NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

September 11, 2017

Enhanced Ground Proximity Warning System (EGPWS)

Specialist's Factual Report
by Bill Tuccio, Ph.D.

1. EVENT

Location:	Teterboro, New Jersey
Date:	May 15, 2017
Aircraft:	Gates Learjet 35A, Registration N452DA
Operator:	Trans-Pacific Air Charter LLC dba Trans-Pacific Jets
NTSB Number:	CEN17MA183

On May 15, 2017, at 1529 eastern daylight time (EDT), a Gates Learjet 35A, N452DA, operated by Trans-Pacific Air Charter LLC doing business as Trans-Pacific Jets, departed controlled flight while on a circling approach to runway 1 at the Teterboro Airport (TEB), Teterboro, New Jersey, and impacted a commercial building and parking lot. The captain and first officer died; no one on the ground was injured. The airplane was destroyed by impact forces and postcrash fire. The airplane was registered to A&C Big Sky Aviation LLC and operated by Trans-Pacific Air Charter LLC under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91 as a positioning flight. Visual meteorological conditions prevailed, and an instrument flight rules (IFR) flight plan was filed. The flight departed from the Philadelphia International Airport (PHL), Philadelphia, Pennsylvania, about 1504 and was destined for TEB.

2. DETAILS OF INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following device:

Device:	Honeywell Enhanced Ground Proximity Warning System (EGPWS) (see section 2.1.2 for model number determination)
Device Serial Number:	Unknown

2.1. Honeywell EGPWS Device Description

The EGPWS non-volatile memory[1] (NVM) does not continuously record; rather, the EGPWS device stores data to NVM only when certain criteria are met. The readout

[1] Non-volatile memory is semiconductor memory that does not require power for data retention.

process at the manufacturer's facility produces several files of flight history data that encompass operational, documentary, fault, and warning information.

The flight history data warning file outputs performance data related to the operation of the aircraft. These data are only recorded when an alert or warning related to the EGPWS function activates, resulting in data points for 20 seconds prior to the activation of the warning and 10 seconds afterwards. The EGPWS parameters are sampled 1 time per second, but the actual time of occurrence can be anywhere within the second.

2.1.1. Honeywell EGPWS Data Recovery

See the *Enhanced Ground Proximity Warning System (EGPWS) Download* Factual Report in the public docket for a description of the recovery process. Notably, the U24 "flight history" chip was recovered, but an additional NVM chip containing configuration information was not recoverable due to impact and/or post-crash heat damage.

2.1.2. Honeywell EGPWS Data Description

The make and model of the EGPWS was determined during the recovery and download process to be a Honeywell KGP-560.

The unit's warning history file contained about 146 minutes of recorded data collected from 3,362 hours of operational history, spanning from 1,263 to 4,625 EGPWS operating hours. Each flight leg is assigned a sequentially incremented number. For this dataset, the sequentially incremented flight leg number reached a maximum value of 2,549 at 3,226 operational hours, and then continued (wrapped) at flight leg number 8 at 4,018 operational hours. The accident flight was identified as flight leg 288. In agreement with the Investigator-in-Charge, the two prior flights that generated alerts which were operated on the east coast of the United States—flight legs 273 and 282—were also examined in this report. Table 1 summarizes the data contained in this report; alert codes are explained in section 2.1.2.1.

Table 1. EGPWS warning history data contained in this report.

Leg	Operating Time Start	Operating Time End	Alert Codes
288	4,625:37:47	4,625:38:29	M1SK, M1PU
282	4,620:18:03	4,620:18:17	TAPU
273	4,605:27:02	4,605:33:52	M1SK, OBCAUT

The accident leg (288), contained four recorded alerts distributed such that the 30-second recording histories overlapped, resulting in a total sample time of 42 seconds. Overlapping, redundant data samples are not shown in this report. Flight leg 273's two alerts were not overlapping as they occurred about six minutes apart. Flight leg 282's initial 14 seconds of data contained invalid GPS positions and are not included in this report.

This installation of the EGPWS did not record parameters such as calibrated or true airspeed, radar altitude, pitch angle, angle of attack, or aircraft accelerations. Additionally, the unit was not enabled for windshear alerts.

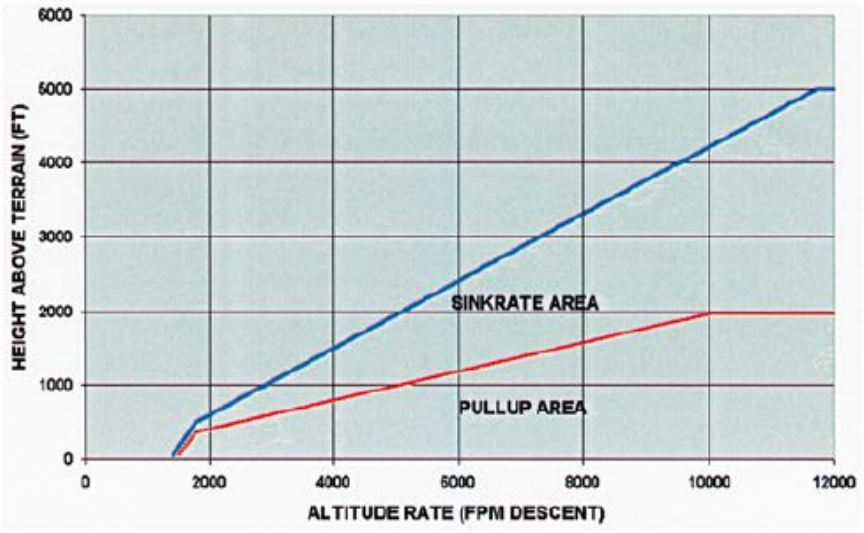
2.1.2.1. Alert Code Descriptions

The codes contained in the data have the following meanings:

- **M1SK**. This is a “mode 1 sink rate” aural warning (shown in geographic overlays as “SK”).
- **M1PU**. This is a “mode 1 pull up” aural warning (shown in geographic overlays as “PU”).

M1SK and M1PU alert warnings are based on an envelope as defined in figure 1. A penetration directly into the “PULLUP AREA” shown in figure 1, without a transition through the “SINKRATE AREA,” will cause a “sink rate” aural alert followed by a “pull up” alert.

Figure 1. Honeywell EGPWS excessive sink rate envelope (figure courtesy of Honeywell).



Excessive Descent Rate

- **TAPU**. Terrain alert, related to the EPGWS Terrain Alert and Display (TAD) functionality. As described by Honeywell, “TAD monitors Aircraft Position (latitude, longitude, and altitude above sea level) relative to terrain data from an onboard database and provides early audio and visual alerts when a terrain threat is detected.”
- **OBCAUT**. Like the TAPU warning, but for obstructions (for example, towers and buildings) as opposed to terrain.

2.1.3. Timing

All times in this report are expressed in EGPWS operational time, showing only minutes and seconds.

3. PLOTS, OVERLAYS, AND TABULAR DATA

Appendix A contains a description of all parameters verified in this report. Geographical overlays were generated using Google Earth. Weather and lighting conditions shown in the overlays are not necessarily representative of the conditions at the time of the recordings.

Figure 2 shows a plot of the accident flight recording. The recording began when the aircraft was on a true track of about 48 degrees at a groundspeed of about 150 knots. At about 38:01, the aircraft began to roll right as the groundspeed increased. While the groundspeed increased, altitude began to decrease, reaching a maximum recorded vertical descent rate during this period of 2,017 feet per minute; the recorded GPS altitude reached a minimum of 314 feet; and “sink rate/pull up” and “sink rate” alerts were generated, followed by a decrease of the vertical descent rate.

By 38:12, the groundspeed reached a maximum of about 165 knots, as the altitude was increasing and the roll was 42.2 degrees right (the maximum recorded roll was 43.6 degrees between 38:10 and 38:11).

After 38:12 until the end of the recording, the groundspeed decreased, reaching the last recorded value of 139 knots at a GPS altitude of 250 feet.

At 38:26, the EGPWS software identified the data sample as invalid. This point is included in the plot as it generally aligned with the trends of the surrounding data samples.

The last EGPWS alert was a “pull up,” 1-second before the end of the recording (38:28) when the aircraft was descending at 1,659 feet per minute. The last EPGWS recorded descent rate at 38:29, was 2,189 feet per minute.

Figures 3 through 8 show geographic overlays of the accident flight recorded data, with select points annotated.

Figures 9 through 11 show the two prior flights that contained alerts.

The corresponding tabular data used to create figures 2 through 11 are provided in electronic (*.csv) format as attachment 1 to this report.

Figure 2. Accident leg 288.

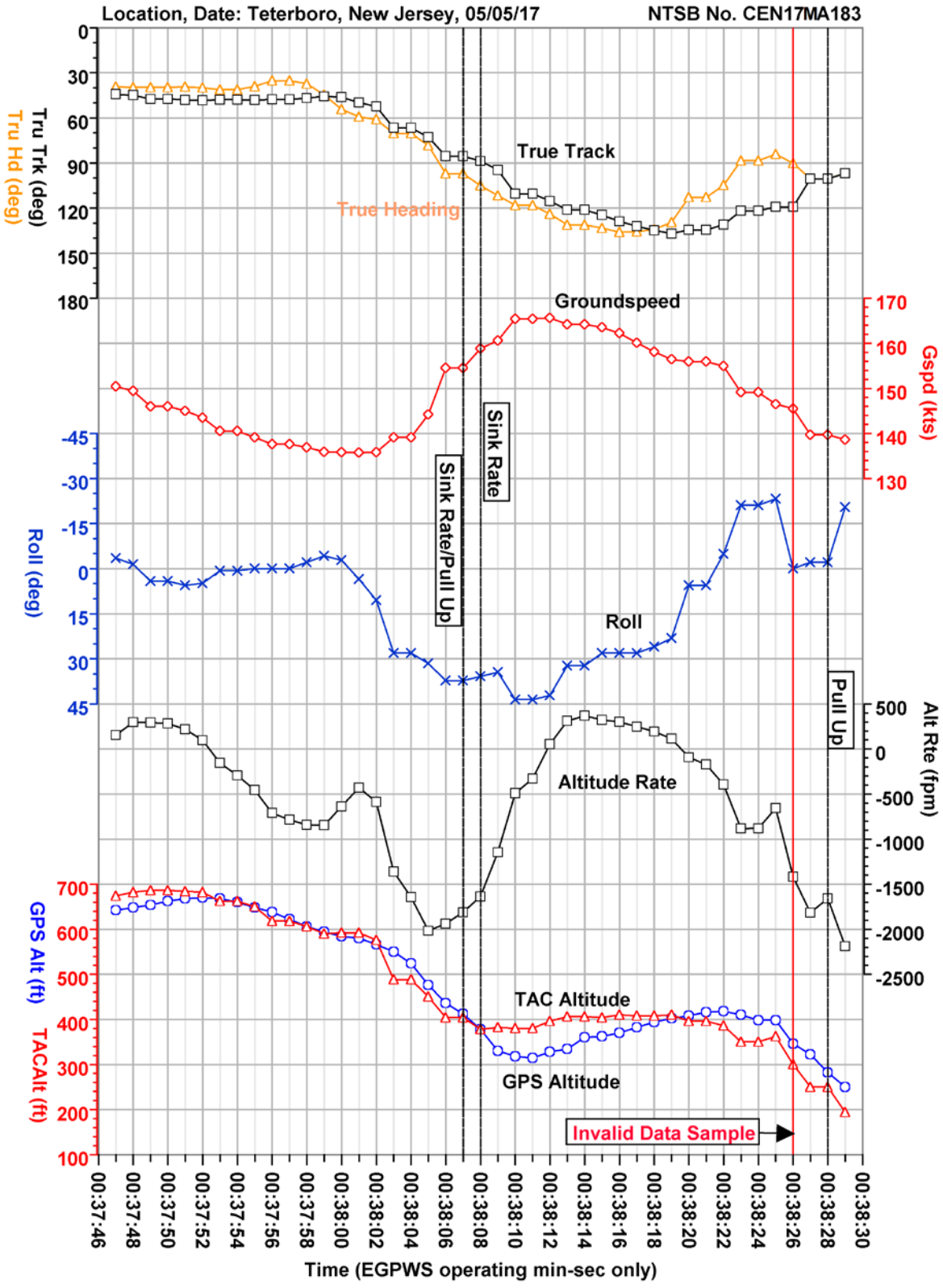


Figure 3. Accident leg 288, satellite overlay (select points and direction of flight annotated).

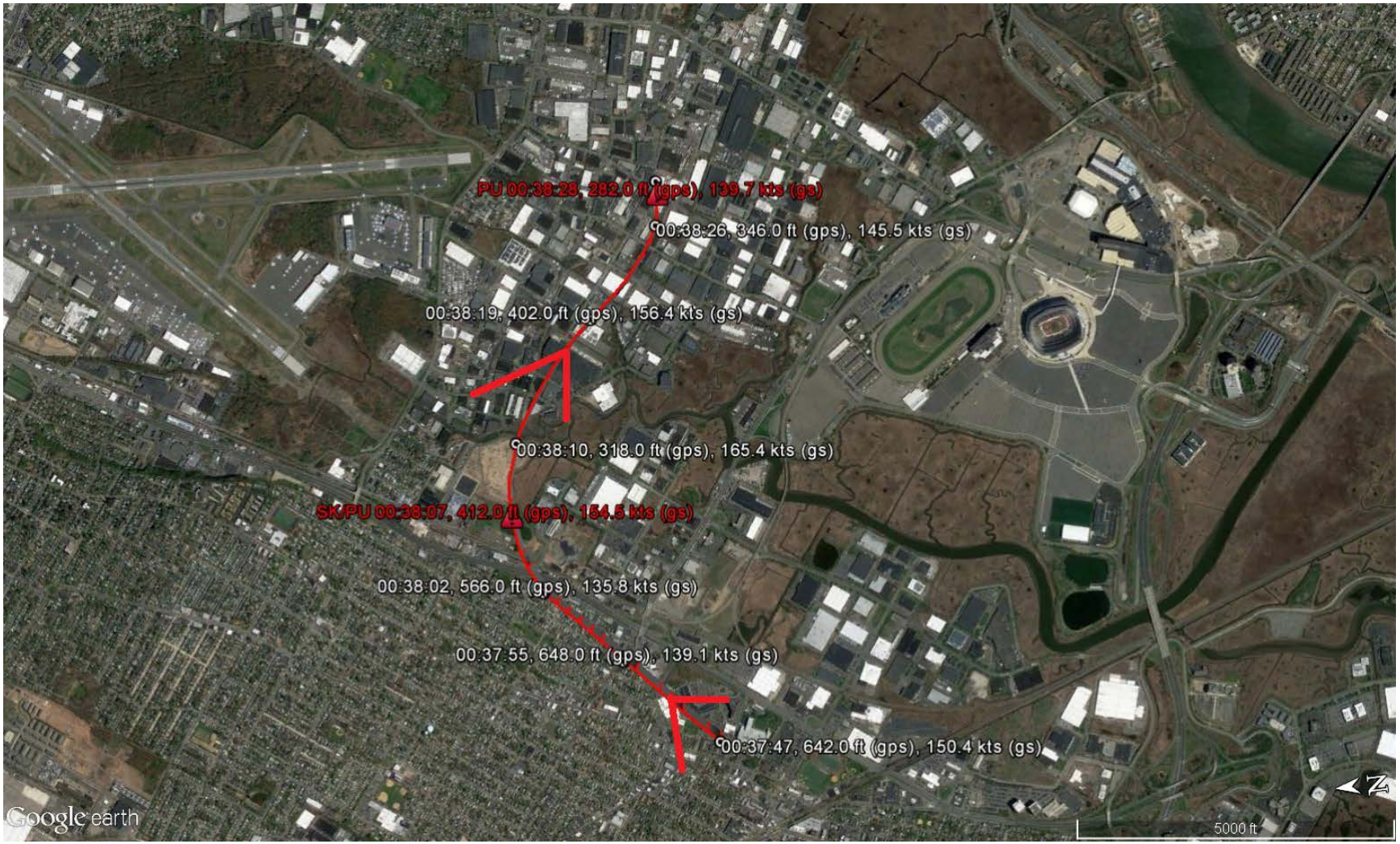


Figure 4. Accident leg 288, FAA ILS 6 approach chart overlay, broad overview (select points annotated).

Figure 5. Accident leg 288, FAA ILS 6 approach chart overlay, detail view (select points annotated).

Figure 6. Accident leg 288, Jeppesen ILS 6 approach chart overlay, broad overview (select points annotated).

Figure 7. Accident leg 288, Jeppesen ILS 6 approach chart overlay, mid-level zoom (select points annotated).

Figure 8. Accident leg 288, Jeppesen ILS 6 approach chart overlay, details (select points annotated).

Figure 9. Leg 282, satellite overlay (select points annotated).

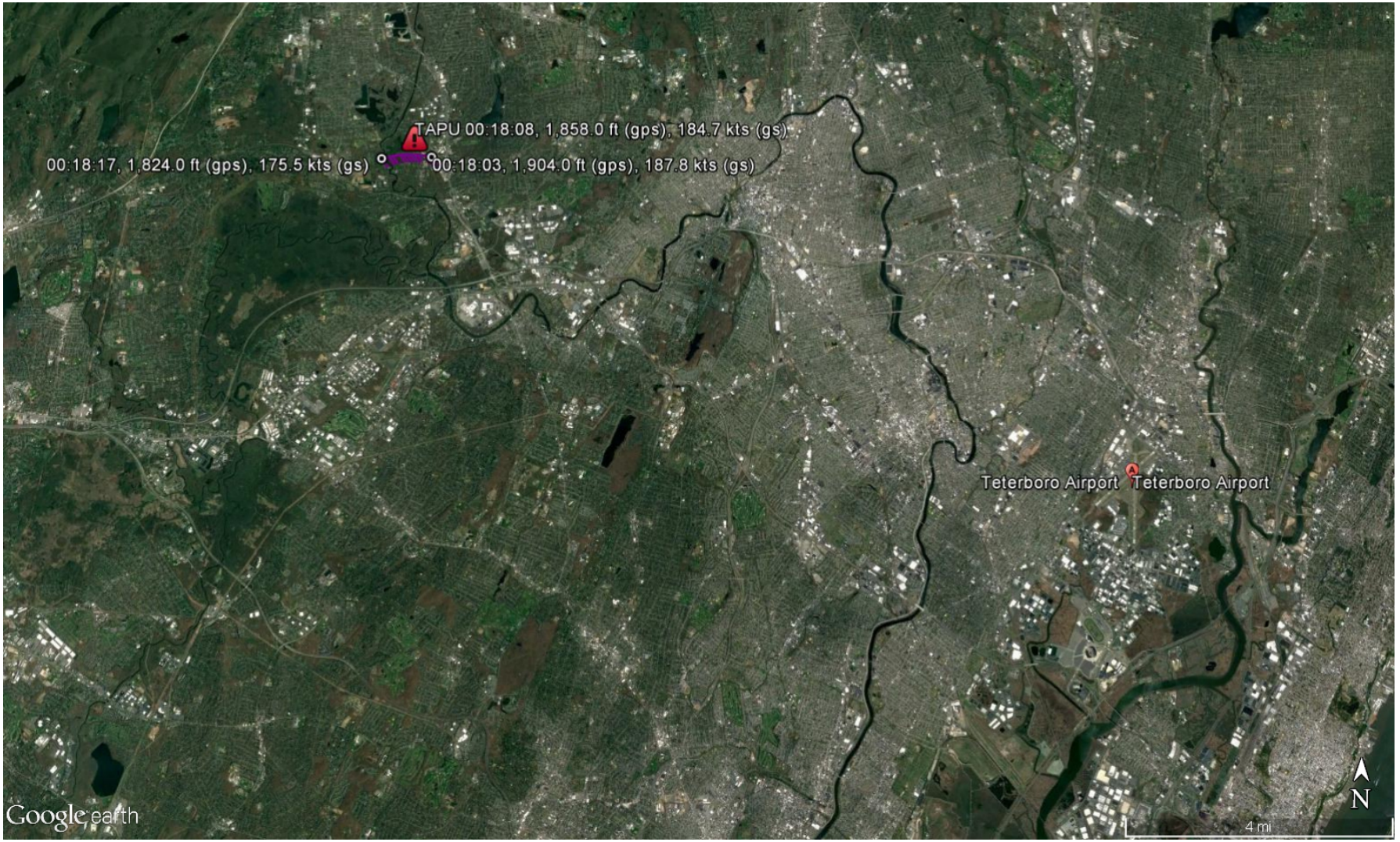


Figure 10. Leg 273, Low altitude IFR enroute chart overlay, first alert (select points annotated).

Figure 11. Leg 273, Low altitude IFR enroute chart overlay, second alert (select points annotated).

APPENDIX A

This appendix describes the parameters provided and verified in this report. Table A-1 lists the parameter names, units, and descriptions.

Table A-2. Verified and provided EGPWS parameters.

Parameter Name	Parameter Description	Unit Description
1. Alt Rte (fpm)	Altitude Rate	feet per minute
2. Flt Leg	Flight Leg (as described in section 2.1.2)	
3. GPS Alt (ft)	GPS Altitude	feet
4. Gspd (kts)	Groundspeed	knots
5. Lat (deg)	Latitude	degrees
6. Long (deg)	Longitude	degrees
7. Oper Time (hhhh:mm:ss)	EGPWS Operating Time (see note 1)	hours:minutes:seconds
8. Roll (deg)	Roll (see note 2)	degrees
9. TACAlt (ft)	Internally Computed Altitude (see note 3)	feet
10. Tru Hd (deg)	True Heading	degrees
11. Tru Trk (deg)	True Track	degrees
12. Warn	Alert Code (as described in section 2.1.2.1)	

Notes:

1. **Oper Time**. Plots, overlays, and narrative descriptions omit the “hours” portion of Operating Time for readability.
2. **Roll**. Roll is either measured from a sensor or derived from GPS track and groundspeed. Because the NVM chip containing configuration information was not recovered, the source of roll was determined from installation information to be derived. Derived roll may not be reliable during a loss of control event as it is modelled on a coordinated turn and also requires high resolution GPS data, which had degraded towards the end of the accident flight.
3. **TACAlt**. This altitude is internally computed (“blended”) using a proprietary algorithm. TACAlt is compared to the EGPWS database of terrain altitudes to generate altitude-related alerts. This EGPWS installation did not receive radar altitude as an input.