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Safety recommendation: ***AIC 19-R02/18-1004***

Addressed to: Honeywell Aerospace

Date issued: 31st January 2019

Date re-issued: 20th May 2019

Investigation link: AIC 18-1004

Action status: Issued

Introduction

On 28th September 2018, the Federated States of Micronesia, Department of Transportation, Communications and Infrastructure (DTC&I) was notified of the aircraft accident referenced in this safety recommendation. DTC&I commenced an investigation and deployed investigators to Chuuk and invited the Papua New Guinea Accident Investigation Commission (AIC) to join the investigation in the capacity of the State of Registry and also a State providing experts and facilities for the investigation. The AIC team is comprised of an Accredited Representative and Technical Advisers. The US National Transportation Safety Board (NTSB) as the State of Manufacture of the aircraft and in response to FSM National Government's request for assistance also sent a team comprised of an Accredited Representative and Technical Advisers from the Federal Aviation Administration (FAA) and Boeing. Technical Advisers from the US National Weather Service are assisting the US Accredited Representative.

The Transportation Safety Board of Canada (TSBC) as the State of Manufacture of specific components appointed an Accredited Representative and Technical Advisers to download the data from the AFIRS.

The PNG AIC has identified a safety deficiency, which if not rectified could result in an inadvertent ditching accident, resulting in injury or loss of life. The FSM investigator in charge supports the PNG AIC issuing this safety recommendation.

Occurrence

On Friday 28th September 2018, a Boeing 737-8BK aircraft, registered P2-PXE, was being operated by Air Niugini Limited, on a scheduled passenger flight from Pohnpei to Chuuk, Federated States of Micronesia.

At 23:17:19 UTC[1] (09:17:19 local time) the aircraft impacted the water of Chuuk Lagoon about 1,443 ft (440 m) short of the runway 04 threshold, during its approach to runway 04 at Chuuk International Airport.

As the aircraft settled in the water, it turned clockwise through 210º and drifted 460 ft (140 m) south east of the runway 04 extended centreline, with the nose of the aircraft pointing about 265º.

1 The 24-hour clock, in Coordinated Universal Time (UTC), is used in this report to describe the local time as specific events occurred. Local time in the area of the accident, Pacific/Chuuk Time is UTC + 10 hours.

There were 12 crew members and 35 passengers on board. Six passengers were seriously injured, and one passenger was fatally injured.

The 12 crew members and 34 passengers exited the aircraft and were promptly rescued and brought to shore by Chuuk State Government boats, Red Cross, Transco, and more than twenty privately-owned boats, and U.S. Navy divers (who were the first on scene). Local divers located the fatally injured passenger in the aircraft 3 days after the accident.

The aircraft was being flown on a RNAV (GPS)[2] approach to runway 04. The aircraft flew a stabilised approach on auto-pilot, tracking 041º from FIGBI 2,500 ft, passing FASPO at 1,700 ft. The PIC disconnected the auto-pilot at 627 ft and flew the aircraft manually.

During the approach at 23:23:53, when the EGPWS Advisory alert (altitude callout) *"Minimums"* sounded, the aircraft was passing through 470 ft with a vertical speed (rate of descent) of 1,344 ft per minute. The MDA(H)[3] was 420 ft.

The missed approach required a left turn to track 306º with a minimum climb of 375 ft / NM to 960 ft to the Missed approach fix DAMAY.

The aircraft was progressively flown below the glideslope, and from 23:24:00 to the time of impact at 23:24:19 the EGPWS issued eight *Glideslope*[4] Alerts (aural alert), and nine *Sink rate*[5] Alerts (aural alert). The first *Sink rate* Alert was issued at 23:24:00 when the aircraft was at a Radio Altitude of 367 ft with a vertical speed (rate of descent) of 1,616 ft per minute. The last *Sink rate* Alert occurred 2 seconds before impact at a Radio Altitude of 13 ft and a vertical speed (rate of descent) of 848 ft per minute. The Caution alerts (aural alerts) were ignored by the crew.

A storm cell situated immediately after the missed approach point was "painting[6]" on the weather radar on the PIC's Navigation Display. The crew continued past the missed approach point and flew into the heavy rain. The aircraft immediately entered instrument meteorological conditions (IMC).

Safety deficiency description

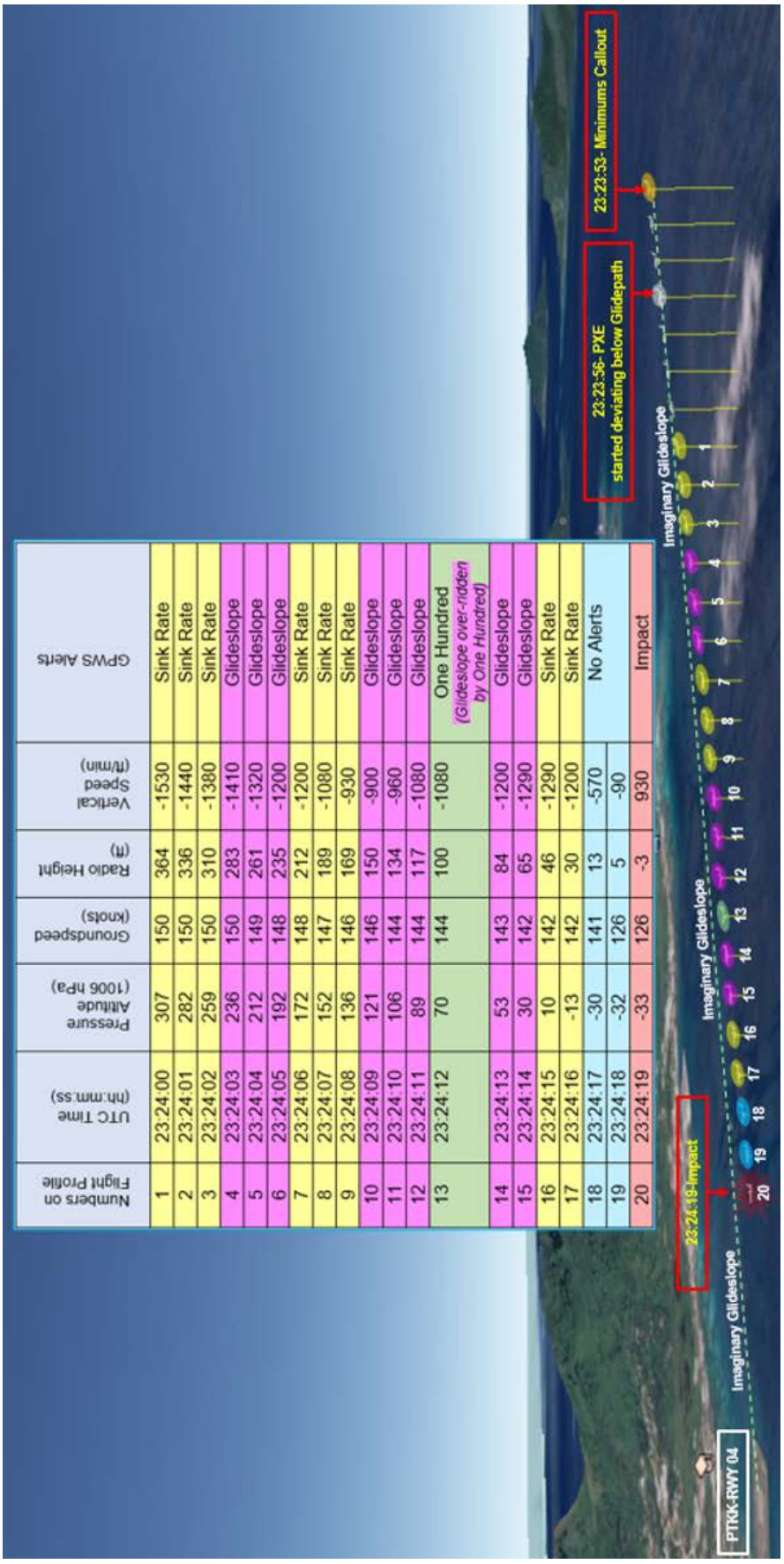
The investigation into this accident has found that the crew did not take any remedial action in response to the *Glideslope* and *Sink rate* Caution Alerts (aural alerts). The EGPWS issued these Caution Alerts (aural alerts) that included the words **PULL UP** appearing steady in red on the Primary Flight Display *(Electronic Flight Instrument System)* when the aircraft penetrated the Sink Rate Envelope of the *Honeywell EGPWS MK V Mode 1 Graph*. See Figure 2.

During the approach, the crew lost situational awareness, with their attention channelised and the aircraft entered the storm cell with heavy rain after passing the *MDA/Missed Approach Point*. The PIC never arrested the excessive rate of descent, and flew the aircraft increasingly below the *Glideslope*.

A steady visual display of **PULL UP** on the Primary Flight Display (*Electronic Flight Instrument System*), was not noticed by either pilot, and therefore was not sufficient to alert them of the imminent danger.

The investigation has determined that a continuous "WHOOP WHOOP PULL UP" hard aural warning, simultaneously with the steady visual display of **PULL UP** on the Primary Flight Display, should replace the *Sink rate* Caution Alerts (aural alerts) when the aircraft continues to descend below 500 ft Radio Altitude and below the glideslope, to alert a crew of the imminent danger.

2 *WENO 1, Federated States of Micronesia RNAV (GPS) Rwy 4* Jeppesen chart dated 26 January 2018 and current at the time of the accident.
3 MDA(H): Minimum descent altitude; sometimes termed minimum decision altitude. (Source *Cambridge Aerospace Dictionary*.)
4 Glideslope Caution Alert is issued by the EGPWS when the aircraft deviates below the 3º Glideslope.
5 Sink rate Caution Alert is issued when the aircraft penetrates the zone shown on the Honeywell EGPWS MK V Mode 1 Graph (See Figure 2)
6 To create blip on radar display, esp. one giving position of aircraft or other object. (Source *Cambridge Aerospace Dictionary*.)



Numbers on Flight Profile	UTC Time (hh:mm:ss)	Pressure Altitude (1006 hPa)	Groundspeed (knots)	Radio Height (ft)	Vertical Speed (ft/min)	GPWS Alerts
1	23:24:00	307	150	364	-1530	Sink Rate
2	23:24:01	282	150	336	-1440	Sink Rate
3	23:24:02	259	150	310	-1380	Sink Rate
4	23:24:03	236	150	283	-1410	Glideslope
5	23:24:04	212	149	261	-1320	Glideslope
6	23:24:05	192	148	235	-1200	Glideslope
7	23:24:06	172	148	212	-1200	Sink Rate
8	23:24:07	152	147	189	-1080	Sink Rate
9	23:24:08	136	146	169	-930	Sink Rate
10	23:24:09	121	146	150	-900	Glideslope
11	23:24:10	106	144	134	-960	Glideslope
12	23:24:11	89	144	117	-1080	Glideslope
13	23:24:12	70	144	100	-1080	One Hundred *(Glideslope over-ridden by One Hundred)*
14	23:24:13	53	143	84	-1200	Glideslope
15	23:24:14	30	142	65	-1290	Glideslope
16	23:24:15	10	142	46	-1290	Sink Rate
17	23:24:16	-13	142	30	-1200	Sink Rate
18	23:24:17	-30	141	13	-570	No Alerts
19	23:24:18	-32	126	5	-90	
20	23:24:19	-33	126	-3	930	Impact

Figure 1: Glideslope and Sink rate aural Alerts graphic plotted using Derived Data
(Revised graphic for clarity)

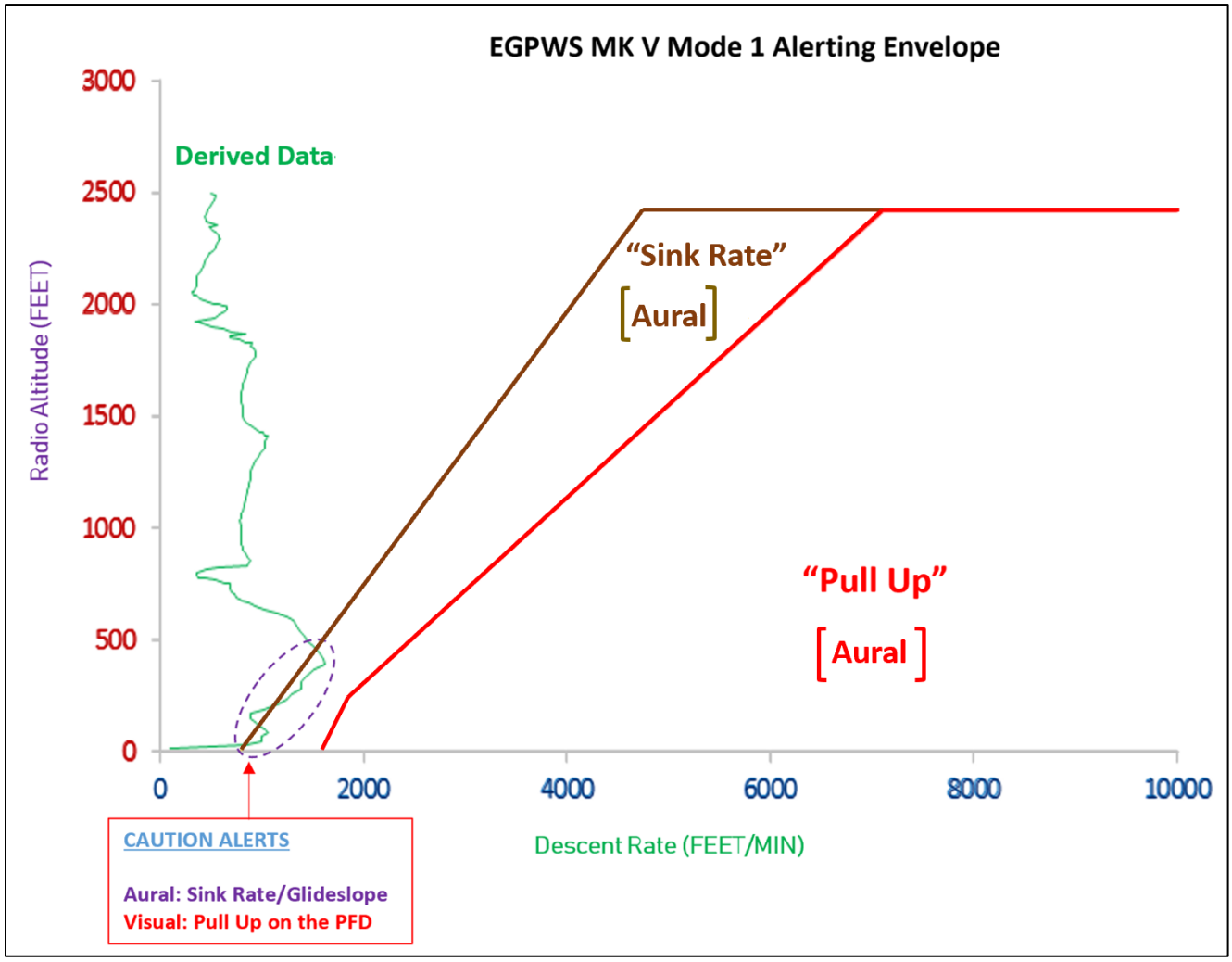


Figure 2: Derived Data plotted against Honeywell EGPWS MK V Mode 1 Graph

Recommendation number *AIC 18-R02/18-1004* to Honeywell Aerospace

The PNG Accident Investigation Commission recommends that Honeywell Aerospace should ensure that the Honeywell EGPWS MK V Computer provides timely and continuous hard aural warning "*WHOOP WHOOP PULL UP,*" simultaneously with the stable visual display of **PULL UP** on the Primary Flight Display, which requires immediate action from the crew, when encountering an excessive Rate of Descent at very low Radio Altitude, similar to that encountered by the crew of P2-PXE as shown in Figure 1.

Action requested

The AIC requests that Honeywell Aerospace note recommendation AIC 19-R02/18-1004, and provide a response to the AIC no later than 1st May 2019 (within 90 days of the issue date), and explain (including with evidence) how Honeywell Aerospace has addressed the safety deficiency identified in the safety recommendation.

HUBERT NAMANI, LLB
Chief Commissioner

Honeywell Aerospace response.

On 30th April 2019, Honeywell Aerospace informed the AIC in response to recommendation *AIC 19-R02/18-1004* that the requested recommendation *AIC 19-R02/18-1004* was not achievable for two reasons:

1. *Boeing and/or operator has chosen to drive a red "**PULL UP**" annunciation on the PFD when the EGPWS triggers a Mode 1 "Sink Rate" caution alert level when another option is available which would not generate the red "**PULL UP**" annunciation with the same caution level alert; and*
2. *If Honeywell were to change the EGPWS Mode 1 Warning curves to generate a "**PULL UP**" aural when a flight profile were to be flown as P2-PXE performed, it would be in violation of TSO-151d (MOPS DO-367) and would be unable to certify the product with the FAA.*

Given the points of this response, Honeywell Aerospace requested that the recommendation be removed from consideration and stated that it would not be feasible nor within Honeywell's control to accomplish.

AIC comment

On 14th February 2019, the Government of the Federated States of Micronesia delegated the whole of the investigation to the PNG Accident Investigation Commission, in accordance with *Para 5.1* of *ICAO Annex 13* to the *Convention on International Civil Aviation*.

The AIC has assessed the Honeywell Aerospace response and has assigned it an *unsatisfactory not accepted rating*[7]. The PNG AIC conducts investigations for the purpose of improving safety. It would not be appropriate, nor would it be in the wider interest of aviation safety, for the AIC to withdraw a safety recommendation because a TSO would not be in agreement with proposed changes.

Therefore, the AIC cannot remove the recommendation as requested by Honeywell Aerospace, but is herewith re-issuing a revised enhanced safety recommendation based on the following research and analysis (see page 9).

Although, the *sink rate* and *glideslope* aural alerts were issued by the EGPWS, they were 'CAUTIONS'[8] and the need for the pilots to react to an aural caution alert was not a high priority for them at that time.

Furthermore, the investigation determined from this flight and the previous flight that the crew's disregard of the aural caution alerts was because they were believed to be nuisance alerts. These alerts typically occur during approach and landing without consequence, which makes them ineffective.

The investigation determined that the crew of P2-PXE were fixated on the task of landing the aircraft and did not notice the steady visual '**PULL UP**' caution alert at the bottom of their Primary Flight Displays (PFD). Therefore, they (crew) did not take any positive action to arrest the high rate of descent and avoid landing in the lagoon. In fact, neither of the pilots were aware of the rapidly unfolding unsafe situation.

The following are Human Factors that contribute to accidents such as PXE at Chuuk:

1. ***Absorption*.** A state of being so focused on a specific task that other tasks are disregarded.
2. ***Fixation*:** A state of being locked onto one task, or one view of a situation, even as evidence accumulates that attention is necessary elsewhere, or that the particular view is incorrect.
3. ***Channelised attention*:** A mental state which exists when a person's full attention is focused on one stimulus to the exclusion of all others. This becomes a problem when the person fails to perform a task or process information of a higher priority and thus fails to notice or has no time to respond to cues requiring immediate attention.
4. ***Fascination*:** An attention anomaly in which a person observes environmental cues, but fails to respond to them.

7 An unsatisfactory not accepted rating applies to situations where, in the AIC's view, the safety deficiency will continue to put persons, property or the environment at risk and is assigned if the respondent demonstrates that no action will be taken to reduce or eliminate the identified safety deficiency.

8 Definitions excerpted from 14 CFR 25.1322:

- **Warning:** For conditions that require immediate flightcrew awareness and immediate flightcrew response;
- **Caution:** For conditions that require immediate flightcrew awareness and subsequent flightcrew response; and
- **Advisory:** For conditions that require flightcrew awareness and may require subsequent flightcrew response.

5. The ***'tunnelling or channelizing'*** that can occur during stressful situations, which is an example of fixation.

Given the extremity of the above mentioned in stressful situations, the possibility of missing effective '*visual cues'*, in particular a steady light, is compounded in the absence of having '*audible cues*' during time-critical situations.

Figure 3: Image from PXE cockpit video[9] showing steady PULL UP on PFD display

An attention-getter is designed to capture a pilot's attention and is often referred to as a "hook."

Anything can be an attention-getter depending on the context. Any phrase or sentence that sparks curiosity and demands action from a pilot will cause the pilot to intently focus on the subsequent instructions and execute immediate time-critical actions. An important part of an effective attention-getter is to contain relevance to the context following or during a time-critical situation.

In the seconds leading up to this accident at Chuuk, the pilots missed an important change of indication on their PFDs. **Why?** Could it have been that there were so many steady indications that the steady 'PULL UP' visual alert just blended into them? Could it have been that the crew did not hear an alert worth reacting to?

The pilots' fixation on the task of landing the aircraft could have been significantly diverted if there was an attention-getter hard aural 'WARNING' alert rather than peripheral reliance on a steady visual '**PULL UP**' caution alert at the bottom of the PFD which was associated with the '*Sink Rate*' caution aural alert as provided by the LAMP Format 1 setting.

The AIC strongly recommends that Honeywell Aerospace should further research this significant safety issue and work with aircraft manufacturers and the certifying authority to determine which pilot attention-getter to use in time-critical situations.

This is particularly important as in PXE's case, to ensure pilots don't miss time-critical alerts and that they (pilots) have every opportunity to recognise the significance of the alerts and safety and effectively operate the aircraft during abnormal situations. Situations differ and pilots react differently. For aviation safety, it is of the utmost importance to determine which aural or visual alerting indications provide the most effective attention-getter.

The AIC Human Factors investigation determined that a hard aural 'WARNING' alert, or a flashing visual '**PULL UP**' also as a 'WARNING' rather than a steady **'PULL UP'** on the PFDs, could have significantly driven the pilots to react positively and decisively, given the severity and significance of a hard warning (see footnote 7 on page 5). It could be the last line of defense for any flight crew who may unknowingly or inadvertently get in a similar fixated situation.

The AIC therefore believes the inclusion of a **flashing visual** '**PULL UP**' WARNING on the PFDs rather than reliance upon peripheral steady visual caution alerts would be a significant enhancement in terms of attention getting alert capability.

The FAA ***Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Control Manual Version 2***, *Chapter 4, section 4.3.1 – Warnings, Cautions and Advisories* states:

9 Image taken from cockpit video taken by jump seat occupant

Unique visual alert information presented in each pilot's primary field of view is acceptable in place of a master visual alert if it provides immediate awareness and sufficient attention-getting characteristics. However, an aural alert, such as an aural command to "pull up," or another sensory cue, would still be required to meet § 25.1322(c)(2). [AC 25.1322-1, 6.c]

For a time-critical warning, use voice information to indicate conditions that demand immediate flightcrew awareness of a specific condition without further reference to other indications in the flight deck. A second attention-getting sensory cue, such as a visual cue, is still required (§25.1322(c)(2)). [AC 25.1322-1, Appendix 2, 3])

*Several visual coding methods can be used to attract attention to specific information on a display, including blinking or **flashing,** reverse video, size coding, color, and location. In non-normal or serious conditions, such coding methods can help the flightcrew distinguish critical information from other information.*

§25.1322(c)(2)[10] states:

(c) Warning and caution alerts must:

(2) Provide timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications.

*Alerts are intended to attract attention and inform of specific airplane operating conditions and events that require pilot and/or flightcrew awareness. As the number of systems on the flight deck has increased, so too has the number of warnings, cautions, and advisories that can be shown. Failure to standardize alerts within the flight deck and across an aircraft fleet can lead to **confusion and recognition errors**. Different alerting characteristics can prevent the flightcrew from reacting quickly to an alert situation because they are not confident of what the alert is indicating and what action is required. Additionally, it can be more difficult to determine which system generated an alert if alert messages are not easy to interpret.*

TSO-C151b, Terrain Awareness and Warning System (TAWS), provides an alert prioritization scheme for *Class A TAWS* equipment, as excerpted below in Table 1.

ALERT PRIORITIZATION SCHEME

Priority	Description	Alert Level [b]	Comments
1	Reactive Windshear Warning	W	
2	Sink Rate Pull-Up Warning	W	continuous
3	Excessive Closure Pull-Up Warning	W	continuous
4	RTC Terrain Warning	W	
5	V_1 Callout	I	
6	Engine Fail Callout	W	
7	FLTA Pull-Up warning	W	continuous
8	PWS Warning	W	
9	RTC Terrain Caution	C	continuous
10	Minimums	I	
11	FLTA Caution	C	7 s period
12	Too Low Terrain	C	
13	PDA ("Too Low Terrain")Caution	C	
14	Altitude Callouts	I	
15	Too Low Gear	C	
16	Too Low Flaps	C	
17	Sink Rate	C	
18	Don't Sink	C	
19	Glideslope	C	3 s period
20	PWS Caution	C	
21	Approaching Minimums	I	
22	Bank Angle	C	
23	Reactive Windshear Caution	C	
Mode 6 [a]	TCAS RA ("*Climb*", "*Descend*", etc.)	W	continuous
Mode 6 [a]	TCAS TA ("*Traffic, Traffic*")	C	Continuous

NOTE 1: These alerts can occur simultaneously with TAWS voice callout alerts.

NOTE 2: W = Warning, C = Caution, A = Advisory, I = Informational

Table 1: *TSO-151b* excerpt, TAWS, Alert Prioritizing scheme

(Refer footnote 7 on page 5 for definition of Warning, Cautions and Advisories)

10 *Electronic Code of Federal Regulations (e-CFR), Space, Chapter, Subchapter C. AIRCRAFT, Part 25. AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES, Subpart F. Equipment, Subjgrp 113. Instruments: Installation, Section 25.1322. Flightcrew alerting.*

Furthermore, Honeywell stated:

> *'if the Warning curve were to be modified to exactly match the DO-367 "Must Not Alert" warning requirement, it would result in more nuisance "PULL UP" alerts being generated which would disturb the crew during normal operations and violate the requirements of the TSO-151d.'*

The logical reasoning for an alert to be interpreted as *'nuisance'* from an operational perspective is for the pilots' to determine whether an alert is a nuisance. It is not logical to term an alert as *'nuisance'* when it is pointing out an unsafe situation. The chart in **Figure 2** of the Honeywell response shows the DO-367 'Must Not Alert' region against Honeywell Aerospace EGPWS Mode 1 alerting graph. However, it is precisely in that zone, at the low altitude and excessively high rate of descent (as depicted), that PXE descended and continued to descend in IMC.

On 27 September, during approach to land at Pohnpei with the same crew, the EGPWS issued a total of twenty-eight (28) *'Glideslope'* aural caution alerts. From the separate pilot interviews and written statements, during the investigations in the first days after the accident, it was clear that during that flight and the subsequent flight into Chuuk, the pilots did not react to the *'Glideslope'* and *'Sink Rate'* aural caution alerts because they regarded them as *'nuisance'* alerts. However, during the flight into Chuuk, the consequences were dire.

The investigation determined that a change of alert from *'caution'* to a hard *'warning'* demanding an immediate flight crew response, is necessary during the time-critical situations.

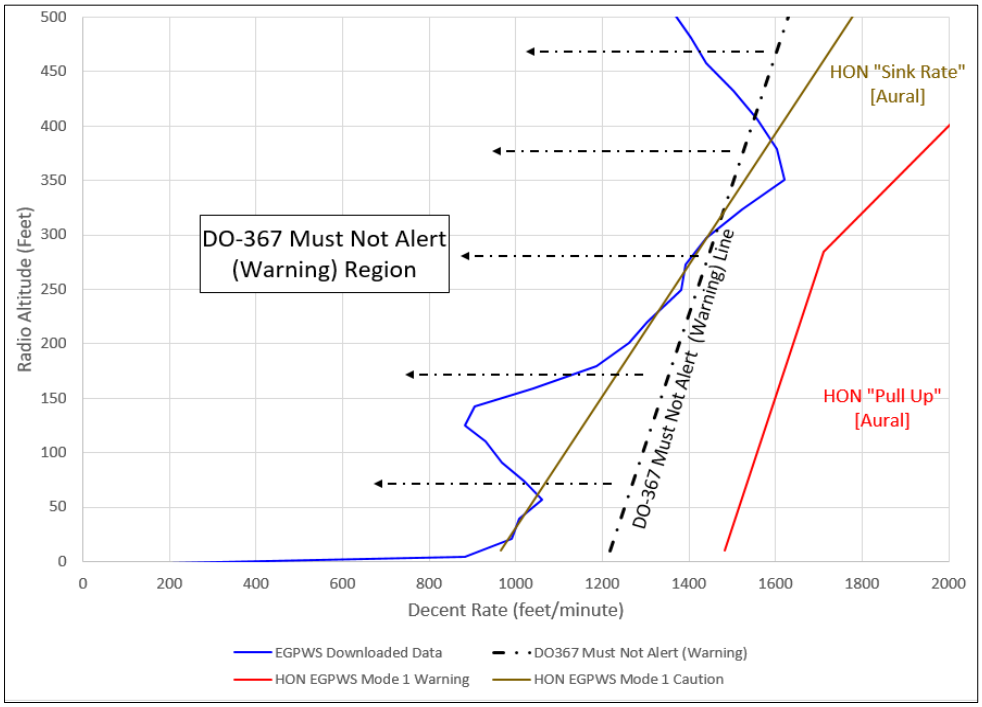


Figure 3: Mode 1 Sink Rate Alert Curves with DO-367 "Must Not Alert (Warning)" Requirement[11]

Figure 3 depicts the HON "Pull Up" [Aural] boundary of the HON EGPWS Mk V Mode 1 Warning.

It shows:

At 275 feet Radio Altitude and 1,750 feet/min rate of descent the time to impact would be 9.4 seconds.

At 200 feet Radio Altitude and 1,650 feet/min rate of descent the time to impact would be 7.2 seconds.

At 100 feet Radio Altitude and 1,750 feet/min rate of descent the time to impact would be 9.4 seconds.

At 50 feet Radio Altitude and 1,500 feet/min rate of descent the time to impact would be 2.0 seconds.

11 Figure 4 from Honeywell Aerospace response to *AIC 19-R02/18-1004*

Table 2 illustrates the time it takes for an aircraft to impact terrain. The data in the table was derived from the ***Mode 1 Sink Rate Alert Curves with DO-367 'Must Not Alert (Warning)' requirement*** graph line as per Honeywell Aerospace's response.

Serial	Altitude (Rad Alt)	Rate of descent	Feet/second	Time to impact
1	500	1610ft/min	27ft/sec	18 sec
2	400	1550ft/min	26ft/sec	15 sec
3	**320**	**1470ft/min**	**26ft/sec**	**12 sec**
4	300	1450ft/min	24ft/sec	13 sec
5	200	1380ft/min	23ft/sec	9 sec
6	100	1280ft/min	21ft/sec	5 sec
7	50	1250ft/min	21ft/sec	2 sec

Table 2: Time to impact terrain

Note: *Jet engine spool-up time is 4-6 seconds, then 3-5 seconds to achieve a positive rate of climb during a go-around at 50 ft at a rate of descent of 700 ft per minute.*

As per ***DO-367 'Must Not Alert (Warning)' requirement*** region (as depicted in Figure 2), with the engine spool-up time and the time it will take to compensate for the loss of altitude for a positive rate of climb, there is insufficient time for pilots to react to an immediate time-critical situation if there is no 'WARNING' alert issued at low altitude after entering the *DO-367 'May Alert' and 'Must Alert' regions*. The rate of descent during the approach into Chuuk as shown in Figure 1, clearly shows that the crew were outside the safety margin.

It is therefore likely that a continuous hard aural warning '*WHOOP WHOOP PULL UP'*, or a **flashing** visual display '**PULL UP' warning** on the Primary Flight Display, would have been effective in alerting the crew to the imminent danger, prompting a pull up and execution of a missed approach, that would have prevented the accident. A hard-aural warning alert or flashing visual warning, demanding an immediate flight crew response would clearly be desirable in the interest of safety enhancement.

However, if the hard aural warning '*WHOOP WHOOP PULL UP'* is not technically possible on older model EGPWS, a **flashing** '**PULL UP**' **warning** would achieve the minimum design considerations for alerting as contemplated in the ***FAA Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls - Version 2.0, Chapter 4 Considerations for Alerting.***

Recommendation number *AIC 18-R0218-1004* to Honeywell Aerospace (revised/re-issued)

The PNG Accident Investigation Commission recommends that Honeywell Aerospace, in consultation with the Federal Aviation Administration, should re-evaluate *TSO's 151b* and *151d* and *DO-367* related to EGPWS warnings and cautions, and ensure that the Honeywell EGPWS MK V Computer provides a **timely warning** in the form of a continuous **flashing** visual display of '**PULL UP'** at the bottom of the Primary Flight Displays, as an absolute minimum standard. The **flashing** visual display '**PULL UP' warning,** simultaneously with the aural caution 'SINK RATE', would require immediate action from the flight crew when encountering an excessive Rate of Descent at very low Radio Altitude, similar to that flown by the crew of P2-PXE as shown in Figure 1.

Action requested

The PNG Accident Investigation Commission requests that Honeywell Aerospace note recommendation *AIC 19-R02/18-1004* (revised/re-issued), and provide a response to the AIC no later than 19th July 2019 (within 60 days of the issue date), and explain (including with evidence) how Honeywell Aerospace has addressed, or proposes to address, the safety deficiency identified in the revised/re-issued safety recommendation. Current status **ACTIVE**.

HUBERT NAMANI, LLB
Chief Commissioner

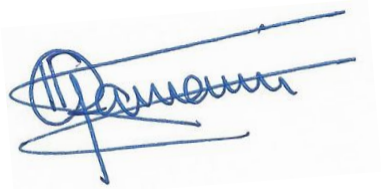
20th May 2019

PNG Accident Investigation Commission update dated 11 July 2019

During subsequent discussions with Honeywell and Boeing, the AIC was informed that such hard-aural warning might not be an option for older generation EGPWS.

Much more research is required and the AIC is actively working with the US NTSB, FAA, Honeywell, and Boeing. The *Safety Recommendations AIC 19-R02/18-1004* and *AIC 19-R17/18-1004* addressed to Honeywell and FAA respectively will remain Active pending the results of the ongoing research.

Status of AIC recommendation: ACTIVE



HUBERT NAMANI, LLB
Chief Commissioner

11th July 2019