Podcast 47 – Flight instruments 2

Welcome everyone to the latest episode of the 737 Talk where we look to give you another resource for learning more and keeping your knowledge current without having to do too much manual thumbing.

Having taken a first delve into where our instrument data comes from, we'll now look at how it's displayed as well as a refresher on those standby instruments.

We have 6 identical and interchangeable, 7.1" display units in our NGs controlled by our 2 DEUs or Display Electronics Units. DEU 1 is powered by the DC Standby bus and normally controls the Captains DUs and the upper DU, while DEU 2 is powered by DC bus 2 normally controlling the first officers and lower DU.

The DEUs do the following functions:

- Collect data from airplane systems including the ADIRUs, and ARINC 429 for things such as GPWC, Wx Radar, FMCS, ILS, VOR, FCCs and many more.
- Change that data to a video signal to show on the display units, and
- Send data to other airplane systems.

The DEU monitors the presence, status, and validity of inputs and cross compares inputs with the other DEU.

Our DUs and DEUs together are known as the Common Display System, or CDS. The DEUs compare critical input signals that are received by both DEUs on the same ARINC 429 input bus. The onside values are compared with the offside values. If the critical comparison data is not the same, CDS shows CDS FAULT on the CDS displays which will annunciate on the ground only, before second engine start and is a stopper.

If a DEU fails in flight, the remaining can automatically power all 6 DUs and we'll get the message DSPLY SOURCE on both PFDs leading us to pull out the QRH and complete the relevant checklist. You will notice from the QRH that flight director indications may be removed and autoflight mode reversions may occur for example if you're in approach mode above 400ft RA with the FDs on then pitch and roll commands will be removed on the failed side. You will also not be able to engage that 2nd Autopilot

Thanks Mark and hello everyone I am here today, think Mark was getting a bit carried away with his love of the display system there.

Part of the interface we have with our CDS are the EFIS control panels which allow us to set minimums, display the Flight path vector, select VOR/ADFs to be displayed as well as our, traffic switch, Weather radar switch and Terrain switch among others.

If a control panel fails, the navigation display changes. The changes you see if a control panel fails are:

- The VOR and ADF selections stay the same
- All map switches are off and do not operate
- The expanded map mode shows
- A range of 40 miles shows
- The weather radar comes on and shows (in the air only).

You will also get the DISPLAY CONTROL PANEL message and the altimeter on the failed side will blank showing the ALT flag. A quick visit to the QRH will give you your full display back.

Back to me now for a look at some of the more interesting parts of the display and what it tells us as pilots.

The speed tape shows the computed airspeed from the ADIRU on a moving scale. Current airspeed shows as a digital readout. When the airspeed is below 30 knots, 30 knots shows. When the speed trend vector shows it indicates the predicted airspeed in 10 seconds based on current acceleration or deceleration. This vector shows when the speed trend is more than 4.5 knots.

On take-off the DEU calculates V2 + 15 and considerately puts a white bug as a marker for us. This speed is important as at this bug we have all full 40° (25° +15 overshoot) bank manoeuvre capability at all takeoff flaps. This friendly bug rears its head again on landing and represents Vref + 15, or Vref + 20 for those aircraft with more up to date CDS block point with manoeuvre speed for the current flap position showing automatically which we'll talk about more in a minute.

At the top and bottom of the speed tape we have our red and black barbers poles. The lower pole shows minimum speed. The top of this pole indicates the speed at which stick shaker will activate. This speed will change with changes in g-load. The upper pole indicates maximum operating speed of 340kts or 0.82m depending on if we've gone through crossover altitude at approximately 26,000ft. Here we will get the overspeed warning at the lowest of VMO,MMO, Flap placard speed or Landing gear down placard speed.

Attached to these barber poles are our hollow amber bands. The upper amber band represents either maximum manoeuvring speed when flaps are up, or, maximum speed for the next flap setting if flaps are not up.

Maximum manoeuvring speed provides 1.3g manoeuvre capability to high-speed buffet which corresponds to that 40° bank again.

The lower amber band shows minimum manoeuvre speed and is displayed with first flap retraction after takeoff. Below 20,000ft this gives that 1.3g manoeuvre capability to stick shaker and above 20,000ft we get the same manoeuvre capability to low speed buffet. Both again correlate to that 40° bank.

Also on the speed tape are the Flap manoeuvring speeds shown in green numbers in relation to the flap position 1,5, 10 etc. These indicate minimum manouevring speed for current flap setting and are available below 20,000ft. During retraction for example when we go from flap

5 to flap 1, normally at flap 5 manoeuvre speed with a positive trend we will momentarily have our 30° protection, 15 + 15 overshoot increasing to our full 40° protection once flap 1 manoeuvre speed is reached.

Other things of interest on our PFD include the slip/skid indicator, which is sat below our roll pointer. If there is no lateral acceleration, the roll pointer and slip/skid indication align, something that assists us in putting the correct amount of rudder in in the event of an engine failure. The slip/skid indication is filled white when the lateral acceleration is at full deflection. Also, if the roll attitude is more than 35 degrees, the slip/skid indication changes to filled amber. We will also get the aural alert from the EGPWS, BANK ANGLE – BANK ANGLE which repeats at 40 and 45°. This system resets once the bank is less than 30°.

The pitch limit indication, or eyebrows as they're sometimes known, show the limit that you can pitch the airplane before the stick shaker activates. The pitch limit indication shows either when flaps are lowered, or when the flaps are up, and the airspeed gets close to the stall speed.

The flight path vector indication, if selected on the EFIS control panel indicates the vector of motion of the airplane relative to the horizon and the airplane heading. It uses inertial and barometric inputs so be aware that it becomes unreliable if you have unreliable primary altimeters. It is a useful tool to fly level, often used in steep turn practise, by keeping the middle of the body on the horizon. It can also give you an idea of crosswind strength and direction on final and current angle of attack by looking at the difference between it and the aircraft pitch attitude. Another useful tip is that when you place the top of the tail just under the horizon line you will achieve an approximately 3° descent making it very useful for those raw data ILS or visual approaches.

On approaches these days we expect to see either our ILS deviation scales or if fitted our NPS, Navigation Performance Scales.

For the localiser we have 4 dots in the non-expanded mode, each representing a deviation of 1°. Our pointer will fill solid magenta when within 2 ½ dots from centre and at low altitudes will flash to indicate excess deviation. Along with the flashing pointer the scales themselves will turn amber. This will also happen when below 1,000ft AGL if you have LNAV engaged and LOC armed but not captured, and also for 2 seconds after the system self-test at 1,500ft RA.

Expanded LOC scales automatically appear when deviation is slightly more than ½ dot and track is within 5 degrees of the selected MCP course, with the LOC mode engaged. One rectangle represents 0.5° deviation and the pointer will park here but remain filled magenta until the equivalent of 2.4 dots deviation from the standard scale where it will become unfilled.

On the glideslope we have 4 dots each representing 0.35° of deviation. Our pointer will fill solid when within 2 ½ dots of centre but will not show when the track and the front course on the MCP differ by more than 90°. At low RA the pointer will flash and the scales turn amber for excessive deviation, again this will also occur for the system self-test.

The Navigation Performance Scales (NPS) show the airplane position in the lateral and vertical path specified by the FMC. The NPS show when LNAV is engaged in FD or autopilot mode. The NPS indications do not show if the FMC does not send an RNP value to the DEU.

The NPS show in four parts:

- LNAV/VNAV deviation scales and pointers
- The Scale identifier annunciation
- The ANP/RNP bars and
- The Anticipation cues

The lateral deviation scale represents current FMC RNP, put in by us or automatically, with the vertical scale current FMC vertical RNP, again this could be entered by us or automatic through FMC logic.

The deviation scales will display if an approach mode is not engaged and either HDG SEL, TO/GA, LNAV or any VNAV mode is engaged.

The Scale ID Annunciation is shown in white above the left corner of the ADI and indicates the source of the displayed deviation. It will be displayed when LNAV, VNAV, HDG SEL, or TOGA are engaged and when current aircraft position is laterally within 1nm or 2 x RNP of the FMC route. You will see either LNAV/VNAV or LOC/VNAV depending on the approach.

The RNP value measures the precision of our navigation system while the ANP value measures the FMC's estimate of the quality of its position estimate. When quality of the FMC position estimate is high, the ANP value will be low. The difference between the RNP and ANP is the permitted flight technical error.

The outer scale marks on the deviation scales show the RNP values in nautical miles. The ANP/RNP bars show at the ends of the deviation scales. The bars show the ANP value in nautical miles. The space between the ends of the bars shows the quantity of the flight technical error. If ANP is zero, the bars do not show. If ANP is smaller than RNP, the bars extend from the edges to the scale centre. If ANP is larger than RNP, the bars show overlap. After 10 seconds of overlap, the bars show as amber. When ANP is larger than RNP, the FMC cannot be sure that the plane is in the navigation limits. An UNABLE REQD NAV PERF-RNP flag shows. If the FMC does not supply an ANP value to the CDS, no bars show.

Our anticipation cues, or ghost pointers, show as an unfilled white diamond and display if valid approach course deviation information is received while the corresponding NPS deviation scale and pointer are displayed. The anticipation cues show when the flight crew tune an ILS or some other landing system. The cues move to the scale centre while we follow the LNAV/VNAV path to the landing path. When the cues touch the scale centre, the plane goes into the armed landing mode. When the plane goes into the landing mode, the landing indications replace the NPS indications, for example the normal LOC indications or IAN FAC indications.

We won't go through the entirety of the altitude indications but some interesting ones that may have escaped the memory for you include that cross hatched area at the bottom which shows FMC landing altitude for destination, or departure runway until 400nm or ½ trip distance away, STD or standard will be in amber and outlined by an amber box under the altimeter when descending 300ft below FMC selected transition level and the same will happen to your barometric setting on the way up when climbing 300ft above transition altitude.

If we've set baro minimums and the barometric minimums alert is active, and the airplane descends through the selected BARO altitude the following displays change to amber:

- Barometric minimums bug
- The word BARO and the
- Digital display.

To reset this alert, we need to either climb above the selected barometric minimums, Push the RST button on the EFIS control panel, or Land.

Vertical speed wise, if the vertical speed is more than 400 feet per minute, then vertical speed shows as a digital value. This digital value shows above the vertical speed scale if it is a positive vertical speed and below if it is negative.

Our ND modes include plan along with the extended and centred versions of MAP, VOR and APP, as well as the VSD. Indications include Heading, Track, Ground speed, True airspeed, Wind, Route, Weather Radar, TCAS data, Enhanced GPWS data, VOR/ADF pointers, VOR deviation and LOC and G/S deviations.

We won't be going into detail on all modes as a lot will be covered in other podcasts as well as some being very self-explanatory. We will however point out some interesting ones to jog the memory.

The vertical deviation pointer shown with a white scale and magenta pointer is displayed in the lower right corner of the ND and shows deviation from the vertical FMC calculated path with a +/- 400ft scale. It will display at the TOD and if deviation is greater than 430ft the pointer parks and a digital readout is displayed. For NPS models you will also get RNP and ANP values in green with the display turning amber in the event ANP is greater than RNP.

Under the aircraft symbol you may also get a lateral deviation numeric in white which shows distance and direction from the LNAV path with the value blanking for values greater than 99.95nm. For NPS versions you also get those ANP RNP values with the same amber display for exceedance.

The trend vector, produced by the DEU, shown attached to our aircraft symbol, shows our predicted position in 30, 60 and 90 seconds based on bank angle and groundspeed. It can be quite useful to judge your turn on to specific tracks, for example the Localiser when doing a raw data ILS.

Failures of input data cause data to be blank and failure flags to show. All flags are shown in amber and include things such as HDG, LOC, G/S, PWS FAIL, TERR FAIL and WXR FAIL to name a few.

As for the engine display, our indications are shown on both the primary and secondary and include Autothrottle limit message, thrust mode and TAT, N1, EGT, N2, Fuel flow/fuel used, and fuel quantity, Crew alert messages, Oil pressure, temperature and quantity and Engine vibration.

All of the data on the primary engine display and secondary engine display can show on the compacted engine display. Secondary engine data that goes above or below tolerance limits shows on the compacted engine display in a box. The colour of the box aligns with the red and amber limit bands that show in the secondary engine display. When the exceedance occurs, the box shows and flashes for 10 seconds. After 10 seconds, the box shows but does not flash.

If one of the centre DUs fails, the data shows on the other centre DU. The display will depend on what was displayed at the time of failure. For example, if the upper DU failed and the lower DU was blank, then the primary engine display would automatically move to the lower DU. If however you had the secondary instruments on display at the time you would automatically get your compacted display on the lower DU.

If one of the centres DUs has failed, you can manually control the data that shows on the other DU. To change between the compacted engine display and the primary engine display, push the ENG button on the engine display control panel.

Our display select panels allow us to change the screen set up as required, generally used if automatic switching does not occur.

CAT 3b messages show below the crew alert messages of START VALVE OPEN, OIL FILTER BYPASS and LOW OIL PRESSURE. If you push the Cancel/Recall button on the Engine Control Panel, the messages are removed. After you cancel a message, the Recall Cue will show. While the Recall Cue shows, you can push the Cancel/Recall button to make the cancelled messages show again. These messages can include NO AUTOLAND, NO LAND 3, NO ILS AUTOLAND, NO ILS LAND 3, NO GLS AUTOLAND or NO GLS LAND 3.

We also have our SYS button which shows us the system display which includes for all hydraulic quantity and pressure and for those who've purchased it brake temperatures and flight control surface positions.

Right, onto those standby instruments now before a well-deserved lie down. We'll start on the standby compass which is located below the overhead panel. It comprises of a circular heading card floating in a case of liquid which stops the card moving at a speed we would be unable to read in flight.

The two parallel magnets are in the horizontal plane and align the compass with the magnetic flux lines of the earth. There are north-south and east-west compensation screws which

change the position of the magnets to correct any deviation. A 28V DC bulb backlights the compass with a switch above the compass itself.

Our ISFD, or Integrated Standby Flight Display, is a backup system displaying

- Pitch attitude
- Roll attitude
- Altitude
- Heading (program pin selection display)
- Indicated airspeed (IAS), and
- ILS localizer and glideslope deviation.

For all data, except the program pin selection heading display, the standby attitude reference system operates independently of the air data inertial reference system.

The ISFD has three connectors at the rear of the unit. One electrical connector supplies the wiring interface for all electrical power and interface signals and two pneumatic connectors are for the pitot air pressure and the static air pressure inputs to the ISFD.

The ISFD has its own dedicated battery which remains charged through the battery bus. If the battery bus was to go off this stand-alone battery can power the unit for 150 minutes.

Those two pneumatic inputs come from the auxiliary pitot and the alternate static systems and provide the data necessary to output airspeed and altitude shown on the left and right of the attitude indicator respectively.

The ISFD has internal inertial sensors that sense angular rate and linear acceleration. These are used to calculate pitch and roll attitude. The ISFD goes through alignment when it first receives power. 90 seconds after it receives power, the pitch and roll attitude scales and pointer show on the display.

The ISFD receives data from the MMR 1 for localizer and glideslope deviation, and the Left air data inertial reference unit (ADIRU) for magnetic heading from the ARINC 429 data buses depending on the option you have installed. Remember to cross check the heading with the standby compass.

The attitude reset (ATT:RST) message shows if the inertial sensors sense angular rate or acceleration more than the maximum for more than 10 seconds. Use the attitude reset switch to make the ISFD reset the attitude. You should do this if there is an error between the ISFD attitude and the real airplane attitude, or if the ATT:RST message shows.

Push the attitude reset switch for a minimum of 2 seconds to start the attitude reset. The ISFD shows the message, ATT 10s. After 10 seconds, the message goes off and the attitude scales and pointer show. You should look to maintain wings level and not to accelerate during this process.

Now, it wouldn’t be a tech episode without:

TALKS TECH TEN:

Q1: What happens to the airspeed readout box should airspeed decrease into the minimum manoeuvre speed amber bar?

Q2: When is the PLI displayed on the PFD?

Q3: In the climb we cross the FMC transition altitude but have not selected STD, what happens to the barometric display on the PFD?

Q4: If you have selected both a DH and a DA but selected RADIO on the minimums reference selector how are they displayed to you on the PFD?

Q5: What message would display on the ND if you had APP mode selected with a VOR

Q6: What does the trend vector on the speed tape indicate?

Q7: What inputs does the standby airspeed indicator use?

Q8: What does the message DPLAY SOURCE on the PFD tell you?

Q9: If the Captains outboard DU fails what display will you get with automatic switching?

Q10: What is the power source to the ISFD?

So, there it is, our second look at flight instruments and displays. This is a big subject and there is still more we can take a look at so we may well return to this again in the future. For now though Mark and I are going to take a break and recoup in order to come back again in another couple of weeks with another 737 Talk for you where we will take a look at another system in-depth but with a procedural side thrown in. Until then feel free to contact us about anything over on b737talk.com, visit the socials or just give yourself a bit of a break too! Any episode suggestions will be attempted too so just let us know. For now though from the both of us fly well, and be safe.