Stability, Controllability and Maneuverability
By Richard Skiba

Looking around any airfield, we can always find a variety of different aircraft. Some have a high wing, some have a low wing, some with T-Tails and many other configurations. This article will consider the role and effects of the various configurations on the stability, controllability and maneuverability of aircraft. As such, a pilot who is about to get into an aircraft that they have never flown before will have an idea of what to expect in the handling of that aircraft by making some observations about its design.

During normal flight an aircraft is subjected to forces which cause it to deviate from its normal horizontal path of flight. These forces may be generated by weather conditions such as rising hot air or down drafts or any other changing weather condition. The term stability refers to the aircraft's tendency to remain straight and level in flight and it's tendency to return to this attitude if disturbed. As such, the stability of an aircraft depends on how it reacts if a wing, nose or tail drops without corrective action from the pilot. In other words, what the aircraft will do if the pilot does not try to bring it back to its original attitude.

Stability may be defined as static and dynamic; Static referring to the initial tendency of the aircraft to return to its original position once disturbed, dynamic stability referring to the overall tendency, after a series of dampened out movements, to return to its original position. Likewise, stability may be defined as positive, neutral or negative stability. An aircraft with a positive stability develops forces which restore it to its original position. Neutral stability implies that the aircraft will not move further away from its original attitude nor move back to it. A condition of negative stability, or instability, tends to develop forces which move it further away from its original position. On this basis, an aircraft which oscillates increasingly after a disturbance, to the point where a stall or dive may result, is considered to have negative dynamic stability.
A stable aircraft will be easy to fly as it has a tendency to return to straight, level and upright flight. The trade-off for this stability, however, lies in the maneuverability which is hampered by the tendency to return to the straight, level and upright attitude. The pilot has to overcome the corrective tendency to change the attitude of the aircraft to maneuver it into the desired attitude, which would be easier with a less positively stable aircraft. Aircraft designers may build in varying levels of static and dynamic stability to achieve a comfort level in maintaining straight and level flight whilst maintaining a suitable level of maneuverability. As an example, this may mean having positive dynamic stability and negative static stability. The stability may vary in the longitudinal, lateral and directional axis dependant on the design of the aircraft, which incidentally may be changed by altering the position of the centre of gravity.

Longitudinal stability refers to pitch stability, or stability around the lateral axis of the aircraft. This type of stability is normally achieved by designing a nose heavy aircraft. As such, should the engine fail (assuming single engine, the aircraft will automatically assume a normal glide as the centre of gravity is ahead of the centre of pressure. The tailplane of the aircraft resists this diving tendency in normal flight.
**Longitudinal Stability**

The tailplane which produces a negative lift in straight, level and upright flight balances out the nose heaviness of the aircraft. The longitudinal stability, therefore, is affected by the size and position of the horizontal stabilizer and the position of the centre of gravity.

The horizontal stabilizer, or tailplane, is located at the end of the fuselage and can therefore act as a lever, and being at the end of a lever arm it has large leverage. In the situation where the angle of attack is increased by some disturbance, the centre of pressure moves forward and the result is that the nose tends to pitch up. The tailplane correspondingly moves down and its angle of attack is increased. Increasing the angle of attack on the tailplane generates more lift at the end of the lever and thus restores balance.

Centre of gravity also plays it's part in longitudinal stability. If the aircraft is loaded such that the centre of gravity is too far aft, it will fly with a nose up attitude if not corrected with down elevator. In this situation, the aircraft will be difficult to control in the longitudinal axis.

**Lateral Stability**

Rolling, Wing up/Wing down - movement around the longitudinal axis
Lateral Stability refers to the roll stability, or stability around the longitudinal axis. There are four main ways in which lateral stability is achieved and the first of these is dihedral. This is the angle that each wing makes with the horizontal.

If one wing drops, the unbalanced force produces a sideslip in the direction of the downgoing wing, causing a flow of air in the opposite direction to the slip. The airflow will then hit the lower wing at a greater angle of attack than the upper wing. As such, the lower wing will have greater lift and the aircraft will roll back into its straight, level and upright position. The dihedral also slopes the wing from the vertical and therefore reduces the lift reaction. Too much dihedral will reduce the lift which opposes weight. The second method of controlling roll stability is keel effect which is used in high wing aircraft (dihedral is usually a characteristic of low wing aircraft). Most high wing aircraft are laterally stable since the wings are attached above the weight. If one wing drops, the weight which is low above the high wing acts as a pendulum to return the aircraft from the roll.

Swept back wings are the third method of controlling this type of stability. In a swept back wing the leading edge of the wing slopes backwards. Should the aircraft drop a wing, the dropped wing presents its leading edge at an angle that is perpendicular to the relative airflow. The low wing then has more lift than the high wing and rises to restore straight, level and upright flight. The final contributor to lateral stability is proper distribution of weight, as with all other types of stability.
The last aspect of stability to consider is about the normal axis, or directional stability. This is primarily controlled by the vertical tail surface by means of the fin and the tail rudder. If the aircraft yaws away from its straight ahead course, the wind hits the side of the tail fin and pushes it back on course. The side area behind the centre of gravity must be greater than the side area before it for this principle to work properly.

From what has been said above, it may be noted that an aircraft which does not have a tendency to generate a restoring force from a pitch up or down, that is one with reduced longitudinal stability, will require a lot of control inputs from the pilot to maintain straight level and upright flying. The pilot will need to constantly correct pitch with the elevator as the lack of longitudinal stability will not allow the aircraft to correct itself to the original attitude.

In a similar way, an aircraft with reduced directional stability, will require constant input from the pilot to correct yaw by using the rudder. Yaw may be generated by not only turbulence but also changes in power that cause changes in the slipstream over the vertical stabiliser. Finally, an aircraft which lacks lateral stability requires constant input to the ailerons to control the roll of the aircraft.

So why are different levels of controllability, stability and maneuverability built into aircraft? It all depends on the designer's and manufacturer's purpose for the aircraft. As an example, military aircraft would favor a high level of maneuverability, thus will less stability, than civil aircraft where most flight is straight level and upright. Private pilots are able to select from a large variety of aircraft on the market to find one which is suited to their flying requirements. To really know the best type of aircraft for a pilot, he/she would best be served by flying a variety of types and observe the differences between them, which at times can be quite subtle.
The main source of information for this article was a web page posted at http://www.allstar.fiu.edu/aero/axes33.htm, which is part of the NASA sponsored site run by the 'Aeronautics Learning Laboratory for Science, Technology and Research'. This site contains a lot of valuable information for all who are interested in aviation with galleries, links, a research section and on-line lessons. The lessons are broken down into three areas: Principles, History and Career, and within each of these areas there are lessons at levels 1, 2 and 3 (1 being the most simple and 3 being the most complex). Those with access to the internet who would like to learn more about the technical aspects of aviation will not be disappointed with the site.

Safe Flying.

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