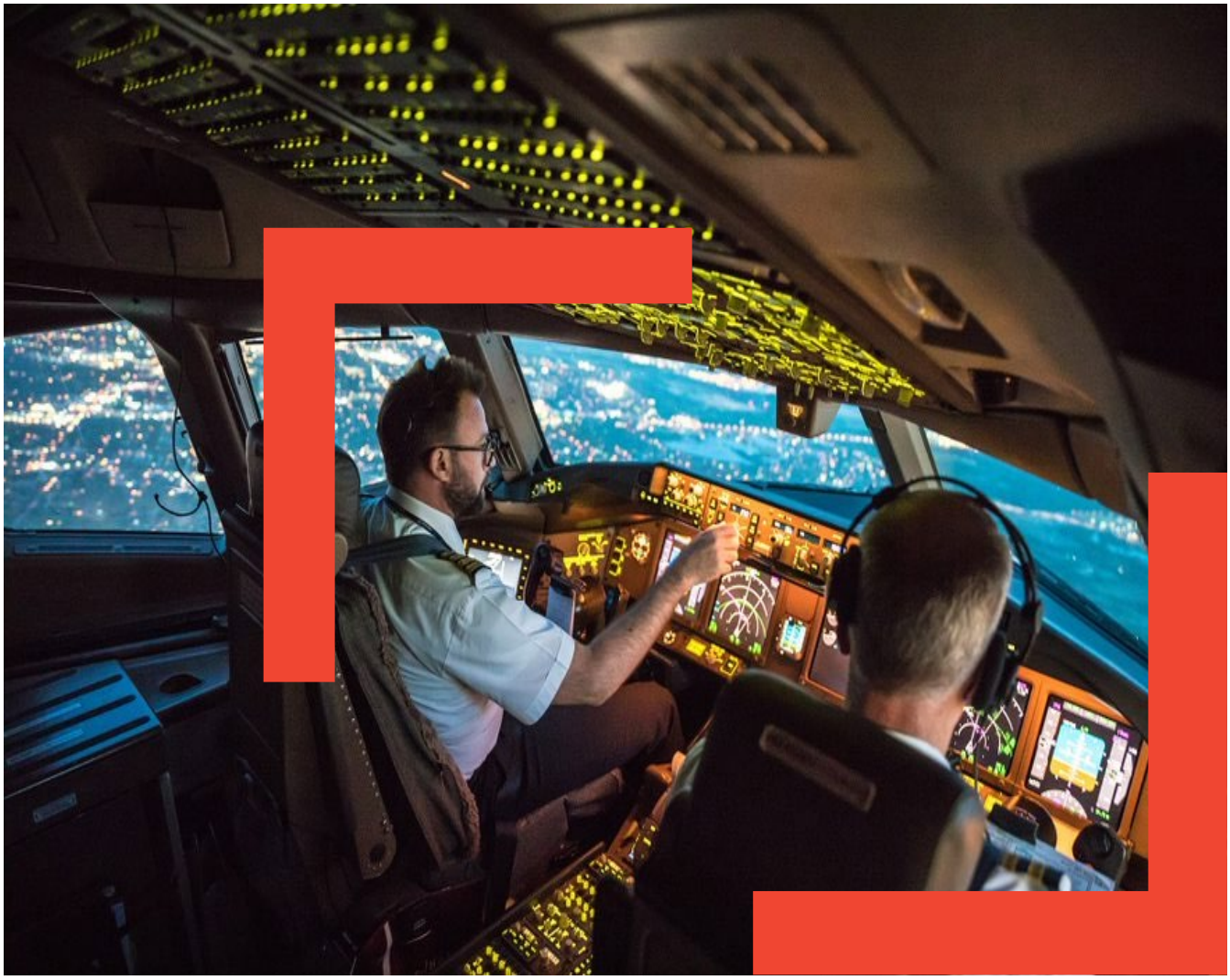
Guidance material

Performance assessment of pilot response to Enhanced Ground Proximity Warning System (EGPWS)



Edition 1- 2019

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CONTENTS

Abbreviations and Acronyms

AGL	Above Ground Level
AFM	Airplane Flight Manual
ASR	Air Safety Report
ATC	Air Traffic Control
CFIT	Controlled Flight into Terrain
EFIS	Electronic Flight Instrument System
EGWPS	Enhanced Ground Proximity Warning System
FDM	Flight Data Monitoring
GA	Go Around
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HFOM	Horizontal Figures of Merit
HDOP	Horizontal Dilution of Precision
IATA	International Air Transport Association
IMC	Instrument Meteorological Conditions
MFD	Multi-Function Display
MOR	Mandatory Occurrence Reporting
ND	Navigation Display
OEM	Original Equipment Manufacturer
PLI	Pitch Limit Indicators
PNF	Pilot Not Flying
RFCF	Runway Field Clearance Floor
ROC	Required Obstacle Clearance
SOPs	Standard Operating Procedures
TAWS	Terrain Awareness and Warning System
TAD	Terrain Awareness and Alerting Display
TCF	Terrain Clearance Floor
TO	Take off
VDOP	Vertical Dilution of Precision
VFOM	Vertical Figures of Merit
VMC	Visual Meteorological Conditions

Introduction

Historic accident data shows that CFIT has been a major cause of fatal accidents. In response to this hazard, the industry developed and implemented the Ground Proximity Warning System (GPWS) which provides warnings to pilots when the aircraft is in potentially hazardous proximity to terrain. This system was introduced in the 1970s to reduce the high number of Controlled Flight into Terrain (CFIT) accidents and incidents. The functionality of GPWS was limited. To overcome the limitations of GPWS, a new technology Enhanced Ground Proximity Warning System (EGWPS), also known as Terrain Awareness and Warning System (TAWS), was introduced; which combines a worldwide digital terrain database with an accurate navigation system, ideally using the Global Positioning System (GPS). EGPWS is not a solution for stopping CFIT accidents but it can help interrupt a flight path which is likely to lead to an accident. EGPWS or TAWS, provides a warning in advance of steeply rising ground and extends the warning area almost to the runway threshold, overcoming the limitations of GPWS.

EGPWS descriptions

The EGPWS is a Terrain Awareness and Alerting system providing terrain alerting and display functions with additional features. The EGPWS uses aircraft inputs including geographic position, attitude, altitude, ground speed, vertical speed and glideslope deviation. These are used with internal terrain, obstacles, and airport databases to predict a potential conflict between the aircraft flight path and terrain or an obstacle. A terrain or obstacle conflict results in the EGPWS providing a visual and audio caution or warning alert.

The EGPWS contains the following databases:

- Terrain database
  - A worldwide terrain database of varying degrees of resolutions
- Obstacle database
  - Known obstacles 100 feet or greater in height
- Runway database
  - Runways 3500 feet or longer in length (2000 feet or longer in some EGPWS models)

Additionally, the EGPWS provides alerts for excessive glideslope deviation, too low with flaps or gear not in landing configuration, and optionally provides bank angle and altitude callouts based on system configuration settings. Detection of severe windshear conditions is also provided for selected aircraft types when enabled.

The EGPWS incorporates the functions of the basic GPWS. This includes the following alerting modes:

- **Mode 1:** Excessive Descent Rate
- **Mode 2:** Excessive Terrain Closure Rate
- **Mode 3:** Descent After Takeoff
- **Mode 4:** Unsafe Terrain Clearance
- **Mode 5:** Descent Below Glideslope
- **Mode 6:** Advisory Callouts (Optional)
- **Mode 7:** Reactive Windshear (Optional)

The EGPWS includes several other enhanced features:

- **Terrain Alerting** algorithms continuously compute terrain clearance envelopes ahead of the aircraft. If the boundaries of these envelopes conflict with terrain/obstacle elevation data in the terrain/obstacle database, then alerts are issued. Two envelopes are computed, one corresponding to a caution alert level and the other to a warning alert level.
- **Terrain Display** provides a graphic display of the surrounding terrain and obstacles on a dedicated weather radar indicator or, on compatible Electronic Flight Instrument System (EFIS), electronic Navigation Display (ND) or Multi-Function Display (MFD). Based on the aircraft's position and the internal database, the terrain topography is presented on the system display for additional situational awareness.
- **Terrain Clearance Floor (TCF)** creates an increasing terrain clearance envelope around a runway. TCF alerts are based on current aircraft location, nearest runway position and radio altitude. TCF complements existing Mode 4 by providing an alert based on insufficient terrain clearance even when in landing configuration.
- **Runway Field Clearance Floor (RFCF)** is similar to the TCF feature except that RFCF is based on height above the runway elevation instead of radio altitude.
- **Geometric Altitude** is a computed aircraft altitude designed to help ensure optimal operation of the EGPWS functions through all phases of flight and atmospheric conditions. Geometric Altitude uses an improved pressure altitude calculation, GPS altitude, radio altitude, and terrain and runway elevation data to reduce errors potentially induced in corrected barometric altitude by temperature extremes, non-standard altitude conditions, and altimeter miss-sets. Geometric Altitude also allows continuous EGPWS operations in QFE environments without custom inputs or special operational procedures.

EGPWS evolvement

The unreliability and limitation of the first generation GPWS was cited where GPWS was plagued by false and nuisance warnings, causing pilots to distrust the equipment when actual hazardous conditions existed. Subsequently, generations of GPWS have become more reliable. A number of studies have examined pilot response times to GPWS alerts and indicate that alerts and warnings in the final 5 seconds of a flight would not give sufficient time for the flight crew and aircraft to respond effectively. This issue has been addressed with EGPWS, which provides the pilot with a greater time to respond to an alert and take avoiding action.

Terrain / obstacle / runway database updates

For the system to work as designed, aircraft operators must ensure the accuracy of terrain, runways, and surrounding obstacles. The Terrain/Obstacle/Runway database applicable to the Honeywell EGPWS is released every 56 days and the release schedule can be found at https://ads.honeywell.com. Appendix A to this report presents an example of the Terrain Database Schedule for 2018, 2019 and 2020.

Response to an EGPWS alert activation

Appropriate response procedures for flight crew are determined by the aircraft type performance capability. They must be clearly defined by operators and defined in an applicable airplane flight manual (AFM). In the case of a warning, flight crew should follow the warnings without hesitation as soon as triggered.

During night or in instrument meteorological conditions (IMC), apply the procedures immediately in response to caution and warning level alerts. Do not delay reaction for diagnosis.

During daylight or in visual meteorological conditions (VMC), take positive corrective action until the alert stops or a safe trajectory is ensured.

Following an EGPWS alert, flight crew should control the aircraft flight path with immediate maximum Required Obstacle Clearance (ROC) and maximum thrust to clear the obstacles threatening the flight. For detailed Standard Operating Procedures (SOP's) consult the respective Original Equipment Manufacturer (OEM) flight operations documentation

Warning level alert

- Aggressively position throttles for maximum rated thrust.
- Apply maximum available power as determined by emergency need. The pilot not flying (PNF) should set power and ensure that takeoff / go-around (TO/GA) power and modes are set.
- If engaged, disengage the autopilot and smoothly but aggressively increase pitch toward "stick shaker" or Pitch Limit Indicators (PLI) to obtain maximum climb performance.
- Continue climbing until the warning is eliminated and safe flight is assured.
- Advise ATC of situation.

NOTE:

- *Climbing is the only recommended response unless operating in visual conditions and/or pilot determines, based on all available information, that turning in addition to the climbing is the safest course of action. Follow established operating procedures.*
- *Navigation must not be based on the use of the Terrain Awareness and Alerting Display (TAD).*

Caution level alert

- Take immediate corrective action as necessary to recover safe terrain clearance.
- Advise ATC of situation as necessary.

Reporting

A written Air Safety Report (ASR) should be submitted to the appropriate Air Traffic Control Unit and the authority in accordance with the mandatory occurrence reporting (MOR) requirements, whenever the aircraft flight path has been modified in response to an EGPWS alert.

This data together with the operational data downloaded from an aircraft's on-board computer at the end of every flight (FDM) can be collected, analyzed and used by the operator, to identify and discover underlying issues that have the potential to negatively affect aviation safety and to enable operators to take appropriate action to mitigate. Aircraft Operators with a flight data monitoring (FDM) process, should have an automatic alerting system for any recording which contains such an occurrence, and this should support an investigation

already initiated by receipt of an ASR or prompt the commencement of a new investigation and/or should reinforce the lesson with dedicated simulator training sessions.

Conclusions

The introduction of terrain awareness technologies, such as the EGPWS / TAWS, have directly or indirectly, contributed to a reduction in the number of CFIT accidents. With such technology, the flight crew gets improved situational awareness and is able to counter act potential CFIT accidents sooner. For the system to work as designed, aircraft operators should keep the software and terrain/obstacle/runway database up to date. The proper and timely responses to EGPWS warnings can result in significantly reducing the risk of a CFIT accident. To achieve this objective, the pilot should demonstrate taking the correct action and perform appropriate recovery maneuvers needed in response to a caution and warning.

Recommendations

- Operators are encouraged to
    - Assess and consider equipping their aircraft with EGPWS equipment;
    - Ensure the use of GPS that feeds direct to EGPWS;
    - Put in place a training program to ensure flight crew can respond effectively to EGPWS cautions and warnings; are aware of factors that can reduce effectiveness of EGPWS and are trained to mitigate the effects of EGPWS degradation;
    - Have procedures in place to ensure that EGPWS software and terrain, runway and obstacle databases are current and continually updated;
    - Have procedures in place to ensure that EGPWS equipment remains activated and serviceable at all times;
    - Include CFIT avoidance maneuvers in recurrent training.

Supporting information

EGPWS statistics

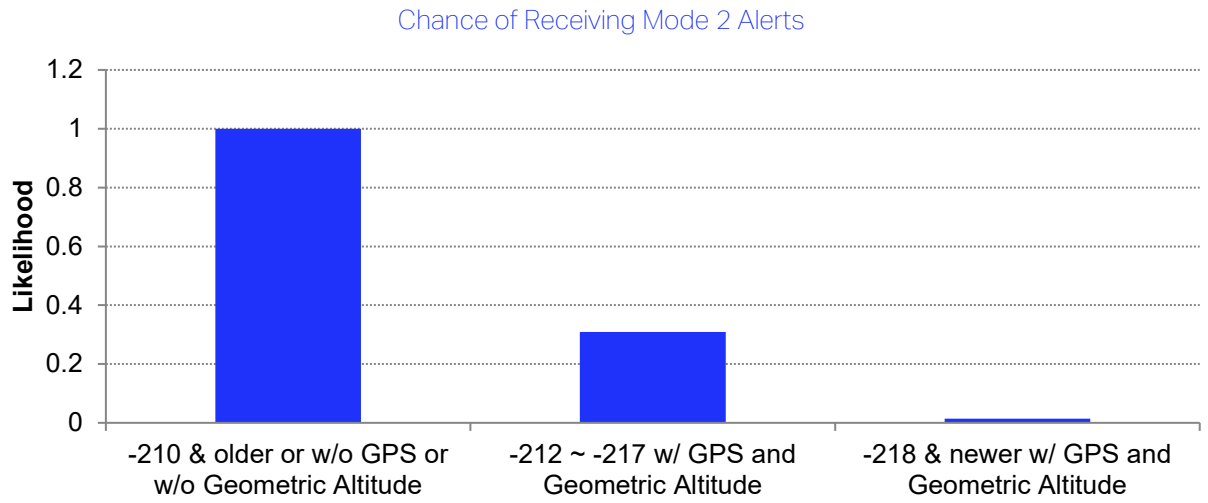
This section presents analysis using Honeywell flight history data recorded in the EGPWS, covering over 18 million flights from 1997 till mid-2012 – it is believed that the information to still be valid today. Below is a summary of findings and conclusions reached by Honeywell following its review of the data recorded. Please note that the data and resulting findings and conclusions have not been independently assessed and vetted by IATA.

Mode 1 (Excessive Descent Rate)

89% of Mode 1 alerts occurred below 500 ft radio altitude, and 67% below 200 ft radio altitude.

Mode 2 (Excessive Terrain Closure Rate)

98% of Mode 2 alerts occurred on airplanes with EGPWS software version older than -217 (or Boeing P/N 965-1690-050 or Airbus P/N 965-1676-001) or without GPS or without Geometric Altitude. In other words, GPS equipped airplanes with EGPWS a software version newer than -218 and Geometric Altitude have significantly less risk of activating unwanted Mode 2 alerts.



Mode 3 (Descent After Takeoff)

The majority of Mode 3 alerts were occurring during a flight in a traffic pattern such as a training flight. However, some Mode 3 alerts were induced by departure procedures.

Mode 4 (Insufficient Terrain Clearance)

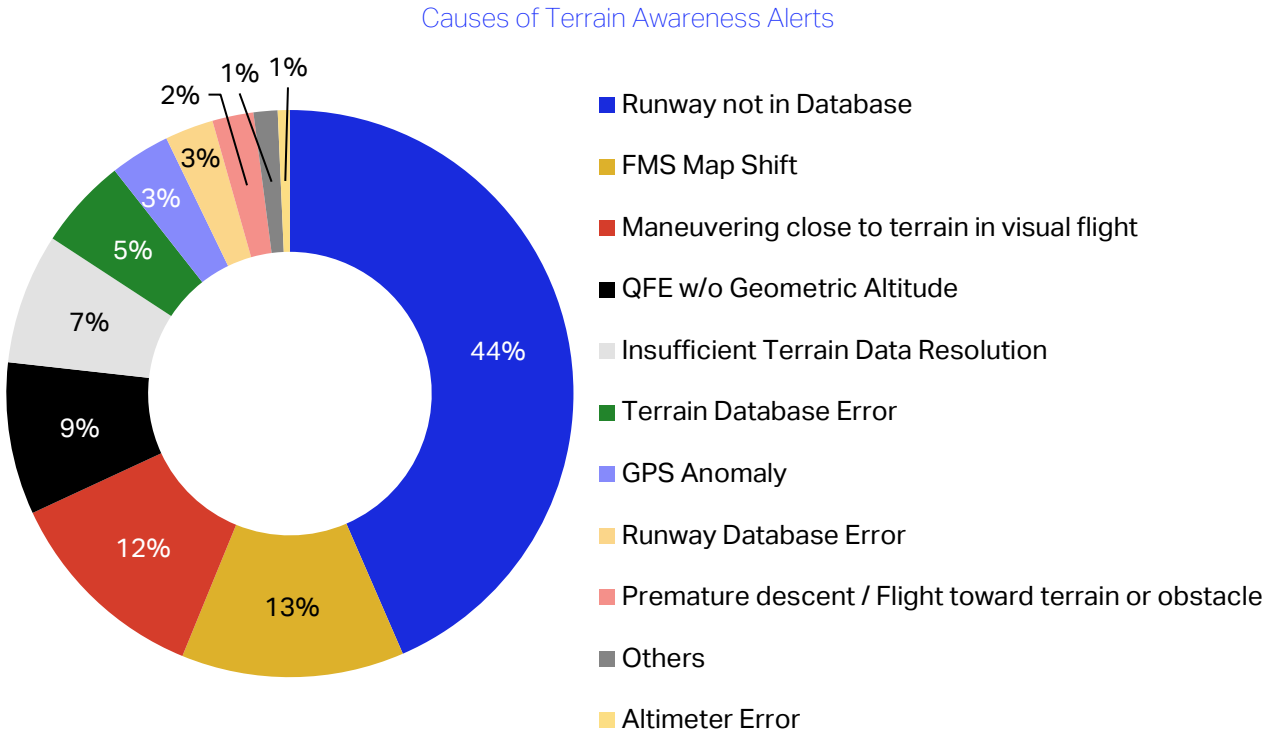
57% of Mode 4 alerts were false alerts caused by external faults. The primary cause of the false alerts was faulty radio altimeter (false tracking).

Mode 5 (Descent Below Glideslope)

34% of Mode 5 glideslope alerts occurred below 100 ft radio altitude. There were a large number of cases where pilots were ducking under the glideslope below 100 ft. Glideslope alerts occurring at higher altitude were often triggered while maneuvering to intercept the localizer below 1000 ft.

Terrain Awareness Alerting and Terrain Clearance Floor (TCF) Functions

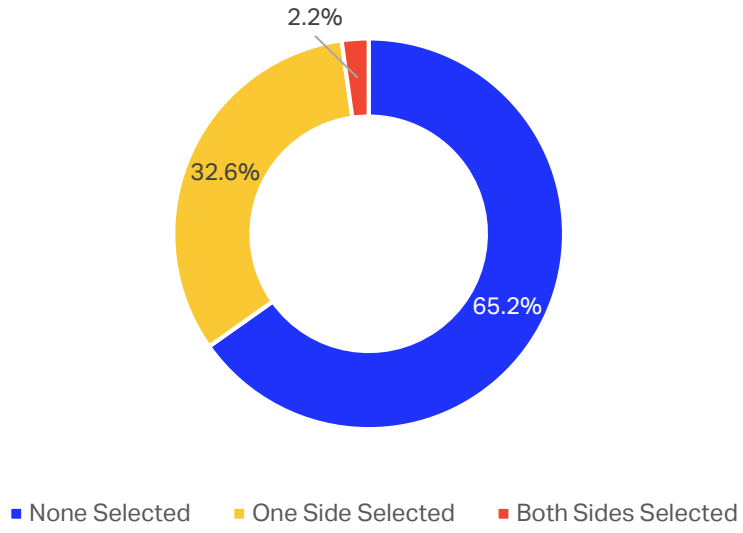
Some causes of Terrain Awareness alerting and TCF/ Runway Field Clearance Floor (RFCF) functions are shown in the figure below.



Majority of the alerts were caused by external signal faults (e.g., FMS map shift or altimeter error) and terrain/obstacle/runway databases. Nearly a half of Terrain Awareness and TCF/RFCF alerts were caused by not having a destination runway in the database. This often meant the latest terrain/runway database was not installed (the database was not kept up-to-date in the EGPWS).

Terrain Awareness Display (TAD)

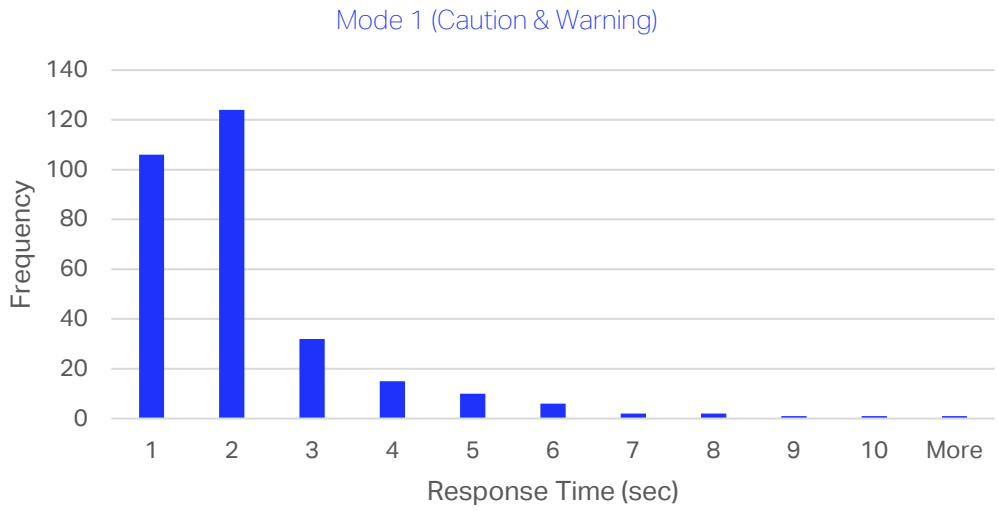
A terrain awareness display had not been selected prior to terrain awareness alerts in 65% of the cases.

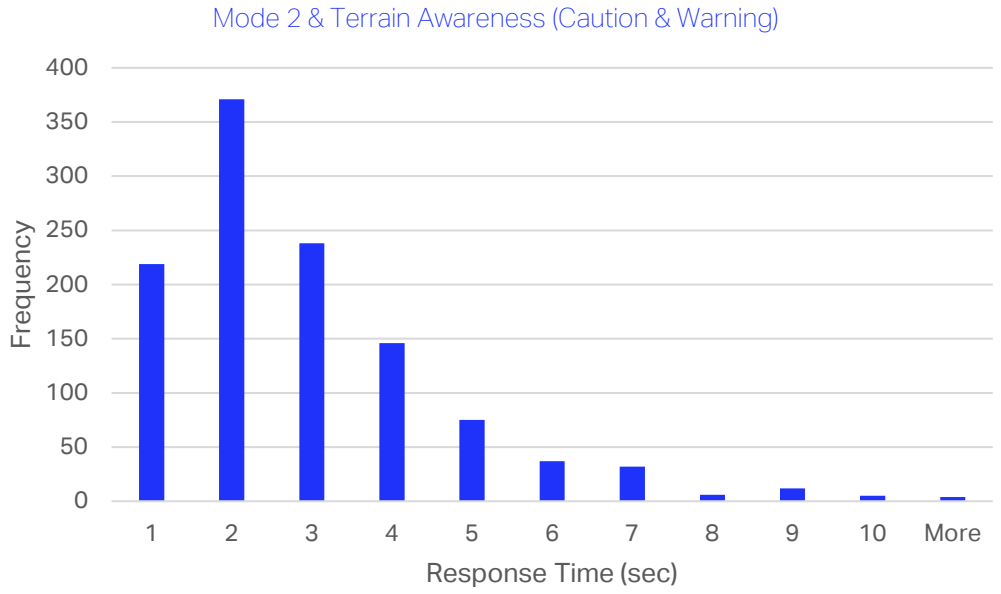


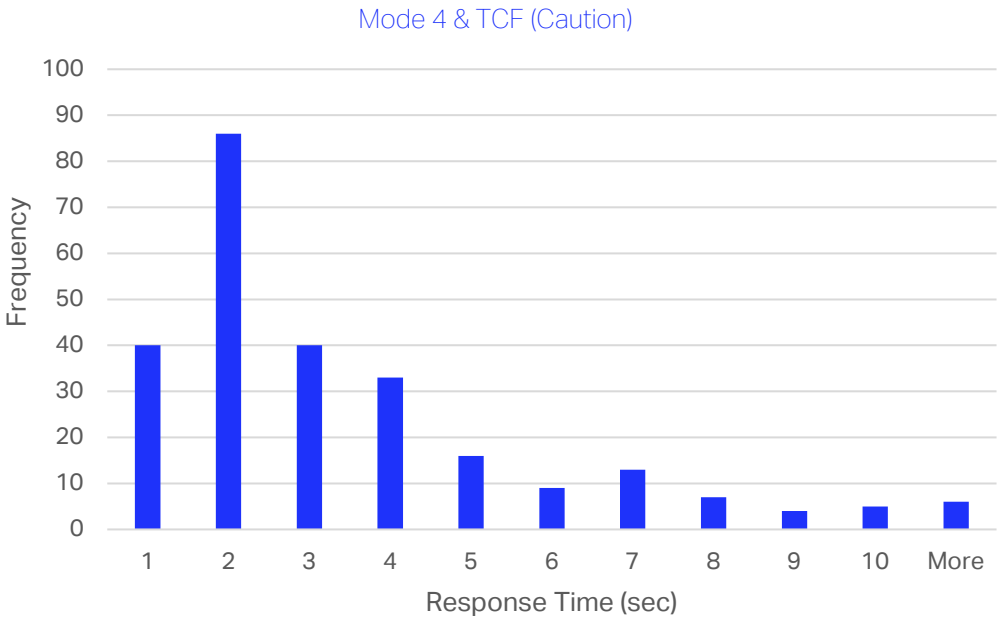
Pilot's response

During EGPWS alert events that pilots responded to, their response time is shown in figures below. For this analysis, a pilot's response time was the time it took for the aircraft pitch to increase more than 1.4° after an alert due to limited availability of parameters that can be used to measure pilot's response in the EGPWS flight history database.

Data collected suggests that pilot's response time is very similar regardless of EGPWS alert types or alert level (caution vs. warning). For that reason, statistics have been aggregated in the diagrams below.




Mode 2 & Terrain Awareness (Caution & Warning)
400
350
300
250
200
150
100
50
0
Frequency
1
2
3
4
5
6
7
8
9
10
More
Response Time (sec)


Mode 4 & TCF (Caution)
100
90
80
70
60
50
40
30
20
10
0
Frequency
1
2
3
4
5
6
7
8
9
10
More
Response Time (sec)

Aircraft fitted with Honeywell EGPWS

The number of commercial jets and turboprop aircraft fitted with Honeywell EGPWS could not be reliably determined.

Honeywell estimates that a majority of western built commercial jets and turbo prop airplanes are equipped with Honeywell EGPWS.

EGPWS algorithm enhancements in software version -218

Major enhancements were introduced in EGPWS software version -218, which was released in 2003.

The Federal Aviation Administration (FAA) issued a Special Airworthiness Information Bulletin (NM-15-11) advising operators of potential safety enhancements made available in -218 software.

Honeywell followed up with a detailed Service Information Letter (SIL D201504000056), available at the MyAerospace portal under the Technical Services tab. For more details, please refer to Honeywell SIL D201504000056.

The following enhancements are available in these software versions:

MK V software version -218-218 and later

MK V (Airbus) software version -002 and later

MK V (Boeing) software version -051 and later

MK VII software version -218-218 and later

MK VI software version -022 and later

MK VIII software version -022 and later

Cessna Sovereign Primus Epic Phase 5.0 and later

Dassault Primus Epic EASy II

- In previous software versions, the Terrain Clearance Floor (TCF) envelope begins between 0.5 and 1.0 nautical mile from the runway threshold, and increases at 100 feet per nautical mile. An enhancement was made to allow TCF envelope to begin 0.25 nautical mile from the runway threshold, and increase at 200 feet per nautical mile for the first mile, providing earlier alerting in landing short scenarios. One such scenario is discussed in FAA SAIB NM-15-11.
- In previous software versions, the Runway Field Clearance Floor (RFCF) envelope begins 1.0 nautical mile from the runway threshold. An enhancement was made to allow RFCF envelope to begin 0.5 nautical mile from the runway threshold, providing earlier alerting in landing short scenarios.
- Compared to previous software versions, the look-ahead distance for the terrain awareness algorithm was increased by 12.5%. In 25% of accidents studied, this would result in earlier terrain alerting.
- In previous software versions, terrain near the airport less than 400 feet above the runway was excluded from the alerting algorithm. An enhancement was made, if runway and terrain quality allow, reducing this limit to terrain 200 feet above the runway, providing improved terrain alerting on final approach.
- Improved the radio altitude reasonable algorithm to further reduce nuisance Mode 2 and Mode 4 alerts when radio altitude inputs are providing a falsely low indication.
- To make GPWS Mode 2 compatible with radar vectoring 1000 feet above terrain, the Mode 2 algorithm maximum height was limited to 950 feet AGL, and 789 feet AGL when within 10 nautical miles of a runway in the database.

- To reduce GPWS Mode 4 nuisance alerts during final approach, the Mode 4A algorithm maximum height was limited to 500 feet Above Ground Level (AGL), and the Mode 4B algorithm maximum height was limited to 245 feet AGL.

Many of the algorithm enhancements mentioned above require the EGPWS to receive GPS input of various signals, including latitude, longitude, altitude, Vertical Figures of Merit (VFOM), Horizontal Figures of Merit (HFOM), Vertical Dilution of Precision (VDOP) and Horizontal Dilution of Precision (HDOP). To ensure optimal performance of the EGPWS, GPS input of these signals should be provided from GPS that meet or exceed TSO-C129a. For more information on GPS as an acceptable source for EGPWS, please refer to Honeywell EGPWS specifications.

Appendix A

An example of the Terrain Database Schedule for 2018 – 2020, the schedule is the following:

Terrain Database Schedule 2018,2019 & 2020

CALENDAR YEAR 2018		CALENDAR YEAR 2019		CALENDAR YEAR 2020	
TDB Version	Release Date	TDB Version	Release Date	TDB Version	Release Date
601	21-Feb	607	20-Feb	613	19-Feb
602	18-Apr	608	17-Apr	614	15-Apr
603(and server)	13-Jun	609(and server)	12-Jun	615(and server)	10-Jun
604	8-Aug	610	7-Aug	616	5-Aug
605	3-Oct	611	2-Oct	617	30-Sep
606(and Server)	28-Nov	612(and server)	27-Nov	618 (and server)	25-Nov