NOVA

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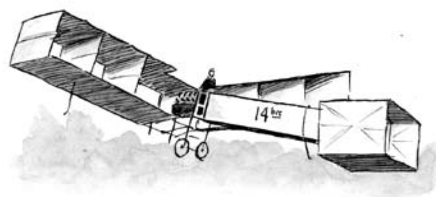
PBS

Wings of Madness

PROGRAM OVERVIEW

NOVA profiles Alberto Santos-Dumont, a legendary inventor who, at the turn of the 20th century, inspired a generation of aeronauts to push the limits of their courage and imagination.



The program:

- presents Santos's dream of making flight an everyday reality that anyone could experience.
- shows how the famous aviator streamlined and simplified dirigible design.
- notes Santos's trial-and-error experimental method, in which he would fly his vehicle, improve it, and then fly it again.
- reviews the vehicles Santos built and tested, including his dirigibles, as well as airplanes like the *#14bis* and the *Demoiselle.*
- features some of the innovations he pioneered, including a backup interior dirigible balloon to counteract changes in hydrogen gas, an efficient gas-fueled engine to power aircraft, and the use of piano wire to connect the many components of his airships.
- chronicles the aviator's efforts to win the Deutsch Prize offered to the first airship that could cover three-and-a-half miles in a half hour.
- presents Santos's endeavors to build a heavier-than-air craft and showcases his box-kite design for *#14bis.*
- reports on the problem being faced by most flight pioneers of the time—maintaining control of the aircraft while in flight.
- features the building and testing of a *#14bis* replica.
- recalls Santos's crash landing in his *Demoiselle* aircraft and the injuries he sustained from the collision.
- notes how the innovative experimenter began to suffer depression when he saw planes being used for military purposes, which led him to eventually take his own life.

BEFORE WATCHING

1 Ask students to think of airplanes they have seen or flown in. Have them describe the wing angles. Show pictures of planes that have different kinds of wings. Have students brainstorm how airflow over the wing and under the wing impacts flight. Describe for students how lift works. For a demonstration of the Bernoulli effect, see "Lift Off!" at www.pbs.org/nova/teachers/activities/2412_barrier.html

2 As students watch the program, assign groups to take notes on the following topics: Santos's vision about aviation, his strengths and weaknesses as an aviation pioneer, the different flying machines he invented, and a time line of his life.

AFTER WATCHING

1 Have students who took notes on the same topic meet, and then ask each group to make a short presentation to the class. What was Santos's dream for aviation? How did he design and test his ideas? How did his approach to sharing his ideas differ from the Wright brothers' approach? What were his notable achievements? What led to his depression and eventual suicide?

2 Santos was not the only scientist who would later regret his work. Provide students with a list of scientists who came to feel the same way about their discoveries (e.g., Alfred Nobel, Sir Henry Maxim, Dr. Benjamin Spock, and J. Robert Oppenheimer). Form groups and assign each group a scientist to research. How was each discovery made and used? What did the scientist come to regret about the discovery and why? Ask groups to present findings to the class.

CLASSROOM ACTIVITY

Activity Summary

Students experiment with a paper airplane model to determine how various wing angles affect flight characteristics.

Materials for Each Team

- copy of the "Winging It" student handout
- copy of the "Airplane Template" student handout
- 4 sheets of 20# typing paper, 21.5 cm x 28 cm
- 2 gum erasers
- 1 ruler

Background

Albert Santos-Dumont was born in 1873 into a wealthy Brazilian family in São Paulo. Inheriting the family fortune, he was educated in France and lived in Paris, where he rubbed shoulders with Parisian high society. He became interested in aeronautics at an early age. He began his experiments with balloons, making his first ascent in 1897. In 1898 he added a gasoline engine and propeller to an elongated balloon of his own design, the first application of this new form. He flew the craft successfully for the first time in 1898.

Santos created a sensation in 1901 when he flew his sixth design through a prescribed course, around the Eiffel Tower and back in 30 minutes, winning the Deutsch Prize of 100,000 francs, more than $20,000 in today's currency. After this feat and several international tours, he turned his attention to heavier-than-air craft, creating the *#14bis* in 1906 and the *Demoiselle* (his last aircraft) in 1908. Stricken in 1910 with what would be diagnosed posthumously as multiple sclerosis, Santos withdrew from aeronautics and took up astronomy.

During World War I Santos was falsely suspected of being a German spy. In disgust, he burned all of his papers. As the severity of his disease progressed, he grew increasingly despondent over the use of aircraft as weapons of war. In 1931, his family brought the emotionally frail Santos back to Brazil. He hanged himself in São Paulo on July 23, 1932. He is buried in Rio de Janeiro.

In this activity, students perform tests to determine how various wing angles affect flight characteristics.

LEARNING OBJECTIVES

Students will be able to:

- recognize and use terminology associated with the design of airplane wings.
- understand, follow, and repeat a sequence of instructions to produce an airplane model.
- determine the cause-and-effect relationship between a wing's shape and its flight characteristics.

KEY TERMS

dihedral: the upward or downward inclination of an aircraft wing from true horizontal.

lateral: acting or moving to the side, or at a 90° angle to an object.

oscillation: the rhythmic pattern of pitch change (the up or down movement) of the nose of an aircraft.

pitch: an up or down movement of the nose of the aircraft.

roll: an up or down movement of the wings of the aircraft.

stall: a sudden loss of lift that occurs when the airflow over the wings is disrupted or lost because the angle of attack (the angle of the wings to the airflow) is too high; as a result, the plane enters into a downward dive.

yaw: movement of the nose of the aircraft from side to side.

CLASSROOM ACTIVITY (CONT.)

Procedure

1 Identify a testing area for the students to use during the activity, such as a school gymnasium or hallway. Introduce the following key terms that will help students create their aircraft and record data about its behavior: *dihedral, roll, lateral, oscillation, pitch, stall,* and *yaw* (see Key Terms on page 2 for definitions).

2 Organize the class into teams and distribute the materials to each team. Review the handout with students.

3 Instruct each team to create a set of four models using the design template. Demonstrate how to fold the wings for each model, using the gum eraser as the guides for the angles of the dihedral in models 2 through 4. (Gum erasers come in small and large sizes, but both have at least one dimension that is 2.5 centimeters, which is what the height should be between the end of the wing tip and the table.) Once students fold the wings upward, the airplane should sit level on the tabletop between the two erasers.

4 Prior to having students test their models, review launching techniques. Demonstrate how to hold and to launch the models from the launching system using a *gentle,* horizontal push. Emphasize the importance of uniform launching. Encourage teams to share their observations and ideas on how to best launch their models, taking into consideration which areas of the room might have any wind currents. Have students practice launching their models before recording data to determine the best launch method.

5 Have teams test their models at the four angles listed on the student handout and complete at least 10 trials at each angle.

6 Reconvene the class to discuss each team's findings. Ask teams to share how their models behaved in flight. Make a chart on the board and have teams describe and record each of the models' behaviors. Was there a difference due to the dihedral wing angle and placement? Determine the differences in behavior of the model types. Which model was able to sustain the smoothest flight? Why might some teams have gotten different results with the same planes as others?

7 As an extension, have students conduct research to identify some other key players who contributed to the development of reliable aircraft. Create a list of at least five aviation pioneers who contributed to flight prior to the First World War (1914–1918). What characteristics did these pioneers share that made them successful in their efforts?

STANDARDS CONNECTION

The "Winging It" activity aligns with the following National Science Education Standards (see books.nap.edu/html/nses).

GRADES 5–8
Science Standard B
Physical Science
- Motions and forces

Video is not required for this activity.

Classroom Activity Author
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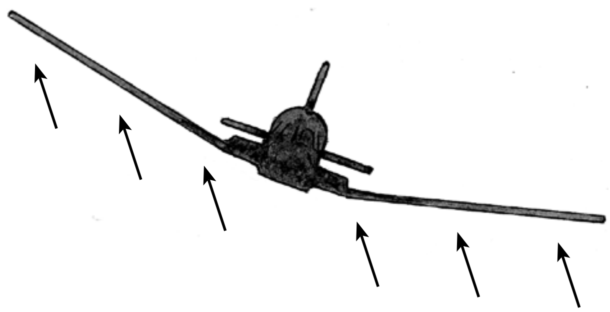
ACTIVITY ANSWER

Aircraft with a dihedral design have a slight angle to their wings that goes upward from where the wing attaches to the body outwards toward the tip. This design is used to improve lateral stability. If one wing begins to drop, the airplane will begin to sideslip in the direction of the dropping wing.



Because of the dihedral angle of the wings, the relative wind (created by movement of an airfoil through the air) will strike the lower wing at a greater angle of attack than the upper wing, producing more lift in the lower wing and helping return the aircraft to a stable lateral position.

The folds at the front of the wing on student models provide a well-defined leading edge and concentration of mass for the paper, causing the airplane to fall forward and to create a basic airfoil shape that generates the lift along the upper surface of the paper. Santos used the dihedral concept in the main wing of the *#14bis*. This design provided stability to his plane as it moved through the air, as the shape (at a low angle) resists roll, one of the three main forces acting on any aircraft.

As students experiment with their models, they will find that the models do not fly exactly the same way each time they are launched. This is common with an ultralight aircraft (a lightweight recreational aircraft), especially in areas where wind currents can be unpredictable. The activity is designed with 10 trials for each model so students can observe the generalized flight characteristics of the models.

Adding dihedral to a wing increases its lateral (roll) stability. However, as dihedral increases, lift is lost as the wing's angle of attack decreases. The dihedral of a wing should be enough to steady the plane and yet not so much as to reduce the lift capacity. In the model where the dihedral angle is high (model 4), the wing remains somewhat stable because the dihedral does not make up the entire length of the wing.

ACTIVITY ANSWER (CONT.)

Student Handout Questions

1 Describe the behavior of your team's models at each angle you tested. *Answers will vary.*

2 What are some variables that affect the flight behavior of the plane? *Some variables include wing angles, wind currents, and differences in how the planes are launched.*

3 Compare the flight stability of the different angles you chose to test. At which wing angle(s) was the flight most stable? At which angle(s) does the plane fail to fly well? What may be the reason? *Models 2 and 3 will fly the best; model 1 will not fly as well because there is no dihedral angle, while model 4 will not fly well because the dihedral angle is too high.*

4 What may be causing any wind currents in the room? What effect may these currents have on the models? *The movement of students in and around each other in a gym or hallway will stir wind currents that may not be perceptible to the students but which readily affect the flight characteristics of the models.*

5 How can the effect of wind currents be determined in the launching area? *Test where no one else is testing, where there are no currents; then test where many students are testing, where there is a lot of air circulating. Observe how wind currents impact flight.*

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LINKS AND BOOKS

Links

NOVA—Wings of Madness
www.pbs.org/nova/santos
Read Santos's own account of his first balloon ascent, learn of his efforts to devise a compact personal aircraft, see a slide show of the Demoiselle, *and view other influential planes of Santos's era.*

Alberto Santos-Dumont
www.aiaa.org/content.cfm?pageid=428
Profiles the life of this early aviation pioneer.

Highlights in Aviation: Alberto Santos-Dumont, Brazil
www.smithsonianeducation.org/scitech/impacto/graphic/aviation/alberto.html
Outlines Santos's contributions as a pivotal innovator in the history of flight.

Books

Man Flies: The Story of Alberto Santos-Dumont, Master of the Balloon
by Nancy Winters.
Ecco Press, 1998.
Tells the story of how wealthy Brazilian heir Santos became interested in, and then abandoned, the development of human flight.

My Airships: The Story of My Life
by Alberto Santos-Dumont.
Dover Publications, Inc., 1973.
Explains, in Santos's own words, his work with balloons and dirigibles.

Wings of Madness: Alberto Santos-Dumont and the Invention of Flight
by Paul Hoffman.
Hyperion, 2003.
Chronicles Santos's triumphs, his brief decade of world fame, and his descent into despair.

Winging It

The wings on modern commercial aircraft are attached to the plane at a slight angle known as a dihedral. This angle allows the plane to achieve the lift it needs to fly, and at the proper angles, keeps the plane stable. This activity provides you an opportunity to experiment with how different dihedral angles and wing shapes affect plane flight.

Procedure

1 Use your "Airplane Template" handout to create a set of four models. When folding the front edge of your airplane, run your ruler over each fold to flatten the fold as much as possible.

2 You can use the gum eraser as a guide for the angles of the dihedral in models 2, 3, and 4. Once you fold the wings upward on those models, the airplane should sit level on a tabletop between the two erasers. Use your "Wing Angles" handout to help you create your four models.

3 You will test your planes at four different angles (0°, 10°, 20°, and 40°). On a separate sheet of paper, write down the four angles and note which one you think will work best and why.

4 Your goal is to find out which of the models has the most stable flight. Conduct 10 trials with your models. Describe the behavior of your models on a separate sheet of paper.

5 After completing your trials, compare the behavior of your models to the behavior of models tested by other teams, then answer the questions to the right.

Questions

Write your answers on a separate sheet of paper.

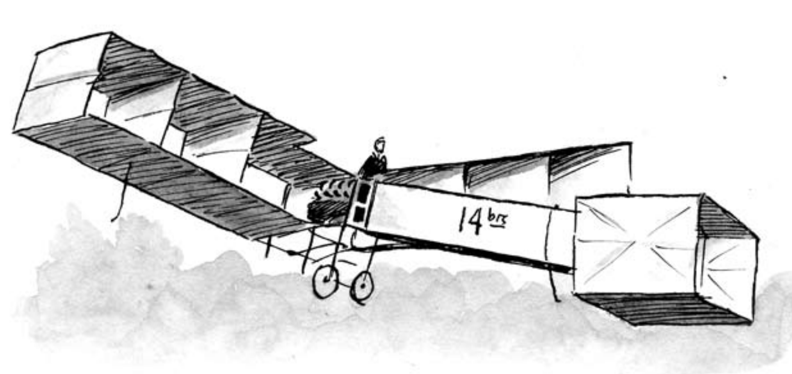
1 Describe the behavior of your team's models at each angle you tested.

2 What are some variables that affect the flight behavior of the plane?

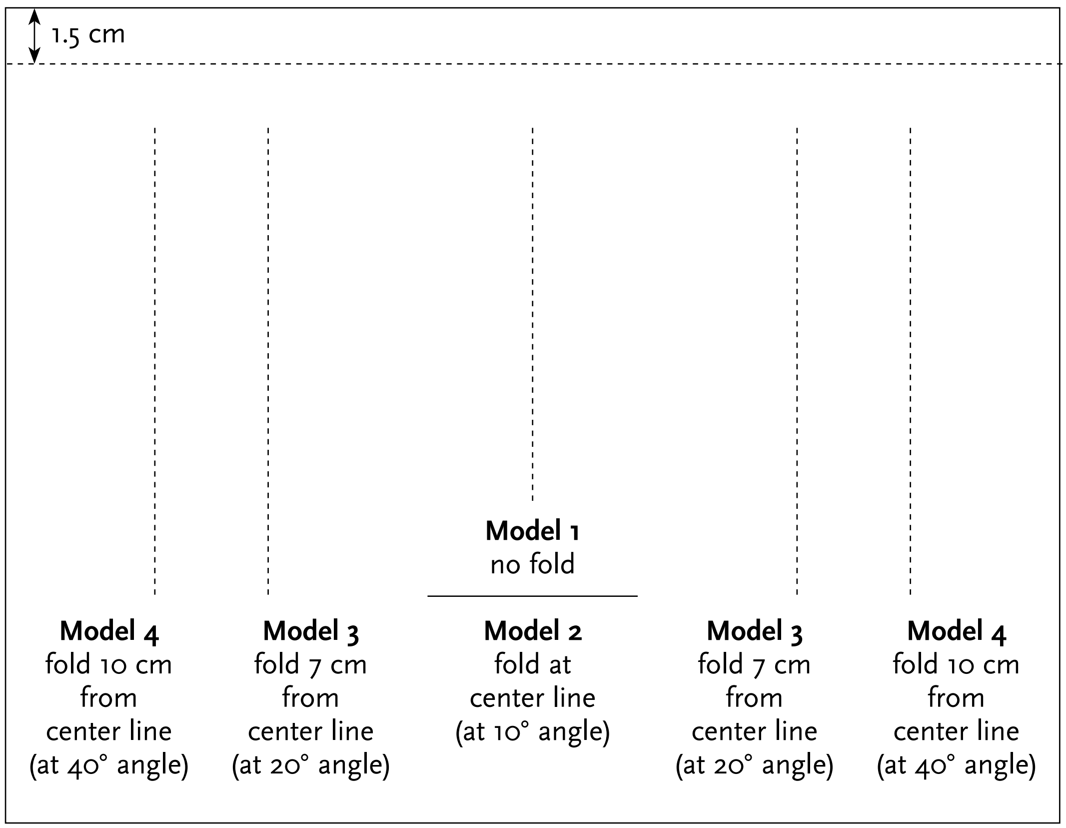
3 Compare the flight stability of the different angles you chose to test. At which wing angle(s) was the flight most stable? At which angle(s) does the plane fail to fly well? What may be the reason?

4 What may be causing any wind currents in the room? What effect may these currents have on the models?

5 How can the effect of wind currents be determined in the launching area?

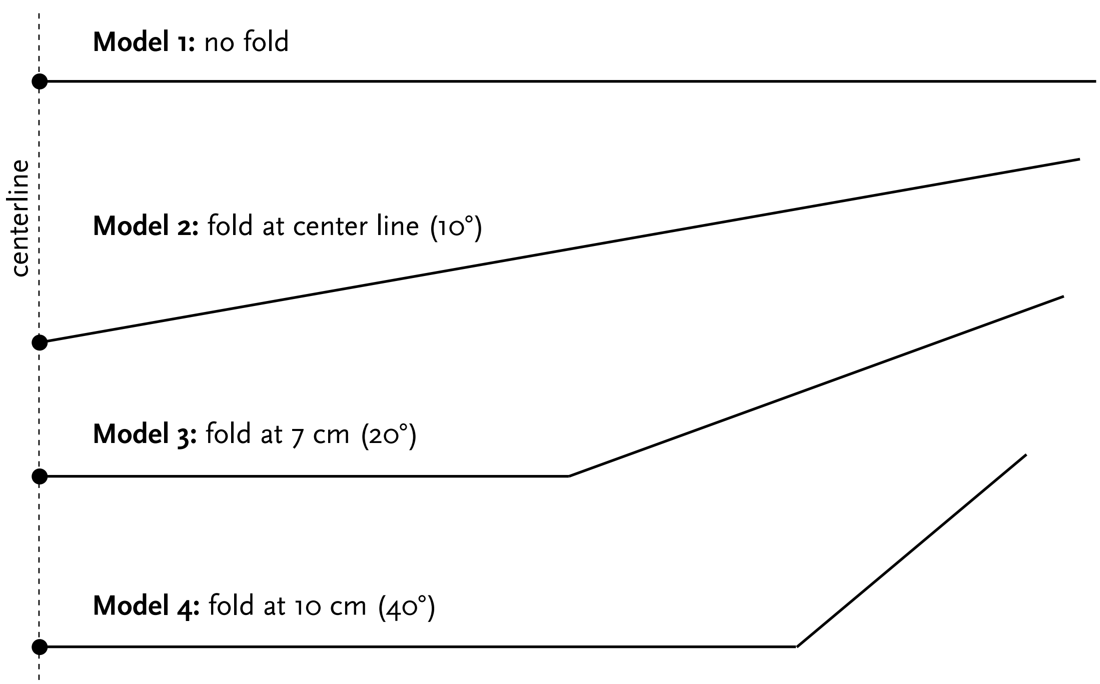


Airplane Template



Fold front edge back five times, creasing paper after each fold.

50 percent scale



100 percent scale