Podcast 45 – Flight Instruments part 1,

Hello everyone and welcome back to another Talk where we're back to the technical side of things today, sorry no competitions for you but you will of course be treated to a Tech Ten which I know you've been missing. Today we're going deeper into the instrument side of things with a look at the pitot static system, the air data module, the ADIRS and the much talked about recently RAs.

We have 6 static ports and 3 pitot probes feeding our total air pressure system. The captain's pitot is on the left with the FOs and auxiliary on the right. Static wise we have a captain, FO, and alternate on each side. There are also 5 drain fittings which remove condensation in the pitot static lines which themselves consist of both flexible and hard pneumatic tubing.

Our two primary pitot probes, and two pairs of the primary static ports connect to their respective Air Data Modules, or ADMs giving us four ADMs in total. The left and right associated static ports are connected giving an average ambient pressure to the associated ADMs. The ADMs then change air pressures to ARINC 429 electrical signals which are sent to the ADIRUs who calculate flight parameters such as airspeed and altitude. The pitot probes are mounted on struts to keep them far enough away from the aircraft skin to avoid turbulence and are heated to avoid icing.

The alternate static and pitot connect to the standby instruments with the alternate static also connecting to the cabin differential pressure indicator. The alternate static ports are not interchangeable with the primary static ports as the primary static ports have a flat face and the alternate static ports have a concave face. No static ports are heated as they are flush with the fuselage.

Let's take a look at the ADIRS system where we'll take a look at a few things associated to the IRS side but as we covered that in a previous podcast we'll focus more on the AD or Air Data side today.

The ADIRS supplies data to us and the aircraft system. This data comprises of altitude, airspeed, temperature, heading, attitude and present position. The ADIRS itself is made up of the 4 Air data modules (ADMs), a Total air temperature (TAT) probe, 2 Angle of attack (AOA) sensors, an Inertial system display unit (ISDU), the Mode select unit (MSU), 2 Air data inertial reference units (ADIRU) and the IRS master caution unit.

As an aside our VMO/MMO warning system gets its signal from the ADIRU with VMO at 340kts when below 25,968ft and above this we are limited by mach number MMO of 0.82. When we push those test switches on the ground switch No. 1 does a test of the overspeed warning circuit in the left ADIRU with Test switch No. 2 doing a test of the overspeed warning circuit in the right ADIRU.

Our ADIRUs calculate our air data by using inputs from the pitot and static system, the TAT probe, the AOA sensors, the CDS (or Common Display System) barometric correction and IR data.

The AOA sensor gives angle of attack information to the ADIRU which uses angle of attack to modify pitot and static values. Some aircraft have an angle of attack indicator on the PFD which shows AOA between -5 and +21° with both an analogue scale and a digital readout. There is a green approach reference band which is displayed when landing flaps are selected and a red stick shaker tick showing the AOA at which the stall warning activates. This tick will move dependent upon configuration and mach number.

The pitot ADM gives the ADIRU total air pressure information, which is used to calculate airspeed and mach number. While the static ADM gives the ADIRU static air pressure information which is used to calculate altitude and airspeed. DEU 1 and DEU 2 give barometric correction to the ADIRUs, with pressure settings inputted by us, which is used to calculate corrected barometric altitude.

The TAT probe gives total air temperature to the ADIRUs to compute TAS and SAT.

Our Air Data outputs from the ADIRS are used in various systems. Both ADIRS supply data over ARINC 429 data buses to various systems. The Left and right ADIRS supply air data to DEU 1 and DEU 2 for display information as well as passing it on to other systems such as the EECs. Data is also sent to the onside FCC for autoflight mode calculations, and the onside SMYD for stall management and yaw damper calculations.

Both also send data to the GPWC, CPCs 1 and 2, ATC 1 and 2, Weather radar and the FMCS. Data is used for the GPWC to detect unsafe flight conditions, the CPCs to calculate pressurisation values, ATC 1 and 2 for altitude reporting, Weather radar for either TAS for predictive windshear calculations or weather condition determination depending on aircraft fit and the FMCs use the data for performance calculations.

The left ADIRU also sends data to the flight data acquisition unit, FDAU, which formats the data and sends it to the digital flight data recorder and also the flap/slat electronic unit, FSEU, for flap load relief calculations and uncommanded motion logic.

We thought we'd take a look at the Radio Altimeter system today as well as it's been much talked about due to the potential interference from 5G ground stations. It is a problem as these stations operate in the C-band, at frequencies close to those used by our rad alts. The US, at the time of writing, had applied restrictions for operations to affected airports including exclusion zones and alternative means of compliance to the 5G Airworthiness Directive.

The US is slightly different in its 5G implementation leading to these restrictions in that the stations there have higher power levels, smaller buffer zones apply and the tilt of the antennas are more skyward among some of the reasons for tighter controls.

Our Radio Altimeters have a range from either -20 or -12, depending on type up to 2,500ft AGL. The transmitted signal is compared to the received signal with computed altitude data is sent out on two ARINC 429 data buses to user systems on the aircraft. Interference can cause the RAs to become inoperative or present erroneous information.

We have two RA systems powered by their respective transfer buses, with the number one system altitude shown on the captain display and the number two system shown on the first officer display.

As we've just mentioned it's the proximity of the frequency to 5G where the potential issue lies. The radio altimeter transmits a frequency modulated, continuous wave (FM/CW) signal through the transmit antenna. This signal is a CW carrier that scans linearly from 4,235 to 4,365 MHz 145 times a second. The 5G frequency range 1 is from 450MHz to 6GHz which of course encompasses the RA range and thus gives the potential for interference and that's about as technical as we're going to get on that one!

Radio Altitude and status information from the ARINC 429 data buses goes out to the following components and therefore these are **which** systems could face interference. FCC A or B, the Autothrottle computer, DEU 1 and DEU 2, the GPWC, the TCAS computer and the FDAU.

Things to watch out for in the case of RA failure or interference could be AP disconnect 2 seconds after glideslope capture and erratic autothrottle behaviour such as in the case of the Turkish flight into Schiphol which we covered in an earlier podcast. Here due to spurious L RA behaviour the Autothrottle retarded the thrust levers to idle thinking the aircraft was on the ground. Thrust reverser deployment may also be compromised potentially leading to longer landing distances, this could also potentially occur on a reject. Another stopping distance factor can be that the speedbrakes do not automatically deploy or may be limited to their in-flight position during manual deployment. On the max the LAM may be erroneous.

There are of course the more obvious effects such as Autoland capability and height call outs being compromised, and also TOGA mode may be unavailable.

Should your RA data become invalid you would get an RA flag where your radio height normally would have been, and the rising runway will disappear. Should the radio altimeter have no computed data, or NCD, the RA display and rising runway symbol are removed but no flag will appear perhaps making this one a little trickier to spot. The NCD occurs when the return RA signals are too weak, or the radio altitude is more than 2500 feet. If the data is purely erroneous then that data will be shown on the PFD as it is sensed.

Should invalid data from the radio altimeter be sensed by the GPWC you will get the amber GPWS INOP light but there have been cases of an EGPWS alert occurring such as in Sydney in 2009. Here left RA spurious data provided an indicated altitude of -7ft on the approach and caused the EGPWS alert together with AP disconnect and the thrust levers moving to idle. Pilot intervention here led to an uneventful landing, but you can imagine the startle and surprise on that one late on in the approach.

A couple of other systems to be mindful of are TCAS and Windshear surveillance. PWS turns on automatically when the airplane descends below 2300 feet radio altitude. TCAS will go into TA only mode below 1,000ft RA with descend RAs inhibited below 1,100ftRA. Notice the RA requirement in there so be aware of the potential for dangerous manoeuvres close to the ground.

You may also get some gear config warnings including the horn depending on the signals given by erroneous RA data.

Be aware of company operating procedures in and out of these airports which include careful monitoring on take-off and arrival as well as different ways to calculate both take-off and landing performance. Specific types of approaches will be prohibited by NOTAM that may include ILS, RNP (AR), Automatic landing ops, the use of the HUD and any EFVS or Enhanced Flight Vision System to touchdown.

At the time of writing there had been no operational incidences regarding 5G and RA interference, but the potential is there and it's also a timely reminder to us of the complex nature of the aircraft we fly and how losing a system can have multiple effects in other areas we perhaps wouldn't immediately think of. One of the reasons of course why trouble shooting outside of the checklists is not recommended.

That about wraps up this week but we'll return to instruments again shortly with a look at those displays, the ILS, VOR and standby instruments among others but it wouldn't be a tech episode without…

TALKS TECH TEN

Q1: Where and when is Radio Altitude displayed

Q2: What gives the vertical speed indicators their data?

Q3: Which probe, and ports gather total pressure data for the standby airspeed indicator?

Q4: What is the power source for the Radio Altimeters?

Q5: When will the flight recorder operate on the ground?

Q6: What is the minimum use height for the Auto Pilot single channel in a 737-700 and 737-800?

Q7: Speedbrakes should only be deployed inflight at radio altitudes greater than what?

Q8: The wing tanks must be full if the centre tank contains more than how much fuel?

Q9: How are the ADIRUs powered normally? And with the loss of AC power?

Q10: When will the ground crew call horn sound?

A couple of memory joggers there we hope you find useful perhaps for a bit of manual surfing! We'll be back in a couple of weeks for another Talk but for now why don't you head over to the socials, @B737Talk and if you have a RA failure story we'd love to hear about it and any unforeseen issues that occurred because of it. We hope as we continue to learn to live with covid 19 more of you are getting back into the skies and finding the podcast useful to help in getting you back into the swing of things or just refreshing your memory. If you do have a second and the platform you listen to us on allows it we'd really appreciate a 5* review to help us move up those podcast tables and make more people aware of us. No need for a written review, but we would of course welcome that too if you feel the need. For now though from us both fly well, and be safe.