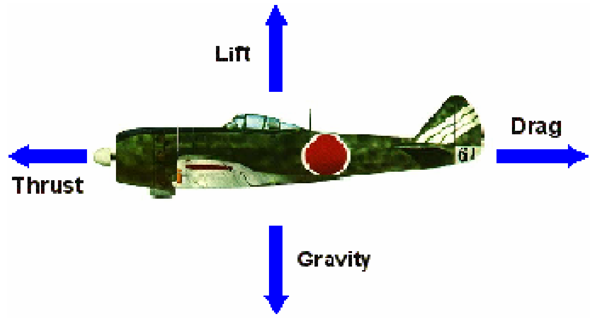
Dynamics of Aces High Flight

by Hammer

Your plane has four basic forces working on it during flight –Thrust, Gravity, Drag, and Lift.



Lift and Thrust are your friends while Gravity and Drag usually work against you but can help in some situations.

Thrust is produced by your engine. It is directed directly back from the propeller. In a propeller driven plane, it is created by the propeller pushing air to the rear of the plane. In a jet, it is created by accelerating the exhaust created by burning the fuel and discharging it to the rear. Thrust pushes (or pulls) your plane forward and thereby creates lift for the wing by generating airflow over it. The amount of thrust produced by your engine can be controlled by the manifold pressure (throttle) or by adjusting the RPMs. Aircraft engines produce different amount of thrust at different altitudes, and some planes' engines are optimized at different altitudes than others.

Gravity (weight) is the pull of the earth on objects. It is the weight of the plane and is always directed towards the center of the earth. Don't confuse this force with centrifugal force, which is what causes you to "pull G's" during a maneuver. Gravity acts on all planes equally at all times.

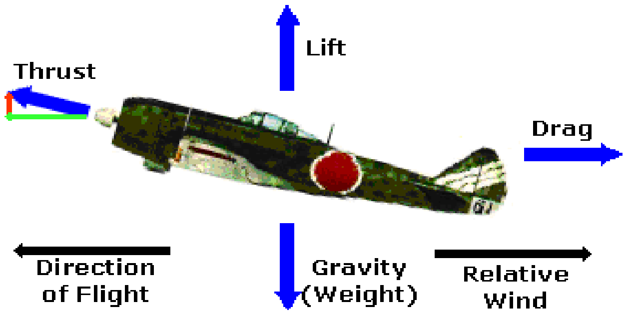
Drag is the resistance of air against the surfaces of your plane. It will always be directed opposite the direction of travel. Because air is less dense at higher altitude, drag decreases at altitude. The force of drag on your plane increases with speed until it cancels out your plane's thrust. When this happens, you have reached your maximum speed. Some planes are much more aerodynamic than others, meaning they have less drag. This can help them go faster and hold energy more efficiently, but it can sometimes cause problems trying to reduce speed if you need to do so in a hurry.

Lift is generated by the wing as it moves through the air. It will always be directed perpendicular to the direction of travel when looking from the side and perpendicular to the leading edge of the wing when looking at the plane from the front. The faster a wing is moving through the air, the more lift is generated by that wing. The second major factor for producing lift is the "Angle of Attack" which is discussed in more detail below.

Force Vectors

In discussions about maneuvering your plane, you will often hear the term "vector" and in particular "lift vector". A vector is a depiction of the direction a force is acting on something. The blue arrows in the picture at the top of this page depict the force vector of each of the forces acting on the plane while it is in flight. For the purpose of almost all discussions of the forces acting on your plane, think of the force vector as acting on the plane's center of gravity.

As discussed above, all of the force vectors act relative to a part of the plane, the direction of travel, or to the center of the earth. The most basic concept in understanding force vectors is they must cancel each other out in order to maintain constant speed level flight. In the picture at the top of the page, Thrust is equal to Drag and Lift is equal to Gravity (weight). In the picture below, however, it is not as simple.

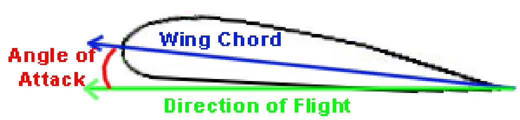


Imagine this plane flying at extreme low speed but maintaining level flight at constant speed. As the speed lowered, the pilot was forced to put his nose up in order to maintain level flight. This creates more lift by increasing the Angle of Attack of the wing (discussed in more detail below). In this nose-up attitude, Gravity is still pulling the plane straight down towards the center of the earth, Drag is still working opposite of the direction of flight, and Lift is still being generated perpendicular to the relative wind. Thrust, however, is now working in a different direction.

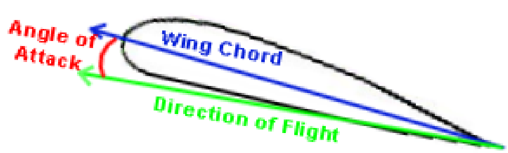
As discussed above, the forces acting on a plane must cancel each other out in order for the plane to fly at a constant speed and altitude. Since Thrust is no longer acting exactly opposite to drag, it is useful to break it into components. In this case, Thrust can be broken into a horizontal component (the green line) and a vertical component (the red line). In level, constant-speed flight, the horizontal component of thrust is equal in magnitude to drag. Lift **+** the vertical component of thrust are equal in magnitude to Gravity.

Angle of Attack, Indicated Air Speed, and Lift

Besides giving a vertical component to thrust, lifting the nose of the plane increases the Angle of Attack of the wing which increases the lift produced by the wing. The Angle of Attack is the angle at which the chord of the wing meets the relative wind. The chord is the line between the leading edge and the trailing edge of the wing. As mentioned above, the relative wind is opposite your direction of flight and equal in force to your indicated air speed.



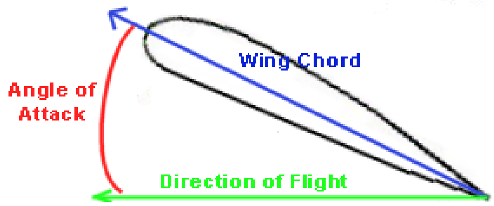
It is important to note the relative wind does not have to be level with the ground. In the pictures below, the wing on the left is in level flight while the wing on the right is climbing at a constant rate and speed. Both wings have the same Angle of Attack.



The two main factors affecting how much lift any given wing produces are indicated airspeed and the Angle of Attack of the wing. Indicated airspeed is important because it takes into account the density of the air as it changes with altitude. The faster the wing moves through the air, the more lift it produces. However, the thinner air at high altitudes produces less lift for a given “true” airspeed than the thicker air at sea level. This difference is accounted for in the indicated airspeed.

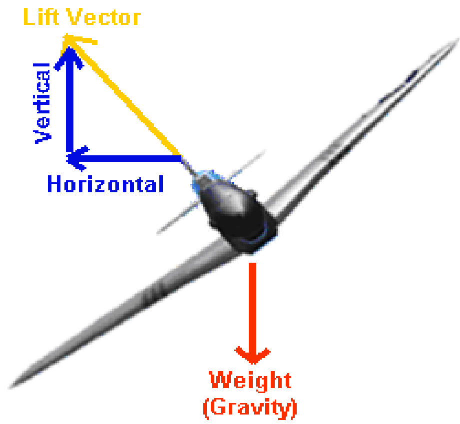
As an aircraft's speed decreases, Lift decreases unless the Angle of Attack is increased. The Angle of Attack can be increased until the wing reaches its "critical angle". This is the Angle of Attack at which airflow over the wing is disrupted to the point that lift is no longer produced. At this point, the wing stalls. The critical angle varies with speed, weight of the plane, and wing design. The Angle of Attack is increased by using the elevator to increase the pitch of the aircraft.

In order to maintain level flight, you must increase the AoA as speed decreases and vice versa. This is why you must raise your nose as you slow down and lower your nose as you speed up if you want to maintain the same altitude.

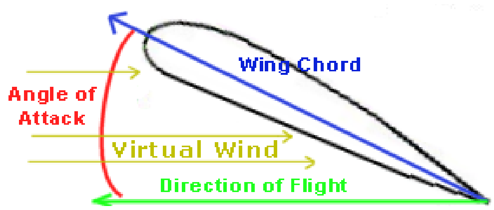


Lift Vector, Angle of Attack, and Maneuvering

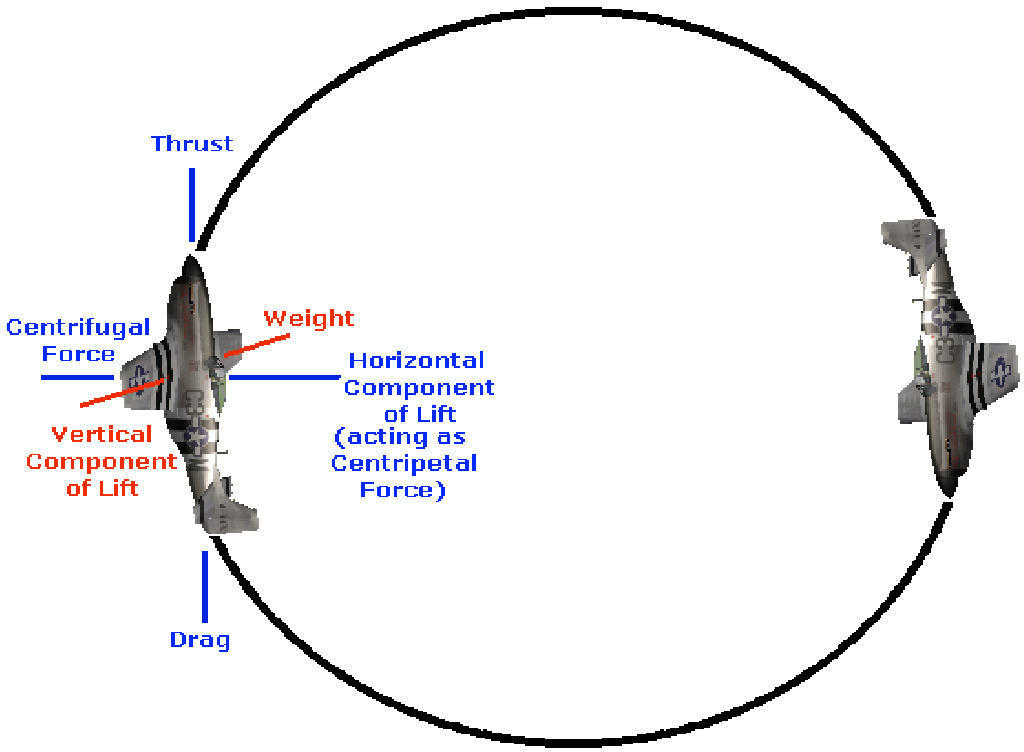
Lift vector is the force vector you will discuss the most when talking about maneuvers. That is because almost all maneuvers are done by manipulating your lift vector and increasing the wing's Angle of Attack. To turn your plane, you first roll your wings so the lift vector is pointed towards the direction you want to go as in the picture below.



By rolling your wings, you change the direction of your lift vector. You can now divide this vector into a horizontal component and a vertical component as shown in the image above. In order to maintain a level turn, the vertical component must equal the weight of the plane. The horizontal component causes the plane to turn. Both components can be increased by applying up elevator to increase your wing's Angle of Attack. This increases the lift vector which in turn increases both the horizontal and vertical components. It also exposes more of the wing to the virtual wind which increases drag and causes you to slow. The higher the angle of attack, the more drag must be overcome because more of the wing (and the other surfaces of the plane) is exposed to the virtual wind.



Besides the four forces always experienced by a plane in flight, a turning plane experiences a virtual force know as *Centrifugal Force*. Centrifugal force does not actually exist, but objects moving in a circle act as thought it does. This is the force that causes you to “Pull G’s”.



“Pulling G’s”

While gravity is a constant force acting on your plane at all times, maneuvering your plane often causes you to “pull G’s”. As noted above, pulling G’s is the result of Centrifugal Force. The University of Virginia’s “Phun Physics” website describes Centrifugal Force like this:

“An object traveling in a circle behaves as if it is experiencing an outward force. This force is known as the centrifugal force. It is important to note that the centrifugal force does not actually exist. Nevertheless, it appears quite real to the object being rotated.”

In level flight, you are at 1 G. When you pull back on your stick, you pull positive G’s. At 6 G’s, you black out. This blackout is preceded by a “grayout”, which is a gradual narrowing of your field of view.

Pushing forward on your stick causes negative G’s. At about 1 negative G, you will red out. Holding at 0 G’s will give your plane its best acceleration.

Stalls

A stall occurs when the airflow over the wing is disrupted to the point that the wing no longer produces enough lift for controlled flight. Stalls are most often associated with getting too slow but may actually occur at any speed. Technically, a stall occurs when the wing exceeds its critical angle of attack. This can be caused by raising the nose in an attempt to maintain level flight at low speeds or by an excessively abrupt maneuver at higher speeds. Any stall caused by a maneuver when flying above stall speed is sometimes called an accelerated stall. Most stalls can be recovered by lowering the nose or increasing throttle. Failure to recover from a stall quickly can result in a spin.

Compression

The last flight dynamic we will discuss is compression. Compression occurs when the air moving over your control surfaces “locks” them so they do not respond. This phenomenon happens at different speeds in different planes. Altitude also affects the speed at which compression occurs with compression setting in sooner at higher altitudes.

In some planes in Aces High, the Combat Trim function can make it seem like you are experiencing compression even if you are not. This is because combat trim tries adjusts your trim for level flight at whatever speed you are going. In some planes, most notably the Bf 109 series, the combat trim will be full down at high speeds. While this keeps you in level flight, it also keeps you from being able to pull out of a dive. To counter this, you must trim up to at least center and preferably trim up. Adjusting trim also helps when you are experiencing true compression.

If you find yourself in a steep dive and your controls won’t respond, reduce throttle, trim up, and use your rudder to skid and hopefully slow you down enough that you regain control.