materials provided by the teacher.



# Passenger Capacity Mission

## NASA PROBLEM

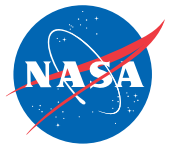
NASA is working to improve aircraft design so that future aircraft can fly further using less fuel. NASA needs your help to design a better aircraft. Your mission is to design an aircraft that can take off carrying the most passengers.

## YOUR CHALLENGE

Design a rubber band propeller powered airplane that can take off from the ground carrying the most passengers (pennies).

## YOUR CRITERIA

- Design an aircraft that can take off carrying the most passengers (pennies or dimes).
- You must be in a design team of 2 or 3 people.
- Each person must contribute to the team effort.
- Your team must design and build a rubber band powered airplane.
- Your team may only use the materials provided by the teacher.



## Aircraft Design and Evaluation Sheet: Hang Time

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_

Team Members: \_\_\_\_\_

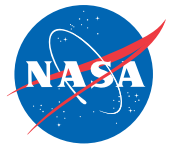
\_\_\_\_\_

1. Sketch a front and side view of the aircraft.

2. Test your design and record the results in the table. (*Flight must be launched by hand and land on a level surface.*)

Trial	Hang Time in Seconds
1	
2	
3	

3. What have you learned from this test that will help you design the next version?



## Aircraft Design and Evaluation Sheet: Passenger Capacity

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_

Team Members: \_\_\_\_\_

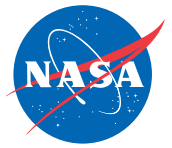
1. Sketch a front and side view of the aircraft showing placement of the passengers.

2. Test your design and record the results in the table.

Trial	Number of Passengers	Liftoff (Y/N)
1		
2		
3		
4		
5		
6		

3. What have you learned from this test that will help you design the next version?





# Final Aircraft Design Solution

Team Name: \_\_\_\_\_ Date: \_\_\_\_\_

Team Members: \_\_\_\_\_

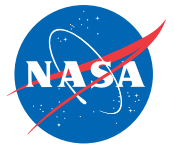
---

1. Sketch a front view of the aircraft you recommend for future research.

2. Why should this aircraft be further studied? What makes it the best design?

3. How did you determine that this was the best design? What process did you use?

4. How did you make sure that your results are reliable and reproducible?

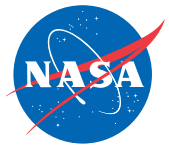


Student Names: \_\_\_\_\_

Teacher: \_\_\_\_\_

## Hang Time Evaluation Criteria

Category	4	3	2	1
<b>Scientific and Engineering Knowledge</b>	Explanations by all group members indicate a clear and accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by all group members indicate a relatively accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by most group members indicate a relatively accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by some group members do not illustrate much understanding of the four forces of flight and how they relate to the construction and design of the aircraft.
<b>Engineering Process</b>	Clear evidence of troubleshooting, testing, and refinements. Students can provide explanation for design modifications.	Clear evidence of troubleshooting, testing, and refinements.	Some evidence of troubleshooting, testing, and refinements.	Little or no evidence of troubleshooting, testing, and refinements.
<b>Data Collection</b>	Data taken several times in a careful manner.	Data taken several times, but some issues with data collection.	Data taken once.	Data not taken carefully or not taken in a reliable manner.
<b>Function</b>	Aircraft has a hang time of more than 10 seconds.	Aircraft has a hang time of more than 5 seconds.	Aircraft has a hang time of more than 2 seconds.	Flaws in function with less than 2 seconds of hang time or crash.

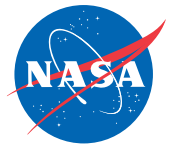


Student Names: \_\_\_\_\_

Teacher: \_\_\_\_\_

## Passenger Capacity Evaluation Criteria

Category	4	3	2	1
<b>Scientific and Engineering Knowledge</b>	Explanations by all group members indicate a clear and accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by all group members indicate a relatively accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by most group members indicate a relatively accurate understanding of the four forces of flight and how they relate to the construction and design of the aircraft.	Explanations by some group members do not illustrate much understanding of the four forces of flight and how they relate to the construction and design of the aircraft.
<b>Engineering Process</b>	Clear evidence of troubleshooting, testing, and refinements. Students can provide explanation for design modifications.	Clear evidence of troubleshooting, testing, and refinements.	Some evidence of troubleshooting, testing, and refinements.	Little or no evidence of troubleshooting, testing, and refinements.
<b>Data Collection</b>	Data taken several times in a careful manner.	Data taken several times, but some issues with data collection.	Data taken once.	Data not taken carefully or not taken in a reliable manner.
<b>Function</b>	Aircraft carries 6 or more passengers, lands on its wheels, and all passengers stay on the aircraft.	Aircraft carries 4 or more passengers, and all passengers stay on the aircraft.	Aircraft carries 2 or more passengers, and all passengers stay on the aircraft.	Flaws in function with fewer than 2 passengers; passengers ejected during takeoff or landing.



Student Names: \_\_\_\_\_

Teacher: \_\_\_\_\_

## Final Aircraft Design Challenge

### Display Board Evaluation Criteria

Category	4	3	2	1
<b>Display</b>	Each element in the display had a function and clearly served to illustrate some aspect of the project. All items, graphs, etc. were neatly and correctly labeled.	Most elements had a function and clearly served to illustrate some aspect of the project. Most items, graphs, etc. were neatly and correctly labeled.	Each element illustrated some aspect of the project, but key elements were missing that were necessary for understanding the project.	The display seemed incomplete or chaotic with no clear plan. Many labels were missing, misspelled, or incorrect.
<b>Data Collection</b>	Data was summarized independently, in a way that clearly describes what was discovered.	Data was summarized independently in a way that somewhat describes what was discovered.	Data is not presented in a summary form and requires active questioning in order to find out the results.	Data is not presented.
<b>Conclusion / Summary</b>	Students provided a detailed final design recommendation clearly based on the data and related to previous research findings.	Students provided final design recommendation clearly based on the data and related to the previous research findings.	Students provided a final design recommendation with some reference to the data and previous research findings.	No design recommendation was apparent OR important details were overlooked.
<b>Overall Knowledge</b>	Students clearly understand the subject matter and can answer questions without assistance.	Students understand subject but need some help to answer questions.	Students have some knowledge of subject but cannot answer questions well.	Students do not demonstrate knowledge of subject.