In order to understand aircraft behavior, it is important to first grasp some basic aerodynamics and also understand the effects of controls. Some controls have primary and secondary effects which I will discuss a little later. To begin let's first look at some basic aerodynamics for light aircraft.

For an aircraft to maintain stable straight and level flight it needs to be in a state of equilibrium, by this I mean it must maintain equal and opposite forces for the four forces acting on it in flight. These forces are:

- **Lift**
- **Weight**
- **Thrust**
- **Drag**

**Forces acting on an Aircraft in Flight**
If any of these forces change in magnitude the aircraft will no longer be in a state of equilibrium and will also no longer maintain steady straight and level flight. When lift exceeds weight the aircraft will climb, when weight exceeds lift it will descend.

When thrust exceeds drag the speed increases and so does the lift produced by the wings, when drag exceeds thrust the aircraft will slow down. Let me briefly describe more about these opposing forces in flight.

**Lift** opposes weight and is primarily produced by the wings, a wing or **aerofoil** has a curved upper and lower surface that impacts the air flow during flight. The upper surface usually has a slightly larger curve which accelerates the airflow over the top of the wing.

This acceleration of airflow is known as negative pressure, put simply it sucks air over the upper wing surface producing a component of lift. The lower surface usually has a much less curvature and is angled slightly nose up so when the airflow impacts this area it also produces lift, similar to having your hand out a car window on the highway angled upwards.

The airflow is known as the **RAF** or **Relative Air Flow** and this strikes the wing at a particular angle known as the **AoA** or **Angle of Attack**.

When you look at an aerofoil’s cross-section you can see the upper and lower curvatures and if you were to draw a line from the leading edge to the trailing edge, this is the chord line. The angle between the chord line and the **RAF** determines your angle of attack.
Below shows the the red line as the AoA and the black line represents the RaF. The red line is also an extension of the chord line. Here you can see how the chord line attacks the airflow producing lift.

**ANGLE OF ATTACK AND THE RELATIVE AIR FLOW**

Usually the higher the nose attitude the greater the lift since the air flow is meeting the wings at a much larger angle of attack. The greater the speed of the air flow and the higher the AoA, the more lift produced, but only up until a point!

Once you exceed a particular angle of attack (usually 16°) you reach what is known as the critical angle or the stalling angle. Anything greater will stall the wings so they can no longer produce lift. This loss of lift can be quite dramatic and in some cases you may even have a sudden and abrupt wing drop, but more on that in another tutorial.

Another aspect of lift comes from thrust which is of course produced by the propeller, this helps to augment lift in two distinct ways, first, while in a climb the slight nose up attitude is vectoring thrust down behind the aircraft offering an extra component of the total lift produced. You might say it is literally pulling the aircraft upwards.

Second the fast moving air running over the inboard section of the wings from the propellers slip stream increases lift in this area. This is due in part to the fact that the propellers slip stream or funnel of air is running faster that the air surrounding this funnel.
Another factor affecting lift is speed, as mentioned before, the faster you go the more lift generated by the wings. This is because you have more air molecules impacting the wing. When you fly slower these air molecules are less and so is the lift!

Flaps also augment lift by actually increasing the surface area of the wing and also increasing the wings angle of attack. This has two advantages, by increasing the wings surface area you end with more air molecules running over the wing resulting in extra lift, also a larger angle of attack also results in extra lift. The bonus is that all this can be produced at a much slower speed.

So in effect flaps give you greater lift at slower speeds, this is why we use them mainly for landing, but they are and can also be used for takeoff.

**Weight** is the affect gravity has on the aircraft, the heavier the aircraft the more lift you need to keep it aloft. When lift is greater than weight the aircraft will climb, when the amount of lift being generated by the wings equals the weight, the aircraft remain level and not climb nor descend.

When weight is greater than lift the aircraft will descend.

**Thrust** is what makes the aircraft move through the air. Thrust is produced by the propeller which in turn sends a fast moving parcel of air acting much like a funnel along and behind the aircraft. When the amount of thrust is greater than the amount of drag the aircraft is propelled forwards through the air.

The greater the amount of thrust, the faster the aircraft moves through the air. The aircraft will only reach a certain speed based on weight, engine power, aircraft design and also the amount of drag being produced. Because drag opposes thrust, the faster you go, the more drag you have on your airframe and this is also another factor that limits the aircrafts speed.
**Drag** is what slows down an aircraft in flight, it pulls in the opposite direction of thrust. There are several different types of drag that all have an impact of aircraft performance. Below briefly describes some kinds of drag:

**Induced Drag**

- **Induced drag** comes from lift, it is a byproduct of lift and is at its maximum at high angles of attack during slow flight.

**Parasite Drag**

- **Skin friction drag** comes from the aircraft's surface area, it is the air molecules pulling the aircraft in the opposite direction at the boundary layer (where the air meets the skin).
- **Form drag** is from appendages such as landing gear, wing struts, aerials, etc. They prevent the smooth flow of air around the airframe and this disturbed flow forms eddies that also pull the aircraft in the opposite direction to flight, much like running your hand through water, you see eddying behind your hand which pulls your hand back.
- **Interference drag** comes from junctions such as wing roots and strut beams adjoining wing sections, landing gear/fuselage sections etc.

Induced drag is sometimes counter-acted by the use of wingtip fairings or winglets as they are commonly known. Because the air on the upper surface of the wing has a span-wise flow that extends out to the tip and the underside also has air that flows towards the wingtip, a vortex forms at the tip which causes extra drag. It is much like a horizontal twister stretching out and behind the wingtip, winglets are designed to help minimize the drag produce from these vortices.

A drawback from speed is parasite drag, basically the faster you go the more drag produced. Parasite and induced drag together are known as total drag.
AIRCRAFT AXIS AND PLANES OF ROTATION

Aircraft pivot and rotate about three primary axis stations known as the longitudinal axis, lateral axis and vertical axis. It is important to understand each axis and how the flight controls affect each one. They all run through and intersect at a center point known as the CoG or centre-of-gravity.

Below briefly describes each axis:

LONGITUDINAL AXIS

The longitudinal axis as depicted by the red line runs from tip to tail and runs along the plane. The aircraft rolls about the longitudinal axis. The ailerons are the primary control surface to roll the aircraft about this axis.

The rudder can also roll the aircraft about this axis but that is a secondary effect, I will explain this lateron in effects of control.
**Lateral Axis**

The lateral axis runs across the plane from wingtip to wingtip, and the aircraft pivots either nose-up or nose-down about this axis, this is known as pitch. The **elevator** is the primary control surface for making the aircraft pitch about the lateral axis or plane of rotation.

**Vertical Axis**

The Vertical axis also known as the **Normal Axis** runs in a vertical plane through the aircraft from top to bottom. The aircraft yaws about this axis. The **rudder** is the primary control surface that **yaws** the aircraft about this axis. Yaw is a left or right movement in the horizontal plane.

The secondary effect of yaw is **roll**.
EFFECTS OF CONTROL

There are several control surfaces on an aeroplane. The main ones function to control the aircraft about its axis or planes of rotation. Below describes each control surface and their primary and secondary effects.

ELEVATOR

The elevator controls pitch, it generally incorporates a trim tab that enables the pilot to release control pressure on the stick or yoke. Back elevator produces a nose up pitching moment and down elevator (stick forward) produces a nose-down pitching moment. Neutral elevator normally provides straight and level flight. The secondary effect of pitch is a change in airspeed.

Sometimes the horizontal stabilizer is the elevator, in this case it is known as a stabilator. The elevators may also simply be a set of hinged control surfaces attached to the back of the horizontal stabilizer like a pair of flippers!
AILERONS

The ailerons are responsible for banking the aircraft. They are the first control you use to turn and bank left or right, their secondary effect is yaw. When one aileron pivots up on one wing the other does the opposite. The down-going aileron creates extra lift on the outer aspect of that wing while the up-going aileron reduces lift on the opposite wing.

The secondary effect of yaw is cause by the increased drag from the down-going aileron. Because this side of the wing is producing extra lift, it is also producing increased drag, (induced drag) and this tends to pull the aircraft into that wing. This is known as adverse aileron yaw.

This is also why you require some rudder during turns to keep the aircraft properly aligned with the longitudinal axis during the turn.

This simply means a left turn requires some left rudder and a right turn requires some right rudder. So long as you fly with the ball centered on the TC turn (co-ordinator) you have the aircraft aligned with the longitudinal axis and it is a balanced turn.
**RUDDER**

The rudder yaws the aircraft in the horizontal plane. It makes the aircraft yaw left or right. Its primary effect is yaw and its secondary effect is roll.

This is because it first yaws the aircraft into the oncoming airflow, almost like a skidding flat turn, what happens next is that the into-wind wing is traveling faster than the other wing. As speed increase lift, the wing that is traveling faster offers more lift than the other and thus it will eventually roll the aircraft into the direction of turn.

Be aware also that the rudder is only the movable section hinged to aft section of the vertical stabilizer, many people believe the complete fin is the rudder.

![Rudder Diagram]

**SUMMARY OF CONTROL EFFECTS**

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ABBREVIATIONS AND EXTRAS:

AEROFOIL - A WING

AOA - ANGLE OF ATTACK

RAF - RELATIVE AIRFLOW

THRUST - PROPELS THE AIRCRAFT THROUGH THE AIR

DRAG - ACTS IN THE OPPOSITE DIRECTION OF TRUST

PITCH - NOSE HIGH OR LOW ATTITUDE

BANK - ROLL

YAW - A TURNING MOMENT IN THE FLAT PLANE

MOMENT - A TURNING ACTION ABOUT AN AXIS

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