How avionics can assist pilots

Avionics isn't just about finding out where you are and how you're oriented. It's also about helping the pilots with their job. The question that we'll examine in this chapter is, how can avionics help the pilots?

1 Landing guidance systems

Avionics can help pilots land an aircraft. The system involved is the **instrument landing system** (ILS). We'll examine how it works. But first, let's examine landing categories.

1.1 Landing categories

The approach and landing are the most dangerous part of the flight. When the pilot has sufficient visibility, he is allowed to perform the landing under **visual flight rules** (VFR). However, when visibility is reduced (e.g. due to bad wheather), the pilot has to use **instrument flight rules** (IFR): he has to land, using only his instruments.

The **International Civil Aviation Organization** (ICAO) has defined three **categories of visibility**. These categories are based on the **decision height** (DH) and the **runway visual range** (RVR). The DH is the height above the runway at which the landing must be aborted, if the runway is not in sight. The RVR is the visibility at the runway surface. The three categories are as follows.

- **Cat I** – DH $\geq$ 200 ft and RVR $\geq$ 2600 ft.
- **Cat II** – DH $\geq$ 100 ft and RVR $\geq$ 1200 ft.
- **Cat III** – DH $<$ 100 ft and RVR $<$ 1200 ft.

Category III is further divided into regions a, b and c. But we won't go into detail on that.

1.2 The ILS localizer antenna

When landing, the aircraft should follow the glide slope. The **ILS localizer** is a subsystem of the ILS. It makes sure that the ILS system knows whether the aircraft is left or right from the glide slope. So how does it work?

The main part of the ILS localizer subsystem is the ILS localizer antenna array. The central antenna of this array sends out a **base signal**. This base signal is the sum of a $90Hz$ AM carrier wave and a $150Hz$ AM carrier wave. No phase difference is present. (The signal thus consists of a **carrier and side bands** (CSB).) Next to this, there are also the **right antennas**. They send out a sum of a $90Hz$ AM carrier wave and a $150Hz$ AM carrier wave as well. However, this time a phase difference is introduced. The $90Hz$ signal has a phase lag of $90°$, while the $150Hz$ signal has a phase lag of $270°$. (This signal has **side bands only** (SBO).) For the **left antennas**, this is exactly opposite. The $90Hz$ signal has a phase lag of $270°$ and the $150Hz$ signal has a phase lag of $90°$. (It is SBO as well.)

The result of this will be a lobe pattern. If we're exactly on the vertical plane through the runway, then we will measure the $90Hz$ AM signal with equal strength as the $150Hz$ signal. But now let's suppose that we're off to the left of the runway (while approaching). In this case, the $90Hz$ signal from the antennas will be amplified, whereas the $150Hz$ signal will be more or less faded. The $90Hz$ signal is thus dominant. Similarly, on the right side, the $150Hz$ signal will be dominant. In this way, we will know whether we're off to the left or to the right of the runway.

1.3 The ILS glide slope antenna

The **ILS glide slope** subsystem measures whether the aircraft is above or below the glide slope. It works in a similar way as the ILS localizer. But there are a few differences. Of course, the ILS glide slope uses a different carrier wave frequency. (In this way, aircraft can distinguish the ILS localizer signal from the ILS glide slope signal.) Also, instead of using a lot of antennas, we now use multipath effects (via the ground).

The ILS glide slope antenna array consists of only two antennas. Antenna A is $10\lambda \approx 9m$ above the ground. It sends out a CSB signal: the $90Hz$ and the $150Hz$ AM signals don't have a phase difference. On the other hand, antenna B is $5\lambda \approx 4.5m$ above the ground. It sends out an SBO signal: the $90Hz$ part has a phase lag of 180°. (The $150Hz$ signal does not have a phase lag.)

Because of multipath effects, a lobing pattern will be present. Antenna A will give maxima at 1.5°, 4.5°, 7.5° and so on. Antenna B gives maxima at 3°, 9°, 15° and so on. The result will be as follows. From 0 to 3 degrees above the horizontal, $150Hz$ dominates. From 3 to 9 degrees, $90Hz$ dominates. From 9 to 15 degrees, $150Hz$ dominates again. And this continues in steps of 6 degrees. So, if an airplane detects a $90Hz$ dominant signal, it will be above the 3° glide slope. But, if it detects a $150Hz$ dominant signal, it is probably below it (or way above it).

The ILS system works quite well. However, it does require a lot flat terrain. Also, obstacles (like buildings and even aircraft and other vehicles) can disturb the signal.

1.4 The microwave landing system

The **microwave landing system** (MLS) gets rid of some of the disadvantages of the ILS system. It works for angles from $-40°$ to $40°$ horizontally (with respect to the runway) and from $0°$ to $20°$ vertically. Its range is $20NM$ up to a maximum height of $20.000ft$. And it uses a **time-reference scanning beam** (TRSB).

How does the TRSB work? We'll examine the horizontal positioning first. TRSB is based on a rotating antenna. Most of the time, this antenna is pointing at the 40° direction. But in regular intervals, it sweeps to the $-40°$ line and back again. An airplane in the corresponding region is thus 'hit' twice by the signal. Based on the time between these two hits, the **azimuth angle** θ can be found.

Finding the (vertical) **elevation angle** ϕ works exactly the same. But, instead of an **azimuth antenna**, we now use an **elevation antenna**. The MLS also has a DME beacon to keep track of the distance of the aircraft.

2 Aircraft instruments

It's nice to know where you are. But how do you tell this to the pilots in the right way? That's what we will examine now.

2.1 An overview of the cockpit

To inform the pilot of the status of the aircraft, the cockpit contains several displays. Among them are the **heads up display** (HUD), the **primary flight display** (PFD), the **navigation display** (ND), the **multi-function display** (MFD), the **control display unit** (CDU), the **engine indicating & crew alerting system** (EICAS) and the **mode control panel** (MCP). An overview of these displays can be seen in figure 1.

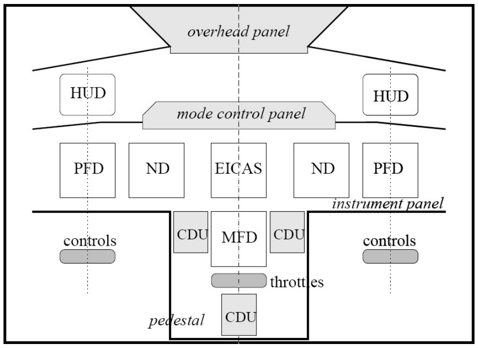

Figure 1: The cockpit human machine interface.

2.2 Creating efficient displays

When displaying data, we want to make things as easy as possible for the pilots. It should cost them as little time as possible to acquire information. How can we reduce the time pilots need to absorb data?

- A first step is to put displays that are related to each other close together. This will result in an **additive display**. An example is the well-known **basic T**.
- But we can do more than switching displays around. We can also take several pieces of data and integrate them in a single display. This gives us an **accumulative display**. An example now is the **attitude direction indicator** (ADI). It contains an artificial horizon, a roll angle index, a bank angle scale, a deviation from ILS, a rate-of-turn indicator, a slip indicator, and much more.
- Finally, we can process available data in a rather advanced way. This would result in an **integrative display**. This time, an example is the **flight director** (FD).

You might be wondering, what is a flight director? A **flight director** (FD) is a system that tells the pilot how he should fly the aircraft. For example, the pilot wants to land at a certain landing strip. He inserts this into the FD. The FD now computes the pitch angle, roll angle, etc. which the pilot should maintain. The flight director should not be confused with an autopilot. The two systems are slightly similar. However, an autopilot controls the airplane on its own. A flight director only tells the pilot how he should control the aircraft. Then, all the pilot has to do, is follow the needle.

2.3 Electronic displays and other future trends

When flight displays were first developed, only mechanical systems could be made. And, since it's impossible to put a huge amount of mechanical systems in a small display, these displays were quite limited. But as time progressed, electronic displays became available. This resulted in the so-called **glass cockpit**. However, initially all that aircraft designers did was take the old mechanical displays, and turn them into a digital display.

Slowly, people got the idea to do more with electronic displays. This resulted in the **electronic flight instrument system** (EFIS). It consists of two parts. First, there is the **electronic attitude and direction indicator** (EADI), also known as the **primary flight display** (PFD). It mainly tells you how you're oriented. Second, there is the **electronic horizontal situation indicator** (EHSI), also known as the **navigation display** (ND). This display mainly informs you about your position.

Still, the EFIS displays the same information as the old mechanical systems were displaying. In the future, this might very well change. One development is the **tunnel in the sky** display: a tunnel is displayed in the sky, which the pilot should follow. Another development is the **head up display** (HUD). With this system, information is superimposed on the pilot's normal view, through the windshield of the aircraft.