

## Podcast 17 – Automatic Flight part 2

Hello and welcome back to part 2 of our journey into the automatic flight system. Today we'll take a look into the practical side of the system in how it interacts with our various flight phases including take off, climb, approach and Go around.

We'll start off by taking a look at takeoff and climb. Take off is a flight director only function of the TOGA mode. Flight director roll and pitch commands are displayed, and the AT maintains N1 thrust limit as selected from the FMC. The AP may be engaged any time after the minimum engagement height.

Both FD's must be on in order to engage the takeoff mode prior to starting takeoff. This is done by pressing the TOGA switch which will engage the AT in N1 and heading and pitch in HDG SEL and TOGA respectively. N1 mode changes to ARM at 84kts and remains here until 800ft AGL where it will switch to ARM and reduction to climb thrust can be made by pushing the N1 switch. This is done for you if you have armed VNAV on the ground.

The FD's can also be engaged in the take off mode with the FD switches OFF. This can be done if a TOGA switch is pushed after 80kts below 2000ft AGL and prior to 150 seconds after lift off, the FD command bars appear automatically for both pilots.

A second press of the TOGA switches will change the thrust limit to GA during a reduced thrust take off. Be aware here that no thrust lever movement will occur if below 800ft AGL in THR HOLD.

Prior to 60kts the FD's will show 10 degrees nose down. At 60kts this will change to 15 degrees nose up.

At lift off the pitch command continues to show 15 degrees until sufficient climb rate is acquired. Pitch then commands MCP speed, which is normally V2, plus 20kts.

If an engine failure occurs on the ground the pitch target at lift off is V2 or airspeed at lift off, whichever is greater. Roll command maintains HDG SEL and bank angle is limited to 8° below 400ft.

If an engine failure occurs after liftoff the pitch command speed is either V2 if airspeed is below V2, existing speed if that is between V2 and V2 + 20, or, V2 + 20 if airspeed is above V2 + 20.

Automatic thrust reduction to climb thrust occurs upon reaching the selected thrust reduction altitude shown on the FMC CDU TAKE OFF REF page 2/2, or when the airplane levels off in ALT HOLD or VNAV PATH.

FD engaged status ends on AP engagement. Engaging the AP will engage pitch in LVL CHG giving the FMA MCP SPD unless another pitch mode has been selected. Roll mode remains in HDG SEL unless another has been selected. LNAV would have engaged at 50ft AGL if it was armed on the ground with the engagement criteria met.

En route the autopilot and FD can be used to fly lateral and vertical navigation through LNAV and VNAV. Other available roll modes are HDG SEL or VOR/LOC with the other available pitch modes being ALT HOLD, LVL CHG and V/S.

The AFDS provides guidance for single AP non-precision approaches. VOR/LOC arms the AFDS for VOR or Localiser tracking with other roll modes of LNAV or HDG SEL also available. The Descent may be accomplished using VNAV or V/S. We also get our AFDS guidance for both single and dual channel approaches. We covered dual channel last time, but we will take a look at the GA for all the different scenarios this time.

For a single channel ILS or F/D only the AP will disengage, and FD bars will be removed if a persistent localiser or glideslope anomaly or system failure is detected.

If your aircraft has Integrated Approach Navigation, or my favourite acronym IAN mode, then this gives you another great option to use for approach. It is armed by the selection of the APP button on the MCP. Once armed the Autopilot and or FD will capture the final approach course and glide path. This gives you a pseudo-ILS type display along with the associated more straight forward procedures when flying non precision approaches thus freeing up extra capacity which is always useful.

For an FMC IAN approach, FAC and GP will be displayed in your FMA's or if you're using a LOC only approach, you'll have VOR/LOC GP. Something I've not done a lot of is a back course approach, but IAN will also help you here giving you B/CRS and GP as your displayed modes.

The source of the information is displayed in white at the top left of the PFD or your scale ID annunciator as it's officially known. This will show either LNAV/VNAV or LOC/VNAV.

As promised, on to those Go arounds. GA mode is engaged by pushing either TOGA switch. For an AP go around you need to have both APs engaged, with the mode armed when FLARE armed is annunciated. If both AP are not operating a manual FD go around is available.

With the AT in ARM AT GA mode is armed when below 2,000ft RA or when flaps or not up or if G/S is captured. This is the case with or without the AFDS engaged.

For the automatic GA a first push of the TOGA switch will engage the AT in GA mode and thrust will advance toward the reduced go around N1 giving a rate of climb of 1000-2000fpm. Pitch mode engages in TOGA with FD pitch commands of 15° nose up until reaching the programmed rate of climb. FD pitch then commands target airspeed for each flap setting based on maximum takeoff weight calculations.

FD roll will command current ground track at or below 400ft RA and above 400ft LNAV will engage. The IAS window will blank, and the command airspeed cursor automatically moves to target airspeed for the existing flap position.

A second push of TOGA will advance thrust levers to full Go around thrust and N1 will show in your thrust FMA.

If the AP is compensating for asymmetric thrust during Go around the AP rudder control is disabled when a new pitch or roll mode is selected.

Above 400ft AGL, if a new roll mode is selected first the selected mode engages in single AP roll operation and is controlled by the AP which was first in command. Pitch will remain in dual AP control in TOGA mode.

If you were to select a pitch mode first the selected mode would engage in single AP pitch operation and is again controlled by the first AP that was in CMD. Here the second AP disengages, and roll mode would engage in CWS R.

The AT GA mode is terminated when either another pitch mode is selected or ALT ACQ engages. There is a cautionary note however that pitch mode cannot be changed from TOGA until sufficient nose-down trim has been input to allow single channel AP operation. This nose down trim is automatically added by the AP to reset the trim input made by the AP at 400ft RA and at 50ft RA during the approach.

If the stabiliser trim is not satisfactory for single AP operation ALT ACQ is inhibited, the AP disengage lights illuminate steady red and pitch remains in TOGA. This is something to bear in mind when monitoring the automatic go around. Perhaps listen out for that nose down trim movement a bit more carefully.

That's the automatic Go around covered so let's look at the manual FD version. Firstly, if you are operating using the single channel AP and push TOGA be aware that this will disengage that AP for you and hand the airplane over to you for manual flight.

A flight director GA is available below that 2000ft RA again and also the flaps not up or G/S capture logic as previously said. However, it is also available if the TOGA switches are activated after wheel spin up on touchdown.

The first push will give you that same GA mode on the AT which if armed will advance the thrust for you. The AP will disengage, and pitch mode TOGA FD commands are the same as for the AP Go around. Roll mode is slightly different in that LNAV will engage above 50ft this time. Below that current ground track is your guidance. This is in order to support RNP RNAV operations for terminal procedures requiring definitive course guidance.

That second TOGA push will again give you the full GA N1 limit.

TOGA mode is terminated from FD Go around above 400ft by selecting a different roll or pitch mode. If roll mode is changed first the FD roll engages in the selected mode while the pitch remains in TOGA. If pitch mode is changed first the FD pitch engages in the selected mode while roll mode automatically changes to HDG SEL.

The AT GA mode if engaged terminates when either another pitch mode is selected or when ALT ACQ is engaged.

Also, to note is that when you engage the AP before exiting the TOGA mode the AP and FDs automatically engage in LVL CHG for pitch.

Finally for GA's we have the single engine FD GA. A push of either TOGA switch in this situation will engage the FD pitch mode in TOGA. This commands 13 degrees nose up and as climb rate increases the FD pitch commands target speed.

If the engine failure occurs prior to GA engagement the FD target speed is the selected MCP speed. If the engine failure occurs after GA engagement, then the target speed depends on whether 10 seconds have elapsed since GA engagement.

Prior to 10 seconds MCP selected approach speed becomes target speed. After 10 seconds, if the airspeed at engine failure is within 5kts of the GA engagement speed, the airspeed that existed at GA engagement becomes target speed. If that airspeed is more than 5kts above go around engagement speed then current airspeed becomes the target. Target airspeed is never less than V2 based on flap position unless in windshear conditions.

FD target speed is displayed in the speed window and on the airspeed cursor. Roll mode engages in LNAV if above 50ft AGL or current ground track if below this.

Our AFS can also help us out in a windshear situation. The AP and FD provide positive corrective action to counteract most shears and the AT aids in recovery by providing quick response to any increase or decrease in speed.

If windshear is encountered during a TO or GA the FD pitch bar commands to maintain a target speed until vertical speed decreases to approximately 600fpm. At this point the pitch command bar commands a 15° nose up pitch attitude.

If V/S continues to decrease the FD commands 15° pitch until a speed of approximately stick shaker is reached. It then commands pitch attitudes that result in intermittent stick shaker.

As the airplane transits the shear the FD programming reverses in that as VS reaches +600fpm the FD commands pitch attitudes which result in acceleration back to target speed.

If shear is encountered during an ILS approach both FD and AP attempt to hold the airplane attitude, or on glideslope after glideslope capture, without regard to AoA or stick shaker limitations. Airspeed could decrease to below stick shaker and into a stall if the pilot does not intervene by pushing TOGA or disengaging the AP and flying manually.

A warning that severe windshear may exceed the performance capability of the system and or airplane is included in the FCOM. Here crew intervention is necessary.

Finally, we'll take a look at command speed limiting and reversion modes. This is independent of the stall warning and mach warning systems.

The AFS provides speed, pitch and thrust commands to avoid exceeding Vmo/Mmo, wing flap placards, landing gear placard and minimum speed.

Command speed can be equal to, but not exceed a limit speed. Speeds greater than Vmo/Mmo cannot be selected on the MCP but speeds which exceed flap or gear placards can be as well as speeds less than minimum speed.

Minimum speed is based on AoA and is approximately 1.3Vs for the current flap configuration. The AoA vanes on either side of the fuselage sense this speed.

If a speed greater than a placard speed or less than minimum speed is selected the AFS allows acceleration or deceleration to slightly short of the limit, then commands limit speed. The A under speed or 8 overspeed symbol will appear in the MCP speed window when the commanded speed cannot be reached.

Either pitch or thrust, whichever is engaged in the speed mode, will attempt to hold the limit speed. A speed 15kts greater than the minimum speed must be selected to remove the under-speed symbol.

We have two reversion modes available if speed control by the AFDS or AT alone are not sufficient to prevent exceeding a limit speed. This reversion occurs slightly before reaching the limit speed.

The first mode is placard limit reversion. When one of the placard limits are reached, gear, flap or Vmo/Mmo the overspeed limit symbol appears on the MCP and the following reversions occur.

If the AFDS is engaged but not in SPEED or CWS mode, and the AT is armed but not in speed control the AT reverts to SPEED and controls the speed to slightly below placard limit.

For Vmo/MMo if the AT is engaged in a speed mode and the thrust levers are at idle, the AFDS, if in V/S mode or CWP, will automatically engage in LVL CHG.

If the AT is not available, no response to gear or flap placard speeds is available and the AFDS reverts to speed control for Vmo/Mmo speed limiting.

The other reversion mode is minimum speed reversion. The AFDS and AT do not control to a speed less than the aforementioned 1.3Vs in the current flap configuration. If actual speed becomes equal to or slightly less than minimum speed, the under-speed symbol on the MCP will appear and if operating in V/S or CWP the AFDS reverts to LVL CHG.

The AFDS will also revert to LVL CHG from VNAV PATH except when flying a level segment. There is no reversion from V/S mode to LVL CHG when the minimum speed is reached, and flaps are greater than 12.5.

The AFS commands a speed 5kts greater than minimum speed and commands nose down pitch if the thrust levers are not advanced. As this speed is reached the under speed symbol disappears.

The AP disengages and the FD command bars retract when in a LVL CHG climb with a command speed equal to minimum speed and a minimum rate of climb cannot be achieved without decelerating.

Minimum speed reversion mode is not available with the AT off and the AFDS is in ALT HOLD or after G/S capture Minimum speed reversion is also not available when in VNAV path and flying a level segment.

Well, that wraps up a pretty vast Auto flight subject. It's important for us as active monitors to know what to expect from our AFS modes and also when to expect them. We hope that this review has helped with that and we will no doubt refer back to it in the future as and when we start to look at failure cases.