Since the early days of flight, angle of attack (AOA) has been a key aeronautical-engineering parameter and is fundamental to understanding many aspects of airplane performance, stability, and control. Virtually any book on these subjects, as well as basic texts and instructional material written for flight crews, defines AOA and discusses its many attributes.

AOA can be used for many indications on the flight deck to improve flight crew awareness of airplane state relative to performance limits. Dedicated AOA indicators have been used on military aircraft for many years, but this form of display has not been used often on commercial airplanes. On Boeing models in current production, AOA is used to drive stall warning (stick shaker), stall margin information on airmass indicators, and the pitch limit indicator (PLI) on the primary attitude displays. AOA information is combined with other data and displayed as an integral part of flight deck displays.

Recent accidents and incidents have resulted in new flight crew training programs for upset recovery and terrain awareness, and these in turn have heightened industry interest in AOA as a useful flight parameter for commercial aviation.

AOA is one of the most important parameters for understanding airplane performance and handling (see "What Is Angle of Attack?" on p. 13) because a typical wing has a limited range of angles of attack over which it can function efficiently. In its simplest form, lift is a function of speed, air density, wing area, and AOA. At a given airspeed, as the AOA of a wing is increased, lift will also increase (fig. 1). Therefore, at the same airspeed, a heavy airplane of the same configuration must fly at a higher AOA than a light one. Conversely, as an airplane decelerates, the AOA must be increased to maintain the same lift. So, in the normal operational range, there is a relationship among lift, speed, and AOA.

This relationship will change if the AOA gets too high (fig. 1). The airflow over the wing will separate from the upper surface, resulting in a loss of lift, or a stall. It should be noted that this stall condition could occur at a wide range of speeds (depending on the airplane weight or load factor, or g loading) and at any attitude (depending on the flight path angle). What is important is the AOA. Therefore, it is imperative to know when the wing is approaching the stall AOA and to take steps to avoid it.

However, many other parameters influence the lift that a wing produces. The most basic is the configuration of the wing, specifically the position of the trailing-edge flaps, leading-edge flaps or slots, and spoilers. As the trailing-edge flaps are extended, the curvature (or camber) and area of the wing are increased, and the wing will produce more lift at the same AOA (fig. 2). Note that although the maximum lift is increased, the AOA at which stall occurs is actually less because the wing cannot sustain the higher lift levels up to the same AOA. The airflow separates earlier.

Wing-mounted speed brakes or spoilers have the opposite effect. They reduce the lift at a given AOA, lowering the leading edge and trailing edge at some average point on the wing. Most commercial jet airplanes use the fuselage centerline or longitudinal axis as the reference line. It makes no difference what the reference line is, as long as it is used consistently.

AOA is sometimes confused with pitch angle or flight path angle. Pitch angle (attitude) is the angle between the longitudinal axis (where the airplane is pointed) and the horizon. This angle is displayed on the attitude indicator or artificial horizon.

Flight path angle is defined in two different ways. To the aerodynamicist, it is the angle of the flight path vector (where the airplane is going) and the local atmosphere. To the flight crew, it is normally known as the angle between the flight path vector and the horizon, also known as the climb (or descent) angle. Airmass-referenced and inertial-referenced flight path angles are the same only in still air (i.e., when there is no wind or vertical air movement). For example, in a headwind or sinking air mass, the flight path angle relative to the ground will be less than that referenced to the air. On the newest commercial jet airplanes, this angle can be displayed on the primary flight display and is calculated referenced to the ground (the inertial flight path angle).

AOA is the difference between pitch angle and flight path angle when the flight path angle is referenced to the atmosphere. Because of the relationship of pitch angle, AOA, and flight path angle, an airplane can reach a very high AOA even with the nose below the horizon, if the flight path angle is a steep descent.