TECH TIME

Helpful tips for the Avionics Technician

BY AL INGLE

Last month we explored the early development of the core technologies of an aircraft autopilot - the closed feedback loop and the gyroscope. To better understand *why* an autopilot performs as it does, a basic comprehension of the aerodynamics of an aircraft is needed and that is the topic covered in this article. While an *aircraft* is described as any vehicle that travels through the air i.e airplane, helicopter, balloon, etc., for the purposes of this series, we will mainly be describing the autopilot's role in a fixed wing aircraft or airplane. Helicopter autopilots operate in a similar manner but with more complexity due to the dynamic lift of the rotary wing.

An autopilot's job is to work with motion and momentum and at the heart of this is Newton's First Law which, in laymen terms states "An object in motion tends to stay in motion, and an object at rest tends to stay at rest, unless the object is acted upon by an outside force". A real world example of this is the behavior of two billiard balls. One ball in motion that strikes another at rest will transfer energy to the motionless ball. Note that both the velocity and direction of both balls may be changed. We may represent this type of energy transfer as a vector. A vector is a symbol showing an object's direction and speed. In this series we will want to use vectors to help describe the many forces acting upon an aircraft or its systems. In Figure 1 below, an aircraft is flying at a speed represented by the length of the vector, in a direction represented by the angle of the vector on the page. There is a crosswind, represented by another vector, again with speed and direction shown by length and angle, acting upon the aircraft. The resultant vector is the actual ground track and velocity (groundspeed) of the aircraft.

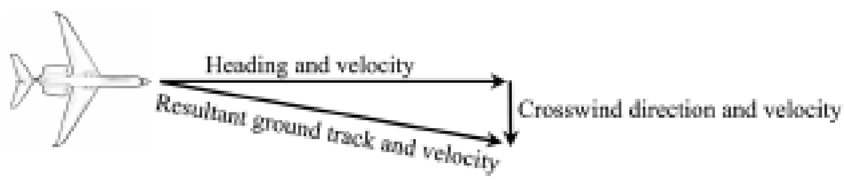

Figure 1 Using vectors to represent forces.

This action/reaction First Law motion occurs continuously and in all axes of an aircraft and must be dealt with by the autopilot. Figure 2 shows the three axes of an aircraft.

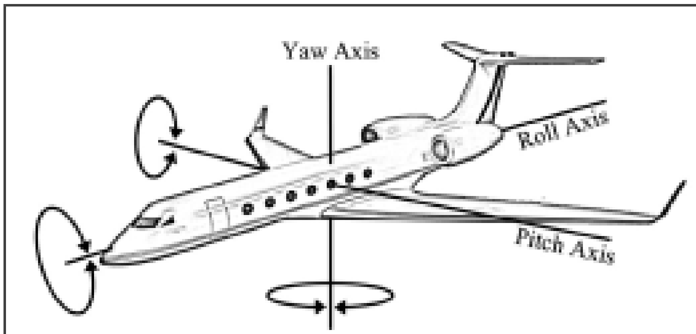

Figure 2 Three axis of an aircraft: Roll, Pitch, and Yaw.

The *longitudinal* or *roll axis* may be visualized as a line running through the center of the fuselage through which the aircraft rotates. The aileron is the control surface used for displacement in the roll axis.

The *lateral* or *pitch axis* may be visualized as a line running crossways through the fuselage at the center of gravity through which the aircraft pitches. The elevator is the primary control surface used for displacement in the pitch axis. However, the pitch axis is unique in that there is a secondary control used to place the aircraft at a primary attitude from which the elevator then controls the pitch angle. This secondary control is called the *pitch trim*. Imagine an airplane in a climb. Without pitch trim, the pilot would be required to hold the elevator control with sufficient force to place the aircraft at this attitude. Additionally, the center of gravity plays into the forces required by the elevator to hold the aircraft at a given attitude. The purpose of the pitch trim is to increase or decrease the lift of the horizontal stabilizer such that the aircraft maintains a given attitude with no input from the pilot. Deviations from this stabilized attitude are now produced by deflections of the elevator that are manageable. Pitch trim is performed either by moving the entire horizontal stabilizer or by moving a small trim tab connected to the elevator.

The *vertical* or *yaw axis* may be visualized as a vertical line passing through the fuselage at the intersection of the longitudinal and lateral axes.

These three axes corresponding to dimensions in space, coupled with the fourth dimension time, are what an autopilot must master. Some of the forces acting on an aircraft that we should be familiar with are listed below:

Thrust/Drag The Thrust force is created by a propeller or turbine that causes the aircraft to accelerate until balanced by the opposing force called Drag, which is increasing with the *square* of the velocity. In vector form the Drag vector subtracts from the magnitude of the Thrust vector. What is left is the velocity of the aircraft.

Lift/Gravity The Lift force is created by air moving over surfaces at different velocities and the resulting pressure differences. Lift is counteracted by Gravity and in level flight, the vector sum is zero.

Adverse Yaw Imagine that you are flying behind and observing an airplane in level flight. To make a left turn, the pilot turns the control wheel to the left causing the starboard (right) aileron to deflect downward and the port (left) aileron to deflect upward. At the moment the ailerons move, the upward deflected control is in a low pressure environment and the downward deflected control is in a high pressure environment. Since the drag induced is proportional to the density of the air and the inertia of the aircraft is great (think of the vector), the aircraft will momentarily yaw to the right, or the opposite of the pilot's intentions. The aileron's deflection of air will quickly overcome this opposing force but this phenomenon must be understood and dealt with. The simple solution to this adverse yaw is to apply slight left rudder in a left turn and conversely apply right rudder in a right turn to negate this yaw action. Analyzing from a vector standpoint, we have smaller forces (adverse yaw verses rudder force) acting within larger forces i.e. aileron forces against the airplane inertia. We want a smooth change in heading, thus the application of rudder. We will expect some autopilots to do likewise.

P Factor In propeller driven airplanes, the propeller produces symmetrical thrust only in level flight. Imagine standing beside the engine nacelle of such an airplane and peering down the length of a propeller. The pitch (or bite into the air) of the propeller is such that when the aircraft is in a climb, the right-hand descending blade is biting into more air and creating more thrust than the left-hand or ascending blade. This creates another type of unwanted yaw and must be balanced with appropriate rudder. Conversely, in a descent the thrust scenarios reverse and opposite rudder is called for.

This concludes a primer on basic flight dynamics. Understanding of these phenomena will be helpful when troubleshooting topics are covered.

Next Month: More autopilots