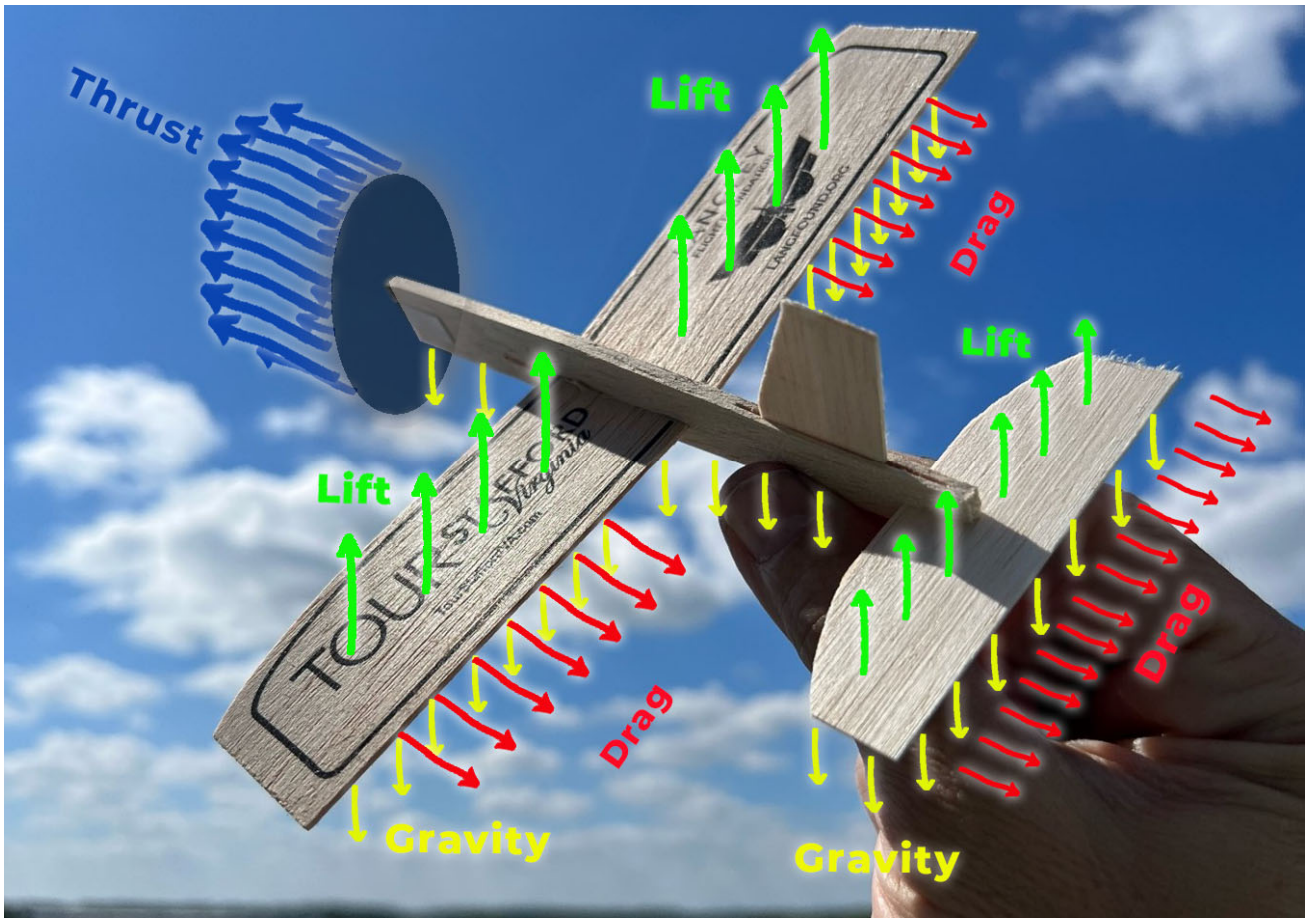
The Principles of Flight

The Langley Flight Foundation balsa airplane model shown below has been chosen as a general representative of an aircraft to illustrate the basic parts of an airplane and their functions.

Forces Acting on an Airplane

When traveling by air there are two primary directions we expect to be carried, forward and upward. Forward motion is generated by **thrust** from the airplane's engine(s). Upward motion is the result of **lift** produced by the airplane's wings. To achieve sustained flight, an airplane's lift force must exceed the force of **gravity** working to pull the airplane back to earth. As an airplane's speed increases, so does aerodynamic **drag**, the force of wind or air resistance pushing in the opposite direction.



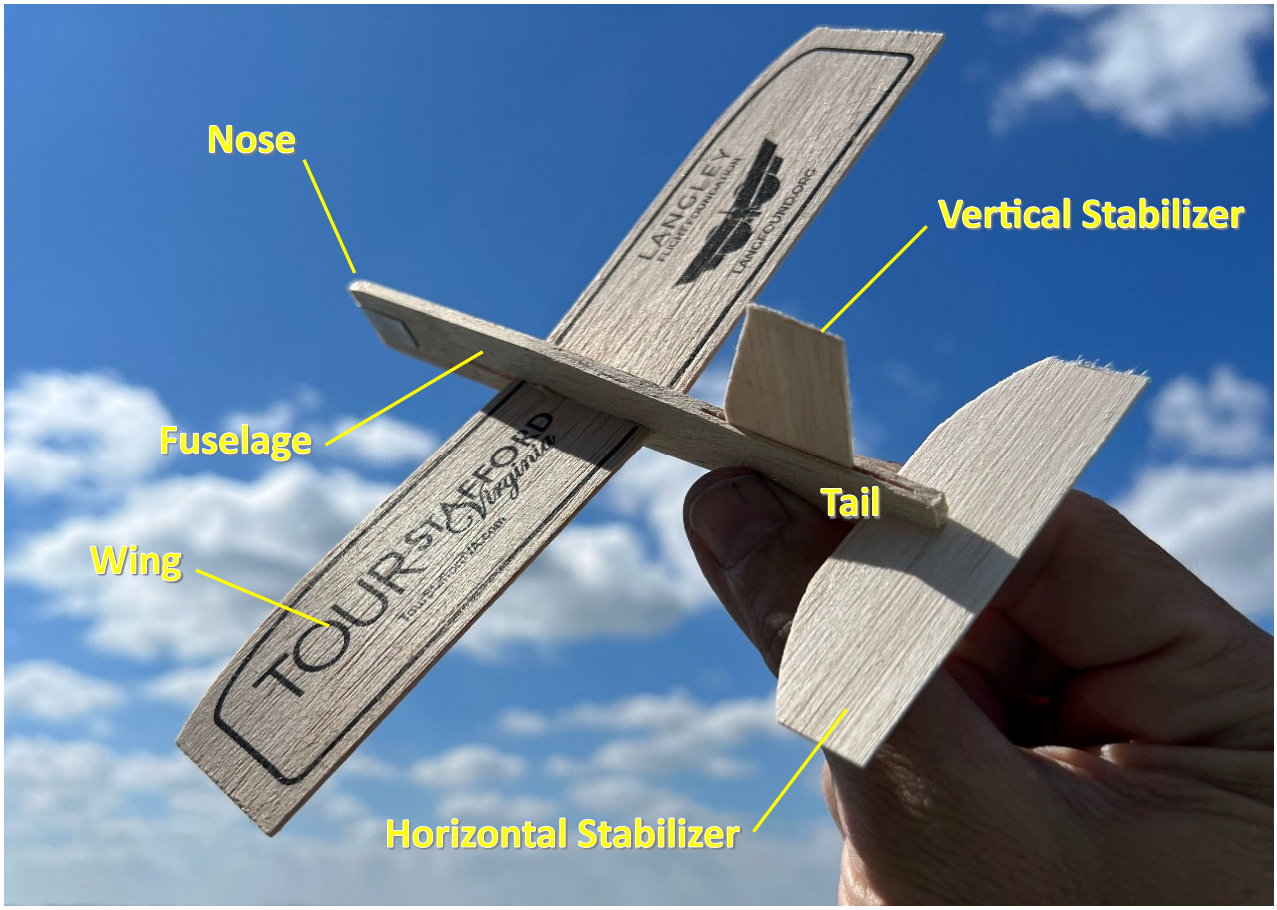
Basic Airplane Components

Fuselage - The fuselage, or body of the airplane, runs from the nose to the tail. It typically contains the cockpit, passenger and cargo compartments, and instruments needed to monitor and control flight. Some aircraft carry fuel in the fuselage and others carry it in the wings.

Wings - For an airplane to fly, it must overcome the force of gravity to lift the weight of the airplane, fuel, passengers, and cargo. Wings generate the lift required to get and hold the plane in the air. To create lift, the wings must be pushed through the air. As air passes over and under the wing, a pocket of lower pressure is generated above the wing compared to below the wing. This pressure differential causes the wing and the airplane rise. A pilot can cause an airplane to descend by reducing power to slow the aircraft. As speed decreases the wings produce less lift, and the airplane will descend when the lift force no longer equals or exceeds the force of gravity.

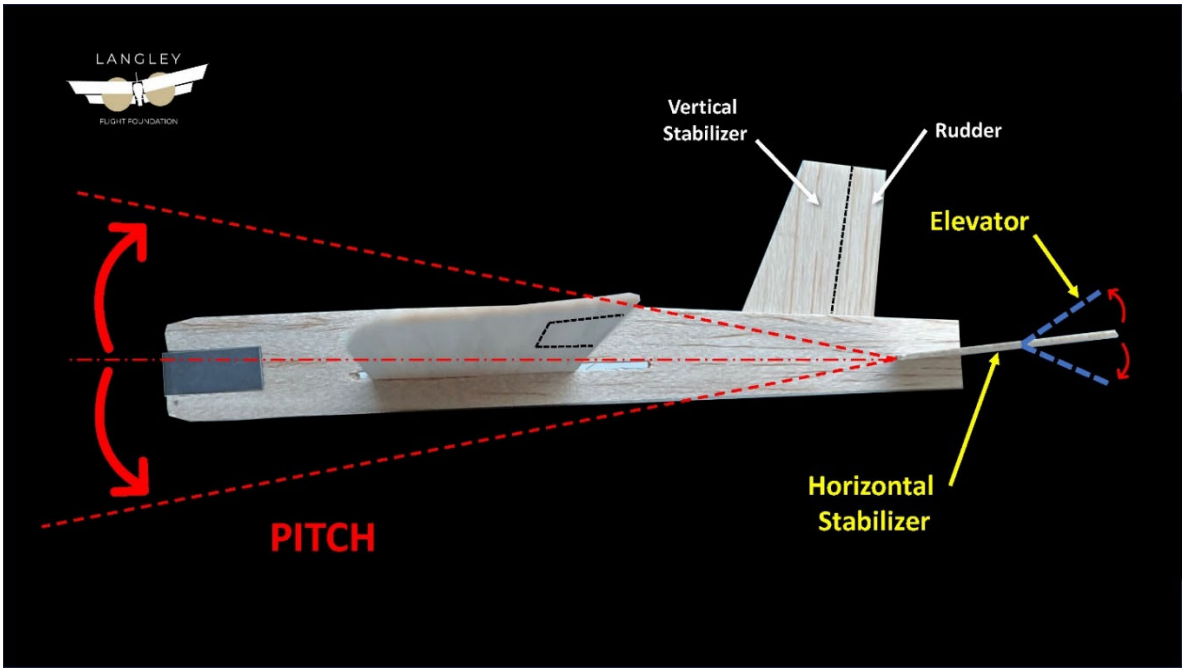
Engine – An airplane's engine generates thrust to propel the airplane forward. This horizontal motion allows the wings to generate lift. In the case of our glider, thrust is provided by the person throwing the airplane. Because no additional thrust is applied during its flight, the glider will eventually fall to the ground. This is because drag forces slow the glider to the point where the wing lift force no longer equals or exceeds the force of gravity.

Tail – Located at the rear of the fuselage, the tail typically includes a fixed horizontal plane, the horizontal stabilizer, and a fixed vertical plane, the vertical stabilizer. the force of wind or air resistance pushing in the opposite direction.

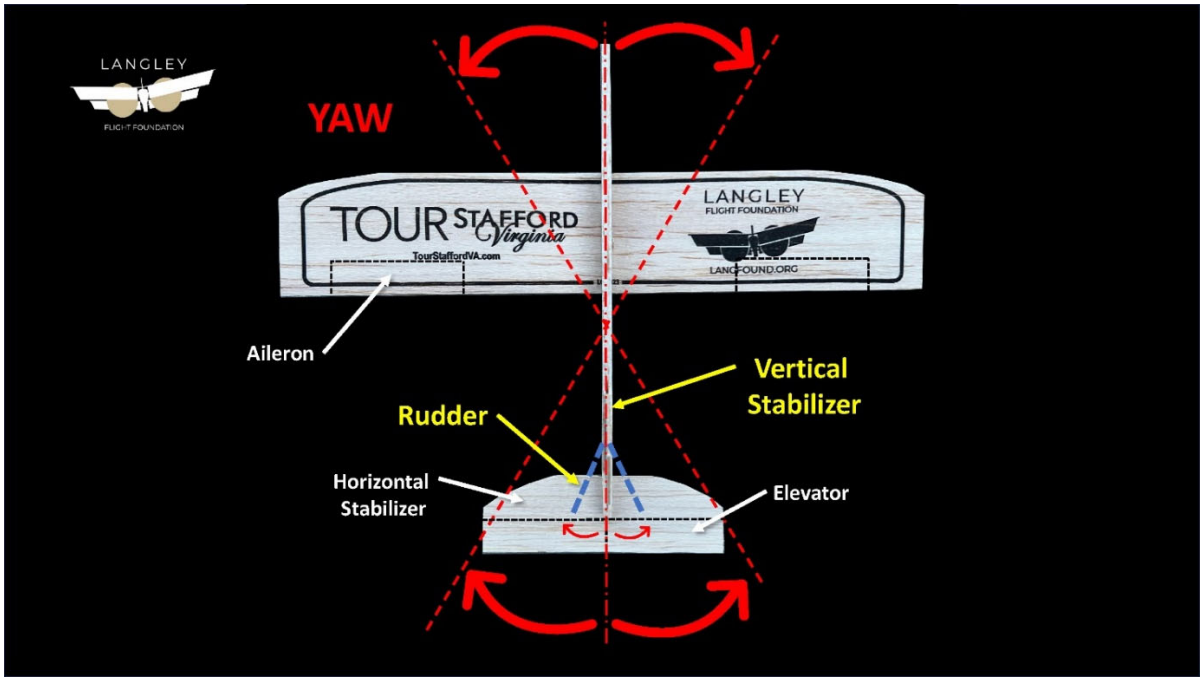


Basic Airplane Control Surfaces

Horizontal Stabilizer – The horizontal stabilizer is a smaller horizontal wing located at the tail of the plane. It provides additional lift for the aircraft, but its primary purpose is to control the vertical angle of attack, or pitch. At the edge of the horizontal stabilizers are moveable **elevators** (up and down) that work in pairs. By adjusting the elevators, the pilot can control the amount of lift generated by the tail, which changes the pitch of the aircraft. More lift at the tail pitches the nose down while less lift pitches the nose up.

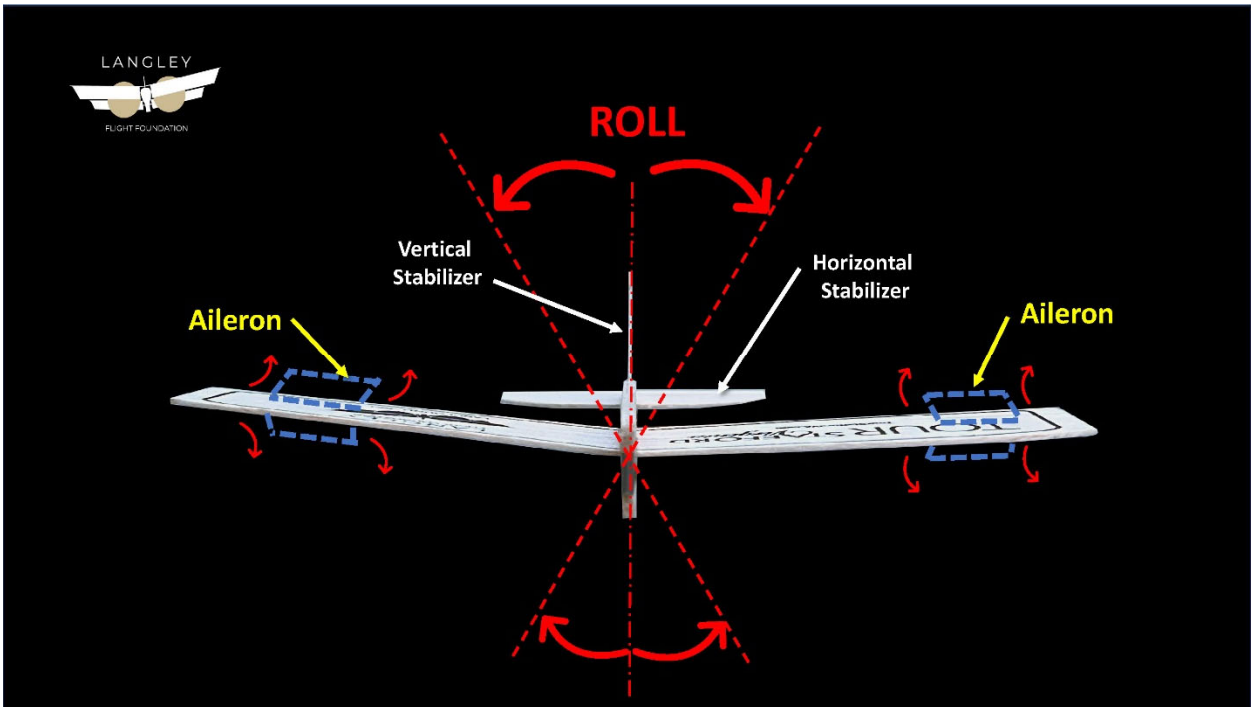


Vertical Stabilizer - The vertical stabilizer is a vertical wing located at the tail of the plane. Its primary purpose is to maintain an airplane's horizontal direction. An airplane's side to side motion is called yaw. Located at the rear of the vertical stabilizer is a moveable rudder.



The rudder is used to deflect the tail to the left and right. When the tail is deflected right, the nose of the plane moves left. When the tail is deflected left, the nose of the plane moves right.

Ailerons – Along the rear of the wings are small, hinged panels called ailerons. The ailerons are responsible for controlling an airplane's rotation around its front-to-back axis. This rotation is called roll. By adjusting the angle of the ailerons, a pilot can roll the wings from side-to-side and allowing the airplane to turn. The ailerons work in tandem in opposite directions. When the left aileron is elevated, the right aileron is depressed. In this configuration the left wing experiences reduced lift and the right wing increased lift, causing the airplane to roll or bank to the left.



Airplane Control Surface Experiments

The basic airplane control mechanics described above can be demonstrated using the Langley Flight Foundation glider and included adhesive tabs which simulate the function of the elevators, rudder, and ailerons of an airplane.

A. Baseline Flights

1. Construct the glider in accordance with the provided directions and conduct a series of throws using a repeatable technique.
2. Record the characteristics of each flight, including flight path, distance, and altitude on the Flight Test Worksheet.

   Purpose: To establish an understanding of normal flight characteristics to compare with subsequent flights with modified glider configurations.

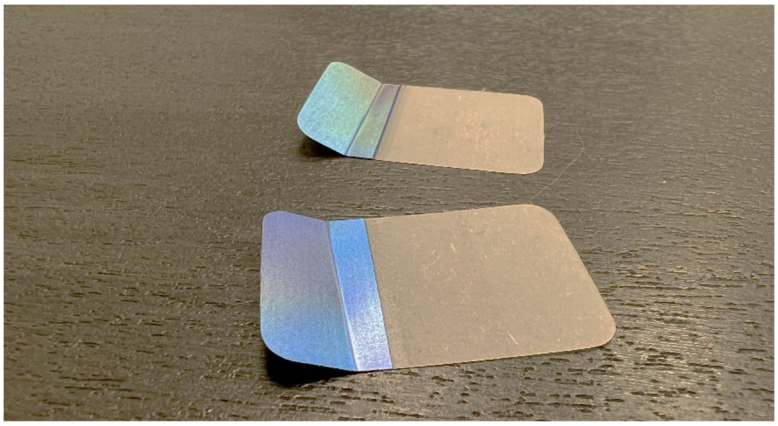
B. Stabilizer Function

1. Remove the vertical stabilizer and launch the glider. Record any changes in flight characteristics.
2. Replace the vertical stabilizer, remove the horizontal stabilizer and launch the glider. Record any changes in flight characteristics.

   Purpose: To observe and understand the function of the vertical stabilizer (maintaining straight flight) and the horizontal stabilizer (maintaining level flight).

C. Elevator Function

1. Create a ¼" flap at the non-adhesive edge of the provided adhesive tabs as shown below. The tabs should be bent upward to form a 15 to 30-degree angle.



2. Apply the tabs to the horizontal stabilizer as **elevators**, to the top of the trailing edge of the horizontal stabilizer as shown below. Launch the glider and observe and record any changes in flight characteristics.

Predicted flight path: Elevators up should result in an upward nose pitch

3. Repeat the experiment with the elevators attached to the bottom of the trailing edge of the horizontal stabilizer (pointing downward) as shown below. Launch the glider, observe and record any changes in flight characteristics.

Predicted flight path: Elevators down should result in a downward nose pitch

Purpose of experiment: To observe and understand the function of the elevators (changing the pitch or angle of attack of the glider). With the elevator installed at the top of the horizontal stabilizer the glider will pitch upward. This is the result of the elevator reducing the horizontal stabilizer's lift. With the elevator installed at the bottom of the horizontal stabilizer the glider will pitch downward. This is the result of the elevator increasing the horizontal stabilizer's lift. Additional launches can be conducted with adjustments to the angle of the elevators.

D. Rudder Function

1. Reusing one sticky tab elevator, simulate a rudder by installing the tab to one side of the trailing edge of the vertical stabilizer at a 15 to 30-degree angle. Launch the glider, observe and record any changes in flight characteristics.

Predicted flight path: Rudder left should result in a counterclockwise yaw

Predicted flight path: Rudder right should result in a clockwise yaw

2. Repeat the experiment with the rudder tab installed on the opposite side of the vertical stabilizer. Launch the glider, observe and record any changes in flight characteristics.

   Purpose of experiment: To observe and understand the function of the rudder (controlling yaw or the rotation around the vertical axis of the glider). With the rudder installed on the right side of the vertical stabilizer the glider's nose will turn to the right. With the rudder installed on the left side of the vertical stabilizer the glider's nose will turn to the left. The extension of the rudder to one side of the glider increases drag, creating a moment force which rotates the glider in flight. Additional launches can be conducted with adjustments to the angle of the rudder.

E. <u>Aileron Function</u>

1. Reusing both sticky tabs, simulate the ailerons on the outside of the trailing edge of the wings. The ailerons work in tandem to control roll and should be installed on opposite surfaces of the wings (one up, one down) as shown in the diagram below. Launch the glider, observe and record any changes in flight characteristics.

Predicted flight path: Roll to the left

2. Repeat the experiment with the aileron tabs installed in the opposite configuration on the trailing edge of the wings as shown below. Launch the glider, observe and record any changes in flight characteristics.

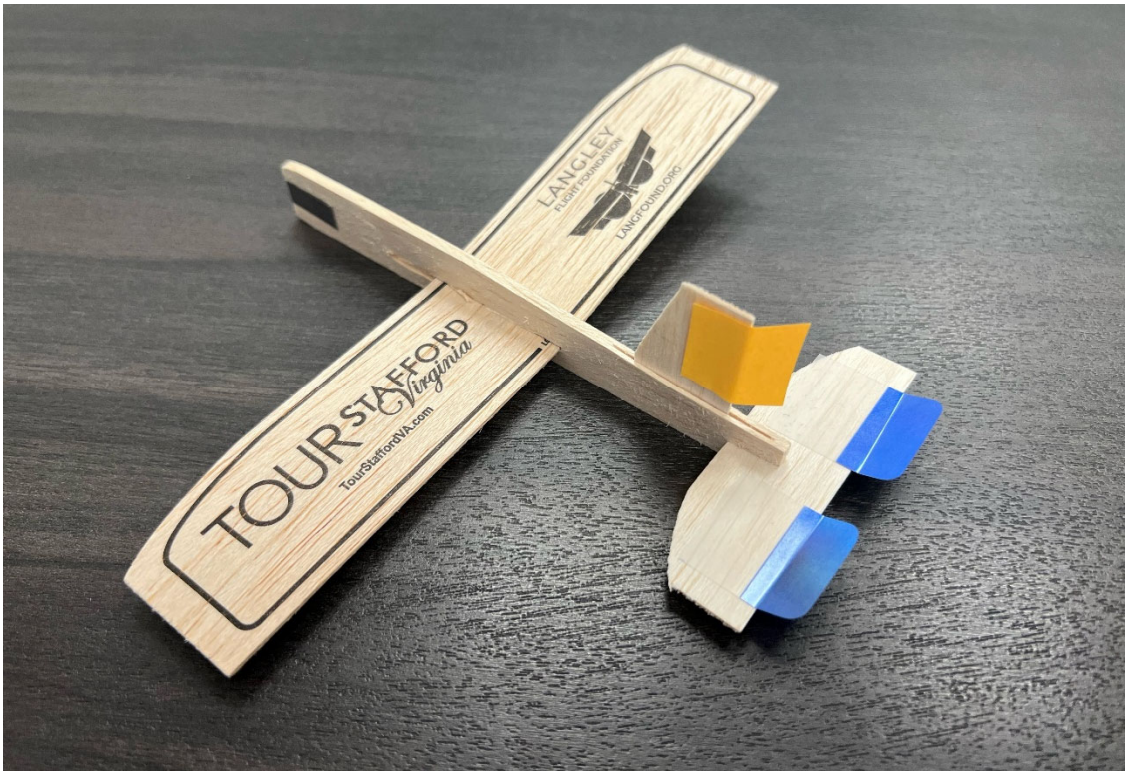
Predicted flight path: Roll to the right

Purpose of experiment: To observe and understand the function of the ailerons (controlling roll or the rotation around the front-to-back axis of the glider). With the aileron flap up on the left

wing and down on the right wing the glider will turn to the left. This is how a pilot turns an aircraft in flight. With the aileron flap down on the left wing and up on the right wing the glider will turn to the right. An aileron in the up-position decreases lift in the wing while lift is increased when it is in the down position. The glider rolls because higher lift on one wing relative to the other creates a rotational force around the axis of the fuselage. Additional launches can be conducted with adjustments to the angle of the ailerons.

F. User Defined Experimentation

1. Once the student has obtained a general understanding of the function of each of the glider's control surface, they can experiment with placing the sticky tabs in different configurations (see example below) and make flight characteristic predictions. Additional control surfaces can be made out of trimmed post-it-notes as shown below. Predict the flight path, launch the glider, observe and record whether the flight test followed the predicted characteristics.



Predicted flight path: The configuration above should result in an upward pitch and a clockwise yaw

Note to Parents/Educators: Without additional thrust added during flight, aerodynamic drag will reduce the speed of the glider until the lift generated by the wings can no longer support the weight of the glider. This is why the glider eventually falls to the ground. In each of the test cases above, additional drag forces are being applied to the glider to change its flight path, further reducing the glider's speed and flight distance. Students who have flown may recognize the pilot increasing the thrust of the engines as the pilot engages the ailerons to turn the plane. This is done to maintain speed and lift to counteract higher drag force events such as turning and rolling.

Dear Parents and Caregivers:

The Langley Flight Foundation and Stafford County Tourism are providing the enclosed balsa airplane and hands-on, aviation-based STEM activity to introduce students to the basic principles of controlled flight and scientific method learning. We hope you have a chance to participate in the activity with your child, ask questions, and encourage further independent experimentation!

You can provide feedback on this STEM activity using QR code below. Please like and follow the Foundation on Facebook and visit our website to help us improve this important initiative!

STEM Activity Feedback

Facebook
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Langley Flight Foundation Website

The Foundation's greater goal is to support Stafford County Schools in developing education pathways that can lead to careers in the aviation industry. Your student and school will be the first participants in Stafford County School's ACES event, sponsored by the Stafford Regional Airport, Germanna Community College, and the Langley Fight Foundation. With your support and feedback, we plan to grow this program to a wider group of Stafford County students in the years to come.

Chris Hornung
President, Langley Flight Foundation

The 2023 ACES event is sponsored by:

STEM and aviation career demonstrations will be provided by: