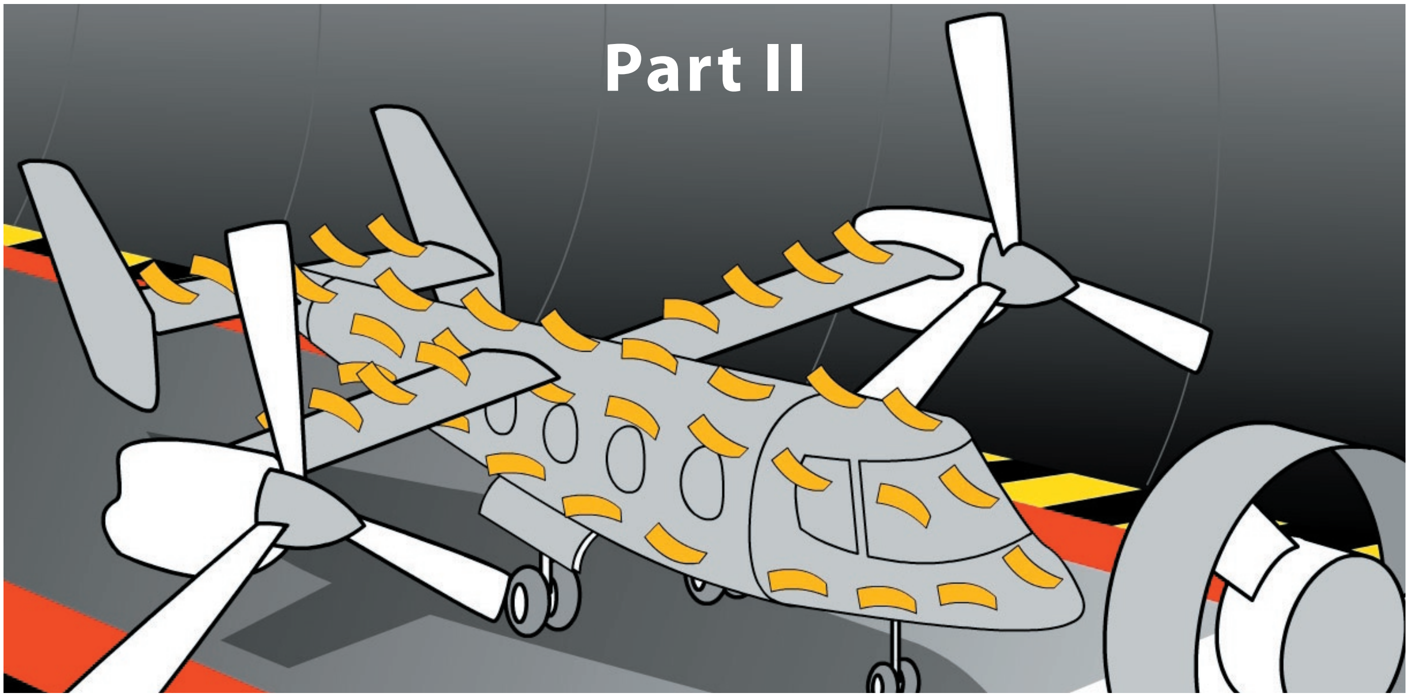
Future Flight Design



Aircraft Design Problem

I Introduction

Welcome to Future Flight Design! In this Web site, you become a NASA researcher and, with your partner, design an aircraft of the future!

You will start by watching the animation that shows the problems with air travel today. Then select a situation, and explore the online labs to come up with possible solutions that will improve our air system in the future. The online multimedia will teach you about aircraft so you can design and build an aircraft suited for short hops, medium distances, and long hauls.

Keep this design log with you as you work through the design process so you can complete the worksheets.

STEP 1 Define the Problem

In this phase, engineers understand the problem and outline the requirements that must be met. They then make a plan for solving the problem.

L Letter from NASA

Dear Students:

NASA is asking for your help to design a future aircraft.

- Crowded roads make it difficult to get to the airport.
- At the airport, flights are often delayed. Current runways and air systems can't handle the growing number of people and goods that need to travel by air.

Changing the current system and airports may help with this problem, but NASA is also interested in what kind of aircraft might also help.

Choose a situation, and explore the Future Flight Design Center labs to come up with a new aircraft design. Your new aircraft will be tested for the following:

- It is able to fly.
- It can carry the number of people for your chosen situation.
- It is cost-effective.
- It is able to fly the distance in your chosen situation.
- It fits your chosen situation in terms of its size.
- It doesn't increase ground traffic.

Good luck and thank you for your assistance in solving this problem.

NASA Official

Designing an aircraft involves the following phases:

1. Define the Problem
2. Generate Ideas
3. Select a Solution
4. Test and Refine the Solution
5. Present the Results

C Choose a Partner

Now that you have agreed to assist NASA, choose your partner.

Write down the names of you and your partner:

1. ____

2. ____

D Discuss the Problem

1. Click "Introduction Movie" at http://futureflight.arc.nasa.gov/welcome.html and watch the animation, and study the letter from NASA. Discuss with your partner the problems with air travel and ground travel. Make a list of the problems.

C Choose a Situation

After watching the movie, click on the "Aircraft Design Problem" link at http://futureflight.arc.nasa.gov/welcome.html. Then scroll past the NASA letter and click on item 2 "Problem Situation." Read the three situations and select one for you and your partner to work on. If you don't have access to a computer right now, you can read the situations below.

Situations

Read the following three situations, then select one. In the online activity, you will design an aircraft for the situation you choose.

Short Hop

You are on a sports team at your school and you've made it to the district championships! Three team members are also on the debating team. They've made it to the debating finals, and those finals are on the same day as the sport finals! This leaves them with only half an hour to get to the sports game! The only way to beat the rush hour traffic is to fly them there. Your challenge is to design an aircraft that will enable these three team members to travel 25 miles across town to the game. *Since your aircraft will be flying within a city, it should be small enough to fit between buildings. The cost can't exceed $4,425,000; however since you're moving so few people, it's best to keep the cost below $250,000.*

Medium Distance

You are on a sports team at your school and you've made it to the regional championships! Your team must travel to a school that is 150 miles away. You could all travel there together by van or take the train, but that would take an entire day. Then you'd miss out on the exciting NASA speaker visiting your school that day. Flying in an aircraft will be much faster, so your challenge is to design an aircraft that doesn't need a runway. Build an aircraft to move all 9 of your team members to the game on time without missing a day at school! *The cost of your aircraft can't exceed $9,800,000.*

Long Haul

You are on a sports team at your school and you've made it to the national championships, which will be at a school 500 miles away. This is a big event, so the cheerleaders, the school band, several students, and parents will all attend the game with the team. You know that there are delays with air travel, but the whole group of 80 can't be late for the game. Your challenge is to design an aircraft that doesn't require a runway so your team can to get to the game on time! *The cost of your aircraft can't be more than $76,000,000.*

L List the Criteria and Constraints for Your Aircraft

As engineers, you need to list both the things that will limit your design (constraints) and the things that your design will need to be able to do (criteria). You can get this information from the letter from NASA and from the situation you selected. Examples of criteria are the number of passengers the aircraft must be able to carry and the distance it must travel. Examples of constraints might include the maximum size or cost of building the aircraft.

The Letter from NASA is at http://futureflight.arc.nasa.gov/design.html
The Situations can be found at http://futureflight.arc.nasa.gov/situations.html

1. List the criteria and constraints that your aircraft must meet.

We chose Situation number: ________

Criteria (standards or requirements)	Constraints (limits to design)

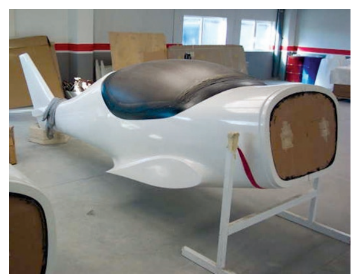
STEP 2 Generate Ideas

In this phase, engineers brainstorm solutions and create a basic design followed by a detailed design of the aircraft.

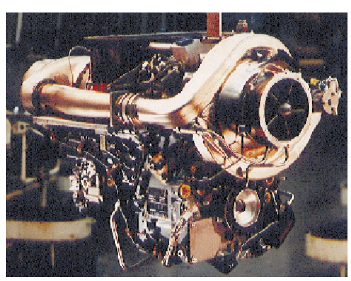
In designing an aircraft, you will need to consider three systems that will work together as a larger aircraft system. These systems are:

1. Lift System:
the parts of the aircraft that work together to give the aircraft enough lift to fly and carry the weight of the people and cargo in your chosen situation

2. Fuselage System:
the body of the aircraft that will hold the people and cargo in your chosen situation



3. Propulsion System:
the parts of the aircraft that work together to give your aircraft enough thrust to move the people and cargo to the destination in your chosen situation



1. Draw an aircraft that you think will work for your situation that includes all three systems. You can use the pictures on the previous page to help in your design.
   - Draw the aircraft in the space below or on a large sheet of paper.
   - Include descriptions of your aircraft, such as how it gets off the ground, the material(s) it is made of, how many people it can carry, and where it gets its power.
   - Include the aircraft's measurements.

Now click on item 3 "Future Flight Design Center" on the Aircraft Design Problem page (http://futureflight.arc.nasa.gov/design.html) and work through the multimedia activities to learn about aircraft, to design an aircraft and to test your aircraft. You can also get directly to the Future Flight Design Center Main Map by going to http://futureflight.arc.nasa.gov/map.html

The Main Map interface will take you to the following sections:

- Aeronautics Lab
- Lift Lab
- Fuselage Lab
- Propulsion Lab
- Design Center
- Test Facilities (CFD, Wind Tunnel and Flight Test)

Go to the Aeronautics Lab first to understand how things fly.

A Aeronautics Lab

The Aeronautics lab teaches you about the four forces involved in flight: **weight, lift, thrust,** and **drag**.

A force is a push or a pull. When you push or pull something, you are applying a force to that object.

Before you start this lab, discuss the following question with your partner:

1. How can a heavy aircraft fly in the air? (Write your conclusions below.)

As you go through the lab, discuss the following questions with your partner and take notes that will help you to design a successful aircraft for your given situation.

Weight

2. Why is weight important in designing an aircraft?

3. In designing an aircraft, what could you do to help with the weight of the aircraft?

Trade-offs: Engineers often have to look at trade-offs.
Engineers can improve a system in one area, but by making this improvement it can worsen the system's performance in another area. This is called a trade-off. For example, engineers may use larger engines, which allow an aircraft to go faster, but it may make the aircraft cost more or may use more fuel. Throughout this problem, see what trade-offs come up and decide what trade-offs you will have to make in your aircraft design.

4. What trade-off(s) do engineers make when using lighter materials in an aircraft?

Lift

5. What helps to create lift?

6. How could you create lift in your aircraft design?

Thrust

7. What are two ways that thrust is important to an aircraft?

8. How can you create more thrust on your aircraft?

Drag

9. What causes drag?

10. When designing an aircraft, how can you reduce drag?

Four Forces

11. When designing your aircraft, what must you make sure is true in order for your aircraft to take off and fly?

12. Systems have parts that work together. One part can affect another.
    What are some ways that the parts of an aircraft work together so that an aircraft can fly?

Career Cockpit

13. Read the career fact sheets and trading cards in this section and learn more about careers related to aeronautics.
    What parts of the jobs described do you like best?

14. After going through the lab, look at the drawing you made of a possible solution to your chosen situation. Modify the drawing of your aircraft with your knowledge of the four forces of flight. Redraw your new design below. Provide notes of how you improved your design.

Now you know the basics of how an aircraft flies!
If you think you're ready to design an aircraft solution, you can visit the Design Center. If your design is unsuccessful during testing, visit the other labs to help you understand the different parts of the aircraft and what makes a good design. We suggest you check out the labs first, so that you can make a better design.

L Lift Lab

Before you start the Lift Lab, discuss the following with your partner and write your answers in the spaces below.

1. What part of an aircraft do you think might lift it or move it up?

2. For the situation you chose, what factors are important in the design of the lift system of your aircraft? (For example, how powerful does the lift system of your aircraft need to be? What kind of environment will it need to fly in? Is size an important factor?)

As you go through the lab, discuss the following questions with your partner and take notes that will help you to design a successful aircraft for your given situation.

Lift Lab: Creating Lift

3. In order for an aircraft to ascend or fly up, what must be true?

4. If an aircraft is hovering, what must be true?

5. How can an aircraft lift off vertically (or straight up)?

6. What's the difference between the systems that a helicopter uses to fly forward and the systems that a tiltrotor uses to fly forward?

7. What causes the aircraft to lift off the ground in each of these situations?

8. Why is a tail rotor important?

Lift Lab: Rotor Size

9. In the tables below, compare rotor blade size.

	Short Blades	Long Blades
Downwash		
Ability to Fit in Tight Spaces		
Fuel Efficiency		
Noise		

	Short Blades	Long Blades	Very Long Blades
Cargo			

10. What happened to the cargo capacity when very long rotor blades were used? Why?

11. What size rotor blades do you think would be best to use in your aircraft? Why?

Lift Lab: Number of Blades

12. In the tables below compare the number of blades.

	Three Blades	Five Blades
Noise		
Weight		

	Five Blades	Seven Blades	Nine Blades
Cargo			

13. What happened to the cargo capacity when nine rotor blades were used? Why?

14. Do you think you should use few or many rotor blades in your aircraft? Why?

Lift Lab: Noise

15. What are some factors that affect how noisy an aircraft is?

16. List some trade-offs for making the rotor blades longer.

17. List some trade-offs for adding more rotor blades to an aircraft.

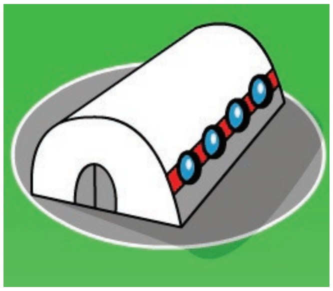
Career Cockpit

18. Read the career fact sheets and trading cards in this section and learn more about careers related to lift. What parts of the jobs described do you like best?

19. After going through the lab, look at the drawing you made of a possible solution to your chosen situation. Draw and label the lift system that will meet the needs of your chosen situation based on what you've learned in this lab. Be sure to include notes on the size and number of rotors you will use, and explain how this lift system meets the criteria and constraints you listed for your situation.

Now you know important factors to think about when designing your lift system!
Check out the other labs to help with the design of other important systems on your aircraft, or if you think you're ready, visit the Design Center to design your solution.

F Fuselage Lab



Before you start the Fuselage Lab, discuss the following with your partner and write your answers in the spaces below.

1. Why do aircraft have different fuselages?

2. For the situation you chose, what factors are important in the design of the fuselage of your aircraft? (For example, do you need a small or large cabin? Is cost a factor?)

As you go through the lab , discuss the following questions with your partner and take notes that will help you to design a successful aircraft for your given situation.

Fuselage Lab: Structure

3. What is the purpose or function of each part of the fuselage?

Cockpit

Cabin

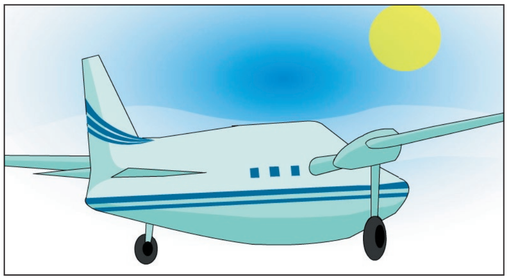
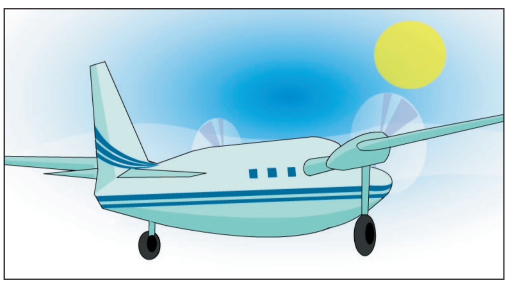
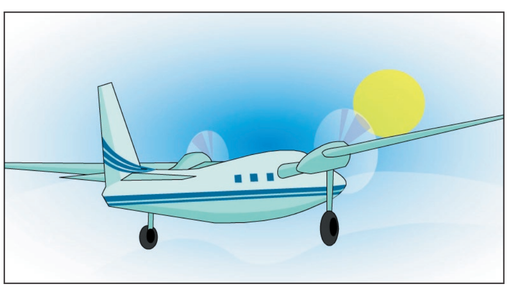
Tail Cone

Empennage

4. How do the parts of the fuselage (cockpit, cabin, tail cone, empennage) work together as a system? Write or draw your conclusions here.

Fuselage Lab: Aerodynamics

5. What observations can you make about each of the aircraft in this lab?

Aircraft	Flight Observations
Largest and blockiest 	
Medium sized, somewhat blocky 	
Small, streamlined 	

6. Based on the animations in this lab, what can you conclude about the shape of the fuselage and how it affects flight? Why?

Fuselage Lab: Materials

7. In the table below compare different materials used over time.

	Linen/wood	Aluminum/steel	Composite
Strength			
Cost			
Weight			

8. What material do you think would be best to use in your aircraft? Why?

9. What trade-off(s) did engineers have to make in the past when selecting materials?

Fuselage Lab: Capacity

10. How does the fuselage size affect the capacity and weight of an aircraft?

11. What trade-off(s) do you need to make when designing a fuselage?

12. What are some things to think about when designing a fuselage for a specific task?

13. How will your fuselage affect the other parts of your aircraft?

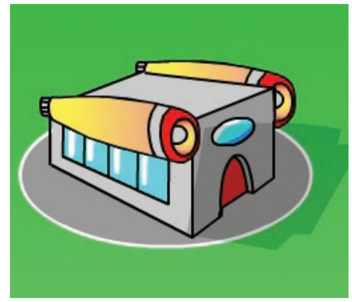
Career Cockpit

14. Read the career fact sheets and trading cards in this section and learn more about careers related to fuselages. What parts of the jobs described do you like best?

15. After going through the lab, look at the drawing you made of a possible solution to your chosen situation. Draw and label the fuselage that will meet the needs of your chosen situation based on what you've learned in this lab. Be sure to include notes on the size, shape, and materials you will use, and explain how this fuselage meets the criteria and constraints you listed for your situation.

Now you know important factors to think about when designing your fuselage!
Check out the other labs to help with the design of other important systems on your aircraft, or if you think you're ready, visit the Design Center to design your solution.

P Propulsion Lab



The word "propulsion" is derived from two Latin words: "pro" meaning before or forwards and "pellere" meaning to drive. Propulsion means to push forward or drive an object forward. A propulsion system is a machine that produces thrust to push an object forward.

Before you start the Propulsion Lab, discuss the following with your partner and write your answers in the spaces below.

1. What part of an aircraft do you think might propel or move it forward?

2. For the situation you chose, what factors are important in the design of the propulsion system of your aircraft? (For example, how powerful does the propulsion system of your aircraft need to be? Is cost a factor?)

As you go through the lab, discuss the following questions with your partner and take notes that will help you to design a successful aircraft for your given situation.

Propulsion Lab: Thrust

3. What are different ways that an aircraft can be thrust or moved forward?

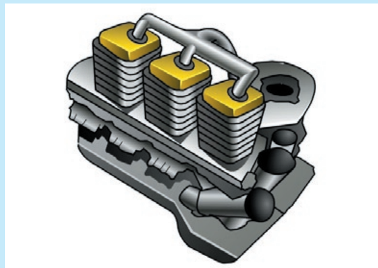
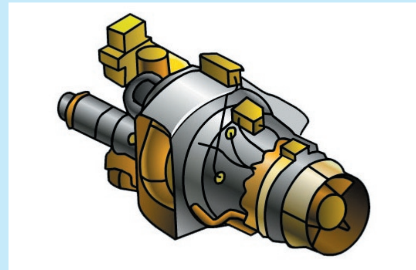
4. What causes the aircraft to move forward in each of these situations?

Propulsion Lab: Engines

5. Choose one engine system and list the parts of the propulsion system, including the parts the engine interacts with to make the aircraft move forward.

6. Draw and explain how these parts work together as a system to propel an aircraft forward.

7. In the table below, compare the two engines.

	Piston Engine 	Turboshaft Engine 
Weight		
Power		
Cost		
Other Notes		

8. Which engine do you think would be best to use in your aircraft? Why?

9. What trade-off(s) do you make when selecting an engine?

Career Cockpit

10. Read the career fact sheets and trading cards in this section and learn more about careers related to propulsion. What parts of the jobs described do you like best?

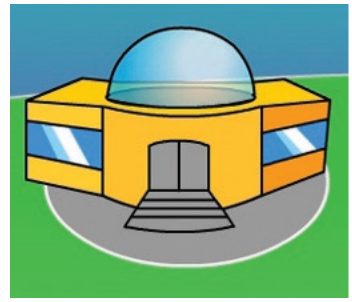
11. After going through the lab, look at the drawing you made of a possible solution to your chosen situation. Draw and label the propulsion system that will meet the needs of your chosen situation based on what you've learned in this lab. Be sure to include notes on the type of engine you will use, and explain how this propulsion system meets the criteria and constraints you listed for your situation.

Now you know important factors to think about when designing your propulsion system! Check out the other labs to help with the design of other important systems on your aircraft, or if you think you're ready, visit the Design Center to design your solution.

STEP 3 Select a Solution

In this phase, engineers select the solution that best meets the criteria and constraints.

D Design Center



Before you start the Design Center:

1. Review the criteria and constraints for your situation by clicking on the Design Options clipboard in the Design Center (http://futureflight.arc.nasa.gov/dCenter.html).
2. Look at your notes and drawings from the labs.
3. Discuss the following with your partner and write your answers in the spaces below.

1. What important factors will you look for when choosing the fuselage, lift system, and engine for your aircraft?

Enter the Assembly Area by clicking on the icon that matches the situation you chose.

As you go through the Design Center, discuss the following questions with your partner and write your answers in the spaces below.

Design Center: Assembly Area

2. As you go through the fuselages, lift systems, and engines you have to choose from, notice the statistical information associated with each part. Draw the combination that you think will work best for your aircraft solution.

3. How does this solution fit the criteria and constraints of your situation?

4. How will the parts you chose work together as a system that will solve your chosen situation?

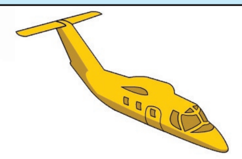
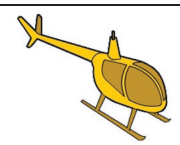
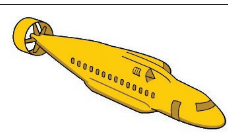
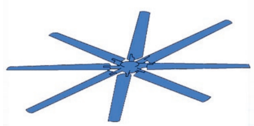
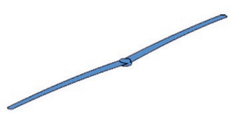
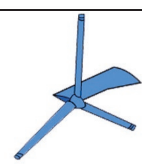
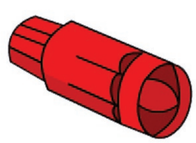
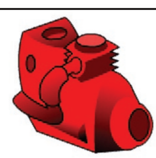
STEP 4 Test and Refine the Solution

In this phase, engineers do a number of tests of their solution. Then they make changes and test again until they have their best solution to meet the criteria and constraints.

Design Center: Testing/Results Area

1. After you build your aircraft, click the Submit button to get feedback on your design. What was the result of your test? Record how your test results compare to the expected criteria and constraints.

Criteria and Constraints	Test Result
Capacity	
Range	
Can it fit in between buildings? (for short hop only)	
Does it fly?	
Does it fit within your budget constraint? (Calculate your budget using the following tables)	

Part	Cost
Fuselage 1 	$5,500,000
Fuselage 2 	$110,000
Fuselage 3 	$50,000,000
Lift 1 	$25,000,000
Lift 2 	$110,000
Lift 3 	$4,000,000
Engine 1 	$150,000 ea
Engine 2 	$100,000 ea
Engine 3 	$25,000 ea

Total Budget

2. Be sure to include the cost of two or three engines for aircraft that require that many. Any aircraft using Fuselage 3 requires three engines. Any aircraft using Lift 3 requires two engines, regardless of the fuselage. All other combinations require only one engine.

Part	Number	Cost per item	Number of Items	Total Cost
Fuselage				
Lift				
Engine				
Total Cost				

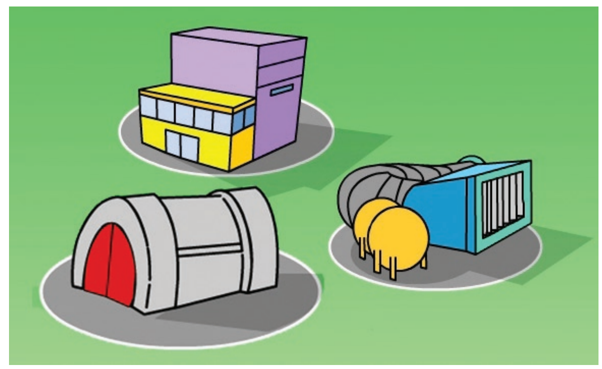
3. Did your design pass this phase of testing?

Engineers seldom come up with the perfect solution the first time, but have to refine their designs and continue to test them until they come up with something that works.

If your design was not approved, look at the results above that need to be improved. Visit the labs with information that will help to improve in those areas or look at your notes from those labs. What do you think you need to change in your design so that it will meet the criteria and constraints? After revisiting the labs, come back to the Design Center. Try again until you build a successful design.

Career Cockpit

4. Read the career fact sheets and trading cards in this section and learn more about careers related to aircraft design. What parts of the jobs described do you like best?



T Test Facilities (CFD, Wind Tunnel, and Flight Test Buildings)

Before you start the Test Facilities, discuss the following with your partner and write your answer in the space below. (You may want to review your log notes.)

1. List the steps you went through to design your solution.

Go to the CFD, Wind Tunnel, and Flight Test buildings to watch some movies about testing aircraft. Also visit the Career Cockpit for each building.

As you go through the Test Facilities, discuss the following questions with your partner and write your answers in the space provided.

2. What are some of the techniques that NASA engineers use to test and refine aircraft?

3. How is the process that you used to design an aircraft similar to the process NASA engineers use?

4. How is the process that you used to design an aircraft different from the process that NASA engineers use?

In the Flight Test building, be sure to click "Test my Aircraft" and see the flight test of your aircraft. Also, be sure to print your certificate as proof of your success or get your customized certificate from your teacher.

5. How does it feel to have successfully designed a new aircraft?

Career Cockpit:

6. Read the career fact sheets and trading cards in each test building and learn more about careers related to CFD, wind tunnel testing and flight testing.

What parts of the jobs described do you like best?

STEP 5 Present the Results

In this phase, engineers present their solution to others for feedback in further improving their design and to see if their solution is accepted for use.

You will be attending a conference on future aircraft designs. Design a poster or presentation about your solution to share with others. You will want to be persuasive to try to convince your colleagues that your solution is the best one and should be recommended to NASA.

Your poster or presentation should include the following information:

- The situation you chose
- Your criteria and constraints
- The lift system you chose and why
- The engine you chose and why
- The fuselage you chose and why
- How these parts work together as a system to solve the given situation
- The test results of this aircraft
- The trade-offs you made
- How your final solution changed compared to your initial design
- A description of how your aircraft flies using the four forces of flight
- The career that interests you the most, why it interests you, and the preparation and planning needed for such a career

Your poster or presentation will be evaluated using the following rubric:

4	• The poster/presentation clearly and accurately describes the solution, how it meets the criteria and constraints, how it works together as a system to fly, and how it solves the given situation. • The poster/presentation has all required parts, is creative and persuasive. It has accurate and clear descriptions and illustrations that make the poster/presentation exceptionally easy to understand.
3	• The poster/presentation clearly and accurately describes the solution, how it meets the criteria and constraints, how it works together as a system to fly, and how it solves the given situation. • The poster/presentation has all required parts. It has accurate and clear descriptions and illustrations that make the poster/presentation easy to understand.
2	• The poster/presentation is not completely clear or accurate in describing the solution, how it meets the criteria and constraints, how it works together as a system to fly, and how it solves the given situation. • The poster/presentation has most required parts. Illustrations or descriptions are a little difficult to read.
1	• The poster/presentation is not clear or accurate in describing the solution, how it meets the criteria and constraints, how it works together as a system to fly, and how it solves the given situation. • The poster/presentation is missing several parts. Illustrations or descriptions are difficult to read.

Glossary

aerodynamics. The science of learning how air flows over objects.

aeronautics. The study of flight and the science of building and operating an aircraft.

airfoil. A special shape that helps to create lift.

aircraft. A machine used for flying.

airline. A system made up of aircraft, pilots, flight attendants, and passengers that flies on scheduled routes and operates out of an airport.

air traffic system. The system that controls and regulates air transportation and travel.

altitude. Height above sea level (on the Earth), or height above the surface level of a planet or moon.

ascent. The act of rising up into the air. Ascent occurs when the force of lift is greater than the force of weight.

aviation. The operation of aircraft.

cabin. The part of an aircraft that is used to transport passengers or cargo. It is usually located in the middle of the aircraft.

capacity. The largest and heaviest amount of cargo or passengers that an aircraft can safely carry.

cargo. The goods that are carried onboard an aircraft.

center of gravity. An imaginary point on an object that is used as the object's center of weight. It is the point on which the object would balance on a flat surface.

cockpit. The part of an aircraft where the pilot sits to control the aircraft. It is usually located near the front of the aircraft.

combustion. Explosion created in an engine when air is compressed inside a chamber and then mixed with fuel. The air and fuel mixture explodes when it is ignited by a spark. Energy released by the explosion is used to power the engine.

composite. A very strong, lightweight material made from carbon fibers.

compress. To squish or tightly pack together.

computational fluid dynamics (CFD). The science of using computers to solve mathematical equations that predict how air moves around objects such as aircraft. CFD allows engineers to "fly an aircraft in a computer."

constraints. Things that limit a design.

cost-effective. When the benefits gained by doing a project are worth the amount of money and time it takes to do that project.

crankshaft. The part of an engine that rotates using the energy created by the piston and cylinder. This rotation can be used to power a rotor.

criteria. Things a design needs to be able to do.

cylinder. A piece of machinery (shaped like a tin can) inside which a piston moves up and down to power an engine.

descent. The act of lowering to the ground. Occurs when the force of weight is greater than the force of lift.

downwash. The flow of air forced downward by the rotor blades.

drag. A resistant force created by air molecules bouncing off an object.

empennage. The tail of the aircraft. It usually includes parts that help steer the aircraft.

flight plan. A report written by a pilot before an aircraft is flown. It tells all of the details of the flight, including the aircraft's route and scheduled times of departure and arrival.

fuselage. The body of an aircraft that contains the cockpit, cabin, empennage, and tail cone.

horizontal. Flat and level with the horizon, like a straight line drawn on the ground.

hover. To hang suspended in the air, without rising or falling. Hovering occurs when the forces of lift and weight are equal.

lift. The upward force that causes an object to fly.

piston. A plug-shaped piece of machinery that moves up and down inside a cylinder to power an engine.

piston engine. An engine that uses piston-and-cylinder machinery to operate small aircraft, like helicopters, that don't need a lot of power.

propulsion. The act of pushing something.

range. How far an aircraft can travel without refueling.

rotor. The set of rotor blades, or propellers, on a helicopter or tiltrotor that spin very fast to create lift and thrust.

rotor blade. A single blade or propeller in a rotor that turns very fast and creates lift and thrust on a helicopter or tiltrotor.

rotor tip speed. The speed at which the tips of the rotor blades turn.

route. The already-planned path of travel that a pilot uses to fly an aircraft to its destination.

runway. A very long road or strip that aircraft use to take off and land.

runway independent aircraft. Aircraft that do not need to travel a long distance on a runway in order to take off or land.

spark plug. The part of an engine that creates the spark the engine needs for combustion.

system. A set of parts (like the pieces of an engine) that come together to work as one.

tail cone. The part of an aircraft that has the mechanical parts and wiring that connect the tail to the rest of the aircraft. It is found near the rear of the aircraft.

tail rotor. The set of rotating blades found on the tail of a helicopter that are used to keep the aircraft from spinning in circles.

thrust. A force that moves an object forward.

tiltrotor. A type of aircraft that takes off and lands like a helicopter but flies like an airplane. It does not need the long runways that airplanes do and may be able to carry more passengers than helicopters.

torque. The force that causes an object to rotate or spin, or the measurement of this force.

trade-off. When an improvement in one area of something results in worse performance somewhere else.

transportation. A way to get from one place to another.

turboshaft engine. An engine that generates a lot of power and is used to operate large aircraft or aircraft that carry heavy loads.

vertical. Straight up and down, like a line drawn from a flat surface up into the air.

weight. The force created when gravity pulls on an object's mass.

wind tunnel. A tube or cylinder where a model of an aircraft or part of an aircraft is placed to test how the aircraft responds to very fast winds. Air is blown past the model so it experiences the same forces as it would if it were actually flying.