

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

March 29, 2017

Cockpit Displays – Recorded Flight Data

Specialist's Factual Report
By Sean Payne

1. EVENT SUMMARY

Location: Alabaster, Alabama
Date: August 27, 2015
Aircraft: Cirrus SR22
Registration: N1116C
Operator: Private
NTSB Number: ERA15FA330

On August 27, 2015, about 1906 central daylight time (CDT), a Cirrus SR22, N1116C, was destroyed when it impacted trees and terrain while on the final leg of the traffic pattern at Shelby County Airport (EET), Alabaster, Alabama. The airplane was owned by Hard Times LLC and operated by a private individual. The private pilot was fatally injured. Visual meteorological conditions prevailed and no flight plan had been filed for the personal flight. The flight was conducted under the provisions of Title 14 *Code of Federal Regulations* Part 91. The flight originated from Birmingham-Shuttlesworth International Airport (BHM), Birmingham, Alabama, about 1830.

2. DETAILS OF INVESTIGATION

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

Recorder Manufacturer/Model: **Avidyne PFD**
Recorder Serial Number: **D1308**

Recorder Manufacturer/Model: **Avidyne MFD Card**
Recorder Serial Number: **N/A**

Recorder Manufacturer/Model: **Avidyne DFC-90 Digital Autopilot**
Recorder Serial Number: **Unknown**

2.1. Avidyne Primary Flight Display (PFD) Description

The PFD unit includes a solid state Air Data and Attitude Heading Reference System (ADAHRS) and displays aircraft parameter data including altitude, airspeed, attitude, vertical speed, and heading. The PFD unit has external pitot/static inputs for altitude, airspeed, and

vertical speed information. Each PFD contains two flash memory devices mounted on a riser card. The flash memory stores information the PFD unit uses to generate the various PFD displays. Additionally, the PFD has a data logging function, which is used by the manufacturer for maintenance and diagnostics. Maintenance and diagnostic information recording consists of system information, event data and flight data.

The PFD samples and stores several data streams in a sequential fashion; when the recording limit of the PFD is reached, the oldest record is dropped and a new record is added. Data from the Attitude/Heading Reference System (AHRS) is recorded at a rate of 5 Hz. Air data information such as pressure altitude, indicated airspeed, and vertical speed are recorded at 1 Hz. Global Positioning System (GPS) and navigation display and setting data are recorded at a rate of 0.25 Hz, and information about pilot settings of heading, altitude, and vertical speed references are recorded when changes are made.

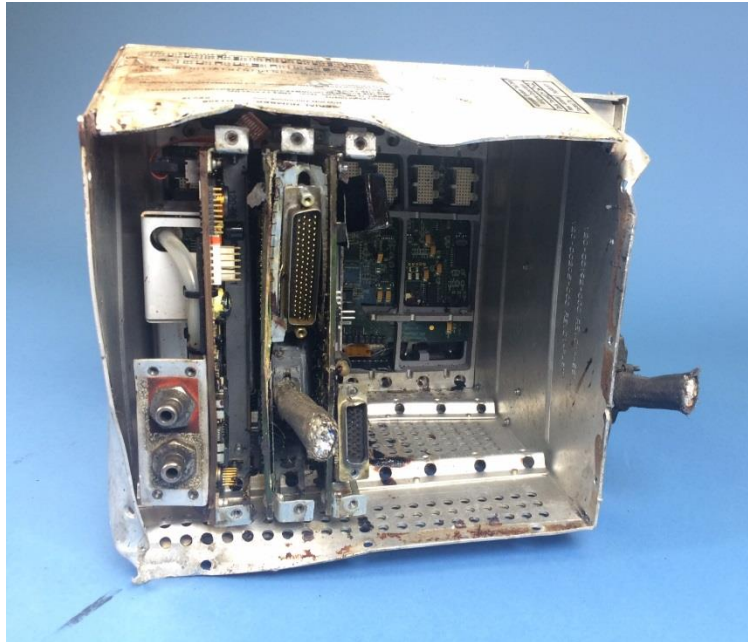
2.1.1. PFD Data Recovery

The recorder was damaged in the event. The extent of the damage is shown in figure 1. Figure 2 shows the back of the unit after the rear face panel of the PFD was removed. The card containing the flight data was removed, installed in a surrogate and the data was retrieved.

Figure 1. Damaged exterior of flight recorder.



Figure 2. Damaged rear of PFD with the back paneling removed.



2.1.2. PFD Data Description

The PFD recording contained records of 8 power cycles. The accident flight was associated with the 8th power cycle.¹ The duration of the 8th power cycle was approximately 59 minutes and 28 seconds. Timing of the PFD data is measured in seconds from power-on.

As stated in section 2.1, the PFD records most data at regular time intervals. The recorded data has shown, at times, to drop data records for up to 6 seconds in duration. The dropout condition has been reported to the manufacturer of the PFD. The condition that causes the dropouts is related to time overruns in the low-priority data logging code, which results in the input buffer overflowing. In later PFD software versions, if a drop-out occurs, an event is recorded in the event log.

2.1.3. PFD Engineering Units Conversions

Conversion of the PFD data from the raw recorded information to engineering units is performed by Avidyne. Acceleration data, as provided by Avidyne, was converted from meters per second-squared (m/s^2) to standard acceleration units (g).

Where applicable, changes to the conversions have been made to ensure the parameters conform to the Safety Board's standard sign convention that climbing right turns are positive (CRT=+).²

¹ During the normal data retrieval process, power is applied to the PFD. Therefore the accident data is not necessarily the last power cycle recorded.

² CRT=+ means that for any parameter recorded that indicates a climb or a right turn, the sign for that value is positive. Also, for any parameter recorded that indicates an action or deflection, if it induces a climb or right turn, the value is positive. Examples: Right Roll = +, Left Aileron Trailing Edge Down = -, Right Aileron Trailing Edge Up = +, Pitch Up = +, Elevator Trailing Edge Up = +.

APPENDIX A lists the PFD parameters verified and provided in this report.

2.2. Avidyne Multi-Function Display (MFD) Description

The MFD unit is able to display the pilot checklist, terrain/map information, approach chart information and other aircraft/operational information depending on the specific configuration and options that are installed. One of the options available is a display of comprehensive engine monitoring and performance data.

Each MFD contains a compact flash (CF) memory card located in a slot on the side of the unit. This memory card contains all of the software that the MFD needs to operate. Additionally, this card contains all of the checklist, approach charts, and map information that the unit uses to generate the various cockpit displays.

During operation, the MFD display receives information from several other units that are installed on the aircraft. Specifically, the MFD receives GPS position, time and track data from the aircraft's GPS receiver. The MFD may also receive information from the aircraft concerning altitude, engine and electrical system parameters, and outside air temperature. This data is also stored on the unit's CF memory card.

The MFD generates new data files for each MFD power-on cycle. The oldest file is dropped and replaced by a new recording once the storage limit has been reached. MFD data are sampled every six seconds, and is recorded to memory once every minute. If an interruption of power occurs during the minute between MFD memory write cycles, data sampled during that portion of a minute are not recorded.

2.2.1. MFD Data Recovery

Only the NVM memory card associated with the MFD was sent to the laboratory. The MFD card was undamaged and is shown in figure 3. The card contained a sticker which noted, "Contains software: 530-00195-110 REV 00." Data was extracted from the MFD card normally, per the manufacturer's suggested procedure.

Figure 3. MFD Card



2.2.2. MFD Data Description

The MFD CF card contained 120 data files. One data file was identified as recording during the incident flight. The data file was approximately 49 minutes and 18 seconds in duration.

The data recorded typical MFD parameters up to 19:00 CDT on the date of the accident. After 19:00 CDT, data was absent. A discussion with the manufacturer yielded that software revision 530-00195-110 contained a bug that could not permit data being recorded across 24:00 on a 24 hour clock. On this version of the software, if a log began prior to 24:00 on any day, it was not possible to log data after 24:00 on the next day unless the unit received a power cycle, thus creating a new log. In this accident, 19:00 CDT corresponds to 24:00 UTC (the logs are initially given in UTC and must be converted to CDT, see section 2.4. Time Correlation). This could provide an explanation for the cessation of recorded data at exactly 19:00 CDT.

2.2.3. MFD Engineering Units Conversions

The data files downloaded from the MFD are in engineering units.

APPENDIX A lists the MFD and PFD parameters verified and provided in this report.

2.3. Avidyne DFC-90 Digital Autopilot (AP) Description

The Avidyne Digital Flight Control (DFC) Autopilot is a digital, attitude-based autopilot system. The DFC90 autopilot uses the output information from the Avidyne PFD's ADAHRS to provide automatic aircraft control. The unit controls the aircraft in both lateral and vertical modes. The unit can also provide speed-based envelope protection.

The unit contains an internal microSD card which logs data and information related to the operation of the DFC90 device. The card logs various parameters at three different rates (low, medium, and high fidelity) depending on the type of information being recorded. System health parameters are logged at a slower rate when compared to acceleration information.

2.3.1. DFC AP Data Recovery

The recorder was damaged in the event. The extent of the damage is shown in figure 4. The memory module is shown in figure 5 seated on the main board normally with the module's ribbon connector affixed to the board. The microSD card was extracted and read in a raw format using a forensic write blocker.³ When read in a raw digital format, the card produced a series of "00" hexadecimal (hex) blocks. Typically, "00" blocks in hex indicates the absence of data. After contact with the manufacturer regarding this matter, the absence of data could not be explained.

³ Forensic write blocker – A hardware device that permits read only operations of a memory device.

Figure 4. Damaged exterior of DFC-90



Figure 5. Close up of DFC-90 memory module seated on DFC-90 board. Module is circled in red.

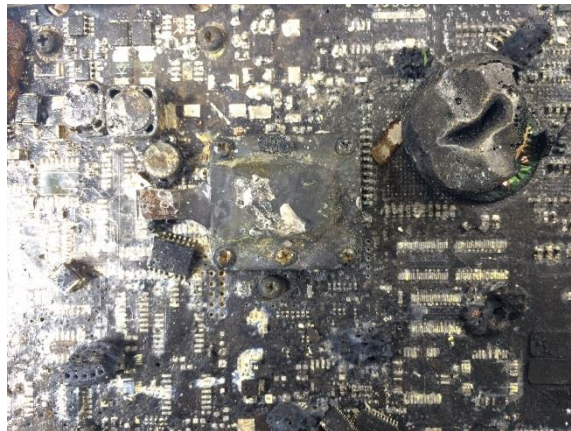


Figure 6. DFC-90 memory module open and microSD card shown seated.



2.3.2. DFC AP Data Description

No data was recovered from the DFC-90.

2.4. Time Correlation

Correlation of the PFD data to CDT was established using the recorded GPS time parameter from the PFD data. Recorded GPS time is updated in 6 second intervals on the PFD.⁴ The GPS time is recorded in Universal Coordinated Time (UTC). The difference between CDT and UTC is 5 hours, or 18,000 seconds. The PFD starts recording when power is applied to the unit. Each power cycle the timing begins at 0 seconds and the PFD data is measured in seconds from power-on. An offset is applied to each power cycle plotted to display the data with the local time zone. Therefore, for the rest of this report, all times are referenced as CDT, not recorded time.

MFD data was recorded in Universal Coordinated Time (UTC). The difference between CDT and UTC is five hours, or 18,000 seconds. The incident flight data has been offset from recorded MFD time to CDT by subtracting 18,000 seconds.

Due to the six second update rate of the GPS time, the times noted in this report could be up to six seconds off from actual GPS time.

2.5. Plots and Corresponding Tabular Data

The following five figures contain PFD and MFD data recorded during the August 27, 2015 event.

Figure 7 is a plot of basic flight parameters recorded from the PFD. The time range is from 18:10 to 19:10 CDT. The data shows takeoff roll began around 18:18:42 and the aircraft became airborne shortly thereafter. The data showed the aircraft landed around 18:32:06 in a manner consistent with a touch and go. The aircraft became airborne once again shortly thereafter. The aircraft appeared to perform another touch and go around 18:36:07. The aircraft appeared to perform a third touch and go around 18:48:01. The aircraft appeared to perform a fourth touch and go around 18:52:23. The aircraft appeared to perform a fifth touch and go around 18:56:41. The aircraft appeared to perform a sixth touch and go around 19:01:41. The recorded magnetic heading changed approximately 360 degrees over the next four minutes and other recording parameters were consistent with the aircraft being flown in a traffic pattern. At 19:05:17, the recorded pitch changed from +1 degree (nose up) to -40 degrees (nose down) at 19:05:21. The recorded airspeed at the time of the rapid onset of the pitch change was 67 knots. During this time, the aircraft rolled 10 degrees to the left. The aircraft was on a magnetic heading of approximately 345 degrees. Indicated airspeed climbed to 79 knots during the time the aircraft was pitched down. The last valid PFD data was recorded at 19:05:21.

Figure 8 is a plot of the same PFD parameters presented in an expanded timeline from 18:57:30 to 19:07:00. The last approximate 8 minutes of flight are shown.

⁴ GPS information is recorded at 4 second (0.25 Hz) intervals; however it is possible to have the same UTC time recorded in consecutive GPS data records due to the 6 second update rate of the GPS time parameter.

Figure 9 is a plot of the same PFD parameters presented in an expanded timeline from 19:04:10 to 19:05:50. The last approximate 70 seconds of flight are shown.

Figure 10 is a plot of basic flight parameters as well as basic engine parameters recorded from both the PFD and MFD during the entire accident flight. The time range is from 18:10 to 19:10 CDT. The engine parameters appear nominal and terminate at 19:00 CDT (24:00 UTC) as discussed in section 2.2.2.

Figure 11 is a plot of basic flight parameters as well as basic engine parameters recorded from both the PFD and MFD during the approximate last 5 minutes of flight. The time range is from 18:55 to 19:07 CDT.

Figure 12 is a top down, north-up Google Earth overlay of the aircraft's recorded GPS position as well as altitude during the entire flight. The aircraft first departed Birmingham-Shuttlesworth International Airport (KBHM), Birmingham, Alabama around 18:13:06. The aircraft left the area and arrived in the traffic pattern at Bessemer Airport (KEY), Bessemer, Alabama around 18:28:30. The aircraft performed two touch and goes on runway 5 then departed the area around 18:38:00. The aircraft flew south and made a right hand 270 degree turn around the Elliottsville, Alabama area. At 18:43:54, the aircraft entered the region near Shelby County Airport (KEET), Alabaster, Alabama. The aircraft performed four touch and goes on runway 34 at KEET. Times are given in the figure that show the time the aircraft entered right base for each one of the laps it made around the pattern. On the fifth circuit of the pattern, the aircraft impacted terrain on short final to runway 34 at KEET. The last data point was recorded at 19:05:18 and is depicted on the overlay.

Figure 13 is a Google Earth overlay of the aircraft's recorded GPS position as well as altitude during the portion of flight in the vicinity of KEET.

Figure 14 is a Google Earth overlay looking toward runway 34 at KEET. The last data point is shown at 19:05:18.

The corresponding tabular data used to create these five plots are provided in electronic (*.csv⁵) format as Attachment 1 to this report.

⁵ Comma Separated Value format.

Figure 7. Plot of basic parameters during entire flight recovered from the PFD.

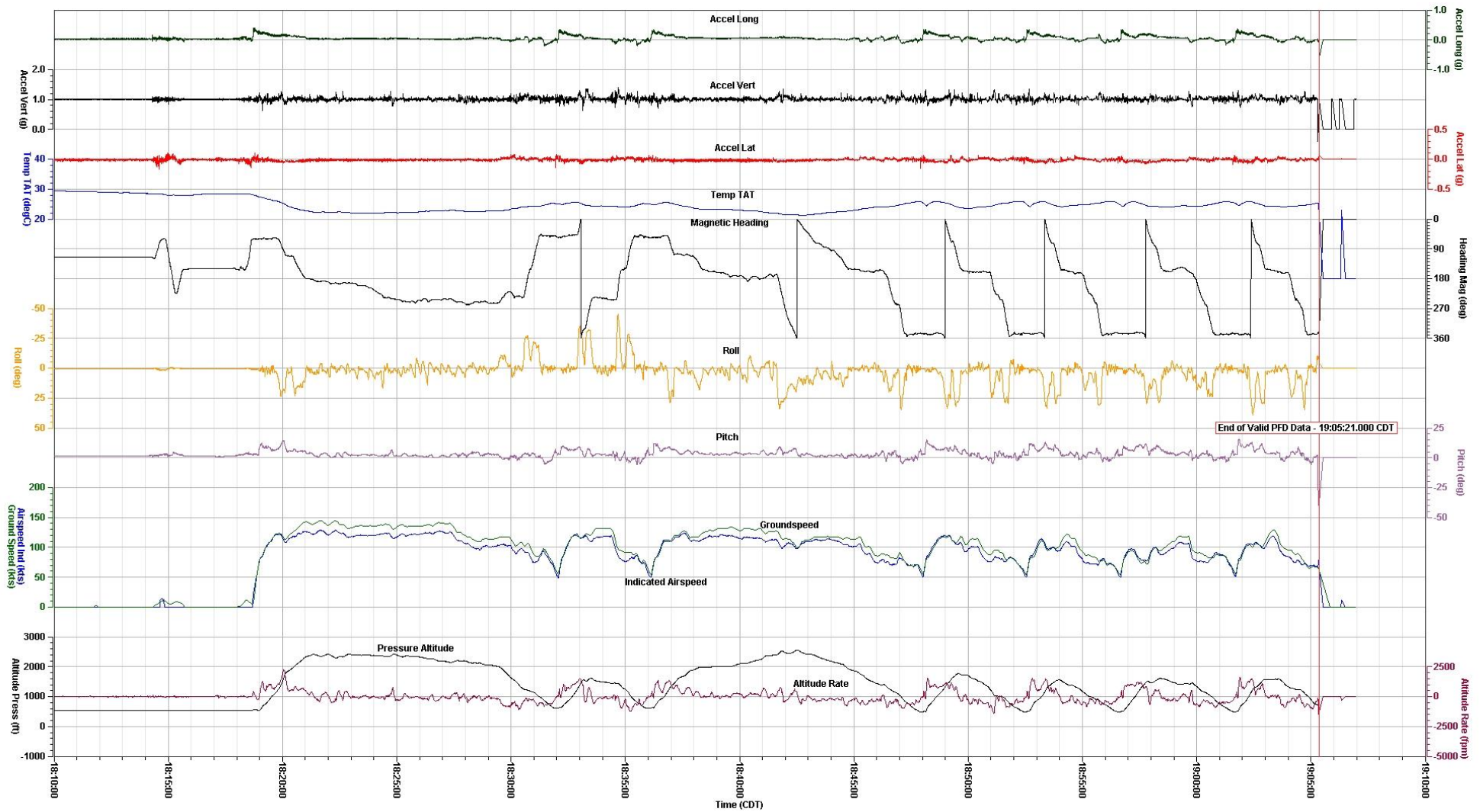


Figure 8. Plot of basic parameters during last 8 minutes of flight recovered from the PFD.

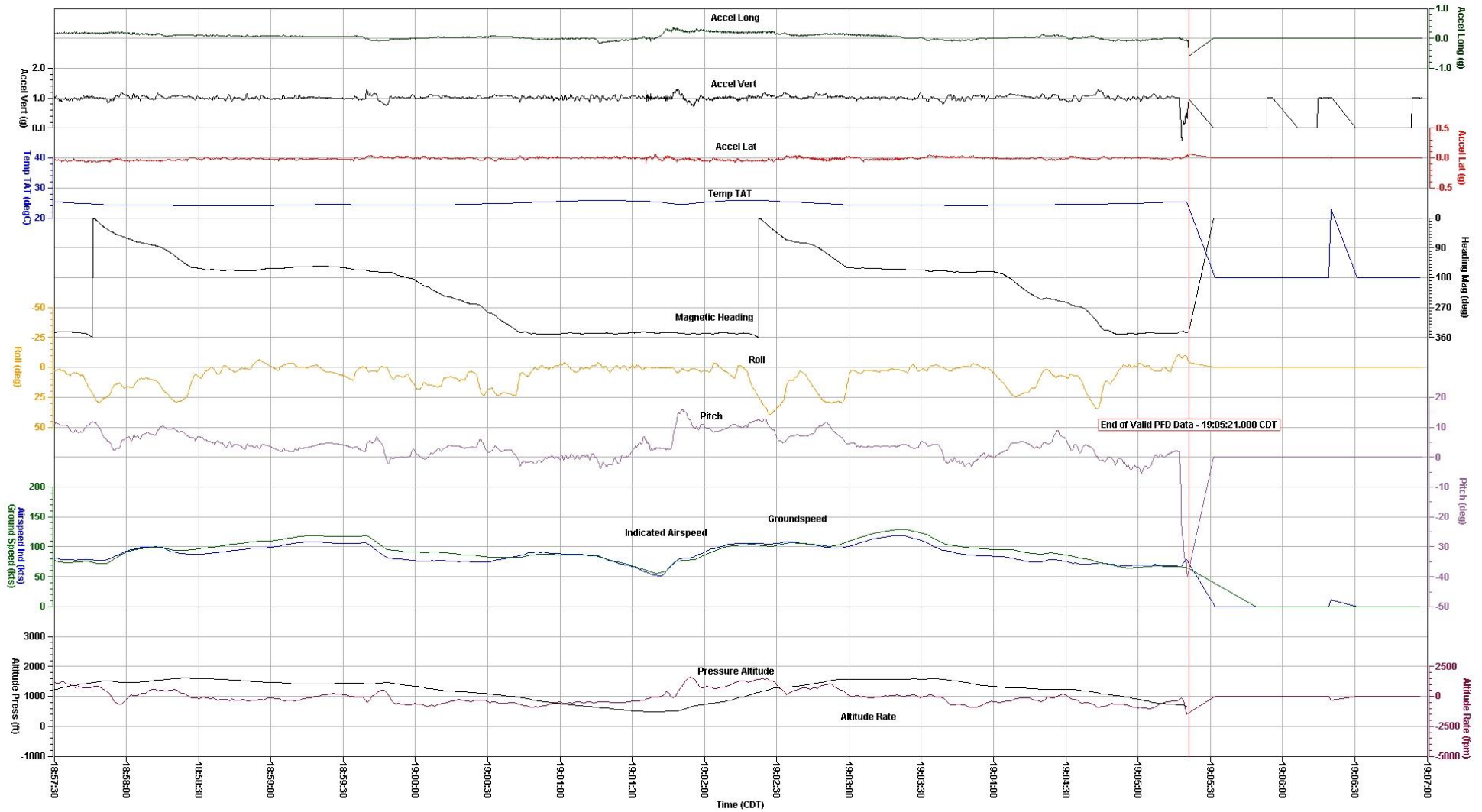


Figure 9. Plot of basic parameters during the last approximate 70 seconds of flight recovered from the PFD.

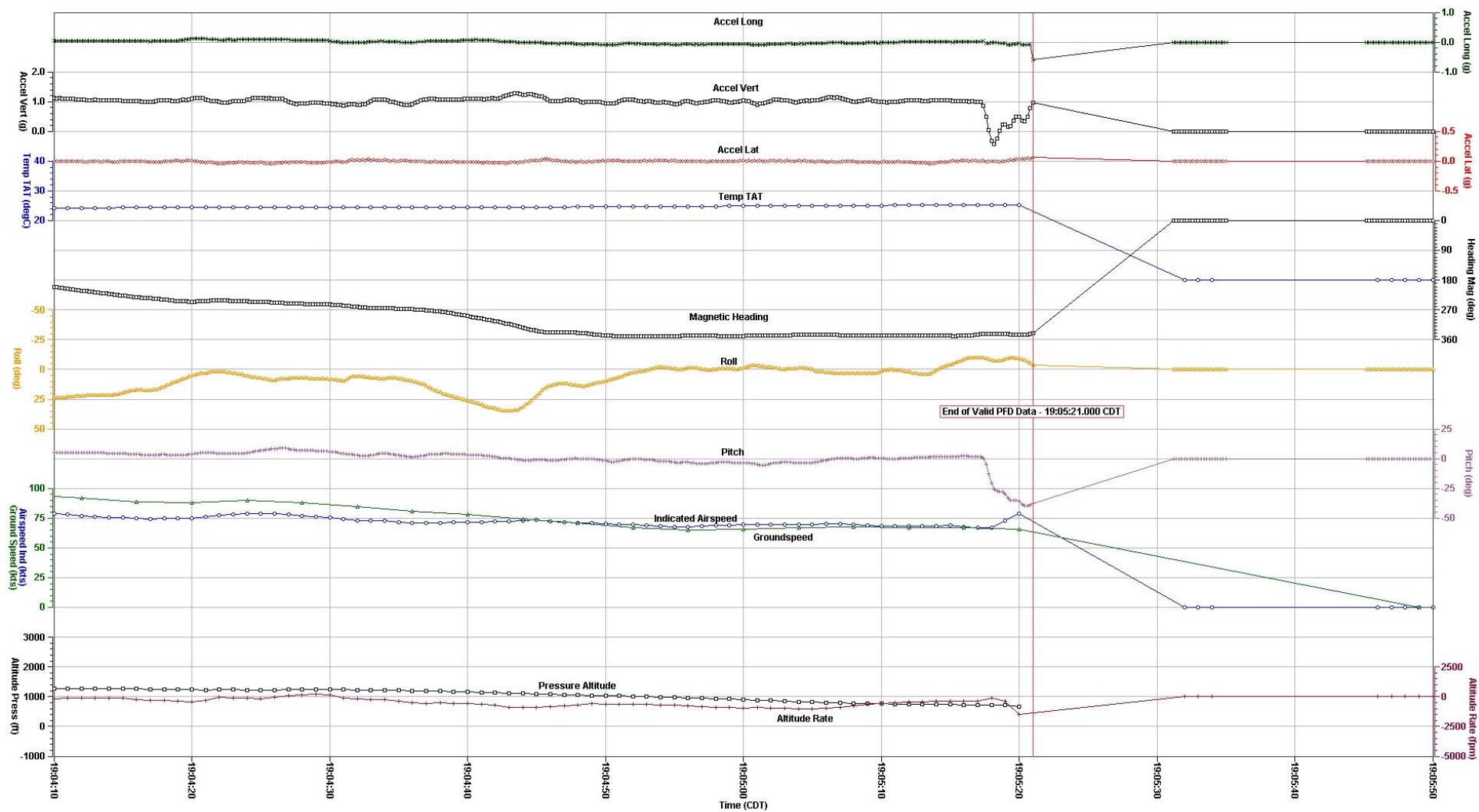


Figure 10. Plot of basic parameters during entire flight recovered from both the PFD and MFD

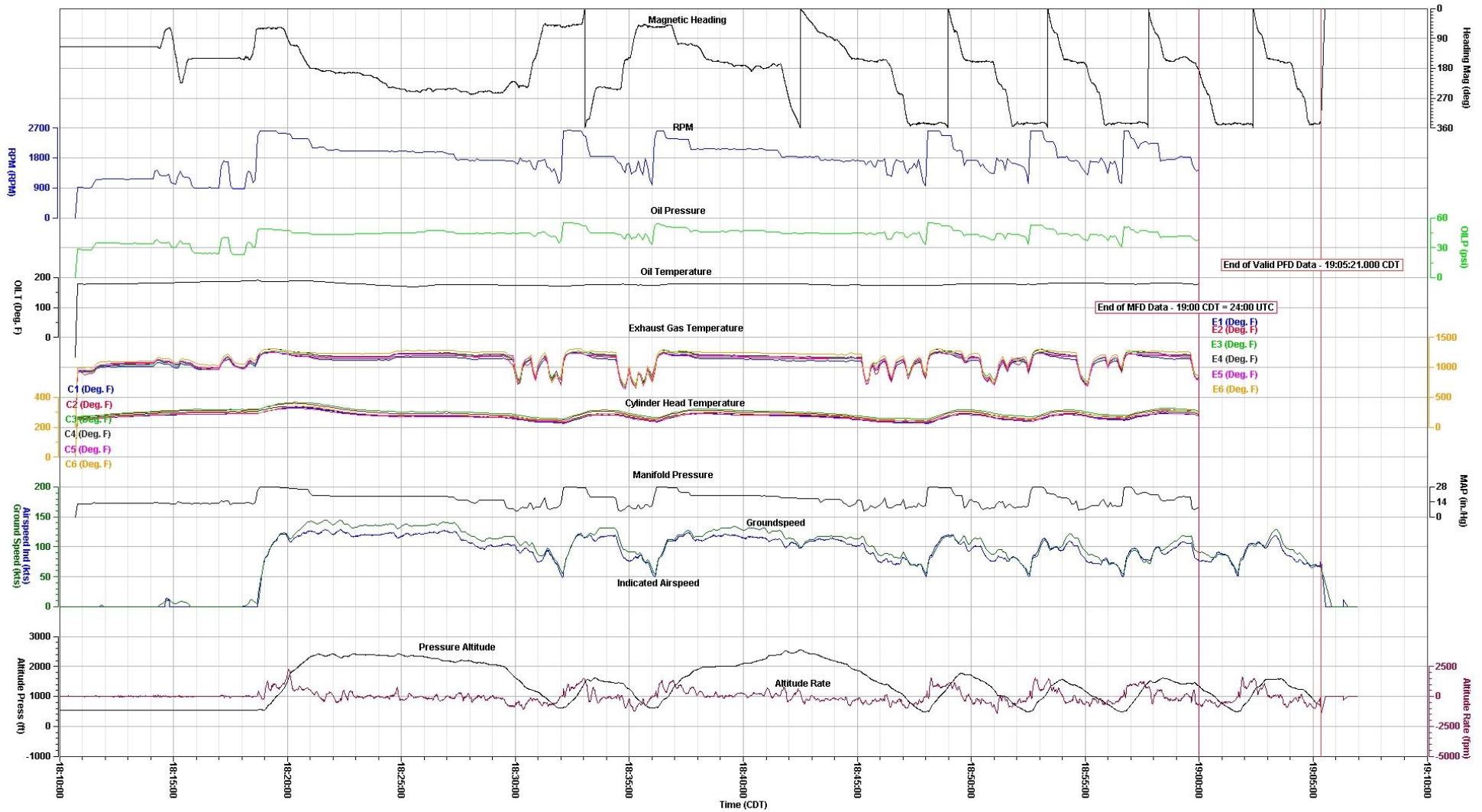


Figure 11. Plot of basic parameters during the last approximate 5 minutes of flight recovered from both the PFD and MFD

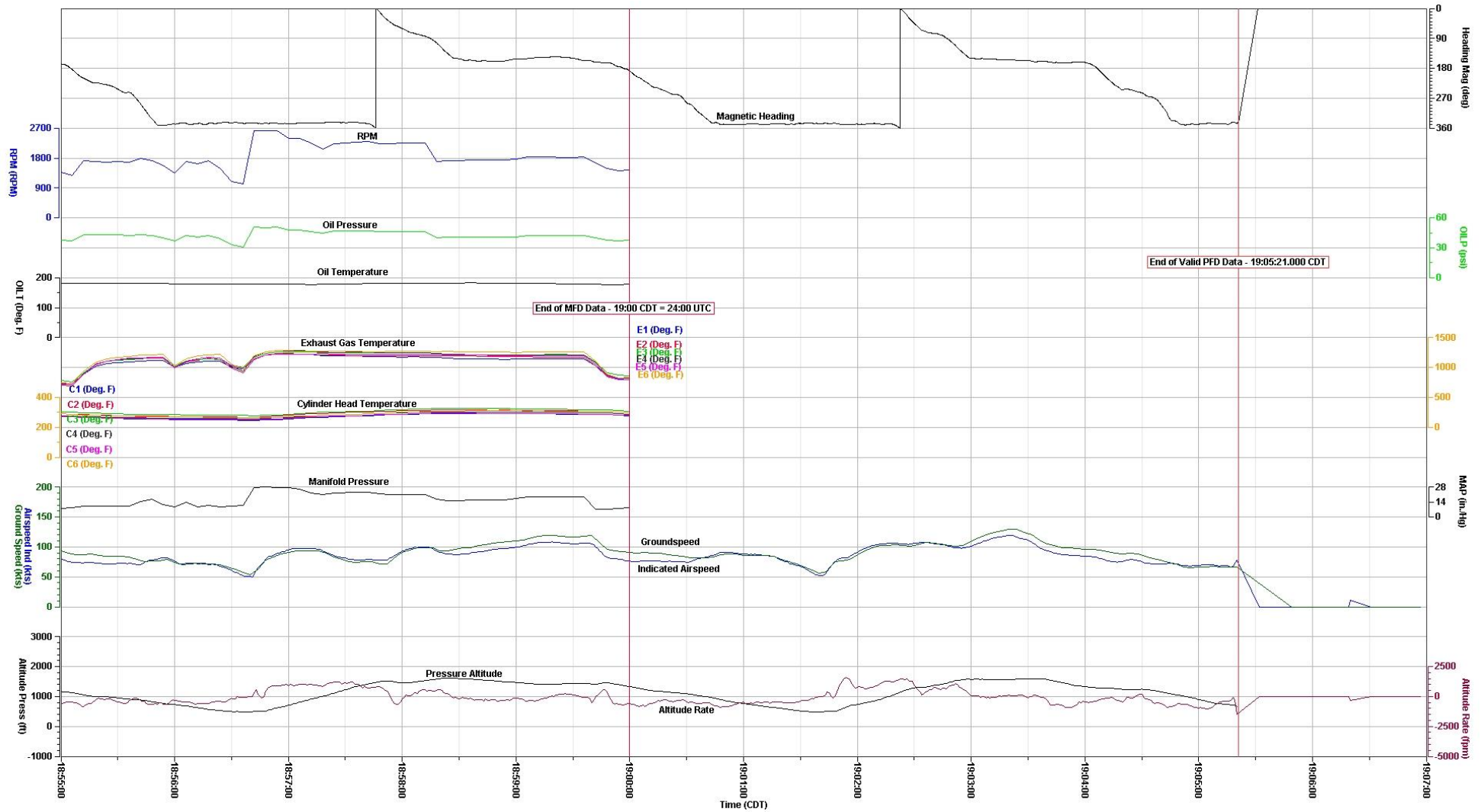


Figure 12. A top down, north up, Google Earth overlay of the recorded position of the aircraft during the accident flight.

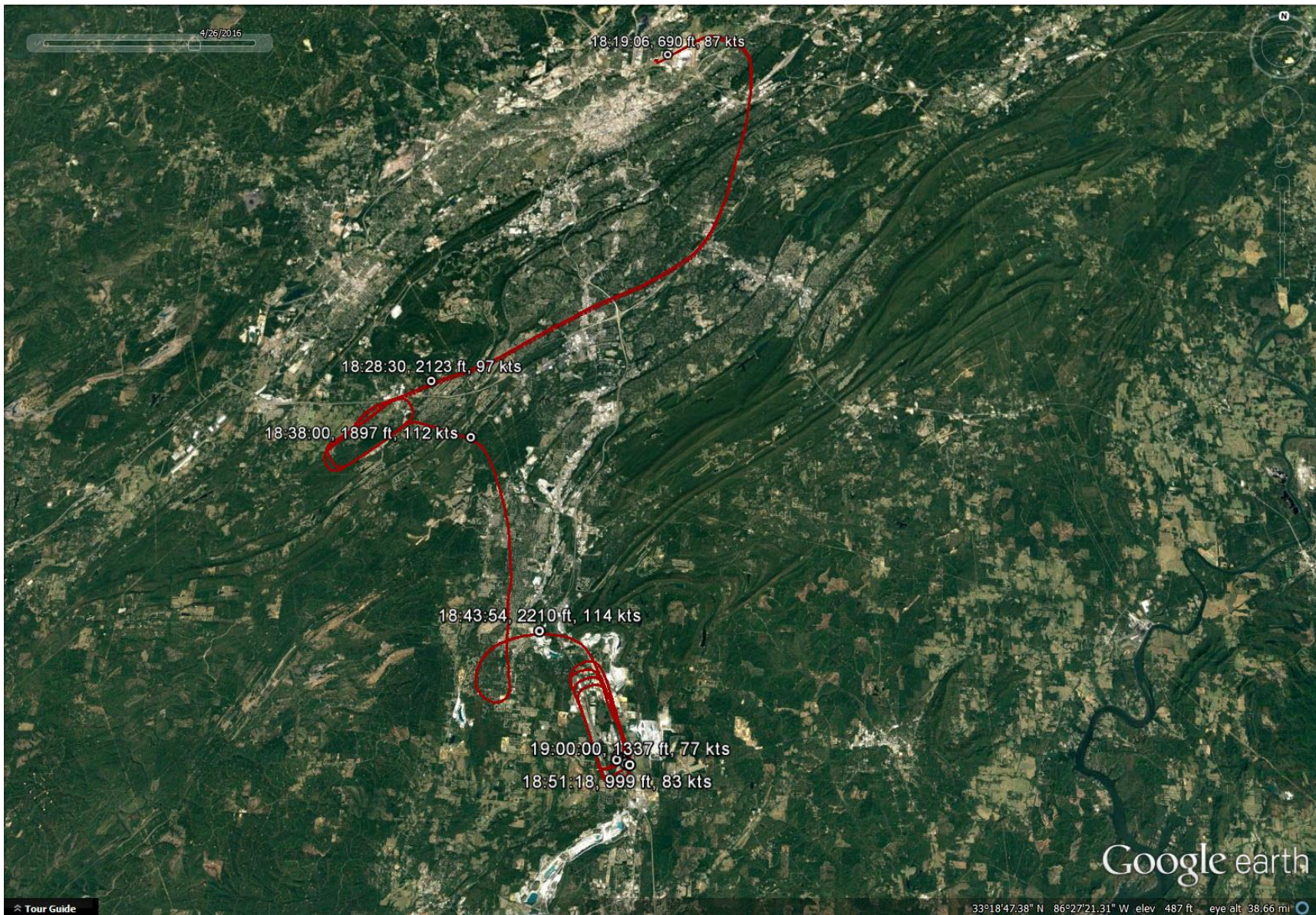


Figure 13. A north up Google Earth overlay of the recorded position of the aircraft in the vicinity of VHM.

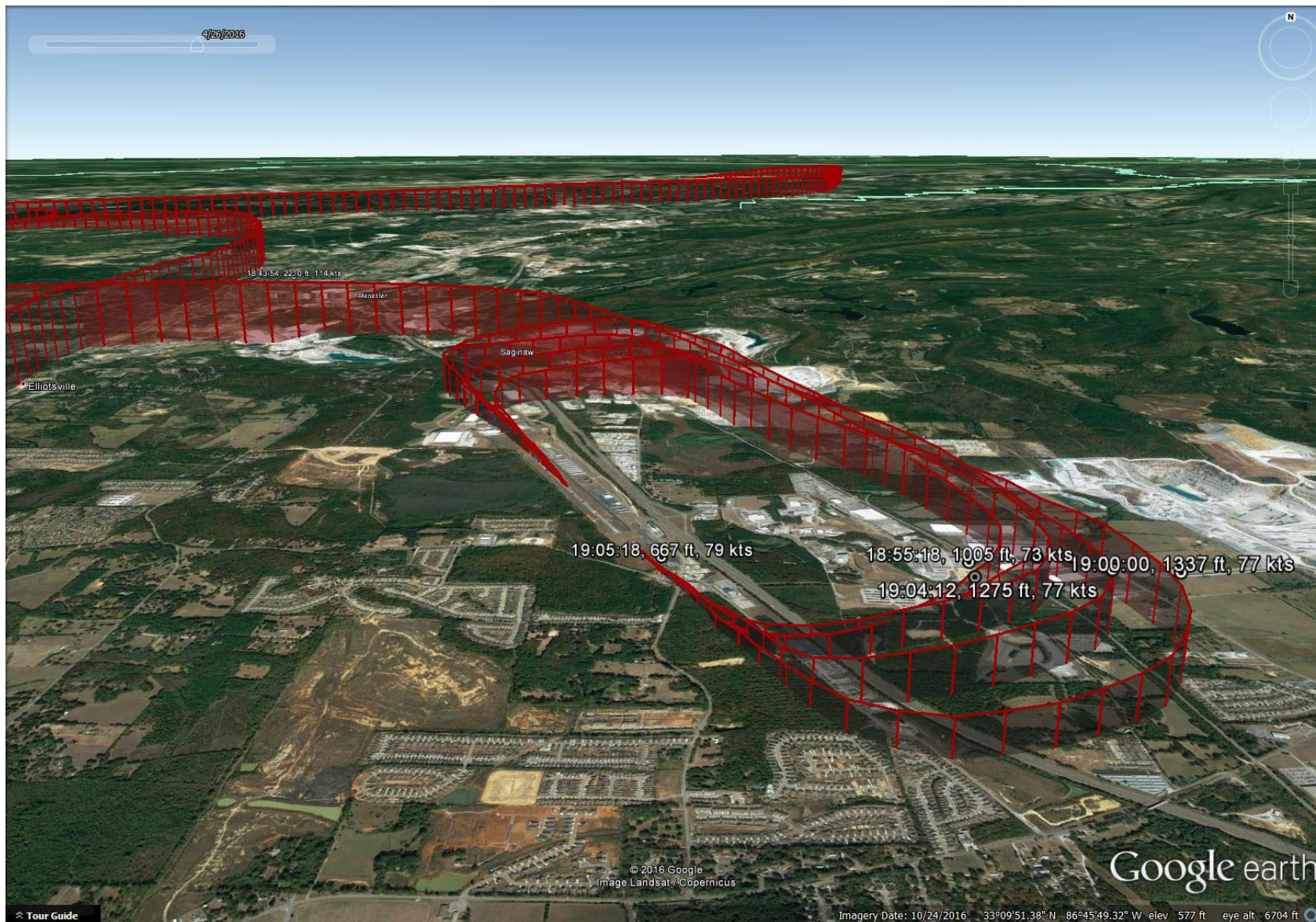
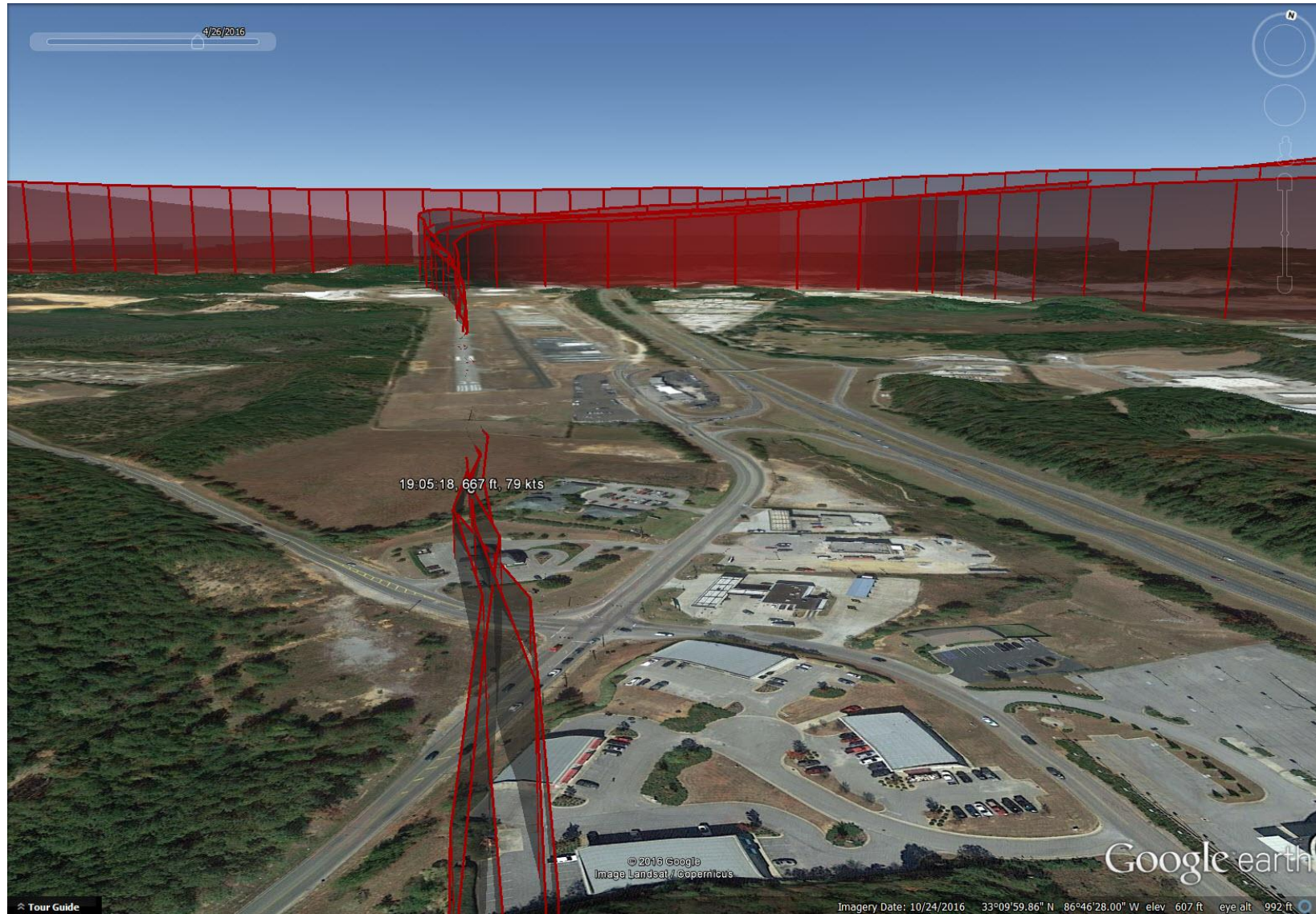


Figure 14. A view looking toward runway 34 at BHM showing the last recorded data point at 19:05:18 UTC.



APPENDIX A - PFD Parameters

This appendix describes the parameters provided and verified in this report. Table A-1 lists the PFD parameters and table A-2 describes the unit abbreviations used in this report for PFD parameters.

Table A-1 - Verified and provided parameters.

Parameter Name	Parameter Description	Source
Accel Lat (g)	Lateral Acceleration	PFD
Accel Long (g)	Longitudinal Acceleration	PFD
Accel Vert (g)	Vertical Acceleration	PFD
Airspeed Ind (kts)	Indicated Airspeed	PFD
Altitude Press (ft)	Pressure Altitude	
Altitude Rate (fpm)	Altitude Rate (Vertical Speed)	PFD
Eng1 CHT Cyl#-MFD (degF)	Engine 1 Cylinder Head Temperature Cylinder # ⁶ (degrees Fahrenheit)	MFD
Eng1 EGT Cyl#-MFD (degF)	Engine 1 Exhaust Gas Temperature Cylinder # (degrees Fahrenheit)	MFD
Eng1 Fuel Flow-MFD (gph)	Engine 1 Fuel Flow (gallons per hour)	MFD
Ground Speed	Groundspeed (GPS)	PFD
Heading Mag (deg)	Magnetic Heading	PFD
Latitude (deg)	Latitude	PFD
Longitude (deg)	Longitude	PFD
Pitch (deg)	Pitch	PFD
Roll (deg)	Roll	PFD
Temp TAT (deg)	Temp TAT	PFD

The PFD records pressure altitude, which is based on a standard altimeter setting of 29.92 inches of mercury (in Hg). The pressure altitude information presented in the plots and in the electronic data has not been corrected for the local altimeter setting at the time of the event.

⁶ Depending on aircraft configuration, the number of cylinders that are instrumented varies. In the data plots the '#' is replaced with the appropriate cylinder ID.

Table A-2 - Unit abbreviations.

Units Abbreviation	Description
rpm	revolutions per minute
deg	degrees
degC	degrees Celsius
degF	degrees Fahrenheit
ft	feet
gph	gallons per hour
in	inches
kts	knots
psi	pounds per square inch

NOTE: For parameters with a unit description of discrete, a discrete is typically a 1-bit parameter that is either a 0 state or a 1 state where each state is uniquely defined for each parameter.