Podcast 016 – Automatic flight part 1

This episode we're back to a technical subject where we'll look at the 737NG automatic flight system and its intricacies. This is a complex subject, so we'll aim to take it in digestible chunks as much as possible. This has meant splitting this vast subject over two podcasts to keep it a reasonable length.

So, we'll dive on in there and hopefully expand your knowledge of the system, I know we did ours when writing this!

The automatic flight system or AFS consists of a whole load of aviation's favourite things, yep you guessed acronyms. We have the AFDS or autopilot flight director system the A/T or Autothrottle, the FMC of flight mode computer and the MCP or mode control panel. Don't worry there will be more to come!

How are these connected? Well, the FMC provides N1 limits and target N1 for the Autothrottle and command speeds for the A/T and AFDS.

The AFDS and A/T are controlled using the MCP and FMC. Normally, the AFDS and A/T are controlled by the FMC to provide optimised lateral and vertical path through the flight profile.

The AFS mode status is displayed to us on the all-important FMA's or Flight Mode Annunciators, told you there would be more acronyms!

Let's talk a bit more about those FCC's. I say those as we have 2, A and B. An important note is that Autothrottle is a function of FCC A only. They are powered by their onside DC bus and each FCC will send control commands to respective pitch and roll hydraulic servos which operate the flight controls through two separate hydraulic systems.

The pitch and heading data for each FCC comes from the onside IRS with roll data coming from the offside IRS. Apart from autoflight the FCC's have other roles in controlling the Speed trim, Mach trim and Altitude Alerting systems.

For Flight Director operation each FCC positions the FD command bars on the respective attitude indicator.

Now for our MCP. The mode selector switches are pushed to select desired command modes for the AFDS and A/T. The switch will illuminate to indicate mode selection and that the mode can be deselected by pushing the switch again. While a mode is active, deselection can be automatically inhibited and is indicated by the switch being extinguished, for example when in the approach mode.

When engagement of a mode conflicts current AFS operation, pushing the mode selector switch has no effect. All AFDS modes can be disengaged by either selecting another command mode or by disengaging the AP and turning the FDs off.

We're not going to go through all the modes of the MCP but we'll point out some interesting parts to some of them.

N1 engages automatically when Level Change is selected except for the first 2 and a half minutes after take off where there is an inhibit period.

VNAV operates in two basic modes. In VNAV SPD the AFDS and AT command target FMC airspeed. In VNAV path the AFDS and AT command target FMC vertical speed. VNAV guidance will become active at 400ft AGL and at level off will go into VNAV ALT if there's an MCP constraint or VNAV path if it's a purely VNAV constraint.

LNAV guidance becomes available at 50ft. This differs for an Autoland GO around where it engages at 400ft AGL. Bank angle is limited in LNAV to 8° below 200ft and 30° above 200ft. For LNAV to be able to be armed on the ground the initial track needs to be within 5° of runway heading.

When airborne LNAV will engage in any heading when within 3nm of the active route segment and, if outside of this engagement will occur if the airplane is on an intercept course of 90° or less and will intercept the route segment before the active waypoint.

A quick gotcha on heading select. Just remember that if you select the heading on the dial before engaging the mode, once you press that switch the airplane turns in the shortest way towards the heading bug.

When a localiser frequency is selected, and VOR/LOC annunciates the VHF NAV radios automatically switch from tail antenna to nose antenna. If this switching does not occur LOC mode is inhibited. Perhaps something to think about in the case of a severely damaged radome.

Approach mode allows the selection of the second autopilot at the latest by 800ft RA. When G/S captures APP extinguishes on the MCP panel as we alluded to earlier.

The speed window is closed whenever the FMC controls the airspeed in VNAV. Changeover from IAS to Mach will occur around FL260. There are over and under speed limiting modes which are displayed in the speed window with either an A or an 8. The A is the under speed with the 8 being the over speed depending on Vmo/MMo, Landing gear limit or Flap limit.

Let's talk a bit about the AP itself. Engagement will be inhibited if a force is being applied to the control wheel or if the STAB TRIM AUTOPLIOT cutout switch is not at normal. You can only engage one AP at a time unless APP mode is engaged and if you are operating single channel a fully automatic flare and touchdown as well as AP go-around are not available.

There could be many reasons for AP disengagement including if you press those TO/GA buttons when operating single channel on the approach. Other interesting ones could be a left or right IRS system failure, the loss of electrical power which prevents proper operation of the engaged AP and the loss of respective hydraulic system pressure.

Remember that old favourite here that if you get a failed generator on the AP side that is engaged, when you start that APU and go to switch power over you will disengage the AP much to the sadistic amusement of the TRI or TRE behind you who will have planned it that way if it is in the simulator.

The Autopilot will also disengage two seconds after LOC and G/S capture when its onside radio altimeter is inoperative.

If you do have one IRU inoperative and need the autopilot the QRH will get you to put the IRS transfer switch to both on L or both on R. The QRH then recommends the autopilot on the operational IRS side be used except during the approach where it is not authorised. When the autopilot is engaged the yaw damper will disengage and cannot be reconnected until the autopilot is disengaged.

Next, we'll take a look at the FD command bars. They display when switched on and pitch and roll modes are engaged and can be used with or without AP and AT. Takeoff mode is a FD only mode, dual guidance is available for single engine operation and the FD's have no landing flare capability hence they disappear from view at approximately 50ft RA on an ILS approach.

Normally FCC A drives the captains command bars and FCC B the first officers. When both FD switches are on the logic for both FD modes is controlled by the master FCC, and both FMA displays show the same mode status. The master FCC is indicated by the illumination of the respective master MA indicator light.

The master is determined by firstly, if neither AP is engaged in CMD, the FCC for the first FD turned on is master. Or, if one or both Aps are engaged then the FCC for the first AP in CMD is the master regardless of which FD is turned on first.

Under certain conditions FD modes are controlled directly from the respective FCC. This independent FD operation occurs when neither AP is in CMD, both FD switches are ON and any of the following exists. APP mode engaged with LOC and G/S captured, GA mode engaged and below 400ft RA or TO mode engaged and below 400ft RA.

Independent operation is indicated by the illumination of both MA lights and terminates when the MA light on the slaved side extinguishes.

If a generator is lost during a FD TO or GA, or while in dual F/D APP mode below 800ft the FCC on the unaffected side positions the FD bars on both attitude indicators.

The FD will Bias out of view for a number of reasons including invalid approach aid signals and flare mode active. One of the more interesting ones is if the IRS transfer switch is not in normal with no A/P in command and both FD switches on in either the TOGA, VOR LOC or APP mode. So, if you had the IRS transfer to both on L the FO's FD would disappear under those conditions.

The AT system can provide automatic thrust control from the start of takeoff to landing under normal conditions. There is a separate servo motor on each lever allowing the AT to move the levers to comply with computed thrust requirements. If we make a manual input the AT may then reposition those levers back to its requirement unless we are in THR HLD or ARM modes.

The AT system operates properly with the EEC's on or in ALTN using FMC N1 limits. Both FCC A and FCC B have AT software but only FCC A software is active.

Moving the AT arm switch to ARM arms the AT for engagement in the N1, MCP SPD or FMC SPD mode. The switch is magnetically held at ARM until the AT is disengaged. Minimum speed protection is provided with the AT in ARM.

Possible reasons for an unselected AT disengage could be a system fault is detected, two seconds have elapsed since touchdown or levers have become more than 10° apart. Disengagement is followed by the ARM switch releasing to OFF and flashing red AT disengage lights. The Disengage lights do not appear with the automatic disengagement after touchdown.

CWS is a mode we don't tend to use in our operations other than for the severe turbulence supplementary procedure, but we will take a look at it here for those who perhaps use it more.

Pushing a CWS switch engages the AP pitch and roll axes in CWS mode. This allows the AP to manoeuvre the airplane is response to pressures applied by either pilot. When control pressure is released the AP holds existing attitude which takes Mark and back to the days of a previous type.

If aileron pressure is released with 6° bank or less the AP rolls wings level and holds existing heading. This is inhibited below 1500ft RA with gear down, after FD VOR capture with TAS 250kts or less and after LOC capture in the APP mode.

The AP will not follow FD commands when in CWS mode. However, CWS P will go into ALT ACQ and ALT HOLD at selected altitude and CWS R will capture selected radio course when VOR/LOC is armed.

We'll finish the first Auto flight podcast with a look at the Dual channel approach. Next time we'll run through the different phases of flight and how the AFS integrates with them.

First thing to say is you can only do a dual channel approach when you have 2 generators powering the buses allowing the isolation of those DC buses.

Here we'll assume a fail operational airplane system although other fits are of course available.

The Autoland status annunciations include Land 3, Land 2 and NO Autoland. With Land 3 annunciated you have 2 autopilots, three inertial sources and the associated sensors are operating normally. The Autoland system level of redundancy is such that a single fault cannot prevent the AP system from making an automatic landing.

Land 2 indicates a failure has occurred above Alert height and redundancy is reduced but the Autoland system is still capable of making an automatic landing. The level of redundancy is such that a single fault cannot cause a significant deviation from the flight path.

NO Autoland indicates the system is unable to make an automatic landing.

An advisory message appears on the upper engine display for any fault which limits the capability of the automatic landing system. NO LAND 3 indicates the system does not have the required redundancy for LAND 3 operations

Should any failure occur below Alert height and the system is still capable of continuing the Autoland and rollout, LAND 3 will remain displayed and the airplane will land and roll out normally without failure annunciation. Failure or Autoland downgrade annunciations will then be displayed when the airplane has decelerated below 40kts and the autopilots have been disengaged.

Back on to that dual channel approach now. We must have both VHF NAV boxes tuned to the ILS frequency and have engaged the second autopilot prior to 800ft AGL.

We will get SINGLE CH after LOC capture which will change to CMD when the system confidence test is done at 1500ft RA, shown by flashing amber ILS scales, and the second autopilot engages. If Flare mode doesn't arm by 350ft RA, the AP will disconnect.

At 400ft the auto trim puts in a large nose up input. This is something to be aware of if you need to disconnect the autopilot below the height for any reason.

At 200ft AGL the rising runway begins to move, and you should see flare mode engage at 50ft followed by Retard at 27ft. At touchdown the AFDS maintains the centreline in ROLLOUT mode by use of rudder and nosewheel steering. This occurs at approximately 2feet RA and ROLLOUT replaces VOR/LOC on the FMA. Rollout guidance will continue until either a full stop or the APs are disengaged.

After touchdown TOGA and TRIM inputs will be ignored so that ROLLOUT won't be affected by inadvertent TOGA activation.

So, there it is and we'll all look forward to the sequel next episode focusing on those flight phases and how the automatic flight system works with them. We hope you all found that a useful refresher and will continue the talk with us on our social media pages.