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CHAPTER 11 – GROUND PROXIMITY WARNING SYSTEM (GPWS)

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CONTENTS	PAGE
CHAPTER 11: GROUND PROXIMITY WARNING SYSTEM (GPWS).....	3
THE PURPOSE OF GPWS	3
GPWS INPUTS /OUTPUTS OF A TYPICAL SYSTEM	3
VOICE WARNINGS	4
GPWS MODES	5
MODE 1	5
MODE 2A.....	5
MODE 2B.....	6
MODE 3	7
MODE 4	7
MODE 5	9
MODE 6 (OPTIONAL).....	10
MODE 7 (OPTIONAL).....	10
OPERATIONAL USE OF GPWS.....	11
PRIORITIES.....	12
ENHANCED GROUND PROXIMITY WARNING SYSTEM.....	12
WHAT FEATURES DOES EGPWS ADD TO THE EARLIER SYSTEM?	13
HOW DOES THE LOOK-AHEAD TERRAIN ALERTING FEATURE WORK?	13
WHAT IS TERRAIN CLEARANCE FLOOR?	13
HOW DOES THE EGPWS TERRAIN DISPLAY WORK?.....	14
WORKSHEET – GROUND PROXIMITY WARNING SYSTEM.....	16

CHAPTER 11: GROUND PROXIMITY WARNING SYSTEM (GPWS)

THE PURPOSE OF GPWS

GPWS is designed to give visible and audible warnings when an aircraft is entering a potentially dangerous ground proximity situation, such as:-

- sinking after take-off
- inadequate terrain clearance
- excessive rate of terrain closure.
- dropping below the correct ILS glide path.

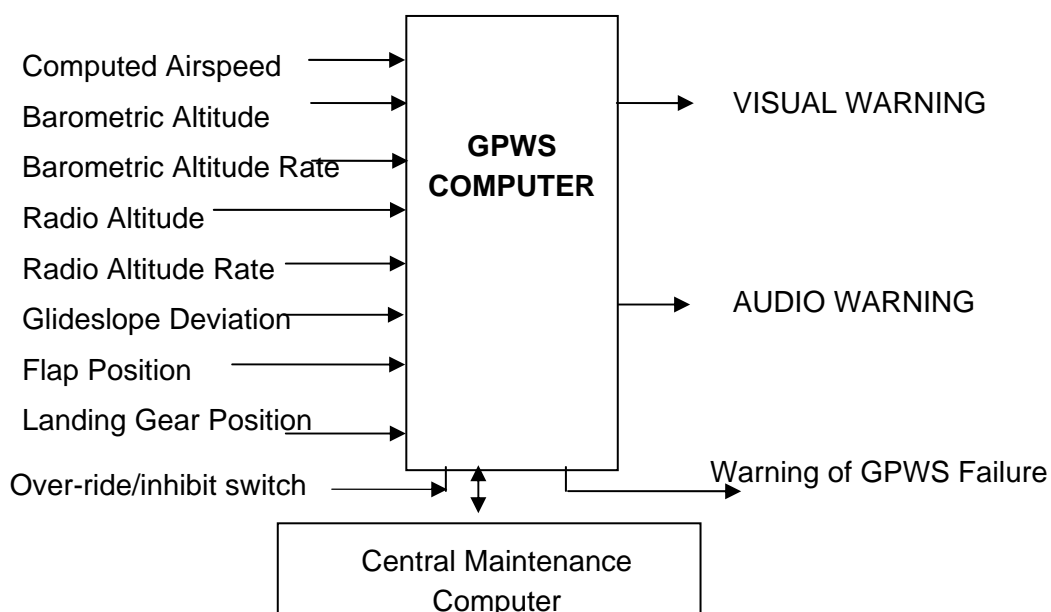


Note: Basic GPWS does not look ahead and so cannot provide warning of terrain ahead of the aircraft.

Note:

- The various modes, methods of warning and override functions vary on different aircraft.
- Alerts and warnings continue until the pilots correct the condition that initiated the warning or alert.

GPWS INPUTS /OUTPUTS OF A TYPICAL SYSTEM



Some systems such as 747-400 include a self-test capability provided by the Central Maintenance Computer and inputs from the Air Data Computer, Inertial Reference System and Flight Management Computer.

VOICE WARNINGS

To identify the cause of the warning or alert, different voice warnings are incorporated, eg.....

"sink rate....."

"terrain, terrain...."

"don't sink....."

"too low gear....."

"too low flaps....."

"too low terrain....."

"glideslope, glideslope....."

In a typical GPWS, voice warnings for Modes 1 and 2A are accompanied by illumination of red PULL UP lights and/or red MASTER WARNING lights. Modes 1 through 5 are accompanied by illumination of the amber "GND PROX / GS INHB" light switch.

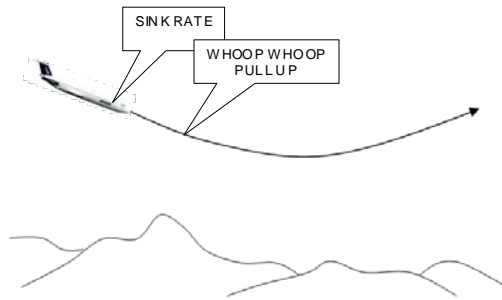


Location of the red PULL UP light (upper) and the amber GND PROX /GS INHB light switch (lower) on the Captain's instrument panel of a B737-400.

GPWS MODES

The mode envelopes in these notes are taken from a B737-400 manual. The GPWS envelopes for other aircraft may be slightly different.

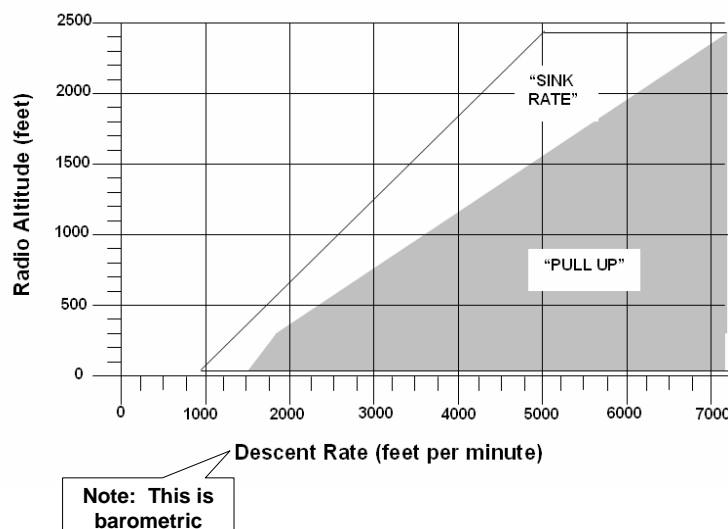
MODE 1



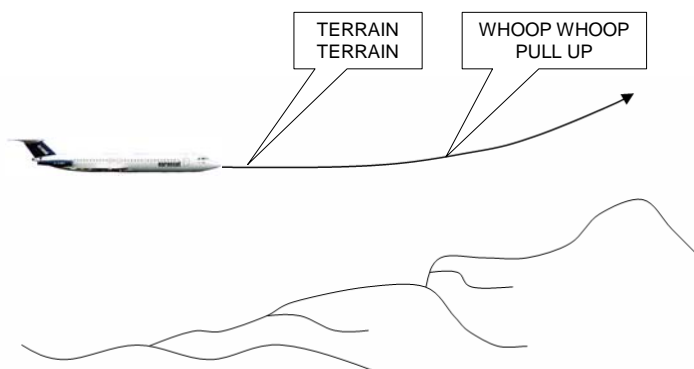
Mode 1 applies to excessive descent rate with respect to terrain clearance. This mode is independent of landing gear and flap positions. Mode 1 indications occur below 2,450 feet radio altitude down to 50 feet, when the barometric altitude rate exceeds a threshold value.

The Mode 1 envelope is divided into two areas: The initial penetration area ("SINK RATE" area), and the inner warning area ("PULL UP" area).

The specific initial penetration area and the inner warning area boundaries for Mode 1 are as shown on the following graph.

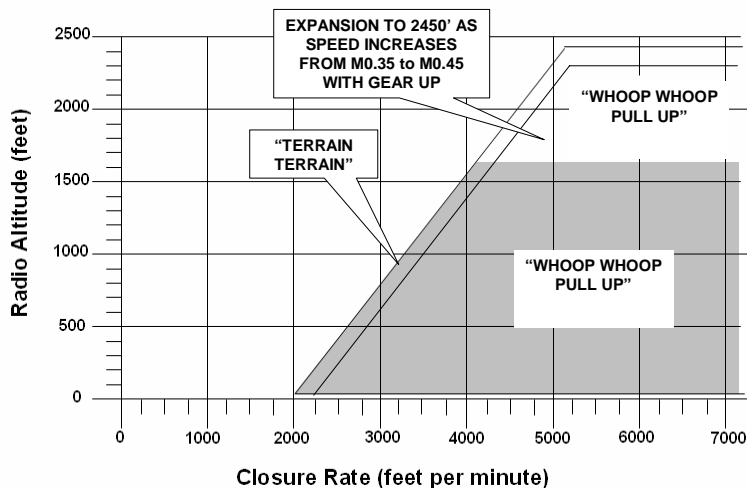


MODE 2A



Mode 2 applies to excessive closure rate with respect to rising terrain. This mode consists of two submodes: If the flaps are not down 25°, mode 2A applies; if the flaps are down 25° or more, mode 2B applies.

The Mode 2A envelope is divided into two areas: The initial penetration area ("TERRAIN, TERRAIN" area), and the inner warning area ("PULL UP" area).



The initial penetration area and the inner warning area boundaries are as shown on the graph.

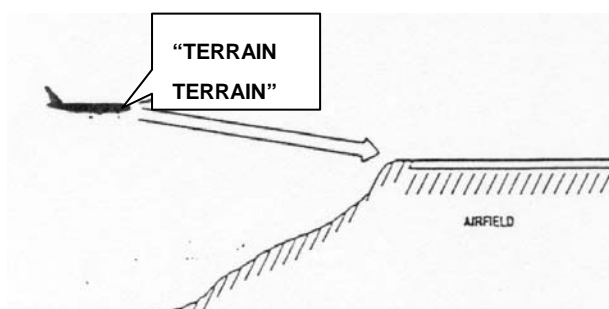
At lower airspeeds the upper boundary is 1,650 feet radio altitude, and the lower boundary is 50 feet. The upper boundary varies according to an airspeed expansion function so that at higher airspeeds the upper boundary is 2,450 feet radio altitude and the lower boundary is 50 feet.

Penetration of the mode 2A envelope can be either on the slope or from the top. The envelope is divided into two areas: the initial penetration area and the inner warning area. The inner warning area is entered after the initial penetration area message "TERRAIN" has been voiced twice upon initial penetration of the mode 2A envelope.

Initial penetration area indications consist of the illumination of the GND PROX G/S INHB light switch (amber), and the aural message "TERRAIN", voiced twice. The indications of the inner warning area are the illumination of the PULL UP light (red), the Master Warning lights (red), and the repeated aural message "WHOOP! WHOOP! PULL UP!.....".

Upon leaving the inner warning area, due to either terrain drop-off or a pull-up manoeuvre, the altitude gain function is activated. During this function, the indications change to the GND PROX G/S INHB light switch (amber) and the repeated aural message "TERRAIN...". The indications continue until the aircraft has gained 300 feet of barometric altitude, or when the landing gear is lowered.

MODE 2B



Mode 2B applies to excessive closure rate with respect to rising terrain with the flaps down 25° or more. It is an advisory-only mode.

The Mode 2B indications occur below 789 feet radio altitude and down to 200-600 feet, depending upon the barometric rate of descent, when the closure rate exceeds threshold values as shown on the appropriate graph.

Mode 2B indications consist of illumination of the GND PROX G/S INHB light switch (amber), and the repeated aural message "TERRAIN...."

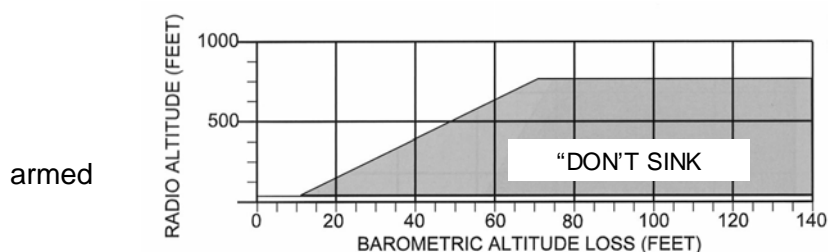
MODE 3



Mode 3 applies to excessive barometric altitude loss after take off, if the flaps are less than 25° or the landing gear is raised: or during a missed approach from below 300 feet.

It is an advisory-only mode. In general, the altitude loss threshold value is about 10% of the current altitude.

During landing approach, Mode 3 is armed after the aircraft has descended below 200 feet in landing configuration (flaps down more than 25° and landing gear down).



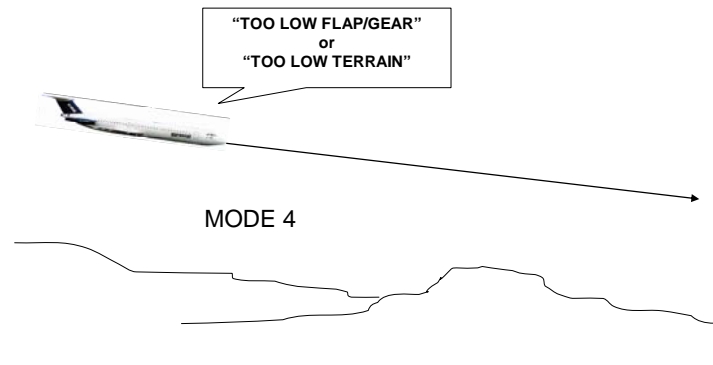
Modes 3 and 4 are mutually exclusive. In climbing, Mode 3 is disabled and Mode 4 is after the aircraft has climbed about 700 feet.

Mode 3 indications occur below 700 feet radio altitude and down to 50 feet, when the barometric altitude loss exceeds the threshold values shown on the graph.

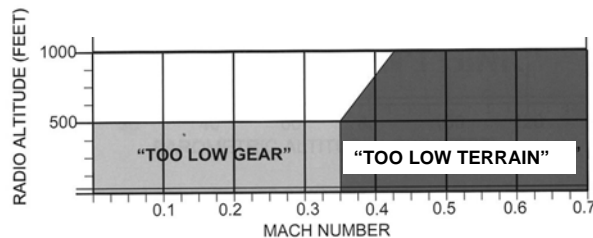
Mode 3 indications include illuminations of the GND PROX G/S INHB light switch and the repeated aural message "DON'T SINK".

MODE 4

Mode 4 usually applies during the landing phase of flight. It is armed above 700 feet after takeoff. It provides warning in the event of insufficient terrain clearance when the aircraft is not in the proper landing configuration.

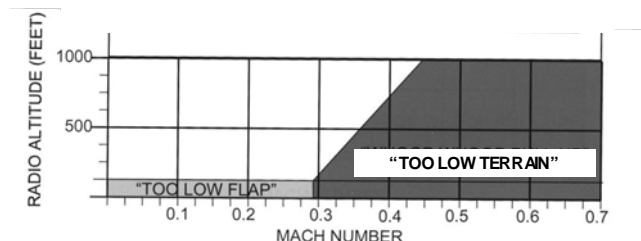


Mode 4 consists of two submodes. When the landing gear is up; Mode 4A operates. When the landing gear is down, but the flaps are less than 25°, Mode 4B operates. Each mode envelope, 4A and 4B, is divided into two advisory areas: one for low airspeeds, and another for high airspeeds.



MODE 4A

In Mode 4A, in the high-air-speed advisory area, the aural message is the repeated "TOO LOW-TERRAIN". In the low-air-speed advisory area, it is the repeated "TOO LOW-Gear".

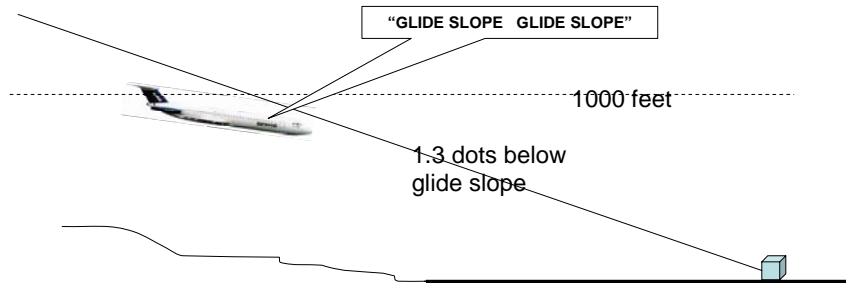


MODE 4B

In Mode 4B, in the high-air-speed advisory area, the aural message is the repeated "TOO LOW-TERRAIN". In the low-air-speed advisory area, it is the repeated "TOO LOW-FLAP".

For Modes 4A and 4B, the visual indication is the illumination of the GND PROX G/S INHB light switch (amber).

MODE 5



Mode 5 applies to excessive deviation below the actual glideslope when making a front-course approach with the gear down. In a back-course landing condition, Mode 5 is inhibited.

Initial penetration of Mode 5 envelope results in a low-level aural warning. A penetration of the inner advisory area is indicated by a normal-level aural warning.

Mode 5 envelope is divided into two advisory areas: the low-level (initial penetration) advisory area, and the normal-level (inner) advisory area.

The low-level advisory area indications occur when.....

below 1000 feet radio altitude and down to 50 feet, and when the glide slope deviation exceeds 1.3 dots (0.46 degrees).

The normal-level advisory area indications occur when.....

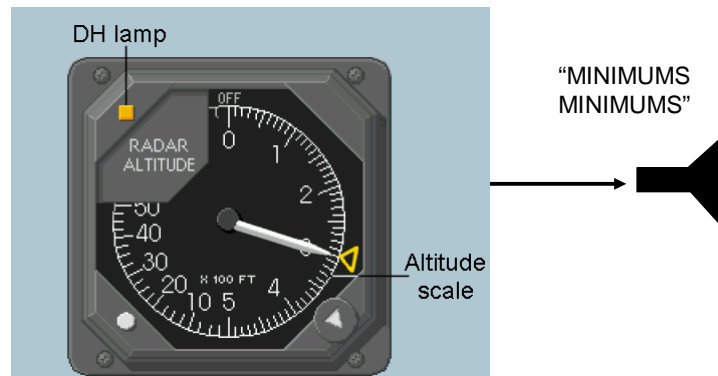
below 300 feet radio altitude and down to 50 feet, and when the glide slope deviation exceeds 2.0 dots (0.7 degrees).

Mode 5 provides warning by the illumination of the GND PROX G/S INHB light switch (amber) and the repeated aural message "GLIDE SLOPE". The sound level in the normal-level advisory area is the same as in Modes 1 through 4, and it is six decibels lower in the low-level advisory area. The "GLIDE SLOPE" message is repeated more rapidly as the terrain clearance decreases and/or the glide slope deviation increases.

Mode 5 indications may be cancelled by pressing the GND PROX G/S INHB light switch when the radio altitude is less than 1,000 feet. Both the aural message and the light indication are cancelled. The mode is automatically rearmed when climbing above 1,000 feet radio altitude or descending below 50 feet radio altitude.

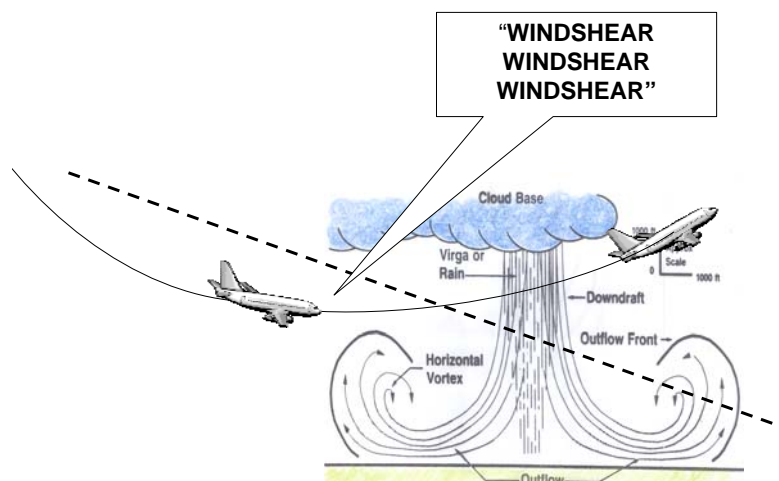
MODE 6 (OPTIONAL)

A Mode 6 voice alert of "MINIMUMS MINIMUMS" will be heard when the aircraft passes with landing gear down through the selected decision height (between 50 and 1000 feet)



MODE 7 (OPTIONAL)

The GPWS using Mode 7 can provide aural and visual warnings of windshear conditions. A typical system will provide aural warning by a siren followed by the words "WINDSHEAR WINDSHEAR". This aural warning is given only once during a windshear encounter but the WINDSHEAR light will remain illuminated until a safe airspeed has been established.



The minimum windshear intensity which activates a warning is dependant on flap position, radio altitude and phase of flight (take-off or approach). Warnings are available only below 1500 feet radio altitude.

Inputs to the windshear protection system are pitot, static, radio altitude, angle of attack, attitude (vertical gyro), flap position and gear position.

OPERATIONAL USE OF GPWS

Note: The following points on the operational use of GPWS are summarised from the UK CAA publication – 'CAP 516 GPWS : Guidance Material'.

An ALERT is a caution to which the immediate response must be to correct the flight path or the configuration so that the alert ceases. Alerts are associated with modes as follows:

Sink rate	Mode 1	Too low, Gear	Mode 4A
Terrain	Mode 2	Too low, Flaps	Mode 4B
Don't sink	Mode 3	Glideslope	Mode 5
		[Minimums]	[Mode 6]

Alerts are only reportable occurrences when a hazard arises or when there is undue repetition.

A WARNING is a command to which normally the immediate response must be to level the wings and to initiate a maximum gradient climb to the minimum safe altitude. Warnings are associated with modes as follows:

Pull Up	Mode 1 or 2
Too Low, Terrain	Mode 4A
Too Low, Terrain	Mode 4B

Warnings are normally reportable occurrences.

All alerts and warnings must be responded to immediately. However a warning may be treated like an alert if:

- a. the aircraft is operating by day with met. conditions as follows:
 - (i) 1nm horizontally clear of cloud
 - (ii) 1000 feet vertically clear of cloud
 - (iii) flight visibility of at least 5nm (8km)

and

- b. the aircraft commander is sure that the aircraft is not in danger with regard to terrain, aircraft configuration or the present manoeuvre.

Unwanted warnings may be 'nuisance' or 'false', the difference is made clear by the following definitions:

GENUINE warnings: The equipment provides a warning in accordance with its technical specifications.

NUISANCE warnings: The equipment provides a warning in accordance with its technical specifications but the pilot is flying an accepted safe procedure.

FALSE warnings: A fault or failure causes the equipment to provide a warning that is not in accordance with its technical specifications.

The Operations Manual will specify the conditions when flight crew may inhibit the GPWS. This may be limited to inhibition of the glide slope alert (Mode 5) but could include non-standard landing gear and flap position inputs (Modes 4A/B)

PRIORITIES

In a typical system, GPWS takes priority over TCAS and Windshear/Stall takes priority over all other GPWS modes. The order of priorities is marked out according to aircraft configuration and danger potential, aural messages cannot be switched off nor have their volumes controlled.

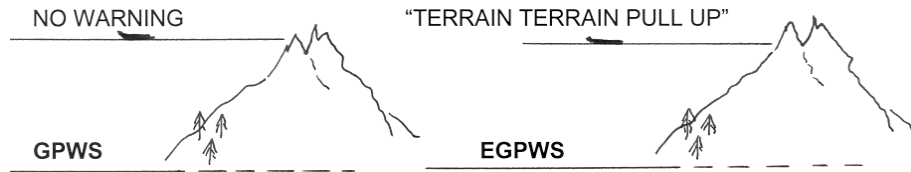
If two or more messages are acquired at any one time the one with the highest priority is the one which will be communicated to the pilots. Only when the problem that caused the higher priority message has been taken care of, will a lower priority message be heard if it is still valid.

<u>Order of priority</u>	<u>Mode</u>	<u>Type (colour)</u>
1-WW Pull-Up	1 and 2	Warning (red)
2-Terrain	2A and 2B	Alert (amber)
3-Too low terrain	4A and 4B	Warning (red)
4-Too low gear	4A	Alert (amber)
5-Too low flaps	4B	Alert (amber)
6-Minimums	6 (alert mode only)	Alert (amber)
7-Sink rate	1	Alert (amber)
8-Don't sink	3 (alert mode only)	Alert (amber)
9-Glideslope	5 (alert mode only)	Alert (amber)

ENHANCED GROUND PROXIMITY WARNING SYSTEM

Since 1979 ICAO has recommended that operators install GPWS and in most countries installation of GPWS is mandatory for IFR RPT and charter aircraft that carry 10 or passengers, or have a take-off weight in excess of 15000 kg. There are approximately 12000 commercial jet aircraft operating worldwide and all but about 200 have a GPWS. Accident rates have been significantly reduced but even so controlled flight into terrain (CFIT) continues to be the major cause of airline fatalities. It has been recognised that the GPWS has limitations for in the period 1987 to 1996 in 38% of CFIT accidents GPWS provided no warning and a further 32% of accidents resulted from late warnings or improper pilot response. The standard GPWS relies on the radio altimeter which cannot sense terrain ahead of the aircraft. This results in very short warning times when flight is towards rapidly rising terrain. Also terrain warnings are inhibited at low airspeeds, being replaced by gear and flap advisories, as GPWS assumes that the aircraft will land at an airport. Enhanced

GPWS (EGPWS) is now standard equipment and is designed to complement GPWS by providing terrain warnings in situations where the earlier system would not.



WHAT FEATURES DOES EGPWS ADD TO THE EARLIER SYSTEM?

EGPWS offers two major new features:

Look-ahead terrain alerting, including terrain clearance floor (TCF)

Terrain display

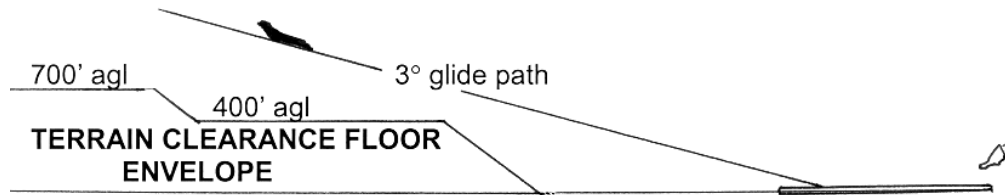
Both features make use of a totally new method of predicting dangerous proximity to terrain. EGPWS has self-contained worldwide airport and terrain databases, which when used in conjunction with aircraft position, barometric altitude and flight path information, allow prediction to be made of potential terrain conflict. The airport database includes all paved runways 3500 feet (1067 metres) or longer and the terrain database contains at least 95% of the world's land surface. Terrain around airports is provided by high-resolution data and lower resolution data is used between airports.

HOW DOES THE LOOK-AHEAD TERRAIN ALERTING FEATURE WORK?

The look-ahead terrain alerting facility provides warnings earlier than is possible with basic GPWS. Aircraft position is determined, either from the FMS or GPS, and barometric altitude from the aircraft's air data system. The position, altitude and computed flight path is then compared with terrain height in the database to determine conflict. As with the basic system, EGPWS computes two levels of terrain alerting envelopes. The look-ahead caution (alert) is provided 40 to 60 seconds before a potential terrain conflict and the look-ahead warning is provided 20 to 30 seconds before conflict. As the envelopes are time related, the distance at the onset of the alert or warning to the conflicting terrain will be greater at higher groundspeed.

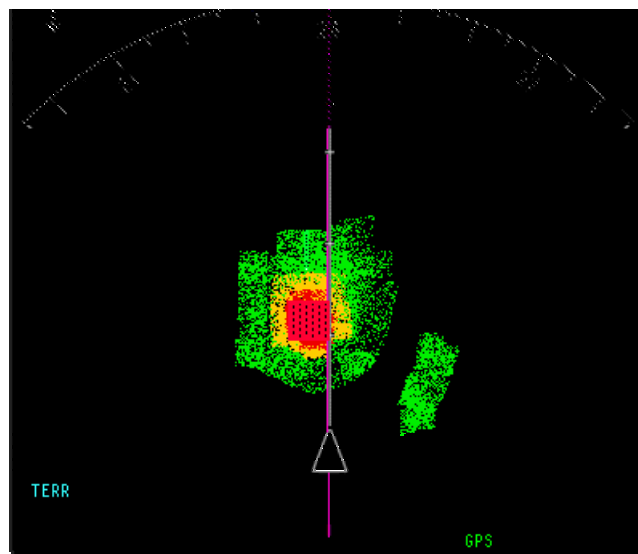
WHAT IS TERRAIN CLEARANCE FLOOR?

Terrain clearance floor (TCF) is an additional element of protection that operates during an approach to land. It compares the aircraft's radio altitude with the TCF envelope and if the aircraft is too low an alert is provided. This radio altitude based alert safeguards the aircraft in situations when barometric altitude error is preventing the look-ahead alert from activating.



HOW DOES THE EGPWS TERRAIN DISPLAY WORK?

Terrain is displayed on the EHSI (Electronic Horizontal Situation Indicator), otherwise known as the Navigation display, or on the weather radar display on aircraft without EFIS. The terrain is shown on the display by means of dotted patterns of red, amber and green. The colours indicate the height of the terrain relative to the current aircraft altitude.



DOTTED RED A red pattern appears when the aircraft is close to significantly high terrain, defined as more than 2000 feet above the aircraft altitude. This terrain represents a potential threat if displayed ahead of the aircraft.

DOTTED AMBER An amber pattern signifies terrain extending anywhere from 500 feet below to 2000 feet above the aircraft's current altitude. It also represents a potential threat if displayed ahead of the aircraft.

DOTTED GREEN A green pattern indicates terrain that is more than 500 feet below the aircraft's current altitude but which is close enough to warrant display. The crew should be aware of its presence. Terrain that is more than 2000 feet below the aircraft will not be displayed.

The EGPWS alerting functions operate in conjunction with those of the earlier GPWS and so the EGPWS aural and visual messages are nearly the same as those of GPWS. Similarly the required pilot response to a EGPWS message is the same as for the equivalent GPWS message. For example a look-ahead caution (alert) will result in the illumination of the amber ground proximity light and the aural message "CAUTION TERRAIN, CAUTION TERRAIN". The required pilot action is to correct the aircraft's flight path. A look-ahead warning will result in the illumination of the red PULL-UP annunciation and the aural message "TERRAIN TERRAIN PULL UP, TERRAIN TERRAIN PULL UP". The required pilot action is the same as for the GPWS "WHOOOP WHOOOP PULL UP".

WORKSHEET – GROUND PROXIMITY WARNING SYSTEM

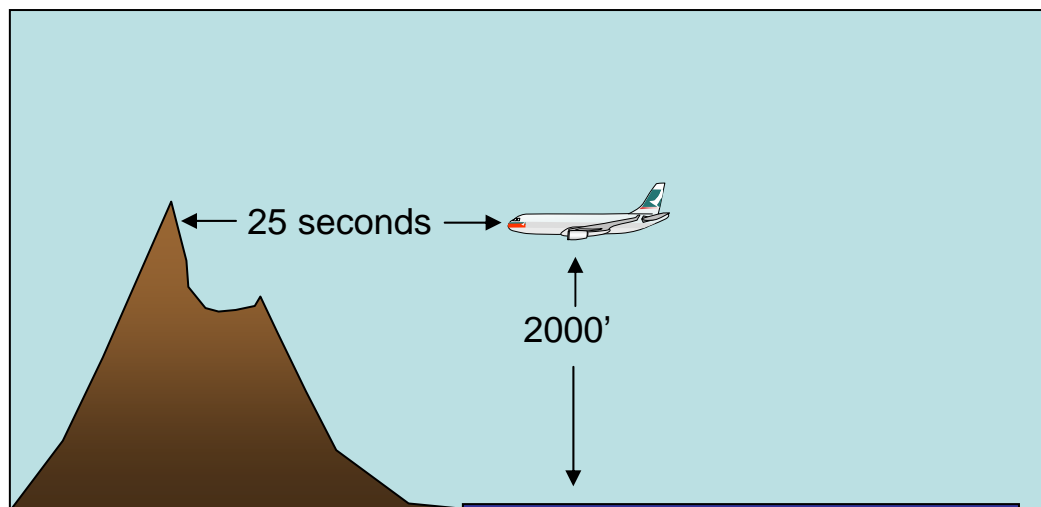
1. The voice message "Terrain Terrain" is an example of a _____.
The immediate response must be to _____.
 - (a) Alert/ correct the flight path so that the alert ceases.
 - (b) Warning/ correct the flight path so that the warning ceases.
 - (c) Alert/ level the wings and to initiate a max. gradient climb.
 - (d) Warning/ level the wings and to initiate a max. gradient climb.

2. Which of the following are correct statements with reference to types of GPWS warnings?
 - (i) A warning may be genuine or nuisance although it is in accordance with technical specifications.
 - (ii) A fault that causes the equipment to provide a warning that is not in accordance with technical specifications will lead to a nuisance warning.
 - (iii) The term "false" may be used to describe both nuisance and unwanted warnings.
 - (a) All statements are true
 - (b) Only (i) and (iii) are true
 - (c) Only (ii) is true
 - (d) Only (i) is true

3. The maximum time in Modes 1 and 2 between the triggering of an alert/warning and contact with the ground if no corrective action is taken is of -----seconds.
 - (a) 20
 - (b) 40
 - (c) 60
 - (d) 80

4. Assuming that the aircraft is equipped with advanced GPWS equipment, with what modes are warnings associated?
 - (a) Modes 1 and 2 only
 - (b) Modes 1,2,3,and 4
 - (c) All modes including windshear (if installed)
 - (d) Modes 1,2 and 4B.

5. A Mode 5 alert may be triggered:
- (a) if the aircraft is within the glide slope service area but is more than 1000 feet radio altitude.
 - (b) when the aircraft is being flown outside the validity area of the glide slope signal provided the aircraft is not above 500 feet radio altitude
 - (c) only when the aircraft is within the glide slope service area and below 1000 feet radio altitude.
 - (d) only when the aircraft is outside the glide slope validity area and above 1000 feet radio altitude.



6. What alert or warning will GPWS provide to the aircraft at the position shown in the diagram above?
- (a) Terrain Terrain
 - (b) Whoop Whoop Pull Up
 - (c) Too Low Terrain
 - (d) No alert or warning
7. Under what circumstances can a GPWS warning be ignored?
- (a) Only if the cause of the warning has been positively identified and the commander is of the opinion that no danger exists
 - (b) Only if flying in day, VMC and it is obvious to the commander that the aircraft is not in a dangerous situation.
 - (c) Only if the commander has reason to believe that the warning is false.
 - (d) Never

8. The maximum height at which the alert "Don't sink" would be heard is:
- (a) 700 feet agl
 - (b) 2450 feet amsl
 - (c) 2450 feet agl
 - (d) 700 feet amsl
9. GPWS monitors six basic modes of the aircraft's operation:
- (a) simultaneously.
 - (b) sequentially
 - (c) according to pilot selection.
 - (d) automatically with no action from the flight-deck crew.
10. An excessive rate of terrain closure (aircraft not in a landing configuration) is associated with Mode_____
- (a) 1
 - (b) 2A
 - (c) 3
 - (d) 4A or 4B
11. With reference to the reporting of GPWS alerts and warnings:
- (a) Both alerts and warnings should always be reported.
 - (b) Alerts and warnings are only reportable when a hazard arises or when there is undue repetition.
 - (c) Warnings are always reportable but alerts are not required to be reported.
 - (d) Warnings are normally reportable but alerts are only reportable when a hazard arises or when there is undue repetition.
12. A typical Mode 7 Windshear warning is only available below 1500 feet and requires _____ inputs. The warnings are _____.
- (a) IRS visual only
 - (b) IRS audio only
 - (c) ADC audio only
 - (d) both IRS and ADC both visual and audio

13. If the aircraft encounters a windshear situation, a typical Windshear Detection System provides:
- i. Aural warning including the words "Windshear Windshear"
 - ii. Visual warning in the form of a red warning light
 - iii. Pitch guidance on the ADI or PFD.
- (a) all of the above
 - (b) i and ii only
 - (c) i and iii only
 - (d) ii and iii only
14. Windshear is detected in a typical system from:
- (a) the rate of change of airspeed measured by accelerometer.
 - (b) a comparison of airspeed and groundspeed
 - (c) dedicated pitot and static sensors, provided for this purpose
 - (d) a comparison between the rate of change of groundspeed and the rate of change of airspeed
15. GPWS is equipped with a fully integrated self-test function referred to as BITE (built-in test equipment). Which of the following statements is true with reference to BITE?
- (a) BITE should be selected before flight and at any time in flight when the proper functioning of the GPWS equipment is in doubt.
 - (b) BITE is an automatic function operating before and in-flight without the requirement for pilot action.
 - (c) Successful testing of GPWS by BITE is indicated by the simultaneous activation of visual and audible warnings.
 - (d) BITE will normally operate in flight whenever an out-of-tolerance condition is detected. Warnings of unserviceability are provided through the EICAS (or ECAM) display.
16. Which of the following correctly lists some input sources to the Windshear Detection System?
- (a) Inertial wind velocity, radio altitude, pitch attitude and TAS.
 - (b) Stall speed, barometric altitude, flap position and GS.
 - (c) A of A transducer, vertical gyro, flap position and pitot/static pressures.
 - (d) VSI, indicated airspeed, configuration and stall speed.