

CAD 516

**GROUND PROXIMITY WARNING
SYSTEM (GPWS):
GUIDANCE MATERIAL**

Issue 1

June 2001

Civil Aviation Department

Hong Kong, China

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1. PURPOSE

The purpose of this publication is to provide to all concerned in the operation of aeroplanes information on, and guidance in the use of, ground proximity warning systems (GPWS). Legislation regarding the requirement to carry GPWS is to be found in the Air Navigation (Hong Kong) Order 1995. In compliance with ICAO Standards, Airworthiness Directives are issued from time to time which amplify the Order and set out amendments to regulatory requirements as equipment performance advances and as changes in aviation safety-related needs are identified.

This document includes information on the different categories of alerts or warnings which may be encountered in flight, together with advice concerning the appropriate flight crew response to each case. The various modes of protection afforded by the equipment are described. However, details of the operating envelopes of the systems are set out in manufacturers' handbooks or company Operations Manuals which should be studied by all personnel involved in the operation of aeroplanes equipped with GPWS. Information is also presented recommending the details which should be included in Checklists, Operations and Training Manuals.

2. DEFINITIONS

2.1 Alert

A caution generated by the GPWS equipment.

2.2 Basic GPWS

A GPWS system which gives no indication of the mode triggered other than Mode 5.

2.3 Predictive GPWS

A GPWS system which contains a facility to enable the prediction of loss of required terrain clearance ahead of the aircraft and the generation of associated warnings.

2.4 **Standard GPWS**

A GPWS system which has no terrain-predictive function.

2.5 **Warning**

A command generated by the GPWS equipment.

2.6 **Types of Warnings**

2.6.1 Genuine

The equipment provides a warning in accordance with its technical specification

2.6.2 Nuisance

The equipment provides a warning in accordance with its technical specification, but the pilot is flying an accepted safe procedure.

2.6.3 False

A fault or failure in the system causes the equipment to provide a warning that is not in accordance with its technical specification.

NOTE: 'Unwanted' may be used to described both nuisance and false.

3. GENERAL

- 3.1 GPWS enhances safety. It is not a foolproof means of preventing collision with the ground. It can prevent some accidents, particularly those which could result from crew errors or distraction, inappropriate ATC instructions or navigation equipment malfunction. In sum, a timely alert or warning can be provided of unintentional closure with the ground.
- 3.2 The response to all alerts or warnings should be positive and immediate – recognition and action. Establishing the cause of GPWS activation should take second place.
- 3.3 There is a risk that repeated experience of unwanted warnings may so reduce crew confidence in the system that response to a warning in the real event may be less urgent than needed. Therefore flight crews should report all alerts and warnings to the operator, thereby ensuring that appropriate analysis or remedial action can be taken. The reports will form a basis on which GPWS performance can be monitored both by the operators and by the CAD. By this means, problems of general concern should be detected at an early stage, and allow action to be taken and necessary advice or information disseminated to all concerned without delay. Details of reporting and follow-up action for GPWS alerts and warnings are given at paragraph 9.

4. PREDICTIVE GROUND PROXIMITY WARNING SYSTEMS

- 4.1 In accordance with ICAO standards, the Hong Kong Civil Aviation Department requires that all Hong Kong registered aeroplanes first issued with a Certificate of Airworthiness on, or after, 1 January 2001 authorised for the carriage of 30 passengers or more, or with a certificated take-off mass in excess of 15,000 kgs, carry GPWS equipment with predictive terrain capability.

This requirement will be extended to all such aircraft for compliance by 1 January 2003.

4.2 In addition to the standard GPWS features, Terrain Awareness and Warning System (TAWS) provides:

- (a) A forward-looking terrain avoidance function which gives look-ahead terrain and obstacle protection along and below the aeroplane's lateral and vertical flight path.
- (b) Premature descent alert function that detects when the aircraft is hazardously below the normal approach path to the nearest runway and provides a timely alert.

4.3 One manufacturer's solution to this ICAO requirement is the development of TAWS. The predictive function is achieved by feeding the aeroplane's known position, as determined by a Flight Management System (FMS) or by a Global Position System (GPS), to a terrain database, enabling the computer to predict terrain ahead and to the side of the aeroplane's flight path. Terrain features can then be displayed to the flight crew. TAWS therefore overcomes shortcomings associated with GPWS in that it produces earlier alerts and warnings of significant terrain that lie ahead at all stages of flight. Furthermore, with reference to terrain around an airfield, it can warn of descent below safe vertical profiles when the aircraft is in a landing configuration and where no ILS glideslope is present.

4.4 TAWS, which has been in use for some time, describes only one solution to the requirement for terrain prediction. Other solutions are now in the course of development or in production. A second solution – Enhanced GPWS (EGPWS) – is also in service and a third – Terrain Awareness and Display (TAD) – is also available.

5. EXAMPLES OF LIMITATIONS OF CURRENT GPWS EQUIPMENT

5.1 Reduced Effectiveness

- 5.1.1 As basic or standard GPWS (non-predictive) equipment does not look ahead, any warning when flight is towards high terrain ahead of the aircraft will be minimal and dependent upon the steepness of the ground. Hence a sheer cliff ahead of the aircraft will not generate any warning and any subsequent warning due to rising ground beyond the cliff will be delayed until the aircraft is over that ground.
- 5.1.2 Alerts and warnings are triggered in Modes 1 and 2, only when the aircraft is below 2500 feet above local terrain. The maximum time in these modes between triggering an alert or warning and contact with the ground if no corrective action is taken, is of the order of 20 seconds. However, this time will be reduced if excessive rates of descent exist or there is rising ground beneath the aircraft.
- 5.1.3 Cessation of a Mode 2 warning means only that the aircraft has cleared the terrain beneath it. There may still be rising terrain ahead of the aircraft.
- 5.1.4 Flight crew should be aware that, with standard GPWS equipment, if the aircraft is fully configured for landing, in the absence of electronic glideslope information, a normal rate of descent to the surface short of a runway will not trigger any alert or warning.

5.2 Unwanted Warnings

CAUTION:

WHERE ANY DOUBT EXISTS THAT THE SAFETY OF THE AIRCRAFT MAY BE IN JEOPARDY, THE CREW MUST TAKE ACTION AS PRESCRIBED IN THIS DOCUMENT RELATING TO GPWS ALERTS AND WARNINGS.

- 5.2.1 Occasionally under certain normal and safe operating conditions an alert or warning may occur due to a combination of descent rate and rising ground, as could happen during ATC vectoring over hilly terrain.
- 5.2.2 A Mode 5 (glideslope) alert may be triggered when the aircraft is being flown outside the validity area of the glideslope signal, eg when visually manoeuvring to land on a runway not provided with an ILS glideslope after making an ILS approach to another runway, or when executing an ILS back beam approach.
- 5.2.3 An alert or warning will be triggered if the aircraft is flown on an approach, below a predictable height, with the flap set in a position other than that normally used for landing.
- 5.2.4 Warnings may occur if a flap or a gear position signal is prevented from reaching the GPWS unit. Ferry flights with the gear locked down and certain circuit breakers pulled may give rise to this condition.
- 5.2.5 Nuisance warnings may be experienced by predictive ground proximity warning systems at certain airports. This can occur when an airport is not in the database, or when the terrain information around the airport utilised by the system is not accurate.

5.2.6 Some predictive ground proximity warning systems require barometric altitude referenced to Mean Sea Level (ie QNH) for correct operation of look-ahead alerting and terrain display. Barometric altitude referenced to airport elevation (QFE) or an error made in altimeter setting therefore, may cause nuisance alerts and incorrect terrain display.

5.3 **Other Limitations**

5.3.1 The terrain display of predictive GPWS is intended to serve only as a situational awareness tool and may not provide the accuracy and/or fidelity upon which to solely base terrain avoidance manoeuvring decisions. Navigation should not, therefore, be predicated upon the use of the database terrain display.

5.3.2 Predictive GPWS database, displays and alerting algorithms may not account for man-made obstructions.

6. **OPERATIONS MANUALS AND CHECK LISTS**

6.1 Operations Manuals should contain, in their introduction to GPWS, information similar to that noted in paragraph 3 above. The fact that a GPWS alert or warning tells the crew that the flight path of the aircraft may not be as *they suppose it to be*, should be emphasised.

6.2 Technical details of the system should contain brief descriptions of:

6.2.1 The input sources, with particular reference to the Radio Altimeter (and Barometric Altimeter in the case of predictive systems);

- 6.2.2 The 'Alert' and 'Warning' modes and their associated envelopes;
 - 6.2.3 The difference between alerts and warnings, along with the information and cautions relevant to the operator's equipment as set out in the notes following paragraph 8.2.1.
 - 6.2.4 Audio and visual indications of alerts and warnings;
 - 6.2.5 Any means by which indications are provided as to which Modes have been triggered;
 - 6.2.6 Limitations of the equipment (noted in paragraph 5 above).
- 6.3 With regard to the limitations of GPWS, crews should be informed that:
- 6.3.1 In certain conditions, they may have a minimal amount of time in which to respond if collision with the ground is to be avoided.
 - 6.3.2 Nuisance alerts or warnings may sometimes occur when aircraft are carrying out published Standard Terminal Approach procedures (STARs) or radar vectoring approaches at aerodromes where there is reduced ground clearance over steeply sloping terrain in the vicinity. In some cases ATC may be able to adjust routes and procedures to remove these difficulties. Failing such satisfactory adjustment, crew response to warnings or alerts encountered in these circumstances is subject to special factors as set out in paragraph 8.3.
 - 6.3.3 Inhibition of the glideslope mode of the GPWS may also be desirable on occasions when a glideslope signal is present but the aircraft is deliberately being flown without reference to it as, for example, when a pilot breaks off an approach from an ILS equipped runway intending to land on another runway. Inhibition may also be required when gear or flap position inputs are known to be non-standard.

6.3.4 For predictive GPWS, inhibition of terrain awareness modes may be necessary if:

- (a) the departure or destination airport is not in the GPWS airport database;
- (b) a QFE setting is entered into the Captain's or First Officer's altimeter;
- (c) a significant Flight Management System (FMS) position error is suspected;
- (d) an alert is issued and the crew can visually determine unequivocally, that no terrain threat exists (i.e. in daylight conditions and in clear sight of the surrounding terrain).

6.3.5 Instructions on inhibition must include a statement that no person may deactivate the GPWS except in accordance with the procedures stated in the Operations Manual. It is essential that this is made clear as there have been accidents in which GPWS had been inhibited in order to silence what were genuine warnings.

6.4 GPWS should be serviceable at dispatch and the Operations Manual should detail the pre-flight checks verifying that the system is functioning correctly. Minimum Equipment Lists should indicate when flights may be dispatched with unserviceable GPWS. Legislation provides that an aircraft may fly or continue to fly with an unserviceable GPWS until it first lands at a place at which it is practicable for the equipment to be repaired or replaced. It is the CAD's view that the aircraft should not be permitted to fly for more than 2 calendar days with unserviceable equipment nor should it depart from or transit through, an aerodrome where the equipment can be repaired or replaced. The aerodromes where equipment may be replaced or repaired and from which the aircraft shall not depart with unserviceable equipment shall be indicated in the Operations Manual.

- 6.5 The Operations Manual must clearly state the actions to be taken by flight crews following receipt of an in-flight alert or warning. Paragraph 8 contains detailed guidance. In the event of a departure from a cleared route or altitude in response to a GPWS alert/warning, Air Traffic Control must be informed as soon as possible.
- 6.6 The Operations Manual should contain the requirements for crews to report all alerts or warnings. The method of reporting to the company and the criteria by which reports may be classified as Mandatory Occurrence Reports (MOR) should also be described. A brief description of the functions of the Operator and of the CAD in the handling of these reports should be included in the Operations Manual. Paragraph 9 contains details of reporting and follow-up action.

7. TRAINING

- 7.1 The objective of GPWS training is to ensure that pilots take appropriate action on alerts, and that **THEY REACT PROMPTLY** to warnings by applying maximum power and adjusting to the **CORRECT PITCH ATTITUDE** for the maximum gradient of climb. The GPWS ground training syllabus should involve a systematic progression through all modes, culminating in a demonstration of each audio alert or warning and the associated visual indications, together with the correct reaction.
- 7.2 Flight crew GPWS training should normally be carried out in a suitably equipped simulator. Careful consideration should be given to relevant regulations before the utilisation of aircraft. Training should be directed towards recognising and responding correctly and rapidly to a GPWS alert/warning.
- 7.3 Refresher training covering procedures in relation to **ALL MODES** capable of being experienced in aeroplanes operated by a company should be undergone by all flight crew over a three-year period.

8. ACTION TO BE TAKEN ON RECEIVING ALERTS AND WARNINGS

8.1 Basic GPWS

(Equipment which gives no indication of Mode other than Mode 5)

Examples of this equipment are Marconi and Sundstrand Mk 1.

8.1.1 Action To Be Taken On Receiving An Alert

With this type of GPWS, alerts can only be associated with Mode 5 and will be indicated aurally by repetition of the audio 'GLIDESLOPE'. The crew is required to take immediate action to regain the ILS glide slope, which will be above the aircraft and, in doing so, will cause the alert to cease.

8.1.2 Action To Be Taken On Receiving a Warning

The immediate response must be to select maximum thrust, level the wings, confirm that speedbrakes are stowed and initiate a maximum gradient climb, which should be maintained until the aircraft attains the minimum safe altitude for that part of the route being operated, and the warning ceases. Unless it is known for certain that maintaining a wings-level attitude will further compromise terrain clearance, a curved recovery path should not be initiated. Where a curved path is deemed to be necessary, the establishment of the maximum climb rate consistent with the required angle of bank must be adopted. When established in the climb every effort shall be made to determine the cause of the warning and to verify the aircraft's position.

The only circumstances when a climb may be discontinued are when:

- (a) the cause of the warning has been positively identified and the warning ceases; or
- (b) the conditions specified in paragraph 8.3 apply.

With this type of GPWS equipment, warnings are associated with Modes 1, 2, 3 and 4, and the audio warning will be 'Whoop Whoop, Pull Up'.

Although operators should ensure that a procedure appropriate to the aircraft type is included in the Checklist, crews should be expected to memorise all actions needed to obtain the immediate objective – establishing the aircraft in a maximum gradient climb.

A typical checklist might be:

Call	GO AROUND
Thrust Levels	MAXIMUM THRUST
Speedbrakes	CONFIRM STOWED
Autopilot	DISENGAGE
Attitude	LEVEL THE WINGS AND ESTABLISH REQUIRED ATTITUDE
Speed	AS REQUIRED FOR MAXIMUM GRADIENT CLIMB
Configuration	RE-CONFIGURE AS PER THE OPERATIONS MANUAL
Air Traffic Control	INFORM

NOTE: The actions in paragraphs 8.1.1 and 8.1.2 are required to be taken with the utmost urgency since, under certain circumstances, the time available to retrieve the situation is minimal.

8.1.3 Subsequent Actions

The crew should check the position of the aircraft in respect to terrain and, where appropriate, confirm that the radio aids being used for navigation are correctly tuned, observe radio altimeter indications, recheck barometric settings on pressure altimeters and confirm that – at the time the warning occurred – the flap and gear positions were appropriate to the flight phase.

8.2 Standard and Predictive GPWS

Examples of this equipment are Sundstrand Mk II & III and Allied Signal Enhanced GPWS.

8.2.1 Action To be Taken On Receiving An Alert

In the cases of alerts (which are to be regarded as ‘cautions’), the immediate response must be to correct the flight path or the configuration of the aircraft, such that the alert ceases. Alerts associated with Modes are:

<i>'Sink Rate'</i>	<i>Mode 1</i>
<i>'Terrain'</i>	<i>Mode 2</i>
<i>'Don't Sink'</i>	<i>Mode 3</i>
<i>'Too Low, Gear'</i>	<i>Mode 4A</i>
<i>'Too Low, Flap'</i>	<i>Mode 4B</i>
<i>'Glideslope'</i>	<i>Mode 5</i>
<i>'Caution Terrain' & 'Terrain Ahead'</i>	<i>Predictive Mode (Reduced Required Terrain Clearance function and Imminent Impact with Terrain function)</i>

With all alerts, appropriate action will vary according to the phase of flight; the immediate action might be to level the aircraft (if descending), or to climb (if already level), or to climb at an increased rate (if already climbing). At the same time the crew should check flight deck instruments and controls to ascertain the reason for the alert and, until the cause has been established, the crew must not continue to follow the original flight path. In the case of an alert caused by incorrect gear or flap configuration, the original flight path must not be resumed until all causes of the alert have been clearly identified, gear and flaps positions have been confirmed as correctly set and that to continue along that flight path is in accordance with the ATC clearance and safe operating practices. If safe terrain clearance is in doubt at any time, a maximum gradient climb should be performed until the alert ceases.

NOTES:

- (I) Some equipment provides an automatic audio call as the aircraft passes through the height 'bugged' by the pilot on a radio altimeter. Manufacturers may term this a Mode 6 alert and its purpose is to remind crews operating to low weather minima, to take such action as may be appropriate to these circumstances.

- (II) Mode 4 is divided into two sub-sections, Mode 4A and 4B, which relate to the inadvertent approach to land with incorrectly configured landing gear or flaps. These misconfigured profiles give rise to the alerts 'Too Low Gear' or 'Too Low Flaps'. These are classified as alerts as the situation may be rectified by reconfiguration. There is, however, a further sub-group to each of these incorrect configurations, whose properties are characterised by entry to the GPWS envelope at a significantly higher airspeed than that of its 'parent' sub-section and which are identified by the audio 'Too Low Terrain' which is a warning. (This speed varies with aircraft type and the mis-setting of landing gear or flaps.) As 'Too Low Terrain' is generated by variable parameters and relates to higher airspeeds, the inherent risk is greater which necessitates treating this message as a warning, requiring the full response from the crew as in 'Whoop Whoop Pull Up' situations.

- (III) Premature Descent Alert is an additional GPWS mode found in predictive systems. It is triggered to alert the crew that the aeroplane on an instrument approach is hazardously below, by reference to GPS, the normal (typically three degree) approach path to the nearest runway. Its manufacturer's classification is that of an *alert* and its associated audio is 'Too Low Terrain'. It should be noted that this same audio is also generated as a *warning* as noted in Note II above.

- (IV) The audio and visual presentations of alerts and warnings in the foregoing text vary between different aircraft and different manufacturers. Manuals relating to specific equipment should be carefully read in order to ensure that the characteristics of that equipment are completely understood.

8.2.2 Action To Be Taken On Receiving A Warning

The immediate response must normally be to level the wings and to initiate a maximum gradient climb and then to maintain this until the aircraft attains the enroute minimum safe altitude for the sector being operated and the warning ceases. When established in the climb every effort shall be made to determine the cause of the warning and to verify the aircraft's position. These actions should include confirmation of the correct radio navigation aids where appropriate.

The only circumstances in which a climb may be discontinued are when:

- (a) The cause of the warning has been positively identified and the warning ceases; or

(b) The conditions specified in paragraph 8.3 apply.

NOTE: There may be exceptional circumstances where it would be inappropriate to level the wings, for example a curved approach or a missed approach procedure involving turns to avoid terrain; or when receiving a “Terrain Ahead Pull Up” warning and the crew concludes, based on all available information, that turning is the safest course of action. However, it should be borne in mind that ‘wings level’ provides the best climb performance.

Typically, warnings associated with this type of GPWS equipment might be:

<i>'Pull Up'</i>	<i>Mode 1 or Mode 2</i>
<i>'Too Low, Terrain'</i>	<i>Mode 4A</i>
<i>'Too Low, Terrain'</i>	<i>Mode 4B</i>
<i>'Too Low, Terrain'</i>	<i>predictive Mode (Premature Descent Alert Function)</i>
<i>'Terrain, Pull Up' &</i>	
<i>'Terrain Ahead, Pull Up'</i>	<i>predictive Mode (Reduced Required Terrain Clearance Function and Imminent Impact with Terrain Function)</i>

Although operators should ensure that a procedure appropriate to the aircraft type is included in the checklist, crews are expected to memorise all actions needed to obtain the immediate objective – establishing the aircraft in a maximum gradient climb. Paragraph 8.1.2 above contains an example of a GPWS procedure.

8.2.3 Subsequent actions

The crew should locate the position of the aircraft with respect to terrain by appropriate means, confirming where necessary the correct setting of radio aids, observe radio altimeter indications, recheck barometric settings on pressure altimeters, and confirm that – at the time the warning occurred – the flap and gear positions were appropriate to the flight phase.

8.3 Discretion - Basic, Standard and Predictive GPWS equipment

All alerts and warnings must be responded to immediately. However, in the case of a *warning*, the response may be limited to that required for an alert, but **ONLY WHEN THE FOLLOWING CONDITIONS APPLY:**

- (a) the aircraft is operating by day and in visual conditions which permit a clear and uninterrupted view of surrounding terrain which remains in sight until safe terrain clearance is achieved;

and

- (b) it is immediately obvious to the commander that the aircraft is not in a dangerous situation with regard to terrain, aircraft configuration or the current flight profile of the aircraft, **AND WILL REMAIN SO.**

9. REPORTING AND FOLLOW-UP OF GPWS ALERTS AND WARNINGS

9.1 General

9.1.1 The possibility of false and nuisance warnings occurring from time to time cannot be ruled out. Departures from normal operating procedures may also result in genuine warnings. If these are allowed to continue unchecked there is a risk that a genuine warning may be unheeded or the response to it may be too slow. It is vital therefore, that all warnings are reported to the Company (and to the CAD if the incident falls into the scope of a ‘reportable occurrence’), their cause established and steps taken to prevent their recurrence.

9.1.2 The CAD also needs to know of potentially hazardous occurrences, what remedial action was taken and, from time to time, what the general GPWS record is like, including situations where alerts or warnings should have been experienced but were not. This information is required so that the overall performance of GPWS can be monitored, any particular problems of general concern circulated and any action initiated to resolve or reduce ‘across the board’ problems.

9.2 Reporting

9.2.1 The Operations Manual should establish company procedures for submission by pilots of reports on all GPWS alerts or warnings (Modes 1-4B inclusive, “Windshear” modes when installed and those modes under TAWS) experienced in flight, or where a pilot considers that an alert or warning should have occurred but did not. The manual should also include information concerning the intended routing of such reports for operational and technical analysis, and for follow-up action as appropriate.

9.2.2 The CAD considers that a warning should be regarded as a 'Reportable Occurrence' in the following circumstances:

- (a) When an aircraft comes into closer proximity to the ground than has been planned or anticipated.
- (b) When any difficulty or hazard arises, or might have arisen, as a result of crew response to a warning; eg possible reduced separation from other traffic. This could include warnings of any Mode or Type (ie Genuine, Nuisance or False), where applicable.
- (c) Where the incident is one of a number of similar occurrences which, though not individually reportable under the Occurrence Reporting Scheme, indicate the possibility of a genuine warning being ignored through repetition: for example:
 - (i) Warnings of any Mode where these occur on a number of occasions at a particular aerodrome.
 - (ii) False warnings associated with certain aircraft, or failure or malfunction of certain equipment in any part of the system.

In such cases it is expected that the reporter will submit a single occurrence report together with supporting evidence of high frequency and/or rate when it is considered that a reportable situation has been reached.

- (d) When a warning experienced in IMC or at night is established as having been triggered by a high rate of descent (Mode 1).

- (e) Where the occurrence involves failure to select gear or land flap by the appropriate point on the approach (Mode 4).

9.2.3 An alert would not normally be regarded as a reportable occurrence. However, the CAD considers an alert should be reported if:

- (a) any difficulty or hazard arises as a result (see 9.2.3(b) above);

or

- (b) there is undue repetition (see 9.2.3(c) above);

9.3 Follow-up Action

9.3.1 On receiving a report, an operator should assess or confirm the type (Genuine, Nuisance or False) and the Mode of the alert or warning. He should also determine whether or not the report should be assessed as a 'reportable occurrence' and, if so, send a copy of the report to the Flight Standards and Airworthiness Division (FSAD) of the CAD (address: 10/F, Commercial Building, Airport Freight Forwarding Centre, 2 Chun Wan Road, Chek Lap Kok, Hong Kong). In the interests of safety, the operator should retain one copy of each report he receives for at least 6 months, so that this may be available for analysis if required.

9.3.2 Further data may be needed to verify the nature of the alert or warning and its likely cause. This should be obtained as soon as possible after the occurrence. In apparently serious cases, it may be advisable to obtain a Flight Data Recorder read out. In such instances, the FSAD should be advised when this has been done.

9.3.3 Once the nature of the warning and its probable cause have been determined, the operator shall take whatever remedial or preventative action may be appropriate. Ultimately, if the occurrence was reportable as a MOR, the operator shall advise the FSAD of the action taken.