Podcast 33 – GPWS

Hello everyone and welcome to episode 33 of the 737 Talk where today Mark and I will explore the 737NG GPWS system and the associated procedures. GPWS systems were developed to help prevent CFIT accidents by alerting crews to potentially hazardous flight conditions involving imminent impact with the ground. It also supplies a warning for windshear conditions.

GPWS provides alerts, using aural messages, lights, and displays, based on radio altitude and combinations of barometric altitude, aircraft glideslope deviation and aircraft configuration. The system operates when the airplane is less than 2450 feet above the ground.

The GPWS uses GPS and disk loadable software data bases to give the flight crew improved terrain awareness. This is done by the display of detailed terrain information for the area around the aircraft. The GPWS also warns us of an early descent.

The GPWS uses 7 Modes. They are:

- Mode 1 - Large descent rates
- Mode 2 - Too much of a closure rate when approaching terrain that is rising
- Mode 3 - Too much altitude loss during climbout (at takeoff or in the go around) when the airplane is not in the landing configuration
- Mode 4 - Not enough terrain clearance
- Mode 5 - Too much deviation below the glideslope
- Mode 6 - Aural callouts when the airplane descends through selected radio altitudes and
- Mode 7 - Warning for windshear conditions.

The enhanced GPWS function contains a worldwide terrain data base. The GPWC compares airplane position and track with this data base to find if there is a warning condition. This is the terrain awareness function.

The enhanced GPWS also contains an airport data base. This data base contains terrain information for all hard surface runways that are more than 3500 feet. The GPWC compares airplane position and runway location to find if there is a warning condition. This is the terrain clearance floor, or TCF, function.

Our look ahead alerts include the “TERRAIN TERRAIN, PULL UP” warning which sounds 20-30 seconds from projected impact. Terrain will be solid red on the ND but only in expanded Map, Centre Map, expanded VOR or expanded Approach modes. Moving the ground proximity terrain inhibit switch to Terrain Inhibit will inhibit this alert.

The CAUTION TERRAIN alert sounds 40-60 seconds from projected impact with the ND showing solid amber terrain on the same modes *just* mentioned. Again, this alert can be inhibited using the TERRAIN INHIBIT switch as referenced, and:

The TOO LOW TERRAIN alert indicates descent below unsafe radio altitude while too far from any airport in the terrain database. This can be inhibited using that same TERRAIN INHIBIT switch. This may be done if flying into an airport known not to be in the terrain database.

The GPWS sends inhibit signals to the TCAS and weather radar systems when GPWS calculates cautions and warnings.

Now for the basic alerts or modes and the list is long here so bear with us.

“PULL UP” follows a SINK RATE alert if excessive descent rate continues or increases. It can also follow the radio altitude based TERRAIN alert if excessive terrain closure rate continues and landing gear and/or flaps are not in the landing configuration.

“TERRAIN” indicates excessive terrain closure rate

“DON’T SINK” alerts us to excessive altitude loss after take-off or go-around.

GLIDESLOPE indicates deviation below glide slope, with some 737’s this also indicates below glide path, and the volume and repetition rate of the alert will increase as deviation increases. Below 1000ft RA this alert can be inhibited or cancelled by pushing the ground proximity BELOW G/S Push to inhibit light.

You will hear SINK RATE in the occurrence of an excessive decent rate.

TOO LOW FLAPS will sound with unsafe terrain clearance at low airspeed with flaps not in a normal landing position. Putting the ground proximity flap inhibit switch to FLAP INHIBIT inhibits this alert, which are all used to doing when we practise Flap 15 landings due to a malfunction when in the simulator.

TOO LOW, GEAR alerts the crew to unsafe Terrain clearance at low airspeed with landing gear not down. This is inhibited by selecting the ground proximity gear inhibit switch to GEAR INHIBIT. This would be used if we had a gear disagree event for landing.

Finally we have TOO LOW, TERRAIN which alerts us to unsafe terrain clearance at high airspeed with either landing gear not down or flaps not in landing position. This will follow from DON’T SINK if another descent is initiated after initial alert, before climbing to the altitude where the initial descent began.

Obstacle alerts provide cautions and warnings for man-made obstacles 100ft and higher that are in the database. Not all 737’s have this function so please check your specific aircrafts fit.

OBSTACLE OBSTACLE PULL UP sounds with 20-30 seconds until projected impact with OBSTACLE shown solid red on the ND in MAP, MAP CTR, VOR or APP modes only. Moving the ground proximity switch to TERRAIN INHIBIT inhibits the alert.

CAUTION OBSTACLE gives you 40-60 seconds notice from projected impact with OBSTACLE shown in solid amber in those same modes mentioned. The Inhibit switch also works in the same way for this alert.

We'll look now at some of the system controls and lights. The Below G/S P-Inhibit light may be pushed below 1000ft RA to inhibit the alert. The GPWS inop light means invalid inputs are being received from the radio altimeter, ADIRU, ILS receiver, IRS, FMC, stall management computers, or EFIS control panel. Some or all alerts will not be available but those that do occur remain valid.

We have three guarded switches for flap, gear and terrain inhibit which when selected will inhibit alerts. The flap inhibit switch simulates a flaps down condition to the GPWC. The use of this switch prevents warnings when the flight crew makes a flaps up approach. When selected, the mode 4 warning TOO LOW FLAP is inhibited. The gear inhibit switch simulates a gear down condition to the GPWC. The use of this switch prevents warnings when the flight crew makes a gear up approach. When selected, the mode 4 warning TOO LOW GEAR is inhibited, and finally the terrain inhibit switch sends a discrete signal to the GPWC. The discrete signal inhibits the terrain clearance floor (TCF) function and the terrain awareness function. When the switch is in the inhibit position, TCF and terrain awareness cautions and warnings do not show on the navigation displays and are not heard over the flight deck speakers. Also, when the terrain inhibit switch is in the inhibit position, the amber TERR INHIBIT message shows on both navigation displays.

The Terrain display select switch, when pushed, shows terrain data in the expanded Map, centre Map, expanded VOR and expanded APP modes. It arms terrain data in PLN, centre VOR and centre APP. A push will deselect weather radar and a second push will deselect the terrain display.

Part of our GPWS is the vertical situation display or VSD. The VSD depicts the vertical situation of the airplane relative to the terrain throughout all phases of flight. The VSD also depicts the vertical situation of the airplane relative to the runway during final approach.

The VSD complements the increased use of constant-angle, area navigation, and required navigation performance (RNP) approaches by providing immediate validation of the selected approach path and allowing full-time monitoring of the airplane position relative to the selected glide path.

The VSD is selected on and off using the center button on the EFIS control panel. To display the VSD we set the Mode select switch to the MAP Mode. Press the center (CTR) switch once to change the display to the Center MAP Mode and then press the CTR switch again to display the VSD at the bottom half of the CTR MAP Mode. The VSD will not display in any mode other than MAP and when selected on, the VSD display will appear on the bottom of the Navigation Display (ND).

The altitude reference scale will be based on the same data as the primary altimeter. The altitude reference scale to horizontal distance scale ratio will be fixed so that a three-degree

approach angle appears the same on all EFIS control panel settings up to 80 nm. This is a great check to ensure correct QNH has been selected as if not the picture on the VSD will be incorrect perhaps showing the aircraft encroaching terrain.

Terrain will be depicted on the VSD even if WXR is being presented on the horizontal map.

The terrain awareness display on the NDs uses dots to show the terrain ahead of the airplane. Dot colour and dot pattern density are based on the terrain altitude and airplane altitude. These are the dot colours and patterns the terrain display uses:

- High density red - Terrain more than 2,000 feet above airplane altitude
- High density yellow - Terrain 1,000 feet to 2,000 feet above airplane altitude
- Medium density yellow - Terrain 500 feet below to 1,000 feet above airplane altitude. Gear down changes this to 500 feet below to 250 feet above
- Medium density green - Terrain 500 feet below to 1,000 feet below airplane altitude. Gear down changes this to 500 feet below to 250 feet below
- Low density green - Terrain 1,000 feet below to 2,000 feet below airplane altitude
- Black - Terrain more than 2,000 feet below airplane altitude
- Magenta - Unknown terrain.

If GPWS detects a terrain caution alert, the threat terrain changes from dots to a solid yellow colour. If GPWS detects a terrain warning alert, the threat terrain changes from dots to a solid red colour. On final approach, terrain near the runway does not show.

The peaks mode display shows terrain below the airplane on the navigation displays (NDs) during cruise. The display shows terrain data at all altitudes with various densities of green to show highest, mid, and lower-level non-threatening terrain.

Terrain elevation numbers show in the bottom left of the navigation display for the highest and lowest terrain shown. The colour of the numbers (red, amber and green) corresponds to the height from highest to lowest. These numbers show terrain in hundreds of feet above mean sea level (MSL). The display of red or yellow terrain is unchanged.

The manoeuvres section of the QRH details our actions in the event of GPWS caution listing the aural alerts we may get in this case. If the GPWC finds the airplane is 60 seconds from a terrain conflict, it makes a terrain caution alert. Should we receive any such caution we are to correct the flight path, airplane configuration or airspeed.

A note in the manoeuvres section of the QRH states. If a terrain caution occurs when flying under daylight VMC, and positive visual verification is made that no obstacle or terrain exists, the alert may be regarded as cautionary, and the approach continued.

We would certainly recommend a thorough scan of all instruments here as well as the visual picture and some clear communication between the crew of their mental pictures and SA before ignoring such an alert.

Another interesting paragraph in the FCTM reads. During RNAV (RNP) AR operations in close proximity to terrain on departure or approach, crews may experience momentary terrain caution-level alerts.

If the alerts are of short duration and have ceased, crews should verify they are on the required path and consider continuing the procedure using LNAV/VNAV. Depending on where the initiation occurs, the risks of terrain contact while executing a terrain avoidance manoeuvre may be higher than continuing on the required track.

This is of real importance to us as the prevalence of RNAV RNP AR departures and arrivals continues to rise. It highlights the importance of SA and terrain awareness at all times while operating below MSA on these procedures.

Next in our manoeuvres section is what to do in the event of the GPWS warning. If the GPWC finds the airplane is 30 seconds from a terrain conflict, it makes a terrain warning alert. PF will disengage the AP and AT, aggressively apply max thrust and simultaneously roll wings level while rotating to an initial pitch attitude of 20°. Speedbrakes should then be retracted and if terrain remains a threat we pitch toward the PLIs or stick shaker or initial buffet. PM should assure max thrust is set and verify all actions are performed calling any omissions. We do not change configuration and we both monitor radio altitude for terrain closure trends with PM calling any trend toward contact. When clear of terrain PF will slowly decrease pitch attitude and accelerate. All this is initiated by your company SOP call.

You'll notice a star on the application of max thrust line. This alludes to the fact that Max thrust is obtained by advancing the thrust levers full forward if the EEC's are in normal mode. It then goes on to say if terrain contact is imminent, advance thrust levers full forward. Being that this is a manoeuvre in response to a GPWS warning we believe that is the case here.

Another note mentions that Aft control column force increases as airspeed decreases. In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit. Flight at intermittent stick shaker may be needed to obtain a positive terrain separation. Use smooth steady controls to avoid a pitch attitude overshoot and stall.

The FCOM states a slightly unnerving warning too that Terrain ahead of the airplane may exceed aircraft climb performance. A GPWS alert does not guarantee terrain clearance. This reinforces the critical nature of us as crew keeping our situational awareness high by always being terrain aware and anticipating any threats.

You are operating the aircraft at its performance limits here so that statement about, smooth steady controls is one really to take to heart. In situations like this you need to squeeze every last drop of performance out which could make the difference between contact or not.

A couple more notes to think about include not using FD commands, so this is a manoeuvre where we must look through the flight directors and also that familiar note from the GPWS caution. If positive visual verification is made that no obstacle or terrain hazard exists when

flying under daylight VMC conditions before a terrain or obstacle warning, the alert may be regarded as cautionary, and the approach may be continued.

Again, we would suggest a thorough scan of instruments, clear, concise and timely crew communication and a clear Situational awareness of the terrain environment before considering continuing through a red warning. What do you think your safest option is here?

A continuation in the FCTM regarding RNAV RNP AR and GPWS warnings says; Terrain warning-level alerts always require immediate action. The most appropriate crew actions regarding airplane bank angle and track during a terrain avoidance manoeuvre depend on where the manoeuvre is initiated. Operators should determine the most appropriate course of action for each leg of the procedure, if necessary, so crews are prepared at all times.

It goes without saying that a thorough interactive crew brief when operating in such environments will ensure these procedures are understood and the importance of always knowing where you are on the departure/arrival in order to execute the correct manoeuvre, needs to be stressed, with perhaps some Fixes and radials used to mitigate against these threats.

As always in any escape manoeuvre the airplane is likely to end up in an undesired state. It is our job therefore to put it back safely into the state which we desire.

Once we have, as a crew, determined terrain is no longer a factor it's time to start the recovery from the recovery. We would likely be at a slow speed here having pitched to 20° or even the PLI's so gently lowering the nose to either continue a gentler climb or level off will start the acceleration process.

We can then control this possibly quite vigorous acceleration by making the call '"Go-around Flap15" once we have our positive speed trend established and a sensible speed. You could then set normal GA thrust, or sufficient thrust to control acceleration should you already be in level flight. Now you can settle into a known profile and configure the aircraft to your desired configuration.

Mitigation against the event is the most important factor here as achieving this successfully will mean the escape manoeuvres become irrelevant. Using your Pilot skills in Planning and briefing, Workload management, communication and flightpath management will avoid ever getting to a GPWS warning event.

If you do get one however, you would apply your knowledge in a timely manner and execute the manoeuvre using correct manual flight path management and effective monitoring through clear communication which will lead to a safe outcome.

Put the aircraft back into your desired state once Terrain is no longer a factor and make your plan for the safe continuation of the flight as a crew.

There's no escape manoeuvre for the next section however so let's get on with… (Talks Tech Ten)

Q1: When can the below G/S alert be cancelled?

Q2: What height terrain do the medium density green dots on our terrain awareness display indicate?

Q3: The PLI symbol moves up and down on the PFD in response to data from what?

Q4: What height is the GPWS windshear aural and visual alert active from?

Q5: When are the PLIs displayed on the PFD?

Q6: Which modes can the GPWS terrain data be displayed on?

Q7: What is normal hydraulic system operating pressure and what parameters are acceptable?

Q8: Which system powers the alternate brakes?

Q9: When is fast alignment of the IRS possible?

Q10: What is the recommended refuelling nozzle pressure?

And that's another talk wrapped up! Thanks for joining us again and we look forward to seeing you again soon on the next Episode in a couple of weeks. In the meantime, head over to the socials @b737talk or check out the talk website b737talk.com for more information and why not sign up to the newsletter there for information on the podcast before anyone else. Until next time though fly well and be safe.